Plumtree Branch
Ecological Restoration Design
(EP-21-003, WP-21-120)

Final Design Report

Howard County, Maryland

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APPENDIX

1.0 INTRODUCTION

1.1 Project Description

Ecological restoration is planned for a 2,208 linear foot section of Plumtree Branch and an unnamed tributary to Plumtree Branch, on several Howard County Department of Recreation and Parks properties off Northfield Road in Ellicott City, Maryland. The project is in partnership with the Howard County Office of Community Sustainability (OCS) and will assist Howard County in accomplishing its 2018-2019 Programmatic Two-Year Milestones to restore the Chesapeake Bay and its local rivers, lakes, and streams. Design funding is provided by the Chesapeake Bay Trust Watershed Assistance Grant Program, a program that supports projects that lead to improved water quality in the Maryland portion of the Chesapeake Bay watershed. This reach of Plumtree Branch and the unnamed tributary were selected for restoration as they are currently in an incised and degraded state. The flows are confined within a single, highly erosive channel with limited aquatic habitat and function. Potential causes of degradation include manipulation of the system to a single thread channel lacking sinuosity and a drainage area composed primarily of urban and impervious areas.

1.2. Project Goals and Objectives

The goals of this project include:

1. Increase aquatic habitat quality and diversity within the project reach.
2. Improve water quality.
3. Increase floodplain connectivity throughout the reach.
4. Create a complex, heterogeneous floodplain habitat.
5. Increase sediment residence time within project reach.
6. Create a self-sustaining, resilient system.
7. Reduce total nutrient and sediment load

2.0 EXISTING CONDITIONS

2.1 Watershed Information

The proposed restoration project is located on several Howard County Department of Recreation and Parks properties between Northfield Road to the north and Columbia Road to the south. The full project encompasses approximately 1,250 linear feet (lf) of Plumtree Branch and approximately 958 linear feet of the unnamed tributary to Plumtree Branch. There are approximately 6.3 acres (ac) of existing wetlands adjacent to the proposed project. The streams run through existing forests and meadow.

Plumtree Branch is a confluent to Red Hill Branch, eventually flowing into the Little Patuxent River (Federal HUC 02060006). Plumtree Branch and the tributary are classified by the Maryland Department of the Environment (MDE) as Use IV-P: recreational trout waters and public water supply. The construction closure period for the streams runs from March 1 through May 31 inclusive of any year.

At the lower terminus of the project, the contributing watershed is approximately 2.93 square miles with 12.7% forest cover, 32.9% impervious cover, and is 75.3% urban according to 2010 Maryland land use data (U.S. Geological Survey Streamstats program, 2016). Dominant land uses within the drainage area consist primarily of low-density residential land with some areas of high and medium density residential land, commercial areas, and parks and open spaces. The project reach is in a depositional region within the watershed and was likely a forested stream-wetland complex prior to European settlement and subsequent deforestation and degradation of the watershed. Stream discharges at their lower terminuses within the project area are shown in Table 1.

Stream Reach	Bankfull Q (cfs)	2 Year Q (cfs)	10 Year Q (cfs)	100 Year Q (cfs)
Plumtree Branch	228	381	995	2600
Unnamed Tributary	84.4	130	300	714

Table 1: Stream discharges (Q) in cubic feet per second (cfs). Discharges are from the U.S. Geological Survey StreamStats program (2016).

The predominant soils within the study corridor, as mapped on the USDA Web Soil Survey, are Hatboro Codorus silt loams. Additional soils present in the project area include Gladstone-Urban land complexes, Mount Lucas silt loam, and Legore-Montalto-Urban land complex (Soil Survey Staff, accessed 2020). The silt loams contain sandy material. As erosion progresses, the silt entrains in the wash load and transported downstream while the sand aggregates within the channel as the energy of the channel wanes. This has resulted in channel bed material that is primarily sand.

Silt loams are found in alluvial valleys and are indicative of depositional systems. These soils are predominately moderately well drained with some that are poorly drained. This soil composition is likely from deposits of legacy sediment and does not represent the historical composition of the valley soils.

Legacy sediment is soil that has eroded from upland areas due to landscape disturbance, such as deforestation, impoundment of flow, and agricultural practices, following European settlement. Layers of legacy sediment built up over hundreds of years, often trapping thousands of tons of sediment in mill ponds (Walter and Merritts, 2008). Accumulation of legacy sediment buries natural floodplains and wetlands, causing easily erodible banks instead of natural, gently sloping ones. Without these natural features, streams have increased stream power that exacerbates erosion. The failing/breaching of historic mill dams release legacy sediment, commonly leading to channel incision, bank erosion, increased suspended sediment loads, and headcut migration upstream (Miller et al., 2019).

Historical mills most likely impacted the project area. Mills were known to be prevalent in the area. The area now known as Ellicott City was formerly known as Ellicott's Mills due to the abundance of mills in the area (Ellicott's Mills Historic District). Simon J. Martenet's map from

1860 (Figure 1) shows the upstream extent of Plumtree Branch in the project area. From historical records such as the Maryland Historical Trust (Ellicott's Mills Historic District), it is known that more mills existed than are indicated on Martenet's map. Some historic mills pre-date the map by more than 60 years. Mills resulted in the accumulation of highly erodible legacy sediment evident in the valley that buried historic floodplains and wetlands. With a historic abundance of mills within the area, is presumable that the project area of Plumtree Branch was impacted by these structures.

Figure 1: Historic map of Howard County, Maryland (Martenet, S. J., 1860). Arrow pointing to approximate upstream extent of Plumtree Branch in the proposed project area.

2.2 Current Stream Conditions

Using the Cluer & Thorne (2013) Stream Evolution Model (SEM), Plumtree Branch is a Stage Four stream transitioning into a Stage Five and the unnamed tributary is a Stage Four stream. According to Cluer and Thorne (2013), Stage Four channels are characterized as, "incising with unstable, retreating banks that collapse by slumping and/or rotational slips. Failed material is scoured away, and the enlarged channel becomes disconnected from its former floodplain." Streams in Stage Five of the SEM are both aggrading and widening. Cluer and Thorne (2013) characterize Stage Five streams as, "bed [is] rising, aggrading, widening channel with unstable banks in which excess load from upstream together with slumped bank material builds berms and silts bed. Banks [are] stabilizing and berming."

Plumtree Branch is degraded and incised for most of the project reach showing signs of vertical accretion in the form of the channel bottom being lacking riffle material but containing sediment bars formed along the channel. Plumtree Branch contains wide, shallow cross sections dominated by sand and silt. The banks are largely vertical and predominantly have minimal surface protection with a high erodibility risk. No clear riffle pool sequence is present. The unnamed tributary is in a state of degradation and widening. Large rock material was previously added to the tributary, which is incised with near vertical banks lacking surface protection. Both Plumtree Branch and the unnamed tributary lack sinuosity. Plumtree Branch carries large amounts of sediment through the homogeneous system as the stream is disconnected from the floodplain except during storm events. Both the unnamed tributary and Plumtree Branch begin in the project reach in a forested area. Plumtree Branch opens into a meadow surrounded by wetlands with dead and dying ash trees bordering the streambanks. A variety of utilities are present on-site including sewers running parallel to and crossing under Plumtree Branch, bridges, and electric lines. Photos of the existing conditions can be seen in Appendix A: Existing Conditions Photo Exhibit.

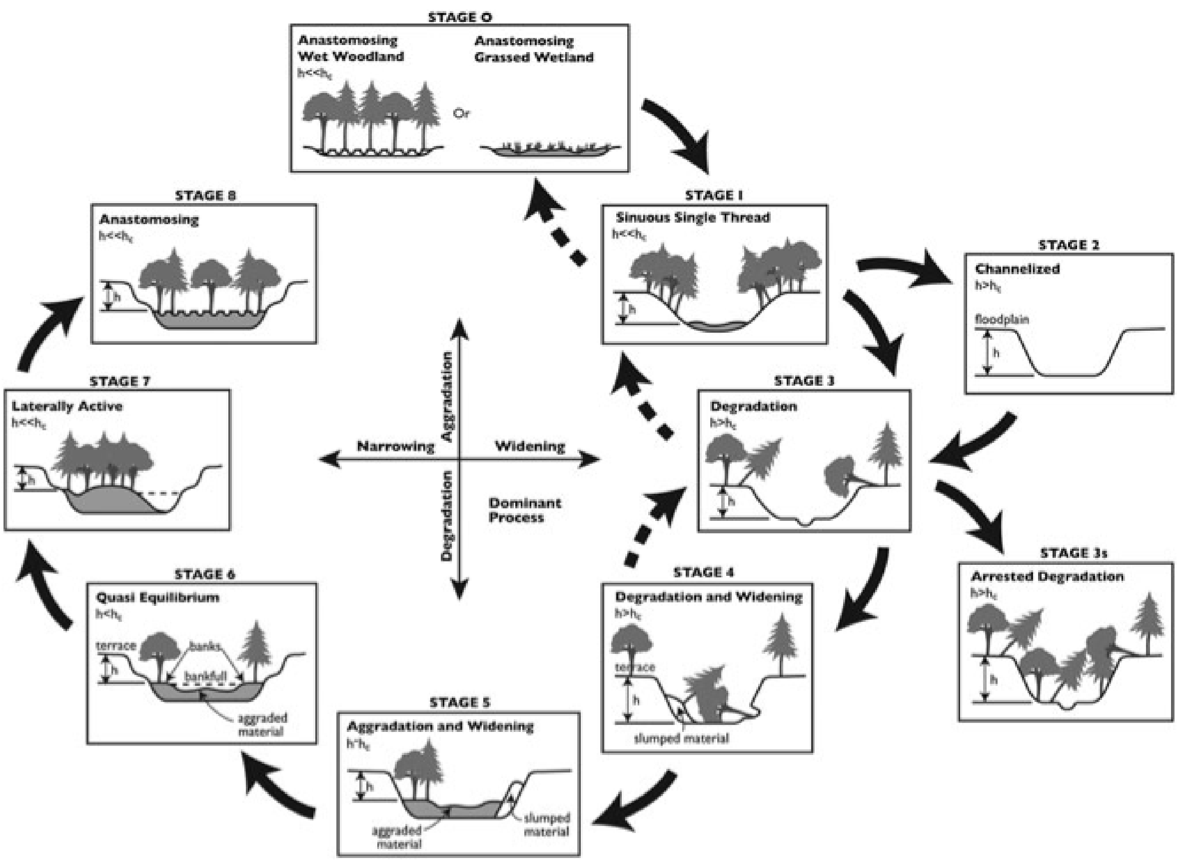

Figure 2: Cluer and Thorne's (2013) Stream Evolution model. Plumtree Branch and the unnamed tributary are currently in a Stage Four, with Plumtree Branch progressing transitioning into a Stage Five.

The Maryland Biological Stream Survey (MBSS) had surveyed at the upstream end of the project reach of Plumtree Branch four times. In 2000 (Site ID 956-2-2000), the sample size of benthic macroinvertibrates collected was too small to accurately determine an index of biological integrity. In 2006 (Site ID 0956-07-2006), 2009 (Site ID 0956-02-2009) and 2017 (Site ID 0956-01-2017), the benthic index of biotic integrity rating is poor. In 2017, the score was 1.86/5 (Maryland Stream Health, 2016). On a location on Plumtree Branch upstream of the project area, just south of Frederick Road, the site was surveyed by MBSS in 1997 and 2017. An index of biotic integrity for fish was determined to be fair on both occasions, with the 2017 score as 3.3/5. The fish found include blacknose dace, creek chub, green sunfish, tessellated darter, rosyside dace, white sucker, bluegill, and yellow bullhead (Maryland Stream Health, 2016).

2.3 Existing Riparian Conditions

Nine non-tidal wetlands were found within or adjacent to the project area. Three wetlands were forested, one wetland is emergent, and the remaining 6 wetlands were a combination of emergent and forested conditions. More information about the wetlands on-site, including data sheets, can be found in the attached Wetland Delineation Report (Appendix C).

Four forest stands were identified within or adjacent to the project area. Forest stand 1 is located in the northeast portion of the project area. It is an early- mid-successional, mixed hardwood forest containing floodplains, wetlands, and wetland buffers. Canopy coverage is approximately 75% and the area is dominated by red maple (*Acer rubrum*) and box elder (*Acer negundo*). The shrub layer and understory are sparse, with approximately 5% cover, and include boxelder. Invasive species are relatively high at 35% of the herbaceous plants. Stand condition is generally good.

Forest stand 2 is located in the southeast portion of the site. It is an early- mid-successional, mixed hardwood forest containing floodplains, wetlands, and wetland buffers. Canopy coverage is approximately 80% and the area is dominated by pin oak (*Quercus palustris*) and box elder (*Acer negundo*). The shrub layer and understory are sparse, with approximately 5% cover, and include boxelder. Invasive species are relatively high at 35% of the herbaceous plants. Stand 2 eventually gives way to a more open floodplain with scattered clusters of dying ash (Fraxinus pensylvanica), and black willow (*Salix nigra*). Stand condition is generally good. Areas with high concentrations of ash are in poor condition.

Forest stand 3 is located in the northwest portion of the project area and is an early- mid-successional, mixed hardwood forest. Canopy coverage is approximately 85% and the area is dominated by box elder (Acer negundo), red maple (*Acer rubrum*), and black cherry (*Prunus serotina*). The shrub layer and understory are sparse, with approximately 5% cover, and include boxelder and red maple with some multiflora rose (*Rosa multifora*) along stand edges and in canopy gaps. Invasive species are relatively high at 30% of the herbaceous plants.

Forest stand 4 is a mid-successional, mixed hardwood forest located on the upland slopes near the southwest portion of the project area. Canopy coverage is approximately 85% and the area is dominated by white oak (*Quercus alba*), tulip poplar (*Liriodendron tulipifera*), red maple (*Acer rubrum*), and white ash (*Fraxinus americana*). The shrub layer and understory are sparse, with approximately 5% cover, and include ironwood (*Carpinus caroliniana*) and red maple. Invasive species are moderate at 20% of the herbaceous plants.

All trees greater than 12" were surveyed and identified. In total, 973 trees were located, with 34 trees being identified as specimen trees. The list of all trees greater than 12" to be removed, can be found in Appendix D.

3.0 GEOMORPHIC ASSESSMENT

3.1 Assessment Introduction and Methods

A geomorphic assessment was conducted on the study reach of Plumtree Branch and the unnamed tributary. Longitudinal profile and cross sections were surveyed using a laser level and stadia rod to determine the current channel condition. The assessment included evaluating bankfull characteristics including effective discharge, width, depth, cross sectional area, velocity, slope, roughness, channel and bed material size, flood prone width, and channel pool/riffle profile. Bankfull indicators were surveyed as part of the geomorphic assessment to assist with the design discharge determination. Bank Erosion Hazard Index (BEHI) forms were completed along Plumtree Branch and the unnamed tributary.

Plumtree Branch and the unnamed tributary were also visually assessed and categorized using the Cluer & Thorne (2013) Stream Evolution Model (SEM). In addition, topography data was collected by CLSI.

3.2 Assessment Results

Plumtree Branch is degraded and incised for most of the project reach showing signs of vertical accretion in the form of the channel bottom being lacking riffle material but containing sediment bars formed along the channel. The unnamed tributary is in a state of degradation and widening. Large riffle material that was added for erosion protection is present in the tributary.

The assessment reveals Plumtree Branch and the unnamed tributary are incised and have minimal floodplain connectivity. The incision prevents stream flow from getting out of bank as frequently as would a natural, resilient stream. The amount of force contained within the channel is likely the cause of the bank erosion and degradation and prevents the stream from transitioning to a more functional condition. Other factors causing channel degradation are large amounts of impervious and urban land in the drainage area that contribute to extremely flashy flows and higher sediment loads. These flows and sediment loads would be better managed by a stream with more floodplain connectivity that can disperse energy and deposit sediment loads. Additionally, the streams lack dense, deep-rooted vegetation along the channel to stabilize the banks. The total nitrogen load using Protocol 1, 2 and 3 is expected to be reduced by 825.5 lb/yr. Total phosphorous load using Protocol 1 and 3 is expected to be reduced by 345.4 lb/yr. Additionally, using Protocol 1, 2, and 3, the approximate sediment reduction is expected to be reduced by 252 ton/yr. The streams are currently functioning as transport reaches, with wide, flat floodplains largely disconnected from the hydrology of the streams. Channel bed material consists of sand, with some cobble material previously added to the tributary.

BEHI results can be found in Appendix B: Bank Erosion Hazard Index Assessment.

While conducting the stream assessment, it was noted that a large amount of sediment approximately 2 feet in depth has accumulated in the floodplain valley. The age of debris lodged in the sediment, such as that pictured in Figure 3, reveals that the sediment deposit is recent.

Figure 3: Debris lodged in the streambanks indicate a recent deposition of approximately 2 feet of sediment.

Further research was conducted to determine the cause of the accumulated sediment. Aerial imagery was obtained from Howard County Maryland's Interactive Map (2015). A historic aerial from 1943 (Figure 4) reveals Plumtree Branch to be a completely straight stream with no buffer on either side. Agricultural fields come nearly to the top of the streambanks and there are minimal impervious surfaces observed. Columbia Road is not yet built. As aerials progress chronologically, land disturbance, construction, and impervious surfaces increase. By the 1980's, the land surrounding Plumtree Branch and the unnamed tributary has been heavily developed. The photos depict the low sinuous stream present today (Figure 4), and a buffer is present around the stream. From these aerials, it is evident that the sediment has already been deposited in the floodplain. The meanders are caused by the stream moving the fine, aggregated sediment. The buffer was likely established as the accumulated silt was soft and saturated, preventing mowing and access to the floodplain and allowing riparian vegetation to develop. While land disturbance and increased impervious area cause erosion and sheet runoff, it was likely that floods and storm events amplified the problems.

When Hurricane Agnes reached Maryland in June of 1972, it "dropped an estimated 10-14 inches of rain on already saturated areas of Maryland…" according to a *Baltimore Sun* article (Rector, 2012). The hurricane caused great flooding in Ellicott City and served as a benchmark for future local disasters (Rector, 2012). The flat floodplain of Plumtree Branch was already waterlogged and flooding from Hurricane Agnes presumably brought a large load of silty sediment that settled in the project area.

Consequentially, it is determined that prior to approximately 1980, construction and land disturbance in the drainage area caused sediment to accumulate in the floodplain, with Hurricane Agnes being an exacerbating event. The combination of these factors led to deposition of approximately 2 feet of sediment accumulating in the valley around 1972, causing an artificial floodplain that the Plumtree Branch and the unnamed tributary are disconnected from.

Figures 4: Side by side comparison of a historic aerial from 1943, prior to extensive development increasing impervious surfaces, and 2017 existing conditions. The project area existing stream centerline is shown in blue (Howard County, Maryland Interactive Map, 2015).

4.0 RESTORATION DESIGN

4.1 Design Approach

The stream evolution model (SEM) describes the cyclical nature of stream geomorphology changes as a stream responds to stimuli that alter the form and function of that system (Cluer & Thorne, 2013). The distinction between this and other channel evolution models is the addition of a pre-disturbance condition referred to as “Stage Zero”. This concept is based on recent research conclusions stating that current gravel-based single thread channels are the result of anthropogenic influence and therefore, are not the best target for stream condition when considering restoration in alluvial valleys (Walter & Merritts, 2008). The SEM model focuses on habitat and ecosystem benefits to assess the condition of a stream system. As a function-based model, it supports the habitat and water quality goals of this project. The assessment targeted the most likely pre-disturbance condition of Plumtree Branch and the unnamed tributary with the intent of maximizing habitat and water quality benefits.

The restoration will help Plumtree Branch and the unnamed tributary become a Stage Eight system. Cluer and Thorne (2013) describe a Stage Eight system as a “meta-stable” channel network. Post-disturbance channel featuring a low flow pilot channel which may ultimately become an anastomosed planform system. This channel is connected to a frequently inundated floodplain that supports wet woodland or grassland that is bounded by set-back terraces on one or both margins. Stage Eight systems function similarly to Stage Zero systems but are not able to access 100% of the floodplain due to various reasons, including infrastructure such as that prevalent at in the project area. The habitat and ecosystem benefits of Stage Eight systems are comparable to those of Stage Zero.

A low-flow, pilot channel carrying approximately one fifth of the current discharge will be created for the mainstem. The pilot channels mimic the radius of curvature and sinuosity of existing, stable reaches of the streams. The restored tributary and Plumtree Branch will have gently sloped banks and will easily and quickly get out of bank during storm events, reconnecting the streams with the floodplain. Existing segments of Plumtree Branch adjacent to the proposed channel will remain. These segments will have fill added and banks graded to create wetland pockets.

The UT Plumtree Branch will be restored using a natural channel design approach. This method was preferred because of site constraints and bed material identified within this area. Additionally, potential access to the floodplain was limited due to the adjacent valley constraints. It was decided that a Rosgen B type channel was appropriate approach due to the level of entrenchment level associated with the channel type and the existing valley constraints.

Energy reducing techniques are proposed throughout the project. A plunge pool proposed at the outfall near the upper terminus of the UT Plumtree Branch will dissipate energy and provide protection against bank and channel erosion. A scour pool is also proposed for the confluence of the UT with the main stem Plumtree Branch. Floodplain roughness is proposed throughout the floodplain. This will increase the roughness or Mannings n which has several benefits including reducing stream power, slowing the water and increasing water surface contact within the restored area, creates habitat, improves hydrology for wetland development and uplift, and can reduce the flood frequency immediately downstream of the site. Wood structures are proposed to reduce energy. These structures will include three inverted trunks with root wads intact that are placed within the center and banks of the low flow channel. Logs will be installed along the floodplain perpendicular to the stream to act as sills to prevent channel bypassing of the root wad structures. Analysis of wood analog structures can be found in Appendix F: Wood Stability Analysis.

The purpose of the low flow pilot channels are to disperse the water across the floodplain and encourage flow to spread out over a wide area. During storm events, the pilot channel will quickly overtop and flood the available width of the floodplain to spread out energy and encourage sediment deposition throughout the floodplain. The stream will be discouraged from incising by installing the wood analog grade control structures and will instead laterally migrate and/or form additional flow paths within the floodplain. Grading is minimized to protect utilities present and avoid impacting natural resources to the furthest extent possible. The grading is net zero, with balanced cut and fill to prevent the need for importing or exporting sediment from the project area. Proposed grading allows for maximum tree retention. Additionally, the trees harvested will be repurposed as mulch for access paths that could be used for community walking paths.

A total of 46 trees are proposed to be removed as a result of the project. Trees range in condition from very poor to good. Three trees larger than 20" diameter at breast height are estimated to be removed. This includes one red maple, one black walnut and one American elm, all of which are in poor condition. All trees except one are being removed as a result of channel grading necessary to establish a stable geometric cross section. One 20" red maple is proposed to be removed for access. Most of the smaller trees proposed to be removed are being removed as a result of channel grading. Channel grading was minimized to the greatest extent to avoid tree and wetland impacts. Trees will be saved to the greatest extent possible during construction. Fewer trees may be taken if it is determined in the field that removal is not necessary. This estimate was an approximate quantity for trees based upon the design plans. All existing trees and trees to be removed can be found in Appendix D: Trees to be Removed.

The restoration will serve to alter the form and SEM stage of the stream system. Current conditions prevent proper sediment transport and storage, flow regimes, floodplain storage and vegetative functions. Restoration will return functions to the system, allow it to function at a higher level, and become more resilient to stimuli as it progresses towards becoming a Stage Eight system. After restoration, the streams will have a higher capacity to respond to changes in the watershed and adjust accordingly to mitigate future loss of function. This project will emphasize and restore the dynamic nature of the channel while protecting existing infrastructure and roadways. The stream realignment, floodplain reconnection, and plantings will create increased functionality for the system and allow the stream to adjust within the valley as an adaptable alluvial system. The woody analog grade control structures will be added to prevent future incision, create habitat, and encourage water dispersion across the floodplain. Community access to the area will be improved by re-purposing mulch from access paths into walking pathways on site.

With the frequent inundation of the floodplain, side channels and wetlands are expected to naturally form, creating a stream-wetland complex. and progression towards a Stage Zero system. Additional flow paths will further reduce the erosion potential of the stream by reducing the overall channel power, promote additional wetland vegetation, and increase the retention time of water and sediment through the system. In turn, this will reduce sediment loads and aid in flood attenuation for downstream reaches. Multiple flow paths would also boost the habitat value of the system by creating the foundations for different complex habitats to develop. This will be beneficial for not only the existing trout use, but in promoting the food trophic levels needed to support fish communities.

4.2 Justification of Design

Wetland functions expected to be enhanced or provided include groundwater recharge and discharge; flood attenuation; fish habitat, food sources, and shade; sediment storage; nutrient removal; organic production export; stabilization of associated streams; and wildlife habitat.

Using Stream Functions Pyramid Framework (Harman et al., 2012), major components that will be enhanced are hydraulics, and geomorphology functions. While improvements to physicochemical and biological functions are anticipated, it is not conclusive.

Hydraulics will be enhanced by restoring the existing straightened Plumtree Branch to resemble that of a floodplain connected stream-wetland complex. A small, low flow pilot channel with a shallow bankfull depth will be created for Plumtree Branch and the tributary. The channels of Plumtree Branch and the unnamed tributary will have a significantly reduced bank height ratios, increased entrenchment ratios, and will promote more frequent out of bank events. This will allow for a frequent hydraulic connection with the existing adjacent wetlands and those expected to naturally form after floodplain reconnection. This hydraulic connection will further promote hydrology from both storm events and ground water connections. Improved flow dynamics will lower stream velocity, shear stress, and stream bank erosion to improve and enhance hyporheic zone for groundwater/surface water exchange.

A shear stress analysis was performed for the existing and proposed conditions using the Streamstats 1.25-yr, 2-yr, 10-yr, and 100-yr flow rates from Table 1 and the proposed floodplain design parameters. The results of the Hec-Ras analyses for shear stress, velocity, and water surface elevation can be seen in the Hec-Ras report (Appendix E). All shear stresses are well below 2.0 psf and should provide a stable foundation for the development of a greatly enhanced wetland complex throughout the floodplain.

Geomorphological functions will be enhanced by creation of bedform diversity, and improved sediment storage, and increased diversity of riparian vegetation. Wood analog grade control structures will be installed to improve bedform diversity and improve habitat as well as other benefits explained throughout the report. A dense riparian buffer of native species will be planted adjacent to the streams and within the constructed wetlands.

Physiochemical enhancement may include improved surface water quality parameters such as temperature, dissolved oxygen, conductivity, pH, and turbidity; improved biological nutrient uptake and storage; and enhanced organic carbon availability and processing. Native vegetation will shade and cool Plumtree Branch and the unnamed tributary while providing a mosaic of habitats valuable to a variety of flora and fauna. Organic matter will be added to the system gradually as leaf fall and natural plant succession. As the stream/wetland complex forms, nitrogen, phosphorus, and sediment will be filtered or stored before impacting downstream reaches.

Post construction the system is anticipated to have increased biodiversity of microbial, macrophytic plant, and aquatic macroinvertebrate communities which will in turn support upper trophic levels including fish. The design will include diverse habitats needed for all stages of fish life cycles.

Research on stream function supports an argument that this type of restoration approach will result in an increase in habitat and ecosystem benefits with an increase in physical complexity (Newson and Newson, 2000). Stream-wetland complexes provide maximal structural complexity throughout the floodplain by creating multiple channels with varying flow regimes and pockets of wetland habitat. This provides excellent habitat for fish, aquatic insects, and microscopic organisms. Stream-wetland complexes also support dense vegetation growth, which provide shade, habitat, cover from predators, and food for primary consumers.

Extremely channelized streams, such as those on-site, show reduced hyporheic connection. Ecotone's proposed restoration approach aims to restore and enhance hyporheic zones throughout the stream valley by morphological features and riparian plantings. Filling the existing channel can raise the water table of the stream valley and supports continuous hyporheic exchange, allowing cool groundwater to enter the stream system and reduce overall water temperature. In addition, the proposed restoration approach facilitates interconnectivity between the streams and their floodplain; dense floodplain and wetland vegetation will provide shade to the stream-wetland complexes and will reduce the input of heat from the sun. Enhanced hyporheic exchange in combination with the resulting high-water table, ensures that groundwater will supply the stream during dry periods and sustain aquatic habitat.

4.3 Planting

A variety of native species of trees and shrubs will be planted in the floodplain as part of the restoration project (Tables 2-4). The riparian buffer adjacent to the stream will consist primarily of species with facultative and facultative wetland indicator status while upland plantings will mostly consist of facultative upland species with upland, facultative, and facultative wetland species mixed in. A riparian buffer species will be planted adjacent to the small baseflow channels so that they establish a stream system controlled by vegetation (Castro & Thorne 2019). The trees and shrubs planted will prefer wetter conditions and will hold the stream together, provide shade to the streams, and encourage complexity both in flows and habitat features. Over time vegetation is expected to take over the stream wetted area and provide the long-term resilience to prevent future degradation. The floodplain planting will improve wildlife habitat, improve soil stabilization and erosion control, and act as a filtration of sediments and runoff pollutants. Additionally, live stakes will be installed in the floodplain.

Existing trees currently growing within the floodplain will be selectively cleared as required during grading operations and used as part of the restoration. This will provide a source for the root wads and log sills used in the wood analog structures and floodplain roughness. There are also small "islands" of trees that are slightly elevated above the proposed floodplain elevation. These will remain, as much as practical, to provide additional habitat and diversity within the proposed floodplain. The design will result in the harvesting of two (2) significant trees, smaller riparian trees, and numerous dead ash trees. The associated grading and limits of disturbance was reduced to the highest extent feasible to provide meaningful restoration while preserving as many existing trees as practicable.

Tables 2-9: Planting tables.

RIPARIAN PLANTINGS TABLE (3.42 ACRES)							
	Quantity	**Scientific Name**	**Common Name**	**Size**	**Condition**	**Spacing**	**Indicator**
TREES	136	*Acer rubrum*	Red Maple	1" cal./6' ht.	container/bare root	15x15'	FAC
	137	*Platanus occidentalis*	American Sycamore	1" cal./6' ht.	container/bare root	15x15'	FACW
	137	*Quercus palustris*	Pin Oak	1" cal./6' ht.	container/bare root	15x15'	FACW
	136	*Salix nigra*	Black Willow	1" cal./6' ht.	container/bare root	15x15'	OBL
	137	*Betula nigra*	River Birch	1" cal./6' ht.	container/bare root	15x15'	FACW
Total	683						
Note: The plant schedule above reflects a planting rate of 200 stems/acre.							

UPLAND PLANTINGS TABLE (0.07 ACRES)							
	Quantity	**Scientific Name**	**Common Name**	**Size**	**Condition**	**Spacing**	**Indicator**
TREES	3	*Prunus serotina*	Black Cherry	1" cal/6' ht.	container/bare root	15x15'	FACU
	2	*Juglans nigra*	Black walnut	1" cal/6' ht.	container/bare root	15x15'	UPL
	3	*Quercus alba*	White Oak	1" cal/6' ht.	container/bare root	15x15'	FACU
	3	*Quercus palustris*	Pin Oak	1" cal/6' ht.	container/bare root	15x15'	FACW
	2	*Quercus rubra*	Northern Red Oak	1" cal/6' ht.	container/bare root	15x15'	FACU
Total	13						
Note: The plant schedule above reflects a planting rate of 200 stems/acre.							

RIPARIAN EXTENDED PLANTING SCHEDULE (6.2 ACRES)							
	Quantity	**Scientific Name**	**Common Name**	**Size**	**Condition**	**Spacing**	**Indicator**
TREES	277	*Betula nigra*	River Birch	1" cal./6' ht.	container/bare root	15x15'	FACW
	276	*Celtis occidentalis*	Hackberry	1" cal./6' ht.	container/bare root	15x15'	FACU
	277	*Platanus occidentalis*	American Sycamore	1" cal./6' ht.	container/bare root	15x15'	FACW
	276	*Quercus bicolor*	Swamp White Oak	1" cal./6' ht.	container/bare root	15x15'	FACW
	277	*Nyssa sylvatica*	Black Gum	1" cal./6' ht.	container/bare root	15x15'	FAC
Total	1383						
Note: The plant schedule above reflects a planting rate of 200 stems/acre.							

LIVE STAKE PLANTING TABLE (4,123 LF)							
	Quantity	**Scientific Name**	**Common Name**	**Size**	**Condition**	**Spacing**	**Indicator**
	2910	*Salix nigra*	Black Willow	-	Live stake	3' triangular	OBL
	2910	*Salix interior*	Sandbar Willow	-	Live stake	3' triangular	OBL
Total	5820						
Note: The plant schedule above reflects a planting rate of 7,260 livestakes/acre based on spacing.							

2" RIPARIAN PLANTINGS TABLE (0.41 ACRES)							
	Quantity	**Scientific Name**	**Common Name**	**Size**	**Condition**	**Spacing**	**Indicator**
TREES	8	*Acer rubrum*	Red Maple	2" cal./6' ht.	container/bare root	22'x22'	FAC
	8	*Platanus occidentalis*	American Sycamore	2" cal./6' ht.	container/bare root	22'x22'	FACW
	7	*Quercus palustris*	Pin Oak	2" cal./6' ht.	container/bare root	22'x22'	FACW
	7	*Salix nigra*	Black Willow	2" cal./6' ht.	container/bare root	22'x22'	OBL
	7	*Betula nigra*	River Birch	2" cal./6' ht.	container/bare root	22'x22'	FACW
Total	37						
Note: The plant schedule above reflects a planting rate of 110 stems/acre.							

2" UPLAND PLANTINGS TABLE (0.15 ACRES)							
	Quantity	**Scientific Name**	**Common Name**	**Size**	**Condition**	**Spacing**	**Indicator**
TREES	3	*Prunus serotina*	Black Cherry	2" cal./6' ht.	container/bare root	22'x22'	FACU
	3	*Juglans nigra*	Black walnut	2" cal./6' ht.	container/bare root	22'x22'	UPL
	3	*Quercus alba*	White Oak	2" cal./6' ht.	container/bare root	22'x22'	FACU
	3	*Quercus palustris*	Pin Oak	2" cal./6' ht.	container/bare root	22'x22'	FACW
	2	*Quercus rubra*	Northern Red Oak	2" cal./6' ht.	container/bare root	22'x22'	FACU
Total	14						
Note: The plant schedule above reflects a planting rate of 110 stems/acre.							

2" RIPARIAN EXTENDED PLANTING SCHEDULE (0.47 ACRES)							
	Quantity	**Scientific Name**	**Common Name**	**Size**	**Condition**	**Spacing**	**Indicator**
TREES	9	*Betula nigra*	River Birch	2" cal./6' ht.	container/bare root	22'x22'	FACW
	9	*Celtis occidentalis*	Hackberry	2" cal./6' ht.	container/bare root	22'x22'	FACU
	9	*Platanus occidentalis*	American Sycamore	2" cal./6' ht.	container/bare root	22'x22'	FACW
	8	*Quercus bicolor*	Swamp White Oak	2" cal./6' ht.	container/bare root	22'x22'	FACW
	8	*Nyssa sylvatica*	Black Gum	2" cal./6' ht.	container/bare root	22'x22'	FAC
Total	43						
Note: The plant schedule above reflects a planting rate of 110 stems/acre.							

4.4 Alternatives Analysis

Alternatives were evaluated to determine which design approach for the project would achieve the goals and objectives of the proposed ecological restoration. The selection of the final design was based on criteria including ability to accomplish goals of the project, ability to protect existing natural resources while still attaining benefits from the project, locations of utilities in the project area, existing stream uses, and landowner and funder considerations and needs. Below are the alternatives that were considered, their benefits, and why they were rejected as the most appropriate approach for this project.

Alternative Design Approach: No Action

The first alternative was a no action approach, i.e., leave the stream in its current condition. This approach would result in failure to meet the project goals and objectives of reducing channel incision, increasing floodplain connectivity and improving aquatic habitat both instream and in the adjacent riparian areas.

Alternative Design Approach: Vegetative Stabilization Approach

The second alternative involved a vegetation stabilization approach, i.e. leave the sinuosity and planform geometry of Plumtree Branch as-is and install a vegetative buffer. However, this approach would fail to meet the project goals and objectives of achieving reduction of sediment and nutrient loading in the watershed while also increasing aquatic habitat.

Alternative Design Approach: Natural Channel Design

The third alternative involved the complete realignment of Plumtree Branch and the unnamed tributary to create a channel in accordance with natural channel design practices. This would create a sinuous, stable, single thread channel that would frequently flood onto its lowered floodplain, reduce bank erosion, and create aquatic habitat in the form of constructed riffles, toewood bank protection, and pools. While the channels would be stable, they would also be static and less resilient than the chosen approach. Most of the energy would still be contained within the channel. This approach would require massive amounts of grading and would remove most of the existing trees in order to construct a new channel and floodplain. Additionally, this design approach would be difficult to effectively implement while working around existing utilities on site such as the sewer line running parallel and crossing under Plumtree Branch. Materials such as rock would need to be imported to construct in-stream features. Materials would be used to construct riffle pool features which do not existing within stable sections of adjacent reaches. This would change the sediment transport dynamics. Project cost would be substantial, and the goals of the project would not be met quickly. The potential temporary impacts to existing wetland habitat and available tree cover are undesirable. The restoration would not align with the historic conditions of the stream and would not ensure a self-sustaining, resilient system. Habitat and sediment and nutrient reductions would not be maximized. While the goals of the project could be partially met with this alternative, it would be more costly and fall short of maximizing the opportunity to fulfill the goals of the project.

Preferred Alternative Design Approach: Restoration to a Stage Eight System

The fourth and selected alternative entails restoration to allow a Stage Eight condition to establish and the creation of a pilot channel for Plumtree Branch. Stage Eight stream systems mirror the functions of Stage Zero stream systems, but do not have access to the entire floodplain. The entirety of the floodplain around Plumtree Branch cannot be accessed due to manholes and existing infrastructure, such as a bridge.

The stream will be restored in order to maximize habitat and water quality benefits, primarily in the form of floodplain reconnection and reducing channel tractive forces. Low flow pilot channels carrying approximately one-fifth of the 1.25 year storm will be designed for Plumtree Branch based on dimensions from assessment data from the stream. The channels will require less grading and disturbance to natural resources than a threshold channel restoration approach. The undersized, low-flow channel with reduced streambank heights coupled with floodplain grading will allow water to frequently get out of bank with storm events and will reduce in-channel stresses.

During high flow events, the floodplain will store sediment that drops out of suspension as velocities are dissipated along the width of the floodplain. Reconnection with floodplain coupled with floodplain grading will recharge existing wetlands and encourage the formation of new wetlands. By lowering the stream bank heights, we will increase the hydrologic interaction between the stream system and floodplain wetlands in addition to reducing impacts of tractive forces on the stream bed and bank.

Additional side channels are expected to form naturally as sediment accumulates and alters flow paths, creating a braided channel design and eventually, a stream-wetland complex. The stream will be resilient to large-scale degradation and instead will be dynamic and depositional which will form a multithreaded system over time. The stream-wetland complex expected to form will provide floodplain protection by slowing the flow of water, allow groundwater to recharge, and encourage the retention of nutrients and sediments.

Due to the aforementioned valley constraints, the UT Plumtree branch would be constructed using threshold channel design techniques. This would include the installation of a riffle pool complex that discharged into a confluence pool with the main branch.

Existing utilities and infrastructure on site will be avoided to the furthest extent possible. This restoration approach will meet the goals of the project to provide water quality benefits, habitat complexity, and reduced erosion in the watershed.

5.0 CONCLUSION

This restoration project is ideal to accomplish the project goals and increase the resiliency of Plumtree Branch and the unnamed tributary while limiting impacts to existing natural resources and on-site utilities while reducing costs. Approximately 2,208 linear feet of stream will be restored while restoring the floodplain connectivity of Plumtree Branch and the unnamed tributary. As sediment accumulates and alters flow paths a braided channel design will be created that is resilient to large-scale degradation and instead will be dynamic and depositional which will form a stream-wetland complex over time. Returning the stream to more functional stages of the SEM will reduce sediment and nutrient loads, flood velocities and tractive forces, and provide ecological uplift to the watershed. Total sediment and nutrient loads are estimated to be reduced by 252 ton/yr. This approach will result in Plumtree Branch and the unnamed tributary becoming self-sustaining systems. Allowing the system to progress to a Stage Eight stream-wetland complex with a pilot channel is an efficient way to restore this stream system while also limiting risk. The streams will exhibit increased resiliency to changes in land use and climate. Based on historical observations and current conditions, this is the ideal option for restoration, that maximizes stream function while minimizing short term impact and cost.

In 20 years, Plumtree Branch and the unnamed tributary will continue to be a resilient stream-wetland complex. This stream-wetland complex will hold onto sediment and nutrients in the project reach for extended periods of time, slowly releasing them to limit downstream impacts. Dense vegetation will shade streams, keeping water cool for fish populations. Groundwater recharge will further cool streams and limit thermal fluctuation. A diverse mosaic of habitat will exist in the wetland complex providing food and refugia for a variety of species.

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Appendix: A

Appendix A: Existing Conditions Photo Exhibit

Photo 1: Existing bridge over the unnamed tributary to Plumtree Branch.

Photo 2: Looking downstream on the unnamed tributary. The stream is incised, and the left bank is almost completely devoid of vegetation. A walking path runs on the top of the left bank.

Photo 3: The left bank of the unnamed tributary is near vertical and lacking vegetation with a rooting depth that would assist in bank stabilization. The bank is approximately 4 feet tall.

Photo 4: Manhole and utility pole on the right bank of the unnamed tributary. Many utilities are present in the project area.

Photo 5: Electric lines running over the unnamed tributary.

Photo 6: A walking path runs parallel to the unnamed tributary on the left bank.

Photo 7: Sediment bars are forming in the channel of Plumtree Branch.

Photo 8: Plumtree Branch lacks sinuosity.

Photo 9: Bridge spanning Plumtree Branch.

Photo 10: Plumtree Branch is incised with near vertical banks. The banks lack deep rooted vegetation to help stabilize the channel.

Photo 11: Vertical bank erosion on the outside of the meander.

Photo 12: Sewer line near Plumtree Branch. The sewer runs parallel to Plumtree Branch and crosses under the stream at several locations.

Photo 13: Walking path and sewer manhole adjacent to Plumtree Branch. Many utilities are present in the project area.

Photo 14: Dead and dying ash trees border the downstream reach of Plumtree Branch in the project area.

Photo 15: Culvert under Columbia Road.

Appendix: B

PROTOCOL 1

Plumtree Run (Dunloggin Middle School)

STEP 1: ESTIMATION OF EROSION RATES

Description	Bank Side (Facing DS)	Station Start	Station End	Bank Height (ft)	Radius of Curvature (ft)	Bankfull Width (ft)	BEHI Score	NBS Score*	Bulk Density of Soil (lb/cf)	Erosion Rate (ft/yr): Colorado, 1989	Erosion Rate (ft/yr): USFWS Draft DC+	Erosion Rate (ft/yr): NRCS, NC+	Length (ft)	Area (sf)	Sediment Load (ton/yr): Colorado, 1989	Sediment Load (ton/yr): USFWS Draft DC	Sediment Load (ton/yr): NRCS, NC
Trib	LEFT	0+00	1+25	10			HIGH	4	88.75	0.575	1.023	0.205	1+25	1250	31.9	56.8	11.4
Trib	RIGHT	0+00	1+25	3.5			moderate	4	88.75	0.420	0.812	0.106	1+25	437.5	8.2	15.8	2.1
Trib	LEFT	1+25	1+90	8			very high	4	88.75	0.575	1.023	0.913	0+65	520	13.3	23.6	21.1
Trib	RIGHT	1+25	1+90	4			moderate	4	88.75	0.420	0.812	0.106	0+65	260	4.8	9.4	1.2
Trib	LEFT	1+90	2+50	11			low	2	88.75	0.036	0.019	---	0+60	660	1.0	0.5	---
Trib	RIGHT	1+90	2+50	4.5			very high	5	88.75	0.872	1.641	1.139	0+60	270	10.4	19.7	13.6
Trib	LEFT	2+50	3+45	9			very high	5	88.75	0.872	1.641	1.139	0+95	855	33.1	62.3	43.2
Trib	RIGHT	2+50	3+45	4			moderate	2	88.75	0.153	0.113	0.016	0+95	380	2.6	1.9	0.3
Trib	LEFT	3+45	4+60	8			moderate	3	88.75	0.253	0.303	0.041	1+15	920	10.3	12.4	1.7
Trib	RIGHT	3+45	4+60	3.5			moderate	3	88.75	0.253	0.303	0.041	1+15	402.5	4.5	5.4	0.7
Trib	LEFT	4+60	5+90	3			low	3	88.75	0.074	0.077	---	1+30	390	1.3	1.3	---
Trib	RIGHT	4+60	5+90	4.5			HIGH	4	88.75	0.575	1.023	0.205	1+30	585	14.9	26.6	5.3
Trib	LEFT	5+90	7+25	5			HIGH	3	88.75	0.380	0.638	0.148	1+35	675	11.4	19.1	4.4
Trib	RIGHT	5+90	7+25	4			moderate	3	88.75	0.253	0.303	0.041	1+35	540	6.1	7.3	1.0
Trib	LEFT	7+25	8+30	3.5			moderate	3	88.75	0.253	0.303	0.041	1+05	367.5	4.1	4.9	0.7
Trib	RIGHT	7+25	8+30	2			low	2	88.75	0.036	0.019	---	1+05	210	0.3	0.2	---
Trib	LEFT	8+30	9+20	5			HIGH	5	88.75	0.872	1.641	0.282	0+90	450	17.4	32.8	5.6
Trib	RIGHT	8+30	9+20	3.5			moderate	3	88.75	0.253	0.303	0.041	0+90	315	3.5	4.2	0.6
Mainstem	LEFT	9+20	10+65	3			low	2	75.55	0.036	0.019	---	1+45	435	0.6	0.3	---
Mainstem	RIGHT	9+20	10+65	5			HIGH	4	75.55	0.575	1.023	0.205	1+45	725	15.8	28.0	5.6
Mainstem	LEFT	10+65	12+00	4			moderate	3	75.55	0.253	0.303	0.041	1+35	540	5.2	6.2	0.8
Mainstem	RIGHT	10+65	12+00	2			low	2	75.55	0.036	0.019	---	1+35	270	0.4	0.2	---
Mainstem	LEFT	12+00	13+60	3			moderate	3	75.55	0.253	0.303	0.041	1+60	480	4.6	5.5	0.7
Mainstem	RIGHT	12+00	13+60	3			low	2	75.55	0.036	0.019	---	1+60	480	0.6	0.3	---
Mainstem	LEFT	13+60	14+15	4			HIGH	4	75.55	0.575	1.023	0.205	0+55	220	4.8	8.5	1.7
Mainstem	RIGHT	13+60	14+15	2			low	2	75.55	0.036	0.019	---	0+55	110	0.1	0.1	---
Mainstem	LEFT	14+15	15+40	1			low	2	75.55	0.036	0.019	---	1+25	125	0.2	0.1	---
Mainstem	RIGHT	14+15	15+40	3			low	2	75.55	0.036	0.019	---	1+25	375	0.5	0.3	---
Mainstem	LEFT	15+40	17+30	4			HIGH	3	75.55	0.380	0.638	0.148	1+90	760	10.9	18.3	4.3
Mainstem	RIGHT	15+40	17+30	3			moderate	3	75.55	0.253	0.303	0.041	1+90	570	5.5	6.5	0.9
Mainstem	LEFT	17+30	18+00	2			low	2	75.55	0.036	0.019	---	0+70	140	0.2	0.1	---
Mainstem	RIGHT	17+30	18+00	4.5			HIGH	5	75.55	0.872	1.641	0.282	0+70	315	10.4	19.5	3.4
Mainstem	LEFT	18+00	18+66	4			moderate	3	75.55	0.253	0.303	0.041	0+66	264	2.5	3.0	0.4
Mainstem	RIGHT	18+00	18+66	3			low	3	75.55	0.074	0.077	---	0+66	198	0.6	0.6	---
Mainstem	LEFT	18+66	19+15	1			low	2	75.55	0.036	0.019	---	0+49	49	0.1	0.0	---
Mainstem	RIGHT	18+66	19+15	3.5			moderate	3	75.55	0.253	0.303	0.041	0+49	171.5	1.6	2.0	0.3
Mainstem	LEFT	19+15	21+00	5			HIGH	4	75.55	0.575	1.023	0.205	1+85	925	20.1	35.8	7.2
Mainstem	RIGHT	19+15	21+00	4			moderate	3	75.55	0.253	0.303	0.041	1+85	740	7.1	8.5	1.1
Mainstem	LEFT	21+00	21+40	3			moderate	3	75.55	0.253	0.303	0.041	0+40	120	1.1	1.4	0.2
Mainstem	RIGHT	21+00	21+40	3			low	2	75.55	0.036	0.019	---	0+40	120	0.2	0.1	---
														Total	**272**	**449**	**139**

*Conservative estimate based on radius of curvature and bankfull estimate. Enter NBS directly when available.

+Low and Moderate set equal to High above NBS 4.

STEP 2: NUTRIENT LOADING

Nutrient	Site Specific (lb/ton)	CBP 2014 (lb/ton)
Phosphorus	1.48	
Nitrogen	3.08	

Estimated Reduction
50%

STEP 3: NUTRIENT REMOVAL

Bank Erosion	Nitrogen (lb/yr)	Phosphorus (lb/yr)	Sediment Load (lb/yr)
Colorado	**419**	**201**	**272253**
DC	**692**	**332**	**449264**
NC	**215**	**103**	**139336**
Average	**442**	**212**	**286951**

Appendix: C

Ecotone, Inc.
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Plumtree Branch at Dunloggin Middle School Stream Restoration – Wetland Delineation Report

Introduction:

Ecotone, Inc. has completed a wetland delineation for the proposed Plumtree Branch at Dunloggin Middle School Stream Restoration Project. The Project aims to provide water quality improvements within the watershed through the reduction and removal of sediment, nitrogen, phosphorus, and other pollutants; increase the habitat availability and variety; and improve channel stability along this reach. This report provides location and presence information of non-tidal wetlands and waterways located within and adjacent to the project area.

Site Description:

The Plumtree Branch at Dunloggin Middle School Stream Restoration Project Site is located near the Dunloggin Middle School at 9129 Northfield Road in the Ellicott City area of Howard County, Maryland. (39.254685, -76.834042). The project affects an approximately 13 ac portion of the 25-acre parcel. The site is located in the Little Patuxent Watershed (02060006), part of the larger Patuxent River sub-basin. The project area is surrounded by institutional uses (school, parkland) and residences. The impacted parcel is zoned low density residential. Historically, uses for the site included forest, and residential uses.

Site Investigation Methodology:

Criteria used to conduct the wetland delineation are consistent with those procedures established by the 1987 U.S. Army Corps of Engineers Wetlands Delineation Manual and the 2010 Regional Supplement to the Corps of Engineers Wetland Delineation Manual: Eastern Mountain and Piedmont Region (Version 2.0). The 1987 Manual describes wetlands as those areas that have permanent or periodic inundation or saturation by surface or ground water to create anaerobic conditions in the soil to support a prevalence of vegetation typically adapted for life in saturated soil conditions. Therefore, environmental criteria for wetlands includes the following:

- Vegetation: the prevalent vegetation is hydrophytic (>50%).
- Hydrology: the area is either permanently or periodically inundated, or the soil is saturated to the surface during the growing season.
- Soils: the soils observed have been classified as hydric, and/or anaerobic conditions have developed in the soils.

As described in the above documents, the Routine Onsite Inspection Determination Method was used for this wetland delineation. This method is a combination of an off-site data review and an on-site inspection to identify wetland boundaries. Off-site sources such as the National Wetland Inventory Map and the USDA Soil Map were consulted during this wetland delineation; final wetland determinations were based field observations. The following describes the approach used to complete the on-site wetland identification and delineation effort:

1. Plant community types were observed and their dominant species identified. Wetland indicator status was obtained, if available, for each species and recorded on the field data sheet. If greater than 50 percent of the dominant species in the plant community were observed to have an

indicator status of facultative (FAC) or wetter (FACW, OBL), then a hydrophytic vegetative community was determined to be present.

2. Prospective wetland areas were examined for the presence of hydrology. If wetland hydrologic indicators (surface water, high water table, saturation, etc.) were observed, then sufficient hydrology for the existence of wetlands was determined to be present.

3. Auger borings of the soil substrate in the prospective wetland areas were examined in multiple locations. The characteristics of the soil were compared to hydric soil indicators as prescribed by the 2012 Regional Supplement. If the soils were observed to have positive hydric soil indicators (depleted matrix, histosol, aquatic moisture regime, low chroma colors, etc.), then hydric soil was determined to be present.

4. If all the above characteristics (hydrophytic vegetation, hydrology, and hydric soils) were found to be present in a prospective wetland area, the area was defined and delineated as a wetland. If the any of the above characteristics were not found in a prospective wetland area, then the area is not considered a wetland. Given the farmed nature of some wetlands and their lack of hydrophytic vegetation, best professional judgement was used in determining wetland presence/absence.

Findings:

Desktop Findings: National Wetlands Inventory map indicated the presence of one linear waterway within the project t area. FEMA-mapped floodplains occur on site (Map Panel Number: 24025C0110E). Soil Survey information was obtained from the USDA National Resource Conservation Service online soil survey mapping website. The following soil types were identified for the project area and are shown on the Wetland Investigation Site Plan:

- GfB: Gladstone Urban Land complex, 0-8% slopes
- GfC: Gladstone Urban Land complex, 8-15% slopes
- Ha:Hatboro-Codorus silt loams, 0-3% slopes
- LoC: Legore-Montalto-Urban Land Complex, 8-15% slopes
- MoB: Mount Lucas silt loam, 3-8% slopes, stony

On-Site Findings: Wetland delineation field activities were conducted on April 27, 2020, Haley Kelly (Professional Wetland Scientist), an Ecotone environmental scientist trained in wetland delineation. During the site visit, it was determined that nontidal wetlands and waters of the U.S. exist on the site. Within the proposed project area, wetland boundaries and stream top-of-bank were identified in the field and located with a Leica GPS unit.

All resources have been located on the attached Existing Conditions Plan. Data were recorded on Wetland Determination Data Forms. A color photographic log depicting the wetland habitats observed during the field effort are included with this report. Presented below are the findings of the on-site wetland identification:

Nine non-tidal wetlands were identified within or adjacent to the project area:

Wetland 1 (approximately 2,904 square feet) is in the northern portion of the project area along the unnamed tributary to Plumtree Branch. It is a forested wetland dominated by box elder (*Acer negundo),* lesser celandine (*Ranunculus ficaria),* reed canary grass *(Phalaris arundinacea),* wild geranium (*Geranium maculatum),* and lurid sedge (*Carex lurida).* Hydrology is associated with surface water, high water table, and saturation. Soils in Wetland 1 meet hydric soil indicator F6 (Redox Dark Surface) and F7 (Depleted Dark Surface).

Wetland 2 (approximately 9,182 square feet) is in the northern portion of the project area along the unnamed tributary to Plumtree Branch. It is a forested wetland dominated by box elder, multiflora rose (*Rosa multiflora),* lesser celandine*,* reed canary grass*,* wild geranium*,* and lurid sedge*.* Hydrology is associated with surface water, high water table, and saturation. Soils in Wetland 1 meet hydric soil indicator F6 (Redox Dark Surface) and F7 (Depleted Dark Surface).

Wetland 3 (approximately 571square feet) is located in the central portion of the site along the west bank of Plumtree Branch. This floodplain depression wetland is dominated by red maple (*Acer rubrum),* multiflora rose, lesser celandine, and Japanese stilt grass (*Microstegium vimineum)*. Wetland hydrology is indicated by saturation, water-stained leaves, and low geomorphic position. Soils meet the F7 hydric soil indicator.

Wetland 3B (approximately 240 square feet) is located in the central portion of the site along the west bank of Plumtree Branch. This floodplain depression wetland is dominated by red maple (*Acer rubrum),* multiflora rose, lesser celandine, and ground ivy (*Glechoma hederacea)*. Wetland hydrology is indicated by saturation, water-stained leaves, and low geomorphic position. Soils meet the F7 hydric soil indicator.

Wetland 4 (approximately 37,862 square feet) is in the south-central portion of the site along the western bank of Plumtree Branch. This floodplain wetland is split evenly between forested and emergent wetland. The vegetative community can be summarized by red maple, lesser celandine, tussock sedge (*Carex stricta),* lurid sedge, and reed canary grass. Wetland hydrology was indicated by saturation, high water table, surface water, and water-stained leaves. Soils meet the F7 hydric soil indicator.

Wetland 5 (approximately 4,945 square feet) is in the southern portion of the site along the western bank of Plumtree Branch. This floodplain wetland is predominantly emergent (PEM) wetland with scattered trees throughout. The vegetative community can be summarized by scattered red maple and pin oak (*Quercus palustris)*, multiflora rose, reed canary grass, lesser celandine, lurid sedge and skunk cabbage (*Symplocarpus foetidus)*. Wetland hydrology was indicated by saturation, high water table, and surface water. Soils meet the F7 hydric soil indicator.

Wetland 6 (approximately 25,427 square feet) is in the southern portion of the site along the western bank of Plumtree Branch. This wetland has forested (PFO) and emergent portions (PEM). The vegetative community can be summarized by box elder, black willow (*Salix nigra),* and reed canary grass. Wetland hydrology was indicated by saturation, high water table, low geomorphic position, and drainage patterns. Soils meet the F7 hydric soil indicator.

Wetland 7 (approximately 71,843 square feet) is located in the southern portion of the site on the eastern bank of Plumtree Branch. This toe-of-slope, floodplain wetland is a predominantly emergent wetland (PEM). The wetland is dominated by reed canary grass and lesser celandine. Wetland hydrology is indicated by surface water, saturation, hydrogen sulfide odor, drainage patterns, and low geomorphic position. Soils consist of mineral layers with redox concentrations typical of an F3 hydric soil indicator and A4 indicator (Hydrogen sulfide).

Wetland 8 (approximately 120,629 square feet) is a toe-of-slope, floodplain wetland in the central portion of the site along the eastern bank of Plumtree Branch. The wetland is dominated by emergent vegetation in the south and forested in the north. Vegetation is dominated by red maple, box elder, multiflora rose, tussock sedge, lurid sedge, and reed canary grass. Wetland hydrology is indicated by high water table, surface water, saturation, hydrogen sulfide, drainage patterns, and low geomorphic position. Soils consist of mineral layers with redox concentrations typical of an F3 hydric soil indicator and A4 indicator (Hydrogen sulfide).

Waters of the U.S. include the following:

Plumtree Branch is an approximately 2,447-linear foot, perennial waterway located in the central portion of the site. The stream enters the project area from the north and flows south until it exits the project area via two 108” culverts under Columbia Road. The stream appears to have been historically straightened is currently experiencing significant bank erosion.

Plumtree Branch Tributary is an approximately 1,016 linear foot, perennial waterway located in the northern portion of the site. It daylights from a storm drain just north of the project boundary and flows down a concrete spillway before transitioning to a natural channel. It continues to flow southwest towards its confluence with Plumtree Branch. This tributary is also experiencing significant bank erosion.

Unnamed Tributary 1 is an approximately 62-linear foot, perennial waterway located in the central portion of the site along the western bank of Plumtree Branch. It enters the project area from the west and flows through a ravine to its confluence with Plumtree Branch.

Unnamed Tributary 2 is an approximately 142-linear foot, perennial waterway in the central portion of the site along the easter bank of Plumtree Branch. It originates just off-the property flows west to its confluence with UT First Mine Branch. This tributary was part of a previous restoration as evidenced by the presence of imbricated rock.

Uplands adjacent to these wetlands are characterized by depleted soils with some redoxomorphic features. The vegetative communities in these areas are similar to the vegetative communities in the neighboring wetlands and include typical floodplain species including box elder, red maple, black willow and reed canary grass. Hydrological indicators in these areas are lacking.

Conclusions:

On-site, there are nine non-tidal wetlands and three unnamed tributaries in addition to Plumtree Branch. Collectively there are approximately 6.28 acres of non-tidal wetland and 3,667 linear feet of stream. Final determination of the limits of Federal/State jurisdiction is the shared responsibility of the U.S. Army Corps of Engineers and Maryland Department of the Environment. If the proposed activities on the property require work within these jurisdictional areas and their applicable buffers, application for approvals from these agencies will be submitted.

WETLAND DETERMINATION DATA FORM- Eastern Mountains and Piedmont

Project/Site: Plumtree Branch/Dunloggin Middle School City/County: Ellicott City, Howard Co. Sampling Date: 4/27/20

Applicant/Owner: Howard County Dept. of Parks and Recreation State: MD Sampling Point: DP-1

Investigator(s): HK Section,Township, Range:

Landform (hillslope, terrace, etc.) Floodplain Local relief (concave, convex, none): Concave Slope (%): 0%

Subregion (LRR or MLRA): LRR S Lat: 39.2557 Long: -76.8344 Datum: WGS84

Soil Map Unit Name: Mob (Mount Lucas Silt Loam, 3-8% slopes, very rocky) NWI classification: N/A

Are climatic / hydrologic conditions on the site typical for this time of year? Yes ☑ No ☐ (If no, explain in Remarks.)

Are Vegetation N , Soil N , or Hydrology N Significantly disturbed? Are "Normal Circumstances" present? Yes ☑ No ☐

Are Vegetation N , Soil N , or Hydrology N Naturally problematic? (If needed, explain any answers in Remarks.)

SUMMARY OF FINDINGS - Attach site map showing sampling point locations, transects, important features, etc.

Hydrophytic Vegetation Present? Yes ☑ No ☐

Hydric Soil Present? Yes ☐ No ☑

Wetland Hydrology Present? Yes ☑ No ☐

Is the Sampled Area within a Wetland? Yes ☐ No ☑

Remarks:

Approximately 2" of rain fell on the site the night before the delineation. Saturation was not used as a sole indicator of hydrology.

HYDROLOGY

Wetland Hydrology Indicators:

Primary Indicators (minimum of one is required: check all that apply)

- ☑ Surface Water (A1)
- ☑ High Water Table (A2)
- ☑ Saturation (A3)
- ☐ Water marks (B1)
- ☐ Sediment Deposits (B2)
- ☐ Drift Deposits (B3)
- ☐ Algal Mat or Crust (B4)
- ☐ Iron Deposits (B5)
- ☐ Inundation Visible on Aerial Imagery (B7)
- ☐ Water-Stained Leaves (B9)
- ☐ Aquatic Fauna (B13)
- ☐ True Aquatic Plants (B14)
- ☐ Hydrogen Sulfide Odor (C1)
- ☐ Oxidized Rhizospheres on Living Roots (C3)
- ☐ Presence of Reduced Iron (C4)
- ☐ Recent Iron Reduction in Tilled Soils (C6)
- ☐ Thin Muck Surface (C7)
- ☐ Other (Explain in Remarks)

Secondary Indicators (minimum of two required)

- ☐ Surface Soil Cracks (B6)
- ☐ Sparsely Vegetated Concave Surface (B8)
- ☐ Drainage Patterns (B10)
- ☐ Moss Trim Lines (B16)
- ☐ Dry-Season Water Table (C2)
- ☐ Crayfish Burrows (C8)
- ☐ Saturation Visible on Aerial Imagery (C9)
- ☐ Stunted or Stressed Plants (D1)
- ☐ Geomorphic Position (D2)
- ☐ Shallow Aquitard (D3)
- ☐ Microtopographic Relief (D4)
- ☐ FAC-Neutral Test (D5)

Field Observations:

Surface Water Present? Yes ☑ No ☐ Depth (inches): 1

Water Table Present? Yes ☑ No ☐ Depth (inches): 3

Saturation Present? (includes capillary fringe) Yes ☑ No ☐ Depth (inches): surface

Wetland Hydrology Present? Yes ☑ No ☐

Describe Recorded Data (stream gage, monitoring well, aerial photos, previous inspections), if available:

Remarks:

VEGETATION - Use scientific names of plants.

Sampling Point: DP-1

Tree Stratum (Plot size: 30 ft radius).	Absolute % Cover	Dominant Species?	Indicator Status
1. *Acer negundo*	5	Yes	FAC
2.			
3.			
4.			
5.			
6.			
7.			
50% total cover: 2.5% 20% total cover: 1.0%	5%	= Total Cover	

Sapling Stratum (Plot size: 15 ft radius).	Absolute % Cover	Dominant Species?	Indicator Status
1.			
2.			
3.			
4.			
5.			
6.			
7.			
50% total cover: 0.0% 20% total cover: 0.0%	0%	= Total Cover	

Shrub Stratum (Plot size: 15 ft radius).	Absolute % Cover	Dominant Species?	Indicator Status
1.			
2.			
3.			
4.			
5.			
6.			
7.			
50% total cover: 0.0% 20% total cover: 0.0%	0%	= Total Cover	

Herb Stratum (Plot size: 5 ft radius).	Absolute % Cover	Dominant Species?	Indicator Status
1. *Ranunculus ficaria*	30	Yes	FAC
2. *Phalaris arundinaceae*	30	Yes	FACW
3. *Stellaria media*	20	Yes	UPL
4. *Galium aparine*	10	No	FACU
5.			
6.			
7.			
8.			
9.			
10.			
11.			
12.			
50% total cover: 45.0% 20% total cover: 18.0%	90%	= Total Cover	

Woody Vine Stratum (Plot size: 30 ft radius).	Absolute % Cover	Dominant Species?	Indicator Status
1.			
2.			
3.			
4.			
7.			
50% total cover: 0.0% 20% total cover: 0.0%	0%	= Total Cover	

Domiance Test worksheet

Number of Dominant Species That are OBL, FACW, or FAC: 3 (A)

Total Number of Dominant Species Across All Strata: 4 (B)

Percent of Dominant Speices that are OBL, FACW, or FAC: 75.0% (A/B)

Prevalence Index worksheet

Total % Cover of:				Multiply by:
OBL species	0	X 1	=	0
FACW species	30	X 2	=	60
FAC species	35	X 3	=	105
FACU species	10	X 4	=	40
UPL species	20	X 5	=	100
Column Totals	95	(A)		305 (B)

Prevalence Index = B/A = 3.21%

Hydrophytic Vegetation Indicators:

- ☐ 1. Rapid Test of Hydrophytic Vegetation
- ☑ 2. Dominance Test is >50%
- ☐ 3. Prevalence Index is ≤3.0[1]
- ☐ 4. Morphological Adaptations[1] (Provide supporting data in Remarks or on a separte sheet)
- ☐ Problematic Hydrophytic Vegetation[1] (Explain)

[1]Indicators of hydric soil and wetland hydrology must be present, unless disturbed or problematic.

Definitions of Vegetation Strata:

Tree - Woody plants, excluding woody vines, approximately 20 ft (6 m) or more in height and 3 in. (7.6 cm) or larger in diameter at breast height (DBH).

Sapling - Woody plants, excluding woody vines, approximately 20 ft (6 m) or more in height and less then 3 in. (7.6 cm) DBH.

Shrub - Woody plants, excluding woody vines, approximately 3 to 20 ft (1 to 6 m) in height.

Herb - All herbaceous (non-woody) plants, including herbaceous vines, regardless of size, and and woody plants, except woody vines, less than approximately 3 ft (1 m) in height

Woody Vine - All woody vines, regardless of height.

Hydropytic Vegetation Present? Yes ☑ No ☐

Remarks: (If observed, list morphological adaptations below).

Soils

Sampling Point: DP-1

Profile Description: (Describe to the depth needed to document the indicator or confirm the absence of indicators.)

Depth (inches)	Matrix Color (moist)	Matrix %	Redox Features Color (moist)	Redox %	Type[1]	Loc[2]	Texture	Remarks
0-15	10YR 4/2	100					clay loam	

[1]Type: C=Concentration, D=Depletion, RM=Reduced Matrix, MS=Masked Sand Grains. [2]Location: PL=Pore Lining, M=Matrix

Hydric Soil Indicators:

- ☐ Histosol (A1)
- ☐ Histic Epipedon (A2)
- ☐ Black Histic (A3)
- ☐ Hydrogen Sulfide (A4)
- ☐ Stratified Layers (A5)
- ☐ 2 cm Muck (A10) (LRR N)
- ☐ Depleted Below Dark Surface (A11)
- ☐ Thick Dark Surface (A12)
- ☐ Sandy Mucky Mineral (S1)(LRR N,MLRA 147,148)
- ☐ Sandy Gleyed Matrix (S4)
- ☐ Sandy Redox (S5)
- ☐ Stripped Matrix (S6)
- ☐ Dark Surface (S7)
- ☐ Polyvalue Below Surace (S8) (MLRA 147,148)
- ☐ Thin Dark Surface (S9) (MLRA 147, 148)
- ☐ Loamy Gleyed Matrix (F2)
- ☐ Depleted Matrix (F3)
- ☐ Redox Dark Surface (F6)
- ☐ Depleted Dark Surface (F7)
- ☐ Redox Depressions (F8)
- ☐ Iron-Manganese Masses (F12) (LRR N, MLRA 136)
- ☐ Umbric Surface (F13) (MLRA 136, 122)
- ☐ Piedmont Floodplain Soils (F19) (MLRA 148)
- ☐ Red Parent Material (F21) (MLRA 127, 147)

Indicators of Problematic Hydric Soils[3]:

- ☐ 2 cm Muck (A10) (MLRA 147)
- ☐ Coast Prairie Redox (A16) (MLRA 147, 148)
- ☐ Piedmont Floodplain Soils (F19) (MLRA 136, 147)
- ☐ Very Shallow Dark Surface (TF12)
- ☐ Other (Explain in Remarks):

[3]Indicators of hydrophytic vegetation and wetland hydrology must be present, unless disturbed or problematic.

Restrictive Layer (if observed):
Type:
Depth (inches):

Hydric Soil Present? Yes ☐ No ☑

Remarks:
Soils were very rocky.

WETLAND DETERMINATION DATA FORM- Eastern Mountains and Piedmont

Project/Site: Plumtree Branch/Dunloggin Middle School City/County: Ellicott City, Howard Co. Sampling Date: 4/27/20

Applicant/Owner: Howard County Dept. of Parks and Recreation State: MD Sampling Point: DP-2

Investigator(s): HK Section,Township, Range:

Landform (hillslope, terrace, etc.) Floodplain Local relief (concave, convex, none): Concave Slope (%): 0%

Subregion (LRR or MLRA): LRR S Lat: 39.2557 Long: -76.8344 Datum: WGS84

Soil Map Unit Name: Mob (Mount Lucas Silt Loam, 3-8% slopes, very rocky) NWI classification: N/A

Are climatic / hydrologic conditions on the site typical for this time of year? Yes ☑ No ☐ (If no, explain in Remarks.)

Are Vegetation N , Soil N , or Hydrology N Significantly disturbed? Are "Normal Circumstances" present? Yes ☑ No ☐

Are Vegetation N , Soil N , or Hydrology N Naturally problematic? (If needed, explain any answers in Remarks.)

SUMMARY OF FINDINGS - Attach site map showing sampling point locations, transects, important features, etc.

Hydrophytic Vegetation Present?	Yes ☑	No ☐		
Hydric Soil Present?	Yes ☑	No ☐	Is the Sampled Area	
Wetland Hydrology Present?	Yes ☑	No ☐	within a Wetland?	Yes ☑ No ☐

Remarks:

In Wetland 1. Approximately 2" of rain fell on the site the night before the delineation. Saturation was not used as a sole indicator of hydrology.

HYDROLOGY

Wetland Hydrology Indicators:

Primary Indicators (minimum of one is required: check all that apply)

- ☑ Surface Water (A1)
- ☑ High Water Table (A2)
- ☑ Saturation (A3)
- ☐ Water marks (B1)
- ☐ Sediment Deposits (B2)
- ☐ Drift Deposits (B3)
- ☐ Algal Mat or Crust (B4)
- ☐ Iron Deposits (B5)
- ☐ Inundation Visible on Aerial Imagery (B7)
- ☐ Water-Stained Leaves (B9)
- ☐ Aquatic Fauna (B13)
- ☐ True Aquatic Plants (B14)
- ☐ Hydrogen Sulfide Odor (C1)
- ☐ Oxidized Rhizospheres on Living Roots (C3)
- ☐ Presence of Reduced Iron (C4)
- ☐ Recent Iron Reduction in Tilled Soils (C6)
- ☐ Thin Muck Surface (C7)
- ☐ Other (Explain in Remarks)

Secondary Indicators (minimum of two required)

- ☐ Surface Soil Cracks (B6)
- ☐ Sparsely Vegetated Concave Surface (B8)
- ☐ Drainage Patterns (B10)
- ☐ Moss Trim Lines (B16)
- ☐ Dry-Season Water Table (C2)
- ☐ Crayfish Burrows (C8)
- ☐ Saturation Visible on Aerial Imagery (C9)
- ☐ Stunted or Stressed Plants (D1)
- ☐ Geomorphic Position (D2)
- ☐ Shallow Aquitard (D3)
- ☐ Microtopographic Relief (D4)
- ☐ FAC-Neutral Test (D5)

Field Observations:

Surface Water Present?	Yes ☑	No ☐	Depth (inches): 2
Water Table Present?	Yes ☑	No ☐	Depth (inches): 3
Saturation Present? (includes capillary fringe)	Yes ☑	No ☐	Depth (inches): surface

Wetland Hydrology Present? Yes ☑ No ☐

Describe Recorded Data (stream gage, monitoring well, aerial photos, previous inspections), if available:

Remarks:

On previous site visit, this area was observed to be saturated even without recent rain.

VEGETATION - Use scientific names of plants.

Sampling Point: DP-2

Tree Stratum (Plot size: 30 ft radius).	Absolute % Cover	Dominant Species?	Indicator Status
1. *Acer negundo*	15	Yes	FAC
2.			
3.			
4.			
5.			
6.			
7.			
50% total cover: 7.5% 20% total cover: 3.0%	15%	= Total Cover	

Sapling Stratum (Plot size: 15 ft radius).	Absolute % Cover	Dominant Species?	Indicator Status
1.			
2.			
3.			
4.			
5.			
6.			
7.			
50% total cover: 0.0% 20% total cover: 0.0%	0%	= Total Cover	

Shrub Stratum (Plot size: 15 ft radius).	Absolute % Cover	Dominant Species?	Indicator Status
1.			
2.			
3.			
4.			
5.			
6.			
7.			
50% total cover: 0.0% 20% total cover: 0.0%	0%	= Total Cover	

Herb Stratum (Plot size: 5 ft radius).	Absolute % Cover	Dominant Species?	Indicator Status
1. *Ranunculus ficaria*	30	Yes	FAC
2. *Phalaris arundinaceae*	10	Yes	FACW
3. *Geranium maculatum*	10	Yes	FACU
4. *Carex lurida*	10	Yes	OBL
5. *Lonicera japonica*	5	No	FAC
6. *Juncus effusus*	5	No	OBL
7. *Allium canadense*	5	No	FACU
8. *Viola sororia*	2	No	FAC
9. *Glechoma hederacea*	2	No	FACU
10.			
11.			
12.			
50% total cover: 39.5% 20% total cover: 15.8%	79%	= Total Cover	

Woody Vine Stratum (Plot size: 30 ft radius).	Absolute % Cover	Dominant Species?	Indicator Status
1.			
2.			
3.			
4.			
7.			
50% total cover: 0.0% 20% total cover: 0.0%	0%	= Total Cover	

Domiance Test worksheet

Number of Dominant Species That are OBL, FACW, or FAC: 4 (A)

Total Number of Dominant Species Across All Strata: 5 (B)

Percent of Dominant Speices that are OBL, FACW, or FAC: 80.0% (A/B)

Prevalence Index worksheet

Total % Cover of:		Multiply by:		
OBL species	15	X 1	=	15
FACW species	10	X 2	=	20
FAC species	52	X 3	=	156
FACU species	17	X 4	=	68
UPL species	0	X 5	=	0
Column Totals	94	(A)		259 (B)

Prevalence Index = B/A = 2.76%

Hydrophytic Vegetation Indicators:

- ☐ 1. Rapid Test of Hydrophytic Vegetation
- ☑ 2. Dominance Test is >50%
- ☑ 3. Prevalence Index is ≤3.0[1]
- ☐ 4. Morphological Adaptations[1] (Provide supporting data in Remarks or on a separte sheet)
- ☐ Problematic Hydrophytic Vegetation[1] (Explain)

[1]Indicators of hydric soil and wetland hydrology must be present, unless disturbed or problematic.

Definitions of Vegetation Strata:

Tree - Woody plants, excluding woody vines, approximately 20 ft (6 m) or more in height and 3 in. (7.6 cm) or larger in diameter at breast height (DBH).

Sapling - Woody plants, excluding woody vines, approximately 20 ft (6 m) or more in height and less then 3 in. (7.6 cm) DBH.

Shrub - Woody plants, excluding woody vines, approximately 3 to 20 ft (1 to 6 m) in height.

Herb - All herbaceous (non-woody) plants, including herbaceous vines, regardless of size, and and woody plants, except woody vines, less than approximately 3 ft (1 m) in height

Woody Vine - All woody vines, regardless of height.

Hydropytic Vegetation Present? Yes ☑ No ☐

Remarks: (If observed, list morphological adaptations below).

Soils

Sampling Point: DP-2

Profile Description: (Describe to the depth needed to document the indicator or confirm the absence of indicators.)

Depth	Matrix		Redox Features					
(inches)	Color (moist)	%	Color (moist)	%	Type[1]	Loc[2]	Texture	Remarks
0-3	10YR 3/2	100					clay	
3-12	10YR 3/2	70	2.5Y 4/1	20	D	M	clay	
			10YR 4/4	10	C	M		

[1]Type: C=Concentration, D=Depletion, RM=Reduced Matrix, MS=Masked Sand Grains. [2]Location: PL=Pore Lining, M=Matrix

Hydric Soil Indicators:

- ☐ Histosol (A1)
- ☐ Histic Epipedon (A2)
- ☐ Black Histic (A3)
- ☐ Hydrogen Sulfide (A4)
- ☐ Stratified Layers (A5)
- ☐ 2 cm Muck (A10) (LRR N)
- ☐ Depleted Below Dark Surface (A11)
- ☐ Thick Dark Surface (A12)
- ☐ Sandy Mucky Mineral (S1)(LRR N,MLRA 147,148)
- ☐ Sandy Gleyed Matrix (S4)
- ☐ Sandy Redox (S5)
- ☐ Stripped Matrix (S6)
- ☐ Dark Surface (S7)
- ☐ Polyvalue Below Surace (S8) (MLRA 147,148)
- ☐ Thin Dark Surface (S9) (MLRA 147, 148)
- ☐ Loamy Gleyed Matrix (F2)
- ☐ Depleted Matrix (F3)
- ☑ Redox Dark Surface (F6)
- ☑ Depleted Dark Surface (F7)
- ☐ Redox Depressions (F8)
- ☐ Iron-Manganese Masses (F12) (LRR N, MLRA 136)
- ☐ Umbric Surface (F13) (MLRA 136, 122)
- ☐ Piedmont Floodplain Soils (F19) (MLRA 148)
- ☐ Red Parent Material (F21) (MLRA 127, 147)

Indicators of Problematic Hydric Soils[3]:

- ☐ 2 cm Muck (A10) (MLRA 147)
- ☐ Coast Prairie Redox (A16) (MLRA 147, 148)
- ☐ Piedmont Floodplain Soils (F19) (MLRA 136, 147)
- ☐ Very Shallow Dark Surface (TF12)
- ☐ Other (Explain in Remarks):

[3]Indicators of hydrophytic vegetation and wetland hydrology must be present, unless disturbed or problematic.

Restrictive Layer (if observed):

Type:

Depth (inches):

Hydric Soil Present? Yes ☑ No ☐

Remarks:

WETLAND DETERMINATION DATA FORM- Eastern Mountains and Piedmont

Project/Site: Plumtree Branch/Dunloggin Middle School | City/County: Ellicott City, Howard Co. | Sampling Date: 4/27/20

Applicant/Owner: Howard County Dept. of Parks and Recreation | State: MD | Sampling Point: DP-3

Investigator(s): HK | Section,Township, Range:

Landform (hillslope, terrace, etc.) Floodplain | Local relief (concave, convex, none): Concave | Slope (%): 0%

Subregion (LRR or MLRA): LRR S | Lat: 39.2557 | Long: -76.8344 | Datum: WGS84

Soil Map Unit Name: Ha (Hatboro-Codorus Silt Loam, 0-3% slopes) | NWI classification: N/A

Are climatic / hydrologic conditions on the site typical for this time of year? Yes ☑ No ☐ (If no, explain in Remarks.)

Are Vegetation N , Soil N , or Hydrology N Significantly disturbed? Are "Normal Circumstances" present? Yes ☑ No ☐

Are Vegetation N , Soil N , or Hydrology N Naturally problematic? (If needed, explain any answers in Remarks.)

SUMMARY OF FINDINGS - Attach site map showing sampling point locations, transects, important features, etc.

Hydrophytic Vegetation Present?	Yes ☑	No ☐
Hydric Soil Present?	Yes ☑	No ☐
Wetland Hydrology Present?	Yes ☑	No ☐

Is the Sampled Area within a Wetland? Yes ☑ No ☐

Remarks:

In Wetland 2. Approximately 2" of rain fell on the site the night before the delineation. Saturation was not used as a sole indicator of hydrology.

HYDROLOGY

Wetland Hydrology Indicators:

Primary Indicators (minimum of one is required: check all that apply)

- ☑ Surface Water (A1)
- ☑ High Water Table (A2)
- ☑ Saturation (A3)
- ☐ Water marks (B1)
- ☐ Sediment Deposits (B2)
- ☐ Drift Deposits (B3)
- ☐ Algal Mat or Crust (B4)
- ☐ Iron Deposits (B5)
- ☐ Inundation Visible on Aerial Imagery (B7)
- ☐ Water-Stained Leaves (B9)
- ☐ Aquatic Fauna (B13)
- ☐ True Aquatic Plants (B14)
- ☐ Hydrogen Sulfide Odor (C1)
- ☐ Oxidized Rhizospheres on Living Roots (C3)
- ☐ Presence of Reduced Iron (C4)
- ☐ Recent Iron Reduction in Tilled Soils (C6)
- ☐ Thin Muck Surface (C7)
- ☐ Other (Explain in Remarks)

Secondary Indicators (minimum of two required)

- ☐ Surface Soil Cracks (B6)
- ☐ Sparsely Vegetated Concave Surface (B8)
- ☐ Drainage Patterns (B10)
- ☐ Moss Trim Lines (B16)
- ☐ Dry-Season Water Table (C2)
- ☐ Crayfish Burrows (C8)
- ☐ Saturation Visible on Aerial Imagery (C9)
- ☐ Stunted or Stressed Plants (D1)
- ☐ Geomorphic Position (D2)
- ☐ Shallow Aquitard (D3)
- ☐ Microtopographic Relief (D4)
- ☐ FAC-Neutral Test (D5)

Field Observations:

Surface Water Present?	Yes ☑	No ☐	Depth (inches): 2
Water Table Present?	Yes ☑	No ☐	Depth (inches): 3
Saturation Present? (includes capillary fringe)	Yes ☑	No ☐	Depth (inches): surface

Wetland Hydrology Present? Yes ☑ No ☐

Describe Recorded Data (stream gage, monitoring well, aerial photos, previous inspections), if available:

Remarks:

On previous site visit, this area was observed to be saturated even without recent rain.

VEGETATION - Use scientific names of plants.

Sampling Point: DP-3

Tree Stratum (Plot size: 30 ft radius).	Absolute % Cover	Dominant Species?	Indicator Status
1. *Acer negundo*	15	Yes	FAC
2.			
3.			
4.			
5.			
6.			
7.			
50% total cover: 7.5% 20% total cover: 3.0%	15%	= Total Cover	

Sapling Stratum (Plot size: 15 ft radius).	Absolute % Cover	Dominant Species?	Indicator Status
1.			
2.			
3.			
4.			
5.			
6.			
7.			
50% total cover: 0.0% 20% total cover: 0.0%	0%	= Total Cover	

Shrub Stratum (Plot size: 15 ft radius).	Absolute % Cover	Dominant Species?	Indicator Status
1. *Rosa multiflora*	10	Yes	FACU
2.			
3.			
4.			
5.			
6.			
7.			
50% total cover: 5.0% 20% total cover: 2.0%	10%	= Total Cover	

Herb Stratum (Plot size: 5 ft radius).	Absolute % Cover	Dominant Species?	Indicator Status
1. *Ranunculus ficaria*	25	Yes	FAC
2. *Phalaris arundinaceae*	10	Yes	FACW
3. *Geranium maculatum*	10	Yes	FACU
4. *Carex lurida*	10	Yes	OBL
5. *Lysimachia nummularia*	10	No	FACW
6. *Arisaema triphyllum*	5	No	FACW
7. *Carex stricta*	5	No	OBL
8. *Lonicera japonica*	5	No	FAC
9. *Juncus effusus*	5	No	OBL
10. *Allium canadense*	2	No	FACU
11. *Viola sororia*	2	No	FAC
12. *Glechoma hederacea*	2	No	FACU
50% total cover: 45.5% 20% total cover: 18.2%	91%	= Total Cover	

Woody Vine Stratum (Plot size: 30 ft radius).	Absolute % Cover	Dominant Species?	Indicator Status
1.			
2.			
3.			
4.			
7.			
50% total cover: 0.0% 20% total cover: 0.0%	0%	= Total Cover	

Domiance Test worksheet

Number of Dominant Species That are OBL, FACW, or FAC: 4 (A)

Total Number of Dominant Species Across All Strata: 6 (B)

Percent of Dominant Speices that are OBL, FACW, or FAC: 66.7% (A/B)

Prevalence Index worksheet

Total % Cover of:		Multiply by:		
OBL species	20	X 1	=	20
FACW species	25	X 2	=	50
FAC species	47	X 3	=	141
FACU species	24	X 4	=	96
UPL species	0	X 5	=	0
Column Totals	116	(A)		307 (B)

Prevalence Index = B/A = 2.65%

Hydrophytic Vegetation Indicators:

- ☐ 1. Rapid Test of Hydrophytic Vegetation
- ☑ 2. Dominance Test is >50%
- ☑ 3. Prevalence Index is ≤3.0[1]
- ☐ 4. Morphological Adaptations[1] (Provide supporting data in Remarks or on a separte sheet)
- ☐ Problematic Hydrophytic Vegetation[1] (Explain)

[1]Indicators of hydric soil and wetland hydrology must be present, unless disturbed or problematic.

Definitions of Vegetation Strata:

Tree - Woody plants, excluding woody vines, approximately 20 ft (6 m) or more in height and 3 in. (7.6 cm) or larger in diameter at breast height (DBH).

Sapling - Woody plants, excluding woody vines, approximately 20 ft (6 m) or more in height and less then 3 in. (7.6 cm) DBH.

Shrub - Woody plants, excluding woody vines, approximately 3 to 20 ft (1 to 6 m) in height.

Herb - All herbaceous (non-woody) plants, including herbaceous vines, regardless of size, and and woody plants, except woody vines, less than approximately 3 ft (1 m) in height

Woody Vine - All woody vines, regardless of height.

Hydropytic Vegetation Present? Yes ☑ No ☐

Remarks: (If observed, list morphological adaptations below).

Soils

Sampling Point: DP-3

Profile Description: (Describe to the depth needed to document the indicator or confirm the absence of indicators.)

Depth	Matrix		Redox Features					
(inches)	Color (moist)	%	Color (moist)	%	Type¹	Loc²	Texture	Remarks
0-3	10YR 3/2	100					clay	
3-12	10YR 3/2	70	2.5Y 4/1	20	D	M	clay	
			10YR 4/4	10	C	M		

¹Type: C=Concentration, D=Depletion, RM=Reduced Matrix, MS=Masked Sand Grains. [2]Location: PL=Pore Lining, M=Matrix

Hydric Soil Indicators:

- ☐ Histosol (A1)
- ☐ Histic Epipedon (A2)
- ☐ Black Histic (A3)
- ☐ Hydrogen Sulfide (A4)
- ☐ Stratified Layers (A5)
- ☐ 2 cm Muck (A10) (LRR N)
- ☐ Depleted Below Dark Surface (A11)
- ☐ Thick Dark Surface (A12)
- ☐ Sandy Mucky Mineral (S1)(LRR N,MLRA 147,148)
- ☐ Sandy Gleyed Matrix (S4)
- ☐ Sandy Redox (S5)
- ☐ Stripped Matrix (S6)
- ☐ Dark Surface (S7)
- ☐ Polyvalue Below Surace (S8) (MLRA 147,148)
- ☐ Thin Dark Surface (S9) (MLRA 147, 148)
- ☐ Loamy Gleyed Matrix (F2)
- ☐ Depleted Matrix (F3)
- ☑ Redox Dark Surface (F6)
- ☑ Depleted Dark Surface (F7)
- ☐ Redox Depressions (F8)
- ☐ Iron-Manganese Masses (F12) (LRR N, MLRA 136)
- ☐ Umbric Surface (F13) (MLRA 136, 122)
- ☐ Piedmont Floodplain Soils (F19) (MLRA 148)
- ☐ Red Parent Material (F21) (MLRA 127, 147)

Indicators of Problematic Hydric Soils[3]:

- ☐ 2 cm Muck (A10) (MLRA 147)
- ☐ Coast Prairie Redox (A16) (MLRA 147, 148)
- ☐ Piedmont Floodplain Soils (F19) (MLRA 136, 147)
- ☐ Very Shallow Dark Surface (TF12)
- ☐ Other (Explain in Remarks):

[3]Indicators of hydrophytic vegetation and wetland hydrology must be present, unless disturbed or problematic.

Restrictive Layer (if observed):
Type:
Depth (inches):

Hydric Soil Present? Yes ☑ No ☐

Remarks:

WETLAND DETERMINATION DATA FORM- Eastern Mountains and Piedmont

Project/Site: Plumtree Branch/Dunloggin Middle School — City/County: Ellicott City, Howard Co. — Sampling Date: 4/27/20

Applicant/Owner: Howard County Dept. of Parks and Recreation — State: MD — Sampling Point: DP-4

Investigator(s): HK — Section,Township, Range:

Landform (hillslope, terrace, etc.) Floodplain — Local relief (concave, convex, none): Concave — Slope (%): 0%

Subregion (LRR or MLRA): LRR S — Lat: 39.2557 — Long: -76.8344 — Datum: WGS84

Soil Map Unit Name: Ha (Hatboro-Codorus Silt loam, 0-3% slopes) — NWI classification: N/A

Are climatic / hydrologic conditions on the site typical for this time of year? Yes ☑ No ☐ (If no, explain in Remarks.)

Are Vegetation N , Soil N , or Hydrology N Significantly disturbed? — Are "Normal Circumstances" present? Yes ☑ No ☐

Are Vegetation N , Soil N , or Hydrology N Naturally problematic? — (If needed, explain any answers in Remarks.)

SUMMARY OF FINDINGS - Attach site map showing sampling point locations, transects, important features, etc.

Hydrophytic Vegetation Present?	Yes ☑	No ☐
Hydric Soil Present?	Yes ☐	No ☑
Wetland Hydrology Present?	Yes ☐	No ☑

Is the Sampled Area within a Wetland? Yes ☐ No ☑

Remarks:

Approximately 2" of rain fell on the site the night before the delineation. Saturation was not used as a sole indicator of hydrology.

HYDROLOGY

Wetland Hydrology Indicators:

Primary Indicators (minimum of one is required: check all that apply)

- ☐ Surface Water (A1)
- ☐ High Water Table (A2)
- ☐ Saturation (A3)
- ☐ Water marks (B1)
- ☐ Sediment Deposits (B2)
- ☐ Drift Deposits (B3)
- ☐ Algal Mat or Crust (B4)
- ☐ Iron Deposits (B5)
- ☐ Inundation Visible on Aerial Imagery (B7)
- ☐ Water-Stained Leaves (B9)
- ☐ Aquatic Fauna (B13)
- ☐ True Aquatic Plants (B14)
- ☐ Hydrogen Sulfide Odor (C1)
- ☐ Oxidized Rhizospheres on Living Roots (C3)
- ☐ Presence of Reduced Iron (C4)
- ☐ Recent Iron Reduction in Tilled Soils (C6)
- ☐ Thin Muck Surface (C7)
- ☐ Other (Explain in Remarks)

Secondary Indicators (minimum of two required)

- ☐ Surface Soil Cracks (B6)
- ☐ Sparsely Vegetated Concave Surface (B8)
- ☐ Drainage Patterns (B10)
- ☐ Moss Trim Lines (B16)
- ☐ Dry-Season Water Table (C2)
- ☐ Crayfish Burrows (C8)
- ☐ Saturation Visible on Aerial Imagery (C9)
- ☐ Stunted or Stressed Plants (D1)
- ☐ Geomorphic Position (D2)
- ☐ Shallow Aquitard (D3)
- ☐ Microtopographic Relief (D4)
- ☐ FAC-Neutral Test (D5)

Field Observations:

Surface Water Present?	Yes ☐	No ☑	Depth (inches):
Water Table Present?	Yes ☐	No ☑	Depth (inches):
Saturation Present? (includes capillary fringe)	Yes ☐	No ☑	Depth (inches):

Wetland Hydrology Present? Yes ☐ No ☑

Describe Recorded Data (stream gage, monitoring well, aerial photos, previous inspections), if available:

Remarks:

VEGETATION - Use scientific names of plants.

Sampling Point: DP-4

Tree Stratum (Plot size: 30 ft radius).	Absolute % Cover	Dominant Species?	Indicator Status
1.			
2.			
3.			
4.			
5.			
6.			
7.			
50% total cover: 0.0% 20% total cover: 0.0%	0%	= Total Cover	

Sapling Stratum (Plot size: 15 ft radius).	Absolute % Cover	Dominant Species?	Indicator Status
1. *Acer rubrum*	5	Yes	FAC
2. *Fraxinus pensylvanica*	5	Yes	FACW
3. *Acer negundo*	5	Yes	FAC
4.			
5.			
6.			
7.			
50% total cover: 7.5% 20% total cover: 3.0%	15%	= Total Cover	

Shrub Stratum (Plot size: 15 ft radius).	Absolute % Cover	Dominant Species?	Indicator Status
1.			
2.			
3.			
4.			
5.			
6.			
7.			
50% total cover: 0.0% 20% total cover: 0.0%	0%	= Total Cover	

Herb Stratum (Plot size: 5 ft radius).	Absolute % Cover	Dominant Species?	Indicator Status
1. *Ranunculus ficaria*	50	Yes	FAC
2. *Glechoma hederacea*	25	Yes	FACU
3. *Festuca rubra*	10	No	FACU
4. *Carex stricta*	10	No	OBL
5.			
6.			
7.			
8.			
9.			
10.			
11.			
12.			
50% total cover: 47.5% 20% total cover: 19.0%	95%	= Total Cover	

Woody Vine Stratum (Plot size: 30 ft radius).	Absolute % Cover	Dominant Species?	Indicator Status
1.			
2.			
3.			
4.			
7.			
50% total cover: 0.0% 20% total cover: 0.0%	0%	= Total Cover	

Domiance Test worksheet

Number of Dominant Species That are OBL, FACW, or FAC: 4 (A)

Total Number of Dominant Species Across All Strata: 5 (B)

Percent of Dominant Speices that are OBL, FACW, or FAC: 80.0% (A/B)

Prevalence Index worksheet

Total % Cover of:		Multiply by:		
OBL species	10	X 1	=	10
FACW species	5	X 2	=	10
FAC species	60	X 3	=	180
FACU species	35	X 4	=	140
UPL species	0	X 5	=	0
Column Totals	110	(A)		340 (B)

Prevalence Index = B/A = 3.09%

Hydrophytic Vegetation Indicators:

- ☐ 1. Rapid Test of Hydrophytic Vegetation
- ☑ 2. Dominance Test is >50%
- ☐ 3. Prevalence Index is ≤3.0[1]
- ☐ 4. Morphological Adaptations[1] (Provide supporting data in Remarks or on a separte sheet)
- ☐ Problematic Hydrophytic Vegetation[1] (Explain)

[1]Indicators of hydric soil and wetland hydrology must be present, unless disturbed or problematic.

Definitions of Vegetation Strata:

Tree - Woody plants, excluding woody vines, approximately 20 ft (6 m) or more in height and 3 in. (7.6 cm) or larger in diameter at breast height (DBH).

Sapling - Woody plants, excluding woody vines, approximately 20 ft (6 m) or more in height and less then 3 in. (7.6 cm) DBH.

Shrub - Woody plants, excluding woody vines, approximately 3 to 20 ft (1 to 6 m) in height.

Herb - All herbaceous (non-woody) plants, including herbaceous vines, regardless of size, and and woody plants, except woody vines, less than approximately 3 ft (1 m) in height

Woody Vine - All woody vines, regardless of height.

Hydropytic Vegetation Present? Yes ☑ No ☐

Remarks: (If observed, list morphological adaptations below).

Soils

Sampling Point: DP-4

Profile Description: (Describe to the depth needed to document the indicator or confirm the absence of indicators.)

Depth	Matrix		Redox Features					
(inches)	Color (moist)	%	Color (moist)	%	Type[1]	Loc[2]	Texture	Remarks
0-4	10YR 3/2	100					clay	
4-10	10YR 4/4	95	10YR 4/6	5	C	M	clay	

[1]Type: C=Concentration, D=Depletion, RM=Reduced Matrix, MS=Masked Sand Grains. [2]Location: PL=Pore Lining, M=Matrix

Hydric Soil Indicators:

- ☐ Histosol (A1)
- ☐ Histic Epipedon (A2)
- ☐ Black Histic (A3)
- ☐ Hydrogen Sulfide (A4)
- ☐ Stratified Layers (A5)
- ☐ 2 cm Muck (A10) (LRR N)
- ☐ Depleted Below Dark Surface (A11)
- ☐ Thick Dark Surface (A12)
- ☐ Sandy Mucky Mineral (S1)(LRR N,MLRA 147,148)
- ☐ Sandy Gleyed Matrix (S4)
- ☐ Sandy Redox (S5)
- ☐ Stripped Matrix (S6)
- ☐ Dark Surface (S7)
- ☐ Polyvalue Below Surace (S8) (MLRA 147,148)
- ☐ Thin Dark Surface (S9) (MLRA 147, 148)
- ☐ Loamy Gleyed Matrix (F2)
- ☐ Depleted Matrix (F3)
- ☐ Redox Dark Surface (F6)
- ☐ Depleted Dark Surface (F7)
- ☐ Redox Depressions (F8)
- ☐ Iron-Manganese Masses (F12) (LRR N, MLRA 136)
- ☐ Umbric Surface (F13) (MLRA 136, 122)
- ☐ Piedmont Floodplain Soils (F19) (MLRA 148)
- ☐ Red Parent Material (F21) (MLRA 127, 147)

Indicators of Problematic Hydric Soils[3]:

- ☐ 2 cm Muck (A10) (MLRA 147)
- ☐ Coast Prairie Redox (A16) (MLRA 147, 148)
- ☐ Piedmont Floodplain Soils (F19) (MLRA 136, 147)
- ☐ Very Shallow Dark Surface (TF12)
- ☐ Other (Explain in Remarks):

[3]Indicators of hydrophytic vegetation and wetland hydrology must be present, unless disturbed or problematic.

Restrictive Layer (if observed):
Type:
Depth (inches):

Hydric Soil Present? Yes ☐ No ☑

Remarks:

WETLAND DETERMINATION DATA FORM- Eastern Mountains and Piedmont

Project/Site: Plumtree Branch/Dunloggin Middle School | City/County: Ellicott City, Howard Co. | Sampling Date: 4/27/20

Applicant/Owner: Howard County Dept. of Parks and Recreation | State: MD | Sampling Point: DP-5

Investigator(s): HK | Section,Township, Range:

Landform (hillslope, terrace, etc.) Floodplain | Local relief (concave, convex, none): Concave | Slope (%): 0%

Subregion (LRR or MLRA): LRR S | Lat: 39.2557 | Long: -76.8344 | Datum: WGS84

Soil Map Unit Name: Ha (Hatboro-Codorus Silt Loam, 0-3% slope) | NWI classification: N/A

Are climatic / hydrologic conditions on the site typical for this time of year? Yes ☑ No ☐ (If no, explain in Remarks.)

Are Vegetation N , Soil N , or Hydrology N Significantly disturbed? Are "Normal Circumstances" present? Yes ☑ No ☐

Are Vegetation N , Soil N , or Hydrology N Naturally problematic? (If needed, explain any answers in Remarks.)

SUMMARY OF FINDINGS - Attach site map showing sampling point locations, transects, important features, etc.

	Yes	No
Hydrophytic Vegetation Present?	☑	☐
Hydric Soil Present?	☑	☐
Wetland Hydrology Present?	☐	☑

Is the Sampled Area within a Wetland? Yes ☐ No ☑

Remarks:

Approximately 2" of rain fell on the site the night before the delineation. Saturation was not used as a sole indicator of wetland hydrology.

HYDROLOGY

Wetland Hydrology Indicators:

Primary Indicators (minimum of one is required: check all that apply)

- ☐ Surface Water (A1)
- ☐ High Water Table (A2)
- ☐ Saturation (A3)
- ☐ Water marks (B1)
- ☐ Sediment Deposits (B2)
- ☐ Drift Deposits (B3)
- ☐ Algal Mat or Crust (B4)
- ☐ Iron Deposits (B5)
- ☐ Inundation Visible on Aerial Imagery (B7)
- ☐ Water-Stained Leaves (B9)
- ☐ Aquatic Fauna (B13)
- ☐ True Aquatic Plants (B14)
- ☐ Hydrogen Sulfide Odor (C1)
- ☐ Oxidized Rhizospheres on Living Roots (C3)
- ☐ Presence of Reduced Iron (C4)
- ☐ Recent Iron Reduction in Tilled Soils (C6)
- ☐ Thin Muck Surface (C7)
- ☐ Other (Explain in Remarks)

Secondary Indicators (minimum of two required)

- ☐ Surface Soil Cracks (B6)
- ☐ Sparsely Vegetated Concave Surface (B8)
- ☐ Drainage Patterns (B10)
- ☐ Moss Trim Lines (B16)
- ☐ Dry-Season Water Table (C2)
- ☐ Crayfish Burrows (C8)
- ☐ Saturation Visible on Aerial Imagery (C9)
- ☐ Stunted or Stressed Plants (D1)
- ☑ Geomorphic Position (D2)
- ☐ Shallow Aquitard (D3)
- ☐ Microtopographic Relief (D4)
- ☐ FAC-Neutral Test (D5)

Field Observations:

	Yes	No	Depth (inches):
Surface Water Present?	☐	☑	
Water Table Present?	☐	☑	
Saturation Present? (includes capillary fringe)	☐	☑	

Wetland Hydrology Present? Yes ☐ No ☑

Describe Recorded Data (stream gage, monitoring well, aerial photos, previous inspections), if available:

Remarks:

VEGETATION - Use scientific names of plants.

Sampling Point: DP-5

Tree Stratum (Plot size: 30 ft radius).	Absolute % Cover	Dominant Species?	Indicator Status
1. *Quercus palustris*	5	Yes	FACW
2.			
3.			
4.			
5.			
6.			
7.			
50% total cover: 2.5% 20% total cover: 1.0%	5%	= Total Cover	

Sapling Stratum (Plot size: 15 ft radius).	Absolute % Cover	Dominant Species?	Indicator Status
1. *Acer negundo*	5	Yes	FAC
2.			
3.			
4.			
5.			
6.			
7.			
50% total cover: 2.5% 20% total cover: 1.0%	5%	= Total Cover	

Shrub Stratum (Plot size: 15 ft radius).	Absolute % Cover	Dominant Species?	Indicator Status
1.			
2.			
3.			
4.			
5.			
6.			
7.			
50% total cover: 0.0% 20% total cover: 0.0%	0%	= Total Cover	

Herb Stratum (Plot size: 5 ft radius).	Absolute % Cover	Dominant Species?	Indicator Status
1. *Ranunculus ficaria*	50	Yes	FAC
2. *Glechoma hederacea*	15	No	FACU
3. *Symplocarpus foetidus*	15	No	OBL
4. *Phalaris arundinacea*	10	No	FACW
5.			
6.			
7.			
8.			
9.			
10.			
11.			
12.			
50% total cover: 45.0% 20% total cover: 18.0%	90%	= Total Cover	

Woody Vine Stratum (Plot size: 30 ft radius).	Absolute % Cover	Dominant Species?	Indicator Status
1. *Vitis riparia*	5	Yes	FACW
2.			
3.			
4.			
7.			
50% total cover: 2.5% 20% total cover: 1.0%	5%	= Total Cover	

Domiance Test worksheet

Number of Dominant Species That are OBL, FACW, or FAC: 4 (A)

Total Number of Dominant Species Across All Strata: 4 (B)

Percent of Dominant Speices that are OBL, FACW, or FAC: 100.0% (A/B)

Prevalence Index worksheet

Total % Cover of:				Multiply by:
OBL species	15	X 1	=	15
FACW species	20	X 2	=	40
FAC species	55	X 3	=	165
FACU species	15	X 4	=	60
UPL species	0	X 5	=	0
Column Totals	105	(A)		280 (B)

Prevalence Index = B/A = 2.67%

Hydrophytic Vegetation Indicators:

- ☐ 1. Rapid Test of Hydrophytic Vegetation
- ☑ 2. Dominance Test is >50%
- ☑ 3. Prevalence Index is ≤3.0[1]
- ☐ 4. Morphological Adaptations[1] (Provide supporting data in Remarks or on a separte sheet)
- ☐ Problematic Hydrophytic Vegetation[1] (Explain)

[1]Indicators of hydric soil and wetland hydrology must be present, unless disturbed or problematic.

Definitions of Vegetation Strata:

Tree - Woody plants, excluding woody vines, approximately 20 ft (6 m) or more in height and 3 in. (7.6 cm) or larger in diameter at breast height (DBH).

Sapling - Woody plants, excluding woody vines, approximately 20 ft (6 m) or more in height and less then 3 in. (7.6 cm) DBH.

Shrub - Woody plants, excluding woody vines, approximately 3 to 20 ft (1 to 6 m) in height.

Herb - All herbaceous (non-woody) plants, including herbaceous vines, regardless of size, and and woody plants, except woody vines, less than approximately 3 ft (1 m) in height

Woody Vine - All woody vines, regardless of height.

Hydropytic Vegetation Present? Yes ☑ No ☐

Remarks: (If observed, list morphological adaptations below).

Soils

Sampling Point: DP-5

Profile Description: (Describe to the depth needed to document the indicator or confirm the absence of indicators.)

Depth	Matrix		Redox Features				Texture	Remarks
(inches)	Color (moist)	%	Color (moist)	%	Type[1]	Loc[2]		
0-5	10YR 2/2	90	10YR 4/6	5	C	M	sandy loam	
			2.5Y 5/4	5	C	M		
5-12	10YR 2/2	90	10YR 4/6	10	C	M	sandy loam	
12-14	5Y 4/1	90	7.5YR 4/6	10	C	M, PL	sandy loam	

[1]Type: C=Concentration, D=Depletion, RM=Reduced Matrix, MS=Masked Sand Grains. [2]Location: PL=Pore Lining, M=Matrix

Hydric Soil Indicators:

- ☐ Histosol (A1)
- ☐ Histic Epipedon (A2)
- ☐ Black Histic (A3)
- ☐ Hydrogen Sulfide (A4)
- ☐ Stratified Layers (A5)
- ☐ 2 cm Muck (A10) (LRR N)
- ☐ Depleted Below Dark Surface (A11)
- ☐ Thick Dark Surface (A12)
- ☐ Sandy Mucky Mineral (S1)(LRR N,MLRA 147,148)
- ☐ Sandy Gleyed Matrix (S4)
- ☐ Sandy Redox (S5)
- ☐ Stripped Matrix (S6)
- ☐ Dark Surface (S7)
- ☐ Polyvalue Below Surace (S8) (MLRA 147,148)
- ☐ Thin Dark Surface (S9) (MLRA 147, 148)
- ☐ Loamy Gleyed Matrix (F2)
- ☐ Depleted Matrix (F3)
- ☐ Redox Dark Surface (F6)
- ☑ Depleted Dark Surface (F7)
- ☐ Redox Depressions (F8)
- ☐ Iron-Manganese Masses (F12) (LRR N, MLRA 136)
- ☐ Umbric Surface (F13) (MLRA 136, 122)
- ☐ Piedmont Floodplain Soils (F19) (MLRA 148)
- ☐ Red Parent Material (F21) (MLRA 127, 147)

Indicators of Problematic Hydric Soils[3]:

- ☐ 2 cm Muck (A10) (MLRA 147)
- ☐ Coast Prairie Redox (A16) (MLRA 147, 148)
- ☐ Piedmont Floodplain Soils (F19) (MLRA 136, 147)
- ☐ Very Shallow Dark Surface (TF12)
- ☐ Other (Explain in Remarks):

[3]Indicators of hydrophytic vegetation and wetland hydrology must be present, unless disturbed or problematic.

Restrictive Layer (if observed):
Type:
Depth (inches):

Hydric Soil Present? Yes ☑ No ☐

Remarks:

WETLAND DETERMINATION DATA FORM- Eastern Mountains and Piedmont

Project/Site: Plumtree Branch/Dunloggin Middle School | City/County: Ellicott City, Howard Co. | Sampling Date: 4/27/20

Applicant/Owner: Howard County Dept. of Parks and Recreation | State: MD | Sampling Point: DP-6

Investigator(s): HK | Section,Township, Range:

Landform (hillslope, terrace, etc.) Floodplain | Local relief (concave, convex, none): Concave | Slope (%): 0%

Subregion (LRR or MLRA): LRR S | Lat: 39.2557 | Long: -76.8344 | Datum: WGS84

Soil Map Unit Name: Ha (Hatboro-Codorus Silt Loam, 0-3% slope) | NWI classification: N/A

Are climatic / hydrologic conditions on the site typical for this time of year? Yes ☑ No ☐ (If no, explain in Remarks.)

Are Vegetation N, Soil N, or Hydrology N Significantly disturbed? Are "Normal Circumstances" present? Yes ☑ No ☐

Are Vegetation N, Soil N, or Hydrology N Naturally problematic? (If needed, explain any answers in Remarks.)

SUMMARY OF FINDINGS - Attach site map showing sampling point locations, transects, important features, etc.

	Yes	No
Hydrophytic Vegetation Present?	☑	☐
Hydric Soil Present?	☑	☐
Wetland Hydrology Present?	☐	☑
Is the Sampled Area within a Wetland?	☐	☑

Remarks:

In Wetland 3. Approximately 2" of rain fell on the site the night before the delineation. Saturation was not used as a sole indicator of wetland hydrology.

HYDROLOGY

Wetland Hydrology Indicators:

Primary Indicators (minimum of one is required: check all that apply)

- ☐ Surface Water (A1)
- ☐ High Water Table (A2)
- ☑ Saturation (A3)
- ☐ Water marks (B1)
- ☐ Sediment Deposits (B2)
- ☐ Drift Deposits (B3)
- ☐ Algal Mat or Crust (B4)
- ☐ Iron Deposits (B5)
- ☐ Inundation Visible on Aerial Imagery (B7)
- ☑ Water-Stained Leaves (B9)
- ☐ Aquatic Fauna (B13)
- ☐ True Aquatic Plants (B14)
- ☐ Hydrogen Sulfide Odor (C1)
- ☐ Oxidized Rhizospheres on Living Roots (C3)
- ☐ Presence of Reduced Iron (C4)
- ☐ Recent Iron Reduction in Tilled Soils (C6)
- ☐ Thin Muck Surface (C7)
- ☐ Other (Explain in Remarks)

Secondary Indicators (minimum of two required)

- ☐ Surface Soil Cracks (B6)
- ☐ Sparsely Vegetated Concave Surface (B8)
- ☐ Drainage Patterns (B10)
- ☐ Moss Trim Lines (B16)
- ☐ Dry-Season Water Table (C2)
- ☐ Crayfish Burrows (C8)
- ☐ Saturation Visible on Aerial Imagery (C9)
- ☐ Stunted or Stressed Plants (D1)
- ☑ Geomorphic Position (D2)
- ☐ Shallow Aquitard (D3)
- ☐ Microtopographic Relief (D4)
- ☐ FAC-Neutral Test (D5)

Field Observations:

	Yes	No	Depth (inches):
Surface Water Present?	☐	☑	
Water Table Present?	☐	☑	
Saturation Present? (includes capillary fringe)	☑	☐	Surface

Wetland Hydrology Present? Yes ☑ No ☐

Describe Recorded Data (stream gage, monitoring well, aerial photos, previous inspections), if available:

Remarks:

VEGETATION - Use scientific names of plants.

Sampling Point: DP-6

Tree Stratum (Plot size: 30 ft radius).	Absolute % Cover	Dominant Species?	Indicator Status
1. *Acer rubrum*	5	Yes	FAC
2.			
3.			
4.			
5.			
6.			
7.			
50% total cover: 2.5% 20% total cover: 1.0%	5%	= Total Cover	

Sapling Stratum (Plot size: 15 ft radius).	Absolute % Cover	Dominant Species?	Indicator Status
1.			
2.			
3.			
4.			
5.			
6.			
7.			
50% total cover: 0.0% 20% total cover: 0.0%	0%	= Total Cover	

Shrub Stratum (Plot size: 15 ft radius).	Absolute % Cover	Dominant Species?	Indicator Status
1. *Rosa multiflora*	5	Yes	FACU
2.			
3.			
4.			
5.			
6.			
7.			
50% total cover: 2.5% 20% total cover: 1.0%	5%	= Total Cover	

Herb Stratum (Plot size: 5 ft radius).	Absolute % Cover	Dominant Species?	Indicator Status
1. *Ranunculus ficaria*	40	Yes	FAC
2. *Microstegium vimineum*	30	Yes	FAC
3. *Symplocarpus foetidus*	10	No	OBL
4. *Arisaema triphyllum*	5	No	FACW
5. *Phalaris arundinacea*	5	No	FACW
6.			
7.			
8.			
9.			
10.			
11.			
12.			
50% total cover: 45.0% 20% total cover: 18.0%	90%	= Total Cover	

Woody Vine Stratum (Plot size: 30 ft radius).	Absolute % Cover	Dominant Species?	Indicator Status
1. *Vitis riparia*	10	Yes	FACW
2.			
3.			
4.			
7.			
50% total cover: 5.0% 20% total cover: 2.0%	10%	= Total Cover	

Domiance Test worksheet

Number of Dominant Species That are OBL, FACW, or FAC: 4 (A)

Total Number of Dominant Species Across All Strata: 5 (B)

Percent of Dominant Speices that are OBL, FACW, or FAC: 80.0% (A/B)

Prevalence Index worksheet

Total % Cover of:		Multiply by:		
OBL species	10	X 1	=	10
FACW species	20	X 2	=	40
FAC species	75	X 3	=	225
FACU species	5	X 4	=	20
UPL species	0	X 5	=	0
Column Totals	110	(A)		295 (B)

Prevalence Index = B/A = 2.68%

Hydrophytic Vegetation Indicators:

- ☐ 1. Rapid Test of Hydrophytic Vegetation
- ☑ 2. Dominance Test is >50%
- ☑ 3. Prevalence Index is ≤3.0[1]
- ☐ 4. Morphological Adaptations[1] (Provide supporting data in Remarks or on a separte sheet)
- ☐ Problematic Hydrophytic Vegetation[1] (Explain)

[1]Indicators of hydric soil and wetland hydrology must be present, unless disturbed or problematic.

Definitions of Vegetation Strata:

Tree - Woody plants, excluding woody vines, approximately 20 ft (6 m) or more in height and 3 in. (7.6 cm) or larger in diameter at breast height (DBH).

Sapling - Woody plants, excluding woody vines, approximately 20 ft (6 m) or more in height and less then 3 in. (7.6 cm) DBH.

Shrub - Woody plants, excluding woody vines, approximately 3 to 20 ft (1 to 6 m) in height.

Herb - All herbaceous (non-woody) plants, including herbaceous vines, regardless of size, and and woody plants, except woody vines, less than approximately 3 ft (1 m) in height

Woody Vine - All woody vines, regardless of height.

Hydropytic Vegetation Present? Yes ☑ No ☐

Remarks: (If observed, list morphological adaptations below).

Soils

Sampling Point: DP-6

Profile Description: (Describe to the depth needed to document the indicator or confirm the absence of indicators.)

Depth (inches)	Matrix Color (moist)	Matrix %	Redox Features Color (moist)	Redox %	Type[1]	Loc[2]	Texture	Remarks
0-5	10YR 2/2	90	10YR 4/6	5	C	M	sandy loam	
			2.5Y 5/4	5	C	M		
5-12	10YR 2/2	90	10YR 4/6	10	C	M	sandy loam	
12-14	5Y 4/1	90	7.5YR 4/6	10	C	M, PL	sandy loam	

[1]Type: C=Concentration, D=Depletion, RM=Reduced Matrix, MS=Masked Sand Grains. [2]Location: PL=Pore Lining, M=Matrix

Hydric Soil Indicators:

- ☐ Histosol (A1)
- ☐ Histic Epipedon (A2)
- ☐ Black Histic (A3)
- ☐ Hydrogen Sulfide (A4)
- ☐ Stratified Layers (A5)
- ☐ 2 cm Muck (A10) (LRR N)
- ☐ Depleted Below Dark Surface (A11)
- ☐ Thick Dark Surface (A12)
- ☐ Sandy Mucky Mineral (S1)(LRR N,MLRA 147,148)
- ☐ Sandy Gleyed Matrix (S4)
- ☐ Sandy Redox (S5)
- ☐ Stripped Matrix (S6)
- ☐ Dark Surface (S7)
- ☐ Polyvalue Below Surace (S8) (MLRA 147,148)
- ☐ Thin Dark Surface (S9) (MLRA 147, 148)
- ☐ Loamy Gleyed Matrix (F2)
- ☐ Depleted Matrix (F3)
- ☐ Redox Dark Surface (F6)
- ☑ Depleted Dark Surface (F7)
- ☐ Redox Depressions (F8)
- ☐ Iron-Manganese Masses (F12) (LRR N, MLRA 136)
- ☐ Umbric Surface (F13) (MLRA 136, 122)
- ☐ Piedmont Floodplain Soils (F19) (MLRA 148)
- ☐ Red Parent Material (F21) (MLRA 127, 147)

Indicators of Problematic Hydric Soils[3]:

- ☐ 2 cm Muck (A10) (MLRA 147)
- ☐ Coast Prairie Redox (A16) (MLRA 147, 148)
- ☐ Piedmont Floodplain Soils (F19) (MLRA 136, 147)
- ☐ Very Shallow Dark Surface (TF12)
- ☐ Other (Explain in Remarks):

[3]Indicators of hydrophytic vegetation and wetland hydrology must be present, unless disturbed or problematic.

Restrictive Layer (if observed):
Type:
Depth (inches):

Hydric Soil Present? Yes ☑ No ☐

Remarks:

WETLAND DETERMINATION DATA FORM- Eastern Mountains and Piedmont

Project/Site: Plumtree Branch/Dunloggin Middle School City/County: Ellicott City, Howard Co. Sampling Date: 4/27/20

Applicant/Owner: Howard County Dept. of Parks and Recreation State: MD Sampling Point: DP-7

Investigator(s): HK Section,Township, Range:

Landform (hillslope, terrace, etc.) Floodplain Local relief (concave, convex, none): Concave Slope (%): 0%

Subregion (LRR or MLRA): LRR S Lat: 39.2557 Long: -76.8344 Datum: WGS84

Soil Map Unit Name: Ha (Hatboro-Codorus Silt Loam, 0-3% slope) NWI classification: N/A

Are climatic / hydrologic conditions on the site typical for this time of year? Yes ☑ No ☐ (If no, explain in Remarks.)

Are Vegetation N , Soil N , or Hydrology N Significantly disturbed? Are "Normal Circumstances" present? Yes ☑ No ☐

Are Vegetation N , Soil N , or Hydrology N Naturally problematic? (If needed, explain any answers in Remarks.)

SUMMARY OF FINDINGS - Attach site map showing sampling point locations, transects, important features, etc.

Hydrophytic Vegetation Present?	Yes ☑	No ☐
Hydric Soil Present?	Yes ☑	No ☐
Wetland Hydrology Present?	Yes ☑	No ☐

Is the Sampled Area within a Wetland? Yes ☑ No ☐

Remarks:

Approximately 2" of rain fell on the site the night before the delineation. Saturation was not used as a sole indicator of wetland hydrology. In Wetland 3B

HYDROLOGY

Wetland Hydrology Indicators:

Primary Indicators (minimum of one is required: check all that apply)

- ☐ Surface Water (A1)
- ☐ High Water Table (A2)
- ☑ Saturation (A3)
- ☐ Water marks (B1)
- ☐ Sediment Deposits (B2)
- ☐ Drift Deposits (B3)
- ☐ Algal Mat or Crust (B4)
- ☐ Iron Deposits (B5)
- ☐ Inundation Visible on Aerial Imagery (B7)
- ☑ Water-Stained Leaves (B9)
- ☐ Aquatic Fauna (B13)
- ☐ True Aquatic Plants (B14)
- ☐ Hydrogen Sulfide Odor (C1)
- ☐ Oxidized Rhizospheres on Living Roots (C3)
- ☐ Presence of Reduced Iron (C4)
- ☐ Recent Iron Reduction in Tilled Soils (C6)
- ☐ Thin Muck Surface (C7)
- ☐ Other (Explain in Remarks)

Secondary Indicators (minimum of two required)

- ☐ Surface Soil Cracks (B6)
- ☐ Sparsely Vegetated Concave Surface (B8)
- ☐ Drainage Patterns (B10)
- ☐ Moss Trim Lines (B16)
- ☐ Dry-Season Water Table (C2)
- ☐ Crayfish Burrows (C8)
- ☐ Saturation Visible on Aerial Imagery (C9)
- ☐ Stunted or Stressed Plants (D1)
- ☑ Geomorphic Position (D2)
- ☐ Shallow Aquitard (D3)
- ☐ Microtopographic Relief (D4)
- ☐ FAC-Neutral Test (D5)

Field Observations:

Surface Water Present?	Yes ☐	No ☑	Depth (inches):
Water Table Present?	Yes ☐	No ☑	Depth (inches):
Saturation Present? (includes capillary fringe)	Yes ☑	No ☐	Depth (inches): Surface

Wetland Hydrology Present? Yes ☑ No ☐

Describe Recorded Data (stream gage, monitoring well, aerial photos, previous inspections), if available:

Remarks:

VEGETATION - Use scientific names of plants.

Sampling Point: DP-7

Tree Stratum (Plot size: 30 ft radius).	Absolute % Cover	Dominant Species?	Indicator Status
1. *Acer rubrum*	5	Yes	FAC
2.			
3.			
4.			
5.			
6.			
7.			
50% total cover: 2.5% 20% total cover: 1.0%	5%	= Total Cover	

Sapling Stratum (Plot size: 15 ft radius).	Absolute % Cover	Dominant Species?	Indicator Status
1.			
2.			
3.			
4.			
5.			
6.			
7.			
50% total cover: 0.0% 20% total cover: 0.0%	0%	= Total Cover	

Shrub Stratum (Plot size: 15 ft radius).	Absolute % Cover	Dominant Species?	Indicator Status
1. *Rosa multiflora*	30	Yes	FACU
2.			
3.			
4.			
5.			
6.			
7.			
50% total cover: 15.0% 20% total cover: 6.0%	30%	= Total Cover	

Herb Stratum (Plot size: 5 ft radius).	Absolute % Cover	Dominant Species?	Indicator Status
1. *Ranunculus ficaria*	40	Yes	FAC
2. *Glechoma hederacea*	40	Yes	FACU
3. *Phalaris arundinacea*	5	No	FACW
4.			
5.			
6.			
7.			
8.			
9.			
10.			
11.			
12.			
50% total cover: 42.5% 20% total cover: 17.0%	85%	= Total Cover	

Woody Vine Stratum (Plot size: 30 ft radius).	Absolute % Cover	Dominant Species?	Indicator Status
1. *Vitis riparia*	10	Yes	FACW
2.			
3.			
4.			
7.			
50% total cover: 5.0% 20% total cover: 2.0%	10%	= Total Cover	

Domiance Test worksheet

Number of Dominant Species That are OBL, FACW, or FAC: 3 (A)

Total Number of Dominant Species Across All Strata: 5 (B)

Percent of Dominant Speices that are OBL, FACW, or FAC: 60.0% (A/B)

Prevalence Index worksheet

Total % Cover of:		Multiply by:		
OBL species	0	X 1	=	0
FACW species	15	X 2	=	30
FAC species	45	X 3	=	135
FACU species	70	X 4	=	280
UPL species	0	X 5	=	0
Column Totals	130	(A)		445 (B)

Prevalence Index = B/A = 3.42%

Hydrophytic Vegetation Indicators:

- ☐ 1. Rapid Test of Hydrophytic Vegetation
- ☑ 2. Dominance Test is >50%
- ☐ 3. Prevalence Index is ≤3.0[1]
- ☐ 4. Morphological Adaptations[1] (Provide supporting data in Remarks or on a separte sheet)
- ☐ Problematic Hydrophytic Vegetation[1] (Explain)

[1]Indicators of hydric soil and wetland hydrology must be present, unless disturbed or problematic.

Definitions of Vegetation Strata:

Tree - Woody plants, excluding woody vines, approximately 20 ft (6 m) or more in height and 3 in. (7.6 cm) or larger in diameter at breast height (DBH).

Sapling - Woody plants, excluding woody vines, approximately 20 ft (6 m) or more in height and less then 3 in. (7.6 cm) DBH.

Shrub - Woody plants, excluding woody vines, approximately 3 to 20 ft (1 to 6 m) in height.

Herb - All herbaceous (non-woody) plants, including herbaceous vines, regardless of size, and and woody plants, except woody vines, less than approximately 3 ft (1 m) in height

Woody Vine - All woody vines, regardless of height.

Hydropytic Vegetation Present? Yes ☑ No ☐

Remarks: (If observed, list morphological adaptations below).

Soils

Sampling Point: DP-7

Profile Description: (Describe to the depth needed to document the indicator or confirm the absence of indicators.)

Depth	Matrix		Redox Features					
(inches)	Color (moist)	%	Color (moist)	%	Type[1]	Loc[2]	Texture	Remarks
0-5	10YR 2/2	90	10YR 4/6	5	C	M	sandy loam	
			2.5Y 5/4	5	C	M		
5-12	10YR 2/2	90	10YR 4/6	10	C	M	sandy loam	
12-14	5Y 4/1	90	7.5YR 4/6	10	C	M, PL	sandy loam	

[1]Type: C=Concentration, D=Depletion, RM=Reduced Matrix, MS=Masked Sand Grains. [2]Location: PL=Pore Lining, M=Matrix

Hydric Soil Indicators:

- ☐ Histosol (A1)
- ☐ Histic Epipedon (A2)
- ☐ Black Histic (A3)
- ☐ Hydrogen Sulfide (A4)
- ☐ Stratified Layers (A5)
- ☐ 2 cm Muck (A10) (LRR N)
- ☐ Depleted Below Dark Surface (A11)
- ☐ Thick Dark Surface (A12)
- ☐ Sandy Mucky Mineral (S1)(LRR N,MLRA 147,148)
- ☐ Sandy Gleyed Matrix (S4)
- ☐ Sandy Redox (S5)
- ☐ Stripped Matrix (S6)
- ☐ Dark Surface (S7)
- ☐ Polyvalue Below Surace (S8) (MLRA 147,148)
- ☐ Thin Dark Surface (S9) (MLRA 147, 148)
- ☐ Loamy Gleyed Matrix (F2)
- ☐ Depleted Matrix (F3)
- ☐ Redox Dark Surface (F6)
- ☑ Depleted Dark Surface (F7)
- ☐ Redox Depressions (F8)
- ☐ Iron-Manganese Masses (F12) (LRR N, MLRA 136)
- ☐ Umbric Surface (F13) (MLRA 136, 122)
- ☐ Piedmont Floodplain Soils (F19) (MLRA 148)
- ☐ Red Parent Material (F21) (MLRA 127, 147)

Indicators of Problematic Hydric Soils[3]:

- ☐ 2 cm Muck (A10) (MLRA 147)
- ☐ Coast Prairie Redox (A16) (MLRA 147, 148)
- ☐ Piedmont Floodplain Soils (F19) (MLRA 136, 147)
- ☐ Very Shallow Dark Surface (TF12)
- ☐ Other (Explain in Remarks):

[3]Indicators of hydrophytic vegetation and wetland hydrology must be present, unless disturbed or problematic.

Restrictive Layer (if observed):
Type:
Depth (inches):

Hydric Soil Present? Yes ☑ No ☐

Remarks:

WETLAND DETERMINATION DATA FORM- Eastern Mountains and Piedmont

Project/Site: Plumtree Branch/Dunloggin Middle School	City/County: Ellicott City, Howard Co.		Sampling Date: 4/27/20
Applicant/Owner: Howard County Dept. of Parks and Recreation		State: MD	Sampling Point: DP-8
Investigator(s): HK	Section,Township, Range:		
Landform (hillslope, terrace, etc.) Floodplain	Local relief (concave, convex, none): Concave		Slope (%): 0%
Subregion (LRR or MLRA): LRR S	Lat: 39.2557	Long: -76.8344	Datum: WGS84
Soil Map Unit Name: Ha (Hatboro-Codorus Silt Loam, 0-3% slope)		NWI classification: N/A	

Are climatic / hydrologic conditions on the site typical for this time of year? Yes ☑ No ☐ (If no, explain in Remarks.)

Are Vegetation N , Soil N , or Hydrology N Significantly disturbed? Are "Normal Circumstances" present? Yes ☑ No ☐

Are Vegetation N , Soil N , or Hydrology N Naturally problematic? (If needed, explain any answers in Remarks.)

SUMMARY OF FINDINGS - Attach site map showing sampling point locations, transects, important features, etc.

Hydrophytic Vegetation Present?	Yes ☑	No ☐
Hydric Soil Present?	Yes ☑	No ☐
Wetland Hydrology Present?	Yes ☑	No ☐

Is the Sampled Area within a Wetland? Yes ☑ No ☐

Remarks:

Approximately 2" of rain fell on the site the night before the delineation. Saturation was not used as a sole indicator of wetland hydrology. In wetland 4

HYDROLOGY

Wetland Hydrology Indicators:

Primary Indicators (minimum of one is required: check all that apply)

- ☑ Surface Water (A1)
- ☑ High Water Table (A2)
- ☑ Saturation (A3)
- ☐ Water marks (B1)
- ☐ Sediment Deposits (B2)
- ☐ Drift Deposits (B3)
- ☐ Algal Mat or Crust (B4)
- ☐ Iron Deposits (B5)
- ☐ Inundation Visible on Aerial Imagery (B7)
- ☑ Water-Stained Leaves (B9)
- ☐ Aquatic Fauna (B13)
- ☐ True Aquatic Plants (B14)
- ☐ Hydrogen Sulfide Odor (C1)
- ☐ Oxidized Rhizospheres on Living Roots (C3)
- ☐ Presence of Reduced Iron (C4)
- ☐ Recent Iron Reduction in Tilled Soils (C6)
- ☐ Thin Muck Surface (C7)
- ☐ Other (Explain in Remarks)

Secondary Indicators (minimum of two required)

- ☐ Surface Soil Cracks (B6)
- ☐ Sparsely Vegetated Concave Surface (B8)
- ☐ Drainage Patterns (B10)
- ☐ Moss Trim Lines (B16)
- ☐ Dry-Season Water Table (C2)
- ☐ Crayfish Burrows (C8)
- ☐ Saturation Visible on Aerial Imagery (C9)
- ☐ Stunted or Stressed Plants (D1)
- ☐ Geomorphic Position (D2)
- ☐ Shallow Aquitard (D3)
- ☐ Microtopographic Relief (D4)
- ☐ FAC-Neutral Test (D5)

Field Observations:

Surface Water Present?	Yes ☑	No ☐	Depth (inches): 1"
Water Table Present?	Yes ☑	No ☐	Depth (inches): Surface
Saturation Present? (includes capillary fringe)	Yes ☑	No ☐	Depth (inches): Surface

Wetland Hydrology Present? Yes ☑ No ☐

Describe Recorded Data (stream gage, monitoring well, aerial photos, previous inspections), if available:

Remarks:

VEGETATION - Use scientific names of plants.

Sampling Point: DP-8

Tree Stratum (Plot size: 30 ft radius).	Absolute % Cover	Dominant Species?	Indicator Status
1. *Acer rubrum*	15	Yes	FAC
2.			
3.			
4.			
5.			
6.			
7.			
50% total cover: 7.5% 20% total cover: 3.0%	15%	= Total Cover	

Sapling Stratum (Plot size: 15 ft radius).	Absolute % Cover	Dominant Species?	Indicator Status
1. *Acer rubrum*	5	Yes	FAC
2.			
3.			
4.			
5.			
6.			
7.			
50% total cover: 2.5% 20% total cover: 1.0%	5%	= Total Cover	

Shrub Stratum (Plot size: 15 ft radius).	Absolute % Cover	Dominant Species?	Indicator Status
1.			
2.			
3.			
4.			
5.			
6.			
7.			
50% total cover: 0.0% 20% total cover: 0.0%	0%	= Total Cover	

Herb Stratum (Plot size: 5 ft radius).	Absolute % Cover	Dominant Species?	Indicator Status
1. *Ranunculus ficaria*	40	Yes	FAC
2. *Carex stricta*	20	Yes	OBL
3. *Carex lurida*	10	No	OBL
4. *Phalaris arundinacea*	5	No	FACW
5.			
6.			
7.			
8.			
9.			
10.			
11.			
12.			
50% total cover: 37.5% 20% total cover: 15.0%	75%	= Total Cover	

Woody Vine Stratum (Plot size: 30 ft radius).	Absolute % Cover	Dominant Species?	Indicator Status
1. *Toxicodendron radicans*	5	Yes	FAC
2.			
3.			
4.			
7.			
50% total cover: 2.5% 20% total cover: 1.0%	5%	= Total Cover	

Domiance Test worksheet

Number of Dominant Species That are OBL, FACW, or FAC: 5 (A)

Total Number of Dominant Species Across All Strata: 5 (B)

Percent of Dominant Speices that are OBL, FACW, or FAC: 100.0% (A/B)

Prevalence Index worksheet

Total % Cover of:				Multiply by:
OBL species	30	X 1	=	30
FACW species	5	X 2	=	10
FAC species	65	X 3	=	195
FACU species	0	X 4	=	0
UPL species	0	X 5	=	0
Column Totals	100	(A)		235 (B)

Prevalence Index = B/A = 2.35%

Hydrophytic Vegetation Indicators:

- ☐ 1. Rapid Test of Hydrophytic Vegetation
- ☑ 2. Dominance Test is >50%
- ☑ 3. Prevalence Index is ≤3.0[1]
- ☐ 4. Morphological Adaptations[1] (Provide supporting data in Remarks or on a separte sheet)
- ☐ Problematic Hydrophytic Vegetation[1] (Explain)

[1]Indicators of hydric soil and wetland hydrology must be present, unless disturbed or problematic.

Definitions of Vegetation Strata:

Tree - Woody plants, excluding woody vines, approximately 20 ft (6 m) or more in height and 3 in. (7.6 cm) or larger in diameter at breast height (DBH).

Sapling - Woody plants, excluding woody vines, approximately 20 ft (6 m) or more in height and less then 3 in. (7.6 cm) DBH.

Shrub - Woody plants, excluding woody vines, approximately 3 to 20 ft (1 to 6 m) in height.

Herb - All herbaceous (non-woody) plants, including herbaceous vines, regardless of size, and and woody plants, except woody vines, less than approximately 3 ft (1 m) in height

Woody Vine - All woody vines, regardless of height.

Hydropytic Vegetation Present? Yes ☑ No ☐

Remarks: (If observed, list morphological adaptations below).

Soils

Sampling Point: DP-8

Profile Description: (Describe to the depth needed to document the indicator or confirm the absence of indicators.)

Depth	Matrix		Redox Features				Texture	Remarks
(inches)	Color (moist)	%	Color (moist)	%	Type[1]	Loc[2]		
0-4	10YR 3/2	90	10YR 4/6	10	C	M	Clay loam	
4-12	2.5Y 5/3	85	10YR 4/6	15	C	M	Clay loam	

[1]Type: C=Concentration, D=Depletion, RM=Reduced Matrix, MS=Masked Sand Grains. [2]Location: PL=Pore Lining, M=Matrix

Hydric Soil Indicators:

- ☐ Histosol (A1)
- ☐ Histic Epipedon (A2)
- ☐ Black Histic (A3)
- ☐ Hydrogen Sulfide (A4)
- ☐ Stratified Layers (A5)
- ☐ 2 cm Muck (A10) (LRR N)
- ☐ Depleted Below Dark Surface (A11)
- ☐ Thick Dark Surface (A12)
- ☐ Sandy Mucky Mineral (S1)(LRR N,MLRA 147,148)
- ☐ Sandy Gleyed Matrix (S4)
- ☐ Sandy Redox (S5)
- ☐ Stripped Matrix (S6)
- ☐ Dark Surface (S7)
- ☐ Polyvalue Below Surace (S8) (MLRA 147,148)
- ☐ Thin Dark Surface (S9) (MLRA 147, 148)
- ☐ Loamy Gleyed Matrix (F2)
- ☐ Depleted Matrix (F3)
- ☐ Redox Dark Surface (F6)
- ☑ Depleted Dark Surface (F7)
- ☐ Redox Depressions (F8)
- ☐ Iron-Manganese Masses (F12) (LRR N, MLRA 136)
- ☐ Umbric Surface (F13) (MLRA 136, 122)
- ☐ Piedmont Floodplain Soils (F19) (MLRA 148)
- ☐ Red Parent Material (F21) (MLRA 127, 147)

Indicators of Problematic Hydric Soils[3]:

- ☐ 2 cm Muck (A10) (MLRA 147)
- ☐ Coast Prairie Redox (A16) (MLRA 147, 148)
- ☐ Piedmont Floodplain Soils (F19) (MLRA 136, 147)
- ☐ Very Shallow Dark Surface (TF12)
- ☐ Other (Explain in Remarks):

[3]Indicators of hydrophytic vegetation and wetland hydrology must be present, unless disturbed or problematic.

Restrictive Layer (if observed):
Type:
Depth (inches):

Hydric Soil Present? Yes ☑ No ☐

Remarks:

WETLAND DETERMINATION DATA FORM- Eastern Mountains and Piedmont

Project/Site: Plumtree Branch/Dunloggin Middle School	City/County: Ellicott City, Howard Co.		Sampling Date: 4/27/20
Applicant/Owner: Howard County Dept. of Parks and Recreation		State: MD	Sampling Point: DP-9
Investigator(s): HK	Section,Township, Range:		
Landform (hillslope, terrace, etc.) Floodplain	Local relief (concave, convex, none): Concave		Slope (%): 0%
Subregion (LRR or MLRA): LRR S	Lat: 39.2557	Long: -76.8344	Datum: WGS84
Soil Map Unit Name: Ha (Hatboro-Codorus Silt Loam, 0-3% slope)		NWI classification: N/A	

Are climatic / hydrologic conditions on the site typical for this time of year? Yes ☑ No ☐ (If no, explain in Remarks.)

Are Vegetation N , Soil N , or Hydrology N Significantly disturbed? Are "Normal Circumstances" present? Yes ☑ No ☐

Are Vegetation N , Soil N , or Hydrology N Naturally problematic? (If needed, explain any answers in Remarks.)

SUMMARY OF FINDINGS - Attach site map showing sampling point locations, transects, important features, etc.

Hydrophytic Vegetation Present?	Yes ☑	No ☑
Hydric Soil Present?	Yes ☑	No ☐
Wetland Hydrology Present?	Yes ☑	No ☐

Is the Sampled Area within a Wetland? Yes ☑ No ☐

Remarks:

Approximately 2" of rain fell on the site the night before the delineation. Saturation was not used as a sole indicator of wetland hydrology. In Wetland 5, but also representative of emergent portion of Wetland 4

HYDROLOGY

Wetland Hydrology Indicators:

Primary Indicators (minimum of one is required: check all that apply)

- ☑ Surface Water (A1)
- ☑ High Water Table (A2)
- ☑ Saturation (A3)
- ☐ Water marks (B1)
- ☐ Sediment Deposits (B2)
- ☐ Drift Deposits (B3)
- ☐ Algal Mat or Crust (B4)
- ☐ Iron Deposits (B5)
- ☐ Inundation Visible on Aerial Imagery (B7)
- ☐ Water-Stained Leaves (B9)
- ☐ Aquatic Fauna (B13)
- ☐ True Aquatic Plants (B14)
- ☐ Hydrogen Sulfide Odor (C1)
- ☐ Oxidized Rhizospheres on Living Roots (C3)
- ☐ Presence of Reduced Iron (C4)
- ☐ Recent Iron Reduction in Tilled Soils (C6)
- ☐ Thin Muck Surface (C7)
- ☐ Other (Explain in Remarks)

Secondary Indicators (minimum of two required)

- ☐ Surface Soil Cracks (B6)
- ☐ Sparsely Vegetated Concave Surface (B8)
- ☐ Drainage Patterns (B10)
- ☐ Moss Trim Lines (B16)
- ☐ Dry-Season Water Table (C2)
- ☐ Crayfish Burrows (C8)
- ☐ Saturation Visible on Aerial Imagery (C9)
- ☐ Stunted or Stressed Plants (D1)
- ☐ Geomorphic Position (D2)
- ☐ Shallow Aquitard (D3)
- ☐ Microtopographic Relief (D4)
- ☐ FAC-Neutral Test (D5)

Field Observations:

Surface Water Present?	Yes ☑	No ☐	Depth (inches): 1"
Water Table Present?	Yes ☑	No ☐	Depth (inches): Surface
Saturation Present? (includes capillary fringe)	Yes ☑	No ☐	Depth (inches): Surface

Wetland Hydrology Present? Yes ☑ No ☐

Describe Recorded Data (stream gage, monitoring well, aerial photos, previous inspections), if available:

Remarks:

VEGETATION - Use scientific names of plants.

Sampling Point: DP-9

Tree Stratum (Plot size: 30 ft radius).	Absolute % Cover	Dominant Species?	Indicator Status
1. *Acer rubrum*	2	Yes	FAC
2. *Quercus palustris*	2	Yes	FACW
3.			
4.			
5.			
6.			
7.			
50% total cover: 2.0% 20% total cover: 0.8%	4%	= Total Cover	

Sapling Stratum (Plot size: 15 ft radius).	Absolute % Cover	Dominant Species?	Indicator Status
1.			
2.			
3.			
4.			
5.			
6.			
7.			
50% total cover: 0.0% 20% total cover: 0.0%	0%	= Total Cover	

Shrub Stratum (Plot size: 15 ft radius).	Absolute % Cover	Dominant Species?	Indicator Status
1. *Rosa multiflora*	5	Yes	FACU
2.			
3.			
4.			
5.			
6.			
7.			
50% total cover: 2.5% 20% total cover: 1.0%	5%	= Total Cover	

Herb Stratum (Plot size: 5 ft radius).	Absolute % Cover	Dominant Species?	Indicator Status
1. *Phalaris arundinacea*	40	Yes	FACW
2. *Ranunculus ficaria*	10	No	FAC
3. *Carex lurida*	5	No	OBL
4. *Symplocarpus foetidus*	5	No	OBL
5.			
6.			
7.			
8.			
9.			
10.			
11.			
12.			
50% total cover: 30.0% 20% total cover: 12.0%	60%	= Total Cover	

Woody Vine Stratum (Plot size: 30 ft radius).	Absolute % Cover	Dominant Species?	Indicator Status
1.			
2.			
3.			
4.			
7.			
50% total cover: 0.0% 20% total cover: 0.0%	0%	= Total Cover	

Domiance Test worksheet

Number of Dominant Species That are OBL, FACW, or FAC: 3 (A)

Total Number of Dominant Species Across All Strata: 4 (B)

Percent of Dominant Speices that are OBL, FACW, or FAC: 75.0% (A/B)

Prevalence Index worksheet

Total % Cover of:		Multiply by:		
OBL species	10	X 1	=	10
FACW species	42	X 2	=	84
FAC species	12	X 3	=	36
FACU species	5	X 4	=	20
UPL species	0	X 5	=	0
Column Totals	69	(A)		150 (B)

Prevalence Index = B/A = 2.17%

Hydrophytic Vegetation Indicators:

- ☐ 1. Rapid Test of Hydrophytic Vegetation
- ☑ 2. Dominance Test is >50%
- ☑ 3. Prevalence Index is ≤3.0[1]
- ☐ 4. Morphological Adaptations[1] (Provide supporting data in Remarks or on a separte sheet)
- ☐ Problematic Hydrophytic Vegetation[1] (Explain)

[1]Indicators of hydric soil and wetland hydrology must be present, unless disturbed or problematic.

Definitions of Vegetation Strata:

Tree - Woody plants, excluding woody vines, approximately 20 ft (6 m) or more in height and 3 in. (7.6 cm) or larger in diameter at breast height (DBH).

Sapling - Woody plants, excluding woody vines, approximately 20 ft (6 m) or more in height and less then 3 in. (7.6 cm) DBH.

Shrub - Woody plants, excluding woody vines, approximately 3 to 20 ft (1 to 6 m) in height.

Herb - All herbaceous (non-woody) plants, including herbaceous vines, regardless of size, and and woody plants, except woody vines, less than approximately 3 ft (1 m) in height

Woody Vine - All woody vines, regardless of height.

Hydropytic Vegetation Present? Yes ☑ No ☐

Remarks: (If observed, list morphological adaptations below).

Soils

Sampling Point: DP-9

Profile Description: (Describe to the depth needed to document the indicator or confirm the absence of indicators.)

Depth (inches)	Matrix Color (moist)	Matrix %	Redox Features Color (moist)	Redox %	Type[1]	Loc[2]	Texture	Remarks
0-3	10YR 3/2	100					Clay loam	
3-6	10YR 4/2	90	10YR 4/6	10	C	M	Clay loam	
6-9	10YR 5/4	85	7.5YR 4/6	15	C	M	Clay loam	
9-15	10YR 5/4	95	7.5YR 4/6	5	C	M	Clay	

[1]Type: C=Concentration, D=Depletion, RM=Reduced Matrix, MS=Masked Sand Grains. [2]Location: PL=Pore Lining, M=Matrix

Hydric Soil Indicators:

- ☐ Histosol (A1)
- ☐ Histic Epipedon (A2)
- ☐ Black Histic (A3)
- ☐ Hydrogen Sulfide (A4)
- ☐ Stratified Layers (A5)
- ☐ 2 cm Muck (A10) (LRR N)
- ☐ Depleted Below Dark Surface (A11)
- ☐ Thick Dark Surface (A12)
- ☐ Sandy Mucky Mineral (S1)(LRR N,MLRA 147,148)
- ☐ Sandy Gleyed Matrix (S4)
- ☐ Sandy Redox (S5)
- ☐ Stripped Matrix (S6)
- ☐ Dark Surface (S7)
- ☐ Polyvalue Below Surace (S8) (MLRA 147,148)
- ☐ Thin Dark Surface (S9) (MLRA 147, 148)
- ☐ Loamy Gleyed Matrix (F2)
- ☐ Depleted Matrix (F3)
- ☐ Redox Dark Surface (F6)
- ☑ Depleted Dark Surface (F7)
- ☐ Redox Depressions (F8)
- ☐ Iron-Manganese Masses (F12) (LRR N, MLRA 136)
- ☐ Umbric Surface (F13) (MLRA 136, 122)
- ☐ Piedmont Floodplain Soils (F19) (MLRA 148)
- ☐ Red Parent Material (F21) (MLRA 127, 147)

Indicators of Problematic Hydric Soils[3]:

- ☐ 2 cm Muck (A10) (MLRA 147)
- ☐ Coast Prairie Redox (A16) (MLRA 147, 148)
- ☐ Piedmont Floodplain Soils (F19) (MLRA 136, 147)
- ☐ Very Shallow Dark Surface (TF12)
- ☐ Other (Explain in Remarks):

[3]Indicators of hydrophytic vegetation and wetland hydrology must be present, unless disturbed or problematic.

Restrictive Layer (if observed):
Type:
Depth (inches):

Hydric Soil Present? Yes ☑ No ☐

Remarks:

WETLAND DETERMINATION DATA FORM- Eastern Mountains and Piedmont

Project/Site: Plumtree Branch/Dunloggin Middle School | City/County: Ellicott City, Howard Co. | Sampling Date: 4/27/20

Applicant/Owner: Howard County Dept. of Parks and Recreation | State: MD | Sampling Point: DP-10

Investigator(s): HK | Section,Township, Range:

Landform (hillslope, terrace, etc.) Floodplain | Local relief (concave, convex, none): Concave | Slope (%): 0%

Subregion (LRR or MLRA): LRR S | Lat: 39.2557 | Long: -76.8344 | Datum: WGS84

Soil Map Unit Name: Ha (Hatboro-Codorus Silt Loam, 0-3% slope) | NWI classification: N/A

Are climatic / hydrologic conditions on the site typical for this time of year? Yes [x] No [ ] (If no, explain in Remarks.)

Are Vegetation N , Soil N , or Hydrology N Significantly disturbed? Are "Normal Circumstances" present? Yes [x] No [ ]

Are Vegetation N , Soil N , or Hydrology N Naturally problematic? (If needed, explain any answers in Remarks.)

SUMMARY OF FINDINGS - Attach site map showing sampling point locations, transects, important features, etc.

Hydrophytic Vegetation Present? Yes [x] No [ ]

Hydric Soil Present? Yes [x] No [ ]

Wetland Hydrology Present? Yes [x] No [ ]

Is the Sampled Area within a Wetland? Yes [x] No [ ]

Remarks:

Approximately 2" of rain fell on the site the night before the delineation. Saturation was not used as a sole indicator of wetland hydrology. In wetland 6

HYDROLOGY

Wetland Hydrology Indicators:

Primary Indicators (minimum of one is required: check all that apply)

- [ ] Surface Water (A1)
- [x] High Water Table (A2)
- [x] Saturation (A3)
- [ ] Water marks (B1)
- [ ] Sediment Deposits (B2)
- [ ] Drift Deposits (B3)
- [ ] Algal Mat or Crust (B4)
- [ ] Iron Deposits (B5)
- [ ] Inundation Visible on Aerial Imagery (B7)
- [ ] Water-Stained Leaves (B9)
- [ ] Aquatic Fauna (B13)
- [ ] True Aquatic Plants (B14)
- [ ] Hydrogen Sulfide Odor (C1)
- [ ] Oxidized Rhizospheres on Living Roots (C3)
- [ ] Presence of Reduced Iron (C4)
- [ ] Recent Iron Reduction in Tilled Soils (C6)
- [ ] Thin Muck Surface (C7)
- [ ] Other (Explain in Remarks)

Secondary Indicators (minimum of two required)

- [ ] Surface Soil Cracks (B6)
- [ ] Sparsely Vegetated Concave Surface (B8)
- [x] Drainage Patterns (B10)
- [ ] Moss Trim Lines (B16)
- [ ] Dry-Season Water Table (C2)
- [ ] Crayfish Burrows (C8)
- [ ] Saturation Visible on Aerial Imagery (C9)
- [ ] Stunted or Stressed Plants (D1)
- [x] Geomorphic Position (D2)
- [ ] Shallow Aquitard (D3)
- [ ] Microtopographic Relief (D4)
- [ ] FAC-Neutral Test (D5)

Field Observations:

Surface Water Present? Yes [ ] No [x] Depth (inches):

Water Table Present? Yes [x] No [ ] Depth (inches): 6"

Saturation Present? (includes capillary fringe) Yes [x] No [ ] Depth (inches): Surface

Wetland Hydrology Present? Yes [x] No [ ]

Describe Recorded Data (stream gage, monitoring well, aerial photos, previous inspections), if available:

Remarks:

VEGETATION - Use scientific names of plants.

Sampling Point: DP-10

Tree Stratum (Plot size: 30 ft radius).	Absolute % Cover	Dominant Species?	Indicator Status
1. *Acer negundo*	5	Yes	FAC
2. *Salix nigra*	5	Yes	OBL
3.			
4.			
5.			
6.			
7.			
50% total cover: 5.0% 20% total cover: 2.0%	10%	= Total Cover	

Sapling Stratum (Plot size: 15 ft radius).	Absolute % Cover	Dominant Species?	Indicator Status
1. *Acer negundo*	5	Yes	FAC
2.			
3.			
4.			
5.			
6.			
7.			
50% total cover: 2.5% 20% total cover: 1.0%	5%	= Total Cover	

Shrub Stratum (Plot size: 15 ft radius).	Absolute % Cover	Dominant Species?	Indicator Status
1.			
2.			
3.			
4.			
5.			
6.			
7.			
50% total cover: 0.0% 20% total cover: 0.0%	0%	= Total Cover	

Herb Stratum (Plot size: 5 ft radius).	Absolute % Cover	Dominant Species?	Indicator Status
1. *Phalaris arundinacea*	50	Yes	FACW
2. *Persicaria perfoliata*	15	No	FAC
3. *Symplocarpus foetidus*	10	No	OBL
4. *Ranunculus ficaria*	10	No	FAC
5. *Carex lurida*	5	No	OBL
6.			
7.			
8.			
9.			
10.			
11.			
12.			
50% total cover: 45.0% 20% total cover: 18.0%	90%	= Total Cover	

Woody Vine Stratum (Plot size: 30 ft radius).	Absolute % Cover	Dominant Species?	Indicator Status
1.			
2.			
3.			
4.			
7.			
50% total cover: 0.0% 20% total cover: 0.0%	0%	= Total Cover	

Domiance Test worksheet

Number of Dominant Species That are OBL, FACW, or FAC: 4 (A)

Total Number of Dominant Species Across All Strata: 4 (B)

Percent of Dominant Speices that are OBL, FACW, or FAC: 100.0% (A/B)

Prevalence Index worksheet

Total % Cover of:		Multiply by:		
OBL species	20	X 1	=	20
FACW species	50	X 2	=	100
FAC species	35	X 3	=	105
FACU species	0	X 4	=	0
UPL species	0	X 5	=	0
Column Totals	105	(A)		225 (B)

Prevalence Index = B/A = 2.14%

Hydrophytic Vegetation Indicators:

- ☐ 1. Rapid Test of Hydrophytic Vegetation
- ☑ 2. Dominance Test is >50%
- ☑ 3. Prevalence Index is ≤3.0[1]
- ☐ 4. Morphological Adaptations[1] (Provide supporting data in Remarks or on a separte sheet)
- ☐ Problematic Hydrophytic Vegetation[1] (Explain)

[1]Indicators of hydric soil and wetland hydrology must be present, unless disturbed or problematic.

Definitions of Vegetation Strata:

Tree - Woody plants, excluding woody vines, approximately 20 ft (6 m) or more in height and 3 in. (7.6 cm) or larger in diameter at breast height (DBH).

Sapling - Woody plants, excluding woody vines, approximately 20 ft (6 m) or more in height and less then 3 in. (7.6 cm) DBH.

Shrub - Woody plants, excluding woody vines, approximately 3 to 20 ft (1 to 6 m) in height.

Herb - All herbaceous (non-woody) plants, including herbaceous vines, regardless of size, and and woody plants, except woody vines, less than approximately 3 ft (1 m) in height

Woody Vine - All woody vines, regardless of height.

Hydropytic Vegetation Present? Yes ☑ No ☐

Remarks: (If observed, list morphological adaptations below).

Soils

Sampling Point: DP-10

Profile Description: (Describe to the depth needed to document the indicator or confirm the absence of indicators.)

Depth	Matrix		Redox Features				Texture	Remarks
(inches)	Color (moist)	%	Color (moist)	%	Type¹	Loc²		
0-10	10YR 3/2	90	10YR 4/6	10	C	M	Clay loam	
10-14	10YR 4/1	98	10YR 4/6	2	C	M	Clay loam	concentrations are faint
14-16	10YR 4/3	80	10YR 4/6	20	C	M	Clay loam	
16-18	10YR 4/1	85	10YR 4/6	15	C	M	Clay	

¹Type: C=Concentration, D=Depletion, RM=Reduced Matrix, MS=Masked Sand Grains. ²Location: PL=Pore Lining, M=Matrix

Hydric Soil Indicators:

- ☐ Histosol (A1)
- ☐ Histic Epipedon (A2)
- ☐ Black Histic (A3)
- ☐ Hydrogen Sulfide (A4)
- ☐ Stratified Layers (A5)
- ☐ 2 cm Muck (A10) (LRR N)
- ☐ Depleted Below Dark Surface (A11)
- ☐ Thick Dark Surface (A12)
- ☐ Sandy Mucky Mineral (S1)(LRR N,MLRA 147,148)
- ☐ Sandy Gleyed Matrix (S4)
- ☐ Sandy Redox (S5)
- ☐ Stripped Matrix (S6)
- ☐ Dark Surface (S7)
- ☐ Polyvalue Below Surace (S8) (MLRA 147,148)
- ☐ Thin Dark Surface (S9) (MLRA 147, 148)
- ☐ Loamy Gleyed Matrix (F2)
- ☐ Depleted Matrix (F3)
- ☐ Redox Dark Surface (F6)
- ☑ Depleted Dark Surface (F7)
- ☐ Redox Depressions (F8)
- ☐ Iron-Manganese Masses (F12) (LRR N, MLRA 136)
- ☐ Umbric Surface (F13) (MLRA 136, 122)
- ☐ Piedmont Floodplain Soils (F19) (MLRA 148)
- ☐ Red Parent Material (F21) (MLRA 127, 147)

Indicators of Problematic Hydric Soils³:

- ☐ 2 cm Muck (A10) (MLRA 147)
- ☐ Coast Prairie Redox (A16) (MLRA 147, 148)
- ☐ Piedmont Floodplain Soils (F19) (MLRA 136, 147)
- ☐ Very Shallow Dark Surface (TF12)
- ☐ Other (Explain in Remarks):

³Indicators of hydrophytic vegetation and wetland hydrology must be present, unless disturbed or problematic.

Restrictive Layer (if observed):
Type:
Depth (inches):

Hydric Soil Present? Yes ☑ No ☐

Remarks:

WETLAND DETERMINATION DATA FORM- Eastern Mountains and Piedmont

Project/Site:	Plumtree Branch/Dunloggin Middle School	City/County:	Ellicott City, Howard Co.	Sampling Date:	4/27/20
Applicant/Owner:	Howard County Dept. of Parks and Recreation	State:	MD	Sampling Point:	DP-11
Investigator(s):	HK	Section,Township, Range:			
Landform (hillslope, terrace, etc.)	Floodplain	Local relief (concave, convex, none):	Concave	Slope (%):	0%
Subregion (LRR or MLRA):	LRR S	Lat: 39.2557	Long: -76.8344	Datum:	WGS84
Soil Map Unit Name:	Ha (Hatboro-Codorus Silt Loam, 0-3% slope)	NWI classification:	N/A		

Are climatic / hydrologic conditions on the site typical for this time of year? Yes ☑ No ☐ (If no, explain in Remarks.)

Are Vegetation N , Soil N , or Hydrology N Significantly disturbed? Are "Normal Circumstances" present? Yes ☑ No ☐

Are Vegetation N , Soil N , or Hydrology N Naturally problematic? (If needed, explain any answers in Remarks.)

SUMMARY OF FINDINGS - Attach site map showing sampling point locations, transects, important features, etc.

Hydrophytic Vegetation Present?	Yes ☑	No ☐
Hydric Soil Present?	Yes ☑	No ☐
Wetland Hydrology Present?	Yes ☑	No ☐

Is the Sampled Area within a Wetland? Yes ☑ No ☐

Remarks:

Approximately 2" of rain fell on the site the night before the delineation. Saturation was not used as a sole indicator of wetland hydrology. In wetland 7

HYDROLOGY

Wetland Hydrology Indicators:

Primary Indicators (minimum of one is required: check all that apply)

- ☑ Surface Water (A1)
- ☐ High Water Table (A2)
- ☑ Saturation (A3)
- ☐ Water marks (B1)
- ☐ Sediment Deposits (B2)
- ☐ Drift Deposits (B3)
- ☐ Algal Mat or Crust (B4)
- ☐ Iron Deposits (B5)
- ☐ Inundation Visible on Aerial Imagery (B7)
- ☐ Water-Stained Leaves (B9)
- ☐ Aquatic Fauna (B13)
- ☐ True Aquatic Plants (B14)
- ☑ Hydrogen Sulfide Odor (C1)
- ☐ Oxidized Rhizospheres on Living Roots (C3)
- ☐ Presence of Reduced Iron (C4)
- ☐ Recent Iron Reduction in Tilled Soils (C6)
- ☐ Thin Muck Surface (C7)
- ☐ Other (Explain in Remarks)

Secondary Indicators (minimum of two required)

- ☐ Surface Soil Cracks (B6)
- ☐ Sparsely Vegetated Concave Surface (B8)
- ☑ Drainage Patterns (B10)
- ☐ Moss Trim Lines (B16)
- ☐ Dry-Season Water Table (C2)
- ☐ Crayfish Burrows (C8)
- ☐ Saturation Visible on Aerial Imagery (C9)
- ☐ Stunted or Stressed Plants (D1)
- ☑ Geomorphic Position (D2)
- ☐ Shallow Aquitard (D3)
- ☐ Microtopographic Relief (D4)
- ☐ FAC-Neutral Test (D5)

Field Observations:

Surface Water Present?	Yes ☑	No ☐	Depth (inches): 1"
Water Table Present?	Yes ☐	No ☑	Depth (inches):
Saturation Present? (includes capillary fringe)	Yes ☑	No ☐	Depth (inches): Surface

Wetland Hydrology Present? Yes ☑ No ☐

Describe Recorded Data (stream gage, monitoring well, aerial photos, previous inspections), if available:

Remarks:

VEGETATION - Use scientific names of plants.

Sampling Point: DP-11

Tree Stratum (Plot size: 30 ft radius).	Absolute % Cover	Dominant Species?	Indicator Status
1.			
2.			
3.			
4.			
5.			
6.			
7.			
50% total cover: 0.0% 20% total cover: 0.0%	0%	= Total Cover	

Sapling Stratum (Plot size: 15 ft radius).	Absolute % Cover	Dominant Species?	Indicator Status
1.			
2.			
3.			
4.			
5.			
6.			
7.			
50% total cover: 0.0% 20% total cover: 0.0%	0%	= Total Cover	

Shrub Stratum (Plot size: 15 ft radius).	Absolute % Cover	Dominant Species?	Indicator Status
1.			
2.			
3.			
4.			
5.			
6.			
7.			
50% total cover: 0.0% 20% total cover: 0.0%	0%	= Total Cover	

Herb Stratum (Plot size: 5 ft radius).	Absolute % Cover	Dominant Species?	Indicator Status
1. *Phalaris arundinacea*	30	Yes	FACW
2. *Ranunculus ficaria*	30	Yes	FAC
3. *Impatiens capensis*	5	No	FACW
4. *Carex lurida*	5	No	OBL
5.			
6.			
7.			
8.			
9.			
10.			
11.			
12.			
50% total cover: 35.0% 20% total cover: 14.0%	70%	= Total Cover	

Woody Vine Stratum (Plot size: 30 ft radius).	Absolute % Cover	Dominant Species?	Indicator Status
1.			
2.			
3.			
4.			
7.			
50% total cover: 0.0% 20% total cover: 0.0%	0%	= Total Cover	

Domiance Test worksheet

Number of Dominant Species That are OBL, FACW, or FAC: 2 (A)

Total Number of Dominant Species Across All Strata: 2 (B)

Percent of Dominant Speices that are OBL, FACW, or FAC: 100.0% (A/B)

Prevalence Index worksheet

Total % Cover of:		Multiply by:		
OBL species	5	X 1	=	5
FACW species	35	X 2	=	70
FAC species	30	X 3	=	90
FACU species	0	X 4	=	0
UPL species	0	X 5	=	0
Column Totals	70	(A)		165 (B)

Prevalence Index = B/A = 2.36%

Hydrophytic Vegetation Indicators:

- ☐ 1. Rapid Test of Hydrophytic Vegetation
- ☑ 2. Dominance Test is >50%
- ☑ 3. Prevalence Index is ≤3.0[1]
- ☐ 4. Morphological Adaptations[1] (Provide supporting data in Remarks or on a separte sheet)
- ☐ Problematic Hydrophytic Vegetation[1] (Explain)

[1]Indicators of hydric soil and wetland hydrology must be present, unless disturbed or problematic.

Definitions of Vegetation Strata:

Tree - Woody plants, excluding woody vines, approximately 20 ft (6 m) or more in height and 3 in. (7.6 cm) or larger in diameter at breast height (DBH).

Sapling - Woody plants, excluding woody vines, approximately 20 ft (6 m) or more in height and less then 3 in. (7.6 cm) DBH.

Shrub - Woody plants, excluding woody vines, approximately 3 to 20 ft (1 to 6 m) in height.

Herb - All herbaceous (non-woody) plants, including herbaceous vines, regardless of size, and and woody plants, except woody vines, less than approximately 3 ft (1 m) in height

Woody Vine - All woody vines, regardless of height.

Hydropytic Vegetation Present? Yes ☑ No ☐

Remarks: (If observed, list morphological adaptations below).

Soils

Sampling Point: DP-11

Profile Description: (Describe to the depth needed to document the indicator or confirm the absence of indicators.)

Depth (inches)	Matrix Color (moist)	Matrix %	Redox Features Color (moist)	Redox %	Type¹	Loc²	Texture	Remarks
0-4	10YR 3/2	90	10YR 4/6	10	C	M	Clay loam	
4-12	2.5Y 5/3	85	10YR 4/6	15	C	M	Clay loam	

[1]Type: C=Concentration, D=Depletion, RM=Reduced Matrix, MS=Masked Sand Grains. [2]Location: PL=Pore Lining, M=Matrix

Hydric Soil Indicators:

- ☐ Histosol (A1)
- ☐ Histic Epipedon (A2)
- ☐ Black Histic (A3)
- ☑ Hydrogen Sulfide (A4)
- ☐ Stratified Layers (A5)
- ☐ 2 cm Muck (A10) (LRR N)
- ☐ Depleted Below Dark Surface (A11)
- ☐ Thick Dark Surface (A12)
- ☐ Sandy Mucky Mineral (S1)(LRR N,MLRA 147,148)
- ☐ Sandy Gleyed Matrix (S4)
- ☐ Sandy Redox (S5)
- ☐ Stripped Matrix (S6)
- ☐ Dark Surface (S7)
- ☐ Polyvalue Below Surace (S8) (MLRA 147,148)
- ☐ Thin Dark Surface (S9) (MLRA 147, 148)
- ☐ Loamy Gleyed Matrix (F2)
- ☐ Depleted Matrix (F3)
- ☐ Redox Dark Surface (F6)
- ☑ Depleted Dark Surface (F7)
- ☐ Redox Depressions (F8)
- ☐ Iron-Manganese Masses (F12) (LRR N, MLRA 136)
- ☐ Umbric Surface (F13) (MLRA 136, 122)
- ☐ Piedmont Floodplain Soils (F19) (MLRA 148)
- ☐ Red Parent Material (F21) (MLRA 127, 147)

Indicators of Problematic Hydric Soils[3]:

- ☐ 2 cm Muck (A10) (MLRA 147)
- ☐ Coast Prairie Redox (A16) (MLRA 147, 148)
- ☐ Piedmont Floodplain Soils (F19) (MLRA 136, 147)
- ☐ Very Shallow Dark Surface (TF12)
- ☐ Other (Explain in Remarks):

[3]Indicators of hydrophytic vegetation and wetland hydrology must be present, unless disturbed or problematic.

Restrictive Layer (if observed):
Type:
Depth (inches):

Hydric Soil Present? Yes ☑ No ☐

Remarks:

WETLAND DETERMINATION DATA FORM- Eastern Mountains and Piedmont

Project/Site: Plumtree Branch/Dunloggin Middle School City/County: Ellicott City, Howard Co. Sampling Date: 4/27/20
Applicant/Owner: Howard County Dept. of Parks and Recreation State: MD Sampling Point: DP-12
Investigator(s): HK Section,Township, Range:
Landform (hillslope, terrace, etc.) Floodplain Local relief (concave, convex, none): Concave Slope (%): 0%
Subregion (LRR or MLRA): LRR S Lat: 39.2557 Long: -76.8344 Datum: WGS84
Soil Map Unit Name: Ha (Hatboro-Codorus Silt Loam, 0-3% slope) NWI classification: N/A
Are climatic / hydrologic conditions on the site typical for this time of year? Yes ☑ No ☐ (If no, explain in Remarks.)

Are Vegetation N , Soil N , or Hydrology N Significantly disturbed? Are "Normal Circumstances" present? Yes ☑ No ☐
Are Vegetation N , Soil N , or Hydrology N Naturally problematic? (If needed, explain any answers in Remarks.)

SUMMARY OF FINDINGS - Attach site map showing sampling point locations, transects, important features, etc.

Hydrophytic Vegetation Present? Yes ☑ No ☐
Hydric Soil Present? Yes ☑ No ☐
Wetland Hydrology Present? Yes ☐ No ☑

Is the Sampled Area within a Wetland? Yes ☐ No ☑

Remarks:

Approximately 2" of rain fell on the site the night before the delineation. Saturation was not used as a sole indicator of wetland hydrology.

HYDROLOGY

Wetland Hydrology Indicators:

Primary Indicators (minimum of one is required: check all that apply)

- ☐ Surface Water (A1)
- ☐ High Water Table (A2)
- ☐ Saturation (A3)
- ☐ Water marks (B1)
- ☐ Sediment Deposits (B2)
- ☐ Drift Deposits (B3)
- ☐ Algal Mat or Crust (B4)
- ☐ Iron Deposits (B5)
- ☐ Inundation Visible on Aerial Imagery (B7)
- ☐ Water-Stained Leaves (B9)
- ☐ Aquatic Fauna (B13)
- ☐ True Aquatic Plants (B14)
- ☐ Hydrogen Sulfide Odor (C1)
- ☐ Oxidized Rhizospheres on Living Roots (C3)
- ☐ Presence of Reduced Iron (C4)
- ☐ Recent Iron Reduction in Tilled Soils (C6)
- ☐ Thin Muck Surface (C7)
- ☐ Other (Explain in Remarks)

Secondary Indicators (minimum of two required)

- ☐ Surface Soil Cracks (B6)
- ☐ Sparsely Vegetated Concave Surface (B8)
- ☐ Drainage Patterns (B10)
- ☐ Moss Trim Lines (B16)
- ☐ Dry-Season Water Table (C2)
- ☐ Crayfish Burrows (C8)
- ☐ Saturation Visible on Aerial Imagery (C9)
- ☐ Stunted or Stressed Plants (D1)
- ☐ Geomorphic Position (D2)
- ☐ Shallow Aquitard (D3)
- ☐ Microtopographic Relief (D4)
- ☐ FAC-Neutral Test (D5)

Field Observations:

Surface Water Present? Yes ☐ No ☑ Depth (inches):
Water Table Present? Yes ☐ No ☑ Depth (inches):
Saturation Present? (includes capillary fringe) Yes ☐ No ☑ Depth (inches):

Wetland Hydrology Present? Yes ☐ No ☑

Describe Recorded Data (stream gage, monitoring well, aerial photos, previous inspections), if available:

Remarks:

VEGETATION - Use scientific names of plants.

Sampling Point: DP-12

Tree Stratum (Plot size: 30 ft radius).	Absolute % Cover	Dominant Species?	Indicator Status
1.			
2.			
3.			
4.			
5.			
6.			
7.			
50% total cover: 0.0% 20% total cover: 0.0%	0%	= Total Cover	

Sapling Stratum (Plot size: 15 ft radius).	Absolute % Cover	Dominant Species?	Indicator Status
1.			
2.			
3.			
4.			
5.			
6.			
7.			
50% total cover: 0.0% 20% total cover: 0.0%	0%	= Total Cover	

Shrub Stratum (Plot size: 15 ft radius).	Absolute % Cover	Dominant Species?	Indicator Status
1.			
2.			
3.			
4.			
5.			
6.			
7.			
50% total cover: 0.0% 20% total cover: 0.0%	0%	= Total Cover	

Herb Stratum (Plot size: 5 ft radius).	Absolute % Cover	Dominant Species?	Indicator Status
1. *Phalaris arundinacea*	60	Yes	FACW
2. *Ranunculus ficaria*	20	Yes	FAC
3. *Impatiens capensis*	5	No	FACW
4. *Carex lurida*	5	No	OBL
5.			
6.			
7.			
8.			
9.			
10.			
11.			
12.			
50% total cover: 45.0% 20% total cover: 18.0%	90%	= Total Cover	

Woody Vine Stratum (Plot size: 30 ft radius).	Absolute % Cover	Dominant Species?	Indicator Status
1.			
2.			
3.			
4.			
7.			
50% total cover: 0.0% 20% total cover: 0.0%	0%	= Total Cover	

Domiance Test worksheet

Number of Dominant Species That are OBL, FACW, or FAC: 2 (A)

Total Number of Dominant Species Across All Strata: 2 (B)

Percent of Dominant Speices that are OBL, FACW, or FAC: 100.0% (A/B)

Prevalence Index worksheet

Total % Cover of:		Multiply by:		
OBL species	5	X 1	=	5
FACW species	65	X 2	=	130
FAC species	20	X 3	=	60
FACU species	0	X 4	=	0
UPL species	0	X 5	=	0
Column Totals	90	(A)	195	(B)

Prevalence Index = B/A = 2.17%

Hydrophytic Vegetation Indicators:

- ☐ 1. Rapid Test of Hydrophytic Vegetation
- ☑ 2. Dominance Test is >50%
- ☑ 3. Prevalence Index is ≤3.0[1]
- ☐ 4. Morphological Adaptations[1] (Provide supporting data in Remarks or on a separte sheet)
- ☐ Problematic Hydrophytic Vegetation[1] (Explain)

[1]Indicators of hydric soil and wetland hydrology must be present, unless disturbed or problematic.

Definitions of Vegetation Strata:

Tree - Woody plants, excluding woody vines, approximately 20 ft (6 m) or more in height and 3 in. (7.6 cm) or larger in diameter at breast height (DBH).

Sapling - Woody plants, excluding woody vines, approximately 20 ft (6 m) or more in height and less then 3 in. (7.6 cm) DBH.

Shrub - Woody plants, excluding woody vines, approximately 3 to 20 ft (1 to 6 m) in height.

Herb - All herbaceous (non-woody) plants, including herbaceous vines, regardless of size, and and woody plants, except woody vines, less than approximately 3 ft (1 m) in height

Woody Vine - All woody vines, regardless of height.

Hydropytic Vegetation Present? Yes ☑ No ☐

Remarks: (If observed, list morphological adaptations below).

Soils

Sampling Point: DP-12

Profile Description: (Describe to the depth needed to document the indicator or confirm the absence of indicators.)

Depth	Matrix		Redox Features				Texture	Remarks
(inches)	Color (moist)	%	Color (moist)	%	Type¹	Loc²		
0-4	10YR 3/2	90	10YR 4/6	10	C	M	Clay loam	
4-12	2.5Y 5/3	85	10YR 4/6	15	C	M	Clay loam	

¹Type: C=Concentration, D=Depletion, RM=Reduced Matrix, MS=Masked Sand Grains. ²Location: PL=Pore Lining, M=Matrix

Hydric Soil Indicators:

- ☐ Histosol (A1)
- ☐ Histic Epipedon (A2)
- ☐ Black Histic (A3)
- ☐ Hydrogen Sulfide (A4)
- ☐ Stratified Layers (A5)
- ☐ 2 cm Muck (A10) (LRR N)
- ☐ Depleted Below Dark Surface (A11)
- ☐ Thick Dark Surface (A12)
- ☐ Sandy Mucky Mineral (S1)(LRR N,MLRA 147,148)
- ☐ Sandy Gleyed Matrix (S4)
- ☐ Sandy Redox (S5)
- ☐ Stripped Matrix (S6)
- ☐ Dark Surface (S7)
- ☐ Polyvalue Below Surace (S8) (MLRA 147,148)
- ☐ Thin Dark Surface (S9) (MLRA 147, 148)
- ☐ Loamy Gleyed Matrix (F2)
- ☐ Depleted Matrix (F3)
- ☐ Redox Dark Surface (F6)
- ☑ Depleted Dark Surface (F7)
- ☐ Redox Depressions (F8)
- ☐ Iron-Manganese Masses (F12) (LRR N, MLRA 136)
- ☐ Umbric Surface (F13) (MLRA 136, 122)
- ☐ Piedmont Floodplain Soils (F19) (MLRA 148)
- ☐ Red Parent Material (F21) (MLRA 127, 147)

Indicators of Problematic Hydric Soils[3]:

- ☐ 2 cm Muck (A10) (MLRA 147)
- ☐ Coast Prairie Redox (A16) (MLRA 147, 148)
- ☐ Piedmont Floodplain Soils (F19) (MLRA 136, 147)
- ☐ Very Shallow Dark Surface (TF12)
- ☐ Other (Explain in Remarks):

[3]Indicators of hydrophytic vegetation and wetland hydrology must be present, unless disturbed or problematic.

Restrictive Layer (if observed):
Type: ______
Depth (inches): ______

Hydric Soil Present? Yes ☑ No ☐

Remarks:

WETLAND DETERMINATION DATA FORM- Eastern Mountains and Piedmont

Project/Site: Plumtree Branch/Dunloggin Middle School | City/County: Ellicott City, Howard Co. | Sampling Date: 4/27/20

Applicant/Owner: Howard County Dept. of Parks and Recreation | State: MD | Sampling Point: DP-13

Investigator(s): HK | Section,Township, Range:

Landform (hillslope, terrace, etc.): Floodplain | Local relief (concave, convex, none): Concave | Slope (%): 0%

Subregion (LRR or MLRA): LRR S | Lat: 39.2557 | Long: -76.8344 | Datum: WGS84

Soil Map Unit Name: Ha (Hatboro-Codorus Silt Loam, 0-3% slope) | NWI classification: N/A

Are climatic / hydrologic conditions on the site typical for this time of year? Yes ☑ No ☐ (If no, explain in Remarks.)

Are Vegetation N, Soil N, or Hydrology N Significantly disturbed? Are "Normal Circumstances" present? Yes ☑ No ☐

Are Vegetation N, Soil N, or Hydrology N Naturally problematic? (If needed, explain any answers in Remarks.)

SUMMARY OF FINDINGS - Attach site map showing sampling point locations, transects, important features, etc.

Hydrophytic Vegetation Present? Yes ☑ No ☐

Hydric Soil Present? Yes ☑ No ☐

Wetland Hydrology Present? Yes ☑ No ☐

Is the Sampled Area within a Wetland? Yes ☑ No ☐

Remarks:

Approximately 2" of rain fell on the site the night before the delineation. Saturation was not used as a sole indicator of wetland hydrology. In Wetland 8

HYDROLOGY

Wetland Hydrology Indicators:

Primary Indicators (minimum of one is required: check all that apply)

- ☑ Surface Water (A1)
- ☑ High Water Table (A2)
- ☑ Saturation (A3)
- ☐ Water marks (B1)
- ☐ Sediment Deposits (B2)
- ☐ Drift Deposits (B3)
- ☐ Algal Mat or Crust (B4)
- ☐ Iron Deposits (B5)
- ☐ Inundation Visible on Aerial Imagery (B7)
- ☐ Water-Stained Leaves (B9)
- ☐ Aquatic Fauna (B13)
- ☐ True Aquatic Plants (B14)
- ☐ Hydrogen Sulfide Odor (C1)
- ☐ Oxidized Rhizospheres on Living Roots (C3)
- ☐ Presence of Reduced Iron (C4)
- ☐ Recent Iron Reduction in Tilled Soils (C6)
- ☐ Thin Muck Surface (C7)
- ☐ Other (Explain in Remarks)

Secondary Indicators (minimum of two required)

- ☐ Surface Soil Cracks (B6)
- ☐ Sparsely Vegetated Concave Surface (B8)
- ☑ Drainage Patterns (B10)
- ☐ Moss Trim Lines (B16)
- ☐ Dry-Season Water Table (C2)
- ☐ Crayfish Burrows (C8)
- ☐ Saturation Visible on Aerial Imagery (C9)
- ☐ Stunted or Stressed Plants (D1)
- ☑ Geomorphic Position (D2)
- ☐ Shallow Aquitard (D3)
- ☐ Microtopographic Relief (D4)
- ☐ FAC-Neutral Test (D5)

Field Observations:

Surface Water Present? Yes ☑ No ☐ Depth (inches): 1"

Water Table Present? Yes ☑ No ☐ Depth (inches): 4"

Saturation Present? (includes capillary fringe) Yes ☑ No ☐ Depth (inches): surface

Wetland Hydrology Present? Yes ☑ No ☐

Describe Recorded Data (stream gage, monitoring well, aerial photos, previous inspections), if available:

Remarks:

VEGETATION - Use scientific names of plants.

Sampling Point: DP-13

Tree Stratum (Plot size: 30 ft radius).	Absolute % Cover	Dominant Species?	Indicator Status
1. *Acer negundo*	5	Yes	FAC
2.			
3.			
4.			
5.			
6.			
7.			
50% total cover: 2.5% 20% total cover: 1.0%	5%	= Total Cover	

Sapling Stratum (Plot size: 15 ft radius).	Absolute % Cover	Dominant Species?	Indicator Status
1. *Acer negundo*	5	Yes	FAC
2.			
3.			
4.			
5.			
6.			
7.			
50% total cover: 2.5% 20% total cover: 1.0%	5%	= Total Cover	

Shrub Stratum (Plot size: 15 ft radius).	Absolute % Cover	Dominant Species?	Indicator Status
1.			
2.			
3.			
4.			
5.			
6.			
7.			
50% total cover: 0.0% 20% total cover: 0.0%	0%	= Total Cover	

Herb Stratum (Plot size: 5 ft radius).	Absolute % Cover	Dominant Species?	Indicator Status
1. *Phalaris arundinacea*	40	Yes	FACW
2. *Carex lurida*	15	Yes	OBL
3. *Ranunculus ficaria*	10	No	FAC
4. *Symplocarpus foetidus*	10	No	OBL
5. *Lysimachia nummularia*	5	No	FACW
6. *Persicaria hydropiper*	5	No	OBL
7.			
8.			
9.			
10.			
11.			
12.			
50% total cover: 42.5% 20% total cover: 17.0%	85%	= Total Cover	

Woody Vine Stratum (Plot size: 30 ft radius).	Absolute % Cover	Dominant Species?	Indicator Status
1.			
2.			
3.			
4.			
7.			
50% total cover: 0.0% 20% total cover: 0.0%	0%	= Total Cover	

Domiance Test worksheet

Number of Dominant Species That are OBL, FACW, or FAC: 3 (A)

Total Number of Dominant Species Across All Strata: 3 (B)

Percent of Dominant Speices that are OBL, FACW, or FAC: 100.0% (A/B)

Prevalence Index worksheet

Total % Cover of:		Multiply by:		
OBL species	30	X 1	=	30
FACW species	45	X 2	=	90
FAC species	20	X 3	=	60
FACU species	0	X 4	=	0
UPL species	0	X 5	=	0
Column Totals	95	(A)		180 (B)

Prevalence Index = B/A = 1.89%

Hydrophytic Vegetation Indicators:

- ☐ 1. Rapid Test of Hydrophytic Vegetation
- ☑ 2. Dominance Test is >50%
- ☑ 3. Prevalence Index is ≤3.0[1]
- ☐ 4. Morphological Adaptations[1] (Provide supporting data in Remarks or on a separte sheet)
- ☐ Problematic Hydrophytic Vegetation[1] (Explain)

[1]Indicators of hydric soil and wetland hydrology must be present, unless disturbed or problematic.

Definitions of Vegetation Strata:

Tree - Woody plants, excluding woody vines, approximately 20 ft (6 m) or more in height and 3 in. (7.6 cm) or larger in diameter at breast height (DBH).

Sapling - Woody plants, excluding woody vines, approximately 20 ft (6 m) or more in height and less then 3 in. (7.6 cm) DBH.

Shrub - Woody plants, excluding woody vines, approximately 3 to 20 ft (1 to 6 m) in height.

Herb - All herbaceous (non-woody) plants, including herbaceous vines, regardless of size, and and woody plants, except woody vines, less than approximately 3 ft (1 m) in height

Woody Vine - All woody vines, regardless of height.

Hydropytic Vegetation Present? Yes ☑ No ☐

Remarks: (If observed, list morphological adaptations below).

Soils

Sampling Point: DP-13

Profile Description: (Describe to the depth needed to document the indicator or confirm the absence of indicators.)

Depth (inches)	Matrix Color (moist)	Matrix %	Redox Features Color (moist)	Redox %	Type[1]	Loc[2]	Texture	Remarks
0-1	10YR 3/2	100					Clay loam	
1-5	10 YR 4/1	95	10YR 4/6	15	C	PL	Clay loam	
5-15	10 YR 5/4	96	10YR 4/6	2	C	M	Clay	faint
			10YR 4/6	2	C	PL		bold concentrations

[1]Type: C=Concentration, D=Depletion, RM=Reduced Matrix, MS=Masked Sand Grains. [2]Location: PL=Pore Lining, M=Matrix

Hydric Soil Indicators:

- ☐ Histosol (A1)
- ☐ Histic Epipedon (A2)
- ☐ Black Histic (A3)
- ☐ Hydrogen Sulfide (A4)
- ☐ Stratified Layers (A5)
- ☐ 2 cm Muck (A10) (LRR N)
- ☐ Depleted Below Dark Surface (A11)
- ☐ Thick Dark Surface (A12)
- ☐ Sandy Mucky Mineral (S1)(LRR N,MLRA 147,148)
- ☐ Sandy Gleyed Matrix (S4)
- ☐ Sandy Redox (S5)
- ☐ Stripped Matrix (S6)
- ☐ Dark Surface (S7)
- ☐ Polyvalue Below Surace (S8) (MLRA 147,148)
- ☐ Thin Dark Surface (S9) (MLRA 147, 148)
- ☐ Loamy Gleyed Matrix (F2)
- ☑ Depleted Matrix (F3)
- ☐ Redox Dark Surface (F6)
- ☐ Depleted Dark Surface (F7)
- ☐ Redox Depressions (F8)
- ☐ Iron-Manganese Masses (F12) (LRR N, MLRA 136)
- ☐ Umbric Surface (F13) (MLRA 136, 122)
- ☐ Piedmont Floodplain Soils (F19) (MLRA 148)
- ☐ Red Parent Material (F21) (MLRA 127, 147)

Indicators of Problematic Hydric Soils[3]:

- ☐ 2 cm Muck (A10) (MLRA 147)
- ☐ Coast Prairie Redox (A16) (MLRA 147, 148)
- ☐ Piedmont Floodplain Soils (F19) (MLRA 136, 147)
- ☐ Very Shallow Dark Surface (TF12)
- ☐ Other (Explain in Remarks):

[3]Indicators of hydrophytic vegetation and wetland hydrology must be present, unless disturbed or problematic.

Restrictive Layer (if observed):
Type:
Depth (inches):

Hydric Soil Present? Yes ☑ No ☐

Remarks:

WETLAND DETERMINATION DATA FORM- Eastern Mountains and Piedmont

Project/Site: Plumtree Branch/Dunloggin Middle School   City/County: Ellicott City, Howard Co.   Sampling Date: 4/27/20

Applicant/Owner: Howard County Dept. of Parks and Recreation   State: MD   Sampling Point: DP-14

Investigator(s): HK   Section,Township, Range:

Landform (hillslope, terrace, etc.) Floodplain   Local relief (concave, convex, none): Concave   Slope (%): 0%

Subregion (LRR or MLRA): LRR S   Lat: 39.2557   Long: -76.8344   Datum: WGS84

Soil Map Unit Name: Ha (Hatboro-Codorus Silt Loam, 0-3% slope)   NWI classification: N/A

Are climatic / hydrologic conditions on the site typical for this time of year? Yes [x] No [ ] (If no, explain in Remarks.)

Are Vegetation N , Soil N , or Hydrology N Significantly disturbed?   Are "Normal Circumstances" present? Yes [x] No [ ]

Are Vegetation N , Soil N , or Hydrology N Naturally problematic?   (If needed, explain any answers in Remarks.)

SUMMARY OF FINDINGS - Attach site map showing sampling point locations, transects, important features, etc.

Hydrophytic Vegetation Present?	Yes [x]	No [ ]		
Hydric Soil Present?	Yes [x]	No [ ]	Is the Sampled Area	
Wetland Hydrology Present?	Yes [x]	No [ ]	within a Wetland?	Yes [ ] No [x]

Remarks:

Approximately 2" of rain fell on the site the night before the delineation. Saturation was not used as a sole indicator of wetland hydrology. In Wetland 8

HYDROLOGY

Wetland Hydrology Indicators:

Primary Indicators (minimum of one is required: check all that apply)

- [ ] Surface Water (A1)
- [ ] High Water Table (A2)
- [x] Saturation (A3)
- [ ] Water marks (B1)
- [ ] Sediment Deposits (B2)
- [ ] Drift Deposits (B3)
- [ ] Algal Mat or Crust (B4)
- [ ] Iron Deposits (B5)
- [ ] Inundation Visible on Aerial Imagery (B7)
- [ ] Water-Stained Leaves (B9)
- [ ] Aquatic Fauna (B13)
- [ ] True Aquatic Plants (B14)
- [x] Hydrogen Sulfide Odor (C1)
- [ ] Oxidized Rhizospheres on Living Roots (C3)
- [ ] Presence of Reduced Iron (C4)
- [ ] Recent Iron Reduction in Tilled Soils (C6)
- [ ] Thin Muck Surface (C7)
- [ ] Other (Explain in Remarks)

Secondary Indicators (minimum of two required)

- [ ] Surface Soil Cracks (B6)
- [ ] Sparsely Vegetated Concave Surface (B8)
- [x] Drainage Patterns (B10)
- [ ] Moss Trim Lines (B16)
- [ ] Dry-Season Water Table (C2)
- [ ] Crayfish Burrows (C8)
- [ ] Saturation Visible on Aerial Imagery (C9)
- [ ] Stunted or Stressed Plants (D1)
- [x] Geomorphic Position (D2)
- [ ] Shallow Aquitard (D3)
- [ ] Microtopographic Relief (D4)
- [ ] FAC-Neutral Test (D5)

Field Observations:

Surface Water Present?	Yes [ ]	No [x]	Depth (inches):
Water Table Present?	Yes [ ]	No [x]	Depth (inches):
Saturation Present? (includes capillary fringe)	Yes [x]	No [ ]	Depth (inches): surface

Wetland Hydrology Present? Yes [x] No [ ]

Describe Recorded Data (stream gage, monitoring well, aerial photos, previous inspections), if available:

Remarks:

VEGETATION - Use scientific names of plants.

Sampling Point: DP-14

Tree Stratum (Plot size: 30 ft radius).	Absolute % Cover	Dominant Species?	Indicator Status
1. *Acer rubrum*	10	Yes	FAC
2.			
3.			
4.			
5.			
6.			
7.			
50% total cover: 5.0% 20% total cover: 2.0%	10%	= Total Cover	

Sapling Stratum (Plot size: 15 ft radius).	Absolute % Cover	Dominant Species?	Indicator Status
1. *Acer rubrum*	5	Yes	FAC
2.			
3.			
4.			
5.			
6.			
7.			
50% total cover: 2.5% 20% total cover: 1.0%	5%	= Total Cover	

Shrub Stratum (Plot size: 15 ft radius).	Absolute % Cover	Dominant Species?	Indicator Status
1. *Rosa multiflora*	5	Yes	FACU
2.			
3.			
4.			
5.			
6.			
7.			
50% total cover: 2.5% 20% total cover: 1.0%	5%	= Total Cover	

Herb Stratum (Plot size: 5 ft radius).	Absolute % Cover	Dominant Species?	Indicator Status
1. *Carex stricta*	30	Yes	OBL
2. *Phalaris arundinacea*	10	Yes	FACW
3. *Bidens frondosa*	5	No	FACW
4. *Arisaema triphyllum*	5	No	FACW
5.			
6.			
7.			
8.			
9.			
10.			
11.			
12.			
50% total cover: 25.0% 20% total cover: 10.0%	50%	= Total Cover	

Woody Vine Stratum (Plot size: 30 ft radius).	Absolute % Cover	Dominant Species?	Indicator Status
1.			
2.			
3.			
4.			
7.			
50% total cover: 0.0% 20% total cover: 0.0%	0%	= Total Cover	

Domiance Test worksheet

Number of Dominant Species That are OBL, FACW, or FAC: 3 (A)

Total Number of Dominant Species Across All Strata: 4 (B)

Percent of Dominant Speices that are OBL, FACW, or FAC: 75.0% (A/B)

Prevalence Index worksheet

Total % Cover of:		Multiply by:		
OBL species	30	X 1	=	30
FACW species	20	X 2	=	40
FAC species	15	X 3	=	45
FACU species	5	X 4	=	20
UPL species	0	X 5	=	0
Column Totals	70	(A)		135 (B)

Prevalence Index = B/A = 1.93%

Hydrophytic Vegetation Indicators:

- ☐ 1. Rapid Test of Hydrophytic Vegetation
- ☑ 2. Dominance Test is >50%
- ☑ 3. Prevalence Index is ≤3.0[1]
- ☐ 4. Morphological Adaptations[1] (Provide supporting data in Remarks or on a separte sheet)
- ☐ Problematic Hydrophytic Vegetation[1] (Explain)

[1]Indicators of hydric soil and wetland hydrology must be present, unless disturbed or problematic.

Definitions of Vegetation Strata:

Tree - Woody plants, excluding woody vines, approximately 20 ft (6 m) or more in height and 3 in. (7.6 cm) or larger in diameter at breast height (DBH).

Sapling - Woody plants, excluding woody vines, approximately 20 ft (6 m) or more in height and less then 3 in. (7.6 cm) DBH.

Shrub - Woody plants, excluding woody vines, approximately 3 to 20 ft (1 to 6 m) in height.

Herb - All herbaceous (non-woody) plants, including herbaceous vines, regardless of size, and and woody plants, except woody vines, less than approximately 3 ft (1 m) in height

Woody Vine - All woody vines, regardless of height.

Hydropytic Vegetation Present? Yes ☑ No ☐

Remarks: (If observed, list morphological adaptations below).

Soils

Sampling Point: DP-14

Profile Description: (Describe to the depth needed to document the indicator or confirm the absence of indicators.)

Depth (inches)	Matrix Color (moist)	Matrix %	Redox Features Color (moist)	Redox %	Type[1]	Loc[2]	Texture	Remarks
0-4	10YR 4/1	95	10YR 4/6				Clay loam	
4-6	10YR 4/2	95	10YR 4/6	5	C	M	Clay loam	
6-13	10YR 4/4	80	10YR 4/1	10	D	M	Clay	
			10YR 4/6	10	C	M		

[1]Type: C=Concentration, D=Depletion, RM=Reduced Matrix, MS=Masked Sand Grains. [2]Location: PL=Pore Lining, M=Matrix

Hydric Soil Indicators:

- ☐ Histosol (A1)
- ☐ Histic Epipedon (A2)
- ☐ Black Histic (A3)
- ☑ Hydrogen Sulfide (A4)
- ☐ Stratified Layers (A5)
- ☐ 2 cm Muck (A10) (LRR N)
- ☐ Depleted Below Dark Surface (A11)
- ☐ Thick Dark Surface (A12)
- ☐ Sandy Mucky Mineral (S1)(LRR N,MLRA 147,148)
- ☐ Sandy Gleyed Matrix (S4)
- ☐ Sandy Redox (S5)
- ☐ Stripped Matrix (S6)
- ☐ Dark Surface (S7)
- ☐ Polyvalue Below Surace (S8) (MLRA 147,148)
- ☐ Thin Dark Surface (S9) (MLRA 147, 148)
- ☐ Loamy Gleyed Matrix (F2)
- ☑ Depleted Matrix (F3)
- ☐ Redox Dark Surface (F6)
- ☐ Depleted Dark Surface (F7)
- ☐ Redox Depressions (F8)
- ☐ Iron-Manganese Masses (F12) (LRR N, MLRA 136)
- ☐ Umbric Surface (F13) (MLRA 136, 122)
- ☐ Piedmont Floodplain Soils (F19) (MLRA 148)
- ☐ Red Parent Material (F21) (MLRA 127, 147)

Indicators of Problematic Hydric Soils[3]:

- ☐ 2 cm Muck (A10) (MLRA 147)
- ☐ Coast Prairie Redox (A16) (MLRA 147, 148)
- ☐ Piedmont Floodplain Soils (F19) (MLRA 136, 147)
- ☐ Very Shallow Dark Surface (TF12)
- ☐ Other (Explain in Remarks):

[3]Indicators of hydrophytic vegetation and wetland hydrology must be present, unless disturbed or problematic.

Restrictive Layer (if observed):
Type:
Depth (inches):

Hydric Soil Present? Yes ☑ No ☐

Remarks:

Appendix: D

Plumtree Branch

Ecological Restoration Design

Trees to be Removed

Tree Number	Common Name	Scientific Name	DBH	Condition
T1	Red Maple	*Acer Rubrum*	18.8	Poor
T2	Sweet Gum	*Liquidambar styraciflua*	16.1	Poor
T3	American Elm	*Ulmus Americana*	18.4	Poor
T4	Black Walnut	*Juglans Nigra*	20.2	Poor
T5	Red Maple	*Acer Rubrum*	19.9	Poor
T6	Unknown	-	17.6	Dead
T7	American Elm	*Ulmus Americana*	11.5	Fair
T8	Black Walnut	*Juglans Nigra*	13.0	Fair
T9	Pin Oak	*Quercus Palustris*	11.9	Fair
T10	American Sycamore	*Platanus occidentalis*	18.0	Fair
T11	Unknown	-	13.4	Dead
T12	Pin Oak	*Quercus Palustris*	13.5	Good
T13	Black Walnut	*Juglans Nigra*	17.9	Fair
T14	Black Walnut	*Juglans Nigra*	15.6	Fair
T15	American Elm	*Ulmus Americana*	10.5	Poor
T16	Black Walnut	*Juglans Nigra*	14.3	Fair
T17	Red Maple	*Acer Rubrum*	19.1	Poor
T18	American Elm	*Ulmus Americana*	21.1	Poor
T19	Black Walnut	*Juglans Nigra*	11.5	Fair
T20	American Elm	*Ulmus Americana*	17.5	Poor
T21	American Elm	*Ulmus Americana*	14.5	Poor
T22	American Elm	*Ulmus Americana*	12.1	Fair
T23	Red Maple	*Acer Rubrum*	10.1	Fair
T24	Pin Oak	*Quercus Palustris*	13.5	Fair
T25	Red Maple	*Acer Rubrum*	22.7	Poor
T26	Red Maple	*Acer Rubrum*	15.6	Fair
T27	American Sycamore	*Platanus occidentalis*	16.0	Fair
T28	Green Ash	*Fraxinus Pennsylvanica*	13.0	Poor
T29	Green Ash	*Fraxinus Pennsylvanica*	15.0	Poor
T30	American Elm	*Ulmus Americana*	14.3	Good
T31	Black Cherry	*Prunus Serotina*	13.5	Poor
T32	Black Cherry	*Prunus Serotina*	18.1	Fair
T33	Red Maple	*Acer Rubrum*	13.4	Poor
T34	Black Cherry	*Prunus Serotina*	12.7	Fair
T35	Black Cherry	*Prunus Serotina*	13.8	Poor
T36	Black Walnut	*Juglans Nigra*	9.6	Fair
T37	Black Cherry	*Prunus Serotina*	12.7	Dead
T38	Black Walnut	*Juglans Nigra*	10.1	Poor
T39	Black Walnut	*Juglans Nigra*	13.7	Poor
T40	Green Ash	*Fraxinus Pennsylvanica*	10.8	Poor
T41	Red Maple	*Acer Rubrum*	10.2	Good
T42	Red Maple	*Acer Rubrum*	14.4	Fair
T43	Red Maple	*Acer Rubrum*	10.1	Poor
T44	Red Maple	*Acer Rubrum*	12.1	Poor
T45	Green Ash	*Fraxinus Pennsylvanica*	12.0	Fair
T46	Silver Maple	*Acer Saccharinum*	11.5	Fair

Appendix: E

PLUMTREE BRANCH STREAM RESTORATION PROJECTS HYDROLOGIC AND HYDRAULIC REPORT HOWARD COUNTY, MARYLAND

Prepared for:

Ecotone, Inc.
129 Industry Lane
Forest Hill, MD 21050

Prepared by:

Ecosystem Planning and Restoration, LLC
8808 Centre Park Drive
Columbia, MD 21045

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1. Introduction

Ecosystem Planning and Restoration (EPR) was contracted by Ecotone, Inc. (Ecotone) to provide H&H modeling for Plumtree Branch and the Unnamed Tributary flowing into it. The proposed Plumtree Branch Restoration project is located in Ellicot City, Howard County, Maryland. The Plumtree Branch project reach is approximately 3,450 linear feet in length and has a drainage area of approximately 3.10 mi^2 at the lower terminus of the project. Services provided in this report include hydrologic analysis of existing regression equations to provide accurate flow regimes, and hydraulic modeling to compare existing and proposed velocities, shear stress, and water surface elevations for the 1.25-, 2-, 10-, and 100-year storm flows. This report documents the methodology and findings of the H&H modeling conducted for the project areas.

2. Hydrology

2.1. Methodology

EPR prepared a hydrologic analysis of Plumtree Branch and Unnamed Tributary using the Effective FEMA hydraulic models for the two stream systems, Stream Stats, and regression equations provided in the Applications of Hydrologic Methods in Maryland (Thomas 2010) document.

Using the FEMA Effective models for Plumtree Branch and the Unnamed Tributary, flow change locations were identified and confirmed based on the flow files used in the hydraulic analysis. Using these cross-section points along the streams, Drainage Areas (DA) were obtained using USGS Stream Stats. The reports generated from Stream Stats provided drainage areas and Percent Impervious Areas (IA) necessary for the Piedmont (Urban) Fixed Region Regression Equations shown below in Figure 1.

Figure 1. Piedmont (Urban) Fixed Region Regression Equations (Thomas 2010)

Piedmont (Urban) Fixed Region Regression Equation	Standard error (percent)	Equivalent years of record
$Q_{1.25} = 17.85\ DA^{0.652}\ (IA+1)^{0.635}$	41.7	3.3
$Q_{1.50} = 24.66\ DA^{0.648}\ (IA+1)^{0.631}$	36.9	3.8
$Q_{2} = 37.01\ DA^{0.635}\ (IA+1)^{0.588}$	35.1	4.5
$Q_{5} = 94.76\ DA^{0.624}\ (IA+1)^{0.499}$	28.5	13
$Q_{10} = 169.2\ DA^{0.622}\ (IA+1)^{0.435}$	26.2	24
$Q_{25} = 341.0\ DA^{0.619}\ (IA+1)^{0.349}$	26.0	38
$Q_{50} = 562.4\ DA^{0.619}\ (IA+1)^{0.284}$	27.7	44
$Q_{100} = 898.3\ DA^{0.619}\ (IA+1)^{0.222}$	30.7	45
$Q_{200} = 1413\ DA^{0.621}\ (IA+1)^{0.160}$	34.8	44
$Q_{500} = 2529\ DA^{0.623}\ (IA+1)^{0.079}$	41.2	40

To properly model the hydraulics of the project, discharge values were calculated using the regression equations above for 1.25-, 2-, 10-, and 100-year storms. Drainage Areas (DA) and Percent Impervious Cover (IA) values are provided in Table 1.

Table 1. Summary of Regression Equation Parameters

Plumtree Branch				**Unnamed Tributary**			
Cross-Section	**Baseline STA**	**DA (mi^2)**	**IA (%)**	**Cross-Section**	**Baseline STA**	**DA (mi^2)**	**IA (%)**
0.3951	33+61	3.05	32.9	76.46746	8+99	0.33	29.3
0.6214	21+92	2.76	32.4				
0.6757	19+00	2.76	32.5				
0.8698	N/A	2.35	33.0				

2.2. Results

The results of the hydrologic regression analysis are summarized in Table 2.

Table 2. Hydrologic Analysis Results

Plumtree Branch					
Cross-Section	**Baseline STA**	**Q1.25 (cfs)**	**Q2 (cfs)**	**Q10 (cfs)**	**Q100 (cfs)**
0.3951	33+61	346	596	1568	3917
0.6214	21+92	321	555	1464	3670
0.6757	19+00	322	556	1466	3672
0.8698	N/A	292	506	1335	3335
Unnamed Tributary					
76.46746	8+99	76	136	374	964

To comply with HEC RAS modeling best practices, flows at XS 21+92 were rounded to match XS 19+00 as differences in flows are minor, due to minor differences in Impervious Area in the watershed.

3. Hydraulic

3.1. Methodology

EPR prepared hydraulic models for Plumtree Creek and Unnamed Tributary using the HEC-RAS, version 6.1, hydraulic modeling program. One-Dimensional (1-D) Steady State models were developed to support the hydrologic model routing (see Section 2.1) and to evaluate existing and proposed conditions. Effective FEMA HEC-RAS hydraulic models were used to develop the project models. Details of the hydraulic modeling are described in the following sections.

3.2. Existing Conditions

Two existing conditions 1D-model were developed to evaluate the 1.25-, 2-, 10-, and 100-year flow frequency events for Plumtree Branch and the Unnamed Tributary flowing into the main branch. The Plumtree Branch model extends from the Columbia Street Road to the convergence of the Unnamed Tributary approximately 500 ft downstream of the Chatham Road Bridge. The Unnamed Tributary model extends from that same convergence to the pedestrian crossing approximately 500 LF downstream of Pebble Branch Road. Stations 21+92 to 0.8698 on Plumtree Branch and Stations 8+99 to 0+30 on the Unnamed Tributary are within the proposed project area. The existing condition cross-section layout is shown on Figures 1 and 2 in Appendix A.

The Effective FEMA geometry was truncated to only include the project area. Station and elevation data were modified using a composite terrain created using 2018 LiDAR and existing condition survey data within the project site provided by the Client. Existing pedestrian crossings were preserved from the FEMA model and capture the backwater areas upstream of the crossings. Additionally, cross-sections were placed to allow for comparison of results with the proposed design within the project site and capture the flood inundation area within the project area.

Bank stations were selected to correspond with bankfull elevations identified in the field and at grade breaks between the channel and the floodplain. Manning's n-values were selected based on the channel material and overbank vegetation ranging from 0.04 in the channel, and 0.06 in the overbanks.

One existing pedestrian crossing was modeled to represent the rectangular opening with sloped abutments that spans the Unnamed Tributary. The pedestrian bridge opening is a 15-ft wide by 10-ft high rectangular opening with a natural bottom. In the Plumtree Branch model, one existing pedestrian bridge is modeled as well. The pedestrian bridge opening is an arched opening that is 120-ft wide and 4.5-ft high that spans the length of the existing floodplain with a natural bottom. Ineffective flow areas were coded, and contraction and expansion coefficients were set at 0.3 and 0.5, respectively, at cross-section 0+30 through 0+56 for the Unnamed Tributary, and cross-section 15+92 through 16+24 for Plumtree Branch to model the crossing structures.

Flow data were input based on the hydrologic methods provided in Section 2.2. The downstream boundary condition was set to normal depth for both models.

3.3. Proposed Conditions

Two proposed conditions 1D-models were developed to evaluate the 1.25-, 2, 10- and 100-year flow frequency events. The existing conditions models were used as the base model for the proposed conditions. Figures 1 and 2, located in Appendix A, shows the proposed cross-section layout.

Cross-section positions were maintained from the existing conditions model through to the proposed model. River Stations were preserved from the existing condition model for comparison purposes. Cross-sections alignments were drawn to be perpendicular with the proposed channel and the overbank flood flow paths. Reach lengths were updated to reflect the proposed channel alignment. Station and elevation data were derived from a composite terrain created using LiDAR, existing survey data and the proposed design grading plan within the project site provided by the Client.

Bank stations were selected to correspond with design bankfull elevation at each cross-section. Manning's n-values were preserved from the existing conditions model ranging from .035 in the channel due to the smaller pilot channel design, and 0.06 in the overbanks to model the wetland complex.

Flow data were input based on the hydrologic methods described in Sections 3.1 and 3.2. The downstream boundary condition was set to normal depth for both models.

3.4. Hydraulic Modeling Results

Tables 3 through 10 present and compare the results of the 1.25-, 2-, 10- and 100-year frequency events for the existing and proposed conditions. Figures 1 and 2 in Appendix A show the 100-year existing and proposed conditions floodplain extents. The results indicate that shear stresses under the proposed design condition are under 2 ft-lbs/ft^2 for all modeled frequencies except at isolated locations for higher frequency events. Additional structural support is included in the design at these higher stress locations. The results indicate a rise of 0.01 feet at cross-section 10+76, though the change in the 100-year water surface elevation is so minor it does not show in the mapped figures. The remaining cross sections indicate no-rise in the 100-year water surface elevations. Detailed HEC-RAS outputs are provided in Appendix B.

Table 3. 1.25-year, 1-D Hydraulic Model Results Plumtree Branch

River Sta	Baseline Sta	Existing Condition			Proposed Condition			Change Ex-Prop		
		W.S. Elev (ft)	Vel Chnl (ft/s)	Shear Chan (lb/sq ft)	W.S. Elev (ft)	Vel Chnl (ft/s)	Shear Chan (lb/sq ft)	W.S. Elev (ft)	Vel Chnl (ft/s)	Shear Chan (lb/sq ft)
0.8698	N/A	331.54	2.48	0.19	331.93	1.59	0.06	0.39	-36%	-68%
0.8287	10+76	331.27	2.70	0.23	331.77	3.08	0.24	0.5	14%	4%
0.7530	14+86	330.71	2.82	0.25	331.1	3.14	0.25	0.39	11%	0%
0.7337	15+92	330.58	2.76	0.24	330.94	2.98	0.23	0.36	8%	-4%
0.7278	16+24	330.54	2.43	0.20	330.73	3.8	0.42	0.19	56%	110%
0.6757	19+00	329.80	4.20	0.58	329.88	3.07	0.27	0.08	-27%	-53%
0.6214	21+92	329.12	3.16	0.33	329.15	3.26	0.3	0.03	3%	-9%

Table 4. 2-year, 1-D Hydraulic Model Results Plumtree Branch

River Sta	Baseline Sta	Existing Condition			Proposed Condition			Change		
		W.S. Elev (ft)	Vel Chnl (ft/s)	Shear Chan (lb/sq ft)	W.S. Elev (ft)	Vel Chnl (ft/s)	Shear Chan (lb/sq ft)	W.S. Elev (ft)	Vel Chnl (ft/s)	Shear Chan (lb/sq ft)
0.8698	N/A	332.20	2.93	0.25	332.55	2.11	0.1	0.35	-28%	-60%
0.8287	10+76	331.89	3.24	0.32	332.34	3.84	0.35	0.45	19%	9%
0.7530	14+86	331.28	3.28	0.32	331.59	3.65	0.32	0.31	11%	0%
0.7337	15+92	331.14	3.31	0.33	331.41	3.66	0.32	0.27	11%	-3%
0.7278	16+24	331.08	2.93	0.27	331.18	4.27	0.5	0.1	46%	85%
0.6757	19+00	330.35	4.57	0.65	330.39	3.56	0.34	0.04	-22%	-48%
0.6214	21+92	329.88	2.94	0.26	329.88	3.08	0.24	0	5%	-8%

Table 5. 10-year, 1-D Hydraulic Model Results Plumtree Branch

River Sta	Baseline Sta	Existing Condition			Proposed Condition			Change		
		W.S. Elev (ft)	Vel Chnl (ft/s)	Shear Chan (lb/sq ft)	W.S. Elev (ft)	Vel Chnl (ft/s)	Shear Chan (lb/sq ft)	W.S. Elev (ft)	Vel Chnl (ft/s)	Shear Chan (lb/sq ft)
0.8698	N/A	333.99	3.63	0.34	334.13	3.22	0.21	0.14	-11%	-38%
0.8287	10+76	333.69	4.08	0.44	333.89	4.73	0.47	0.2	16%	7%
0.7530	14+86	333.31	3.30	0.28	333.38	3.85	0.31	0.07	17%	11%
0.7337	15+92	333.23	3.32	0.28	333.28	3.85	0.3	0.05	16%	7%
0.7278	16+24	333.18	2.95	0.23	333.18	3.62	0.29	0	23%	26%
0.6757	19+00	332.98	3.10	0.25	332.97	2.97	0.18	-0.01	-4%	-28%
0.6214	21+92	332.87	2.14	0.11	332.87	2.39	0.11	0	12%	0%

Table 6. 100-year, 1-D Hydraulic Model Results Plumtree Branch

River Sta	Baseline Sta	Existing Condition			Proposed Condition			Change		
		W.S. Elev (ft)	Vel Chnl (ft/s)	Shear Chan (lb/sq ft)	W.S. Elev (ft)	Vel Chnl (ft/s)	Shear Chan (lb/sq ft)	W.S. Elev (ft)	Vel Chnl (ft/s)	Shear Chan (lb/sq ft)
0.8698	N/A	339.59	2.74	0.15	339.59	2.81	0.12	0	3%	-20%
0.8287	10+76	339.54	2.73	0.15	339.55	3.21	0.17	0.01	18%	13%
0.7530	14+86	339.48	2.18	0.10	339.48	2.52	0.1	0	16%	0%
0.7337	15+92	339.47	2.13	0.09	339.47	2.43	0.09	0	14%	0%
0.7278	16+24	339.46	1.94	0.08	339.46	2.2	0.08	0	13%	0%
0.6757	19+00	339.43	2.01	0.08	339.43	2.13	0.07	0	6%	-13%
0.6214	21+92	339.41	1.65	0.05	339.41	1.9	0.05	0	15%	0%

Table 7. 1.25-year, 1-D Hydraulic Model Results Unnamed Tributary

River Sta	Baseline Sta	Existing Condition			Proposed Condition			Change		
		W.S. Elev (ft)	Vel Chnl (ft/s)	Shear Chan (lb/sq ft)	W.S. Elev (ft)	Vel Chnl (ft/s)	Shear Chan (lb/sq ft)	W.S. Elev (ft)	Vel Chnl (ft/s)	Shear Chan (lb/sq ft)
950.6651	0+30	336.23	1.62	0.08	337.44	2.1	0.16	1.21	30%	100%
924.3994	0+56	334.07	3.18	0.30	334.14	2.16	0.18	0.07	-32%	-40%
687.7156	2+84	332.59	4.84	0.76	333.17	3.76	0.65	0.58	-22%	-14%
453.6399	5+20	331.38	3.46	0.36	331.66	2.78	0.33	0.28	-20%	-8%
76.46746	8+99	329.88	3.73	0.41	330.11	2.48	0.27	0.23	-34%	-34%

Table 8. 2-year, 1-D Hydraulic Model Results Unnamed Tributary

River Sta	Baseline Sta	Existing Condition			Proposed Condition			Change		
		W.S. Elev (ft)	Vel Chnl (ft/s)	Shear Chan (lb/sq ft)	W.S. Elev (ft)	Vel Chnl (ft/s)	Shear Chan (lb/sq ft)	W.S. Elev (ft)	Vel Chnl (ft/s)	Shear Chan (lb/sq ft)
950.6651	0+30	336.95	2.03	0.11	338.04	2.57	0.22	1.09	27%	100%
924.3994	0+56	334.81	3.77	0.41	334.51	3.15	0.37	-0.3	-16%	-10%
687.7156	2+84	333.29	5.36	0.84	333.55	3.47	0.5	0.26	-35%	-40%
453.6399	5+20	332.12	4.12	0.47	332.08	3.54	0.5	-0.04	-14%	6%
76.46746	8+99	330.71	3.05	0.30	330.36	2.78	0.32	-0.35	-9%	7%

Table 9. 10-year, 1-D Hydraulic Model Results Unnamed Tributary

River Sta	Baseline Sta	Existing Condition			Proposed Condition			Change		
		W.S. Elev (ft)	Vel Chnl (ft/s)	Shear Chan (lb/sq ft)	W.S. Elev (ft)	Vel Chnl (ft/s)	Shear Chan (lb/sq ft)	W.S. Elev (ft)	Vel Chnl (ft/s)	Shear Chan (lb/sq ft)
950.6651	0+30	338.90	2.96	0.19	340.3	1.31	0.05	1.4	-56%	-74%
924.3994	0+56	335.85	6.21	0.99	335.58	5.21	0.96	-0.27	-16%	-3%
687.7156	2+84	334.43	5.43	0.81	334.26	4.39	0.69	-0.17	-19%	-15%
453.6399	5+20	332.90	5.98	0.90	332.68	4.96	0.88	-0.22	-17%	-2%
76.46746	8+99	331.35	3.62	0.39	330.84	3.28	0.41	-0.51	-9%	5%

Table 10. 100-year, 1-D Hydraulic Model Results Unnamed Tributary

River Sta	Baseline Sta	Existing Condition			Proposed Condition			Change		
		W.S. Elev (ft)	Vel Chnl (ft/s)	Shear Chan (lb/sq ft)	W.S. Elev (ft)	Vel Chnl (ft/s)	Shear Chan (lb/sq ft)	W.S. Elev (ft)	Vel Chnl (ft/s)	Shear Chan (lb/sq ft)
950.6651	0+30	341.53	2.58	0.12	341.16	2.71	0.19	-0.37	5%	58%
924.3994	0+56	337.12	10.31	2.40	336.74	8.62	2.3	-0.38	-16%	-4%
687.7156	2+84	335.62	7.42	1.32	335.22	6.13	1.19	-0.4	-17%	-10%
453.6399	5+20	333.81	8.38	1.61	333.43	6.61	1.41	-0.38	-21%	-12%
76.46746	8+99	332.09	4.62	0.56	331.52	4.04	0.56	-0.57	-13%	0%

4. References

1. Thomas, Jr., W.O. and G.E. Moglen. 2010. *An Update of Regression Equations for Maryland, Appendix 3 in Application of Hydrologic Methods in Maryland, Third Edition, September 2010.* Maryland State Highway Administration and Maryland Department of the Environment. 38 pp.

Appendix A

Hydraulic Figures

PLUMTREE BRANCH (MAINSTEM)

SCALE: 1"=100'

0 100 200 Feet

LEGEND

— —	PROPERTY BOUNDARY	——	HECRAS CROSS-SECTIONS
- - -	EX. CONTOURS	——	PROPOSED FLOODPLAIN
—·—	EX. STREAM CENTERLINE	——	EXISTING FLOODPLAIN
— LOD —	LIMIT OF DISTURBANCE		

PLUMTREE BRANCH
AT DUNLOGGIN MIDDLE SCHOOL

PLUMTREE BRANCH (MAINSTEM)
FLOODPLAIN EXHIBIT
9129 NORTHFIELD RD
ELLICOTT CITY, MD 21042

REVISIONS

No.	DATE	DESCRIPTION	REV. BY

CHECKED BY:
DESIGNED: CRH
DRAWN: RG
PROJECT No.: 19-05-003
DATE: 5/19/2022
SHEET:

1 of 2

ecotone
ecological restoration
129 Industry Lane · Forest Hill, Maryland 21050
(410) 420 2600 · www.ecotoneinc.com

C:\Users\choy\Desktop\Projects\Plumtree\19-05-003-LAYOUT-HECRAS-EXHIBIT.dwg CHOY

TRIBUTARY TO PLUMTREE BRANCH

SCALE: 1"=50'

0 50 100 Feet

LEGEND

- PROPERTY BOUNDARY
- EX. CONTOURS
- EX. STREAM CENTERLINE
- LOD LIMIT OF DISTURBANCE
- HECRAS CROSS-SECTIONS
- PROPOSED FLOODPLAIN
- EXISTING FLOODPLAIN

PLUMTREE BRANCH
AT DUNLOGGIN MIDDLE SCHOOL

TRIBUTARY TO PLUMTREE BRANCH
FLOODPLAIN EXHIBIT
9129 NORTHFIELD RD
ELLICOTT CITY, MD 21042

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REVISIONS			
No.	DATE	DESCRIPTION	REV. BY

CHECKED BY:
DESIGNED: CRH
DRAWN: RG
PROJECT No.: 19-05-003
DATE: 5/19/2022
SHEET:

Appendix B

Hydraulic Modeling Results

Table 1. Proposed 1.25-year, 1-D Standard Table 1 Plumtree Branch

Reach	River Sta	Baseline Sta	Profile	Q Total (cfs)	Min Ch El (ft)	W.S. Elev (ft)	Crit W.S. (ft)	E.G. Elev (ft)	E.G. Slope (ft/ft)	Vel Chnl (ft/s)	Flow Area (sq ft)	Top Width (ft)	Froude # Chl
1	0.8698	N/A	Q1.25	292	328	331.93	330	331.96	0.000299	1.59	310.43	160.69	0.16
1	0.8287	10+76	Q1.25	292	328.81	331.77		331.83	0.001602	3.08	205.99	148.04	0.34
1	0.753	14+86	Q1.25	292	328.39	331.1		331.16	0.001673	3.14	221.3	197.41	0.35
1	0.7337	15+92	Q1.25	292	328.04	330.94	330.16	330.99	0.001434	2.98	227.55	185.52	0.33
1	0.73	16+08		Bridge									
1	0.7278	16+24	Q1.25	292	328.03	330.73		330.88	0.004194	3.8	139.05	170.69	0.52
1	0.6757	19+00	Q1.25	322	327.03	329.88		329.98	0.002525	3.07	182.45	180.13	0.41
1	0.6214	21+92	Q1.25	322	327	329.15		329.21	0.002659	3.26	221.85	218.44	0.42

Table 2. Proposed 2-year, 1-D Standard Table 1 Plumtree Branch

Reach	River Sta	Baseline Sta	Profile	Q Total (cfs)	Min Ch El (ft)	W.S. Elev (ft)	Crit W.S. (ft)	E.G. Elev (ft)	E.G. Slope (ft/ft)	Vel Chnl (ft/s)	Flow Area (sq ft)	Top Width (ft)	Froude # Chl
1	0.8698	N/A	Q2	506	328	332.55	330.59	332.59	0.000418	2.11	417.95	187.05	0.19
1	0.8287	10+76	Q2	506	328.81	332.34		332.42	0.001893	3.84	303.54	189.53	0.38
1	0.753	14+86	Q2	506	328.39	331.59		331.67	0.001776	3.65	323.84	218.31	0.37
1	0.7337	15+92	Q2	506	328.04	331.41	330.48	331.48	0.001736	3.66	319.45	207.71	0.37
1	0.73	16+08		Bridge									
1	0.7278	16+24	Q2	506	328.03	331.18		331.35	0.003831	4.27	225.04	209.38	0.52
1	0.6757	19+00	Q2	556	327.03	330.39		330.5	0.002414	3.56	279.43	201.99	0.42
1	0.6214	21+92	Q2	556	327	329.88		329.93	0.001531	3.08	391.93	247.84	0.34

Table 3. Proposed 10-year, 1-D Standard Table 1 Plumtree Branch

Reach	River Sta	Baseline Sta	Profile	Q Total (cfs)	Min Ch El (ft)	W.S. Elev (ft)	Crit W.S. (ft)	E.G. Elev (ft)	E.G. Slope (ft/ft)	Vel Chnl (ft/s)	Flow Area (sq ft)	Top Width (ft)	Froude # Chl
1	0.8698	N/A	Q10	1335	328	334.13	331.58	334.21	0.000621	3.22	751.35	232.76	0.24
1	0.8287	10+76	Q10	1335	328.81	333.89		334	0.00167	4.73	618.19	222.64	0.39
1	0.753	14+86	Q10	1335	328.39	333.38		333.45	0.001052	3.85	769.82	273.99	0.31
1	0.7337	15+92	Q10	1335	328.04	333.28	331.23	333.34	0.001021	3.85	786.22	281.65	0.31
1	0.73	16+08		Bridge									
1	0.7278	16+24	Q10	1335	328.03	333.18		333.27	0.001134	3.62	727.93	288.24	0.32
1	0.6757	19+00	Q10	1466	327.03	332.97		333.03	0.000609	2.97	953.65	307.92	0.24
1	0.6214	21+92	Q10	1466	327	332.87		332.89	0.000331	2.39	1297.6	348.15	0.18

Table 4. Proposed 100-year, 1-D Standard Table 1 Plumtree Branch

Reach	River Sta	Baseline Sta	Profile	Q Total (cfs)	Min Ch El (ft)	W.S. Elev (ft)	Crit W.S. (ft)	E.G. Elev (ft)	E.G. Slope (ft/ft)	Vel Chnl (ft/s)	Flow Area (sq ft)	Top Width (ft)	Froude # Chl
1	0.8698	N/A	Q100	3335	328	339.59	333.06	339.65	0.000188	2.81	2290.01	337.62	0.15
1	0.8287	10+76	Q100	3335	328.81	339.55		339.6	0.000266	3.21	2205.8	333.47	0.18
1	0.753	14+86	Q100	3335	328.39	339.48		339.51	0.00015	2.52	2720.96	358.36	0.13
1	0.7337	15+92	Q100	3335	328.04	339.47	332.35	339.5	0.000138	2.43	2841.11	372.14	0.13
1	0.73	16+08		Bridge									
1	0.7278	16+24	Q100	3335	328.03	339.46		339.49	0.000122	2.2	2905.2	388.99	0.12
1	0.6757	19+00	Q100	3672	327.03	339.43		339.46	0.000101	2.13	3295.47	409.02	0.11
1	0.6214	21+92	Q100	3672	327	339.41		339.43	0.000074	1.9	3956.44	455.14	0.1

Table 5. Existing 1.25-year, 1-D Standard Table 1 Plumtree Branch

Reach	River Sta	Baseline Sta	Profile	Q Total (cfs)	Min Ch El (ft)	W.S. Elev (ft)	Crit W.S. (ft)	E.G. Elev (ft)	E.G. Slope (ft/ft)	Vel Chnl (ft/s)	Flow Area (sq ft)	Top Width (ft)	Froude # Chl
1	0.8698	N/A	Q1.25	292	328	331.54	330.03	331.6	0.000977	2.48	211.85	151.84	0.24
1	0.8287	10+76	Q1.25	292	327	331.27		331.35	0.001341	2.7	170.09	131.01	0.28
1	0.753	14+86	Q1.25	292	327	330.71		330.8	0.001428	2.82	178.29	174.27	0.29
1	0.7337	15+92	Q1.25	292	327	330.58	329.62	330.66	0.001296	2.76	194.76	165.07	0.27
1	0.73	16+08		Bridge									
1	0.7278	16+24	Q1.25	292	326.89	330.54		330.6	0.001337	2.43	201.89	172.69	0.27
1	0.6757	19+00	Q1.25	322	326	329.8		329.99	0.003481	4.2	145.39	162.62	0.43
1	0.6214	21+92	Q1.25	322	325.75	329.12		329.2	0.002041	3.16	215.48	224.05	0.33

Table 6. Existing 2-year, 1-D Standard Table 1 Plumtree Branch

Reach	River Sta	Baseline Sta	Profile	Q Total (cfs)	Min Ch El (ft)	W.S. Elev (ft)	Crit W.S. (ft)	E.G. Elev (ft)	E.G. Slope (ft/ft)	Vel Chnl (ft/s)	Flow Area (sq ft)	Top Width (ft)	Froude # Chl
1	0.8698	N/A	Q2	506	328	332.2	330.92	332.28	0.001066	2.93	318.35	178.07	0.26
1	0.8287	10+76	Q2	506	327	331.89		332	0.00151	3.24	253.02	137.08	0.3
1	0.753	14+86	Q2	506	327	331.28		331.39	0.001516	3.28	288.82	204.16	0.31
1	0.7337	15+92	Q2	506	327	331.14	330.14	331.24	0.001494	3.31	295.57	194.66	0.3
1	0.73	16+08		Bridge									
1	0.7278	16+24	Q2	506	326.89	331.08		331.16	0.001504	2.93	303.11	203.7	0.29
1	0.6757	19+00	Q2	556	326	330.35		330.53	0.003279	4.57	254.38	210.86	0.43
1	0.6214	21+92	Q2	556	325.75	329.88		329.93	0.00129	2.94	398.63	257.86	0.27

Table 7. Existing 10-year, 1-D Standard Table 1 Plumtree Branch

Reach	River Sta	Baseline Sta	Profile	Q Total (cfs)	Min Ch El (ft)	W.S. Elev (ft)	Crit W.S. (ft)	E.G. Elev (ft)	E.G. Slope (ft/ft)	Vel Chnl (ft/s)	Flow Area (sq ft)	Top Width (ft)	Froude # Chl
1	0.8698	N/A	Q10	1335	328	333.99	331.93	334.09	0.000994	3.63	684.78	229.93	0.27
1	0.8287	10+76	Q10	1335	327	333.69		333.83	0.001388	4.08	584.56	207.6	0.31
1	0.753	14+86	Q10	1335	327	333.31		333.39	0.000841	3.3	778.76	271.67	0.25
1	0.7337	15+92	Q10	1335	327	333.23	331.12	333.3	0.000831	3.32	802.32	279.58	0.24
1	0.73	16+08		Bridge									
1	0.7278	16+24	Q10	1335	326.89	333.18		333.24	0.000767	2.95	826.93	287.63	0.23
1	0.6757	19+00	Q10	1466	326	332.98		333.04	0.000719	3.1	947.56	308.26	0.22
1	0.6214	21+92	Q10	1466	325.75	332.87		332.9	0.000305	2.14	1316.65	347.88	0.15

Table 8. Existing 100-year, 1-D Standard Table 1 Plumtree Branch

Reach	River Sta	Baseline Sta	Profile	Q Total (cfs)	Min Ch El (ft)	W.S. Elev (ft)	Crit W.S. (ft)	E.G. Elev (ft)	E.G. Slope (ft/ft)	Vel Chnl (ft/s)	Flow Area (sq ft)	Top Width (ft)	Froude # Chl
1	0.8698	N/A	Q100	3335	328	339.59	333.23	339.64	0.000228	2.74	2250.07	330.55	0.14
1	0.8287	10+76	Q100	3335	327	339.54		339.59	0.000234	2.73	2197.64	328.28	0.14
1	0.753	14+86	Q100	3335	327	339.48		339.51	0.000136	2.18	2740.92	356.85	0.11
1	0.7337	15+92	Q100	3335	327	339.47	332.36	339.5	0.00013	2.13	2855.41	371.66	0.11
1	0.73	16+08		Bridge									
1	0.7278	16+24	Q100	3335	326.89	339.46		339.49	0.000116	1.94	2980.77	387.29	0.1
1	0.6757	19+00	Q100	3672	326	339.43		339.46	0.000115	2.01	3285.23	408.57	0.1
1	0.6214	21+92	Q100	3672	325.75	339.41		339.43	0.000072	1.65	3999.09	459.48	0.08

Table 9. Proposed 1.25-year, 1-D Standard Table 1 Unnamed Tributary

Reach	River Sta	Baseline Sta	Profile	Q Total (cfs)	Min Ch El (ft)	W.S. Elev (ft)	Crit W.S. (ft)	E.G. Elev (ft)	E.G. Slope (ft/ft)	Vel Chnl (ft/s)	Flow Area (sq ft)	Top Width (ft)	Froude # Chl
PT_T2	950.6651	0+30	Q1.25	76	335.1	337.44	336.46	337.5	0.001372	2.1	48.58	96.45	0.27
PT_T2	937.5322	0+43		Bridge									
PT_T2	924.3994	0+56	Q1.25	76	331.47	334.14	332.89	334.21	0.001715	2.16	35.15	20.15	0.29
PT_T2	687.7156	2+84	Q1.25	76	331.94	333.17	333.17	333.37	0.011277	3.76	29.38	93.13	0.68
PT_T2	453.6399	5+20	Q1.25	76	329.81	331.66		331.78	0.004331	2.78	27.34	22.04	0.44
PT_T2	76.46746	8+99	Q1.25	76	328.64	330.11	329.58	330.2	0.004006	2.48	43.15	170.67	0.42

Table 10. Proposed 2-year, 1-D Standard Table 1 Unnamed Tributary

Reach	River Sta	Baseline Sta	Profile	Q Total (cfs)	Min Ch El (ft)	W.S. Elev (ft)	Crit W.S. (ft)	E.G. Elev (ft)	E.G. Slope (ft/ft)	Vel Chnl (ft/s)	Flow Area (sq ft)	Top Width (ft)	Froude # Chl
PT_T2	950.6651	0+30	Q2	136	335.1	338.04	336.81	338.12	0.001421	2.57	74	111.85	0.29
PT_T2	937.5322	0+43		Bridge									
PT_T2	924.3994	0+56	Q2	136	331.47	334.51	333.37	334.67	0.003176	3.15	43.13	22.24	0.4
PT_T2	687.7156	2+84	Q2	136	331.94	333.55		333.67	0.006157	3.47	65.66	101.45	0.53
PT_T2	453.6399	5+20	Q2	136	329.81	332.08	331.44	332.27	0.005661	3.54	46.72	119.51	0.52
PT_T2	76.46746	8+99	Q2	136	328.64	330.36	329.92	330.45	0.004004	2.78	92.82	254.12	0.43

Table 11. Proposed 10-year, 1-D Standard Table 1 Unnamed Tributary

Reach	River Sta	Baseline Sta	Profile	Q Total (cfs)	Min Ch El (ft)	W.S. Elev (ft)	Crit W.S. (ft)	E.G. Elev (ft)	E.G. Slope (ft/ft)	Vel Chnl (ft/s)	Flow Area (sq ft)	Top Width (ft)	Froude # Chl
PT_T2	950.6651	0+30	Q10	374	335.1	340.3	337.85	340.31	0.000158	1.31	479.24	164.57	0.11
PT_T2	937.5322	0+43		Bridge									
PT_T2	924.3994	0+56	Q10	374	331.47	335.58	334.66	336	0.00737	5.21	71.8	44.71	0.62
PT_T2	687.7156	2+84	Q10	374	331.94	334.26		334.43	0.005542	4.39	142.87	113.87	0.54
PT_T2	453.6399	5+20	Q10	374	329.81	332.68	332.55	332.95	0.007045	4.96	132.6	169.17	0.61
PT_T2	76.46746	8+99	Q10	374	328.64	330.84	330.59	330.93	0.003996	3.28	221.63	275.82	0.45

Table 12. Proposed 100-year, 1-D Standard Table 1 Unnamed Tributary

Reach	River Sta	Baseline Sta	Profile	Q Total (cfs)	Min Ch El (ft)	W.S. Elev (ft)	Crit W.S. (ft)	E.G. Elev (ft)	E.G. Slope (ft/ft)	Vel Chnl (ft/s)	Flow Area (sq ft)	Top Width (ft)	Froude # Chl
PT_T2	950.6651	0+30	Q100	964	335.1	341.16	339.2	341.21	0.000538	2.71	606.69	187.41	0.2
PT_T2	937.5322	0+43		Bridge									
PT_T2	924.3994	0+56	Q100	964	331.47	336.74	336.43	337.89	0.011712	8.62	113.75	109.27	0.84
PT_T2	687.7156	2+84	Q100	964	331.94	335.22		335.53	0.006447	6.13	257.5	123.83	0.62
PT_T2	453.6399	5+20	Q100	964	329.81	333.43	333.23	333.81	0.00825	6.61	284.89	232.68	0.7
PT_T2	76.46746	8+99	Q100	964	328.64	331.52	330.9	331.62	0.004001	4.04	498.28	476.69	0.47

Table 13. Existing 1.25-year, 1-D Standard Table 1 Unnamed Tributary

Reach	River Sta	Baseline Sta	Profile	Q Total (cfs)	Min Ch El (ft)	W.S. Elev (ft)	Crit W.S. (ft)	E.G. Elev (ft)	E.G. Slope (ft/ft)	Vel Chnl (ft/s)	Flow Area (sq ft)	Top Width (ft)	Froude # Chl
PT_T2	950.6651	0+30	Q1.25	76	333.34	336.23	335.06	336.27	0.000746	1.62	46.87	80.63	0.22
PT_T2	937.5322	0+43		Bridge									
PT_T2	924.3994	0+56	Q1.25	76	331.34	334.07	333.13	334.23	0.00314	3.18	25.34	16.4	0.43
PT_T2	687.7156	2+84	Q1.25	76	330.97	332.59	332.31	332.96	0.009803	4.84	15.7	11.5	0.73
PT_T2	453.6399	5+20	Q1.25	76	328.97	331.38		331.57	0.003756	3.46	21.96	12.8	0.47
PT_T2	76.46746	8+99	Q1.25	76	327.01	329.88	328.98	330.1	0.004006	3.73	20.36	10.52	0.47

Table 14. Existing 2-year, 1-D Standard Table 1 Unnamed Tributary

Reach	River Sta	Baseline Sta	Profile	Q Total (cfs)	Min Ch El (ft)	W.S. Elev (ft)	Crit W.S. (ft)	E.G. Elev (ft)	E.G. Slope (ft/ft)	Vel Chnl (ft/s)	Flow Area (sq ft)	Top Width (ft)	Froude # Chl
PT_T2	950.6651	0+30	Q2	136	333.34	336.95	335.43	337.02	0.000723	2.03	67.67	85.24	0.23
PT_T2	937.5322	0+43		Bridge									
PT_T2	924.3994	0+56	Q2	136	331.34	334.81	333.73	335.02	0.00371	3.77	39.38	22.48	0.48
PT_T2	687.7156	2+84	Q2	136	330.97	333.29	333.1	333.71	0.008112	5.36	37.66	68.99	0.68
PT_T2	453.6399	5+20	Q2	136	328.97	332.12	331.15	332.37	0.003969	4.12	46.02	123.69	0.49
PT_T2	76.46746	8+99	Q2	136	327.01	330.71	329.64	330.82	0.004002	3.05	96.28	195.26	0.47

Table 15. Existing 10-year, 1-D Standard Table 1 Unnamed Tributary

Reach	River Sta	Baseline Sta	Profile	Q Total (cfs)	Min Ch El (ft)	W.S. Elev (ft)	Crit W.S. (ft)	E.G. Elev (ft)	E.G. Slope (ft/ft)	Vel Chnl (ft/s)	Flow Area (sq ft)	Top Width (ft)	Froude # Chl
PT_T2	950.6651	0+30	Q10	374	333.34	338.9	336.33	339.03	0.0007	2.96	146.48	125.95	0.25
PT_T2	937.5322	0+43		Bridge									
PT_T2	924.3994	0+56	Q10	374	331.34	335.85	335.31	336.41	0.006436	6.21	75.06	73.28	0.67
PT_T2	687.7156	2+84	Q10	374	330.97	334.43		334.72	0.006653	5.43	150.22	115.91	0.64
PT_T2	453.6399	5+20	Q10	374	328.97	332.9	332.76	333.3	0.005532	5.98	169.07	189.73	0.62
PT_T2	76.46746	8+99	Q10	374	327.01	331.35	330.94	331.46	0.004003	3.62	309.43	457	0.49

Table 16. Existing 100-year, 1-D Standard Table 1 Unnamed Tributary

Reach	River Sta	Baseline Sta	Profile	Q Total (cfs)	Min Ch El (ft)	W.S. Elev (ft)	Crit W.S. (ft)	E.G. Elev (ft)	E.G. Slope (ft/ft)	Vel Chnl (ft/s)	Flow Area (sq ft)	Top Width (ft)	Froude # Chl
PT_T2	950.6651	0+30	Q100	964	333.34	341.53	337.98	341.6	0.000297	2.58	712.71	251.19	0.18
PT_T2	937.5322	0+43		Bridge									
PT_T2	924.3994	0+56	Q100	964	331.34	337.12	337.05	338.61	0.010558	10.31	127.69	124.8	0.91
PT_T2	687.7156	2+84	Q100	964	330.97	335.62		336.09	0.006984	7.42	296.04	129.06	0.71
PT_T2	453.6399	5+20	Q100	964	328.97	333.81	333.66	334.37	0.007583	8.38	374.09	262.22	0.75
PT_T2	76.46746	8+99	Q100	964	327.01	332.09	331.56	332.22	0.004	4.62	683.24	591.48	0.52

Table 17. Proposed 1.25-year, 1-D Standard Table 2 Plumtree Branch

Reach	River Sta	Baseline Sta	Profile	E.G. Elev (ft)	W.S. Elev (ft)	Vel Head (ft)	Frctn Loss (ft)	C & E Loss (ft)	Q Left (cfs)	Q Channel (cfs)	Q Right (cfs)	Top Width (ft)
1	0.8698	N/A	Q1.25	331.96	331.93	0.03	0.13	0	114.59	176.25	1.15	160.69
1	0.8287	10+76	Q1.25	331.83	331.77	0.06	0.67	0	193.56	78.06	20.38	148.04
1	0.753	14+86	Q1.25	331.16	331.1	0.06	0.16	0	131.42	93.6	66.99	197.41
1	0.7337	15+92	Q1.25	330.99	330.94	0.05	0.01	0.01	190.72	77.99	23.29	185.52
1	0.73	16+08		Bridge								
1	0.7278	16+24	Q1.25	330.88	330.73	0.15	0.87	0.03	105.13	180.61	6.26	170.69
1	0.6757	19+00	Q1.25	329.98	329.88	0.09	0.76	0.01	133.69	180.16	8.15	180.13
1	0.6214	21+92	Q1.25	329.21	329.15	0.05	0.54	0	190.99	64.33	66.69	218.44

Table 18. Proposed 2-year, 1-D Standard Table 2 Plumtree Branch

Reach	River Sta	Baseline Sta	Profile	E.G. Elev (ft)	W.S. Elev (ft)	Vel Head (ft)	Frctn Loss (ft)	C & E Loss (ft)	Q Left (cfs)	Q Channel (cfs)	Q Right (cfs)	Top Width (ft)
1	0.8698	N/A	Q2	332.59	332.55	0.04	0.17	0	223.93	278	4.07	187.05
1	0.8287	10+76	Q2	332.42	332.34	0.08	0.75	0	345.99	118.85	41.16	189.53
1	0.753	14+86	Q2	331.67	331.59	0.07	0.19	0	254.91	130.41	120.68	218.31
1	0.7337	15+92	Q2	331.48	331.41	0.07	0.01	0.02	335.67	112.77	57.56	207.71
1	0.73	16+08		Bridge								
1	0.7278	16+24	Q2	331.35	331.18	0.16	0.82	0.03	226.09	259.01	20.9	209.38
1	0.6757	19+00	Q2	330.5	330.39	0.11	0.55	0.02	258.61	269.17	28.22	201.99
1	0.6214	21+92	Q2	329.93	329.88	0.04	0.34	0	319.04	84.55	152.42	247.84

Table 19. Proposed 10-year, 1-D Standard Table 2 Plumtree Branch

Reach	River Sta	Baseline Sta	Profile	E.G. Elev (ft)	W.S. Elev (ft)	Vel Head (ft)	Frctn Loss (ft)	C & E Loss (ft)	Q Left (cfs)	Q Channel (cfs)	Q Right (cfs)	Top Width (ft)
1	0.8698	N/A	Q10	334.21	334.13	0.09	0.21	0	687.83	599.29	47.88	232.76
1	0.8287	10+76	Q10	334	333.89	0.11	0.54	0.01	1004.2	220.02	110.75	222.64
1	0.753	14+86	Q10	333.45	333.38	0.07	0.11	0	762.77	220.16	352.06	273.99
1	0.7337	15+92	Q10	333.34	333.28	0.07	0.02	0	878.67	190.52	265.8	281.65
1	0.73	16+08		Bridge								
1	0.7278	16+24	Q10	333.27	333.18	0.09	0.22	0.01	718.79	427.73	188.48	288.24
1	0.6757	19+00	Q10	333.03	332.97	0.06	0.13	0.01	806.75	482.73	176.52	307.92
1	0.6214	21+92	Q10	332.89	332.87	0.02	0.1	0	827.97	141.04	496.99	348.15

Table 20. Proposed 100-year, 1-D Standard Table 2 Plumtree Branch

Reach	River Sta	Baseline Sta	Profile	E.G. Elev (ft)	W.S. Elev (ft)	Vel Head (ft)	Frctn Loss (ft)	C & E Loss (ft)	Q Left (cfs)	Q Channel (cfs)	Q Right (cfs)	Top Width (ft)
1	0.8698	N/A	Q100	339.65	339.59	0.05	0.05	0	1842	1047.8	445.24	337.62
1	0.8287	10+76	Q100	339.6	339.55	0.05	0.08	0	2660.2	330.55	344.28	333.47
1	0.753	14+86	Q100	339.51	339.48	0.03	0.02	0	2047	328.35	959.63	358.36
1	0.7337	15+92	Q100	339.5	339.47	0.03	0	0	2122.3	271.1	941.63	372.14
1	0.73	16+08		Bridge								
1	0.7278	16+24	Q100	339.49	339.46	0.03	0.03	0	1873.9	659.21	801.87	388.99
1	0.6757	19+00	Q100	339.46	339.43	0.03	0.03	0	2203.1	808.14	660.78	409.02
1	0.6214	21+92	Q100	339.43	339.41	0.02	0.03	0	2164.3	243.88	1263.8	455.14

Table 21. Existing 1.25-year, 1-D Standard Table 2 Plumtree Branch

Reach	River Sta	Baseline Sta	Profile	E.G. Elev (ft)	W.S. Elev (ft)	Vel Head (ft)	Frctn Loss (ft)	C & E Loss (ft)	Q Left (cfs)	Q Channel (cfs)	Q Right (cfs)	Top Width (ft)
1	0.8698	N/A	Q1.25	331.6	331.54	0.06	0.25	0	111.89	179.01	1.1	151.84
1	0.8287	10+76	Q1.25	331.35	331.27	0.09	0.55	0	72.28	219.67	0.05	131.01
1	0.753	14+86	Q1.25	330.8	330.71	0.1	0.14	0.01	57.65	219.08	15.27	174.27
1	0.7337	15+92	Q1.25	330.66	330.58	0.08	0.01	0	101.72	180.85	9.43	165.07
1	0.73	16+08		Bridge								
1	0.7278	16+24	Q1.25	330.6	330.54	0.06	0.57	0.04	107.19	180.1	4.71	172.69
1	0.6757	19+00	Q1.25	329.99	329.8	0.19	0.76	0.03	94.5	216.93	10.57	162.62
1	0.6214	21+92	Q1.25	329.2	329.12	0.08	0.52	0	152.79	144.14	25.08	224.05

Table 22. Existing 2-year, 1-D Standard Table 2 Plumtree Branch

Reach	River Sta	Baseline Sta	Profile	E.G. Elev (ft)	W.S. Elev (ft)	Vel Head (ft)	Frctn Loss (ft)	C & E Loss (ft)	Q Left (cfs)	Q Channel (cfs)	Q Right (cfs)	Top Width (ft)
1	0.8698	N/A	Q2	332.28	332.2	0.08	0.27	0	249.45	253.57	2.98	178.07
1	0.8287	10+76	Q2	332	331.89	0.11	0.6	0	186.71	319.03	0.27	137.08
1	0.753	14+86	Q2	331.39	331.28	0.11	0.15	0	157.52	303.54	44.94	204.16
1	0.7337	15+92	Q2	331.24	331.14	0.1	0.01	0.02	217.38	254.59	34.03	194.66
1	0.73	16+08		Bridge								
1	0.7278	16+24	Q2	331.16	331.08	0.08	0.6	0.03	222.21	262.52	21.27	203.7
1	0.6757	19+00	Q2	330.53	330.35	0.18	0.56	0.04	231.02	280.25	44.72	210.86
1	0.6214	21+92	Q2	329.93	329.88	0.06	0.34	0	284.88	170	101.12	257.86

Table 23. Existing 10-year, 1-D Standard Table 2 Plumtree Branch

Reach	River Sta	Baseline Sta	Profile	E.G. Elev (ft)	W.S. Elev (ft)	Vel Head (ft)	Frctn Loss (ft)	C & E Loss (ft)	Q Left (cfs)	Q Channel (cfs)	Q Right (cfs)	Top Width (ft)
1	0.8698	N/A	Q10	334.09	333.99	0.1	0.25	0	821.51	457.96	55.53	229.93
1	0.8287	10+76	Q10	333.83	333.69	0.14	0.43	0.02	725.61	601.62	7.78	207.6
1	0.753	14+86	Q10	333.39	333.31	0.08	0.08	0	626.84	478.84	229.32	271.67
1	0.7337	15+92	Q10	333.3	333.23	0.07	0.01	0.01	705.35	398.19	231.47	279.58
1	0.73	16+08		Bridge								
1	0.7278	16+24	Q10	333.24	333.18	0.06	0.2	0	715.86	443.36	175.78	287.63
1	0.6757	19+00	Q10	333.04	332.98	0.06	0.13	0.01	875.11	331.87	259.02	308.26
1	0.6214	21+92	Q10	332.9	332.87	0.02	0.1	0	799.36	226.58	440.06	347.88

Table 24. Existing 100-year, 1-D Standard Table 2 Plumtree Branch

Reach	River Sta	Baseline Sta	Profile	E.G. Elev (ft)	W.S. Elev (ft)	Vel Head (ft)	Frctn Loss (ft)	C & E Loss (ft)	Q Left (cfs)	Q Channel (cfs)	Q Right (cfs)	Top Width (ft)
1	0.8698	N/A	Q100	339.64	339.59	0.05	0.05	0	2141.64	682.91	510.45	330.55
1	0.8287	10+76	Q100	339.59	339.54	0.05	0.07	0.01	2272.66	837.47	224.87	328.28
1	0.753	14+86	Q100	339.51	339.48	0.03	0.01	0	1877.22	666.59	791.19	356.85
1	0.7337	15+92	Q100	339.5	339.47	0.03	0	0	1914.57	529.35	891.09	371.66
1	0.73	16+08		Bridge								
1	0.7278	16+24	Q100	339.49	339.46	0.02	0.03	0	1921.78	643.1	770.12	387.29
1	0.6757	19+00	Q100	339.46	339.43	0.02	0.03	0	2381.01	439.42	851.57	408.57
1	0.6214	21+92	Q100	339.43	339.41	0.01	0.03	0	2116.19	347.33	1208.48	459.48

Table 25. Proposed 1.25-year, 1-D Standard Table 2 Unnamed Tributary

Reach	River Sta	Baseline Sta	Profile	E.G. Elev (ft)	W.S. Elev (ft)	Vel Head (ft)	Frctn Loss (ft)	C & E Loss (ft)	Q Left (cfs)	Q Channel (cfs)	Q Right (cfs)	Top Width (ft)
PT_T2	950.6651	0+30	Q1.25	337.5	337.44	0.05	0.04	0.11	7.14	55.05	13.81	96.45
PT_T2	937.5322	0+43		Bridge								
PT_T2	924.3994	0+56	Q1.25	334.21	334.14	0.07	0.81	0.04		76		20.15
PT_T2	687.7156	2+84	Q1.25	333.37	333.17	0.2	1.56	0.02	0	67.31	8.68	93.13
PT_T2	453.6399	5+20	Q1.25	331.78	331.66	0.12	1.57	0.01		76		22.04
PT_T2	76.46746	8+99	Q1.25	330.2	330.11	0.09				71.13	4.87	170.67

Table 26. Proposed 2-year, 1-D Standard Table 2 Unnamed Tributary

Reach	River Sta	Baseline Sta	Profile	E.G. Elev (ft)	W.S. Elev (ft)	Vel Head (ft)	Frctn Loss (ft)	C & E Loss (ft)	Q Left (cfs)	Q Channel (cfs)	Q Right (cfs)	Top Width (ft)
PT_T2	950.6651	0+30	Q2	338.12	338.04	0.08	0.04	0.15	22.61	88.42	24.97	111.85
PT_T2	937.5322	0+43		Bridge								
PT_T2	924.3994	0+56	Q2	334.67	334.51	0.15	0.98	0.01		136		22.24
PT_T2	687.7156	2+84	Q2	333.67	333.55	0.13	1.39	0.01	0.11	86.66	49.23	101.45
PT_T2	453.6399	5+20	Q2	332.27	332.08	0.19	1.79	0.03	0	132.24	3.76	119.51
PT_T2	76.46746	8+99	Q2	330.45	330.36	0.09				98.91	37.09	254.12

Table 27. Proposed 10-year, 1-D Standard Table 2 Unnamed Tributary

Reach	River Sta	Baseline Sta	Profile	E.G. Elev (ft)	W.S. Elev (ft)	Vel Head (ft)	Frctn Loss (ft)	C & E Loss (ft)	Q Left (cfs)	Q Channel (cfs)	Q Right (cfs)	Top Width (ft)
PT_T2	950.6651	0+30	Q10	340.31	340.3	0.01	0.01	0.09	65.57	85.6	222.83	164.57
PT_T2	937.5322	0+43		Bridge								
PT_T2	924.3994	0+56	Q10	336	335.58	0.42	1.45	0.13		373.99	0.01	44.71
PT_T2	687.7156	2+84	Q10	334.43	334.26	0.17	1.47	0.01	1.13	168.93	203.94	113.87
PT_T2	453.6399	5+20	Q10	332.95	332.68	0.28	1.97	0.06	2.34	260.58	111.08	169.17
PT_T2	76.46746	8+99	Q10	330.93	330.84	0.09				161.08	212.92	275.82

Table 28. Proposed 100-year, 1-D Standard Table 2 Unnamed Tributary

Reach	River Sta	Baseline Sta	Profile	E.G. Elev (ft)	W.S. Elev (ft)	Vel Head (ft)	Frctn Loss (ft)	C & E Loss (ft)	Q Left (cfs)	Q Channel (cfs)	Q Right (cfs)	Top Width (ft)
PT_T2	950.6651	0+30	Q100	341.21	341.16	0.05	0.02	0.16	189.09	208.88	566.02	187.41
PT_T2	937.5322	0+43		Bridge								
PT_T2	924.3994	0+56	Q100	337.89	336.74	1.15	1.94	0.42	2.52	958.24	3.24	109.27
PT_T2	687.7156	2+84	Q100	335.53	335.22	0.31	1.71	0.01	5.33	348.54	610.12	123.83
PT_T2	453.6399	5+20	Q100	333.81	333.43	0.38	2.1	0.08	21.92	475.38	466.7	232.68
PT_T2	76.46746	8+99	Q100	331.62	331.52	0.1			42.19	281.88	639.93	476.69

Table 29. Existing 1.25-year, 1-D Standard Table 2 Unnamed Tributary

Reach	River Sta	Baseline Sta	Profile	E.G. Elev (ft)	W.S. Elev (ft)	Vel Head (ft)	Frctn Loss (ft)	C & E Loss (ft)	Q Left (cfs)	Q Channel (cfs)	Q Right (cfs)	Top Width (ft)
PT_T2	950.6651	0+30	Q1.25	336.27	336.23	0.04	0.02	0.14	0.01	75.99		80.63
PT_T2	937.5322	0+43		Bridge								
PT_T2	924.3994	0+56	Q1.25	334.23	334.07	0.16	1.21	0.06	0.84	75.16		16.4
PT_T2	687.7156	2+84	Q1.25	332.96	332.59	0.36	1.34	0.05		76		11.5
PT_T2	453.6399	5+20	Q1.25	331.57	331.38	0.19	1.46	0		76		12.8
PT_T2	76.46746	8+99	Q1.25	330.1	329.88	0.22				76		10.52

Table 30. Existing 2-year, 1-D Standard Table 2 Unnamed Tributary

Reach	River Sta	Baseline Sta	Profile	E.G. Elev (ft)	W.S. Elev (ft)	Vel Head (ft)	Frctn Loss (ft)	C & E Loss (ft)	Q Left (cfs)	Q Channel (cfs)	Q Right (cfs)	Top Width (ft)
PT_T2	950.6651	0+30	Q2	337.02	336.95	0.06	0.02	0.19	0.17	135.83		85.24
PT_T2	937.5322	0+43		Bridge								
PT_T2	924.3994	0+56	Q2	335.02	334.81	0.22	1.25	0.06	3.15	132.85		22.48
PT_T2	687.7156	2+84	Q2	333.71	333.29	0.42	1.29	0.05		128.96	7.04	68.99
PT_T2	453.6399	5+20	Q2	332.37	332.12	0.26	1.5	0.04	0	132.72	3.28	123.69
PT_T2	76.46746	8+99	Q2	330.82	330.71	0.11				105.27	30.73	195.26

Table 31. Existing 10-year, 1-D Standard Table 2 Unnamed Tributary

Reach	River Sta	Baseline Sta	Profile	E.G. Elev (ft)	W.S. Elev (ft)	Vel Head (ft)	Frctn Loss (ft)	C & E Loss (ft)	Q Left (cfs)	Q Channel (cfs)	Q Right (cfs)	Top Width (ft)
PT_T2	950.6651	0+30	Q10	339.03	338.9	0.13	0.02	0.32	15.43	358.57		125.95
PT_T2	937.5322	0+43		Bridge								
PT_T2	924.3994	0+56	Q10	336.41	335.85	0.57	1.55	0.13	11.98	352.39	9.63	73.28
PT_T2	687.7156	2+84	Q10	334.72	334.43	0.3	1.42	0.01	0.02	234.75	139.23	115.91
PT_T2	453.6399	5+20	Q10	333.3	332.9	0.39	1.76	0.09	2.52	262.66	108.82	189.73
PT_T2	76.46746	8+99	Q10	331.46	331.35	0.11			12.3	197.39	164.31	457

Table 32. Existing 100-year, 1-D Standard Table 2 Unnamed Tributary

Reach	River Sta	Baseline Sta	Profile	E.G. Elev (ft)	W.S. Elev (ft)	Vel Head (ft)	Frctn Loss (ft)	C & E Loss (ft)	Q Left (cfs)	Q Channel (cfs)	Q Right (cfs)	Top Width (ft)
PT_T2	950.6651	0+30	Q100	341.6	341.53	0.07	0.01	0.07	87.55	642.45	233.99	251.19
PT_T2	937.5322	0+43		Bridge								
PT_T2	924.3994	0+56	Q100	338.61	337.12	1.49	2.02	0.51	40.83	864.59	58.57	124.8
PT_T2	687.7156	2+84	Q100	336.09	335.62	0.47	1.71	0.01	1.29	494.83	467.88	129.06
PT_T2	453.6399	5+20	Q100	334.37	333.81	0.56	2.01	0.13	20.38	480.78	462.84	262.22
PT_T2	76.46746	8+99	Q100	332.22	332.09	0.13			94.02	364.42	505.56	591.48

Appendix: F

Directions for LW Stability Analysis Tool

This design tool may be used by practitioners if they cite the developer on each sheet.

Disclaimer:
This Microsoft Excel 2010 spreadsheet tool is provided free of charge. Use this tool at your own risk. In offering this tool, the author, the U.S. Forest Service, and Colorado State University do not accept any responsibility or liability for the tool's use by third parties. This tool has specific uses and limits of applicability. Design practitioners shall take full responsibility for the final large wood structure design and performance. Designers are expected to verify the calculated values and validity of the design method. Designers should be qualified to work in river environments, and depending on the State, they may be required to be licensed as a professional engineer to design large wood structures. You cannot be sure the tool is authentic and unmolested unless downloaded from the following website:
https://www.fs.fed.us/biology/nsaec/products-tools.html#tools-stabilitylargewoodstructures

DATA INPUT

Order of Input

Update the worksheets from "left to right"
Update the spreadsheet cells from "left to right" and "top to bottom"

IMPORTANT - User should only edit the following cells:

Cell Format	Directions
Dropdown List	Select value from dropdown list
User Input	Type value into cell
User Verify	Verify value in cell (edit if necessary)

User should verify, but not edit the following cells because these cells contain formulas or headings:

Cell Format	Directions
Heading	Table Heading (Scroll over sample heading for description of comments)
Automatic Value	Verify value in cell which is automatically calculated by formulas
Key Value	Verify value of force calculation
Solution	Verify value of force balance or factor of safety calculation
Background Value	Optional - Verify value of background calculation (outside of print area)

The "Single Log" and "Multi-Log" spreadsheets have several built-in error messages (in column 'K'):

Error Message	
"CHECK"	Prompts user to check a specific input
"ERROR"	Prompts user to change a specific input

User Input Note 1 - Several worksheets have a built in "clear inputs" button linked to a macro (these are the only macros built into the tool). Be aware that you can't undo the "clear input" command.

User Input Note 2 - User may enter a custom "bank soil type", "wood species", or "anchor type" by scrolling over to the right to find the lookup table and editing the "custom" cells.

User Input Note 3 - The spreadsheet is not locked, and therefore every cell can be manually edited. However, the

user is encouraged to exercise caution to avoid unintended consequences of changing reference formulas.

User Input Note 4 - User should also be very careful when removing or adding cells (at least scroll over and down to see what other cells may be impacted). Hiding unused rows or columns is recommended instead of deleting them. If the user needs to add cells on the "Single Log Design" spreadsheet, they should add a row of cells for all columns between 'A' and 'J'. Important: Adding cells will break the code in the "Clear Inputs" macro, and cause it to clear the wrong cells.

User Input Note 5 - To avoid compounding potential errors, the user should use the original download version of the spreadsheet (without personal edits) at the beginning of each design.

User Input Note 6 - Input values should be in English units, with one exception: D_{50} for the bed substrate gradation (mm).

ANALYSIS OF MULTIPLE LOG STRUCTURES

The LW Stability Analysis Tool can also be used to design multiple log structures. The user must manually translate the resulting vertical and horizontal forces from one log design sheet into another (or write their own formulas). This data should be entered in the "Interaction Forces with Adjacent Logs" section of the "Single Log Design" worksheet. In theory, there is no limit to the number of logs that can be considered, although the force balance accounting may become cumbersome beyond a few logs. The general procedure is as follows:

Step 1 Begin by creating a preliminary structure layout (in AutoCAD or similar) to define the quantity of logs, locate intersect points, and identify key members. Key members are typically the largest logs (or the logs that are going to be have anchors attached).

Step 2 Fill out Sheets 1 through 5 of this tool. Next, input the channel geometry in a blank "Single Log Design" worksheet (Sheet 6), and then make copies for analysis of each log.

Step 3 Complete a preliminary force balance analysis for each stacked member log, ignoring the "Interaction Forces with Adjacent Logs" and "Anchor Forces" sections. The user should manually record the resisting forces required to stabilize each stacked member in a table. The required vertical force can be found in cell 'K61' of the "Single Log Design" worksheet, and the required horizontal force can be found in cell 'K72'. If the log is already vertically or horizontally stable, record the excess force that may be applied to resist driving forces of the adjacent log(s). This information can be found in cell 'K62' and 'K73'. An example table is shown to the right of these directions →

Step 4 Complete a force balance analysis for the key members. In the "Interaction Forces with Adjacent Logs" section on the force balance sheet, enter the relative position of each adjacent stacked log in contact with the key member, the connection type (gravity or pinned), the intersection point, and the required vertical and horizontal forces to achieve stability for each stacked member. If the load from the adjacent logs is spread over multiple key members, divide the required forces by the number of key members sharing the load (note--these loads do not need to be evenly distributed between key members). If an adjacent log is either horizontally or vertically stable, then enter any excess force (see Step 3 above) value as a negative number in the key member design spreadsheet. The tool will automatically determine which loads are transferable to the next layer of logs. For instance, a non-pinned log situated above the key member will not transfer buoyancy force to the key member.

Step 5 Add "Anchor Forces" as necessary to stabilize the key members.

Step 6 Return to the stacked member log worksheets and in the "Interaction Forces with Adjacent Logs" section, input the forces that were resisted by the stability analysis of the key members. Add additional "Anchor Forces" as necessary to stabilize the forces that were not resisted by the design of the key members. It is advisable to create a copy of the "preliminary" design worksheets for the stacked member logs to create a separate "final" design worksheet. This will make it easier for the user to review the interaction forces between logs or make necessary edits.

Tip 1: It is recommended that the user creates a spreadsheet to tally the transferred forces for each log.

Tip 2: The design of multiple log structures should initially focus on achieving vertical stability, before moving on to horizontal stability, and finally the moment analysis.

Note 1: Most design procedures for larger wood jams (ELJ's) typically ignore the lift and moment forces, and the drag coefficient may be assumed to be between 0.6 and 0.7 for the entire structure (plus corrections for constriction, or blockage, of the channel). Therefore, the analysis procedure described above is likely conservative for larger

structures.
Note 2: The designer should also perform scour computations and consider the structure's potential to trap mobile wood. The design and/or factor of safety may need modified accordingly.

TO PRINT WORKBOOK
Highlight tabs numbered 1 through 7, and click "Print". Pages are pre-formatted except the "Anchors" Lookup sheet, which is not intended to be printed.

User is encouraged to provide comments and feedback for:
Suitability: Range of application or limitations
Ease of use
Results: Are they reasonable and verified?
Any other comments for improvement
E-mail comments to: mrafferty@interfluve.com

TOOL UPDATES

Version 1.0 July 2, 2013

Version 1.1 January 8, 2016

Sheet, Cell	
S1, A42	Added reference on cover sheet to new companion paper (USFS National Stream and Aquatic Ecology Ce
S2, A6,7	Changed default factor of safety to 1.5 (from 2.0) for horizontal and moment force balances
S6, B6	Updated log structure types in pull-down list on worksheet for single log design
S6, B9	Added terminology of "key", "stacked", and "wracked" logs to dropdown list for consistency with guidelines
S6, B25	Added error message restricting input values for orientation angle (can not equal exactly 0)
S6, B26	Added error message restricting input values for tilt angle (can not equal exactly 0, 90, 180, 270, or 360)
S6, D83	Changed soil type from stream bed to bank soils in formula for $F_{A,V}$ applied by additional soil ballast
Multiple	General updates to cell formats
Multiple	Fixed page layouts for printing

Version 1.2 January 21, 2020

Update of tools link on NSAEC webpage

Plumtree Branch - Salvaged Log/Root Wad

Large Wood Structure Stability Analysis

TABLE OF CONTENTS

Date of Last Revision: January 7, 2016

Designer:
Insert Name

Reviewed by:
Insert Name

Large Wood Structure Stability Analysis Spreadsheet was developed by Michael Rafferty, P.E.
Version 1.1

Reference for Companion Paper:

Rafferty, M. 2016. *Computational Design Tool for Evaluating the Stability of Large Wood Structures.* Technical Note TN-103.1. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, National Stream & Aquatic Ecology Center. 27 p.

Plumtree Branch - Salvaged Log/Root Wad
Factors of Safety and Design Constants

Spreadsheet developed by
Michael Rafferty, P.E.

Symbol	Description	Value
FS_V	Factor of Safety for Vertical Force Balance	**1.00**
FS_H	Factor of Safety for Horizontal Force Balance	**1.00**
FS_M	Factor of Safety for Moment Force Balance	**1.00**

Symbol	Description	Units	Value
C_{Lrock}	Coefficient of lift for submerged boulder (D'Aoust, 2000)	-	0.17
C_{Drock}	Coefficient of drag for submerged boulder (Schultz, 1954)	-	0.85
g	Gravitational acceleration constant	ft/s^2	32.174
DF_{RW}	Diameter factor for rootwad ($DF_{RW} = D_{RW}/D_{TS}$)	-	3.00
LF_{RW}	Length factor for rootwad ($LF_{RW} = L_{RW}/D_{TS}$)	-	1.50
SG_{rock}	Specific gravity of quartz particles	-	2.65
γ_{rock}	Dry unit weight of boulders	lb/ft^3	165.0
γ_w	Specific weight of water at 50ºF	lb/ft^3	62.40
η	Rootwad porosity from NRCS Tech Note 15 (2001)	-	0.20
ν	Kinematic viscosity of water at 50ºF	ft/s^2	1.41E-05

Plumtree Branch - Salvaged Log/Root Wad
Hydrologic and Hydraulic Inputs

Spreadsheet developed by
Michael Rafferty, P.E.

Average Return Interval (ARI) of Design Discharge: 100 yr

Site ID	Proposed Station	Design Discharge, Q_{des} (cfs)	Maximum Depth, d_w (ft)	Average Velocity, u_{avg} (ft/s)	Bankfull Width, W_{BF} (ft)	Wetted Area, A_W (ft^2)	Radius of Curvature, R_c (ft)
XS 0.6757 Channel		2,600	11.29	2.13	409.0	411	1,000

Plumtree Branch - Salvaged Log/Root W
Stream Bed Substrate Properties

Spreadsheet developed by
Michael Rafferty, P.E.

Site ID	Proposed Station	Stream bed D_{50} (mm)	Stream Bed Substrate Grain Size Class	Bed Soil Class	Dry Unit Weight[1], γ_{bed} (lb/ft^3)	Buoyant Unit Weight, γ'_{bed} (lb/ft^3)	Friction Angle, ϕ_{bed} (deg)
S 0.6757 Chann	Channel	14.10	Medium gravel	5	121.4	75.6	36

Source: Compiled from Julien (2010) and Shen and Julien (1993); soil classes from NRCS Table TS14E–2 Soil classification

[1] γ_{bed} (kg/m^3) = 1,600 + 300 log D_{50} (mm) (from Julien 2010)

1 kg/m^3 = 0.062 1 lb/ft^3

Plumtree Branch - Salvaged Log/R

Bank Soil Properties

Spreadsheet developed by
Michael Rafferty, P.E.

Site ID	Proposed Station	Bank Soils (from field observations)	Bank Soil Class	Dry Unit Weight, γ_{bank} (lb/ft^3)	Buoyant Unit Weight, γ'_{bank} (lb/ft^3)	Friction Angle, ϕ_{bank} (deg)
S 0.6757 Chann	Channel	**Clayey silt**	6	84.0	52.3	27

Plumtree Branch - Salvaged Log/Root Wad
Large Wood Properties

Spreadsheet developed by
Michael Rafferty, P.E.

Project Location: Mid-Atlantic

Timber Unit Weights			Air-dried[1] γ_{Td} (lb/ft^3)	Green[2] γ_{Tgr} (lb/ft^3)
Selected Species	**Common Name**	**Scientific Name**		
Tree Type #1:	**Beech, American**	Fagus grandifolia	44.7	54.0
Tree Type #2:	**Cherry, Black**	Prunus serotina	34.9	45.0
Tree Type #3:	**Walnut, Black**	Juglans nigra	38.4	57.0
Tree Type #4:	**Oak, Pin**	Quercus palustris	44.0	64.0
Tree Type #5:	**Maple, Red**	Acer rubrum	37.7	50.0
Tree Type #6:	**Ash, White**	Fraxinus americana	41.9	50.0
Tree Type #7:	**Willow, Black**	Salix nigra	27.3	51.0
Tree Type #8:	**Box Elder**	(user selection in input table)	27.3	51.0
Tree Type #9:				
Tree Type #10:				

[1] **Air-dried unit weight, γ_{Td}** = Average unit weight of wood after exposure to air on a 12% moisture content volume basis. Air-dried unit weight is used in the force balance calculations for the portion of wood that is above the proposed thalweg elevation (assuming unsaturated conditions).

[2] **Green unit weight, γ_{Tgr}** = Average unit weight of freshly sawn wood when the cell walls are completely saturated with water. Green unit weight is used in the force balance calculations as a conservative estimate of the unit weight for the portion of wood that is below the proposed thalweg elevation (assuming saturated conditions). For comparison, Thevenet, Citterio, & Piegay (1998) determined wood unit weight typically increases by more than 100% after less than 24 hours exposure to water.

Source for timber unit weights:

U.S. Department of Agriculture, U.S. Forest Service. (2009) Specific Gravity and Other Properties of Wood and Bark for 156 Tree Species Found in North America. Research Note NRS-38. Table 1A.

Plumtree Branch - Salvaged Log/Root Wad

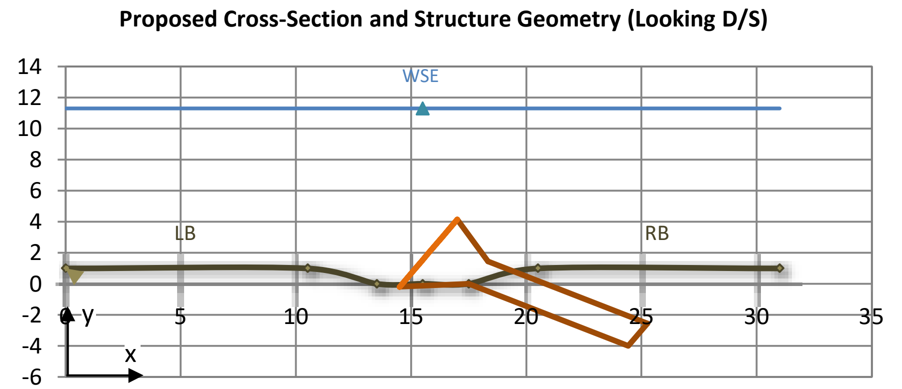
Spreadsheet developed by Michael Rafferty, P.E.

Single Log Stability Analysis Model Inputs

Site ID	Structure Type	Structure Position	Meander	Station	d_w (ft)	R_c/W_{BF}	u_{des} (ft/s)
0.6757 Chan	Rootwad	Right bank	Straight	+	11.29	2.44	2.13

Multi-Log Structures	Layer	Log ID
	Key Log	1

Channel Geometry Coordinates		
Proposed	x (ft)	y (ft)
Fldpln LB	0.00	1.00
Top LB	10.50	1.00
Toe LB	13.50	0.00
Thalweg	15.50	0.00
Toe RB	17.50	0.00
Top RB	20.50	1.00
Fldpln RB	31.00	1.00

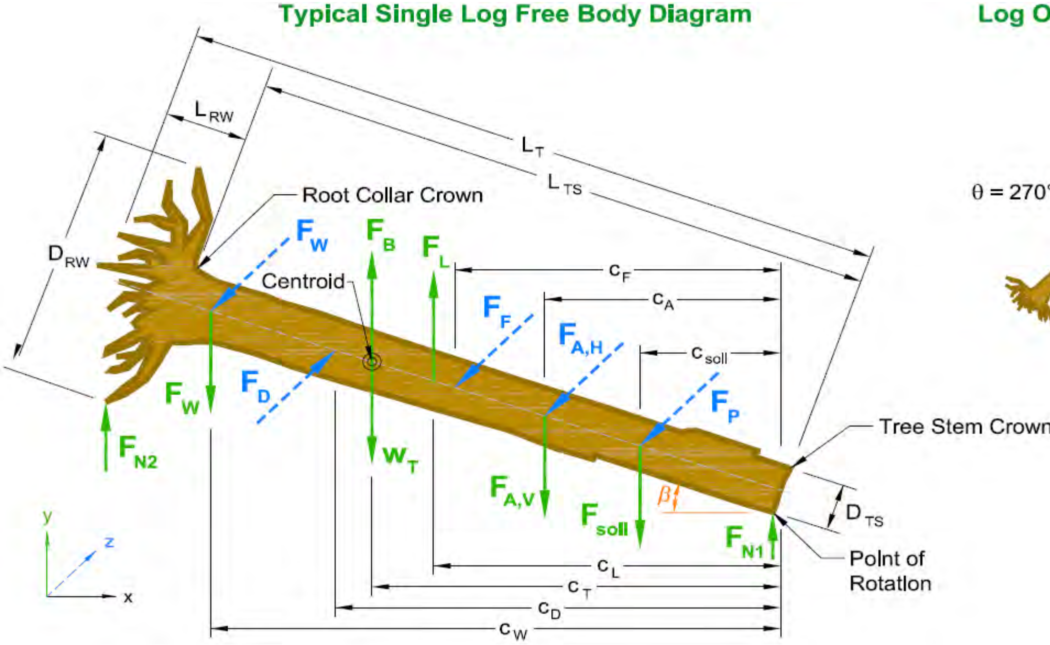


Wood Species	Rootwad	L_T (ft)	D_{TS} (ft)	L_{RW} (ft)	D_{RW} (ft)	γ_{Td} (lb/ft^3)	γ_{Tgr} (lb/ft^3)
Willow, Black	Yes	10.5	1.67	2.50	5.00	27.3	51.0

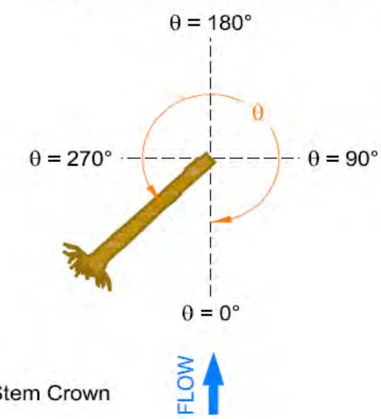
Structure Geometry	θ (deg)	β (deg)	Define Fixed Point	x_T (ft)	y_T (ft)	$y_{T,min}$ (ft)	$y_{T,max}$ (ft)	A_{Tp} (ft^2)
	270.1	-30.0	Root collar: Bottom	17.50	0.00	-4.00	4.14	6.76

Soils	Material	γ_s (lb/ft^3)	γ'_s (lb/ft^3)	φ (deg)	Soil Class	$L_{T,em}$ (ft)	$d_{b,max}$ (ft)	$d_{b,avg}$ (ft)
Stream Bed	Medium gravel	121.4	75.6	36.0	5	0.00	0.00	0.00
Bank	Clayey silt	84.0	52.3	27.0	6	6.52	3.56	1.91

Typical Single Log Free Body Diagram



Log Orientation (Plan View)



Vertical Force Analysis

Net Buoyancy Force

Wood	V_{TS} (ft^3)	V_{RW} (ft^3)	V_T (ft^3)	W_T (lbf)	F_B (lbf)
↑WSE	0.0	0.0	0.0	0	0
↓WS↑Thw	3.1	18.8	21.9	597	1,367
↓Thalweg	14.3	0.1	14.4	737	902
Total	17.5	18.9	36.4	1,334	2,269

Lift Force

C_{LT}	0.06
F_L (lbf)	2

Vertical Force Balance

F_B (lbf)	2,269	↑
F_L (lbf)	2	↑
W_T (lbf)	1,334	↓
F_{soil} (lbf)	1,082	↓
$F_{W,V}$ (lbf)	0	
$F_{A,V}$ (lbf)	0	
ΣF_V (lbf)	145	↓
FS_V	1.06	✓

Soil Ballast Force

Soil	V_{dry} (ft^3)	V_{sat} (ft^3)	V_{soil} (ft^3)	F_{soil} (lbf)
Bed	0.0	0.0	0.0	0
Bank	0.0	20.7	20.7	1,082
Total	0.0	20.7	20.7	1,082

Horizontal Force Analysis

Drag Force

A_{Tp} / A_W	Fr_L	C_{Di}	C_w	C_D*	F_D (lbf)
0.02	0.29	1.10	0.00	1.13	34

Horizontal Force Balance

F_D (lbf)	34	→
F_P (lbf)	1,440	←
F_F (lbf)	80	←
$F_{W,H}$ (lbf)	0	
$F_{A,H}$ (lbf)	0	
ΣF_H (lbf)	1,487	←
FS_H	45.04	✓

Passive Soil Pressure / Friction Force

Soil	K_P	F_P (lbf)	L_{Tf} (ft)	μ	F_F (lbf)
Bed	3.85	0	2.00	0.73	20
Bank	2.66	1,440	8.37	0.51	60
Total	-	1,440	10.37	-	80

Moment Force Balance

Driving Moment Centroids / Resisting Moment Centroids

$c_{T,B}$ (ft)	c_L (ft)	c_D (ft)	$c_{T,W}$ (ft)	c_{soil} (ft)	$c_{F\&N}$ (ft)	c_P (ft)
6.2	9.0	8.5	6.2	3.3	4.2	4.3

*Distances are from the stem tip

Point of Rotation: Stem Tip

Moment Force Balance

M_d (lbf)	12,429	
M_r (lbf)	16,431	
FS_M	1.32	✓

Anchor Forces

Additional Soil Ballast

V_{Adry} (ft^3)	V_{Awet} (ft^3)	c_{Asoil} (ft)	$F_{A,Vsoil}$ (lbf)	$F_{A,HP}$ (lbf)
			0	0

Mechanical Anchors

Type	c_{Am} (ft)	Soils	F_{Am} (lbf)
			0
			0

Boulder Ballast

Position	D_r (ft)	c_{Ar} (ft)	$V_{r,dry}$ (ft^3)	$V_{r,wet}$ (ft^3)	W_r (lbf)	$F_{L,r}$ (lbf)	$F_{D,r}$ (lbf)	$F_{A,Vr}$ (lbf)	$F_{A,Hr}$ (lbf)
								0	0
								0	0
								0	0

Plumtree Branch - Salvaged Log/Root Wad

Spreadsheet developed by Michael Rafferty, P.E.

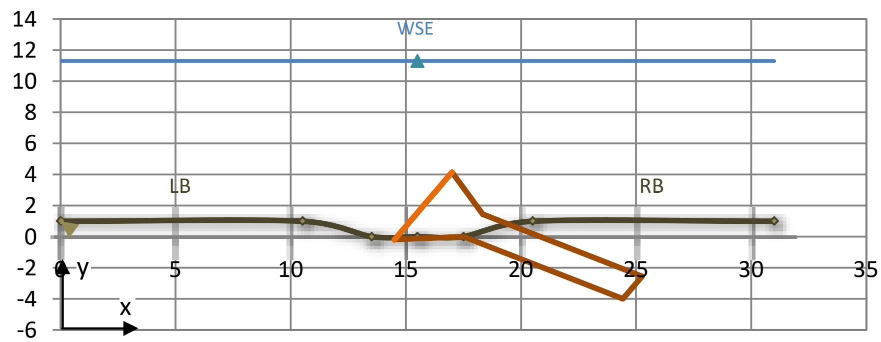
Single Log Stability Analysis Model Inputs

Site ID	Structure Type	Structure Position	Meander	Station	d_w (ft)	R_c/W_{BF}	u_{des} (ft/s)
0.6757 Chan	Rootwad	Right bank	Straight	+	11.29	2.44	2.13

Multi-Log Structures	Layer	Log ID
	Key Log	1

Channel Geometry Coordinates		
Proposed	x (ft)	y (ft)
Fldpln LB	0.00	1.00
Top LB	10.50	1.00
Toe LB	13.50	0.00
Thalweg	15.50	0.00
Toe RB	17.50	0.00
Top RB	20.50	1.00
Fldpln RB	31.00	1.00

Proposed Cross-Section and Structure Geometry (Looking D/S)

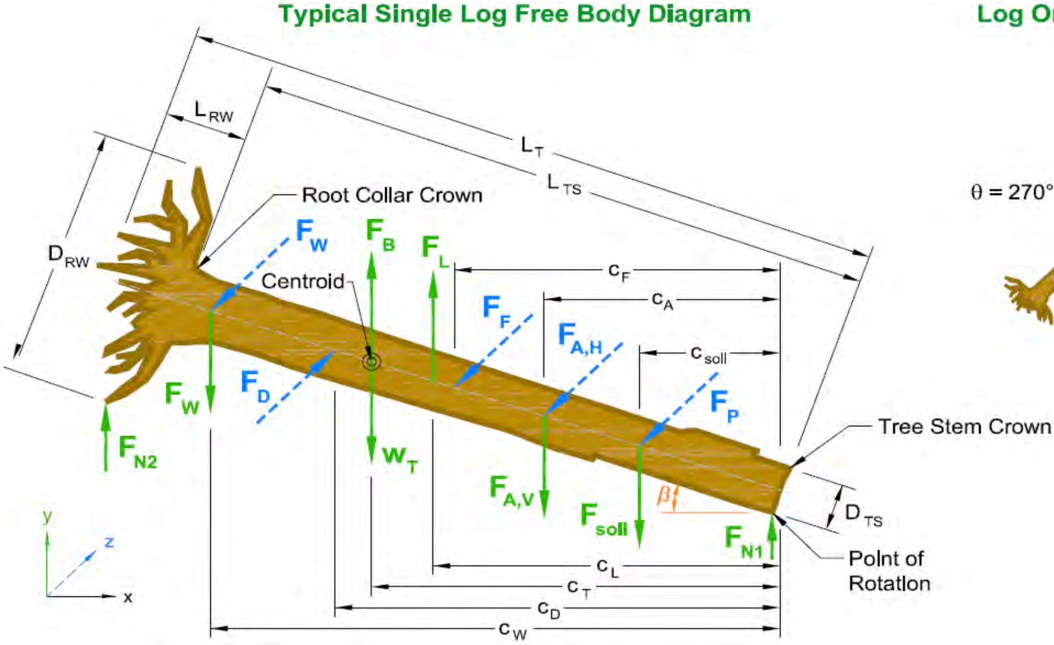


Wood Species	Rootwad	L_T (ft)	D_{TS} (ft)	L_{RW} (ft)	D_{RW} (ft)	γ_{Td} (lb/ft^3)	γ_{Tgr} (lb/ft^3)
Cherry, Black	Yes	10.5	1.67	2.50	5.00	34.9	45.0

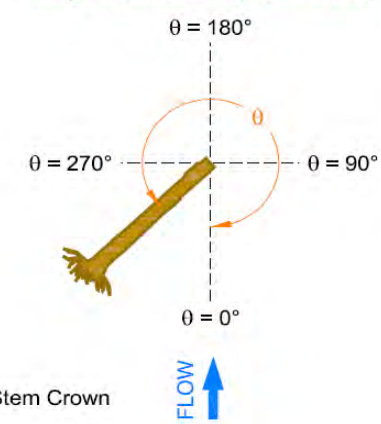
Structure Geometry	θ (deg)	β (deg)	Define Fixed Point	x_T (ft)	y_T (ft)	$y_{T,min}$ (ft)	$y_{T,max}$ (ft)	A_{Tp} (ft^2)
	270.1	-30.0	Root collar: Bottom	17.50	0.00	-4.00	4.14	6.76

Soils	Material	γ_s (lb/ft^3)	γ'_s (lb/ft^3)	ϕ (deg)	Soil Class	$L_{T,em}$ (ft)	$d_{b,max}$ (ft)	$d_{b,avg}$ (ft)
Stream Bed	Medium gravel	121.4	75.6	36.0	5	0.00	0.00	0.00
Bank	Clayey silt	84.0	52.3	27.0	6	6.52	3.56	1.91

Typical Single Log Free Body Diagram



Log Orientation (Plan View)



Vertical Force Analysis

Net Buoyancy Force

Wood	V_{TS} (ft^3)	V_{RW} (ft^3)	V_T (ft^3)	W_T (lbf)	F_B (lbf)
↑WSE	0.0	0.0	0.0	0	0
↓WS↑Thw	3.1	18.8	21.9	766	1,367
↓Thalweg	14.3	0.1	14.4	650	902
Total	17.5	18.9	36.4	1,416	2,269

Lift Force

C_{LT}	0.06
F_L (lbf)	2

Vertical Force Balance

F_B (lbf)	2,269	↑
F_L (lbf)	2	↑
W_T (lbf)	1,416	↓
F_{soil} (lbf)	1,082	↓
$F_{W,V}$ (lbf)	0	
$F_{A,V}$ (lbf)	0	
ΣF_V (lbf)	227	↓
FS_V	1.10	✓

Soil Ballast Force

Soil	V_{dry} (ft^3)	V_{sat} (ft^3)	V_{soil} (ft^3)	F_{soil} (lbf)
Bed	0.0	0.0	0.0	0
Bank	0.0	20.7	20.7	1,082
Total	0.0	20.7	20.7	1,082

Horizontal Force Analysis

Drag Force

A_{Tp} / A_W	Fr_L	C_{Di}	C_w	C_D*	F_D (lbf)
0.02	0.29	1.10	0.00	1.13	34

Horizontal Force Balance

F_D (lbf)	34	→
F_P (lbf)	1,440	←
F_F (lbf)	125	←
$F_{W,H}$ (lbf)	0	
$F_{A,H}$ (lbf)	0	
ΣF_H (lbf)	1,532	←
FS_H	46.38	✓

Passive Soil Pressure / Friction Force

Soil	K_P	F_P (lbf)	L_{Tf} (ft)	μ	F_F (lbf)
Bed	3.85	0	2.00	0.73	32
Bank	2.66	1,440	8.37	0.51	93
Total	-	1,440	10.37	-	125

Moment Force Balance

Driving Moment Centroids / Resisting Moment Centroids

$c_{T,B}$ (ft)	c_L (ft)	c_D (ft)	$c_{T,W}$ (ft)	c_{soil} (ft)	$c_{F\&N}$ (ft)	c_P (ft)
6.6	9.0	8.5	6.6	3.3	4.2	4.3

*Distances are from the stem tip

Point of Rotation: Stem Tip

Moment Force Balance

M_d (lbf)	13,302
M_r (lbf)	17,872
FS_M	1.34 ✓

Anchor Forces

Additional Soil Ballast

V_{Adry} (ft^3)	V_{Awet} (ft^3)	c_{Asoil} (ft)	$F_{A,Vsoil}$ (lbf)	$F_{A,HP}$ (lbf)
			0	0

Mechanical Anchors

Type	c_{Am} (ft)	Soils	F_{Am} (lbf)
			0
			0

Boulder Ballast

Position	D_r (ft)	c_{Ar} (ft)	$V_{r,dry}$ (ft^3)	$V_{r,wet}$ (ft^3)	W_r (lbf)	$F_{L,r}$ (lbf)	$F_{D,r}$ (lbf)	$F_{A,Vr}$ (lbf)	$F_{A,Hr}$ (lbf)
								0	0
								0	0
								0	0

Plumtree Branch - Salvaged Log/Root Wad

Spreadsheet developed by Michael Rafferty, P.E.

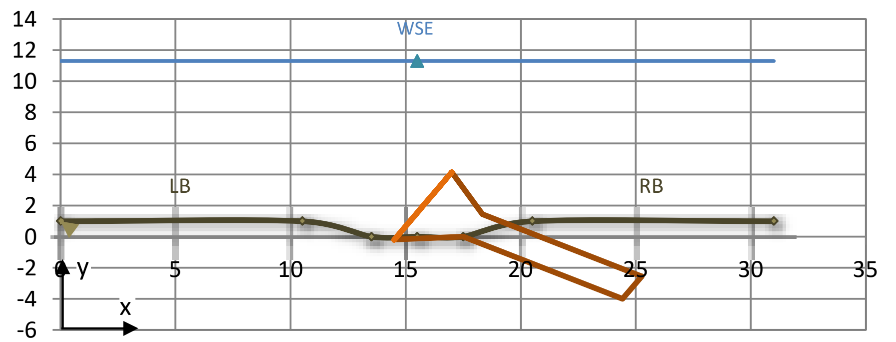
Single Log Stability Analysis Model Inputs

Site ID	Structure Type	Structure Position	Meander	Station	d_w (ft)	R_c/W_{BF}	u_{des} (ft/s)
0.6757 Chan	Rootwad	Right bank	Straight	+	11.29	2.44	2.13

Multi-Log Structures	Layer	Log ID
	Key Log	1

Channel Geometry Coordinates		
Proposed	x (ft)	y (ft)
Fldpln LB	0.00	1.00
Top LB	10.50	1.00
Toe LB	13.50	0.00
Thalweg	15.50	0.00
Toe RB	17.50	0.00
Top RB	20.50	1.00
Fldpln RB	31.00	1.00

Proposed Cross-Section and Structure Geometry (Looking D/S)

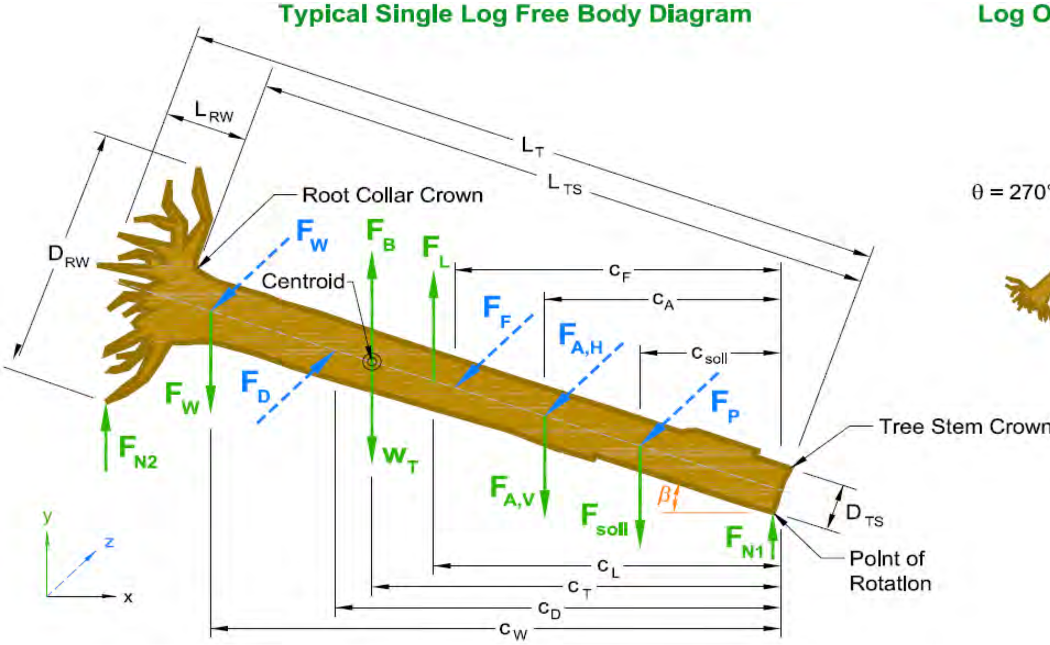


Wood Species	Rootwad	L_T (ft)	D_{TS} (ft)	L_{RW} (ft)	D_{RW} (ft)	γ_{Td} (lb/ft^3)	γ_{Tgr} (lb/ft^3)
Maple, Red	Yes	10.5	1.67	2.50	5.00	37.7	50.0

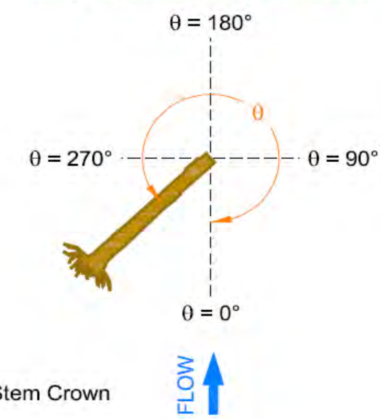
Structure Geometry	θ (deg)	β (deg)	Define Fixed Point	x_T (ft)	y_T (ft)	$y_{T,min}$ (ft)	$y_{T,max}$ (ft)	A_{Tp} (ft^2)
	270.1	-30.0	Root collar: Bottom	17.50	0.00	-4.00	4.14	6.76

Soils	Material	γ_s (lb/ft^3)	γ'_s (lb/ft^3)	ϕ (deg)	Soil Class	$L_{T,em}$ (ft)	$d_{b,max}$ (ft)	$d_{b,avg}$ (ft)
Stream Bed	Medium gravel	121.4	75.6	36.0	5	0.00	0.00	0.00
Bank	Clayey silt	84.0	52.3	27.0	6	6.52	3.56	1.91

Typical Single Log Free Body Diagram



Log Orientation (Plan View)



Vertical Force Analysis

Net Buoyancy Force

Wood	V_{TS} (ft^3)	V_{RW} (ft^3)	V_T (ft^3)	W_T (lbf)	F_B (lbf)
↑WSE	0.0	0.0	0.0	0	0
↓WS↑Thw	3.1	18.8	21.9	827	1,367
↓Thalweg	14.3	0.1	14.4	722	902
Total	17.5	18.9	36.4	1,549	2,269

Lift Force

C_{LT}	0.06
F_L (lbf)	2

Vertical Force Balance

F_B (lbf)	2,269	↑
F_L (lbf)	2	↑
W_T (lbf)	1,549	↓
F_{soil} (lbf)	1,082	↓
$F_{W,V}$ (lbf)	0	
$F_{A,V}$ (lbf)	0	
ΣF_V (lbf)	360	↓
FS_V	1.16	✓

Soil Ballast Force

Soil	V_{dry} (ft^3)	V_{sat} (ft^3)	V_{soil} (ft^3)	F_{soil} (lbf)
Bed	0.0	0.0	0.0	0
Bank	0.0	20.7	20.7	1,082
Total	0.0	20.7	20.7	1,082

Horizontal Force Analysis

Drag Force

A_{Tp} / A_W	Fr_L	C_{Di}	C_w	C_D*	F_D (lbf)
0.02	0.29	1.10	0.00	1.13	34

Horizontal Force Balance

F_D (lbf)	34	→
F_P (lbf)	1,440	←
F_F (lbf)	199	←
$F_{W,H}$ (lbf)	0	
$F_{A,H}$ (lbf)	0	
ΣF_H (lbf)	1,605	←
FS_H	48.56	✓

Passive Soil Pressure / Friction Force

Soil	K_P	F_P (lbf)	L_{Tf} (ft)	μ	F_F (lbf)
Bed	3.85	0	2.00	0.73	50
Bank	2.66	1,440	8.37	0.51	148
Total	-	1,440	10.37	-	199

Moment Force Balance

Driving Moment Centroids / Resisting Moment Centroids

$c_{T,B}$ (ft)	c_L (ft)	c_D (ft)	$c_{T,W}$ (ft)	c_{soil} (ft)	$c_{F\&N}$ (ft)	c_P (ft)
6.6	9.0	8.5	6.6	3.3	4.2	4.3

*Distances are from the stem tip

Point of Rotation: Stem Tip

Moment Force Balance

M_d (lbf)	13,236
M_r (lbf)	19,343
FS_M	1.46 ✓

Anchor Forces

Additional Soil Ballast

V_{Adry} (ft^3)	V_{Awet} (ft^3)	c_{Asoil} (ft)	$F_{A,Vsoil}$ (lbf)	$F_{A,HP}$ (lbf)
			0	0

Mechanical Anchors

Type	c_{Am} (ft)	Soils	F_{Am} (lbf)
			0
			0

Boulder Ballast

Position	D_r (ft)	c_{Ar} (ft)	$V_{r,dry}$ (ft^3)	$V_{r,wet}$ (ft^3)	W_r (lbf)	$F_{L,r}$ (lbf)	$F_{D,r}$ (lbf)	$F_{A,Vr}$ (lbf)	$F_{A,Hr}$ (lbf)
								0	0
								0	0
								0	0

Plumtree Branch - Salvaged Log/Root Wad

Spreadsheet developed by
Michael Rafferty, P.E.

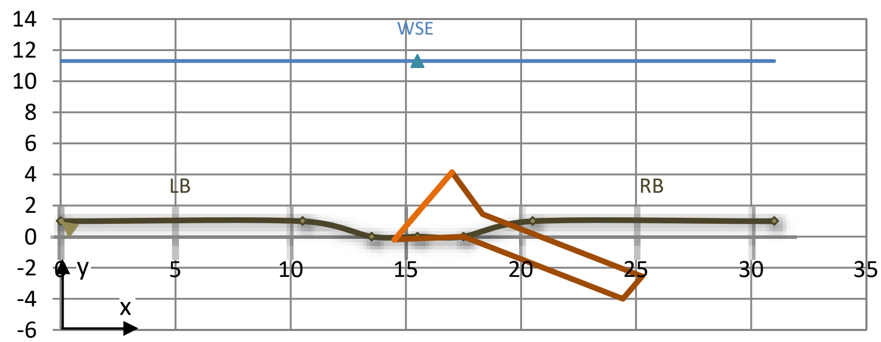
Single Log Stability Analysis Model Inputs

Site ID	Structure Type	Structure Position	Meander	Station	d_w (ft)	R_c/W_{BF}	u_{des} (ft/s)
0.6757 Chan	Rootwad	Right bank	Straight	+	11.29	2.44	2.13

Multi-Log Structures	Layer	Log ID
	Key Log	1

Channel Geometry Coordinates		
Proposed	x (ft)	y (ft)
Fldpln LB	0.00	1.00
Top LB	10.50	1.00
Toe LB	13.50	0.00
Thalweg	15.50	0.00
Toe RB	17.50	0.00
Top RB	20.50	1.00
Fldpln RB	31.00	1.00

Proposed Cross-Section and Structure Geometry (Looking D/S)

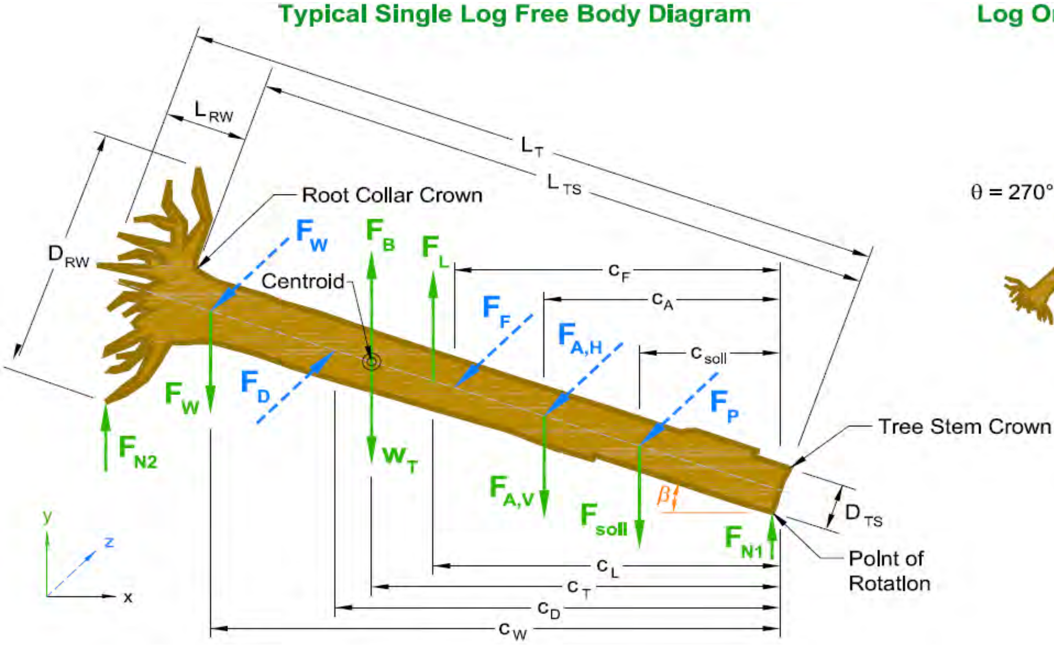


Wood Species	Rootwad	L_T (ft)	D_{TS} (ft)	L_{RW} (ft)	D_{RW} (ft)	γ_{Td} (lb/ft^3)	γ_{Tgr} (lb/ft^3)
Walnut, Black	Yes	10.5	1.67	2.50	5.00	38.4	57.0

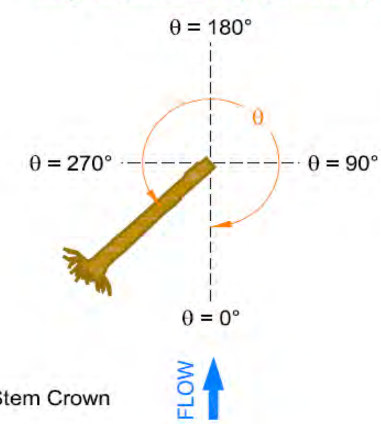
Structure Geometry	θ (deg)	β (deg)	Define Fixed Point	x_T (ft)	y_T (ft)	$y_{T,min}$ (ft)	$y_{T,max}$ (ft)	A_{Tp} (ft^2)
	270.1	-30.0	Root collar: Bottom	17.50	0.00	-4.00	4.14	6.76

Soils	Material	γ_s (lb/ft^3)	γ'_s (lb/ft^3)	φ (deg)	Soil Class	$L_{T,em}$ (ft)	$d_{b,max}$ (ft)	$d_{b,avg}$ (ft)
Stream Bed	Medium gravel	121.4	75.6	36.0	5	0.00	0.00	0.00
Bank	Clayey silt	84.0	52.3	27.0	6	6.52	3.56	1.91

Typical Single Log Free Body Diagram



Log Orientation (Plan View)



Vertical Force Analysis

Net Buoyancy Force

Wood	V_{TS} (ft^3)	V_{RW} (ft^3)	V_T (ft^3)	W_T (lbf)	F_B (lbf)
↑WSE	0.0	0.0	0.0	0	0
↓WS↑Thw	3.1	18.8	21.9	842	1,367
↓Thalweg	14.3	0.1	14.4	824	902
Total	17.5	18.9	36.4	1,666	2,269

Lift Force

C_{LT}	0.06
F_L (lbf)	2

Vertical Force Balance

F_B (lbf)	2,269	↑
F_L (lbf)	2	↑
W_T (lbf)	1,666	↓
F_{soil} (lbf)	1,082	↓
$F_{W,V}$ (lbf)	0	
$F_{A,V}$ (lbf)	0	
ΣF_V (lbf)	477	↓
FS_V	1.21	✓

Soil Ballast Force

Soil	V_{dry} (ft^3)	V_{sat} (ft^3)	V_{soil} (ft^3)	F_{soil} (lbf)
Bed	0.0	0.0	0.0	0
Bank	0.0	20.7	20.7	1,082
Total	0.0	20.7	20.7	1,082

Horizontal Force Analysis

Drag Force

A_{Tp} / A_W	Fr_L	C_{Di}	C_w	C_D*	F_D (lbf)
0.02	0.29	1.10	0.00	1.13	34

Horizontal Force Balance

F_D (lbf)	34	→
F_P (lbf)	1,440	←
F_F (lbf)	263	←
$F_{W,H}$ (lbf)	0	
$F_{A,H}$ (lbf)	0	
ΣF_H (lbf)	1,670	←
FS_H	50.46	✓

Passive Soil Pressure / Friction Force

Soil	K_P	F_P (lbf)	L_{Tf} (ft)	μ	F_F (lbf)
Bed	3.85	0	2.00	0.73	67
Bank	2.66	1,440	8.37	0.51	196
Total	-	1,440	10.37	-	263

Moment Force Balance

Driving Moment Centroids / Resisting Moment Centroids

$c_{T,B}$ (ft)	c_L (ft)	c_D (ft)	$c_{T,W}$ (ft)	c_{soil} (ft)	$c_{F\&N}$ (ft)	c_P (ft)
6.5	9.0	8.5	6.5	3.3	4.2	4.3

*Distances are from the stem tip

Point of Rotation: Stem Tip

Moment Force Balance

M_d (lbf)	12,972	↻
M_r (lbf)	20,468	↺
FS_M	1.58	✓

Anchor Forces

Additional Soil Ballast

V_{Adry} (ft^3)	V_{Awet} (ft^3)	c_{Asoil} (ft)	$F_{A,Vsoil}$ (lbf)	$F_{A,HP}$ (lbf)
			0	0

Mechanical Anchors

Type	c_{Am} (ft)	Soils	F_{Am} (lbf)
			0
			0

Boulder Ballast

Position	D_r (ft)	c_{Ar} (ft)	$V_{r,dry}$ (ft^3)	$V_{r,wet}$ (ft^3)	W_r (lbf)	$F_{L,r}$ (lbf)	$F_{D,r}$ (lbf)	$F_{A,Vr}$ (lbf)	$F_{A,Hr}$ (lbf)
								0	0
								0	0
								0	0

Plumtree Branch - Salvaged Log/Root Wad

Spreadsheet developed by
Michael Rafferty, P.E.

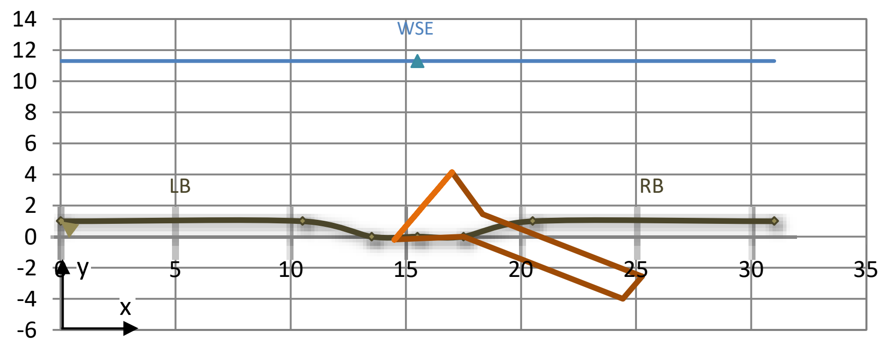
Single Log Stability Analysis Model Inputs

Site ID	Structure Type	Structure Position	Meander	Station	d_w (ft)	R_c/W_{BF}	u_{des} (ft/s)
0.6757 Chan	Rootwad	Right bank	Straight	+	11.29	2.44	2.13

Multi-Log Structures	Layer	Log ID
	Key Log	1

Channel Geometry Coordinates		
Proposed	x (ft)	y (ft)
Fldpln LB	0.00	1.00
Top LB	10.50	1.00
Toe LB	13.50	0.00
Thalweg	15.50	0.00
Toe RB	17.50	0.00
Top RB	20.50	1.00
Fldpln RB	31.00	1.00

Proposed Cross-Section and Structure Geometry (Looking D/S)

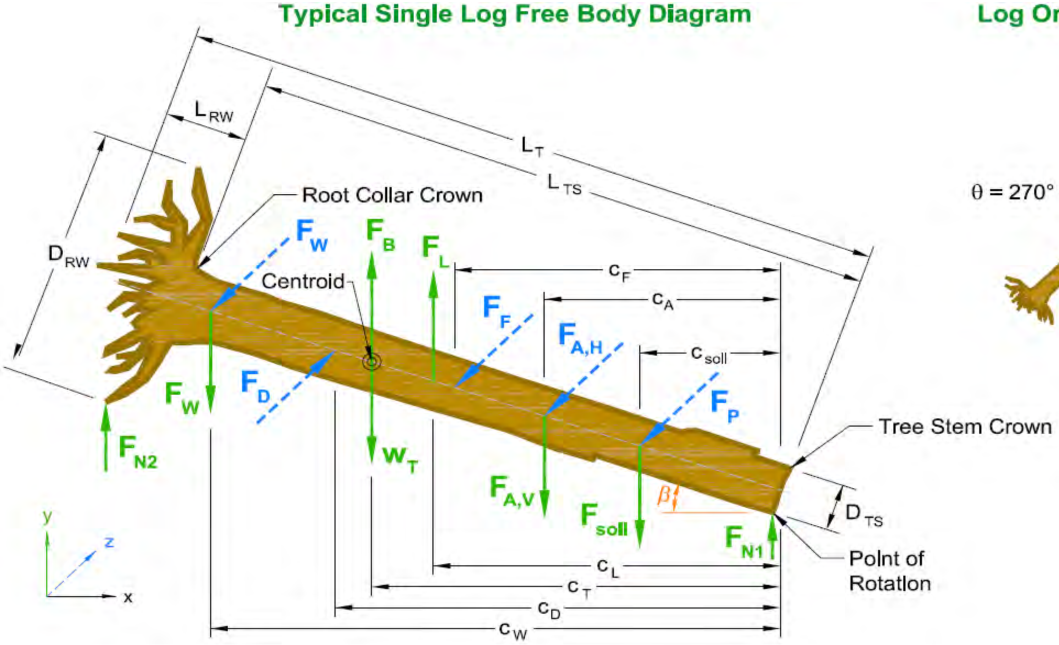


Wood Species	Rootwad	L_T (ft)	D_{TS} (ft)	L_{RW} (ft)	D_{RW} (ft)	γ_{Td} (lb/ft^3)	γ_{Tgr} (lb/ft^3)
Ash, White	Yes	10.5	1.67	2.50	5.00	41.9	50.0

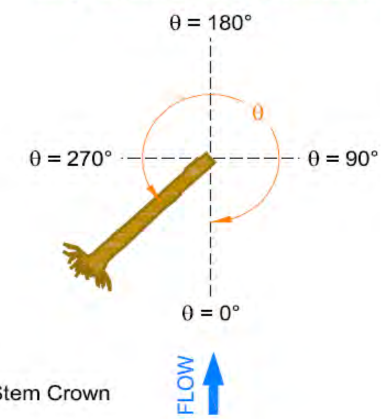
Structure Geometry	θ (deg)	β (deg)	Define Fixed Point	x_T (ft)	y_T (ft)	$y_{T,min}$ (ft)	$y_{T,max}$ (ft)	A_{Tp} (ft^2)
	270.1	-30.0	Root collar: Bottom	17.50	0.00	-4.00	4.14	6.76

Soils	Material	γ_s (lb/ft^3)	γ'_s (lb/ft^3)	ϕ (deg)	Soil Class	$L_{T,em}$ (ft)	$d_{b,max}$ (ft)	$d_{b,avg}$ (ft)
Stream Bed	Medium gravel	121.4	75.6	36.0	5	0.00	0.00	0.00
Bank	Clayey silt	84.0	52.3	27.0	6	6.52	3.56	1.91

Typical Single Log Free Body Diagram



Log Orientation (Plan View)



Vertical Force Analysis

Net Buoyancy Force

Wood	V_{TS} (ft^3)	V_{RW} (ft^3)	V_T (ft^3)	W_T (lbf)	F_B (lbf)
↑WSE	0.0	0.0	0.0	0	0
↓WS↑Thw	3.1	18.8	21.9	919	1,367
↓Thalweg	14.3	0.1	14.4	722	902
Total	17.5	18.9	36.4	1,641	2,269

Lift Force

C_{LT}	0.06
F_L (lbf)	2

Vertical Force Balance

F_B (lbf)	2,269	↑
F_L (lbf)	2	↑
W_T (lbf)	1,641	↓
F_{soil} (lbf)	1,082	↓
$F_{W,V}$ (lbf)	0	
$F_{A,V}$ (lbf)	0	
ΣF_V (lbf)	452	↓
FS_V	1.20	✓

Soil Ballast Force

Soil	V_{dry} (ft^3)	V_{sat} (ft^3)	V_{soil} (ft^3)	F_{soil} (lbf)
Bed	0.0	0.0	0.0	0
Bank	0.0	20.7	20.7	1,082
Total	0.0	20.7	20.7	1,082

Horizontal Force Analysis

Drag Force

A_{Tp} / A_W	Fr_L	C_{Di}	C_w	C_D*	F_D (lbf)
0.02	0.29	1.10	0.00	1.13	34

Horizontal Force Balance

F_D (lbf)	34	→
F_P (lbf)	1,440	←
F_F (lbf)	249	←
$F_{W,H}$ (lbf)	0	
$F_{A,H}$ (lbf)	0	
ΣF_H (lbf)	1,656	←
FS_H	50.06	✓

Passive Soil Pressure / Friction Force

Soil	K_P	F_P (lbf)	L_{Tf} (ft)	μ	F_F (lbf)
Bed	3.85	0	2.00	0.73	63
Bank	2.66	1,440	8.37	0.51	186
Total	-	1,440	10.37	-	249

Moment Force Balance

Driving Moment Centroids / Resisting Moment Centroids

$c_{T,B}$ (ft)	c_L (ft)	c_D (ft)	$c_{T,W}$ (ft)	c_{soil} (ft)	$c_{F\&N}$ (ft)	c_P (ft)
6.7	9.0	8.5	6.7	3.3	4.2	4.3

*Distances are from the stem tip

Point of Rotation: Stem Tip

Moment Force Balance

M_d (lbf)	13,480
M_r (lbf)	20,560
FS_M	1.53 ✓

Anchor Forces

Additional Soil Ballast

V_{Adry} (ft^3)	V_{Awet} (ft^3)	c_{Asoil} (ft)	$F_{A,Vsoil}$ (lbf)	$F_{A,HP}$ (lbf)
			0	0

Mechanical Anchors

Type	c_{Am} (ft)	Soils	F_{Am} (lbf)
			0
			0

Boulder Ballast

Position	D_r (ft)	c_{Ar} (ft)	$V_{r,dry}$ (ft^3)	$V_{r,wet}$ (ft^3)	W_r (lbf)	$F_{L,r}$ (lbf)	$F_{D,r}$ (lbf)	$F_{A,Vr}$ (lbf)	$F_{A,Hr}$ (lbf)
								0	0
								0	0
								0	0

Plumtree Branch - Salvaged Log/Root Wad

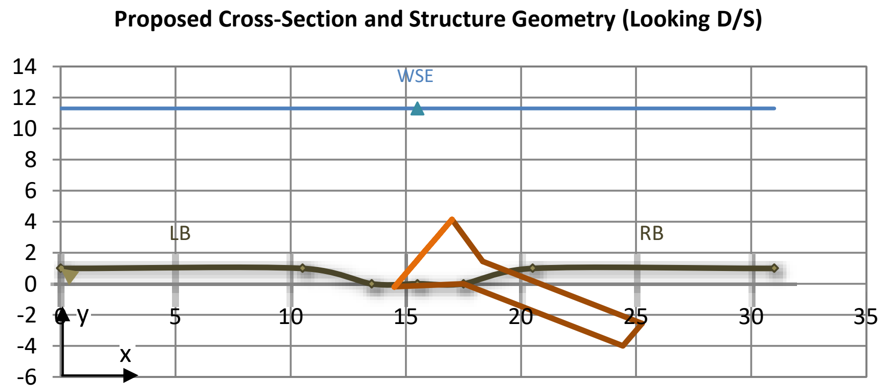
Spreadsheet developed by Michael Rafferty, P.E.

Single Log Stability Analysis Model Inputs

Site ID	Structure Type	Structure Position	Meander	Station	d_w (ft)	R_c/W_{BF}	u_{des} (ft/s)
0.6757 Chan	Rootwad	Right bank	Straight	+	11.29	2.44	2.13

Multi-Log Structures	Layer	Log ID
	Key Log	1

Channel Geometry Coordinates		
Proposed	x (ft)	y (ft)
Fldpln LB	0.00	1.00
Top LB	10.50	1.00
Toe LB	13.50	0.00
Thalweg	15.50	0.00
Toe RB	17.50	0.00
Top RB	20.50	1.00
Fldpln RB	31.00	1.00

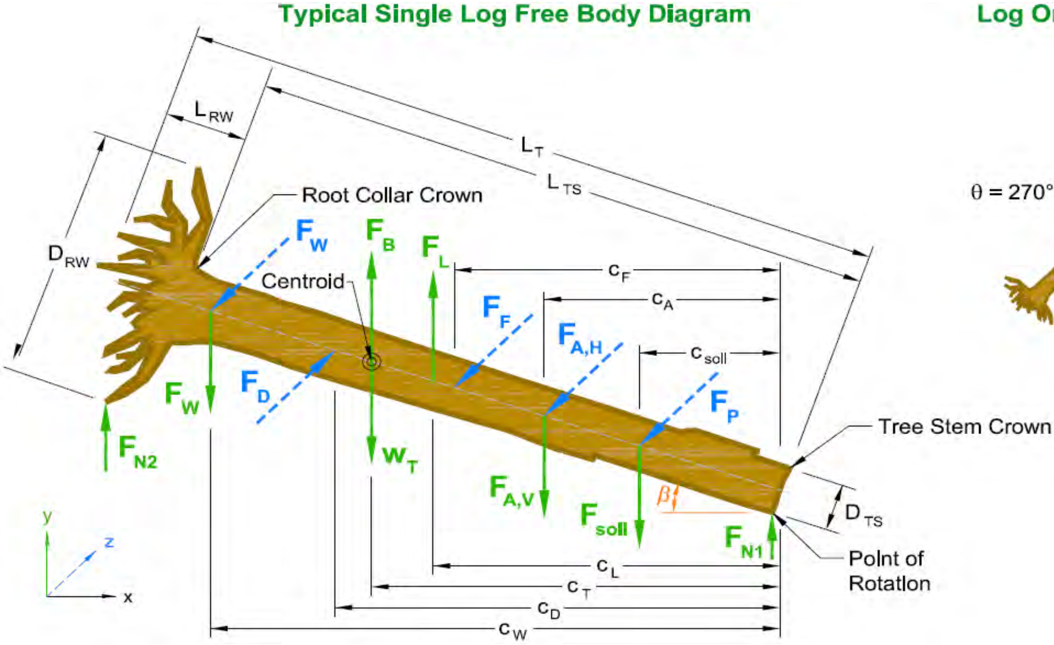


Wood Species	Rootwad	L_T (ft)	D_{TS} (ft)	L_{RW} (ft)	D_{RW} (ft)	γ_{Td} (lb/ft^3)	γ_{Tgr} (lb/ft^3)
Oak, Pin	Yes	10.5	1.67	2.50	5.00	44.0	64.0

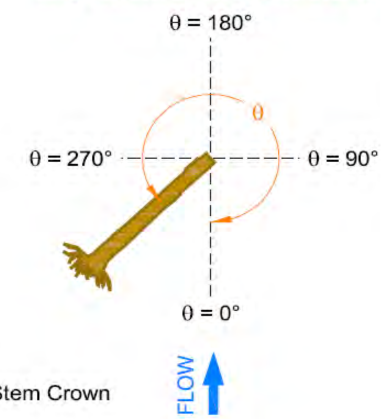
Structure Geometry	θ (deg)	β (deg)	Define Fixed Point	x_T (ft)	y_T (ft)	$y_{T,min}$ (ft)	$y_{T,max}$ (ft)	A_{Tp} (ft^2)
	270.1	-30.0	Root collar: Bottom	17.50	0.00	-4.00	4.14	6.76

Soils	Material	γ_s (lb/ft^3)	γ'_s (lb/ft^3)	φ (deg)	Soil Class	$L_{T,em}$ (ft)	$d_{b,max}$ (ft)	$d_{b,avg}$ (ft)
Stream Bed	Medium gravel	121.4	75.6	36.0	5	0.00	0.00	0.00
Bank	Clayey silt	84.0	52.3	27.0	6	6.52	3.56	1.91

Typical Single Log Free Body Diagram



Log Orientation (Plan View)



Vertical Force Analysis

Net Buoyancy Force

Wood	V_{TS} (ft^3)	V_{RW} (ft^3)	V_T (ft^3)	W_T (lbf)	F_B (lbf)
↑WSE	0.0	0.0	0.0	0	0
↓WS↑Thw	3.1	18.8	21.9	965	1,367
↓Thalweg	14.3	0.1	14.4	925	902
Total	17.5	18.9	36.4	1,890	2,269

Lift Force

C_{LT}	0.06
F_L (lbf)	2

Vertical Force Balance

F_B (lbf)	2,269	↑
F_L (lbf)	2	↑
W_T (lbf)	1,890	↓
F_{soil} (lbf)	1,082	↓
$F_{W,V}$ (lbf)	0	
$F_{A,V}$ (lbf)	0	
ΣF_V (lbf)	701	↓
FS_V	1.31	✓

Soil Ballast Force

Soil	V_{dry} (ft^3)	V_{sat} (ft^3)	V_{soil} (ft^3)	F_{soil} (lbf)
Bed	0.0	0.0	0.0	0
Bank	0.0	20.7	20.7	1,082
Total	0.0	20.7	20.7	1,082

Horizontal Force Analysis

Drag Force

A_{Tp} / A_W	Fr_L	C_{Di}	C_w	C_D*	F_D (lbf)
0.02	0.29	1.10	0.00	1.13	34

Horizontal Force Balance

F_D (lbf)	34	→
F_P (lbf)	1,440	←
F_F (lbf)	386	←
$F_{W,H}$ (lbf)	0	
$F_{A,H}$ (lbf)	0	
ΣF_H (lbf)	1,793	←
FS_H	54.11	✓

Passive Soil Pressure / Friction Force

Soil	K_P	F_P (lbf)	L_{Tf} (ft)	μ	F_F (lbf)
Bed	3.85	0	2.00	0.73	98
Bank	2.66	1,440	8.37	0.51	288
Total	-	1,440	10.37	-	386

Moment Force Balance

Driving Moment Centroids / Resisting Moment Centroids

$c_{T,B}$ (ft)	c_L (ft)	c_D (ft)	$c_{T,W}$ (ft)	c_{soil} (ft)	$c_{F\&N}$ (ft)	c_P (ft)
6.5	9.0	8.5	6.5	3.3	4.2	4.3

*Distances are from the stem tip

Point of Rotation: Stem Tip

Moment Force Balance

M_d (lbf)	13,019
M_r (lbf)	23,014
FS_M	1.77

Anchor Forces

Additional Soil Ballast

V_{Adry} (ft^3)	V_{Awet} (ft^3)	c_{Asoil} (ft)	$F_{A,Vsoil}$ (lbf)	$F_{A,HP}$ (lbf)
			0	0

Mechanical Anchors

Type	c_{Am} (ft)	Soils	F_{Am} (lbf)
			0
			0

Boulder Ballast

Position	D_r (ft)	c_{Ar} (ft)	$V_{r,dry}$ (ft^3)	$V_{r,wet}$ (ft^3)	W_r (lbf)	$F_{L,r}$ (lbf)	$F_{D,r}$ (lbf)	$F_{A,Vr}$ (lbf)	$F_{A,Hr}$ (lbf)
								0	0
								0	0
								0	0

Plumtree Branch - Salvaged Log/Root Wad

Spreadsheet developed by
Michael Rafferty, P.E.

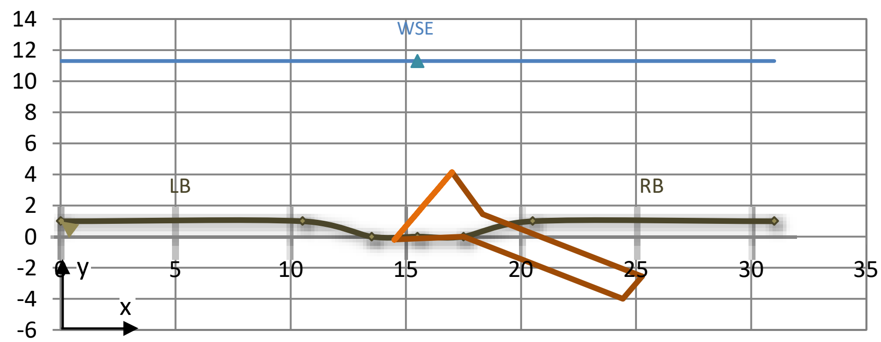
Single Log Stability Analysis Model Inputs

Site ID	Structure Type	Structure Position	Meander	Station	d_w (ft)	R_c/W_{BF}	u_{des} (ft/s)
0.6757 Chan	Rootwad	Right bank	Straight	+	11.29	2.44	2.13

Multi-Log Structures	Layer	Log ID
	Key Log	1

Channel Geometry Coordinates		
Proposed	x (ft)	y (ft)
Fldpln LB	0.00	1.00
Top LB	10.50	1.00
Toe LB	13.50	0.00
Thalweg	15.50	0.00
Toe RB	17.50	0.00
Top RB	20.50	1.00
Fldpln RB	31.00	1.00

Proposed Cross-Section and Structure Geometry (Looking D/S)

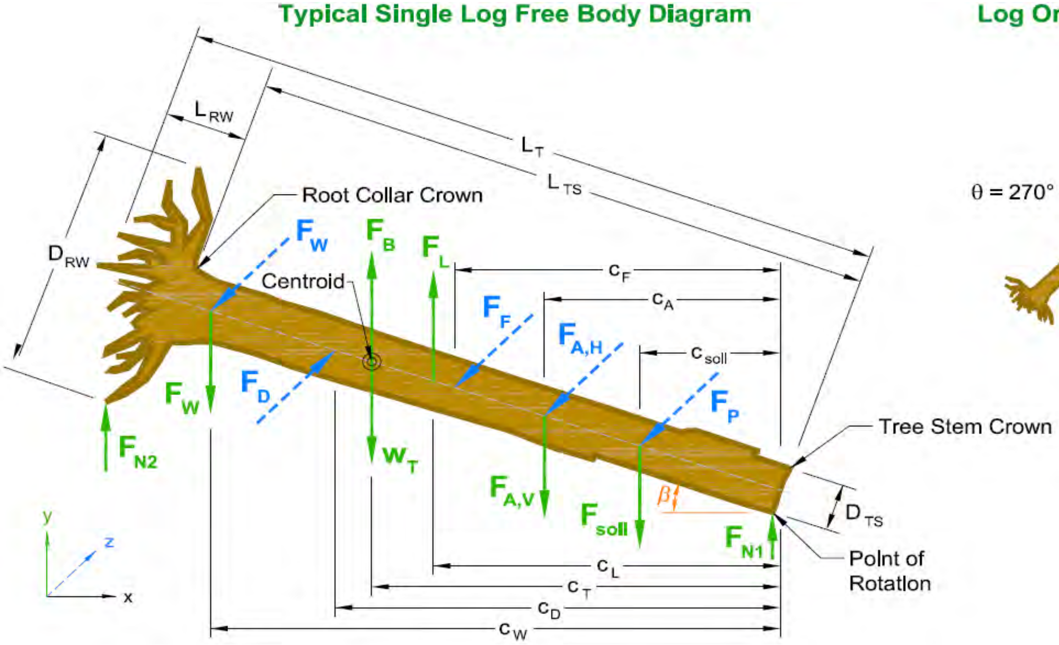


Wood Species	Rootwad	L_T (ft)	D_{TS} (ft)	L_{RW} (ft)	D_{RW} (ft)	γ_{Td} (lb/ft^3)	γ_{Tgr} (lb/ft^3)
Beech, American	Yes	10.5	1.67	2.50	5.00	44.7	54.0

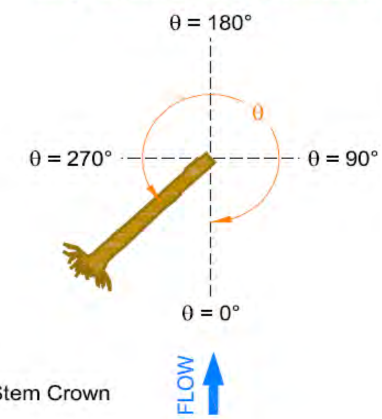
Structure Geometry	θ (deg)	β (deg)	Define Fixed Point	x_T (ft)	y_T (ft)	$y_{T,min}$ (ft)	$y_{T,max}$ (ft)	A_{Tp} (ft^2)
	270.1	-30.0	Root collar: Bottom	17.50	0.00	-4.00	4.14	6.76

Soils	Material	γ_s (lb/ft^3)	γ'_s (lb/ft^3)	ϕ (deg)	Soil Class	$L_{T,em}$ (ft)	$d_{b,max}$ (ft)	$d_{b,avg}$ (ft)
Stream Bed	Medium gravel	121.4	75.6	36.0	5	0.00	0.00	0.00
Bank	Clayey silt	84.0	52.3	27.0	6	6.52	3.56	1.91

Typical Single Log Free Body Diagram



Log Orientation (Plan View)



Vertical Force Analysis

Net Buoyancy Force

Wood	V_{TS} (ft^3)	V_{RW} (ft^3)	V_T (ft^3)	W_T (lbf)	F_B (lbf)
↑WSE	0.0	0.0	0.0	0	0
↓WS↑Thw	3.1	18.8	21.9	980	1,367
↓Thalweg	14.3	0.1	14.4	780	902
Total	17.5	18.9	36.4	1,760	2,269

Lift Force

C_{LT}	0.06
F_L (lbf)	2

Vertical Force Balance

F_B (lbf)	2,269	↑
F_L (lbf)	2	↑
W_T (lbf)	1,760	↓
F_{soil} (lbf)	1,082	↓
$F_{W,V}$ (lbf)	0	
$F_{A,V}$ (lbf)	0	
ΣF_V (lbf)	571	↓
FS_V	1.25	✓

Soil Ballast Force

Soil	V_{dry} (ft^3)	V_{sat} (ft^3)	V_{soil} (ft^3)	F_{soil} (lbf)
Bed	0.0	0.0	0.0	0
Bank	0.0	20.7	20.7	1,082
Total	0.0	20.7	20.7	1,082

Horizontal Force Analysis

Drag Force

A_{Tp} / A_W	Fr_L	C_{Di}	C_w	C_D*	F_D (lbf)
0.02	0.29	1.10	0.00	1.13	34

Horizontal Force Balance

F_D (lbf)	34	→
F_P (lbf)	1,440	←
F_F (lbf)	315	←
$F_{W,H}$ (lbf)	0	
$F_{A,H}$ (lbf)	0	
ΣF_H (lbf)	1,722	←
FS_H	52.00	✓

Passive Soil Pressure / Friction Force

Soil	K_P	F_P (lbf)	L_{Tf} (ft)	μ	F_F (lbf)
Bed	3.85	0	2.00	0.73	80
Bank	2.66	1,440	8.37	0.51	235
Total	-	1,440	10.37	-	315

Moment Force Balance

Driving Moment Centroids / Resisting Moment Centroids

$c_{T,B}$ (ft)	c_L (ft)	c_D (ft)	$c_{T,W}$ (ft)	c_{soil} (ft)	$c_{F\&N}$ (ft)	c_P (ft)
6.7	9.0	8.5	6.7	3.3	4.2	4.3

*Distances are from the stem tip

Point of Rotation: Stem Tip

Moment Force Balance

M_d (lbf)	13,452
M_r (lbf)	21,899
FS_M	1.63 ✓

Anchor Forces

Additional Soil Ballast

V_{Adry} (ft^3)	V_{Awet} (ft^3)	c_{Asoil} (ft)	$F_{A,Vsoil}$ (lbf)	$F_{A,HP}$ (lbf)
			0	0

Mechanical Anchors

Type	c_{Am} (ft)	Soils	F_{Am} (lbf)
			0
			0

Boulder Ballast

Position	D_r (ft)	c_{Ar} (ft)	$V_{r,dry}$ (ft^3)	$V_{r,wet}$ (ft^3)	W_r (lbf)	$F_{L,r}$ (lbf)	$F_{D,r}$ (lbf)	$F_{A,Vr}$ (lbf)	$F_{A,Hr}$ (lbf)
								0	0
								0	0
								0	0

Plumtree Branch - Salvaged Log/Root Wad
Notation, Units, and List of Symbols

Notation

Symbol	Description	Unit
A_W	Wetted area of channel at design discharge	ft^2
A_{Tp}	Projected area of wood in plane perpendicular to flow	ft^2
c_D	Centroid of the drag force along log axis	ft
c_{Am}	Centroid of a mechanical anchor along log axis	ft
c_{Ar}	Centroid of a ballast boulder along log axis	ft
c_{Asoil}	Centroid of the added ballast soil along log axis	ft
$c_{F\&N}$	Centroid of friction and normal forces along log axis	ft
c_L	Centroid of the lift force along log axis	ft
c_P	Centroid of the passive soil force along log axis	ft
c_{soil}	Centroid of the vertical soil forces along log axis	ft
$c_{T,B}$	Centroid of the buoyancy force along log axis	ft
$c_{T,W}$	Centroid of the log volume along log axis	ft
c_{WI}	Centroid of a wood interaction force along log axis	ft
C_{Lrock}	Coefficient of lift for submerged boulder	-
C_{LT}	Effective coefficient of lift for submerged tree	-
C_{Di}	Base coefficient of drag for tree, before adjustments	-
C_D*	Effective coefficient of drag for submerged tree	-
C_{Di}	Base coefficient of drag for tree, before adjustments	-
C_W	Wave drag coefficient of submerged tree	-
$d_{b,avg}$	Average buried depth of log	ft
$d_{b,max}$	Maximum buried depth of log	ft
d_w	Maximum flow depth at design discharge in reach	ft
D_{50}	Median grain size in millimeters (SI units)	mm
D_r	Equivalent diameter of boulder	ft
D_{RW}	Assumed diameter of rootwad	ft
D_{TS}	Nominal diameter of tree stem (DBH)	ft
DF_{RW}	Diameter factor for rootwad ($DF_{RW} = D_{RW}/D_{TS}$)	-
e	Void ratio of soils	-
$F_{A,H}$	Total horizontal load capacity of anchor techniques	lbf
$F_{A,HP}$	Passive soil pressure applied to log from soil ballast	lbf
$F_{A,Hr}$	Horizontal resisting force on log from boulder	lbf
F_{Am}	Load capacity of mechanical anchor	lbf
$F_{A,V}$	Total vertical load capacity of anchor techniques	lbf
$F_{A,Vr}$	Vertical resisting force on log from boulder	lbf
$F_{A,Vsoil}$	Vertical soil loading on log from added ballast soil	lbf
F_B	Buoyant force applied to log	lbf
F_D	Drag forces applied to log	lbf
$F_{D,r}$	Drag forces applied to boulder	lbf
F_F	Friction force applied to log	lbf
F_H	Resultant horizontal force applied to log	lbf
F_L	Lift force applied to log	lbf
$F_{L,r}$	Lift force applied to boulder	lbf
F_P	Passive soil pressure force applied to log	lbf
F_{soil}	Vertical soil loading on log	lbf
$F_{W,H}$	Horizontal forces from interactions with other logs	lbf
$F_{W,V}$	Vertical forces from interactions with other logs	lbf

Notation (continued)

Symbol	Description	Unit
F_V	Resultant vertical force applied to log	lbf
Fr_L	Log Froude number	-
FS_V	Factor of Safety for Vertical Force Balance	-
FS_H	Factor of Safety for Horizontal Force Balance	-
FS_M	Factor of Safety for Moment Force Balance	-
g	Gravitational acceleration constant	ft/s^2
K_P	Coefficient of Passive Earth Pressure	-
$L_{T,em}$	Total embedded length of log	ft
L_{RW}	Assumed length of rootwad	ft
L_T	Total length of tree (including rootwad)	ft
L_{Tf}	Length of log in contact with bed or banks	ft
L_{TS}	Length of tree stem (not including rootwad)	ft
$L_{TS,ex}$	Exposed length of tree stem	ft
LF_{RW}	Length factor for rootwad ($LF_{RW} = L_{RW}/D_{TS}$)	-
M_d	Driving moment about embedded tip	lbf
M_r	Driving moment about embedded tip	lbf
N	Blow count of standard penetration test	-
p_o	Porosity of soil volume	-
Q_{des}	Design discharge	cfs
R	Radius	ft
R_c	Radius of curvature at channel centerline	ft
SG_r	Specific gravity of quartz particles	-
SG_T	Specific gravity of tree	-
u_{avg}	Average velocity of cross section in reach	ft/s
u_{des}	Design velocity	ft/s
u_m	Adjusted velocity at outer meander bend	ft/s
V_{dry}	Volume of soils above stage level of design flow	ft^3
V_{sat}	Volume of soils below stage level of design flow	ft^3
V_{soil}	Total volume of soils over log	ft^3
V_{RW}	Volume of rootwad	ft^3
V_S	Volume of solids in soil (void ratio calculation)	ft^3
V_T	Total volume of log	ft^3
V_{TS}	Total volume of tree	ft^3
V_V	Volume of voids in soil	ft^3
V_{Adry}	Volume of ballast above stage of design flow	ft^3
V_{Awet}	Volume of ballast below stage of design flow	ft^3
$V_{r,dry}$	Volume of boulder above stage of design flow	ft^3
$V_{r,wet}$	Volume of boulder below stage of design flow	ft^3
W_{BF}	Bankfull width at structure site	ft
W_r	Effective weight of boulder	lbf
W_T	Total log weight	lbf
x	Horizontal coordinate (distance)	ft
y	Vertical coordinate (elevation)	ft
$y_{T,max}$	Minimum elevation of log	ft
$y_{T,min}$	Maximum elevation of log	ft

Greek Symbols

Symbol	Description	Unit
β	Tilt angle from stem tip to vertical	deg
γ_{bank}	Dry specific weight of bank soils	lb/ft^3
$\gamma_{bank,sat}$	Saturated unit weight of bank soils	lb/ft^3
γ'_{bank}	Effective buoyant unit weight of bank soils	lb/ft^3
γ_{bed}	Dry specific weight of stream bed substrate	lb/ft^3
γ'_{bed}	Effective buoyant unit weight of stream bed substrate	lb/ft^3
γ_{rock}	Dry unit weight of boulders	lb/ft^3
γ_s	Dry specific weight of soil	lb/ft^3
γ'_s	Effective buoyant unit weight of soil	lb/ft^3
γ_{Td}	Air-dried unit weight of tree (12% MC basis)	lb/ft^3
γ_{Tgr}	Green unit weight of tree	lb/ft^3
γ_w	Specific weight of water at 50ºF	lb/ft^3
η	Rootwad porosity	-
θ	Rootwad (or large end of log) orientation to flow	deg
μ	Coefficient of friction	-
ν	Kinematic viscosity of water at 50ºF	ft/s^2
Σ	Sum of forces	-
ϕ_{bank}	Internal friction angle of bank soils	deg
ϕ_{bed}	Internal friction angle of stream bed substrate	deg

Units

Notation	Description
cfs	Cubic feet per second
ft	Feet
lb	Pound
lbf	Pounds force
kg	Kilograms
m	Meters
mm	Millimeters
s	Seconds
yr	Year

Abbreviations

Notation	Description
ARI	Average return interval
Avg	Average
DBH	Diameter at breast height
deg	Degrees
Dia	Diameter
Dist	Distance
D/S	Downstream
ELJ	Engineered log jam
Ex	Example
Fldpln	Floodplain
H&H	Hydrologic and hydraulic
ID	Identification
i.e.	That is
LB	Left bank
LW	Large wood
Max	Maximum
MC	Moisture content
Min	Minimum
ML	Multi-log
SL	Single log
N/A	Not applicable
no	Number
Pt	Point
rad	Radians
RB	Right bank
RW	Rootwad
SL	Single log
Thw	Thalweg (lowest elevation in channel bed)
Typ	Typical
U.S.	United States
WS	Water surface
WSE	Water surface elevation
↑	Above
↓	Below

Reference Sheet - Anchoring Techniques

Anchor Technique Lookup Table (average holding capacities)

Soil Class	Soil Description	Blow Count (N)	Manta Ray			Stingray			Duckbill			
			MR-1 Capacity (lb)	MR-2 Capacity (lb)	MR-SR Capacity (lb)	SR-1 Capacity (lb)	SR-2 Capacity (lb)	SR-3 Capacity (lb)	DB-40 Capacity (lb)	DB-68 Capacity (lb)	DB-88 Capacity (lb)	DB-138 Capacity (lb)
4	Dense gravels; gravel/cobble; very hard silts and clays	40-100+	24,000	15,000	32,000	39,000	62,000	85,000	user input	user input	user input	user input
5	Dense coarse sand; gravel/sand; loose gravels; stiff slits and clays	14-40	15,000	9,000	18,000	24,000	31,000	48,000	300	1,100	3,000	5,000
6	Loose coarse sand; dense fine sand; firm silts and clays	7-14	10,000	7,000	14,000	16,000	27,000	37,000	user input	user input	user input	user input
7	Loose fine sand; alluvium; soft silts and clays; silty sanc	4-8	8,000	5,000	9,000	13,000	19,000	24,000	user input	user input	user input	user input

Soil Class	Platipus Stealth				Platipus Bat					Custom (User Selection)		
	P-S02 Capacity (lb)	P-S04 Capacity (lb)	P-S06 Capacity (lb)	P-S08 Capacity (lb)	P-B04T Capacity (lb)	P-B06T Capacity (lb)	P-B08T Capacity (lb)	P-B10T Capacity (lb)	P-B12T Capacity (lb)	Custom#1 Capacity (lb)	Custom#2 Capacity (lb)	Custom#3 Capacity (lb)
4	300	1,000	3,500	4,500	6,000	11,000	16,500	22,000	33,000	(user input)	(user input)	(user input)
5	150	600	2,000	2,500	3,500	6,500	9,000	14,000	20,000	(user input)	(user input)	(user input)
6	50	300	800	1,500	2,500	4,000	6,500	11,000	16,000	(user input)	(user input)	(user input)
7	N/A	200	400	1,000	2,000	3,500	5,500	9,000	13,000	(user input)	(user input)	(user input)

Notes:
1. All types -- Use this chart for estimation only. Values shown reflect the manufacturer's minimum expected holding capacity for a given condition. User is responsible for verifying load capacities. The true capacity must be tested by proof-loading. Minimum 2:1 Safety Factor is recommended.
2. Installation may be difficult. Pilot hole may be required.
3. Holding capacity limited by working load of anchors.
4. Holding capacity limited by soil failure.
5. Wide variation in soil properties reduces prediction accuracy. Pre-constructed field test recommended.
6. Duckbill anchors are rated in an average (class 5) soil condition. Proof-loading is the only way to insure the exact capacity of each installation. Anchor holding capacity will vary in different soils. Increased capacities can be expected in harder soil classes (numerically higher blow count classifications) and lower capacity can be expected in the softer soil classes (numerically lower blow count).
7. Platipus Stealth and Bat anchors are given a wide range for holding capacities. The high manufacturer's rating was applied to class 4 soils, while the low value was assigned to class 7 soils. Holding capacities for class 5 and 6 soils were interpolated as a guide only. User is responsible for verifying all rating capacities.

Anchor/Ballast Technique Lookup Table

Technique	Description
Added Soil Ballast	Add coarse material soil lifts on top of structure to increase burial depth
Boulder Ballast	Place boulder on top of structure. Alternatively, secure structure to boulder located beside or beneath structure.
Wood Pile (In development)	Drive or bury vertical wood piles into the bed or banks to brace structure. Alternatively, brace structure against existing large tree.
Mechanical Anchor	Secure structure to soil anchor which uses overlying soil to resist pullout. Alternatively, secure the structure to bedrock using a rock anchor.

Four common alternatives exist for securing or stabilizing placements of large wood in water. In order of preference for habitat formation, they are:
1. No added stability -- where wood is supplied to the stream and allowed to be stable without manipulation or, as conditions develop, moved by the flow.
2. Passive stability -- where the weight and shape of the structure is the anchor, and movement at some flow level is acceptable (includes ballast).
3. Flexible stability -- such as tethering the structure so some degree of movement is allowed with varying flows.
4. Rigid stability -- holding the logs permanently in place with no movement allowed.
(Source: 2012 WA Stream Habitat Restoration Guidelines)

Directions for LW Stability Analysis Tool

This design tool may be used by practitioners if they cite the developer on each sheet.

Disclaimer:
This Microsoft Excel 2010 spreadsheet tool is provided free of charge. Use this tool at your own risk. In offering this tool, the author, the U.S. Forest Service, and Colorado State University do not accept any responsibility or liability for the tool's use by third parties. This tool has specific uses and limits of applicability. Design practitioners shall take full responsibility for the final large wood structure design and performance. Designers are expected to verify the calculated values and validity of the design method. Designers should be qualified to work in river environments, and depending on the State, they may be required to be licensed as a professional engineer to design large wood structures. You cannot be sure the tool is authentic and unmolested unless downloaded from the following website:
https://www.fs.fed.us/biology/nsaec/products-tools.html#tools-stabilitylargewoodstructures

DATA INPUT

Order of Input

Update the worksheets from "left to right"
Update the spreadsheet cells from "left to right" and "top to bottom"

IMPORTANT - User should only edit the following cells:

Cell Format	Directions
Dropdown List	Select value from dropdown list
User Input	Type value into cell
User Verify	Verify value in cell (edit if necessary)

User should verify, but not edit the following cells because these cells contain formulas or headings:

Cell Format	Directions
Heading	Table Heading (Scroll over sample heading for description of comments)
Automatic Value	Verify value in cell which is automatically calculated by formulas
Key Value	Verify value of force calculation
Solution	Verify value of force balance or factor of safety calculation
Background Value	Optional - Verify value of background calculation (outside of print area)

The "Single Log" and "Multi-Log" spreadsheets have several built-in error messages (in column 'K'):

Error Message	
"CHECK"	Prompts user to check a specific input
"ERROR"	Prompts user to change a specific input

User Input Note 1 - Several worksheets have a built in "clear inputs" button linked to a macro (these are the only macros built into the tool). Be aware that you can't undo the "clear input" command.

User Input Note 2 - User may enter a custom "bank soil type", "wood species", or "anchor type" by scrolling over to the right to find the lookup table and editing the "custom" cells.

User Input Note 3 - The spreadsheet is not locked, and therefore every cell can be manually edited. However, the

user is encouraged to exercise caution to avoid unintended consequences of changing reference formulas.

User Input Note 4 - User should also be very careful when removing or adding cells (at least scroll over and down to see what other cells may be impacted). Hiding unused rows or columns is recommended instead of deleting them. If the user needs to add cells on the "Single Log Design" spreadsheet, they should add a row of cells for all columns between 'A' and 'J'. Important: Adding cells will break the code in the "Clear Inputs" macro, and cause it to clear the wrong cells.

User Input Note 5 - To avoid compounding potential errors, the user should use the original download version of the spreadsheet (without personal edits) at the beginning of each design.

User Input Note 6 - Input values should be in English units, with one exception: D_{50} for the bed substrate gradation (mm).

ANALYSIS OF MULTIPLE LOG STRUCTURES

The LW Stability Analysis Tool can also be used to design multiple log structures. The user must manually translate the resulting vertical and horizontal forces from one log design sheet into another (or write their own formulas). This data should be entered in the "Interaction Forces with Adjacent Logs" section of the "Single Log Design" worksheet. In theory, there is no limit to the number of logs that can be considered, although the force balance accounting may become cumbersome beyond a few logs. The general procedure is as follows:

Step 1 Begin by creating a preliminary structure layout (in AutoCAD or similar) to define the quantity of logs, locate intersect points, and identify key members. Key members are typically the largest logs (or the logs that are going to be have anchors attached).

Step 2 Fill out Sheets 1 through 5 of this tool. Next, input the channel geometry in a blank "Single Log Design" worksheet (Sheet 6), and then make copies for analysis of each log.

Step 3 Complete a preliminary force balance analysis for each stacked member log, ignoring the "Interaction Forces with Adjacent Logs" and "Anchor Forces" sections. The user should manually record the resisting forces required to stabilize each stacked member in a table. The required vertical force can be found in cell 'K61' of the "Single Log Design" worksheet, and the required horizontal force can be found in cell 'K72'. If the log is already vertically or horizontally stable, record the excess force that may be applied to resist driving forces of the adjacent log(s). This information can be found in cell 'K62' and 'K73'. An example table is shown to the right of these directions →

Step 4 Complete a force balance analysis for the key members. In the "Interaction Forces with Adjacent Logs" section on the force balance sheet, enter the relative position of each adjacent stacked log in contact with the key member, the connection type (gravity or pinned), the intersection point, and the required vertical and horizontal forces to achieve stability for each stacked member. If the load from the adjacent logs is spread over multiple key members, divide the required forces by the number of key members sharing the load (note--these loads do not need to be evenly distributed between key members). If an adjacent log is either horizontally or vertically stable, then enter any excess force (see Step 3 above) value as a negative number in the key member design spreadsheet. The tool will automatically determine which loads are transferable to the next layer of logs. For instance, a non-pinned log situated above the key member will not transfer buoyancy force to the key member.

Step 5 Add "Anchor Forces" as necessary to stabilize the key members.

Step 6 Return to the stacked member log worksheets and in the "Interaction Forces with Adjacent Logs" section, input the forces that were resisted by the stability analysis of the key members. Add additional "Anchor Forces" as necessary to stabilize the forces that were not resisted by the design of the key members. It is advisable to create a copy of the "preliminary" design worksheets for the stacked member logs to create a separate "final" design worksheet. This will make it easier for the user to review the interaction forces between logs or make necessary edits.

Tip 1: It is recommended that the user creates a spreadsheet to tally the transferred forces for each log.
Tip 2: The design of multiple log structures should initially focus on achieving vertical stability, before moving on to horizontal stability, and finally the moment analysis.
Note 1: Most design procedures for larger wood jams (ELJ's) typically ignore the lift and moment forces, and the drag coefficient may be assumed to be between 0.6 and 0.7 for the entire structure (plus corrections for constriction, or blockage, of the channel). Therefore, the analysis procedure described above is likely conservative for larger

structures.
Note 2: The designer should also perform scour computations and consider the structure's potential to trap mobile wood. The design and/or factor of safety may need modified accordingly.

TO PRINT WORKBOOK

Highlight tabs numbered 1 through 7, and click "Print". Pages are pre-formatted except the "Anchors" Lookup sheet, which is not intended to be printed.

User is encouraged to provide comments and feedback for:
Suitability: Range of application or limitations
Ease of use
Results: Are they reasonable and verified?
Any other comments for improvement
E-mail comments to: mrafferty@interfluve.com

TOOL UPDATES

Version 1.0 July 2, 2013

Version 1.1 January 8, 2016

Sheet, Cell	
S1, A42	Added reference on cover sheet to new companion paper (USFS National Stream and Aquatic Ecology Ce
S2, A6,7	Changed default factor of safety to 1.5 (from 2.0) for horizontal and moment force balances
S6, B6	Updated log structure types in pull-down list on worksheet for single log design
S6, B9	Added terminology of "key", "stacked", and "wracked" logs to dropdown list for consistency with guidelines
S6, B25	Added error message restricting input values for orientation angle (can not equal exactly 0)
S6, B26	Added error message restricting input values for tilt angle (can not equal exactly 0, 90, 180, 270, or 360)
S6, D83	Changed soil type from stream bed to bank soils in formula for $F_{A,V}$ applied by additional soil ballast
Multiple	General updates to cell formats
Multiple	Fixed page layouts for printing

Version 1.2 January 21, 2020

Update of tools link on NSAEC webpage

Plumtree Branch - Floodplain Sill

Large Wood Structure Stability Analysis

TABLE OF CONTENTS

Date of Last Revision: January 7, 2016

Designer:
Insert Name

Reviewed by:
Insert Name

Large Wood Structure Stability Analysis Spreadsheet was developed by Michael Rafferty, P.E.
Version 1.1

Reference for Companion Paper:
Rafferty, M. 2016. *Computational Design Tool for Evaluating the Stability of Large Wood Structures.* Technical Note TN-103.1. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, National Stream & Aquatic Ecology Center. 27 p.

Plumtree Branch - Floodplain Sill
Factors of Safety and Design Constants

Spreadsheet developed by
Michael Rafferty, P.E.

Symbol	Description	Value
FS_V	Factor of Safety for Vertical Force Balance	**1.00**
FS_H	Factor of Safety for Horizontal Force Balance	**1.00**
FS_M	Factor of Safety for Moment Force Balance	**1.00**

Symbol	Description	Units	Value
C_{Lrock}	Coefficient of lift for submerged boulder (D'Aoust, 2000)	-	0.17
C_{Drock}	Coefficient of drag for submerged boulder (Schultz, 1954)	-	0.85
g	Gravitational acceleration constant	ft/s^2	32.174
DF_{RW}	Diameter factor for rootwad ($DF_{RW} = D_{RW}/D_{TS}$)	-	3.00
LF_{RW}	Length factor for rootwad ($LF_{RW} = L_{RW}/D_{TS}$)	-	1.50
SG_{rock}	Specific gravity of quartz particles	-	2.65
γ_{rock}	Dry unit weight of boulders	lb/ft^3	165.0
γ_w	Specific weight of water at 50ºF	lb/ft^3	62.40
η	Rootwad porosity from NRCS Tech Note 15 (2001)	-	0.20
ν	Kinematic viscosity of water at 50ºF	ft/s^2	1.41E-05

Plumtree Branch - Floodplain Sill
Hydrologic and Hydraulic Inputs

Spreadsheet developed by
Michael Rafferty, P.E.

Average Return Interval (ARI) of Design Discharge: 100 yr

Site ID	Proposed Station	Design Discharge, Q_{des} (cfs)	Maximum Depth, d_w (ft)	Average Velocity, u_{avg} (ft/s)	Bankfull Width, W_{BF} (ft)	Wetted Area, A_W (ft^2)	Radius of Curvature, R_c (ft)
XS 0.6757 Channel		2,600	11.29	2.13	409.0	411	1,000

Plumtree Branch - Floodplain Sill
Stream Bed Substrate Properties

Spreadsheet developed by
Michael Rafferty, P.E.

Site ID	Proposed Station	Stream bed D_{50} (mm)	Stream Bed Substrate Grain Size Class	Bed Soil Class	Dry Unit Weight[1], γ_{bed} (lb/ft^3)	Buoyant Unit Weight, γ'_{bed} (lb/ft^3)	Friction Angle, ϕ_{bed} (deg)
S 0.6757 Chann	Channel	**14.10**	Medium gravel	5	121.4	75.6	36

Source: Compiled from Julien (2010) and Shen and Julien (1993); soil classes from NRCS Table TS14E–2 Soil classification

[1] γ_{bed} (kg/m^3) = 1,600 + 300 log D_{50} (mm) (from Julien 2010)

1 kg/m^3 = 0.062 1 lb/ft^3

Plumtree Branch - Floodplain Sill
Bank Soil Properties

Spreadsheet developed by
Michael Rafferty, P.E.

Site ID	Proposed Station	Bank Soils (from field observations)	Bank Soil Class	Dry Unit Weight, γ_{bank} (lb/ft^3)	Buoyant Unit Weight, γ'_{bank} (lb/ft^3)	Friction Angle, ϕ_{bank} (deg)
S 0.6757 Chann	Channel	**Clayey silt**	6	84.0	52.3	27

Plumtree Branch - Floodplain Sill
Large Wood Properties

Spreadsheet developed by
Michael Rafferty, P.E.

Project Location: **Mid-Atlantic**

Timber Unit Weights			Air-dried[1] γ_{Td} (lb/ft^3)	Green[2] γ_{Tgr} (lb/ft^3)
Selected Species	**Common Name**	**Scientific Name**		
Tree Type #1:	**Beech, American**	Fagus grandifolia	44.7	54.0
Tree Type #2:	**Cherry, Black**	Prunus serotina	34.9	45.0
Tree Type #3:	**Walnut, Black**	Juglans nigra	38.4	57.0
Tree Type #4:	**Oak, Pin**	Quercus palustris	44.0	64.0
Tree Type #5:	**Maple, Red**	Acer rubrum	37.7	50.0
Tree Type #6:	**Ash, White**	Fraxinus americana	41.9	50.0
Tree Type #7:	**Willow, Black**	Salix nigra	27.3	51.0
Tree Type #8:	**Box Elder**	(user selection in input table)	27.0	(input)
Tree Type #9:				
Tree Type #10:				

[1] **Air-dried unit weight,** γ_{Td} = Average unit weight of wood after exposure to air on a 12% moisture content volume basis. Air-dried unit weight is used in the force balance calculations for the portion of wood that is above the proposed thalweg elevation (assuming unsaturated conditions).

[2] **Green unit weight,** γ_{Tgr} = Average unit weight of freshly sawn wood when the cell walls are completely saturated with water. Green unit weight is used in the force balance calculations as a conservative estimate of the unit weight for the portion of wood that is below the proposed thalweg elevation (assuming saturated conditions). For comparison, Thevenet, Citterio, & Piegay (1998) determined wood unit weight typically increases by more than 100% after less than 24 hours exposure to water.

Source for timber unit weights:

U.S. Department of Agriculture, U.S. Forest Service. (2009) Specific Gravity and Other Properties of Wood and Bark for 156 Tree Species Found in North America. Research Note NRS-38. Table 1A.

Plumtree Branch - Floodplain Sill

Spreadsheet developed by
Michael Rafferty, P.E.

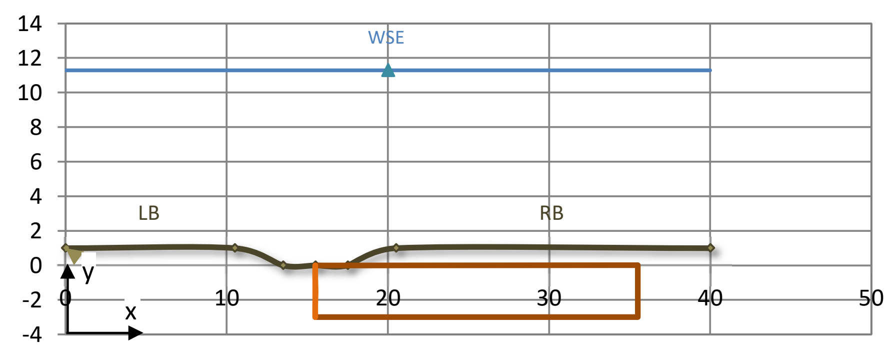
Single Log Stability Analysis Model Inputs

Site ID	Structure Type	Structure Position	Meander	Station	d_w (ft)	R_c/W_{BF}	u_{des} (ft/s)
0.6757 Chan	Full-Span	Full span	Straight	+	11.29	2.44	2.13

Multi-Log Structures	Layer	Log ID
	Key Log	1

Channel Geometry Coordinates		
Proposed	x (ft)	y (ft)
Fldpln LB	0.00	1.00
Top LB	10.50	1.00
Toe LB	13.50	0.00
Thalweg	15.50	0.00
Toe RB	17.50	0.00
Top RB	20.50	1.00
Fldpln RB	40.00	1.00

Proposed Cross-Section and Structure Geometry (Looking D/S)

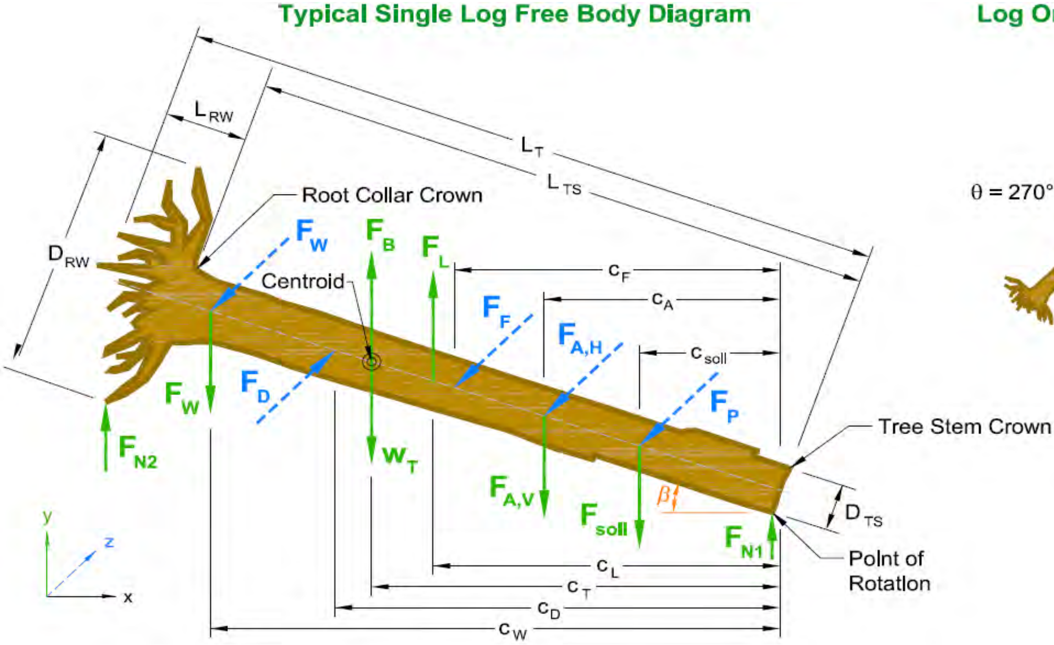


Wood Species	Rootwad	L_T (ft)	D_{TS} (ft)	L_{RW} (ft)	D_{RW} (ft)	γ_{Td} (lb/ft^3)	γ_{Tgr} (lb/ft^3)
Willow, Black	No	20.0	3.00	-	-	27.3	51.0

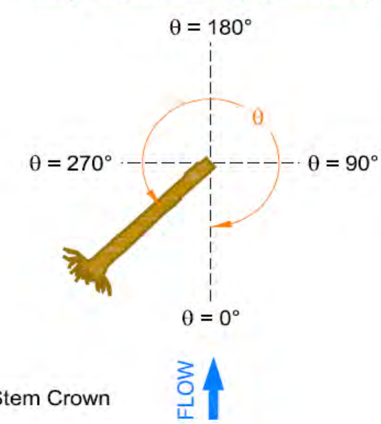
Structure Geometry	θ (deg)	β (deg)	Define Fixed Point	x_T (ft)	y_T (ft)	$y_{T,min}$ (ft)	$y_{T,max}$ (ft)	A_{Tp} (ft^2)
	270.1	0.0	Root collar: Crown	15.50	0.00	-3.00	0.00	0.00

Soils	Material	γ_s (lb/ft^3)	γ'_s (lb/ft^3)	φ (deg)	Soil Class	$L_{T,em}$ (ft)	$d_{b,max}$ (ft)	$d_{b,avg}$ (ft)
Stream Bed	Medium gravel	121.4	75.6	36.0	5	2.00	0.00	0.00
Bank	Clayey silt	84.0	52.3	27.0	6	18.00	1.00	0.92

Typical Single Log Free Body Diagram



Log Orientation (Plan View)



Vertical Force Analysis

Net Buoyancy Force

Wood	V_{TS} (ft³)	V_{RW} (ft³)	V_T (ft³)	W_T (lbf)	F_B (lbf)
↑WSE	0.0	0.0	0.0	0	0
↓WS↑Thw	0.0	0.0	0.0	0	0
↓Thalweg	141.4	0.0	141.4	7,210	8,821
Total	141.4	0.0	141.4	7,210	8,822

Lift Force

C_{LT}	0.00
F_L (lbf)	0

Vertical Force Balance

F_B (lbf)	8,822	↑
F_L (lbf)	0	
W_T (lbf)	7,210	↓
F_{soil} (lbf)	2,584	↓
$F_{W,V}$ (lbf)	0	
$F_{A,V}$ (lbf)	0	
ΣF_V (lbf)	972	↓
FS_V	1.11	✓

Soil Ballast Force

Soil	V_{dry} (ft³)	V_{sat} (ft³)	V_{soil} (ft³)	F_{soil} (lbf)
Bed	0.0	0.0	0.0	0
Bank	0.0	49.4	49.4	2,584
Total	0.0	49.4	49.4	2,584

Horizontal Force Analysis

Drag Force

A_{Tp} / A_W	Fr_L	C_{Di}	C_w	C_D*	F_D (lbf)
0.00	0.22	0.90	0.00	0.90	0

Horizontal Force Balance

F_D (lbf)	0	
F_P (lbf)	3,440	←
F_F (lbf)	534	←
$F_{W,H}$ (lbf)	0	
$F_{A,H}$ (lbf)	0	
ΣF_H (lbf)	3,974	←
FS_H	7,949.33	✓

Passive Soil Pressure / Friction Force

Soil	K_P	F_P (lbf)	L_{Tf} (ft)	μ	F_F (lbf)
Bed	3.85	0	4.05	0.73	130
Bank	2.66	3,440	17.95	0.51	404
Total	-	3,440	22.00	-	534

Moment Force Balance

Driving Moment Centroids / Resisting Moment Centroids

$c_{T,B}$ (ft)	c_L (ft)	c_D (ft)	$c_{T,W}$ (ft)	c_{soil} (ft)	$c_{F\&N}$ (ft)	c_P (ft)
10.0	0.0	0.0	10.0	9.0	10.0	11.9

*Distances are from the stem tip

Point of Rotation: Stem Tip

Moment Force Balance

M_d (lbf)	88,216	
M_r (lbf)	151,328	
FS_M	1.72	✓

Anchor Forces

Additional Soil Ballast

V_{Adry} (ft³)	V_{Awet} (ft³)	c_{Asoil} (ft)	$F_{A,Vsoil}$ (lbf)	$F_{A,HP}$ (lbf)
			0	0

Mechanical Anchors

Type	c_{Am} (ft)	Soils	F_{Am} (lbf)
			0
			0

Boulder Ballast

Position	D_r (ft)	c_{Ar} (ft)	$V_{r,dry}$ (ft³)	$V_{r,wet}$ (ft³)	W_r (lbf)	$F_{L,r}$ (lbf)	$F_{D,r}$ (lbf)	$F_{A,Vr}$ (lbf)	$F_{A,Hr}$ (lbf)
								0	0
								0	0
								0	0

Plumtree Branch - Floodplain Sill
Notation, Units, and List of Symbols

Notation

Symbol	Description	Unit
A_W	Wetted area of channel at design discharge	ft^2
A_{Tp}	Projected area of wood in plane perpendicular to flow	ft^2
c_D	Centroid of the drag force along log axis	ft
c_{Am}	Centroid of a mechanical anchor along log axis	ft
c_{Ar}	Centroid of a ballast boulder along log axis	ft
c_{Asoil}	Centroid of the added ballast soil along log axis	ft
$c_{F\&N}$	Centroid of friction and normal forces along log axis	ft
c_L	Centroid of the lift force along log axis	ft
c_P	Centroid of the passive soil force along log axis	ft
c_{soil}	Centroid of the vertical soil forces along log axis	ft
$c_{T,B}$	Centroid of the buoyancy force along log axis	ft
$c_{T,W}$	Centroid of the log volume along log axis	ft
c_{WI}	Centroid of a wood interaction force along log axis	ft
C_{Lrock}	Coefficient of lift for submerged boulder	-
C_{LT}	Effective coefficient of lift for submerged tree	-
C_{Di}	Base coefficient of drag for tree, before adjustments	-
$C_D{}^*$	Effective coefficient of drag for submerged tree	-
C_{Di}	Base coefficient of drag for tree, before adjustments	-
C_W	Wave drag coefficient of submerged tree	-
$d_{b,avg}$	Average buried depth of log	ft
$d_{b,max}$	Maximum buried depth of log	ft
d_w	Maximum flow depth at design discharge in reach	ft
D_{50}	Median grain size in millimeters (SI units)	mm
D_r	Equivalent diameter of boulder	ft
D_{RW}	Assumed diameter of rootwad	ft
D_{TS}	Nominal diameter of tree stem (DBH)	ft
DF_{RW}	Diameter factor for rootwad ($DF_{RW} = D_{RW}/D_{TS}$)	-
e	Void ratio of soils	-
$F_{A,H}$	Total horizontal load capacity of anchor techniques	lbf
$F_{A,HP}$	Passive soil pressure applied to log from soil ballast	lbf
$F_{A,Hr}$	Horizontal resisting force on log from boulder	lbf
F_{Am}	Load capacity of mechanical anchor	lbf
$F_{A,V}$	Total vertical load capacity of anchor techniques	lbf
$F_{A,Vr}$	Vertical resisting force on log from boulder	lbf
$F_{A,Vsoil}$	Vertical soil loading on log from added ballast soil	lbf
F_B	Buoyant force applied to log	lbf
F_D	Drag forces applied to log	lbf
$F_{D,r}$	Drag forces applied to boulder	lbf
F_F	Friction force applied to log	lbf
F_H	Resultant horizontal force applied to log	lbf
F_L	Lift force applied to log	lbf
$F_{L,r}$	Lift force applied to boulder	lbf
F_P	Passive soil pressure force applied to log	lbf
F_{soil}	Vertical soil loading on log	lbf
$F_{W,H}$	Horizontal forces from interactions with other logs	lbf
$F_{W,V}$	Vertical forces from interactions with other logs	lbf

Notation (continued)

Symbol	Description	Unit
F_V	Resultant vertical force applied to log	lbf
Fr_L	Log Froude number	-
FS_V	Factor of Safety for Vertical Force Balance	-
FS_H	Factor of Safety for Horizontal Force Balance	-
FS_M	Factor of Safety for Moment Force Balance	-
g	Gravitational acceleration constant	ft/s^2
K_P	Coefficient of Passive Earth Pressure	-
$L_{T,em}$	Total embedded length of log	ft
L_{RW}	Assumed length of rootwad	ft
L_T	Total length of tree (including rootwad)	ft
L_{Tf}	Length of log in contact with bed or banks	ft
L_{TS}	Length of tree stem (not including rootwad)	ft
$L_{TS,ex}$	Exposed length of tree stem	ft
LF_{RW}	Length factor for rootwad ($LF_{RW} = L_{RW}/D_{TS}$)	-
M_d	Driving moment about embedded tip	lbf
M_r	Driving moment about embedded tip	lbf
N	Blow count of standard penetration test	-
p_o	Porosity of soil volume	-
Q_{des}	Design discharge	cfs
R	Radius	ft
R_c	Radius of curvature at channel centerline	ft
SG_r	Specific gravity of quartz particles	-
SG_T	Specific gravity of tree	-
u_{avg}	Average velocity of cross section in reach	ft/s
u_{des}	Design velocity	ft/s
u_m	Adjusted velocity at outer meander bend	ft/s
V_{dry}	Volume of soils above stage level of design flow	ft^3
V_{sat}	Volume of soils below stage level of design flow	ft^3
V_{soil}	Total volume of soils over log	ft^3
V_{RW}	Volume of rootwad	ft^3
V_S	Volume of solids in soil (void ratio calculation)	ft^3
V_T	Total volume of log	ft^3
V_{TS}	Total volume of tree	ft^3
V_V	Volume of voids in soil	ft^3
V_{Adry}	Volume of ballast above stage of design flow	ft^3
V_{Awet}	Volume of ballast below stage of design flow	ft^3
$V_{r,dry}$	Volume of boulder above stage of design flow	ft^3
$V_{r,wet}$	Volume of boulder below stage of design flow	ft^3
W_{BF}	Bankfull width at structure site	ft
W_r	Effective weight of boulder	lbf
W_T	Total log weight	lbf
x	Horizontal coordinate (distance)	ft
y	Vertical coordinate (elevation)	ft
$y_{T,max}$	Minimum elevation of log	ft
$y_{T,min}$	Maximum elevation of log	ft

Greek Symbols

Symbol	Description	Unit
β	Tilt angle from stem tip to vertical	deg
γ_{bank}	Dry specific weight of bank soils	lb/ft^3
$\gamma_{bank,sat}$	Saturated unit weight of bank soils	lb/ft^3
γ'_{bank}	Effective buoyant unit weight of bank soils	lb/ft^3
γ_{bed}	Dry specific weight of stream bed substrate	lb/ft^3
γ'_{bed}	Effective buoyant unit weight of stream bed substrate	lb/ft^3
γ_{rock}	Dry unit weight of boulders	lb/ft^3
γ_s	Dry specific weight of soil	lb/ft^3
γ'_s	Effective buoyant unit weight of soil	lb/ft^3
γ_{Td}	Air-dried unit weight of tree (12% MC basis)	lb/ft^3
γ_{Tgr}	Green unit weight of tree	lb/ft^3
γ_w	Specific weight of water at 50ºF	lb/ft^3
η	Rootwad porosity	-
θ	Rootwad (or large end of log) orientation to flow	deg
μ	Coefficient of friction	-
ν	Kinematic viscosity of water at 50ºF	ft/s^2
Σ	Sum of forces	-
ϕ_{bank}	Internal friction angle of bank soils	deg
ϕ_{bed}	Internal friction angle of stream bed substrate	deg

Units

Notation	Description
cfs	Cubic feet per second
ft	Feet
lb	Pound
lbf	Pounds force
kg	Kilograms
m	Meters
mm	Millimeters
s	Seconds
yr	Year

Abbreviations

Notation	Description
ARI	Average return interval
Avg	Average
DBH	Diameter at breast height
deg	Degrees
Dia	Diameter
Dist	Distance
D/S	Downstream
ELJ	Engineered log jam
Ex	Example
Fldpln	Floodplain
H&H	Hydrologic and hydraulic
ID	Identification
i.e.	That is
LB	Left bank
LW	Large wood
Max	Maximum
MC	Moisture content
Min	Minimum
ML	Multi-log
SL	Single log
N/A	Not applicable
no	Number
Pt	Point
rad	Radians
RB	Right bank
RW	Rootwad
SL	Single log
Thw	Thalweg (lowest elevation in channel bed)
Typ	Typical
U.S.	United States
WS	Water surface
WSE	Water surface elevation
↑	Above
↓	Below

Reference Sheet - Anchoring Techniques

Anchor Technique Lookup Table (average holding capacities)

Soil Class	Soil Description	Blow Count (N)
4	Dense gravels; gravel/cobble; very hard silts and clays	40-100+
5	Dense coarse sand; gravel/sand; loose gravels; stiff slits and clays	14-40
6	Loose coarse sand; dense fine sand; firm silts and clays	7-14
7	Loose fine sand; alluvium; soft silts and clays; silty sand	4-8

Notes:
1. All types -- Use this chart for estimation only. Values shown reflect the manufacturer's
User is responsible for verifying load capacities. The true capacity must be tested by pro
2. Installation may be difficult. Pilot hole may be required.
3. Holding capacity limited by working load of anchors.
4. Holding capacity limited by soil failure.
5. Wide variation in soil properties reduces prediction accuracy. Pre-constructed field tes
6. Duckbill anchors are rated in an average (class 5) soil condition. Proof-loading is the c
Anchor holding capacity will vary in different soils. Increased capacities can be expected
classifications) and lower capacity can be expected in the softer soil classes (numerically
7. Platipus Stealth and Bat anchors are given a wide range for holding capacities. The hi
the low value was assigned to class 7 soils. Holding capacities for class 5 and 6 soils we
verifying all rating capacities.

Anchor/Ballast Technique Lookup Table

Technique	Description
Added Soil Ballast	Add coarse material soil lifts on top of structure to increase burial depth
Boulder Ballast	Place boulder on top of structure. Alternatively, secure structure to boulder located beside or beneath structure.
Wood Pile (In development)	Drive or bury vertical wood piles into the bed or banks to brace structure. Alternatively, brace structure against existing large tree.
Mechanical Anchor	Secure structure to soil anchor which uses overlying soil to resist pullout. Alternatively, secure the structure to bedrock using a rock anchor.

Four common alternatives exist for securing or stabilizing placements of large wood in water. In order of preference for habitat formation, they are:

1. No added stability -- where wood is supplied to the stream and allowed to be stable without manipulation or, as conditions develop, moved by the flow.
2. Passive stability -- where the weight and shape of the structure is the anchor, and movement at some flow level is acceptable (includes ballast).
3. Flexible stability -- such as tethering the structure so some degree of movement is allowed with varying flows.
4. Rigid stability -- holding the logs permanently in place with no movement allowed.

(Source: 2012 WA Stream Habitat Restoration Guidelines)

Manta Ray			Stingray			
MR-1 Capacity (lb)	MR-2 Capacity (lb)	MR-SR Capacity (lb)	SR-1 Capacity (lb)	SR-2 Capacity (lb)	SR-3 Capacity (lb)	DB-40 Capacity (lb)
24,000	15,000	32,000	39,000	62,000	85,000	user input
15,000	9,000	18,000	24,000	31,000	48,000	300
10,000	7,000	14,000	16,000	27,000	37,000	user input
8,000	5,000	9,000	13,000	19,000	24,000	user input

minimum expected holding capacity for a given condition.
of-loading. Minimum 2:1 Safety Factor is recommended.

t recommended.
nly way to insure the exact capacity of each installation.
in harder soil classes (numerically higher blow count
lower blow count).
gh manufacturer's rating was applied to class 4 soils, while
re interpolated as a guide only. User is responsible for

Duckbill			Platipus Stealth			
DB-68 Capacity (lb)	DB-88 Capacity (lb)	DB-138 Capacity (lb)	P-S02 Capacity (lb)	P-S04 Capacity (lb)	P-S06 Capacity (lb)	P-S08 Capacity (lb)
user input	user input	user input	300	1,000	3,500	4,500
1,100	3,000	5,000	150	600	2,000	2,500
user input	user input	user input	50	300	800	1,500
user input	user input	user input	N/A	200	400	1,000

Platipus Bat					Cu
P-B04T Capacity (lb)	P-B06T Capacity (lb)	P-B08T Capacity (lb)	P-B10T Capacity (lb)	P-B12T Capacity (lb)	Custom#1 Capacity (lb)
6,000	11,000	16,500	22,000	33,000	(user input)
3,500	6,500	9,000	14,000	20,000	(user input)
2,500	4,000	6,500	11,000	16,000	(user input)
2,000	3,500	5,500	9,000	13,000	(user input)

stom (User Selection)	
Custom#2	Custom#3
Capacity (lb)	Capacity (lb)
(user input)	(user input)
(user input)	(user input)
(user input)	(user input)
(user input)	(user input)

Directions for LW Stability Analysis Tool

This design tool may be used by practitioners if they cite the developer on each sheet.

Disclaimer:
This Microsoft Excel 2010 spreadsheet tool is provided free of charge. Use this tool at your own risk. In offering this tool, the author, the U.S. Forest Service, and Colorado State University do not accept any responsibility or liability for the tool's use by third parties. This tool has specific uses and limits of applicability. Design practitioners shall take full responsibility for the final large wood structure design and performance. Designers are expected to verify the calculated values and validity of the design method. Designers should be qualified to work in river environments, and depending on the State, they may be required to be licensed as a professional engineer to design large wood structures. You cannot be sure the tool is authentic and unmolested unless downloaded from the following website:
https://www.fs.fed.us/biology/nsaec/products-tools.html#tools-stabilitylargewoodstructures

DATA INPUT

Order of Input

Update the worksheets from "left to right"
Update the spreadsheet cells from "left to right" and "top to bottom"

IMPORTANT - User should only edit the following cells:

Cell Format	Directions
Dropdown List	Select value from dropdown list
User Input	Type value into cell
User Verify	Verify value in cell (edit if necessary)

User should verify, but not edit the following cells because these cells contain formulas or headings:

Cell Format	Directions
Heading	Table Heading (Scroll over sample heading for description of comments)
Automatic Value	Verify value in cell which is automatically calculated by formulas
Key Value	Verify value of force calculation
Solution	Verify value of force balance or factor of safety calculation
Background Value	Optional - Verify value of background calculation (outside of print area)

The "Single Log" and "Multi-Log" spreadsheets have several built-in error messages (in column 'K'):

Error Message	
"CHECK"	Prompts user to check a specific input
"ERROR"	Prompts user to change a specific input

User Input Note 1 - Several worksheets have a built in "clear inputs" button linked to a macro (these are the only macros built into the tool). Be aware that you can't undo the "clear input" command.

User Input Note 2 - User may enter a custom "bank soil type", "wood species", or "anchor type" by scrolling over to the right to find the lookup table and editing the "custom" cells.

User Input Note 3 - The spreadsheet is not locked, and therefore every cell can be manually edited. However, the

user is encouraged to exercise caution to avoid unintended consequences of changing reference formulas.

User Input Note 4 - User should also be very careful when removing or adding cells (at least scroll over and down to see what other cells may be impacted). Hiding unused rows or columns is recommended instead of deleting them. If the user needs to add cells on the "Single Log Design" spreadsheet, they should add a row of cells for all columns between 'A' and 'J'. Important: Adding cells will break the code in the "Clear Inputs" macro, and cause it to clear the wrong cells.

User Input Note 5 - To avoid compounding potential errors, the user should use the original download version of the spreadsheet (without personal edits) at the beginning of each design.

User Input Note 6 - Input values should be in English units, with one exception: D_{50} for the bed substrate gradation (mm).

ANALYSIS OF MULTIPLE LOG STRUCTURES

The LW Stability Analysis Tool can also be used to design multiple log structures. The user must manually translate the resulting vertical and horizontal forces from one log design sheet into another (or write their own formulas). This data should be entered in the "Interaction Forces with Adjacent Logs" section of the "Single Log Design" worksheet. In theory, there is no limit to the number of logs that can be considered, although the force balance accounting may become cumbersome beyond a few logs. The general procedure is as follows:

Step 1 Begin by creating a preliminary structure layout (in AutoCAD or similar) to define the quantity of logs, locate intersect points, and identify key members. Key members are typically the largest logs (or the logs that are going to be have anchors attached).

Step 2 Fill out Sheets 1 through 5 of this tool. Next, input the channel geometry in a blank "Single Log Design" worksheet (Sheet 6), and then make copies for analysis of each log.

Step 3 Complete a preliminary force balance analysis for each stacked member log, ignoring the "Interaction Forces with Adjacent Logs" and "Anchor Forces" sections. The user should manually record the resisting forces required to stabilize each stacked member in a table. The required vertical force can be found in cell 'K61' of the "Single Log Design" worksheet, and the required horizontal force can be found in cell 'K72'. If the log is already vertically or horizontally stable, record the excess force that may be applied to resist driving forces of the adjacent log(s). This information can be found in cell 'K62' and 'K73'. An example table is shown to the right of these directions →

Step 4 Complete a force balance analysis for the key members. In the "Interaction Forces with Adjacent Logs" section on the force balance sheet, enter the relative position of each adjacent stacked log in contact with the key member, the connection type (gravity or pinned), the intersection point, and the required vertical and horizontal forces to achieve stability for each stacked member. If the load from the adjacent logs is spread over multiple key members, divide the required forces by the number of key members sharing the load (note--these loads do not need to be evenly distributed between key members). If an adjacent log is either horizontally or vertically stable, then enter any excess force (see Step 3 above) value as a negative number in the key member design spreadsheet. The tool will automatically determine which loads are transferable to the next layer of logs. For instance, a non-pinned log situated above the key member will not transfer buoyancy force to the key member.

Step 5 Add "Anchor Forces" as necessary to stabilize the key members.

Step 6 Return to the stacked member log worksheets and in the "Interaction Forces with Adjacent Logs" section, input the forces that were resisted by the stability analysis of the key members. Add additional "Anchor Forces" as necessary to stabilize the forces that were not resisted by the design of the key members. It is advisable to create a copy of the "preliminary" design worksheets for the stacked member logs to create a separate "final" design worksheet. This will make it easier for the user to review the interaction forces between logs or make necessary edits.

Tip 1: It is recommended that the user creates a spreadsheet to tally the transferred forces for each log.

Tip 2: The design of multiple log structures should initially focus on achieving vertical stability, before moving on to horizontal stability, and finally the moment analysis.

Note 1: Most design procedures for larger wood jams (ELJ's) typically ignore the lift and moment forces, and the drag coefficient may be assumed to be between 0.6 and 0.7 for the entire structure (plus corrections for constriction, or blockage, of the channel). Therefore, the analysis procedure described above is likely conservative for larger

structures.
Note 2: The designer should also perform scour computations and consider the structure's potential to trap mobile wood. The design and/or factor of safety may need modified accordingly.

TO PRINT WORKBOOK

Highlight tabs numbered 1 through 7, and click "Print". Pages are pre-formatted except the "Anchors" Lookup sheet, which is not intended to be printed.

User is encouraged to provide comments and feedback for:
Suitability: Range of application or limitations
Ease of use
Results: Are they reasonable and verified?
Any other comments for improvement
E-mail comments to: mrafferty@interfluve.com

TOOL UPDATES

Version 1.0 July 2, 2013

Version 1.1 January 8, 2016

Sheet, Cell	
S1, A42	Added reference on cover sheet to new companion paper (USFS National Stream and Aquatic Ecology Ce
S2, A6,7	Changed default factor of safety to 1.5 (from 2.0) for horizontal and moment force balances
S6, B6	Updated log structure types in pull-down list on worksheet for single log design
S6, B9	Added terminology of "key", "stacked", and "wracked" logs to dropdown list for consistency with guidelines
S6, B25	Added error message restricting input values for orientation angle (can not equal exactly 0)
S6, B26	Added error message restricting input values for tilt angle (can not equal exactly 0, 90, 180, 270, or 360)
S6, D83	Changed soil type from stream bed to bank soils in formula for $F_{A,V}$ applied by additional soil ballast
Multiple	General updates to cell formats
Multiple	Fixed page layouts for printing

Version 1.2 January 21, 2020

Update of tools link on NSAEC webpage

Plumtree Branch - Wood Analog Structure

Large Wood Structure Stability Analysis

TABLE OF CONTENTS

Date of Last Revision: January 7, 2016

Designer:
Insert Name

Reviewed by:
Insert Name

Large Wood Structure Stability Analysis Spreadsheet was developed by Michael Rafferty, P.E.
Version 1.1

Reference for Companion Paper:
Rafferty, M. 2016. *Computational Design Tool for Evaluating the Stability of Large Wood Structures.* Technical Note TN-103.1. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, National Stream & Aquatic Ecology Center. 27 p.

Plumtree Branch - Wood Analog Structure
Factors of Safety and Design Constants

Spreadsheet developed by
Michael Rafferty, P.E.

Symbol	Description	Value
FS_V	Factor of Safety for Vertical Force Balance	**1.00**
FS_H	Factor of Safety for Horizontal Force Balance	**1.00**
FS_M	Factor of Safety for Moment Force Balance	**1.00**

Symbol	Description	Units	Value
C_{Lrock}	Coefficient of lift for submerged boulder (D'Aoust, 2000)	-	0.17
C_{Drock}	Coefficient of drag for submerged boulder (Schultz, 1954)	-	0.85
g	Gravitational acceleration constant	ft/s^2	32.174
DF_{RW}	Diameter factor for rootwad ($DF_{RW} = D_{RW}/D_{TS}$)	-	3.00
LF_{RW}	Length factor for rootwad ($LF_{RW} = L_{RW}/D_{TS}$)	-	1.50
SG_{rock}	Specific gravity of quartz particles	-	2.65
γ_{rock}	Dry unit weight of boulders	lb/ft^3	165.0
γ_w	Specific weight of water at 50ºF	lb/ft^3	62.40
η	Rootwad porosity from NRCS Tech Note 15 (2001)	-	0.20
ν	Kinematic viscosity of water at 50ºF	ft/s^2	1.41E-05

Plumtree Branch - Wood Analog Structure
Hydrologic and Hydraulic Inputs

Spreadsheet developed by
Michael Rafferty, P.E.

Average Return Interval (ARI) of Design Discharge: 100 yr

Site ID	Proposed Station	Design Discharge, Q_{des} (cfs)	Maximum Depth, d_w (ft)	Average Velocity, u_{avg} (ft/s)	Bankfull Width, W_{BF} (ft)	Wetted Area, A_W (ft^2)	Radius of Curvature, R_c (ft)
XS 0.6757 Channel		2,600	11.29	2.13	409.0	411	0

Plumtree Branch - Wood Analog Structu
Stream Bed Substrate Properties

Spreadsheet developed by
Michael Rafferty, P.E.

Site ID	Proposed Station	Stream bed D_{50} (mm)	Stream Bed Substrate Grain Size Class	Bed Soil Class	Dry Unit Weight[1], γ_{bed} (lb/ft^3)	Buoyant Unit Weight, γ'_{bed} (lb/ft^3)	Friction Angle, ϕ_{bed} (deg)
S 0.6757 Chann	Channel	14.10	Medium gravel	5	121.4	75.6	36

Source: Compiled from Julien (2010) and Shen and Julien (1993); soil classes from NRCS Table TS14E–2 Soil classification

[1] γ_{bed} (kg/m^3) = 1,600 + 300 log D_{50} (mm) (from Julien 2010)

1 kg/m^3 = 0.062 1 lb/ft^3

Plumtree Branch - Wood Analog S
Bank Soil Properties

Spreadsheet developed by
Michael Rafferty, P.E.

Site ID	Proposed Station	Bank Soils (from field observations)	Bank Soil Class	Dry Unit Weight, γ_{bank} (lb/ft^3)	Buoyant Unit Weight, γ'_{bank} (lb/ft^3)	Friction Angle, ϕ_{bank} (deg)
S 0.6757 Chanr	Channel	**Clayey silt**	6	84.0	52.3	27

Plumtree Branch - Wood Analog Structure
Large Wood Properties

Spreadsheet developed by
Michael Rafferty, P.E.

Project Location: Mid-Atlantic

Timber Unit Weights			Air-dried[1] γ_{Td} (lb/ft^3)	Green[2] γ_{Tgr} (lb/ft^3)
Selected Species	**Common Name**	**Scientific Name**		
Tree Type #1:	**Beech, American**	Fagus grandifolia	44.7	54.0
Tree Type #2:	**Cherry, Black**	Prunus serotina	34.9	45.0
Tree Type #3:	**Walnut, Black**	Juglans nigra	38.4	57.0
Tree Type #4:	**Oak, Pin**	Quercus palustris	44.0	64.0
Tree Type #5:	**Maple, Red**	Acer rubrum	37.7	50.0
Tree Type #6:	**Ash, White**	Fraxinus americana	41.9	50.0
Tree Type #7:	**Willow, Black**	Salix nigra	27.3	51.0
Tree Type #8:				
Tree Type #9:				
Tree Type #10:				

[1] **Air-dried unit weight,** γ_{Td} = Average unit weight of wood after exposure to air on a 12% moisture content volume basis. Air-dried unit weight is used in the force balance calculations for the portion of wood that is above the proposed thalweg elevation (assuming unsaturated conditions).

[2] **Green unit weight,** γ_{Tgr} = Average unit weight of freshly sawn wood when the cell walls are completely saturated with water. Green unit weight is used in the force balance calculations as a conservative estimate of the unit weight for the portion of wood that is below the proposed thalweg elevation (assuming saturated conditions). For comparison, Thevenet, Citterio, & Piegay (1998) determined wood unit weight typically increases by more than 100% after less than 24 hours exposure to water.

Source for timber unit weights:

U.S. Department of Agriculture, U.S. Forest Service. (2009) Specific Gravity and Other Properties of Wood and Bark for 156 Tree Species Found in North America. Research Note NRS-38. Table 1A.

Plumtree Branch - Wood Analog Structure

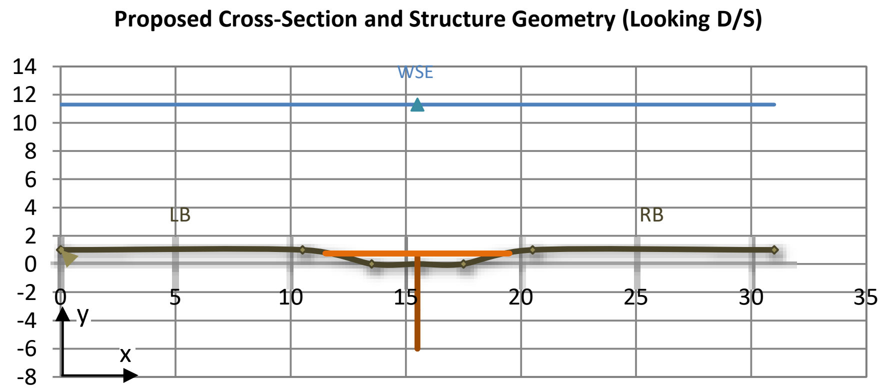
Spreadsheet developed by Michael Rafferty, P.E.

Single Log Stability Analysis Model Inputs

Site ID	Structure Type	Structure Position	Meander	Station	d_w (ft)	R_c/W_{BF}	u_{des} (ft/s)
0.6757 Chan	Rootwad	Mid-channel	Straight	+	11.29	0.00	2.13

Multi-Log Structures	Layer	Log ID
	Key Log	1

Channel Geometry Coordinates		
Proposed	x (ft)	y (ft)
Fldpln LB	0.00	1.00
Top LB	10.50	1.00
Toe LB	13.50	0.00
Thalweg	15.50	0.00
Toe RB	17.50	0.00
Top RB	20.50	1.00
Fldpln RB	31.00	1.00

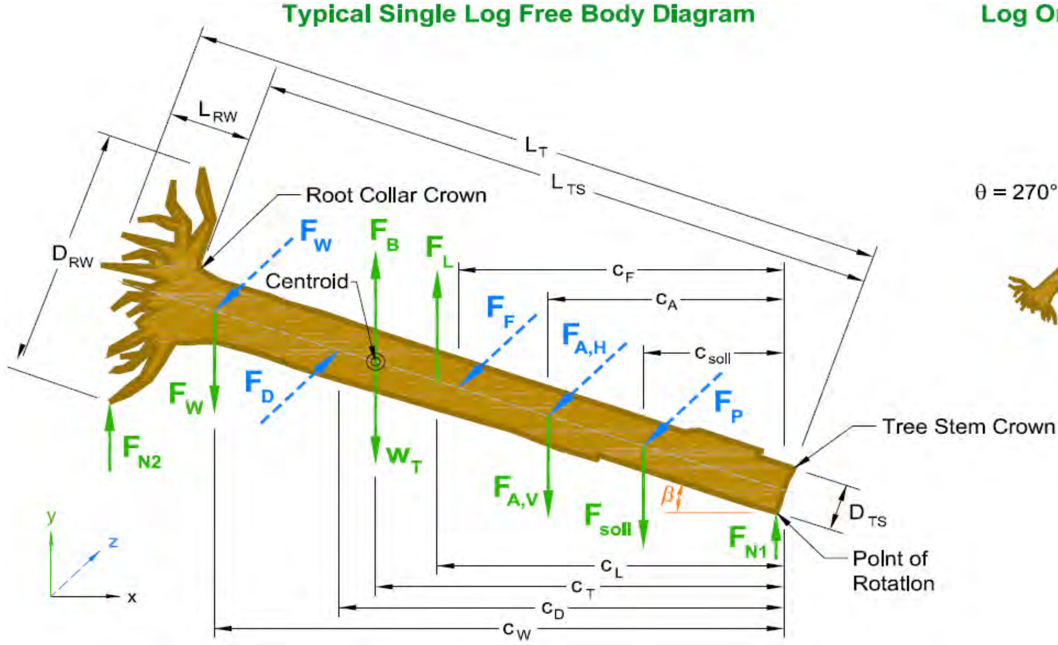


Wood Species	Rootwad	L_T (ft)	D_{TS} (ft)	L_{RW} (ft)	D_{RW} (ft)	γ_{Td} (lb/ft^3)	γ_{Tgr} (lb/ft^3)
Willow, Black	Yes	6.8	2.67	4.00	8.00	27.3	51.0

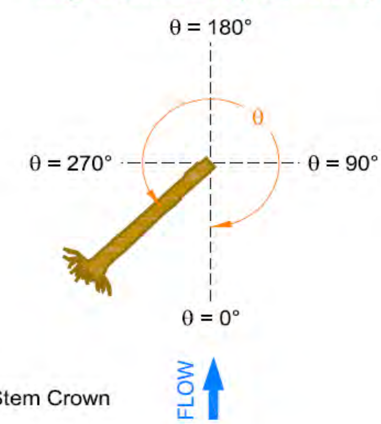
Structure Geometry	θ (deg)	β (deg)	Define Fixed Point	x_T (ft)	y_T (ft)	$y_{T,min}$ (ft)	$y_{T,max}$ (ft)	A_{Tp} (ft^2)
	0.0	-89.9	Stem tip: Crown	15.50	-6.00	-6.00	0.75	50.27

Soils	Material	γ_s (lb/ft^3)	γ'_s (lb/ft^3)	φ (deg)	Soil Class	$L_{T,em}$ (ft)	$d_{b,max}$ (ft)	$d_{b,avg}$ (ft)
Stream Bed	Medium gravel	121.4	75.6	36.0	5	6.00	6.00	3.01
Bank	Clayey silt	84.0	52.3	27.0	6	0.00	0.00	0.00

Typical Single Log Free Body Diagram



Log Orientation (Plan View)



Vertical Force Analysis

Net Buoyancy Force

Wood	V_{TS} (ft^3)	V_{RW} (ft^3)	V_T (ft^3)	W_T (lbf)	F_B (lbf)
↑WSE	0.0	0.0	0.0	0	0
↓WS↑Thw	0.0	77.4	77.4	2,111	4,833
↓Thalweg	15.4	0.0	15.4	783	958
Total	15.4	77.4	92.8	2,894	5,791

Lift Force

C_{LT}	0.32
F_L (lbf)	72

Vertical Force Balance

F_B (lbf)	5,791	↑
F_L (lbf)	72	↑
W_T (lbf)	2,894	↓
F_{soil} (lbf)	3,629	↓
$F_{W,V}$ (lbf)	0	
$F_{A,V}$ (lbf)	0	
ΣF_V (lbf)	660	↓
FS_V	1.11	✓

Soil Ballast Force

Soil	V_{dry} (ft^3)	V_{sat} (ft^3)	V_{soil} (ft^3)	F_{soil} (lbf)
Bed	0.0	48.0	48.0	3,629
Bank	0.0	0.0	0.0	0
Total	0.0	48.0	48.0	3,629

Horizontal Force Analysis

Drag Force

A_{Tp} / A_W	Fr_L	C_{Di}	C_w	C_D*	F_D (lbf)
0.12	0.23	1.20	0.00	1.57	346

Horizontal Force Balance

F_D (lbf)	346	→
F_P (lbf)	6,988	←
F_F (lbf)	480	←
$F_{W,H}$ (lbf)	0	
$F_{A,H}$ (lbf)	0	
ΣF_H (lbf)	7,122	←
FS_H	21.57	✓

Passive Soil Pressure / Friction Force

Soil	K_P	F_P (lbf)	L_{Tf} (ft)	μ	F_F (lbf)
Bed	3.85	6,988	7.99	0.73	480
Bank	2.66	0	0.00	0.51	0
Total	-	6,988	7.99	-	480

Moment Force Balance

Driving Moment Centroids / Resisting Moment Centroids

$c_{T,B}$ (ft)	c_L (ft)	c_D (ft)	$c_{T,W}$ (ft)	c_{soil} (ft)	$c_{F\&N}$ (ft)	c_P (ft)
4.3	6.4	6.4	4.3	3.0	3.0	4.0

*Distances are from the stem tip

Point of Rotation: Stem Tip

Moment Force Balance

M_d (lbf)	48
M_r (lbf)	95
FS_M	1.98 ✓

Anchor Forces

Additional Soil Ballast

V_{Adry} (ft^3)	V_{Awet} (ft^3)	c_{Asoil} (ft)	$F_{A,Vsoil}$ (lbf)	$F_{A,HP}$ (lbf)
			0	0

Mechanical Anchors

Type	c_{Am} (ft)	Soils	F_{Am} (lbf)
			0
			0

Boulder Ballast

Position	D_r (ft)	c_{Ar} (ft)	$V_{r,dry}$ (ft^3)	$V_{r,wet}$ (ft^3)	W_r (lbf)	$F_{L,r}$ (lbf)	$F_{D,r}$ (lbf)	$F_{A,Vr}$ (lbf)	$F_{A,Hr}$ (lbf)
								0	0
								0	0
								0	0

Plumtree Branch - Wood Analog Structure

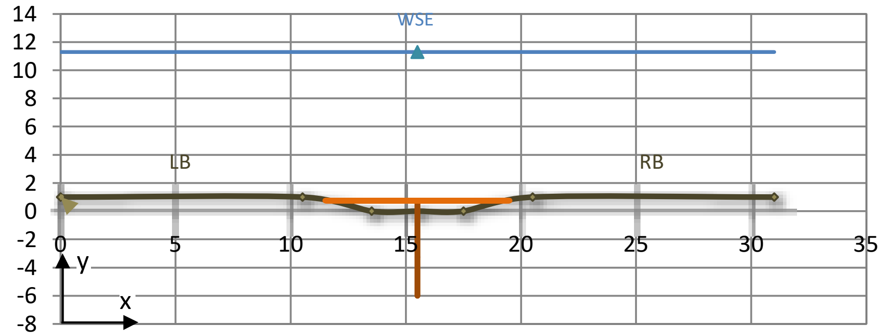
Spreadsheet developed by
Michael Rafferty, P.E.

Single Log Stability Analysis Model Inputs

Site ID	Structure Type	Structure Position	Meander	Station	d_w (ft)	R_c/W_{BF}	u_{des} (ft/s)
0.6757 Chan	Rootwad	Mid-channel	Straight	+	11.29	0.00	2.13

Multi-Log Structures	Layer	Log ID
	Key Log	1

Channel Geometry Coordinates		
Proposed	x (ft)	y (ft)
Fldpln LB	0.00	1.00
Top LB	10.50	1.00
Toe LB	13.50	0.00
Thalweg	15.50	0.00
Toe RB	17.50	0.00
Top RB	20.50	1.00
Fldpln RB	31.00	1.00

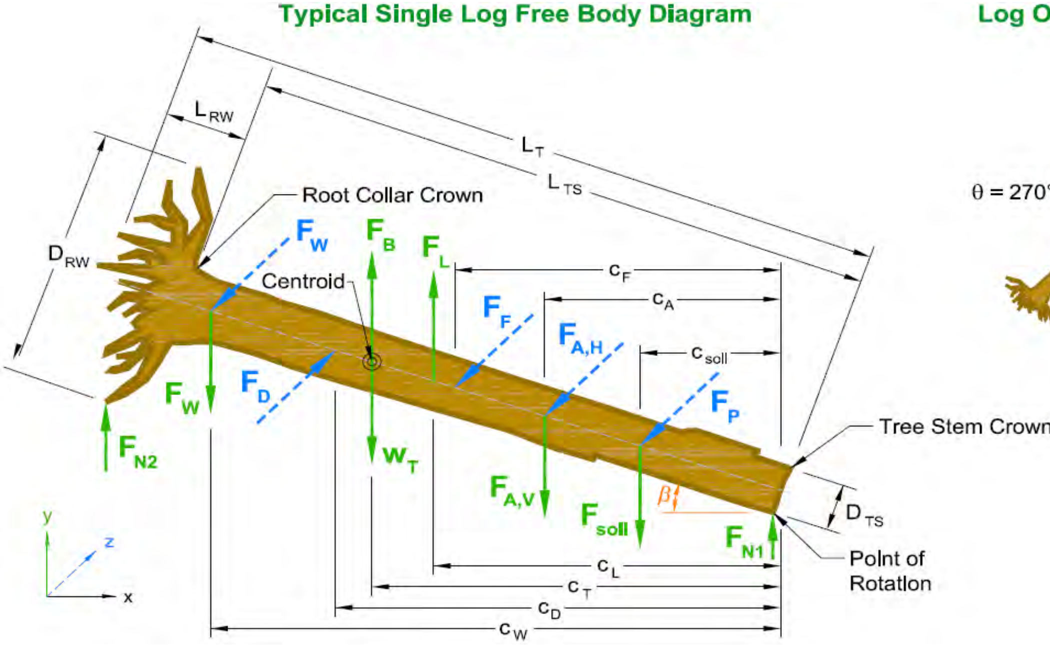


Wood Species	Rootwad	L_T (ft)	D_{TS} (ft)	L_{RW} (ft)	D_{RW} (ft)	γ_{Td} (lb/ft^3)	γ_{Tgr} (lb/ft^3)
Cherry, Black	Yes	6.8	2.67	4.00	8.00	34.9	45.0

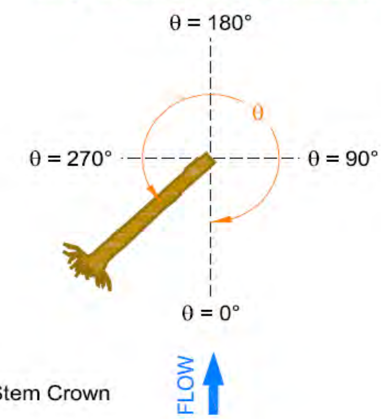
Structure Geometry	θ (deg)	β (deg)	Define Fixed Point	x_T (ft)	y_T (ft)	$y_{T,min}$ (ft)	$y_{T,max}$ (ft)	A_{Tp} (ft^2)
	0.0	-89.9	Stem tip: Crown	15.50	-6.00	-6.00	0.75	50.27

Soils	Material	γ_s (lb/ft^3)	γ'_s (lb/ft^3)	φ (deg)	Soil Class	$L_{T,em}$ (ft)	$d_{b,max}$ (ft)	$d_{b,avg}$ (ft)
Stream Bed	Medium gravel	121.4	75.6	36.0	5	6.00	6.00	3.01
Bank	Clayey silt	84.0	52.3	27.0	6	0.00	0.00	0.00

Typical Single Log Free Body Diagram



Log Orientation (Plan View)



Vertical Force Analysis

Net Buoyancy Force

Wood	V_{TS} (ft^3)	V_{RW} (ft^3)	V_T (ft^3)	W_T (lbf)	F_B (lbf)
↑WSE	0.0	0.0	0.0	0	0
↓WS↑Thw	0.0	77.4	77.4	2,706	4,833
↓Thalweg	15.4	0.0	15.4	691	958
Total	15.4	77.4	92.8	3,397	5,791

Lift Force

C_{LT}	0.32
F_L (lbf)	72

Vertical Force Balance

F_B (lbf)	5,791
F_L (lbf)	72
W_T (lbf)	3,397
F_{soil} (lbf)	3,629
$F_{W,V}$ (lbf)	0
$F_{A,V}$ (lbf)	0
ΣF_V (lbf)	1,163
FS_V	1.20

Soil Ballast Force

Soil	V_{dry} (ft^3)	V_{sat} (ft^3)	V_{soil} (ft^3)	F_{soil} (lbf)
Bed	0.0	48.0	48.0	3,629
Bank	0.0	0.0	0.0	0
Total	0.0	48.0	48.0	3,629

Horizontal Force Analysis

Drag Force

A_{Tp} / A_W	Fr_L	C_{Di}	C_w	C_D*	F_D (lbf)
0.12	0.23	1.20	0.00	1.57	346

Horizontal Force Balance

F_D (lbf)	346
F_P (lbf)	6,988
F_F (lbf)	845
$F_{W,H}$ (lbf)	0
$F_{A,H}$ (lbf)	0
ΣF_H (lbf)	7,487
FS_H	22.62

Passive Soil Pressure / Friction Force

Soil	K_P	F_P (lbf)	L_{Tf} (ft)	μ	F_F (lbf)
Bed	3.85	6,988	7.99	0.73	845
Bank	2.66	0	0.00	0.51	0
Total	-	6,988	7.99	-	845

Moment Force Balance

Driving Moment Centroids / Resisting Moment Centroids

$c_{T,B}$ (ft)	c_L (ft)	c_D (ft)	$c_{T,W}$ (ft)	c_{soil} (ft)	$c_{F\&N}$ (ft)	c_P (ft)
4.6	6.4	6.4	4.6	3.0	3.0	4.0

*Distances are from the stem tip

Point of Rotation: Stem Tip

Moment Force Balance

M_d (lbf)	51
M_r (lbf)	105
FS_M	2.07

Anchor Forces

Additional Soil Ballast

V_{Adry} (ft^3)	V_{Awet} (ft^3)	c_{Asoil} (ft)	$F_{A,Vsoil}$ (lbf)	$F_{A,HP}$ (lbf)
			0	0

Mechanical Anchors

Type	c_{Am} (ft)	Soils	F_{Am} (lbf)
			0
			0

Boulder Ballast

Position	D_r (ft)	c_{Ar} (ft)	$V_{r,dry}$ (ft^3)	$V_{r,wet}$ (ft^3)	W_r (lbf)	$F_{L,r}$ (lbf)	$F_{D,r}$ (lbf)	$F_{A,Vr}$ (lbf)	$F_{A,Hr}$ (lbf)
								0	0
								0	0
								0	0

Plumtree Branch - Wood Analog Structure

Spreadsheet developed by
Michael Rafferty, P.E.

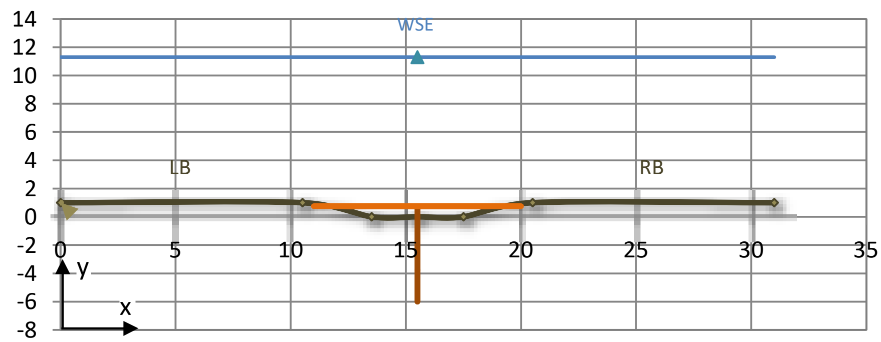
Single Log Stability Analysis Model Inputs

Site ID	Structure Type	Structure Position	Meander	Station	d_w (ft)	R_c/W_{BF}	u_{des} (ft/s)
0.6757 Chan	Rootwad	Mid-channel	Straight	+	11.29	0.00	2.13

Multi-Log Structures	Layer	Log ID
	Key Log	1

Channel Geometry Coordinates		
Proposed	x (ft)	y (ft)
Fldpln LB	0.00	1.00
Top LB	10.50	1.00
Toe LB	13.50	0.00
Thalweg	15.50	0.00
Toe RB	17.50	0.00
Top RB	20.50	1.00
Fldpln RB	31.00	1.00

Proposed Cross-Section and Structure Geometry (Looking D/S)

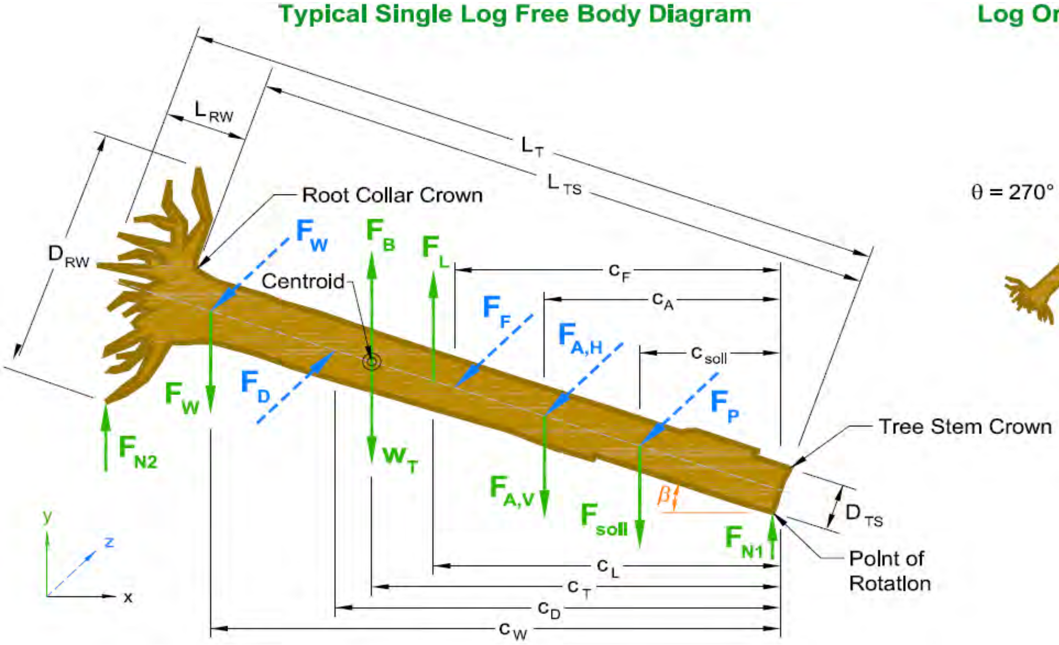


Wood Species	Rootwad	L_T (ft)	D_{TS} (ft)	L_{RW} (ft)	D_{RW} (ft)	γ_{Td} (lb/ft^3)	γ_{Tgr} (lb/ft^3)
Maple, Red	Yes	6.8	3.00	4.50	9.00	37.7	50.0

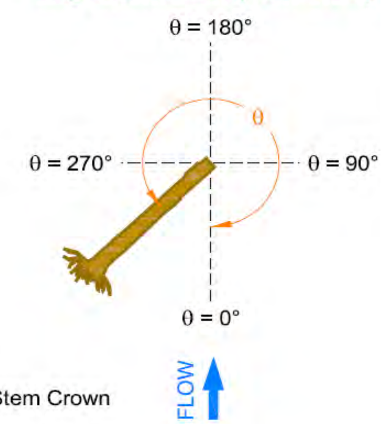
Structure Geometry	θ (deg)	β (deg)	Define Fixed Point	x_T (ft)	y_T (ft)	$y_{T,min}$ (ft)	$y_{T,max}$ (ft)	A_{Tp} (ft^2)
	0.0	-89.9	Stem tip: Crown	15.50	-6.00	-6.01	0.76	63.62

Soils	Material	γ_s (lb/ft^3)	γ'_s (lb/ft^3)	φ (deg)	Soil Class	$L_{T,em}$ (ft)	$d_{b,max}$ (ft)	$d_{b,avg}$ (ft)
Stream Bed	Medium gravel	121.4	75.6	36.0	5	6.00	6.00	3.01
Bank	Clayey silt	84.0	52.3	27.0	6	0.00	0.00	0.00

Typical Single Log Free Body Diagram



Log Orientation (Plan View)



Vertical Force Analysis

Net Buoyancy Force

Wood	V_{TS} (ft^3)	V_{RW} (ft^3)	V_T (ft^3)	W_T (lbf)	F_B (lbf)
↑WSE	0.0	0.0	0.0	0	0
↓WS↑Thw	0.0	110.3	110.3	4,161	6,881
↓Thalweg	15.9	0.0	15.9	795	993
Total	15.9	110.3	126.2	4,957	7,873

Lift Force

C_{LT}	0.34
F_L (lbf)	95

Vertical Force Balance

F_B (lbf)	7,873	↑
F_L (lbf)	95	↑
W_T (lbf)	4,957	↓
F_{soil} (lbf)	4,082	↓
$F_{W,V}$ (lbf)	0	
$F_{A,V}$ (lbf)	0	
ΣF_V (lbf)	1,071	↓
FS_V	1.13	✓

Soil Ballast Force

Soil	V_{dry} (ft^3)	V_{sat} (ft^3)	V_{soil} (ft^3)	F_{soil} (lbf)
Bed	0.0	54.0	54.0	4,082
Bank	0.0	0.0	0.0	0
Total	0.0	54.0	54.0	4,082

Horizontal Force Analysis

Drag Force

A_{Tp} / A_W	Fr_L	C_{Di}	C_w	C_D*	F_D (lbf)
0.15	0.22	1.20	0.00	1.69	474

Horizontal Force Balance

F_D (lbf)	474	→
F_P (lbf)	7,862	←
F_F (lbf)	778	←
$F_{W,H}$ (lbf)	0	
$F_{A,H}$ (lbf)	0	
ΣF_H (lbf)	8,166	←
FS_H	18.24	✓

Passive Soil Pressure / Friction Force

Soil	K_P	F_P (lbf)	L_{Tf} (ft)	μ	F_F (lbf)
Bed	3.85	7,862	7.99	0.73	778
Bank	2.66	0	0.00	0.51	0
Total	-	7,862	7.99	-	778

Moment Force Balance

Driving Moment Centroids / Resisting Moment Centroids

$c_{T,B}$ (ft)	c_L (ft)	c_D (ft)	$c_{T,W}$ (ft)	c_{soil} (ft)	$c_{F\&N}$ (ft)	c_P (ft)
4.5	6.4	6.4	4.5	3.0	3.0	4.0

*Distances are from the stem tip

Point of Rotation: Stem Tip

Moment Force Balance

M_d (lbf)	69	
M_r (lbf)	125	
FS_M	1.82	✓

Anchor Forces

Additional Soil Ballast

V_{Adry} (ft^3)	V_{Awet} (ft^3)	c_{Asoil} (ft)	$F_{A,Vsoil}$ (lbf)	$F_{A,HP}$ (lbf)
			0	0

Mechanical Anchors

Type	c_{Am} (ft)	Soils	F_{Am} (lbf)
			0
			0

Boulder Ballast

Position	D_r (ft)	c_{Ar} (ft)	$V_{r,dry}$ (ft^3)	$V_{r,wet}$ (ft^3)	W_r (lbf)	$F_{L,r}$ (lbf)	$F_{D,r}$ (lbf)	$F_{A,Vr}$ (lbf)	$F_{A,Hr}$ (lbf)
								0	0
								0	0
								0	0

Plumtree Branch - Wood Analog Structure
Notation, Units, and List of Symbols

Notation

Symbol	Description	Unit
A_W	Wetted area of channel at design discharge	ft^2
A_{Tp}	Projected area of wood in plane perpendicular to flow	ft^2
c_D	Centroid of the drag force along log axis	ft
c_{Am}	Centroid of a mechanical anchor along log axis	ft
c_{Ar}	Centroid of a ballast boulder along log axis	ft
c_{Asoil}	Centroid of the added ballast soil along log axis	ft
$c_{F\&N}$	Centroid of friction and normal forces along log axis	ft
c_L	Centroid of the lift force along log axis	ft
c_P	Centroid of the passive soil force along log axis	ft
c_{soil}	Centroid of the vertical soil forces along log axis	ft
$c_{T,B}$	Centroid of the buoyancy force along log axis	ft
$c_{T,W}$	Centroid of the log volume along log axis	ft
c_{WI}	Centroid of a wood interaction force along log axis	ft
C_{Lrock}	Coefficient of lift for submerged boulder	-
C_{LT}	Effective coefficient of lift for submerged tree	-
C_{Di}	Base coefficient of drag for tree, before adjustments	-
C_D*	Effective coefficient of drag for submerged tree	-
C_{Di}	Base coefficient of drag for tree, before adjustments	-
C_W	Wave drag coefficient of submerged tree	-
$d_{b,avg}$	Average buried depth of log	ft
$d_{b,max}$	Maximum buried depth of log	ft
d_w	Maximum flow depth at design discharge in reach	ft
D_{50}	Median grain size in millimeters (SI units)	mm
D_r	Equivalent diameter of boulder	ft
D_{RW}	Assumed diameter of rootwad	ft
D_{TS}	Nominal diameter of tree stem (DBH)	ft
DF_{RW}	Diameter factor for rootwad ($DF_{RW} = D_{RW}/D_{TS}$)	-
e	Void ratio of soils	-
$F_{A,H}$	Total horizontal load capacity of anchor techniques	lbf
$F_{A,HP}$	Passive soil pressure applied to log from soil ballast	lbf
$F_{A,Hr}$	Horizontal resisting force on log from boulder	lbf
F_{Am}	Load capacity of mechanical anchor	lbf
$F_{A,V}$	Total vertical load capacity of anchor techniques	lbf
$F_{A,Vr}$	Vertical resisting force on log from boulder	lbf
$F_{A,Vsoil}$	Vertical soil loading on log from added ballast soil	lbf
F_B	Buoyant force applied to log	lbf
F_D	Drag forces applied to log	lbf
$F_{D,r}$	Drag forces applied to boulder	lbf
F_F	Friction force applied to log	lbf
F_H	Resultant horizontal force applied to log	lbf
F_L	Lift force applied to log	lbf
$F_{L,r}$	Lift force applied to boulder	lbf
F_P	Passive soil pressure force applied to log	lbf
F_{soil}	Vertical soil loading on log	lbf
$F_{W,H}$	Horizontal forces from interactions with other logs	lbf
$F_{W,V}$	Vertical forces from interactions with other logs	lbf

Notation (continued)

Symbol	Description	Unit
F_V	Resultant vertical force applied to log	lbf
Fr_L	Log Froude number	-
FS_V	Factor of Safety for Vertical Force Balance	-
FS_H	Factor of Safety for Horizontal Force Balance	-
FS_M	Factor of Safety for Moment Force Balance	-
g	Gravitational acceleration constant	ft/s^2
K_P	Coefficient of Passive Earth Pressure	-
$L_{T,em}$	Total embedded length of log	ft
L_{RW}	Assumed length of rootwad	ft
L_T	Total length of tree (including rootwad)	ft
L_{Tf}	Length of log in contact with bed or banks	ft
L_{TS}	Length of tree stem (not including rootwad)	ft
$L_{TS,ex}$	Exposed length of tree stem	ft
LF_{RW}	Length factor for rootwad ($LF_{RW} = L_{RW}/D_{TS}$)	-
M_d	Driving moment about embedded tip	lbf
M_r	Driving moment about embedded tip	lbf
N	Blow count of standard penetration test	-
p_o	Porosity of soil volume	-
Q_{des}	Design discharge	cfs
R	Radius	ft
R_c	Radius of curvature at channel centerline	ft
SG_r	Specific gravity of quartz particles	-
SG_T	Specific gravity of tree	-
u_{avg}	Average velocity of cross section in reach	ft/s
u_{des}	Design velocity	ft/s
u_m	Adjusted velocity at outer meander bend	ft/s
V_{dry}	Volume of soils above stage level of design flow	ft^3
V_{sat}	Volume of soils below stage level of design flow	ft^3
V_{soil}	Total volume of soils over log	ft^3
V_{RW}	Volume of rootwad	ft^3
V_S	Volume of solids in soil (void ratio calculation)	ft^3
V_T	Total volume of log	ft^3
V_{TS}	Total volume of tree	ft^3
V_V	Volume of voids in soil	ft^3
V_{Adry}	Volume of ballast above stage of design flow	ft^3
V_{Awet}	Volume of ballast below stage of design flow	ft^3
$V_{r,dry}$	Volume of boulder above stage of design flow	ft^3
$V_{r,wet}$	Volume of boulder below stage of design flow	ft^3
W_{BF}	Bankfull width at structure site	ft
W_r	Effective weight of boulder	lbf
W_T	Total log weight	lbf
x	Horizontal coordinate (distance)	ft
y	Vertical coordinate (elevation)	ft
$y_{T,max}$	Minimum elevation of log	ft
$y_{T,min}$	Maximum elevation of log	ft

Greek Symbols

Symbol	Description	Unit
β	Tilt angle from stem tip to vertical	deg
γ_{bank}	Dry specific weight of bank soils	lb/ft^3
$\gamma_{bank,sat}$	Saturated unit weight of bank soils	lb/ft^3
γ'_{bank}	Effective buoyant unit weight of bank soils	lb/ft^3
γ_{bed}	Dry specific weight of stream bed substrate	lb/ft^3
γ'_{bed}	Effective buoyant unit weight of stream bed substrate	lb/ft^3
γ_{rock}	Dry unit weight of boulders	lb/ft^3
γ_s	Dry specific weight of soil	lb/ft^3
γ'_s	Effective buoyant unit weight of soil	lb/ft^3
γ_{Td}	Air-dried unit weight of tree (12% MC basis)	lb/ft^3
γ_{Tgr}	Green unit weight of tree	lb/ft^3
γ_w	Specific weight of water at 50ºF	lb/ft^3
η	Rootwad porosity	-
θ	Rootwad (or large end of log) orientation to flow	deg
μ	Coefficient of friction	-
ν	Kinematic viscosity of water at 50ºF	ft/s^2
Σ	Sum of forces	-
ϕ_{bank}	Internal friction angle of bank soils	deg
ϕ_{bed}	Internal friction angle of stream bed substrate	deg

Units

Notation	Description
cfs	Cubic feet per second
ft	Feet
lb	Pound
lbf	Pounds force
kg	Kilograms
m	Meters
mm	Millimeters
s	Seconds
yr	Year

Abbreviations

Notation	Description
ARI	Average return interval
Avg	Average
DBH	Diameter at breast height
deg	Degrees
Dia	Diameter
Dist	Distance
D/S	Downstream
ELJ	Engineered log jam
Ex	Example
Fldpln	Floodplain
H&H	Hydrologic and hydraulic
ID	Identification
i.e.	That is
LB	Left bank
LW	Large wood
Max	Maximum
MC	Moisture content
Min	Minimum
ML	Multi-log
SL	Single log
N/A	Not applicable
no	Number
Pt	Point
rad	Radians
RB	Right bank
RW	Rootwad
SL	Single log
Thw	Thalweg (lowest elevation in channel bed)
Typ	Typical
U.S.	United States
WS	Water surface
WSE	Water surface elevation
↑	Above
↓	Below

Reference Sheet - Anchoring Techniques

Anchor Technique Lookup Table (average holding capacities)

Soil Class	Soil Description	Blow Count (N)	Manta Ray			Stingray			Duckbill				Platipus Stealth				Platipus Bat					Custom (User Selection)		
			MR-1 Capacity (lb)	MR-2 Capacity (lb)	MR-SR Capacity (lb)	SR-1 Capacity (lb)	SR-2 Capacity (lb)	SR-3 Capacity (lb)	DB-40 Capacity (lb)	DB-68 Capacity (lb)	DB-88 Capacity (lb)	DB-138 Capacity (lb)	P-S02 Capacity (lb)	P-S04 Capacity (lb)	P-S06 Capacity (lb)	P-S08 Capacity (lb)	P-B04T Capacity (lb)	P-B06T Capacity (lb)	P-B08T Capacity (lb)	P-B10T Capacity (lb)	P-B12T Capacity (lb)	Custom#1 Capacity (lb)	Custom#2 Capacity (lb)	Custom#3 Capacity (lb)
4	Dense gravels; gravel/cobble; very hard silts and clays	40-100+	24,000	15,000	32,000	39,000	62,000	85,000	user input	user input	user input	user input	300	1,000	3,500	4,500	6,000	11,000	16,500	22,000	33,000	(user input)	(user input)	(user input)
5	Dense coarse sand; gravel/sand; loose gravels; stiff slits and clays	14-40	15,000	9,000	18,000	24,000	31,000	48,000	300	1,100	3,000	5,000	150	600	2,000	2,500	3,500	6,500	9,000	14,000	20,000	(user input)	(user input)	(user input)
6	Loose coarse sand; dense fine sand; firm silts and clays	7-14	10,000	7,000	14,000	16,000	27,000	37,000	user input	user input	user input	user input	50	300	800	1,500	2,500	4,000	6,500	11,000	16,000	(user input)	(user input)	(user input)
7	Loose fine sand; alluvium; soft silts and clays; silty sanc	4-8	8,000	5,000	9,000	13,000	19,000	24,000	user input	user input	user input	user input	N/A	200	400	1,000	2,000	3,500	5,500	9,000	13,000	(user input)	(user input)	(user input)

Notes:
1. All types -- Use this chart for estimation only. Values shown reflect the manufacturer's minimum expected holding capacity for a given condition. User is responsible for verifying load capacities. The true capacity must be tested by proof-loading. Minimum 2:1 Safety Factor is recommended.
2. Installation may be difficult. Pilot hole may be required.
3. Holding capacity limited by working load of anchors.
4. Holding capacity limited by soil failure.
5. Wide variation in soil properties reduces prediction accuracy. Pre-constructed field test recommended.
6. Duckbill anchors are rated in an average (class 5) soil condition. Proof-loading is the only way to insure the exact capacity of each installation. Anchor holding capacity will vary in different soils. Increased capacities can be expected in harder soil classes (numerically higher blow count classifications) and lower capacity can be expected in the softer soil classes (numerically lower blow count).
7. Platipus Stealth and Bat anchors are given a wide range for holding capacities. The high manufacturer's rating was applied to class 4 soils, while the low value was assigned to class 7 soils. Holding capacities for class 5 and 6 soils were interpolated as a guide only. User is responsible for verifying all rating capacities.

Anchor/Ballast Technique Lookup Table

Technique	Description
Added Soil Ballast	Add coarse material soil lifts on top of structure to increase burial depth
Boulder Ballast	Place boulder on top of structure. Alternatively, secure structure to boulder located beside or beneath structure.
Wood Pile (In development)	Drive or bury vertical wood piles into the bed or banks to brace structure. Alternatively, brace structure against existing large tree.
Mechanical Anchor	Secure structure to soil anchor which uses overlying soil to resist pullout. Alternatively, secure the structure to bedrock using a rock anchor.

Four common alternatives exist for securing or stabilizing placements of large wood in water. In order of preference for habitat formation, they are:
1. No added stability -- where wood is supplied to the stream and allowed to be stable without manipulation or, as conditions develop, moved by the flow.
2. Passive stability -- where the weight and shape of the structure is the anchor, and movement at some flow level is acceptable (includes ballast).
3. Flexible stability -- such as tethering the structure so some degree of movement is allowed with varying flows.
4. Rigid stability -- holding the logs permanently in place with no movement allowed.
(Source: 2012 WA Stream Habitat Restoration Guidelines)

Directions for LW Stability Analysis Tool

This design tool may be used by practitioners if they cite the developer on each sheet.

Disclaimer:
This Microsoft Excel 2010 spreadsheet tool is provided free of charge. Use this tool at your own risk. In offering this tool, the author, the U.S. Forest Service, and Colorado State University do not accept any responsibility or liability for the tool's use by third parties. This tool has specific uses and limits of applicability. Design practitioners shall take full responsibility for the final large wood structure design and performance. Designers are expected to verify the calculated values and validity of the design method. Designers should be qualified to work in river environments, and depending on the State, they may be required to be licensed as a professional engineer to design large wood structures. You cannot be sure the tool is authentic and unmolested unless downloaded from the following website:

https://www.fs.fed.us/biology/nsaec/products-tools.html#tools-stabilitylargewoodstructures

DATA INPUT

Order of Input

Update the worksheets from "left to right"
Update the spreadsheet cells from "left to right" and "top to bottom"

IMPORTANT - User should only edit the following cells:

Cell Format	Directions
Dropdown List	Select value from dropdown list
User Input	Type value into cell
User Verify	Verify value in cell (edit if necessary)

User should verify, but not edit the following cells because these cells contain formulas or headings:

Cell Format	Directions
Heading	Table Heading (Scroll over sample heading for description of comments)
Automatic Value	Verify value in cell which is automatically calculated by formulas
Key Value	Verify value of force calculation
Solution	Verify value of force balance or factor of safety calculation
Background Value	Optional - Verify value of background calculation (outside of print area)

The "Single Log" and "Multi-Log" spreadsheets have several built-in error messages (in column 'K'):

Error Message	
"CHECK"	Prompts user to check a specific input
"ERROR"	Prompts user to change a specific input

User Input Note 1 - Several worksheets have a built in "clear inputs" button linked to a macro (these are the only macros built into the tool). Be aware that you can't undo the "clear input" command.

User Input Note 2 - User may enter a custom "bank soil type", "wood species", or "anchor type" by scrolling over to the right to find the lookup table and editing the "custom" cells.

User Input Note 3 - The spreadsheet is not locked, and therefore every cell can be manually edited. However, the

user is encouraged to exercise caution to avoid unintended consequences of changing reference formulas.

User Input Note 4 - User should also be very careful when removing or adding cells (at least scroll over and down to see what other cells may be impacted). Hiding unused rows or columns is recommended instead of deleting them. If the user needs to add cells on the "Single Log Design" spreadsheet, they should add a row of cells for all columns between 'A' and 'J'. Important: Adding cells will break the code in the "Clear Inputs" macro, and cause it to clear the wrong cells.

User Input Note 5 - To avoid compounding potential errors, the user should use the original download version of the spreadsheet (without personal edits) at the beginning of each design.

User Input Note 6 - Input values should be in English units, with one exception: D_{50} for the bed substrate gradation (mm).

ANALYSIS OF MULTIPLE LOG STRUCTURES

The LW Stability Analysis Tool can also be used to design multiple log structures. The user must manually translate the resulting vertical and horizontal forces from one log design sheet into another (or write their own formulas). This data should be entered in the "Interaction Forces with Adjacent Logs" section of the "Single Log Design" worksheet. In theory, there is no limit to the number of logs that can be considered, although the force balance accounting may become cumbersome beyond a few logs. The general procedure is as follows:

Step 1 Begin by creating a preliminary structure layout (in AutoCAD or similar) to define the quantity of logs, locate intersect points, and identify key members. Key members are typically the largest logs (or the logs that are going to be have anchors attached).

Step 2 Fill out Sheets 1 through 5 of this tool. Next, input the channel geometry in a blank "Single Log Design" worksheet (Sheet 6), and then make copies for analysis of each log.

Step 3 Complete a preliminary force balance analysis for each stacked member log, ignoring the "Interaction Forces with Adjacent Logs" and "Anchor Forces" sections. The user should manually record the resisting forces required to stabilize each stacked member in a table. The required vertical force can be found in cell 'K61' of the "Single Log Design" worksheet, and the required horizontal force can be found in cell 'K72'. If the log is already vertically or horizontally stable, record the excess force that may be applied to resist driving forces of the adjacent log(s). This information can be found in cell 'K62' and 'K73'. An example table is shown to the right of these directions →

Step 4 Complete a force balance analysis for the key members. In the "Interaction Forces with Adjacent Logs" section on the force balance sheet, enter the relative position of each adjacent stacked log in contact with the key member, the connection type (gravity or pinned), the intersection point, and the required vertical and horizontal forces to achieve stability for each stacked member. If the load from the adjacent logs is spread over multiple key members, divide the required forces by the number of key members sharing the load (note--these loads do not need to be evenly distributed between key members). If an adjacent log is either horizontally or vertically stable, then enter any excess force (see Step 3 above) value as a negative number in the key member design spreadsheet. The tool will automatically determine which loads are transferable to the next layer of logs. For instance, a non-pinned log situated above the key member will not transfer buoyancy force to the key member.

Step 5 Add "Anchor Forces" as necessary to stabilize the key members.

Step 6 Return to the stacked member log worksheets and in the "Interaction Forces with Adjacent Logs" section, input the forces that were resisted by the stability analysis of the key members. Add additional "Anchor Forces" as necessary to stabilize the forces that were not resisted by the design of the key members. It is advisable to create a copy of the "preliminary" design worksheets for the stacked member logs to create a separate "final" design worksheet. This will make it easier for the user to review the interaction forces between logs or make necessary edits.

Tip 1: It is recommended that the user creates a spreadsheet to tally the transferred forces for each log.

Tip 2: The design of multiple log structures should initially focus on achieving vertical stability, before moving on to horizontal stability, and finally the moment analysis.

Note 1: Most design procedures for larger wood jams (ELJ's) typically ignore the lift and moment forces, and the drag coefficient may be assumed to be between 0.6 and 0.7 for the entire structure (plus corrections for constriction, or blockage, of the channel). Therefore, the analysis procedure described above is likely conservative for larger

structures.
Note 2: The designer should also perform scour computations and consider the structure's potential to trap mobile wood. The design and/or factor of safety may need modified accordingly.

TO PRINT WORKBOOK
Highlight tabs numbered 1 through 7, and click "Print". Pages are pre-formatted except the "Anchors" Lookup sheet, which is not intended to be printed.

User is encouraged to provide comments and feedback for:
Suitability: Range of application or limitations
Ease of use
Results: Are they reasonable and verified?
Any other comments for improvement
E-mail comments to: mrafferty@interfluve.com

TOOL UPDATES

Version 1.0 July 2, 2013

Version 1.1 January 8, 2016

Sheet, Cell	
S1, A42	Added reference on cover sheet to new companion paper (USFS National Stream and Aquatic Ecology Ce
S2, A6,7	Changed default factor of safety to 1.5 (from 2.0) for horizontal and moment force balances
S6, B6	Updated log structure types in pull-down list on worksheet for single log design
S6, B9	Added terminology of "key", "stacked", and "wracked" logs to dropdown list for consistency with guidelines
S6, B25	Added error message restricting input values for orientation angle (can not equal exactly 0)
S6, B26	Added error message restricting input values for tilt angle (can not equal exactly 0, 90, 180, 270, or 360)
S6, D83	Changed soil type from stream bed to bank soils in formula for $F_{A,V}$ applied by additional soil ballast
Multiple	General updates to cell formats
Multiple	Fixed page layouts for printing

Version 1.2 January 21, 2020

Update of tools link on NSAEC webpage

Plumtree Branch - Wooden Posts

Large Wood Structure Stability Analysis

TABLE OF CONTENTS

Date of Last Revision: January 7, 2016

Designer:
Insert Name

Reviewed by:
Insert Name

Large Wood Structure Stability Analysis Spreadsheet was developed by Michael Rafferty, P.E.
Version 1.1

Reference for Companion Paper:

Rafferty, M. 2016. *Computational Design Tool for Evaluating the Stability of Large Wood Structures.* Technical Note TN-103.1. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, National Stream & Aquatic Ecology Center. 27 p.

Plumtree Branch - Wooden Posts
Factors of Safety and Design Constants

Spreadsheet developed by
Michael Rafferty, P.E.

Symbol	Description	Value
FS_V	Factor of Safety for Vertical Force Balance	**1.00**
FS_H	Factor of Safety for Horizontal Force Balance	**1.00**
FS_M	Factor of Safety for Moment Force Balance	**1.00**

Symbol	Description	Units	Value
C_{Lrock}	Coefficient of lift for submerged boulder (D'Aoust, 2000)	-	0.17
C_{Drock}	Coefficient of drag for submerged boulder (Schultz, 1954)	-	0.85
g	Gravitational acceleration constant	ft/s^2	32.174
DF_{RW}	Diameter factor for rootwad ($DF_{RW} = D_{RW}/D_{TS}$)	-	3.00
LF_{RW}	Length factor for rootwad ($LF_{RW} = L_{RW}/D_{TS}$)	-	1.50
SG_{rock}	Specific gravity of quartz particles	-	2.65
γ_{rock}	Dry unit weight of boulders	lb/ft^3	165.0
γ_w	Specific weight of water at 50ºF	lb/ft^3	62.40
η	Rootwad porosity from NRCS Tech Note 15 (2001)	-	0.20
ν	Kinematic viscosity of water at 50ºF	ft/s^2	1.41E-05

Plumtree Branch - Wooden Posts
Hydrologic and Hydraulic Inputs

Spreadsheet developed by
Michael Rafferty, P.E.

Average Return Interval (ARI) of Design Discharge: 100 yr

Site ID	Proposed Station	Design Discharge, Q_{des} (cfs)	Maximum Depth, d_w (ft)	Average Velocity, u_{avg} (ft/s)	Bankfull Width, W_{BF} (ft)	Wetted Area, A_W (ft^2)	Radius of Curvature, R_c (ft)
XS 0.6757 Channel		2,600	11.29	2.13	409.0	411	1,000

Plumtree Branch - Wooden Posts
Stream Bed Substrate Properties

Spreadsheet developed by
Michael Rafferty, P.E.

Site ID	Proposed Station	Stream bed D_{50} (mm)	Stream Bed Substrate Grain Size Class	Bed Soil Class	Dry Unit Weight[1], γ_{bed} (lb/ft^3)	Buoyant Unit Weight, γ'_{bed} (lb/ft^3)	Friction Angle, ϕ_{bed} (deg)
S 0.6757 Chann	Channel	14.10	Medium gravel	5	121.4	75.6	36

Source: Compiled from Julien (2010) and Shen and Julien (1993); soil classes from NRCS Table TS14E–2 Soil classification

[1] γ_{bed} (kg/m^3) = 1,600 + 300 log D_{50} (mm) (from Julien 2010)

1 kg/m^3 = 0.062 1 lb/ft^3

Plumtree Branch - Wooden Posts
Bank Soil Properties

Spreadsheet developed by
Michael Rafferty, P.E.

Site ID	Proposed Station	Bank Soils (from field observations)	Bank Soil Class	Dry Unit Weight, γ_{bank} (lb/ft^3)	Buoyant Unit Weight, γ'_{bank} (lb/ft^3)	Friction Angle, ϕ_{bank} (deg)
S 0.6757 Chann	Channel	**Clayey silt**	6	84.0	52.3	27

Plumtree Branch - Wooden Posts
Large Wood Properties

Spreadsheet developed by
Michael Rafferty, P.E.

Project Location: Mid-Atlantic

Timber Unit Weights			Air-dried[1] γ_{Td} (lb/ft^3)	Green[2] γ_{Tgr} (lb/ft^3)
Selected Species	**Common Name**	**Scientific Name**		
Tree Type #1:	**Beech, American**	Fagus grandifolia	44.7	54.0
Tree Type #2:	**Cherry, Black**	Prunus serotina	34.9	45.0
Tree Type #3:	**Walnut, Black**	Juglans nigra	38.4	57.0
Tree Type #4:	**Oak, Pin**	Quercus palustris	44.0	64.0
Tree Type #5:	**Maple, Red**	Acer rubrum	37.7	50.0
Tree Type #6:	**Ash, White**	Fraxinus americana	41.9	50.0
Tree Type #7:	**Willow, Black**	Salix nigra	27.3	51.0
Tree Type #8:	**Box Elder**	(user selection in input table)	27.3	51.0
Tree Type #9:				
Tree Type #10:				

[1] **Air-dried unit weight,** γ_{Td} = Average unit weight of wood after exposure to air on a 12% moisture content volume basis. Air-dried unit weight is used in the force balance calculations for the portion of wood that is above the proposed thalweg elevation (assuming unsaturated conditions).

[2] **Green unit weight,** γ_{Tgr} = Average unit weight of freshly sawn wood when the cell walls are completely saturated with water. Green unit weight is used in the force balance calculations as a conservative estimate of the unit weight for the portion of wood that is below the proposed thalweg elevation (assuming saturated conditions). For comparison, Thevenet, Citterio, & Piegay (1998) determined wood unit weight typically increases by more than 100% after less than 24 hours exposure to water.

Source for timber unit weights:

U.S. Department of Agriculture, U.S. Forest Service. (2009) Specific Gravity and Other Properties of Wood and Bark for 156 Tree Species Found in North America. Research Note NRS-38. Table 1A.

Plumtree Branch - Wooden Posts

Spreadsheet developed by Michael Rafferty, P.E.

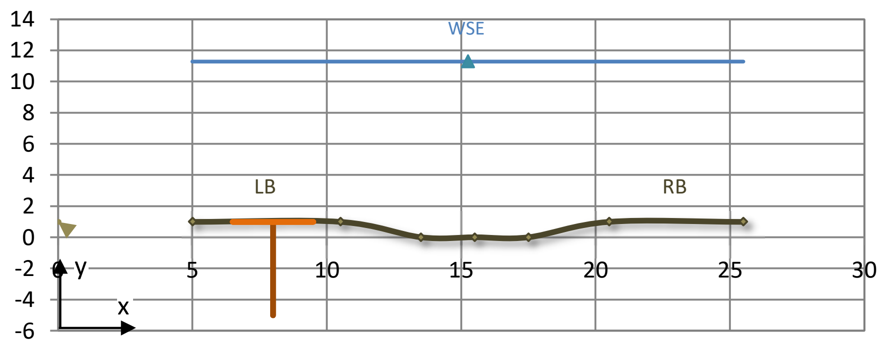
Single Log Stability Analysis Model Inputs

Site ID	Structure Type	Structure Position	Meander	Station	d_w (ft)	R_c/W_{BF}	u_{des} (ft/s)
0.6757 Chan	Floodplain	Left bank	Straight	+	11.29	2.44	2.13

Multi-Log Structures	Layer	Log ID
	Key Log	1

Channel Geometry Coordinates		
Proposed	x (ft)	y (ft)
Fldpln LB	5.00	1.00
Top LB	10.50	1.00
Toe LB	13.50	0.00
Thalweg	15.50	0.00
Toe RB	17.50	0.00
Top RB	20.50	1.00
Fldpln RB	25.50	1.00

Proposed Cross-Section and Structure Geometry (Looking D/S)

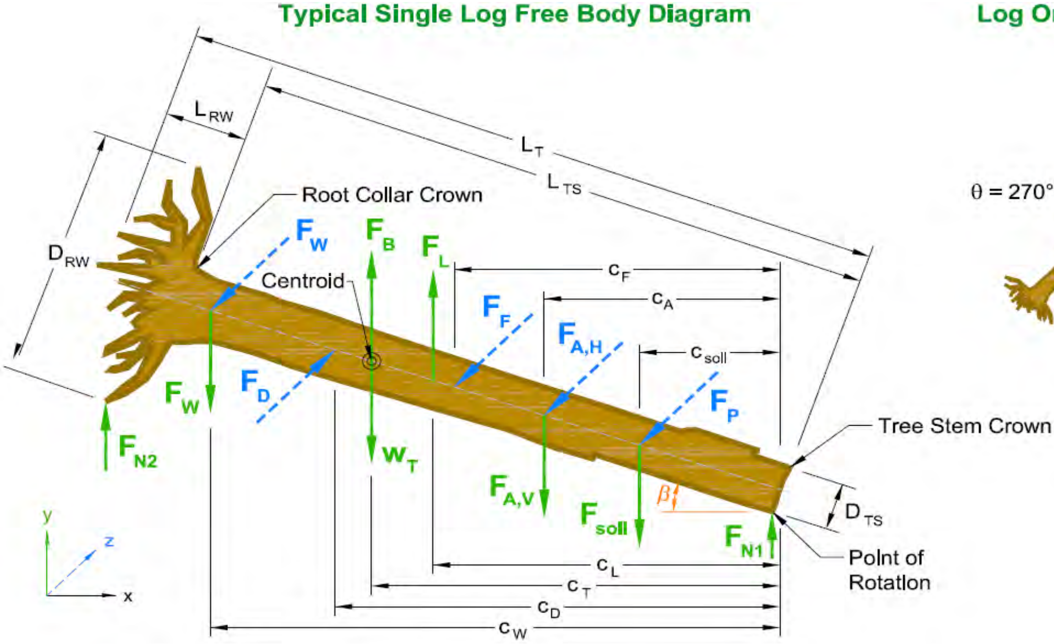


Wood Species	Rootwad	L_T (ft)	D_{TS} (ft)	L_{RW} (ft)	D_{RW} (ft)	γ_{Td} (lb/ft^3)	γ_{Tgr} (lb/ft^3)
Willow, Black	No	6.0	3.00	-	-	27.3	51.0

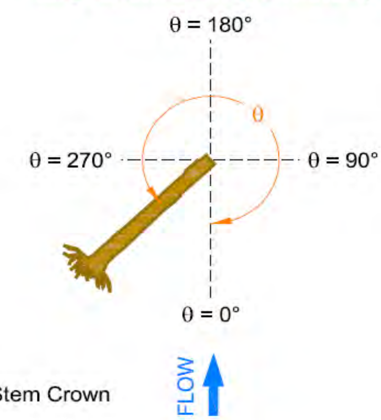
Structure Geometry	θ (deg)	β (deg)	Define Fixed Point	x_T (ft)	y_T (ft)	$y_{T,min}$ (ft)	$y_{T,max}$ (ft)	A_{Tp} (ft^2)
	0.0	-89.9	Stem tip: Crown	8.00	-5.00	-5.01	1.00	0.00

Soils	Material	γ_s (lb/ft^3)	γ'_s (lb/ft^3)	φ (deg)	Soil Class	$L_{T,em}$ (ft)	$d_{b,max}$ (ft)	$d_{b,avg}$ (ft)
Stream Bed	Medium gravel	121.4	75.6	36.0	5	0.00	0.00	0.00
Bank	Clayey silt	84.0	52.3	27.0	6	0.00	6.00	3.00

Typical Single Log Free Body Diagram



Log Orientation (Plan View)



Vertical Force Analysis

Net Buoyancy Force

Wood	V_{TS} (ft^3)	V_{RW} (ft^3)	V_T (ft^3)	W_T (lbf)	F_B (lbf)
↑WSE	0.0	0.0	0.0	0	0
↓WS↑Thw	7.1	0.0	7.1	192	440
↓Thalweg	35.4	0.0	35.4	1,803	2,207
Total	42.4	0.0	42.4	1,996	2,646

Lift Force

C_{LT}	0.00
F_L (lbf)	0

Vertical Force Balance

F_B (lbf)	2,646
F_L (lbf)	0
W_T (lbf)	1,996
F_{soil} (lbf)	2,824
$F_{W,V}$ (lbf)	0
$F_{A,V}$ (lbf)	0
ΣF_V (lbf)	2,173
FS_V	1.82

Soil Ballast Force

Soil	V_{dry} (ft^3)	V_{sat} (ft^3)	V_{soil} (ft^3)	F_{soil} (lbf)
Bed	0.0	0.0	0.0	0
Bank	0.0	54.0	54.0	2,824
Total	0.0	54.0	54.0	2,824

Horizontal Force Analysis

Drag Force

A_{Tp} / A_W	Fr_L	C_{Di}	C_w	C_D*	F_D (lbf)
0.00	0.22	1.12	0.00	1.11	0

Horizontal Force Balance

F_D (lbf)	0
F_P (lbf)	3,760
F_F (lbf)	1,225
$F_{W,H}$ (lbf)	0
$F_{A,H}$ (lbf)	0
ΣF_H (lbf)	4,986
FS_H	324,543.55

Passive Soil Pressure / Friction Force

Soil	K_P	F_P (lbf)	L_{Tf} (ft)	μ	F_F (lbf)
Bed	3.85	0	2.00	0.73	395
Bank	2.66	3,760	6.00	0.51	831
Total	-	3,760	8.00	-	1,225

Moment Force Balance

Driving Moment Centroids / Resisting Moment Centroids

$c_{T,B}$ (ft)	c_L (ft)	c_D (ft)	$c_{T,W}$ (ft)	c_{soil} (ft)	$c_{F\&N}$ (ft)	c_P (ft)
3.0	0.0	0.0	3.0	3.0	3.0	3.0

*Distances are from the stem tip

Point of Rotation: Root Collar

Moment Force Balance

M_d (lbf)	14
M_r (lbf)	63
FS_M	4.53

Anchor Forces

Additional Soil Ballast

V_{Adry} (ft^3)	V_{Awet} (ft^3)	c_{Asoil} (ft)	$F_{A,Vsoil}$ (lbf)	$F_{A,HP}$ (lbf)
			0	0

Mechanical Anchors

Type	c_{Am} (ft)	Soils	F_{Am} (lbf)
			0
			0

Boulder Ballast

Position	D_r (ft)	c_{Ar} (ft)	$V_{r,dry}$ (ft^3)	$V_{r,wet}$ (ft^3)	W_r (lbf)	$F_{L,r}$ (lbf)	$F_{D,r}$ (lbf)	$F_{A,Vr}$ (lbf)	$F_{A,Hr}$ (lbf)
								0	0
								0	0
								0	0

Plumtree Branch - Wooden Posts
Notation, Units, and List of Symbols

Notation

Symbol	Description	Unit
A_W	Wetted area of channel at design discharge	ft^2
A_{Tp}	Projected area of wood in plane perpendicular to flow	ft^2
c_D	Centroid of the drag force along log axis	ft
c_{Am}	Centroid of a mechanical anchor along log axis	ft
c_{Ar}	Centroid of a ballast boulder along log axis	ft
c_{Asoil}	Centroid of the added ballast soil along log axis	ft
$c_{F\&N}$	Centroid of friction and normal forces along log axis	ft
c_L	Centroid of the lift force along log axis	ft
c_P	Centroid of the passive soil force along log axis	ft
c_{soil}	Centroid of the vertical soil forces along log axis	ft
$c_{T,B}$	Centroid of the buoyancy force along log axis	ft
$c_{T,W}$	Centroid of the log volume along log axis	ft
c_{WI}	Centroid of a wood interaction force along log axis	ft
C_{Lrock}	Coefficient of lift for submerged boulder	-
C_{LT}	Effective coefficient of lift for submerged tree	-
C_{Di}	Base coefficient of drag for tree, before adjustments	-
C_D*	Effective coefficient of drag for submerged tree	-
C_{Di}	Base coefficient of drag for tree, before adjustments	-
C_W	Wave drag coefficient of submerged tree	-
$d_{b,avg}$	Average buried depth of log	ft
$d_{b,max}$	Maximum buried depth of log	ft
d_w	Maximum flow depth at design discharge in reach	ft
D_{50}	Median grain size in millimeters (SI units)	mm
D_r	Equivalent diameter of boulder	ft
D_{RW}	Assumed diameter of rootwad	ft
D_{TS}	Nominal diameter of tree stem (DBH)	ft
DF_{RW}	Diameter factor for rootwad ($DF_{RW} = D_{RW}/D_{TS}$)	-
e	Void ratio of soils	-
$F_{A,H}$	Total horizontal load capacity of anchor techniques	lbf
$F_{A,HP}$	Passive soil pressure applied to log from soil ballast	lbf
$F_{A,Hr}$	Horizontal resisting force on log from boulder	lbf
F_{Am}	Load capacity of mechanical anchor	lbf
$F_{A,V}$	Total vertical load capacity of anchor techniques	lbf
$F_{A,Vr}$	Vertical resisting force on log from boulder	lbf
$F_{A,Vsoil}$	Vertical soil loading on log from added ballast soil	lbf
F_B	Buoyant force applied to log	lbf
F_D	Drag forces applied to log	lbf
$F_{D,r}$	Drag forces applied to boulder	lbf
F_F	Friction force applied to log	lbf
F_H	Resultant horizontal force applied to log	lbf
F_L	Lift force applied to log	lbf
$F_{L,r}$	Lift force applied to boulder	lbf
F_P	Passive soil pressure force applied to log	lbf
F_{soil}	Vertical soil loading on log	lbf
$F_{W,H}$	Horizontal forces from interactions with other logs	lbf
$F_{W,V}$	Vertical forces from interactions with other logs	lbf

Notation (continued)

Symbol	Description	Unit
F_V	Resultant vertical force applied to log	lbf
Fr_L	Log Froude number	-
FS_V	Factor of Safety for Vertical Force Balance	-
FS_H	Factor of Safety for Horizontal Force Balance	-
FS_M	Factor of Safety for Moment Force Balance	-
g	Gravitational acceleration constant	ft/s^2
K_P	Coefficient of Passive Earth Pressure	-
$L_{T,em}$	Total embedded length of log	ft
L_{RW}	Assumed length of rootwad	ft
L_T	Total length of tree (including rootwad)	ft
L_{Tf}	Length of log in contact with bed or banks	ft
L_{TS}	Length of tree stem (not including rootwad)	ft
$L_{TS,ex}$	Exposed length of tree stem	ft
LF_{RW}	Length factor for rootwad ($LF_{RW} = L_{RW}/D_{TS}$)	-
M_d	Driving moment about embedded tip	lbf
M_r	Driving moment about embedded tip	lbf
N	Blow count of standard penetration test	-
p_o	Porosity of soil volume	-
Q_{des}	Design discharge	cfs
R	Radius	ft
R_c	Radius of curvature at channel centerline	ft
SG_r	Specific gravity of quartz particles	-
SG_T	Specific gravity of tree	-
u_{avg}	Average velocity of cross section in reach	ft/s
u_{des}	Design velocity	ft/s
u_m	Adjusted velocity at outer meander bend	ft/s
V_{dry}	Volume of soils above stage level of design flow	ft^3
V_{sat}	Volume of soils below stage level of design flow	ft^3
V_{soil}	Total volume of soils over log	ft^3
V_{RW}	Volume of rootwad	ft^3
V_S	Volume of solids in soil (void ratio calculation)	ft^3
V_T	Total volume of log	ft^3
V_{TS}	Total volume of tree	ft^3
V_V	Volume of voids in soil	ft^3
V_{Adry}	Volume of ballast above stage of design flow	ft^3
V_{Awet}	Volume of ballast below stage of design flow	ft^3
$V_{r,dry}$	Volume of boulder above stage of design flow	ft^3
$V_{r,wet}$	Volume of boulder below stage of design flow	ft^3
W_{BF}	Bankfull width at structure site	ft
W_r	Effective weight of boulder	lbf
W_T	Total log weight	lbf
x	Horizontal coordinate (distance)	ft
y	Vertical coordinate (elevation)	ft
$y_{T,max}$	Minimum elevation of log	ft
$y_{T,min}$	Maximum elevation of log	ft

Greek Symbols

Symbol	Description	Unit
β	Tilt angle from stem tip to vertical	deg
γ_{bank}	Dry specific weight of bank soils	lb/ft^3
$\gamma_{bank,sat}$	Saturated unit weight of bank soils	lb/ft^3
γ'_{bank}	Effective buoyant unit weight of bank soils	lb/ft^3
γ_{bed}	Dry specific weight of stream bed substrate	lb/ft^3
γ'_{bed}	Effective buoyant unit weight of stream bed substrate	lb/ft^3
γ_{rock}	Dry unit weight of boulders	lb/ft^3
γ_s	Dry specific weight of soil	lb/ft^3
γ'_s	Effective buoyant unit weight of soil	lb/ft^3
γ_{Td}	Air-dried unit weight of tree (12% MC basis)	lb/ft^3
γ_{Tgr}	Green unit weight of tree	lb/ft^3
γ_w	Specific weight of water at 50ºF	lb/ft^3
η	Rootwad porosity	-
θ	Rootwad (or large end of log) orientation to flow	deg
μ	Coefficient of friction	-
ν	Kinematic viscosity of water at 50ºF	ft/s^2
Σ	Sum of forces	-
ϕ_{bank}	Internal friction angle of bank soils	deg
ϕ_{bed}	Internal friction angle of stream bed substrate	deg

Units

Notation	Description
cfs	Cubic feet per second
ft	Feet
lb	Pound
lbf	Pounds force
kg	Kilograms
m	Meters
mm	Millimeters
s	Seconds
yr	Year

Abbreviations

Notation	Description
ARI	Average return interval
Avg	Average
DBH	Diameter at breast height
deg	Degrees
Dia	Diameter
Dist	Distance
D/S	Downstream
ELJ	Engineered log jam
Ex	Example
Fldpln	Floodplain
H&H	Hydrologic and hydraulic
ID	Identification
i.e.	That is
LB	Left bank
LW	Large wood
Max	Maximum
MC	Moisture content
Min	Minimum
ML	Multi-log
SL	Single log
N/A	Not applicable
no	Number
Pt	Point
rad	Radians
RB	Right bank
RW	Rootwad
SL	Single log
Thw	Thalweg (lowest elevation in channel bed)
Typ	Typical
U.S.	United States
WS	Water surface
WSE	Water surface elevation
↑	Above
↓	Below

Reference Sheet - Anchoring Techniques

Anchor Technique Lookup Table (average holding capacities)

Soil Class	Soil Description	Blow Count (N)
4	Dense gravels; gravel/cobble; very hard silts and clays	40-100+
5	Dense coarse sand; gravel/sand; loose gravels; stiff slits and clays	14-40
6	Loose coarse sand; dense fine sand; firm silts and clays	7-14
7	Loose fine sand; alluvium; soft silts and clays; silty sand	4-8

Notes:

1. All types -- Use this chart for estimation only. Values shown reflect the manufacturer's
User is responsible for verifying load capacities. The true capacity must be tested by pro
2. Installation may be difficult. Pilot hole may be required.
3. Holding capacity limited by working load of anchors.
4. Holding capacity limited by soil failure.
5. Wide variation in soil properties reduces prediction accuracy. Pre-constructed field tes
6. Duckbill anchors are rated in an average (class 5) soil condition. Proof-loading is the c
Anchor holding capacity will vary in different soils. Increased capacities can be expected
classifications) and lower capacity can be expected in the softer soil classes (numerically
7. Platipus Stealth and Bat anchors are given a wide range for holding capacities. The hi
the low value was assigned to class 7 soils. Holding capacities for class 5 and 6 soils we
verifying all rating capacities.

Anchor/Ballast Technique Lookup Table

Technique	Description
Added Soil Ballast	Add coarse material soil lifts on top of structure to increase burial depth
Boulder Ballast	Place boulder on top of structure. Alternatively, secure structure to boulder located beside or beneath structure.
Wood Pile (In development)	Drive or bury vertical wood piles into the bed or banks to brace structure. Alternatively, brace structure against existing large tree.
Mechanical Anchor	Secure structure to soil anchor which uses overlying soil to resist pullout. Alternatively, secure the structure to bedrock using a rock anchor.

Four common alternatives exist for securing or stabilizing placements of large wood in water. In order of preference for habitat formation, they are:
1. No added stability -- where wood is supplied to the stream and allowed to be stable without manipulation or, as conditions develop, moved by the flow.
2. Passive stability -- where the weight and shape of the structure is the anchor, and movement at some flow level is acceptable (includes ballast).
3. Flexible stability -- such as tethering the structure so some degree of movement is allowed with varying flows.
4. Rigid stability -- holding the logs permanently in place with no movement allowed.
(Source: 2012 WA Stream Habitat Restoration Guidelines)

Manta Ray			Stingray			
MR-1 Capacity (lb)	MR-2 Capacity (lb)	MR-SR Capacity (lb)	SR-1 Capacity (lb)	SR-2 Capacity (lb)	SR-3 Capacity (lb)	DB-40 Capacity (lb)
24,000	15,000	32,000	39,000	62,000	85,000	user input
15,000	9,000	18,000	24,000	31,000	48,000	300
10,000	7,000	14,000	16,000	27,000	37,000	user input
8,000	5,000	9,000	13,000	19,000	24,000	user input

minimum expected holding capacity for a given condition.
of-loading. Minimum 2:1 Safety Factor is recommended.

t recommended.
›nly way to insure the exact capacity of each installation.
in harder soil classes (numerically higher blow count
› lower blow count).
gh manufacturer's rating was applied to class 4 soils, while
re interpolated as a guide only. User is responsible for

Duckbill			Platipus Stealth			
DB-68 Capacity (lb)	DB-88 Capacity (lb)	DB-138 Capacity (lb)	P-S02 Capacity (lb)	P-S04 Capacity (lb)	P-S06 Capacity (lb)	P-S08 Capacity (lb)
user input	user input	user input	300	1,000	3,500	4,500
1,100	3,000	5,000	150	600	2,000	2,500
user input	user input	user input	50	300	800	1,500
user input	user input	user input	N/A	200	400	1,000

Platipus Bat					Cu
P-B04T Capacity (lb)	P-B06T Capacity (lb)	P-B08T Capacity (lb)	P-B10T Capacity (lb)	P-B12T Capacity (lb)	Custom#1 Capacity (lb)
6,000	11,000	16,500	22,000	33,000	(user input)
3,500	6,500	9,000	14,000	20,000	(user input)
2,500	4,000	6,500	11,000	16,000	(user input)
2,000	3,500	5,500	9,000	13,000	(user input)

stom (User Selection)	
Custom#2	Custom#3
Capacity (lb)	Capacity (lb)
(user input)	(user input)
(user input)	(user input)
(user input)	(user input)
(user input)	(user input)