Climate Resiliency Planning for Howard County Communities & Ecosystems

Restoration Guidebook

Funded by Transform Howard

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ECOSYSTEM SERVICES

Front cover picture from Lori Lilly

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Prepared for:

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Executive Summary

This restoration guidebook provides information that will assist in the planning, design, implementation, and monitoring of community-scale ecological interventions. These practices may cumulatively improve the resilience of a watershed to climate change. Where applicable, examples of the practices performed as part of the grant deliverables will be referenced and appendices will provide additional information. The projects evaluated are listed in table 1 below and a site map is shown in figure 1. While this guidebook may be shared to other organizations, it is oriented for use by Howard EcoWorks. The guidebook is expected to be adapted and revised as additional experience is gained to incorporate changes in practices, regulations, and lessons-learned.

Ecological interventions, and restoration specifically, seeks to assist in the recovery or establishment of ecosystem functions. While restoring an ecosystem to a historical antecedent may be desired, it is not always possible; because of this, the term restoration will also apply to practices that restore, improve, or establish one or multiple ecological functions. Community-scale restoration is typically performed by volunteers or workforces with minimal professional experience. The practices employed typically require minimal equipment and the initial intervention can be performed in a short time span; however, that does not mean that the effort, hazards, or outcomes of these projects should be underestimated.

Climate resilience refers to the ability of a system or community to accommodate and recover from the impacts of climate related impacts (IPCC, 2014). In this context, ecological interventions oriented towards improving climate resilience tend to address an ecosystem's susceptibility to disturbance. Since a characteristic of high functioning natural systems is that they are resilient, specific references to resilience will be limited within this document. The functions focused on for this guide include landscape water retention, sediment and wood retention, soil productivity, and forest health.

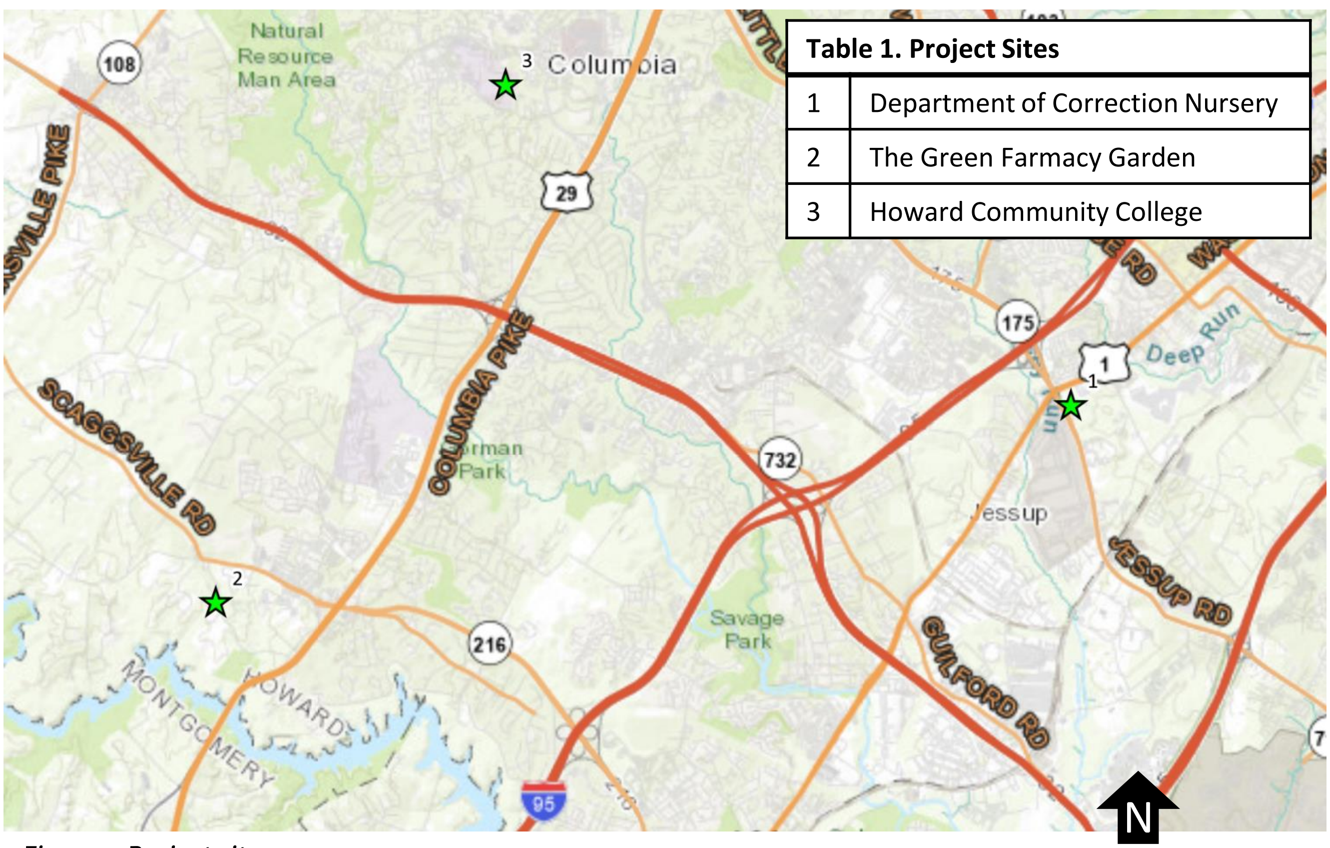

Table 1. Project Sites	
1	Department of Correction Nursery
2	The Green Farmacy Garden
3	Howard Community College

Figure 1. Project sites

Project Overview

Three project sites were identified by Howard EcoWorks to plan and implement ecological interventions. While an intervention was not implemented at each site, steps were taken to the extent practicable to further the planning and design process. These projects are cited within this document where instructive to act as examples of how to navigate the process in real-world settings. A description of each site is provided below.

Site #1: Department of Corrections Nursery
This site was selected because it is currently the site of the EcoWorks nursery and can accommodate additional restoration activities. The site is an adjacent wooded area (see Appendix A) where invasive species management and native planting has already occurred. Due to the presence of wetland species and poorly drained soils, a proposed forested wetland project was identified for this site. Site assessments revealed that wetland restoration/creation would be feasible if hydrology could be maintained. The installation of water control structures at the two downstream road crossings was a design alternative considered. Alternatively, grading could produce a berm around the interior forested area. Due to the need to place water control structures in the right of way, coordination with the entity that owns and operates the road was conducted. The installation of water control structures was deemed unacceptable. At this time, the level of disturbance to produce a wetland through construction of berms was not feasible with the current funding. Land management interventions such as invasive removal and tree planting were determined as a more appropriate intervention.

Site #2: The Green Farmacy
This site was identified because of landowner interest, it is a headwater system, and observations of eroded stream conditions. A stream improvement intervention was selected because of the headwater landscape condition, the severity of the downstream conditions, and the availability of onsite resources. See Appendix B for a site map. Since permitting would be a likely constraint for this project, the extent of ephemeral channel was determined since an intervention could be implemented in this area without additional agency coordination. The Baltimore District of the US Corps of Engineers and Howard County were contacted for permitting consultations. Downstream baseline erosion condition was assessed as a potential indicator of project impact. The stream channel was assessed and determined to lack structure and floodplain or lateral connectivity. A series of Post Assisted Log Structures (PALS) or Beaver Dam Analogs (BDA) were designed for installation along the ephemeral channel. Three of these structures were installed in the channel primarily with onsite material.

Site #3: Howard Community College
This site was identified because of EcoWorks active projects on the campus and their interest in further research. Projects that would improve riparian forest conditions were of interest for this project site because of the prevalence of forest edge, invasive species, and relatively high-quality forest interior. The low percentage of organic material and prevalence of invasive species along the forest edge made management and soil amendment with biochar a suitable intervention at this site. Vegetation plots were inventoried for areas where biochar treatment was proposed and control sites where no action was proposed. Soil moisture was also measured at each plot. Invasive removal was conducted, and the material used to produce biochar using a mobile kiln. Biochar was spread along the forest edge and within the treatment areas. Native plants appropriate to the landscape position were installed after the treatment and soil amendment.

1. Planning & Design

Overview

There are many guidance documents that propose methods for planning different types of environmental and design projects; however, they all follow a general process as outlined in figure 2 below. Each step will be tailored to the specific goals and conditions of the site. And each step is iterative; a later step may require that a previous one is revised – this is part of the planning and design process and should be accounted for at the outset. While small-scale community project, the subject of this guide, may require less detail than an engineered design, each step is still valuable for informing the project and increasing the likelihood of success.

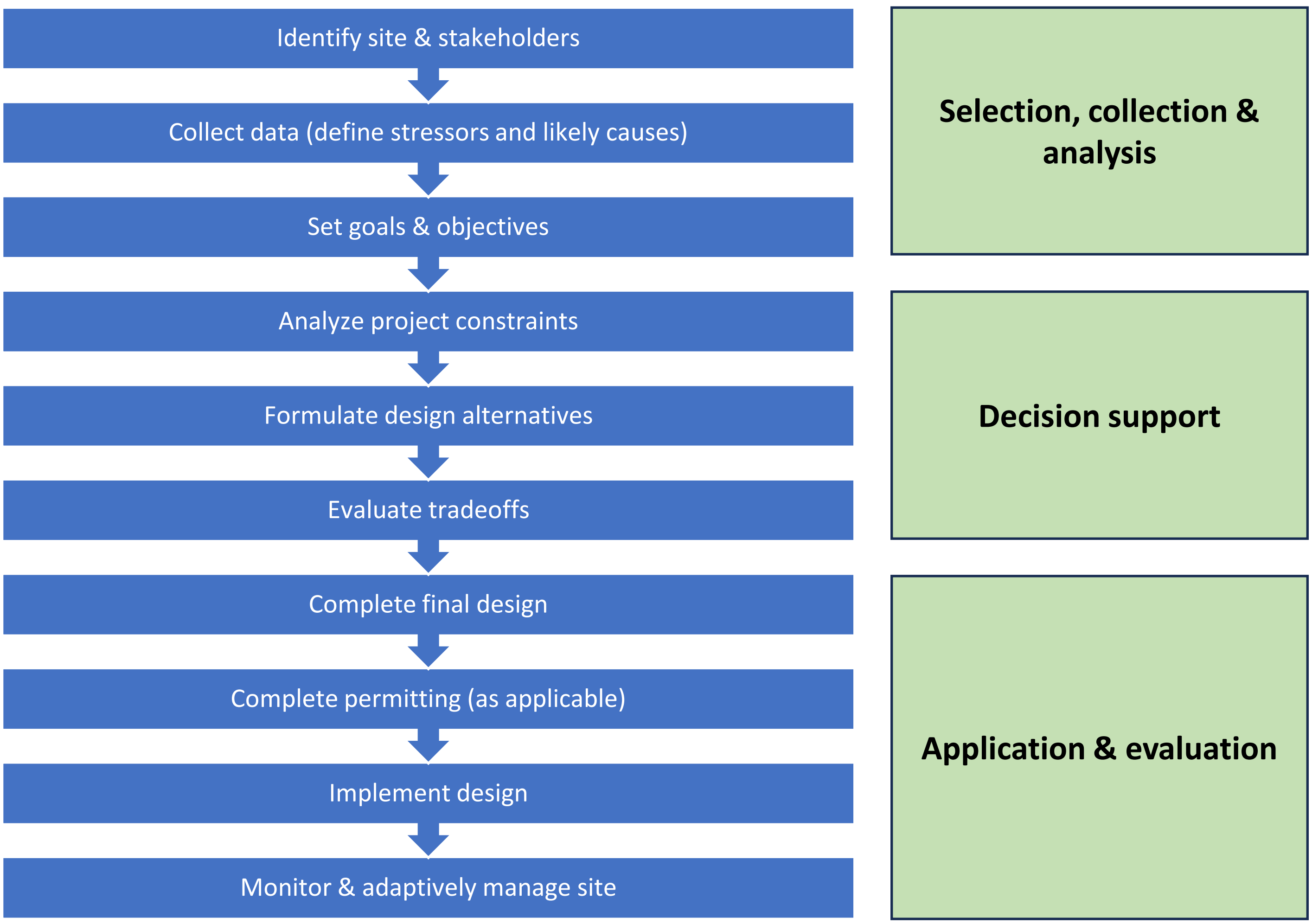

Figure 2. Planning & design process (adapted from NRCS 2007, chapter 2)

Site & Stakeholder Identification

Planning for any ecological intervention should follow the identification of an impairment or stressor to an ecosystem function at a specific site. There are many ways to identify an impairment or likely stressor including visual observation, direct monitoring, historical information, and review of assessment studies and environmental data. If a location was previously the site of a restoration project or if there is active resource management, review all available data such as monitoring reports and in particular the original goals and objectives of the project to help orient future interventions. Many projects are opportunistic, which means that landowners, resource managers, or others identify a site with an issue that they would like addressed. Even in these cases, it is important to conduct a site visit and collect data relevant to categorizing potential stressors that could be responsible for the issue to determine if an intervention is appropriate.

1. Planning & Design

Site & Stakeholder Identification (continued)

During the site identification stage of a project, it is important to identify and engage with potential project stakeholders. Determine their interest, knowledge of the site, and expected level of participation in the process. There may be stakeholders that will desire to be updated on the project or some that would volunteer or provide valuable information in shaping the outcome of an intervention. Project stakeholders are integral to a successful project and frequently are the very arbiters of success.

Data Collection

Collecting watershed and site level data are critical steps in project planning. This information should answer questions about the likely stressors that are leading to or have led to an identified impairment, their associated causes, the project constraints, and the opportunities for restoration. In Howard County, there is a wealth of information that can be collected from publicly available sources. Table 2 below shows some of the relevant data and sources that can be collected from a desktop analysis. Many of these sites have the same data sources, but the table provides highlighted resources that may be of interest for project planning.

Table 2. GIS data for ecological planning

Highlighted Resource	Managed by	Web link
• Aerial photography (historical) • Development & Construction Projects • Flood maps • Green infrastructure maps	Howard County	https://data.howardcountymd.gov/
• Heat vulnerability • Tree canopy • Property boundaries	Howard County	https://data.howardcountymd.gov/InteractiveMap.html#
Watershed studies	Howard County	https://www.howardcountymd.gov/bureau-environmental-services/watershed-management#:~:text=Howard%20County%20lies%20within%20the,drains%20the%20remaining%20one%20quarter
• Watershed • Streams • Wetlands • SSURGO Soils	MERLIN, MDNR	https://maryland.maps.arcgis.com/apps/webappviewer/index.html?id=434b195197364344a661da85c9bab3c9
15-minute & hourly precipitation	NOAA	https://www.ncei.noaa.gov/maps/alltimes/
Precipitation	CoCoRaHS	https://www.cocorahs.org/Maps/

Site level data should also be collected and typically relates to information that will be used in the design process (constraints or opportunities) or data related to the project goals that can be monitored for success. Appendix C provides the data collected for the soil amendment and native planting project site at Howard Community College (Site 3) and Appendix B provides a perenniality determination and Bank Erosion Hazard Index (BEHI) that were needed to investigate the stream at the site.

For any site where digging is proposed or needed for data collection, call 811 for Miss Utility to have utility locations marked prior to digging.

1. Planning & Design

Data Collection (continued)
This section provides some specific guidance related to site specific data collection that is recommended for different interventions.

Soils:
Many previously disturbed soils – whether from urban development, silvicultural and agricultural activities, or restoration sites – may have poor soil health. Understanding soil conditions can help design interventions that can improve native plant conditions, soil microbial processes, soil stability, and carbon sequestration among other benefits to ecosystem services and climate related resilience.

Collecting information about the soils at a prospective site is the first step in determining what, if any, intervention is appropriate. Visual observation noting ponded water, bare ground, or poor vegetation health can be indicators of poor soil health. In addition to visual observations and collecting soils data from a desktop GIS application like MERLIN (see table 2), collecting soil samples for analysis can reveal deficiencies and help identify an appropriate intervention. The table in figure 3 on the following page provides regional soil testing labs. Additional information regarding soil tests can be found at https://extension.umd.edu/resource/soil-testing-and-soil-testing-labs/.

Soil testing should focus on evaluating parameters that are important to the goals of the project, and as such, it is likely that the data collection will come during or after design alternatives have been evaluated. Soil characteristics that are important for resiliency are those that are directly related to hydrologic conditions or the capacity of the soil to support native, healthy vegetation. The former category typically involves the soil's relation to infiltration and runoff while the later category relates to chemical characteristics such as pH and nutrients. Appendix D provides a document titled Interpreting Soil Fertility Analyses that can be used as guidance in understanding soil conditions and preparing soil amendments for a project site.

Compaction can impact plant growth and can be an indicator of soil health. It can be measured using a penetrometer or through bulk density testing. Bulk densities of different soil series can be found using the NRCS SSURGO data from the MERLIN (see table 2) GIS application. This can provide a useful baseline when comparing site specific values to determine the level of compaction for a given soil type. Additionally, soil bulk density is used to determine mass soil loss when conducting erosion rate analyses for streams. The method used to determine site specific bulk density is provided in Appendix D. Soil water content is a related parameter that is derived within the process of determining bulk density and is also useful to evaluate for a project site; however, this parameter is highly dependent on recent precipitation and water table. Alternatively, a soil moisture probe may be used for comparing relative moisture content of soils. Repeated soil testing over a period of time can help track trends and patterns of soil conditions to better understand the conditions at a site and develop an appropriate intervention.

Soil infiltration rate is another useful parameter for understanding how to intervene on a project site. Infiltration rates relate to groundwater recharge – an important ecosystem service. Professional infiltration tests tend to rely on specific equipment such as an infiltrometer or an Amoozemeter; however, simpler methods can be used to get a relative understanding of infiltration rates sufficient for evaluating whether practices that encourage infiltration such as bioretention, rain gardens, or infiltration trenches could be feasible or whether wetland restoration is a more appropriate intervention. These methods typically involve the following steps outlined on the following page.

1. Planning & Design

Data Collection (continued)

Soils:

1. Make sure to test the soil under normal conditions, i.e., not during a drought and not 24-hrs after a storm event.
2. Dig a hole at least 12" deep at the soil stratum of interest. Measure the depth and fill it with water.
3. Allow the water to saturate for at least an hour and refill it.
4. Allow the water to saturate for 24-hrs and measure the depth.
5. Divide the depth drained by 24-hrs to determine the rate in inches per hour.

Guidance varies, but an infiltration rate of 1-inch/hour or more is typically a functional rate for most practices.

Soil testing labs	Soil testing labs
AgroLab, Inc. 101 Clukey Dr. Harrington, DE 19952 **Phone**: 302-566-6094 www.agrolab.us **Basic test includes** pH, P, K, Mg, Ca, CEC, OM	**University of Delaware Soil Testing Program** 152 Townsend Hall 531 S. College Avenue Newark, DE 19717-1303 **Phone:** 302-831-1392 https://www.udel.edu/academics/colleges/canr/cooperative-extension/environmental-stewardship/soil-testing/ **Basic test includes** pH, P, K, Ca, Mg, Mn, Cu, Zn, Fe, B, S, Al, Pb, OM (lead testing included).
Pennsylvania Agricultural Analytical Services Lab Penn State University 111 Ag Analytical Services Lab University Park, PA 16802 **Phone:** 814-863-0841 http://agsci.psu.edu/aasl **Basic test includes** pH, P, K, Ca, Mg Zn, Cu,S	**Spectrum Analytic, Inc.** PO Box 639 1087 Jamison Road NW Washington Court House, OH 43160 **Phone:** 800-321-1562 www.spectrumanalytic.com **Basic test includes** pH, P, K, Ca, Mg, CEC, OM
Waypoint Analytical 7621 Whitepine Rd. Richmond, VA 23237 **Phone:** 804-743-9401 http://www.waypointanalytical.com/ Under soil testing, on the right side of the page, find submittal forms, choose either WA Pennsylvania or WA Virginia-Soil Sample Information Sheet. **Basic test includes** pH, P, K, Ca, Mg, CEC, OM	

Figure 3. Regional soil testing labs (source: https://extension.umd.edu/resource/soil-testing-and-soil-testing-labs/)

1. Planning & Design

Data Collection (continued)

Streams:

Stream corridors can have significant impact on the resiliency of a watershed and are useful indicators of upstream impairments as well. Water quality evaluations, whether utilizing chemical analysis such as water quality sondes, or benthic surveys to determine biotic indexes such as the Maryland Biological Stream Survey, provide useful information on the watershed and stream's condition and its ability to support aquatic life.

Community-scale interventions are more likely to focus on the stream functions of headwater systems higher in the watershed. This is for two reasons: first, stream conditions are cumulative and what happens upstream impacts the downstream condition, so intervening upstream is often the best place to start; and secondly, temporary and permanent impacts to perennial (i.e., streams that flow all year) and intermittent (i.e., streams that flow seasonally) streams are regulated by State and Federal agencies, and require additional permitting, while ephemeral (i.e., flowing only after rain events) streams currently do not. Projects on intermittent and perennial streams may be necessary depending on the level of intervention and goals of the project; however, focusing on headwater systems can yield significant benefits and should be considered first.

Given that flow determinations (i.e., whether a stream is perennial, intermittent, or ephemeral) is a significant factor in the permitting and design of an intervention, it should be evaluated early in the site selection and initial data collection stage of a project. The North Carolina Department of Environmental Quality provides a guidance document with background information and an assessment form (found in Appendix D) that can be used for determinations of stream flow. Additionally, the Baltimore District of the USACE released a public notice recommending use of the EPA's Beta Streamflow Duration Assessment Methods for the Northeast and Southeast. Both of these resources are identified in the resources section of this document. The Beta method has a web application to assist in determining streamflow for a given project:
https://ecosystemplanningrestoration.shinyapps.io/beta_sdam_nese/. It is recommended that both methods be evaluated unless being conducted by an experienced professional.

Fluvial geomorphic parameters (i.e., the physical shape of stream channels due to moving water) can be useful characteristics for evaluating stream corridors and for designing interventions. The following parameters are recommended to be collected for the primary channel being evaluated at a minimum:

- Width
- Depth
- Channel slope
- Valley slope

A full geomorphic survey may be of benefit depending on the intervention being proposed, but this information will be useful for screening projects in combination with desktop information. Additional stream characteristics such as substrate (i.e., streambed material) type size will be collected during the flow determination.

Observations and qualitative surveys of streambank erosion are also useful in determining the suitability of practices. The Bank Erosion Hazard Index (BEHI) is a commonly used assessment for evaluating the likelihood for erosion of a given streambank. The method for conducting this assessment can be found in Appendix D. The BEHI assessment should be used when the goal of an intervention is slowing or preventing erosion.

1. Planning & Design

Data Collection (continued)

Streams:

Other site assessments that may be associated with community-scale interventions include woody debris inventories such as the "Application of the Large Woody Debris Index: A Field Manual" (Harman, 2017). Large woody debris and debris jams are important functional characteristics for stream corridors and relate directly to climate resiliency through the storing and sequestration of carbon, maintaining floodplain connection, and retaining moisture on the landscape among other benefits. In some locations, this can conflict with other management goals, so understanding if there is infrastructure or utilities in the stream corridor that could be impacted by woody debris is necessary and must be part of the data collection as well. Most streams are lacking structure (i.e., woody debris) due to the age of our riparian forests and the well documented removal of wood by colonists and subsequently by farmers and resource managers. Some interventions may focus on adding debris jams, direct felling of riparian trees into a channel, or placing woody debris in the floodplain. An assessment of the woody debris in a stream corridor can provide a baseline for understanding both deficits and improvements after a project is completed.

The Field Manual provides assessment worksheets and a printable field guide for creating an inventory. The worksheet is provided in Appendix D.

Wetlands:

Wetland ecosystems, sometimes referred to as "nature's sponge", are hot-spots of biodiversity, can facilitate carbon sequestration, reduce or process pollutants from upstream runoff, slows and soaks up runoff during wet periods and releases hydrology during periods of low rainfall. In agricultural and urban environments, historic wetlands, or areas that could potentially support wetland conditions, have been drained or managed to encourage runoff downstream and create farmable land. These areas can sometimes be modified to promote wetland conditions. Similar to interventions in stream corridors, data should be collected to identify any infrastructure that conflicts with the proposed conditions. Wetland definitions are based on three criteria: hydrology at or within 1-foot of the surface; hydric soils, or soils adapted to wet conditions; and hydrophytic, or water-loving, vegetation.

Collecting site information associated with these criteria is important for identifying missing characteristics that could be modified to promote wetland conditions. If a site has some wetland vegetation or has buried hydric soils, it's possible that modifying the hydrology – the groundwater level and surface water passing through a site – may be enough to create a wetland ecosystem. Wetland identification can be done by professional wetland scientists to ensure that an area is not already a wetland. The next step would be monitoring the seasonal water level and precipitation. This is done through the installation of a groundwater monitoring well. Onset HOBO Water Level Loggers and rain gauges or equivalents are low-cost methods for monitoring site conditions. A field procedure for launching and installing monitoring equipment is provided in Appendix D.

If the seasonal water level during the growing season is not within one foot of the ground surface for an extended period, it will not support wetland vegetation. By installing monitoring equipment, current water level and precipitation patterns can be documented and analyzed to see if the site would be a good fit for an intervention and also provide baseline information for monitoring an intervention after it is completed.

1. Planning & Design

Data Collection (continued)

Vegetation:

A vegetation survey can provide useful information regarding types of plant communities, composition trajectory, and health. Vegetation should be sampled in homogenous plots large enough to represent the species composition and abundance and should be documented so it is relatively repeatable. Eash stratum should be represented including tree, shrub, and field or herb stratum (see figure 4). Species are documented and the percent canopy cover identified. If cover-scales are used than the Braun-Blanquet cover-abundance scale classes are recommended (see table 3 below). For most restoration applications, identifying if the plant species is considered invasive is important. Depending on the goals of the project, wetland indicator status can be identified as well.

It is recommended to mark the vegetation plot and if possible, take a GPS measurement and record the latitude and longitude.

Table 3

Braun-Blanquet Rating	**Value**
r	<5% cover, very few individuals
+	<5% cover, few individuals
1	<5% cover, numerous individuals
2	5-25% cover
3	25-50% cover
4	50-75% cover
5	>75% cover

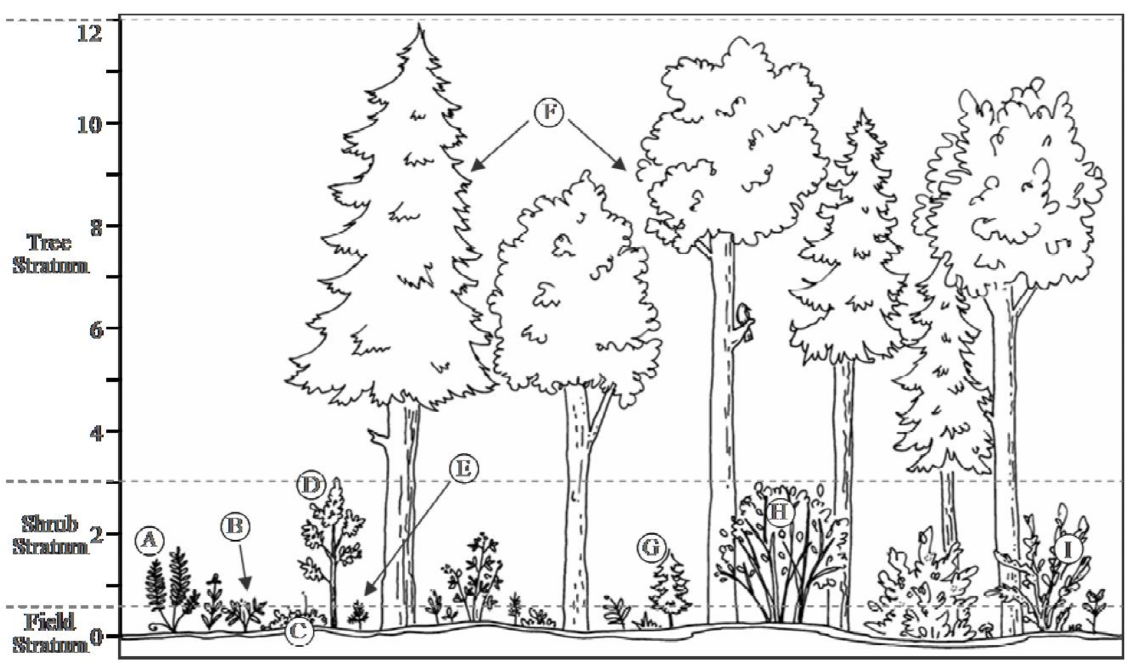

Figure 4. Illustration of strata in a vegetation plot (FGDC, 2008)

1. Planning & Design

Goals & Objectives

Developing goals and objectives should start with determining the ecological endpoint desired for a given ecosystem. Whether the intervention is oriented towards bringing it about in whole or in part, the understanding of what recovery would look like is important for setting realistic project goals. Using the functional framework published by EPA (Harman, 2012) can be a helpful way to categorize data collection and for determining interdependencies that may influence restoration success. Another helpful framework is the Standards for the Practice of Ecological Restoration published by the Society for Ecological Restoration (SER) (Gann, 2019). While the functional framework works best for stream corridor projects, it could be adapted for upland or watershed projects. The ecological restoration standards developed by SER are more general and can be useful for any project. The recovery wheel (see Appendix D) was developed to be tailored to projects while communicating the degree to which each goal can be accomplished or set in motion.

While goals may be less well defined, such as "improve water quality", objectives should be measurable, such as "reduce total suspended sediment by 20-tons/year". Making sure the objective is realistic and achievable, may require additional analysis during the design process and may require additional data collection; however, the additional effort is warranted to ensure that practices are defensible. Even if a project is designed more as an experiment, having an objective to test can be an important step towards understanding how systems will respond to interventions. Measurable objectives can then become part of the monitoring process once a project has been implemented. While the goals and objectives shown in Table 3 are for each individual site, projects focusing on community-scale climate resilience may benefit from being measured for their cumulative effects in addition to the objectives at a more local scale. The objectives may change at larger scales as well and may be more important to the community or project sponsors than the local improvements.

Table 4. Goals & Objectives

Site	Goal	Objectives
1. Dept. of Corrections	• Hydrology/Biology: Create wetland habitat • Biology: Improve native forest conditions	• Create 1-acre of forested wetland habitat • Reduce invasive cover to no more than 5%
2. The Green Farmacy	• Hydrology: Increase flooding • Geomorphology: Reduce downstream erosion	• Increase 1% Annual Exceedance Probability storm flooding by 10% • Prevent headcut from advancing • Reduce BEHI score by one rating in one year
3. Howard Community College	• Biology: Improve forest health	• Reduce invasive cover to no more than 5% • Increase % organic matter to greater than 6%

1. Planning & Design

Project Constraints

After collecting data for the project sites and identifying your goals, the next step is to understand the project constraints. A framework for understanding constraints is to categorize them into environmental, physical, regulatory, legal, social, and economic. The table below provides example constraints that may apply to a project. These categories may be combined or reorganized as needed for the specific project. Since project constraints can significantly alter a project or prevent it from moving forward, it is important to consider project constraints when collecting data and developing goals for a potential project. In a way, these three steps are best performed somewhat concurrently. For example, during the data collection stage of planning for site 1, Department of Corrections, it was determined that work would be required in the road right of way. Coordination with the entity that owns and manages the road revealed that this work would not be allowed. This very quickly required that the project either be modified or discontinued.

Table 5. Potential Project Constraints

Constraint Type	Project Constraint
Environmental	• Invasive species • Local wildlife • High quality forest/wetland/streams • Climatological conditions (precipitation, temperature, etc.) • Beaver activity • Water quality • Watershed land cover conditions • Soil properties/conditions (infiltration, compaction, moisture content, etc.)
Physical	• Infrastructure (utility lines, roads, culverts, etc.) • Geology & bedrock • Steep slopes • Dams (historic or active)
Regulatory	• Jurisdictional waters (regulated streams and wetlands) • Riparian forest • Land disturbance thresholds • Threatened & endangered species • Historic resources • Flow releases (from upstream regulated dams) • Regulatory floodplains
Legal	• Easements • Land ownership • Dam operation
Social	• Aesthetic preferences • Environmental expectations • Community organizations • Land uses (historic or current) • Political perceptions • Employment opportunities
Economic	• Funding opportunities • Results from cost-benefit analysis • Economic impact • Maintenance costs

1. Planning & Design

Design

Design should be oriented around the goals of the project and is an iterative process. Identifying design alternatives should be a first step in the process. The design alternatives are frequently different stages along the trajectory to a desired endpoint (i.e., the project goal). For example, at Site #2, the Green Farmacy, the stream improvement design alternatives could range from changing watershed land cover to a fully engineered stream corridor restoration. These design alternatives could all have the same endpoint of a healthy stream and floodplain condition defined by a high frequency of floodplain inundation, appropriate riparian forest composition and density, low stream erosion, and optimal habitat conditions. A more invasive restoration approach is not necessarily better or worse but the cost, disturbance, permitting, and other factors are all likely different. Depending on the system, "no action" may be a reasonable design alternative and should generally be considered. This is because natural systems may equilibrate to conditions that are ecologically beneficial; however, the time scale that is acceptable and disturbance regime required for this recovery should be considered in the context of the design goal. If greater intervention is warranted, then the design process can proceed to consider more invasive approaches. Adding structure (i.e., woody material) to a stream may encourage deposition, floodplain access, and habitat development. Planting may improve native forest composition. More engineered solutions may be required to speed up recovery of a system if time scales for natural recovery or more process-based solutions will not achieve the desired goals. The Restorative Continuum is a helpful graphic from SER for conceptualizing the different endpoints that ecological goals may intend to bring about (see figure 3 below).

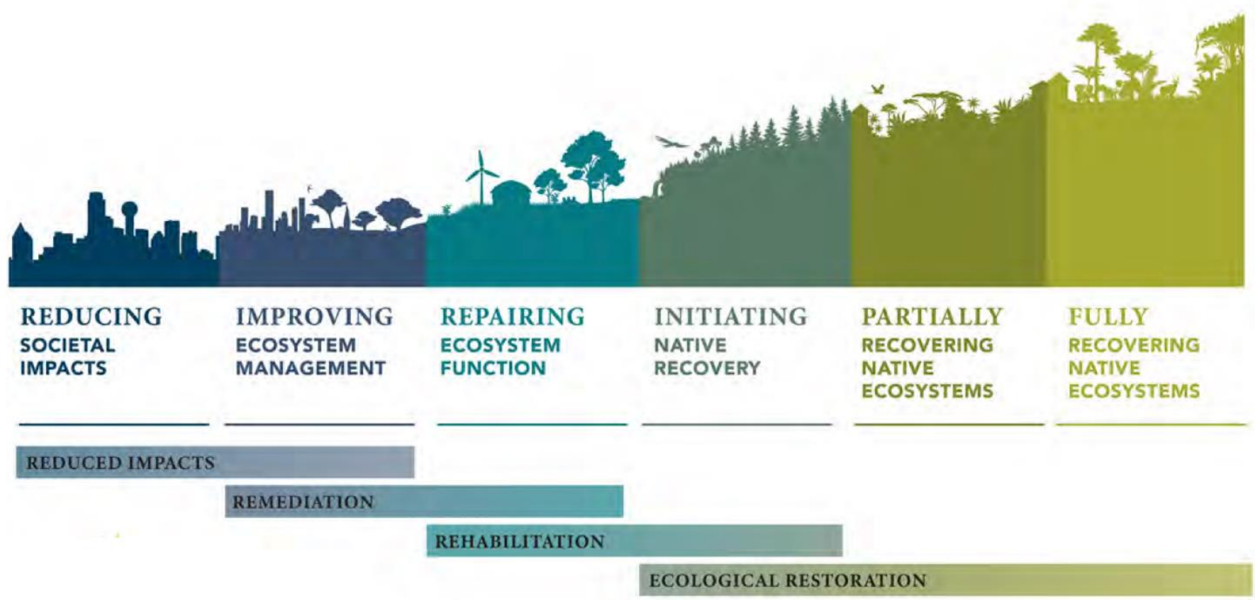

Figure 5. SER Restorative Continuum (Gann, 2019)

Most community-scale interventions are going to fall in the *reduce/mitigate impacts* through *initiating recovery* on the continuum. Guidance for restoration design changes over time and can vary significantly depending on the goals and constraints of a project. Even if a single community-scale intervention does not achieve the desired end-point, cumulatively these practices can have a wider impact towards greater climate resilience. Implementing multiple types of interventions within a single watershed can also be a successful approach and is frequently referred to as a "watershed approach". Fundamental to this approach is minimizing impacts from the causal sources of impairment or ecosystem stressors while initiating downstream recovery.

1. Planning & Design

Design

This document does not provide design standards for each possible intervention; however, table 5 below provides a list of the common types of interventions and their basis of design. The references section of this document has links where possible to design standards and guidance documents that can help with the design process. Consulting with a design professional is also recommended, particularly for more complicated interventions or where substantial permitting is required. That said, community-scale interventions that pose little risk of unintended consequences can be implemented by volunteers and non-professionals in many cases.

Table 6. Community-scale Ecological Interventions

Type	Intervention	Basis of design
Management	• Invasive species removal • Regenerative agriculture • Cattle exclusion fencing • Mowing changes • Nutrient management • Source reduction • Rainwater harvesting	• Practice guidance • Reference ecosystem • Regulatory guidance • Total Maximum Daily Load (TMDL)
Landcover	• Impervious reduction • Upland reforestation • Meadow restoration • Riparian buffer installation	• Reference ecosystem • Native plant guidance
Resource Amendments	• Soil amendments (e.g. compost, biochar) • Large woody debris addition • Direct felling	• Reference ecosystem • Soil testing • Resource surveys
Low-tech Process Based Restoration	• Post Assisted Log Structure (PALS) • Beaver Dam Analogs (BDA) • Water control structures • Removal of drainpipes • Livestake or plug installation • Streambank stabilization	• Reference ecosystem • Geomorphic analysis • Water budget • Large woody debris index • Analytic design (modeling)
Green Infrastructure	• Rain gardens or bioretention • Downspout disconnection • Urban tree planting	• Best Management Practice (BMP) manuals

1. Planning & Design

Evaluation of Tradeoffs

Each design alternative can be weighed against their associated tradeoffs. The list of constraints is a helpful inventory for evaluating a design alternative's impact to each item. For example, Site #1 at the Dept. of Corrections, had to evaluate tradeoffs between level of disturbance and hydrologic retention. Decisions about tradeoffs are not always static and if conditions change, tradeoffs that were once unacceptable may be acceptable in the future.

Evaluating tradeoffs, and making decisions knowing that tradeoffs are inevitable, requires a level of compromise. There are excellent guidance manuals for navigating compromises and unintended consequences including documents such as the Center for Watershed Protection's *Maintaining Forests in Stream Corridor Restoration* (Fraley-McNeal, 2022).

Documenting tradeoffs associated with benefits and impacts through the development of a multi-criterion decision analysis tool is another method for evaluating alternatives. Whether formal or informal, it is best to be clear about the tradeoffs and avoid making assumptions about what is acceptable to communities, project funders, and other stakeholders.

It is important to avoid moving forward with a design just because of the effort that has been expended on a project thus far – the sunk-cost fallacy. While it can be disappointing, if a design approach has unacceptable tradeoffs, because of project location, community feedback, regulatory implications, or other project characteristics, it is best to stop.

Complete Final Design

If a design decision has been made and the tradeoffs are acceptable, the final design can be completed. This may require additional data collection to add detail for implementation or for permitting requirements. If there are any data gaps needed for successful implementation, these can be evaluated or collected during this stage.

The final design should be detailed enough to clearly communicate the design intent, the required materials and specifications, the spatial extents, and any conditions necessary for successful implementation. Diagrams, plans, details, and narratives are all helpful design documents. Google Earth or other free GIS programs can be helpful for determining the spatial extents of a practice.

For more complicated design projects, particularly ones that require significant regulatory coordination, a professional will likely be needed to prepare design plans. However, if the previous steps have been taken and the information can be organized in a detailed scope of services, costs for restoration design professionals can be significantly reduced. Additionally, community-scale restoration details for a particular setting or watershed may be repeated within the area where it is applicable rather than needing custom designs for each location. Care should be taken to ensure that the design is applicable; however, this model has been successful for Best Management Practices in certain settings. Appendix E provides some typical details associated with ecological interventions.

1. Planning & Design

Permitting

Permits may be required for ecological intervention and should be identified during the design alternative and tradeoff evaluation stage. While professionals will be needed for most projects that require permitting, understanding when permits are required, and the associated steps can save money and time. Since many interventions involve work in sensitive areas such as streams and wetlands and riparian forests, coordinating with agencies that regulate these areas is crucial. Regulatory agencies can provide helpful guidance and sometimes will even perform site visits or review preliminary material to determine whether a permit is required.

Jurisdictional waters are streams and wetlands that are protected by State and Federal law or regulations. To determine if a resource is jurisdictional, you will likely need to coordinate with a professional that can complete a Jurisdictional Determination, sometimes also referred to as a wetland delineation. This process may also involve completing a perennial flow determination (see Appendix D). Depending on the practice, interventions in ephemeral streams may not require a permit. While impacts to jurisdictional resources may be permitted for ecological interventions, coordination with agencies is required to attain permit coverage. Permits may also be required for disturbances or activities above a certain threshold or in protected areas such as floodplains and riparian areas. Table 6 below provides a summary permits that may be required for ecological interventions. This list is not exhaustive, and coordination with agencies is recommended to ensure that the project can be implemented.

Table 7. Typical Permits & Regulatory Processes for Ecological Interventions

Type	Agency	When it is required
Grading & Sediment Control Plan	Howard Soil Conservation District	Disturbances that are cumulatively greater than 5,000 SF, greater than 100 CY of cut/fill, or greater than 100 ft of trench
Site Development Plan or Necessary Disturbance	Howard County	Disturbances in regulatory floodplain or construction of stream restoration or drainage improvements
General Permit 6	US Army Corps of Engineers	Temporary or permanent impacts to jurisdictional waters: https://www.nab.usace.army.mil/Portals/63/MDSPGP-6%20Permit%20Final%20with%20Appendicies%2020210930.pdf
TMDL Regional General Permit	US Army Corps of Engineers	Temporary or permanent impacts to jurisdictional waters for a TMDL project: https://www.nab.usace.army.mil/Portals/63/NAB-2019-00527_TMDL_RGP_1.PDF
Nationwide 27	US Army Corps of Engineers	Temporary or permanent impacts to jurisdictional waters for habitat restoration:

2. Implementation

Once a design alternative has been selected and applicable permits have been acquired, the project is ready for implementation. Successful implementation requires preparation. Below are some items that should be considered prior to implementing any project.

1. Safety: Make sure that workers are trained in safety protocols, understand how to use the required equipment, have Personal Protective Equipment (PPE) such as gloves, hardhat, eye/ear protection, and boots. First aid kits and equipment should also be available. Working in stream corridors and natural areas can have their own specific considerations such as ticks, poisonous or hazardous insects and animals, poison ivy and other hazardous vegetation, risk of flooding or swift water, risk of landslides or collapsing streambanks, risk of falls, and risk of tree limb falls. If working in wadable streams, workers should understand the risk of drowning and depending on the water quality conditions, the risk of infection or exposure to pollutants. Wilderness First Aid Training is recommended for crew leaders if possible. Invasive species treatment requiring herbicide application should only be done by certified applicators; however, if others are working these areas, they should be made aware of the dangers and specific safety protocols.
2. Weather: Check the weather conditions and be sure to prepare accordingly. For most projects, precipitation of any kind will delay work; however, drought or drier than normal conditions may not be optimal for implementation either, particularly for planting. Precaution should be taken if extreme heat or cold is forecasted.
3. Design: Review the design together with workers to go over key components, sequence, and overall approach and desired end-points. It may be surprising, but small changes in how someone works can have a significant impact on project outcomes. Community-scale restoration may have less detail associated with design plans, so making sure that questions are answered in advance will help speed up the process and avoid mistakes.
4. Tools & equipment: Prepare the needed tools and equipment, and confirm that workers have experience working with them or are trained prior to implementation. Further guidance on equipment for Low-Tech practices is provided in Appendix B.
5. Materials: Requirements for building materials will vary depending on the project. The design should be consulted to determine and quantify the needed materials. Onsite materials are preferred for most ecological interventions; however, care should be taken to not impact or create unnecessary disturbance while harvesting onsite materials. Additional permitting may be required depending on where materials are located. Further guidance on materials for Low-Tech practices is provided in Appendix B.

Developing checklists appropriate for the type of intervention is suggested. These will help reduce trips and reduce the likelihood of accidents. Of the community-scale restoration projects discussed in this document, beaver dam analogs (BDAs) or post assisted log structures (PALS) are likely the most complex interventions followed by wetland water control structures. Green infrastructure or stormwater facilities are also complicated and may require heavy equipment. When undertaking these projects, it is suggested to develop site specific construction sequences and quantities of building materials. Chapter 5 of the Low-Tech Process-Based Restoration of Riverscapes (Wheaton, 2019) provides specific guidance for the installation of BDAs and PALS. Appendix E has common low-tech details that may be adapted to project specific conditions.

3. Monitoring & Adaptive Management

Monitoring methods will vary from project to project, but frequently they will repeat those utilized during the data collection phase of the project. Monitoring should be specific to the project goals and will frequently involve collecting data associated with the basis of design. For example, for vegetative interventions, collecting data about invasive species or species composition will help document any changes or needed adaptive management. Community-scale restoration projects rely on adaptive management for success. This recognizes the complexity of intervening in natural systems and the fact that even with considerable expertise, "over-planning" can be a wasted effort. If projects require permitting, regulatory agencies may prescribe monitoring methods.

For all projects, visual and photographic monitoring is recommended. Photographic stations marked in the field or noted by latitude and longitude can be a useful method for tracking changes over time. Seasonal photographs or taking photographs at the same time each year is also recommended.

When projects are conducted in stream corridors, it is important to monitor conditions after significant rain events. While developed for engineered restoration projects, the Fish and Wildlife Service's rapid stream monitoring protocol is a useful framework for evaluating riparian and stream conditions through a qualitative and consequential scoring methodology (Davis, 2014). This method does not require significant measurements and can be completed quickly in the field.

For interventions associated with planting and soil amendments, the frequency of direct monitoring can be important to detect changes in conditions. In place of these methods, utilizing indicators such as plant community composition, growth observations, and percent canopy cover can be an indirect measurement of success and more related to the goals of a project.

Adaptive management and corrective action refer to altering, adding, or removing elements of a restoration intervention. It is not possible to be provide a comprehensive list of potential adaptive management techniques. It is recommended to prioritize the project goals when conducting adaptive management and not get stuck trying to adapt a non-functional element in a project. A benefit of community-scale restoration is that the practices can be completed more quickly and more numerously than traditional engineered practices. For this reason, it is recommended to manage projects to ensure they are performing in the general trajectory of restoration goals instead of requiring that they meet strict metrics of success.

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Appendix A: Dept. of Corrections Nursery (Project 1)

Contents

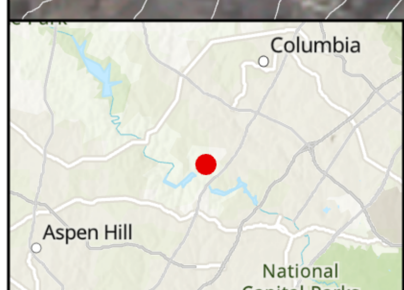
- Site map

Legend
Contours (1-ft)
Buildings
Parcel Lines
Maryland SSURGO Soils
Proposed Wetland (1-acre)
Outlet
WATERLOO RD
Columbia
Dept. of Corrections
County of Anne Arundel, VITA, Esri, HERE, Garmin, INCREMENT P, USGS, EPA, USDA, County of Anne Arundel, VGIN, Esri, TomTom, Garmin, SafeGraph, FAO, METI/NASA, USGS, EPA, NPS, USFWS, Esri, NASA, NGA, USGS, MD iMAP, The U.S. Department of Agriculture, Natural Resources Conservation Service, should be acknowledged as the data
N
0
50
100
US Feet

Appendix B: The Green Farmacy Stream Improvement (Project 2)

Contents

- Site Map
- Installation Photographs
- Perennial Flow Determination Form
- BEHI Form
- BDA Detail & Example Photographs



FARMACY STREAM IMPROVEMENT

ECOSYSTEM SERVICES | Howard County, Maryland

1102 Carlton Ave. Charlottesville, VA 22902 | 540.239.1428 | www.ecosystemservices.us

Legend

- Ephemeral Stream
- Contours (1-ft)
- Streams (Howard County)
- BDA
- Buildings
- Parcel Lines
- MD_SixInchImagery

N

0 25 50 US Feet

Post Assisted Log Structure (PALS) or Beaver Dam Analog(BDA) Installation

caption

Post Assisted Log Structure (PALS) or Beaver Dam Analog(BDA) Installation

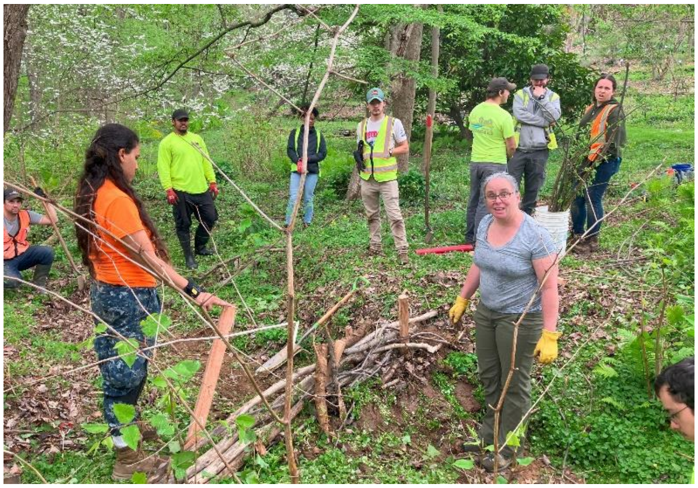





Post Assisted Log Structure (PALS) or Beaver Dam Analog(BDA) Installation





NC DWQ Stream Identification Form Version 4.11

Date: 12/5/2023	Project/Site: Farmacy	Latitude:
Evaluator: WKM	County: 12/5/2023	Longitude:
Total Points: *Stream is at least intermittent if ≥ 19 or perennial if ≥ 30** 13.5	Stream Determination (circle one) **Ephemeral** Intermittent Perennial	Other *e.g. Quad Name*:

A. Geomorphology (Subtotal = 8.5)	Absent	Weak	Moderate	Strong
1[a] Continuity of channel bed and bank	0	1	**2**	3
2. Sinuosity of channel along thalweg	0	**1**	2	3
3. In-channel structure: ex. riffle-pool, step-pool, ripple-pool sequence	**0**	1	2	3
4. Particle size of stream substrate	0	**1**	2	3
5. Active/relict floodplain	0	1	**2**	3
6. Depositional bars or benches	**0**	1	2	3
7. Recent alluvial deposits	0	**1**	2	3
8. Headcuts	**0**	1	2	3
9. Grade control	0	**0.5**	1	1.5
10. Natural valley	0	0.5	**1**	1.5
11. Second or greater order channel	**No = 0**		Yes = 3	

[a] artificial ditches are not rated; see discussions in manual

B. Hydrology (Subtotal = 3)	Absent	Weak	Moderate	Strong
12. Presence of Baseflow	0	**1**	2	3
13. Iron oxidizing bacteria	**0**	1	2	3
14. Leaf litter	1.5	**1**	0.5	0
15. Sediment on plants or debris	0	**0.5**	1	1.5
16. Organic debris lines or piles	0	**0.5**	1	1.5
17. Soil-based evidence of high water table?	**No = 0**		Yes = 3	

C. Biology (Subtotal = 2)	Absent	Weak	Moderate	Strong
18. Fibrous roots in streambed	3	2	**1**	0
19. Rooted upland plants in streambed	3	2	**1**	0
20. Macrobenthos (note diversity and abundance)	**0**	1	2	3
21. Aquatic Mollusks	**0**	1	2	3
22. Fish	**0**	0.5	1	1.5
23. Crayfish	**0**	0.5	1	1.5
24. Amphibians	**0**	0.5	1	1.5
25. Algae	**0**	0.5	1	1.5
26. Wetland plants in streambed	FACW = 0.75; OBL = 1.5 **Other = 0**			

*perennial streams may also be identified using other methods. See p. 35 of manual.

Notes:

Sketch:

The Green Farmacy: Downstream

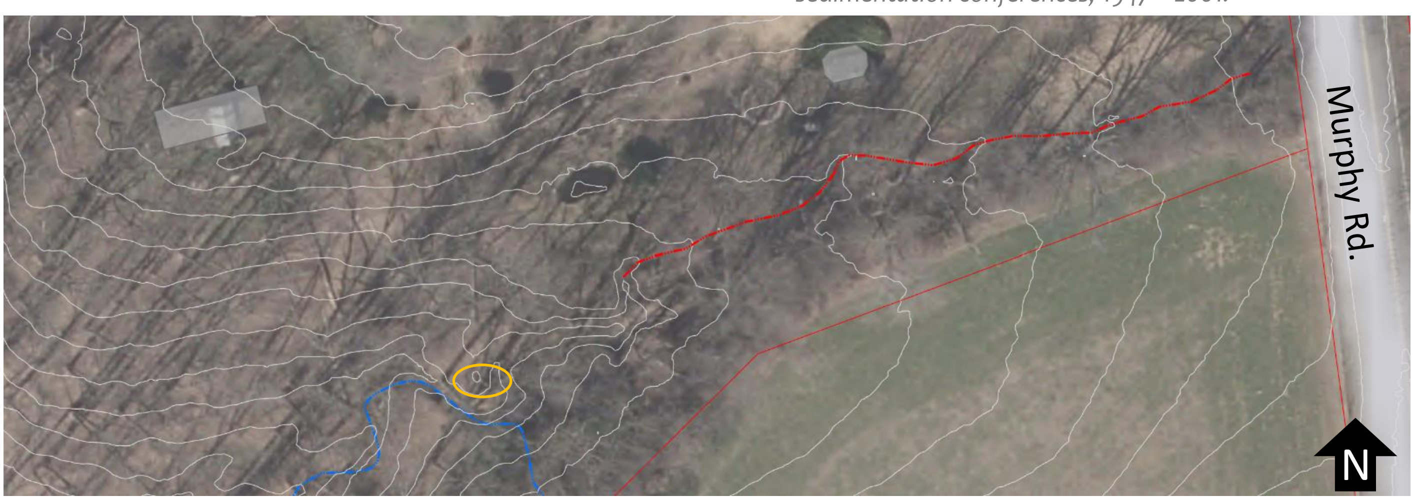
Stream:	UT to the Patuxent River	Location:	
Station:	NA	Bank:	Left
Survey Date:	4/18/2024	Region:	Piedmont

Field Measurements		Calculation		BEHI Score
Study bank height (ft) =	7.5	Study bank height / Bankfull height =	15	10
Bankfull height (ft) =	0.5			
Root depth (ft) =	0.83	Root depth / Study bank height=	0.11	8.3
Root density (%) =	30	Density x (root depth / bank height) =	3.32	10
Bank angle (°) =	80			5.9
Surface protection (%) =	20			7.2

Looking upstream

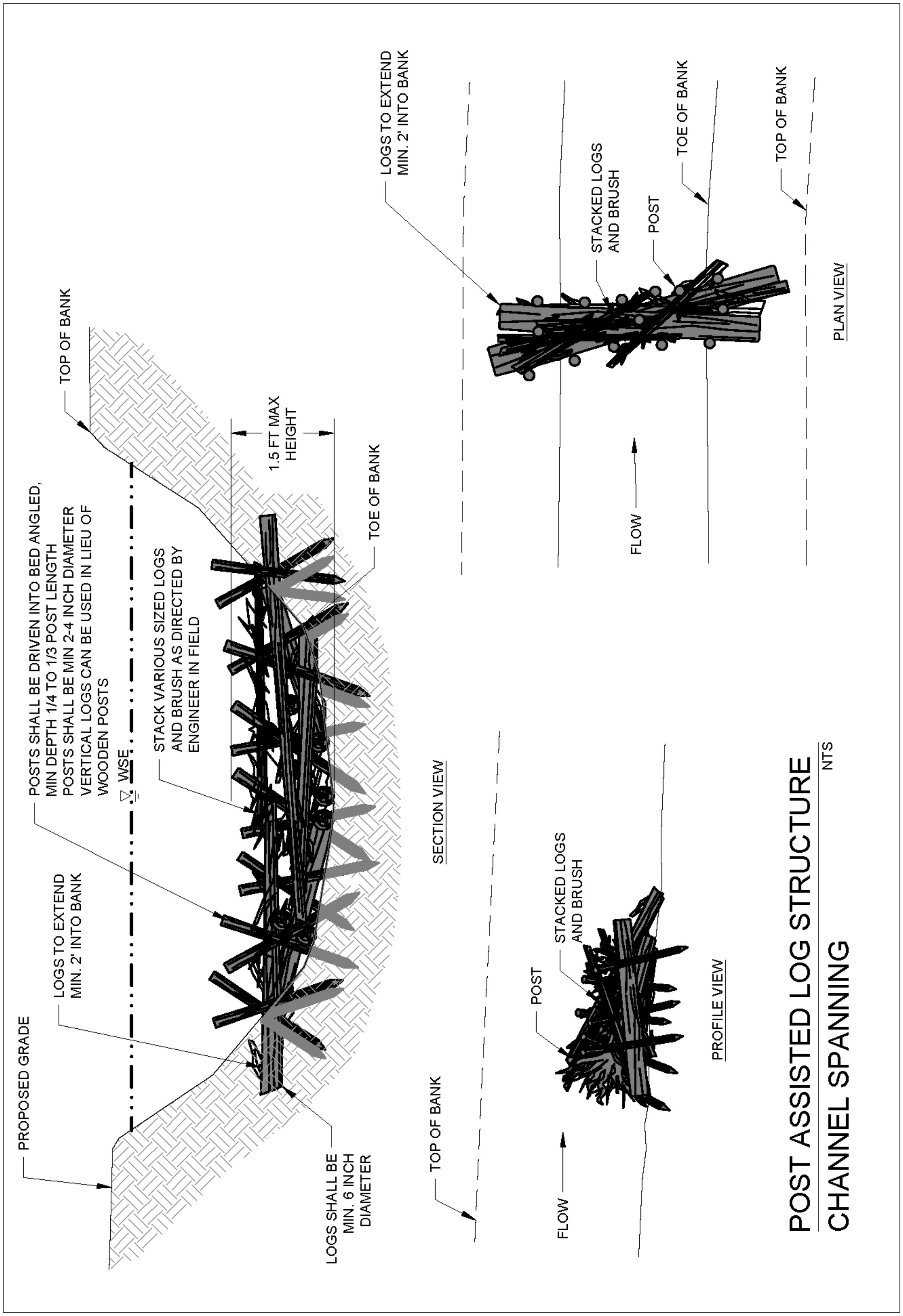
Bank material adjustment:	0
Stratification adjustment:	0
Total BEHI Score =	41.5
Adjective Rating:	Very High

Source: Rosgen, D.L. 2001. A practical method to predict stream bank erosion. In: U.S. Subcommittee on Sedimentation. Proceedings of the federal interagency sedimentation conferences, 1947 – 2001.



Yellow oval shows the general location of the streambank assessed

Beaver Dam Analog (BDA) Detail



BDA Example Photo

Equipment List

A) Safety Gear > **Gloves, First Aid Kit, Hard Hat, eye/ear protection, closed toe work boots, full gloves**

B) Hand Tools – Cutting & Digging

- **Shovels, picks, digging bars and 5-gallon plastic buckets** – for digging**,** gathering and moving materials

- **Clippers, lopers handsaws, chainsaws, brush cutters –** for cutting and harvesting shrub and woody material, trimming posts; chainsaws can also be used for felling trees to create instant wood structures.

- **Razorbade, knife –** for cutting matting in sections

- **Griphoist** – for pulling in or over trees, dead snags, and/or down trees

See [USGS Handtools for Trail Work] for additional information

C) Loading and Moving Material

- **Wheel barrow, Trailer, Log Hauler, Buckets**

D) Post Driver Options

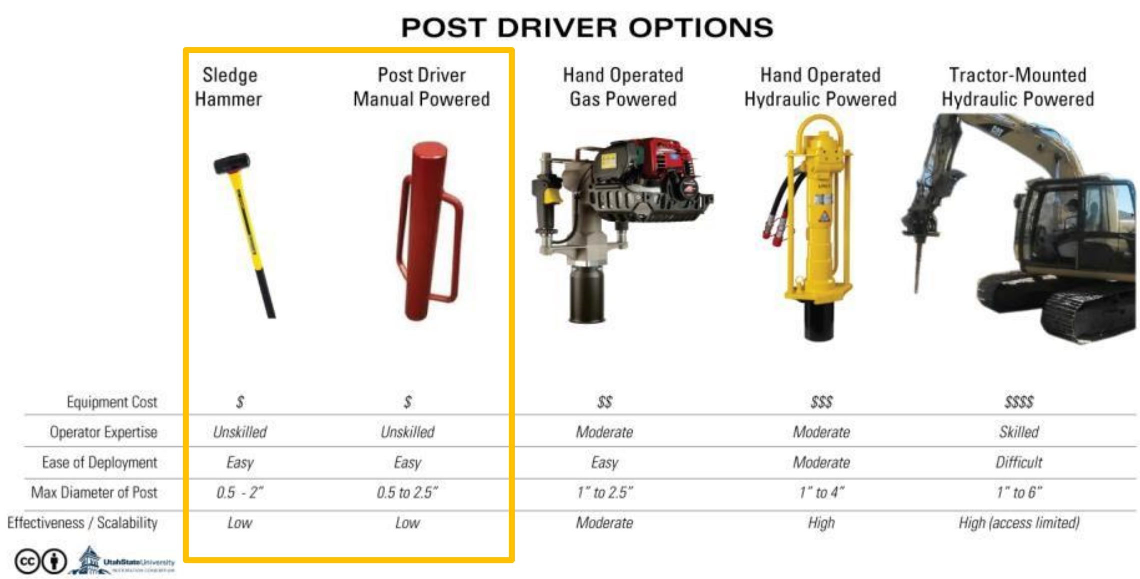


Figure 16 – Post drivers come in a huge variety of options, but each have tradeoffs in terms of equipment cost, operator expertise required, ease of deployment, maximum diameter of posts they can drive (varies with substrate) and their overall effectiveness and scalability when doing 10's to 100's of structures over many miles of streams.

Materials List

A) Wood Material
  - Posts – for vertical posts to be driven into bed using post driver
  - Brush – smaller wood material to be woven around vertical posts
  - Leaf Matter/Channel & Bank sediment – to be used as backfill around structure

B) Natural Fiber Matting – to be used on upstream face of structure
  - Double layered biodegradable erosion control fabric made up of an outer layer of high strength coir fabric and an inner layer of lightweight jute fabric tied together at regular intervals

KoirMat™ 400

Technical Specification of KoirMat™ 400

KoirMat™ 700

Technical Specification of KoirMat™ 700

KoirMat™ 900

KoirMat™ 1000

Appendix C: Howard Community College Forest Health (Project 3)

Contents

- Site Map
- Vegetation Plots
- Soil Analysis


Legend
Vegetation Plots
Streams (Howard County)
Control Plot #1
Control Plot #2
Field 2 Plot 2
Field 2 plot 1
Field 1 Plot 2
Field 1 plot 1
Columbia
Howard Community College
Baltimore County Government, VITA, Esri, HERE, Garmin, INCREMENT P, USGS, EPA, USDA, Baltimore County Government, VGIN, Esri, TomTom, Garmin, SafeGraph, FAO, METI/NASA, USGS, EPA, NPS, USFWS, Esri, NASA, NGA, USGS, Source: U.S. Census Bureau, MD iMAP, DoIT
N
US Feet
0
60
120

Vegetation Plots: Field 1

Field 1, Plot 1			
Location: Forest Edge			
Scientific Name	**Common Name**	**Percent Cover**	**Notes**
Invasive Species			
Alliaria petiolata	Garlic mustard	<1%	Individual plants around plot
Berberis thunbergii	Japanese barberry	5%	Small individualy shrubs
Lonicera japonica	Japanese honeysuckle	5%	Small individual vines, mostly on ground
Microstegium vimeneum	Japanese stiltgrass	40%	Scattered populations throughout plot. Forms dense mats
Rosa multiflora	Multiflora rose	<1%	Individual plants around plot
Non-Invasive Species			
Geum canadense	White avens		Native
Lindera benzoin	Northern spicebush		Native
Liriodendron tulipfera	Tulip poplar		Native

Field 1, Plot 2			
Location: Forest edge/interior near access road. Land distrubance around area.			
Scientific Name	**Common Name**	**Percent Cover**	**Notes**
Invasive Species			
Alliaria petiolata	Garlic mustard	10%	Individual plants around plot
Eleagnus umbellata	Autumn olive	60%	Small individualy shrubs
Lonicera japonica	Japanese honeysuckle	10%	Small individual vines, mostly on ground
Microstegium vimeneum	Japanese stiltgrass	40%	Scattered populations throughout plot. Forms dense mats
Rosa multiflora	Multiflora rose	<1%	Individual plants around plot
Non-Invasive Species			
Prunus serotina	Black Cherry		Native
Cinna arundinacea	Wood reedgrass		Native
Vitis riparius	Riparian grape		Native
Lindera benzoin	Northern spicebush		Native
Vitis riparius	Riparian grape		Native

Vegetation Plots: Field 2

Field 2, Plot 1			
Location: Interior Forest			
Scientific Name	**Common Name**	**Percent Cover**	**Notes**
Invasive Species			
Eleagnus umbellata	Autumn olive	20%	Small individualy shrubs
Lonicera japonica	Japanese honeysuckle	10%	Small individual vines, mostly on ground
Microstegium vimeneum	Japanese stiltgrass	60%	Dense monocultures throughout
Rosa multiflora	Multiflora rose	<1%	Individual plants around plot
Non-Invasive Species			
Acer rubrum	Red maple		Native
Danthonia spicata	Poverty oat-grass		Native
Lindera benzoin	Northern spicebush		Native
Smilax rotundifolia	Common greenbriar		Native
Vitis riparius	Riparian grape		Native

Field 2, Plot 2			
Location: Forest Edge			
Scientific Name	**Common Name**	**Percent Cover**	**Notes**
Invasive Species			
Alliaria petiolata	Garlic mustard	<1%	Individual plants throughout plot
Eleagnus umbellata	Autumn olive	40%	Small individualy shrubs
Lonicera japonica	Japanese honeysuckle	20%	Small individual vines, mostly on ground
Microstegium vimeneum	Japanese stiltgrass	100%	Scattered populations throughout plot. Forms dense mats
Rosa multiflora	Multiflora rose	<1%	Individual plants around plot
Non-Invasive Species			
Allium vineale	Field garlic		Non-native
Crataegus sp.	Hawthorne sp.		Native
Prunus serotina	Black cherry		Native

Vegetation Plots: Control

Control Plot #1			
Location: Forest Edge			
Scientific Name	**Common Name**	**Percent Cover**	**Notes**
Invasive Species			
Alliaria petiolata	Garlic mustard	<1%	Individual plants throughout plot
Eleagnus umbellata	Autumn olive	50%	Small individualy shrubs
Lonicera japonica	Japanese honeysuckle	10%	Small individual vines, mostly on ground
Microstegium vimeneum	Japanese stiltgrass	20%	Dense monocultures throughout
Rosa multiflora	Multiflora rose	<1%	Individual plants throughout plot at ground level
Rubus phoenicolasius	Wineberry	<1%	Individual plants around plot
Non-Invasive Species			
Acer rubrum	Red maple		Native
Geum canadense	White avens		Native
Lindera benzoin	Northern spicebush		Native
Rubus allegheniensis	Allegheny blackberry		Native
Smilax rotundifolia	Common greenbriar		Native
Vitis riparius	Riparian grape		Native

Control Plot #2			
Location: Interior Forest			
Scientific Name	**Common Name**	**Percent Cover**	**Notes**
Invasive Species			
Alliaria petiolata	Garlic mustard	<1%	Individual plants throughout plot
Celastrus orbiculatus	Asiatic bittersweet	5%	Small vines climbing mature trees
Eleagnus umbellata	Autumn olive	20%	Small individualy shrubs
Lonicera japonica	Japanese honeysuckle	20%	Small individual vines, climbing mature trees
Microstegium vimeneum	Japanese stiltgrass	100%	Dense monocultures throughout entire plot covering 100% of the herbaceous layer.
Rosa multiflora	Multiflora rose	<1%	Individual plants throughout plot at ground level
Rubus phoenicolasius	Wineberry	5%	Small scattered populations
Non-Invasive Species			
Allium vineale	Field garlic		Non-native
Crataegus sp.	Hawthorne sp.		Native
Geum canadense	White avens		Native
Liriodendron tulipfera	Tulip poplar		Native

Report Number: 24-012-1181
Account Number: 10940

Send To: Eco System Services
Jon
1102 Carlton Ave
Charlottesville VA 22902

Waypoint ANALYTICAL

7621 Whitepine Road, Richmond, VA 23237
Main 804-743-9401 ° Fax 804-271-6446
www.waypointanalytical.com

"Every acre...Every year."™

Grower: HCEW

SOIL ANALYSIS REPORT

Analytical Method(s): Mehlich 3 SMP Buffer pH Loss On Ignition Water pH

Date Received: 01/12/2024 **Date Of Analysis:** 01/15/2024 **Date Of Report:** 01/15/2024

Sample ID Field ID	Lab Number	OM		W/V	ENR	Phosphorus						Potassium		Magnesium		Calcium		Sodium		pH		Acidity	C.E.C
		%	Rate	Soil Class	lbs/A	M3 ppm	M3 Rate	ppm	Rate	ppm	Rate	K ppm	K Rate	Mg ppm	Mg Rate	Ca ppm	Ca Rate	Na ppm	Na Rate	Soil pH	Buffer Index	H meq/100g	meq/100g
F1P1	21792	4.7	M		120	7	VL					121	L	123	VL	3133	VH	11	VL	7.0		0.0	17.0
F1P2	21793	4.7	M		134	16	L					74	L	110	M	933	M	11	VL	5.8	6.79	1.4	7.2
F2P1	21794	5.6	H		148	12	VL					194	VH	200	H	1315	M	16	VL	6.5		0.7	9.5
F2P2	21795	5.0	H		137	13	VL					149	H	170	H	1160	M	15	VL	5.9	6.77	1.6	9.3
CNT 1 PT1	21797	2.7	M		98	6	VL					93	H	94	H	506	M	12	VL	6.2		0.5	4.1

Sample ID Field ID	Percent Base Saturation					Nitrate		Sulfur		Zinc		Manganese		Iron		Copper		Boron		Soluble Salts			
	K %	Mg %	Ca %	Na %	H %	NO_3 N ppm	Rate	S ppm	Rate	Zn ppm	Rate	Mn ppm	Rate	Fe ppm	Rate	Cu ppm	Rate	B ppm	Rate	SS ms/cm	Rate		
F1P1	1.8	6.0	92.1	0.3	0.0			6	VL	3.3	M	60	VH	80	VH	0.9	M	0.4	L				
F1P2	2.6	12.7	64.8	0.7	19.4			11	L	2.7	M	30	H	97	VH	0.8	L	0.2	VL				
F2P1	5.2	17.5	69.2	0.7	7.4			9	VL	5.7	H	68	VH	123	VH	1.2	M	0.4	L				
F2P2	4.1	15.2	62.4	0.7	17.2			10	L	5.3	H	37	H	118	VH	1.0	M	0.2	VL				
CNT 1 PT1	5.8	19.1	61.7	1.3	12.2			7	VL	2.4	M	30	H	88	VH	0.7	L	0.2	VL				

Values on this report represent the plant available nutrients in the soil. Rating after each value: VL (Very Low), L (Low), M (Medium), H (High), VH (Very High). ENR - Estimated Nitrogen Release. C.E.C. - Cation Exchange Capacity.

Explanation of symbols: % (percent), ppm (parts per million), lbs/A (pounds per acre), ms/cm (milli-mhos per centimeter), meq/100g (milli-equivalent per 100 grams). Conversions: ppm x 2 = lbs/A, Soluble Salts ms/cm x 640 = ppm.

This report applies to sample(s) tested. Samples are retained a maximum of thirty days after testing.

Analysis prepared by: Waypoint Analytical Virginia, Inc.

by: Brandi Watson

Brandi Watson

Report Number: 24-012-1181
Account Number: 10940

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Jon
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Waypoint ANALYTICAL

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Grower: HCEW

SOIL ANALYSIS REPORT

Analytical Method(s): Mehlich 3 SMP Buffer pH Loss On Ignition Water pH

Date Received: 01/12/2024 **Date Of Analysis:** 01/15/2024 **Date Of Report:** 01/15/2024

Sample ID Field ID	Lab Number	OM % Rate	W/V Soil Class	ENR lbs/A	Phosphorus M3 ppm	Rate	ppm	Rate	ppm	Rate	Potassium K ppm	Rate	Magnesium Mg ppm	Rate	Calcium Ca ppm	Rate	Sodium Na ppm	Rate	pH Soil pH	Buffer Index	Acidity H meq/100g	C.E.C meq/100g
CNT 1 PT 2	21798	6.3 H		150	11	VL					169	VH	184	H	1288	H	9	VL	6.7		0.4	8.8
CNT 1 PT	21799	3.4 M		112	6	VL					109	H	112	H	583	M	12	VL	6.5		0.3	4.5

Sample ID Field ID	Percent Base Saturation K %	Mg %	Ca %	Na %	H %	Nitrate NO_3 N ppm	Rate	Sulfur S ppm	Rate	Zinc Zn ppm	Rate	Manganese Mn ppm	Rate	Iron Fe ppm	Rate	Copper Cu ppm	Rate	Boron B ppm	Rate	Soluble Salts SS ms/cm	Rate		
CNT 1 PT 2	4.9	17.4	73.2	0.4	4.5			7	VL	3.5	H	50	H	106	VH	1.2	M	0.6	M				
CNT 1 PT	6.2	20.7	64.8	1.2	6.7			7	VL	2.9	M	30	H	114	VH	0.9	M	0.2	VL				

Values on this report represent the plant available nutrients in the soil. Rating after each value: VL (Very Low), L (Low), M (Medium), H (High), VH (Very High). ENR - Estimated Nitrogen Release. C.E.C. - Cation Exchange Capacity.

Explanation of symbols: % (percent), ppm (parts per million), lbs/A (pounds per acre), ms/cm (milli-mhos per centimeter), meq/100g (milli-equivalent per 100 grams). Conversions: ppm x 2 = lbs/A, Soluble Salts ms/cm x 640 = ppm.

This report applies to sample(s) tested. Samples are retained a maximum of thirty days after testing.

Analysis prepared by: Waypoint Analytical Virginia, Inc.

by: Brandi Watson

Brandi Watson

Appendix D: Resources

- Perennial Flow Determination Form
- Chesapeake Bay Field Office Bank Erosion Hazard Index (BEHI) Standard Operating Procedure
- BEHI Form
- Interpreting Soil Fertility Analysis
- NRCS Soil Bulk Density Testing Procedure
- Large Woody Debris Field Form
- SER Restoration Wheel

NC DWQ Stream Identification Form Version 4.11

Date:	Project/Site:	Latitude:
Evaluator:	County:	Longitude:
Total Points: *Stream is at least intermittent if ≥ 19 or perennial if ≥ 30**	Stream Determination (circle one) Ephemeral Intermittent Perennial	Other *e.g. Quad Name:*

A. Geomorphology (Subtotal =________)	Absent	Weak	Moderate	Strong
1[a.] Continuity of channel bed and bank	0	1	2	3
2. Sinuosity of channel along thalweg	0	1	2	3
3. In-channel structure: ex. riffle-pool, step-pool, ripple-pool sequence	0	1	2	3
4. Particle size of stream substrate	0	1	2	3
5. Active/relict floodplain	0	1	2	3
6. Depositional bars or benches	0	1	2	3
7. Recent alluvial deposits	0	1	2	3
8. Headcuts	0	1	2	3
9. Grade control	0	0.5	1	1.5
10. Natural valley	0	0.5	1	1.5
11. Second or greater order channel	No = 0		Yes = 3	

[a] artificial ditches are not rated; see discussions in manual

B. Hydrology (Subtotal = _________)				
12. Presence of Baseflow	0	1	2	3
13. Iron oxidizing bacteria	0	1	2	3
14. Leaf litter	1.5	1	0.5	0
15. Sediment on plants or debris	0	0.5	1	1.5
16. Organic debris lines or piles	0	0.5	1	1.5
17. Soil-based evidence of high water table?	No = 0		Yes = 3	

C. Biology (Subtotal = _________)				
18. Fibrous roots in streambed	3	2	1	0
19. Rooted upland plants in streambed	3	2	1	0
20. Macrobenthos (note diversity and abundance)	0	1	2	3
21. Aquatic Mollusks	0	1	2	3
22. Fish	0	0.5	1	1.5
23. Crayfish	0	0.5	1	1.5
24. Amphibians	0	0.5	1	1.5
25. Algae	0	0.5	1	1.5
26. Wetland plants in streambed	FACW = 0.75; OBL = 1.5 Other = 0			

*perennial streams may also be identified using other methods. See p. 35 of manual.

Notes:

Sketch:

Standards for Rosgen Bank Erosion Hazard Index

1. PURPOSE

The Bank Erosion Hazard Index (BEHI) is a field method to evaluate bank erodibility potential at a typical study bank or a study bank length. Several bank characteristics are measured including top of bank and bankfull height, rooting depth, root density, bank angle, percent bank protection, bank composition, and bank material stratification. This information, used in conjunction with field estimated near bank shear stress (NBS) ratings, allows one to predict bank erosion quantities and rate of erosion using existing bank erodibility curves developed by Rosgen for Yellowstone and Colorado (Rosgen 2001). A bank erodibility curve is a graph that relates combinations of BEHI and NBS ratings with actual erosion rates. Repeated measurements at monumented cross sections for representative conditions allow for validations of quantities and rates.

Surveyors should also read and understand the Near Bank Shear Stress (NBS) Standards prior to using these standards in the field as the BEHI and NBS are generally conducted at the same time.

The purpose of this standard is to document methods for collecting and recording field data.

2. METHODS

The methods, procedures, and definitions presented within this protocol are drawn from several sources, including:

- Brady, N.C. 1990. The nature and properties of soils. Tenth edition. Macmillan Publishing Co., NY.
- Rosgen, D. L. 1996. Applied river morphology. Wildland Hydrology, Pagosa Springs, Colorado.
- Rosgen, D.L. 2001. A practical method to predict stream bank erosion. In: U.S. Subcommittee on Sedimentation. Proceedings of the federal interagency sedimentation conferences, 1947 – 2001.
- Rosgen, D.L. 2003. Wildland Hydrology. 2003. River Assessment and Monitoring Field Guide.

3. DEFINTIONS

- Duripan: mineral soils, in the form of a hard pan, and strongly cemented by silica.
- Fragipan: mineral soils in the form of a brittle pan, usually loamy textured, and weakly cemented.
- Hemic soil materials: organic soils with an intermediate degree of organic material decay.

4. FIELD EQUIPMENT

- Field Forms: (1) Rosgen Reach BEHI and NBS Field Form and (2) Rosgen - XS BEHI Bank Profile Field Form.
- Completed geomorphic map, sketch, or aerial photograph with mylar overlay.
- Survey rod, pocket rod, and clinometer.
- Digital camera.

5. BEHI CALIBRATION, MEASUREMENTS, AND REVIEW

When several workers are assessing a watershed, they should initially work together to familiarize themselves with the existing bank conditions and calibrate their observations. The BEHI requires an examination of the amount of bank material susceptible to erosion processes, such as, freeze/thaw, rotational failure, mass wasting, water piping, etc. Take measurements in feet and tenths-of-feet, degrees, and percentages. Prior to completing the BEHI for the reach or cross section, the observer(s) should review the BEHI data and consider if the results are representative of the bank conditions.

6. BEHI FIELD PROCEDURES

Surveyors will conduct two types of BEHI assessments: 1. Reach BEHIs to predict sediment contributions from bank erosion, and 2. Cross section BEHIs to validate bank erosion rates. The field methods for selection are discussed separately below. In some situations, such as an entrenched stream, it may be necessary to assess bank conditions on each side of the stream.

1. Reach BEHI Assessment

    a. Assess all stream banks prone to erosion, excluding banks with significant deposition or stable concrete revetment (*i.e.*, no indications of erosion along the revetment).

    b. Partition the study banks based on different combinations of BEHI and NBS conditions (*e.g.*, study bank with one BEHI rating but two NBS conditions should be assessed as two separate study banks).

    c. Note the study bank locations on an aerial photograph with mylar overlay, site sketch, or a geomorphic map.

    d. Evaluate BEHI conditions for the entire length of study bank

    e. Draw a typical bank profile in the space provided in the field form, with illustrations of rooting depth, bank protection, bank composition, and bank stratification.

    f. Photograph the study bank with a surveyor or survey rod in the foreground as reference.

    g. Identify reach BEHI location and length on the geomorphic map.

    h. If a repeat survey, use the same reach BEHI bank map labels, if BEHI and NBS conditions are the same.

    i. Use the same reach BEHI bank map labels and add a sequential letter if additional bank labels are required (*e.g.*, Bank 9, Bank 9A, and Bank 9B).

2. Cross Section BEHI Assessment

    a. Surveyors should conduct the cross section BEHI assessment following the completion of each cross section survey.

    b. BEHIs at monumented cross sections should represent the various BEHI and NBS combinations found in the study reach in order to validate bank erosion predictions.

    c. Assess the study bank directly in line with the cross section.

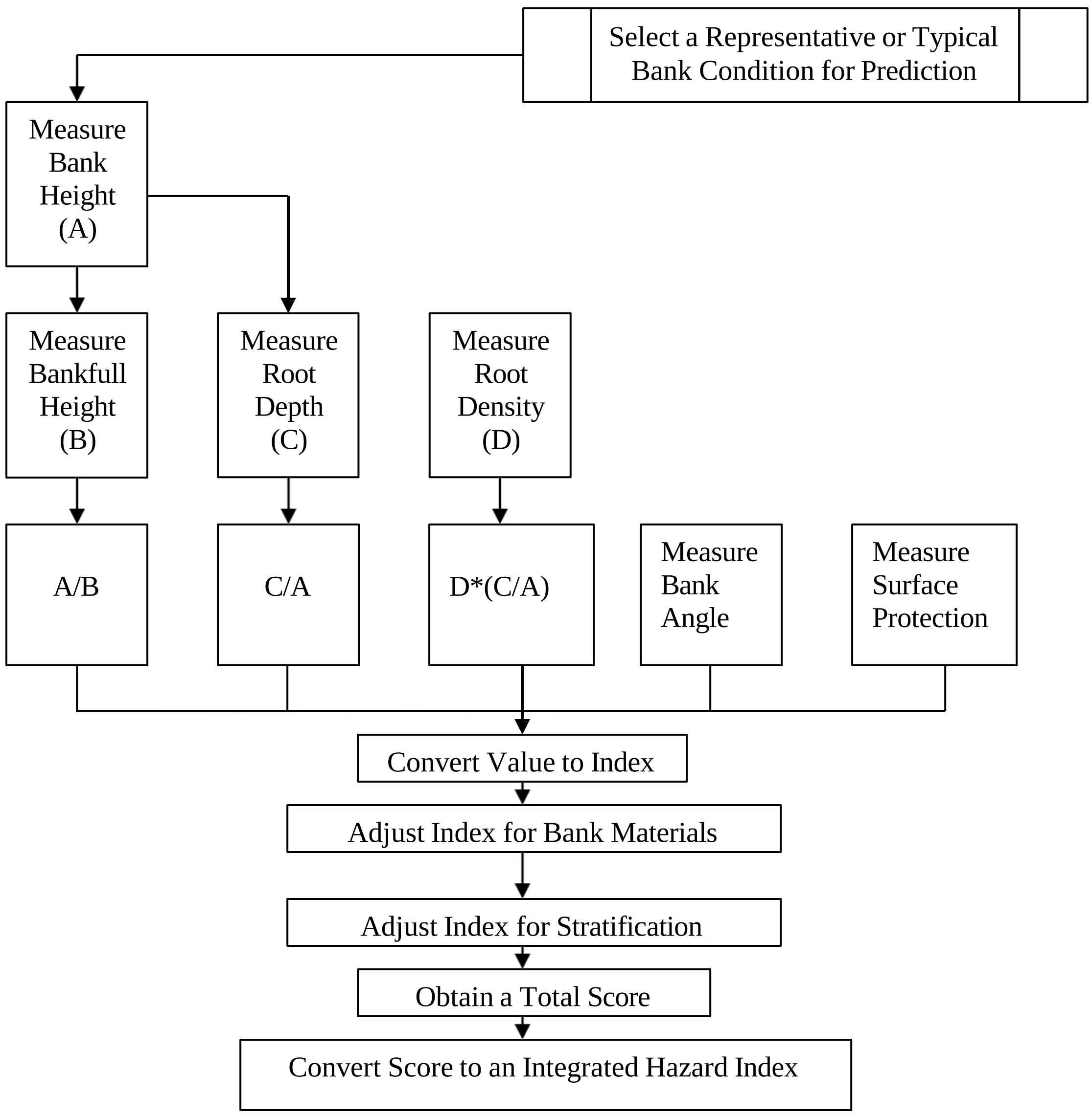
d. Avoid evaluating upstream and downstream influences, such as boulder diversions or protection, when assessing the study bank.

e. Photograph the study bank with surveyor or survey rod in the foreground as reference.

For study bank BEHIs, the assessment location and BEHI characteristics (*e.g.*, top of bank to bankfull height ratio, rooting depth-bank height ratio, *etc.*) should represent average bank conditions in the study reach. For example, if the bank angles within a study reach ranged from 50^o to 60^o the average bank angle would be 55^o for the study reach.

BEHI CRITERIA AND PROCEDURES

The flow diagram below (from Rosgen 2003) outlines the general BEHI procedure and relationship between variables. Figure 1 provides a graphic display for general measurement and Figure 2 is the BEHI Index and Value chart. Outlined below are the seven BEHI criteria and procedures for measurement. In some cases, specific examples from the mid-Atlantic region are provided for explanatory purposes.



Chesapeake Bay Field Office ***Annapolis, MD***
Stream Habitat Assessment and Restoration Program

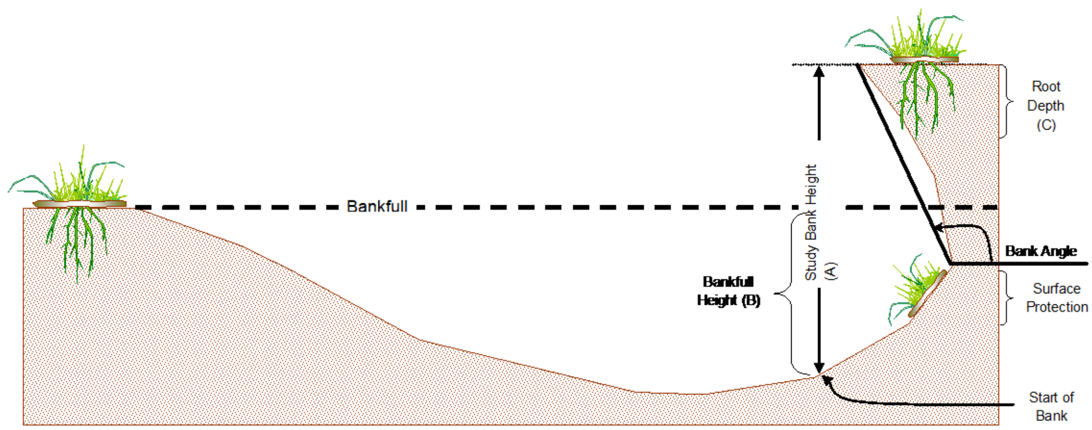


Figure 1. BEHI Variables (Rosgen 2003).

Bank Erosion Hazard Index								
			Bank Erosion Potential					
			Very Low	*Low*	*Moderate*	*High*	*Very High*	*Extreme*
Erodibility Variable	*Bank Height/ Bankfull Height*	Value	1.0 - 1.1	1.11 - 1.19	1.2 - 1.5	1.6 - 2.0	2.1 - 2.8	>2.8
		Index	1.0 - 1.9	2.0 - 3.9	4.0 - 5.9	6.0 - 7.9	8.0 - 9.0	10
	Root Depth/ Bank Height	Value	1.0 - 0.9	0.89 - 0.5	0.49 - 0.3	0.29 - 0.15	0.14 - 0.05	<0.05
		Index	1.0 - 1.9	2.0 - 3.9	4.0 - 5.9	6.0 - 7.9	8.0 - 9.0	10
	Weighted Root Density	Value	100 - 80	79 - 55	54 - 30	29 - 15	14 - 5.0	<5.0
		Index	1.0 - 1.9	2.0 - 3.9	4.0 - 5.9	6.0 - 7.9	8.0 - 9.0	10
	Bank Angle	Value	0 - 20	21 - 60	61 - 80	81 - 90	91 - 119	>119
		Index	1.0 - 1.9	2.0 - 3.9	4.0 - 5.9	6.0 - 7.9	8.0 - 9.0	10
	Surface Protection	Value	100 - 80	79 - 55	54 - 30	29 - 15	14 - 10	<10
		Index	1.0 - 1.9	2.0 - 3.9	4.0 - 5.9	6.0 - 7.9	8.0 - 9.0	10

Bank Materials
Bedrock (Bedrock banks have very low bank erosion potential)
Boulders (Banks composed of boulders have low bank erosion potential)
Cobble (Subtract 10 points. If sand/gravel matrix greater than 50% of bank material, do not adjust)
Gravel (Add 5-10 points depending on percentage of bank material that is composed of sand)
Sand/Silt/Clay loam (Add 5 points, where sand is 50-75% or the composition)
Sand (Add 10 points if sand comprises > 75 % and is exposed to erosional processes)
Silt/Clay (+ 0: no adjustment)

Stratification
Add 5-10 points depending on position of unstable layers in relation to bankfull stage

Total Score

Very Low	*Low*	*Moderate*	*High*	*Very High*	*Extreme*
5-9.5	10-19.5	20-29.5	30-39.5	40-45	46-50

Figure 2. BEHI Value and Index table (Rosgen 1996).

Top of Bank Height to Bankfull Height Ratio

a. Measure the top of bank and bankfull heights from the bank toe (Figures 1 and 3).

b. For BEHIs at a cross section survey, determine the top of bank and bankfull heights from the survey data.

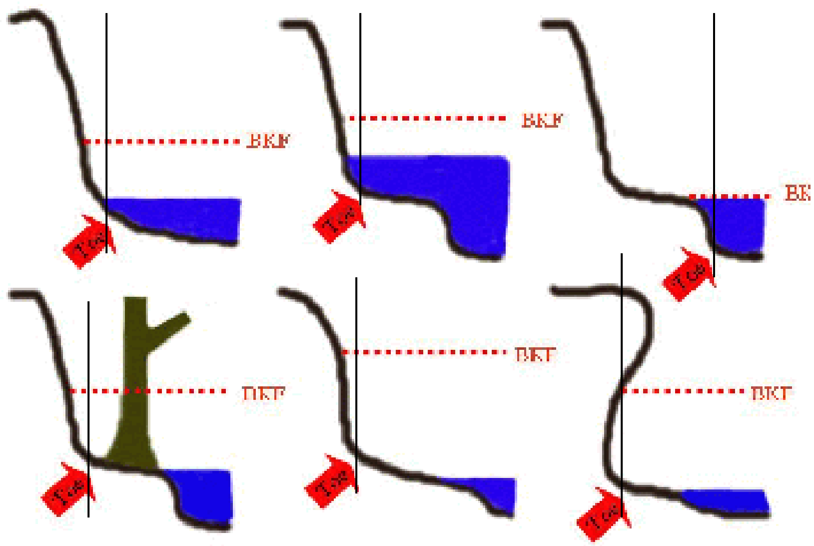


Figure 3. Bank toe location examples.

1. Rooting Depth to Top of Bank Height Ratio

Rooting depth to bank height ratio is a measure of rooting depth in relation to the top of bank height (Figure 4). For example, if the bank is gently sloped to the toe and covered with grasses, the rooting depth is only the depth of the vegetation, in relation to the height of the bank. Rooting depth is highly variable and depends on vegetation type and soil conditions. Familiarity with annual and perennial growth for a particular region and an understanding of how conditions may change seasonally is essential. Rooting depth is often species and location dependent. Table 1 provides average root depths for various vegetation types; however, one should look for evidence in the field of rooting depths for the particular vegetation growing at the study sites.

Table 1. Average Root Depths (adapted from Colorado State University cooperative extension newsletter).

Vegetation Type	Root Depth (ft)	Vegetation Type	Root Depth (ft)
Annuals	0.16 - 0.25	Shrubs	0.67 - 1.00
Perennials	0.33 - 0.83	Trees	0.83 – 1.5
Turf grass	0.50 - 0.67		

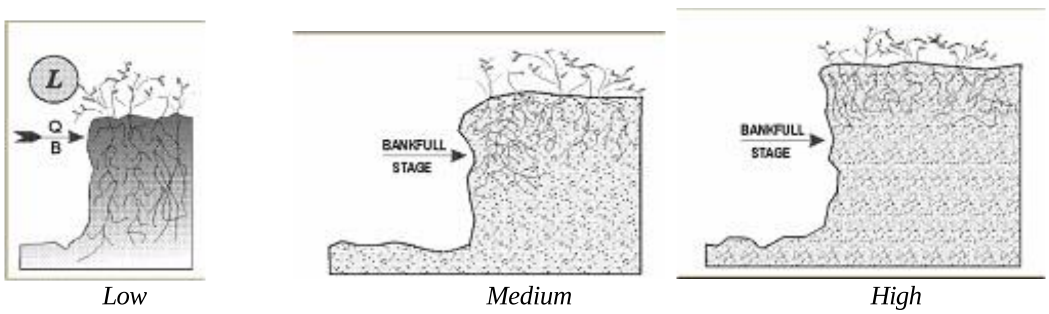


Figure 4. Examples of low, medium, and high BEHIs for rooting depth (Rosgen 1996).

a. Where the upper bank is accessible (but not at the cross section location), clear the soil to expose the roots and assess the root depth. If the upper bank is not accessible, look for areas with exposed roots or use Table 1 to determine rooting depths.

b. Where the tree and/or tree roots extend down the bank, the extent of the roots down the bank (*i.e.*, the height of the root ball) is the rooting depth (Figure 5).

c. It is important to consider soil conditions (*e.g.*, duripan, fragipans, and hemic soil materials) that will affect rooting depths. Duripans and fragipans tend to retard rooting depths. Hemic soil materials tend to promote rooting depth because of its high organic matter.

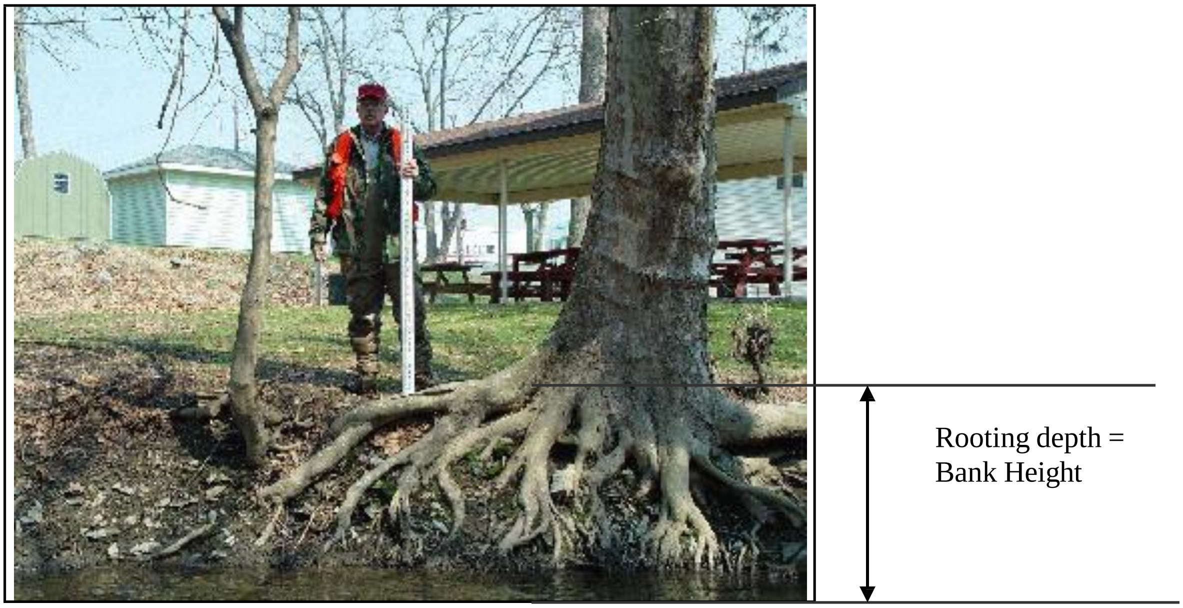


Figure 5. Tree roots extending down the stream bank.

3. <u>Weighted Root Density</u>

   Weighted root density is a percentage of root density within the rooting depth. This is an ocular estimate, (*e.g.*, if the bank as a 60 percent density but only on 1 percent of the bank, then root density is less than 5 percent (extreme category)). Similar to rooting depth, root density is highly variable and depends on vegetation type and soil conditions.

   a. Where the upper bank is accessible, clear the soil (except at the cross section) to expose the roots and assess the root density.

   b. When estimating root density, it maybe helpful to compress the surface area of the root and visualize what percent that area comprises of the total rooting depth area (Figure 6).

   c. If the upper bank is not accessible, look for areas with exposed roots to determine root density.

   d. It is important to note soil conditions (see 2.d. above).

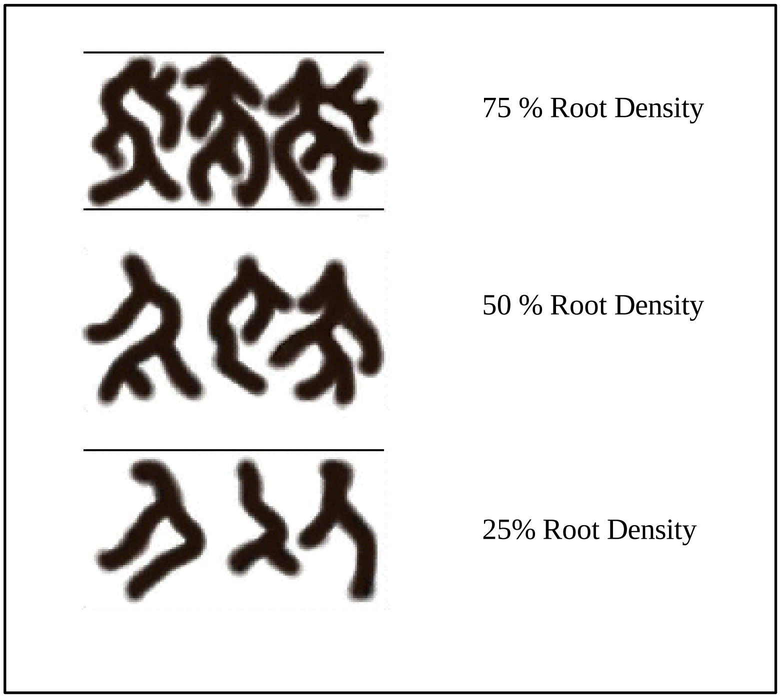


Figure 6. Root density examples.

4. Bank Angle
   Bank angle is a measure of the angle-of-repose of the bank. Figure 7 provides five common bank angle scenarios.

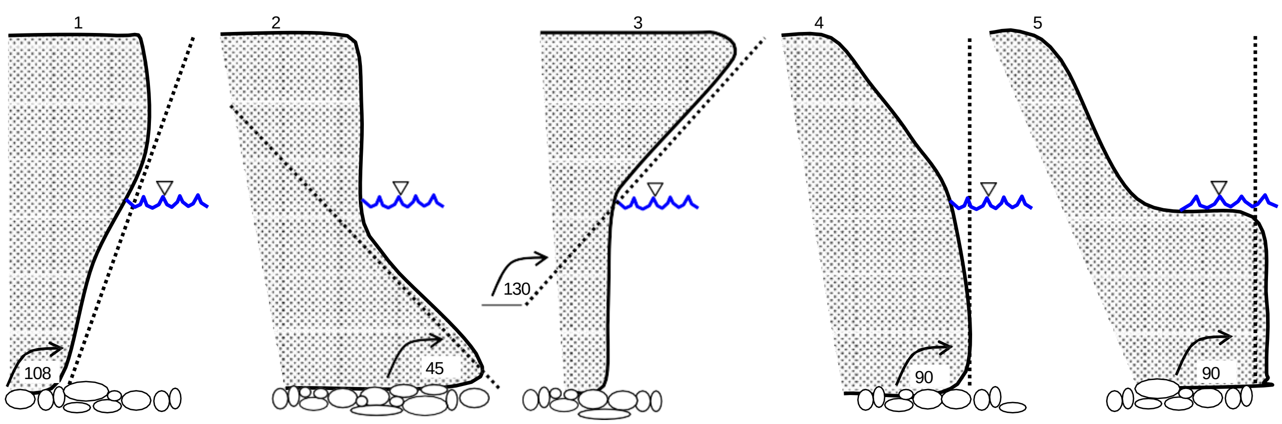


Figure 7. Bank angle scenarios (perspective: cross-section view)(Rosgen 2003).

a. In general, measure the angle of steepest slope or slope most prone to failure, at bankfull.

b. If possible, place a survey rod on the slope face.

c. Using a clinometer, place the base of the clinometer on the survey rod and measure the angle. If using a compass with a clinometer, remember to set the bezel so that the clinometer reads 0^{o} when the compass base is flat and 90^{o} when it is vertical.

5. Surface Protection

Surface protection characterizes bank conditions (*e.g.*, boulders, vegetation) that attenuate erosional forces along the bank. Surface protection is a percentage measurement of the surface area of the bank protected from erosion. The surface protection can be vegetation, debris, rootwads, etc.

a. Determine areas along the bank that have surface protection.

b. Determine the protected percent of the total bank height.

c. For banks vegetated with vines, brambles annuals, and/or moss, determine the vegetated percent of the bank. It may be easier to determine the percent of exposed soil, and calculate the remaining vegetated percentage (Figure 8).

Figure 8. Herbaceous bank vegetation.

d. To determine bank protection for banks vegetated with shrubs and trees, determine the percent of the bank influenced by the root fan (Figure 9). Soil exposed within the area of the root fan is less a consideration with woody vegetation.

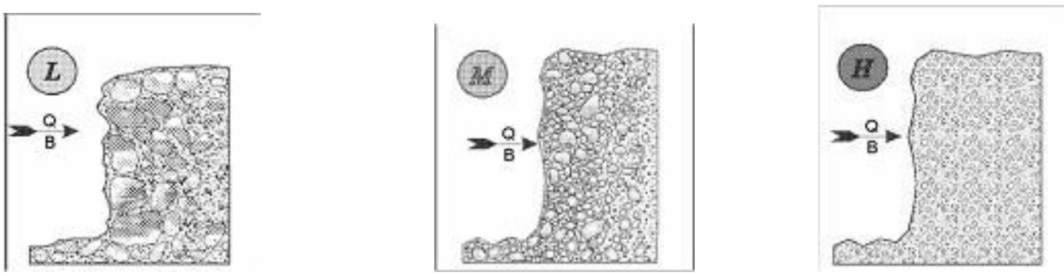
Figure 9. Woody bank vegetation.

e. When evaluating suspended logs, and trees and boulders in the channel, determine the percent of the bank protected at the near bank (Figure 10).

Figure10.Suspended log bank protection.

6. Bank Material Adjustment

Bank material adjustment characterizes the composition and consolidation of the bank (Figure 11).



(0 points) (5 points) (10 points)

Figure 11. Examples of low, medium, and high erodibility bank material composition (Rosgen 1996).

a. Determine the general bank composition. Stream flow may influence surface appearance, if necessary, remove the surface layer of soil.

b. Adjust the overall BEHI score using values from Table 2.

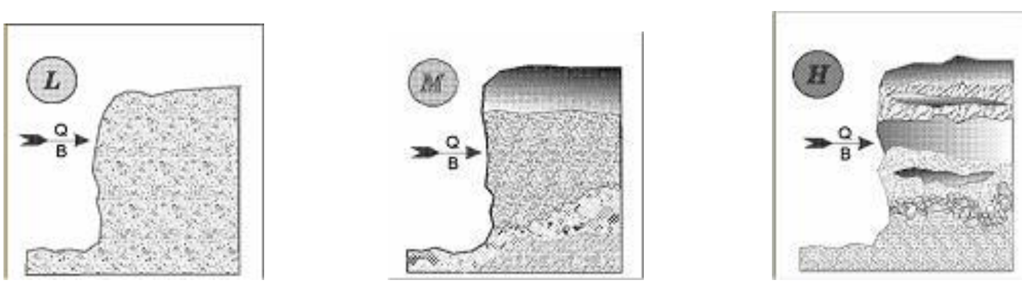
Table 2. Bank Material Adjustment

Bank Material	BEHI Rating Adjustment
Bedrock	BEHI for bedrock banks are “very low erosion potential”.
Boulders	BEHI for boulder banks are “low erosion potential”.
Cobble	Subtract 10 points. No adjustment if sand/gravel composes greater than 50 percent of bank.
Sand/Silt/Clay Loam	Add 5 points, if composition is 50 – 75 percent sand.
Gravel	Add 5-10 points depending on percentage of bank material composed of sand.
Sand	Add 10 points if sand comprises greater than 75 percent and is exposed to erosional processes.

Table 2. Bank Material Adjustment	
Bank Material	BEHI Rating Adjustment
Silt/Clay	Subtract up to 20 points depending on percentage of bank material composed of clay. *Note: this is a new adjustment

7. Bank Stratification Adjustment

Bank stratification adjustment characterizes unstable soil horizons that are prone to erosion in relation to the bankfull stage (Figure 12). There are several processes of bank erosion to consider when evaluating bank stratification adjustments: fluvial entrainment, rotational failure, soil piping, and freeze/thaw.



(0 points) (5 points) (10 points)

Figure 12. Examples of low, medium, and high erodibility soil stratification (Rosgen 1996).

a. Observe the bank profile and soil horizons along the bank.

b. Identify any zone(s) where water concentrates, and area(s) of rotational failures and soil piping.

c. Evaluate the horizon's consolidation by attempting to dislodge the bank materials. Stream flow may influence surface appearance, if necessary, remove the surface layer of soil.

d. Adjustment values depend on the location of horizons prone to erosion, for example, if the bank has a gravel lens in the lower third of the bank add 10 points. Add 5-10 points depending on position of unstable layers in relation to bankfull stage.

8. PHOTOGRAPHIC DOCUMENTATION

Photographic documentation is required for each BEHI assessment. The photograph should represent bank conditions assessed for the BEHI. Reach BEHIs may require multiple photographs, while site BEHIs may require only one photograph.

1. If possible, incorporate a reference (*e.g.*, survey rod) into the photograph.

2. If necessary, take the photograph at an oblique angle to accentuate bank conditions.

3. Record the camera number, photograph number, and photograph description on the BEHI data sheet.

Appendix C. Nutrient Concentrations in Stream Bank Soils

Project Number	Location by Physiographic Province	Test Year	# Samples	Total N Conc. Range (ppm)	Total N Conc. Avg. (ppm)	Total P Conc. Range (ppm)	Total P Conc. Avg. (ppm)
1	Coastal Plain	2013	2	n/a	n/a	<100-504	302
2	Coastal Plain	2011	n/a	n/a	n/a	n/a	133
3	Coastal Plain	2011	5	n/a	n/a	<100-138	112
4	Coastal Plain	2011	5	n/a	n/a	168-204	189
5	Coastal Plain	2011	5	n/a	n/a	<100-188	136.6
6	Coastal Plain	2011	5	n/a	n/a	<100-249	164
7	Coastal Plain	2013	1	n/a	n/a	103	103
8	Coastal Plain	2013	1	n/a	n/a	<100	100
9	Piedmont, lowlands	2010	4	120-890	445	40-130	90
10	Piedmont, lowlands	2010	4	40-560	255	50-100	65
11	Piedmont, lowlands	2010	4	50-660	273	20-180	130
12	Piedmont, lowlands	2010	2	200-290	245	40-110	75
13	Coastal Plain	2011	10	30-1560	340	109-2120	568
14	Piedmont, upland	2008	12	n/a	n/a	10-200	101
15	Piedmont, upland	2008	48	n/a	n/a	100-740	280
16	Piedmont, upland	2009	16	n/a	n/a	10-150	61
TOTAL			124				
AVERAGE					312		163
MEDIAN					273		121

NOTE 1: Soil concentrations reported as "<100" reported here as 100; therefore actual average will be less.

NOTE 2: All samples tested at A&L Eastern Laboratories in Richmond, VA.

NOTE 3: Project 9, 10, 11, and 12 are at one project location, which contained 4 physically disparate reaches grouped into a large watershed.

NOTE 4: In all cases, USEPA SW-846 method was used to measure Total Phosphorus

-from Stantec

Worksheet 3-11. Form to calculate Bank Erosion Hazard Index (BEHI) variables and an overall BEHI rating. Use **Figure 3-7** with BEHI variables to determine BEHI score.

Stream: Location:

Station: Observers:

Date: Stream Type: Valley Type:

BEHI Score (Fig. 3-7)

Study Bank Height / Bankfull Height (C)

Study Bank Height (ft) =	(A)	Bankfull Height (ft) =	(B)	(A) / (B) =	(C)	

Root Depth / Study Bank Height (E)

Root Depth (ft) =	(D)	Study Bank Height (ft) =	(A)	(D) / (A) =	(E)	

Weighted Root Density (G)

Root Density as % =	(F)	(F) × (E) =	(G)	

Bank Angle (H)

Bank Angle as *Degrees* =	(H)	

Surface Protection (I)

Surface Protection as % =	(I)	

Bank Material Adjustment:

- **Bedrock** (Overall Very Low BEHI)
- **Boulders** (Overall Low BEHI)
- **Cobble** (Subtract 10 points if uniform medium to large cobble)
- **Gravel or Composite Matrix** (Add 5–10 points depending on percentage of bank material that is composed of sand)
- **Sand** (Add 10 points)
- **Silt/Clay** (no adjustment)

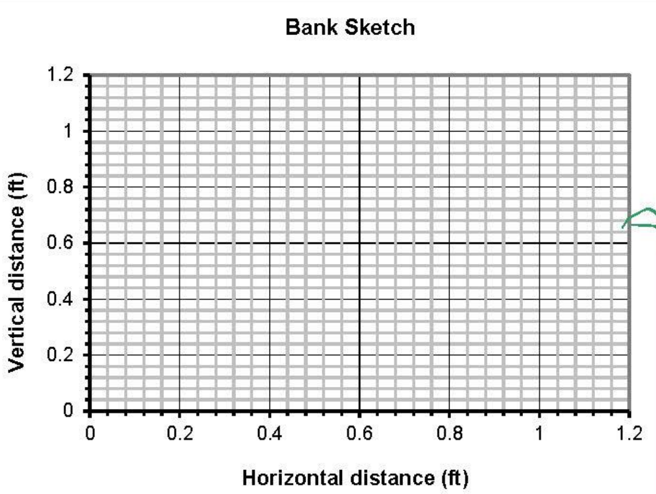
Bank Material Adjustment

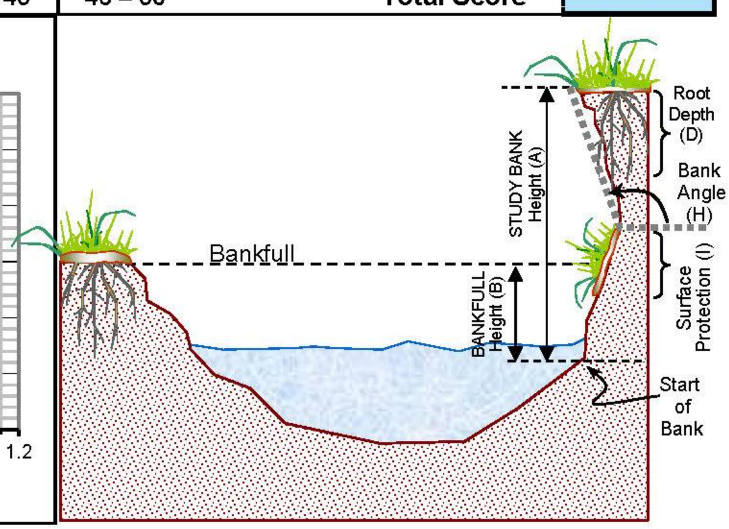
Stratification Adjustment

Add 5–10 points, depending on position of unstable layers in relation to bankfull stage

Very Low	Low	Moderate	High	Very High	Extreme
5 – 9.5	10 – 19.5	20 – 29.5	30 – 39.5	40 – 45	46 – 50

Adjective Rating and **Total Score**





Worksheet 3-11. Form to calculate Bank Erosion Hazard Index (BEHI) variables and an overall BEHI rating. Use **Figure 3-7** with BEHI variables to determine BEHI score.

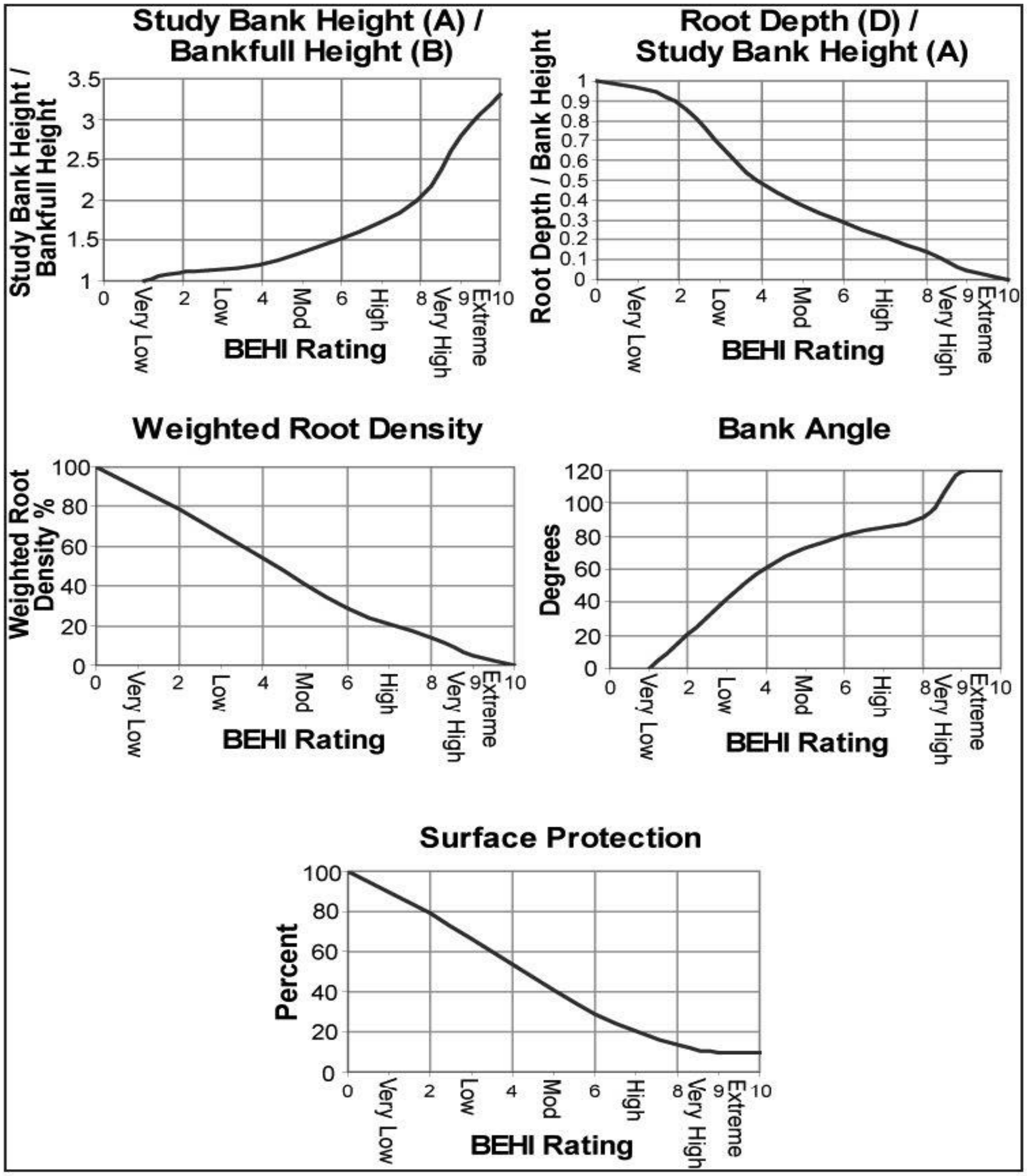


Figure 3-7. Streambank erodibility criteria showing conversion of measured ratios and bank variables to a BEHI rating (Rosgen, 1996, 2001b, 2006b). Use **Worksheet 3-11** to determine BEHI score.

SOILS
Interpreting Soil Fertility Analyses

May 24, 2018
Revised: June 17, 2024

Written by: Jon Roller, PSS
Edited by: Kip Mumaw, PE

The purpose of this document is to assist with the interpretation of soil fertility analyses from area laboratories. This memo will highlight the information within the analysis that is important to know and understand. The importance of sampling soils within restoration projects serves multiple purposes. It assists with determining pollutant reductions for the purposes of TMDL crediting or pollutant reduction. These results are also often required for certain grant-funded projects. But understanding the soil fertility of the site can have huge implications on the success of establishment of target plant species versus invasive species, that are more adept at surviving and thriving in soils with low fertility, too low or too high pH, low organic matter content, or soils that have been disturbed or compacted.

A quick soils lesson and the relationship between soils and plants….

Below is an image that illustrates the ability of a plant to survive based on limited resources. "*Liebig's Law of the Minimum"* or often referred to as Liebig's Barrel, can be used to ensure that plants have optimum growing conditions. This law states that "the growth of your plants is not controlled by the total amount of nutrients/factors available, but by the scarcest nutrient/factor – the limiting factor." This law can be extended to include other factors such as water and pH, which are the two most limiting factors influencing growing conditions. When one (1) of these nutrients or growth factors is substantially limited, then the plant can only grow to what that limiting factor allows.

For soil fertility, the most important nutrients are N-P-K (nitrogen, phosphorus, and potassium). These are the three (3) critical macronutrients that show up on commercial fertilizer bags (i.e. 10-10-10, etc.). These numbers indicate the percentage of the nutrient per pound of fertilizer. For example, 10 pounds of 10-10-10 equates to 1 pound of N, 1 pound of P, and 1 pound of K. Soil analyses typically also include other important macronutrients such as magnesium (Mg), calcium (Ca), and sulfur (S). Other nutrients are also included, but in a natural setting, these elements occur naturally and would typically not require any additional supplementing.

Before interpreting the soil fertility analysis, first decide what the purpose is of the analysis. For restoration projects, it's typically for one of two purposes:

1) Testing for pollutant reduction reporting; and/or
2) Testing for suitability as a plant growth medium

Interpreting Soil Fertility Analyses for Pollutant Reduction Reporting

First, it's worth noting that different laboratories report nutrients with different units. For example, Waypoint Labs uses the Mehlich III analytical method for measuring phosphorus, which is then displayed as parts per million (ppm), but the Virginia Tech Soils Lab uses the Mehlich I analytical method, which displays phosphorus as pounds of P/acre in the form of P2O5.

When using this information, it is important to understand the appropriate conversion method (i.e. ppm to lbs). Below is a recent example of a soil analysis. Steps to interpret this form are below the figure.

Page 1 of 1
Report Number: 18-137-0668
Account Number: 10940

Send To: Eco System Services
Jon
1739 Allied St Suite A
Charlottesville VA 22903

Waypoint ANALYTICAL
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7621 Whitepine Road, Richmond, VA 23237
Main 804-743-9401 ° Fax 804-271-6446
www.waypointanalytical.com

Grower: Ecosystem Services LLC

SOIL ANALYSIS REPORT

Analytical Method(s): Mehlich 3 SMP Buffer pH Loss On Ignition Water pH

Date Received: 05/17/2018 **Date Of Analysis:** 05/18/2018 **Date Of Report:** 05/24/2018

Sample ID Field ID	Lab Number	OM	W/V	ENR	Phosphorus						Potassium		Magnesium		Calcium		Sodium		pH		Acidity	C.E.C
		% Rate	Soil Class	lbs/A	M3 ppm	Rate	ppm	Rate	ppm	Rate	K ppm	Rate	Mg ppm	Rate	Ca ppm	Rate	Na ppm	Rate	Soil pH	Buffer Index	H meq/100g	meq/100g
QC-A	03063	1.5 L		75	41	M					17	VL	24	L	154	VL	23	L	4.3	6.71	2.2	3.3
QC-B	03064	2.4 L		91	118	VH					23	VL	51	L	261	VL	27	L	4.4	6.61	3.2	5.1
QC-C	03066	5.6 H		148	272	VH					34	VL	83	L	826	L	41	VL	4.8	6.49	4.4	9.5
Laul-D	03067	4.1 M		108	23	L					71	VL	244	VL	8515	VH	30	VL	7.1		0.0	94.9

Sample ID Field ID	Percent Base Saturation					Nitrate		Sulfur		Zinc		Manganese		Iron		Copper		Boron		Soluble Salts		Nitrogen, Total	Total Kjeldahl Nitrogen
	K %	Mg %	Ca %	Na %	H %	NO_3N ppm	Rate	S ppm	Rate	Zn ppm	Rate	Mn ppm	Rate	Fe ppm	Rate	Cu ppm	Rate	B ppm	Rate	SS ms/cm	Rate	ppm	ppm
QC-A	1.3	6.1	23.3	3.0	66.7	2	VL	32	H	3.6	H	6	L	258	VH	22.1	VH	0.5	L			542	540.0
QC-B	1.2	8.3	25.6	2.3	62.7	5	L	33	H	22.8	VH	22	H	250	VH	63.3	VH	0.4	L			495	490.0
QC-C	0.9	7.3	43.5	1.9	46.3	8	L	27	H	50.9	VH	15	M	279	VH	142.3	VH	0.5	L			1798	1790.0
Laul-D	0.2	2.1	97.6	0.1	0.0	13	M	27	H	7.8	H	53	VH	65	VH	9.5	VH	0.8	M			1983	1970.0

Values on this report represent the plant available nutrients in the soil. Rating after each value: VL (Very Low), L (Low), M (Medium), H (High), VH (Very High). ENR - Estimated Nitrogen Release. C.E.C. - Cation Exchange Capacity.

Explanation of symbols: % (percent), ppm (parts per million), lbs/A (pounds per acre), ms/cm (milli-mhos per centimeter), meq/100g (milli-equivalent per 100 grams). Conversions: ppm x 2 = lbs/A, Soluble Salts ms/cm x 640 = ppm.

This report applies to sample(s) tested. Samples are retained a maximum of thirty days after testing.

Analysis prepared by: Waypoint Analytical Virginia, Inc.

by: Pauric McGroary

Pauric McGroary

For pollutant reduction reporting, interpreting the analysis is limited to Total Phosphorus and Total Nitrogen. This data, along with the sample ID, are the three (3) most important pieces of info. This information is then used to calculate the amount of nutrients prevented from entering the waterbody. The rest of this information is incidental and while valuable for fertility purposes, it can be ignored for pollution reduction reporting.

Interpreting Soil Fertility Analyses for Suitability as a Plant Growth Medium

Below is the same example of a soil analysis, steps to interpret this form are below the figure.

Page 1 of 1
Report Number: 18-137-0668
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SOIL ANALYSIS REPORT

Analytical Method(s): Mehlich 3 SMP Buffer pH Loss On Ignition Water pH

Date Received: 05/17/2018 **Date Of Analysis:** 05/18/2018 **Date Of Report:** 05/24/2018

Sample ID Field ID	Lab Number	OM	W/V	ENR	Phosphorus						Potassium		Magnesium		Calcium		Sodium		pH		Acidity	C.E.C
		% Rate	Soil Class	lbs/A	M3 ppm	Rate	ppm	Rate	ppm	Rate	K ppm	Rate	Mg ppm	Rate	Ca ppm	Rate	Na ppm	Rate	Soil pH	Buffer Index	H meq/100g	meq/100g
QC-A	03063	1.5 L		75	41	M					17	VL	24	L	154	VL	23	L	4.3	6.71	2.2	3.3
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QC-C	03066	5.6 H		148	272	VH					34	VL	83	L	826	L	41	VL	4.8	6.49	4.4	9.5
Laul-D	03067	4.1 M		108	23	L					71	VL	244	VL	8515	VH	30	VL	7.1		0.0	94.9

Sample ID Field ID	Percent Base Saturation					Nitrate		Sulfur		Zinc		Manganese		Iron		Copper		Boron		Soluble Salts		Nitrogen, Total	Total Kjeldahl Nitrogen
	K %	Mg %	Ca %	Na %	H %	NO_3N ppm	Rate	S ppm	Rate	Zn ppm	Rate	Mn ppm	Rate	Fe ppm	Rate	Cu ppm	Rate	B ppm	Rate	SS ms/cm	Rate	ppm	ppm
QC-A	1.3	6.1	23.3	3.0	66.7	2	VL	32	H	3.6	H	6	L	258	VH	22.1	VH	0.5	L			542	540.0
QC-B	1.2	8.3	25.6	2.3	62.7	5	L	33	H	22.8	VH	22	H	250	VH	63.3	VH	0.4	L			495	490.0
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Values on this report represent the plant available nutrients in the soil. Rating after each value: VL (Very Low), L (Low), M (Medium), H (High), VH (Very High). ENR - Estimated Nitrogen Release. C.E.C. - Cation Exchange Capacity.

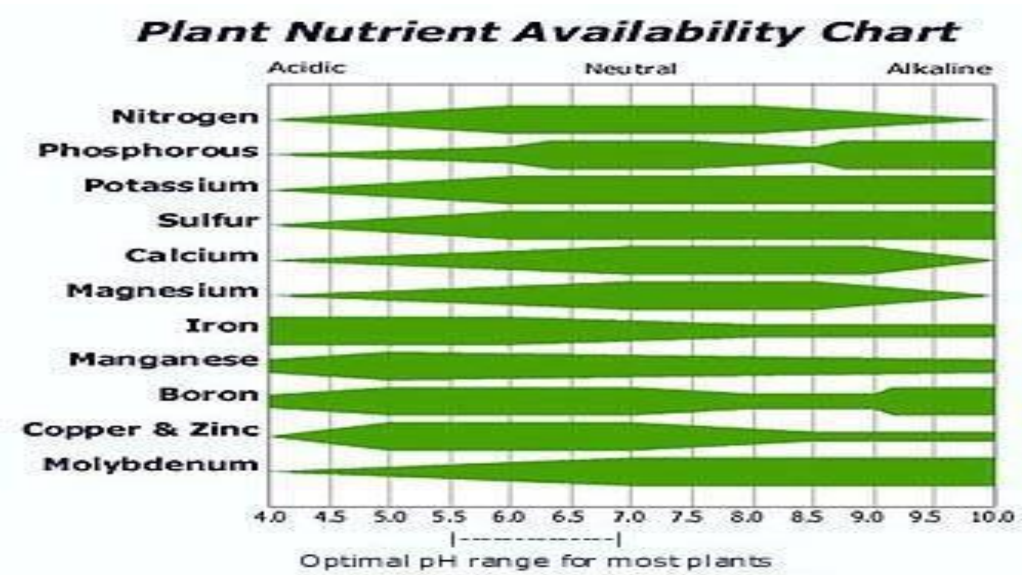
Explanation of symbols: % (percent), ppm (parts per million), lbs/A (pounds per acre), ms/cm (milli-mhos per centimeter), meq/100g (milli-equivalent per 100 grams). Conversions: ppm x 2 = lbs/A, Soluble Salts ms/cm x 640 = ppm.

This report applies to sample(s) tested. Samples are retained a maximum of thirty days after testing.

Analysis prepared by: Waypoint Analytical Virginia, Inc.

by: Pauric McGroary

Remember Liebig's Law of the Minimum when reviewing a soil fertility analysis for plant growth suitability. The hierarchy suggested for use (for potential supplement or amendment recommendations), is as follows: pH (soil pH and buffer pH), organic matter %, total nitrogen, total phosphorus, and total potassium. In all growing condition situations, water is the most limiting factor, but altering hydrologic conditions involves additional considerations. In terms of what we can control, the soil's pH or measure of its acidity, is the most important factor. This factor is best illustrated by the nutrient availability chart below.



Soil pH

The pH of a soil limits the plant's ability to update available nutrients. Generally, the more acidic or the more basic the pH of the soil, the less available nutrients are for use by a plant. Nutrients are most available when the pH is close to neutral (7.0), but anything above 6.0 and below 8.0 is optimal.

Organic Matter (%) and Cation Exchange Capacity (CEC)

While these two factors are not dependent on each other, they are interrelated and critical for a plant's survival. Organic matter is important because the existence of carbon is the basis for life on this Earth. Soils with moderate to large amounts of organic matter provide more water holding capacity for use by plants, stable and neutral pH, higher drought tolerance, and the ability provide, hold, and release nutrients to plants. Organic Matter percentage is based on weight and not volume, so these percentages are lower than many expect. A percentage of 3% to 6% will typically not prove to be a limiting factor for plant growth. Higher organic matter content may hold more water and resist compaction.

Cation Exchange Capacity or CEC is the ability of a soil to hold exchangeable cations or positively charged ions. This includes numerous macronutrients so the higher the CEC, the more fertile the soil. The only way to increase CEC is to incorporate more organic matter into a soil.

In general, a low pH yields a low CEC.

Nitrogen (N), Phosphorus (P), and Potassium (K)

These three (3) nutrients are the most important to the success of plant growth. Their roles are as follows:

1) Nitrogen – The building block of amino acids and proteins. Plants don't exist without proteins. Deficiencies in nitrogen in plants typically manifest with interveinal chlorosis (yellowing of leaves with green veins)
2) Phosphorus – Phosphorus plays a major role in photosynthesis, respiration, energy storage and transfer, cell division, cell enlargement and several other processes in plants.
3) Potassium - In Photosynthesis, potassium regulates the opening and closing of stomata, and therefore regulates CO_2 uptake. Potassium regulates the ability of a plant to transpire and release O_2.

For grasses, shrubs, and trees, nutrient application rates and timing can be found in the Department of Conservation's "Virginia Nutrient Management Standards and Criteria," revised July 2014. Tables are included within this document that provide recommendations on nutrient application rates versus current conditions. For example, Quantico Creek Sample B (QC-B) is very low in potassium (K), the S&C suggests 50-80 lbs of K/ac.

Other Macro- and Micronutrients

Other macronutrients that are common to the building blocks of plants are calcium and magnesium. These nutrients are often deficient in low pH (acidic) soils, but can be added through the addition of lime, which is comprised of, most commonly, calcium carbonate and other magnesium derivatives.

With increased saltification of our waterways due to our society's overuse of salts for road treatment, soils are tying up a lot of salt/sodium (Na), which can negatively affect plant growth. This can be an issue in urban areas where roads are treated throughout the late fall and winter months. Understanding this as a potential issue prior to planting, can allow for remediation options. This issue is also exacerbated by sea-level rise and global warming.

General Comments

Tremendous resources are put into the implementation of restoration projects, but often very little attention is given to the soil and its ability to function as a plant growth medium. Special care should be taken to understand the fertility of the soil, whether its in situ, imported in, or a subsoil that is exposed and used as a new ground surface.

Helpful Resources

Virginia Nutrient Management Standards & Criteria: https://www.dcr.virginia.gov/document/standardsandcriteria.pdf

Chesapeake Bay Program Expert Panel: Nutrient Management Practices - https://d18lev1ok5leia.cloudfront.net/chesapeakebay/documents/Phase_6_NM_Panel_Report_11-28-2016_New_Template_FINAL.pdf

Cornell University, Soil Fertility Unit: http://hwwff.cce.cornell.edu/learning8b91.html?unit=2

Oregon State University, OSU Extension, Interpreting Soil Fertility: https://extension.oregonstate.edu/catalog/pub/ec-1478-soil-test-interpretation-guide#:~:text=Soil%20test%20results%20(see%20figure,may%20increase%20growth%20or%20yield.

4. Bulk Density Test

The bulk density measurement should be performed at the soil surface and/or in a compacted zone (plow pan, etc.) if one is present . Measure bulk density near (between 1 and 2 feet) the site of the respiration and infiltration tests. To get a more representative bulk density measurement of the area, additional samples may be taken.

Materials needed to measure bulk density:

- **3-inch diameter ring**
- **hand sledge**
- **wood block**
- **garden trowel**
- **flat-bladed knife**
- **sealable bags and marker pen**
- **scale (0.1 g precision)**
- **1/8 cup (30 mL) measuring scoop**
- **paper cups**
- **18-inch metal rod**
- **access to a microwave oven**

Did You Know?
Bulk density is the weight of soil for a given volume. It is used to measure compaction. In general, the greater the density, the less pore space for water movement, root growth and penetration, and seedling germination.

Considerations: For rocky or gravelly soils, use the alternate procedure on page 11.

1 **Drive Ring into Soil**

- Using the hand sledge and block of wood, drive the 3-inch diameter ring, beveled edge down, to a depth of 3 inches **(Figure 4.1)**.
- The exact depth of the ring must be determined for accurate measurement of soil volume. To do this, the height of the ring above the soil should be measured. Take four measurements (evenly spaced) of the height from the soil surface to the top of the ring and calculate the average. Record the average on the Soil Data worksheet.

Figure 4.1

NOTE: Use the metal rod to probe the soil for depth to a compacted zone. If one is found, dig down to the top of this zone and make a level surface. Proceed with Step 1.

2 **Remove 3-inch Ring**

Dig around the ring and **with the trowel underneath it,** carefully lift it out to prevent any loss of soil.

(3) **Remove Excess Soil**

Remove excess soil from the sample with a flat-bladed knife. The bottom of the sample should be flat and even with the edges of the ring **(see Figure 4.2).**

Figure 4.2

(4) **Place Sample in Bag and Label**

Touch the sample as little as possible. Using the flat-bladed knife, push out the sample into a plastic sealable bag. Make sure the entire sample is placed in the plastic bag. Seal and label the bag.

NOTE: Steps 5-7 can be done in a lab or office if a scale is not available in the field. Step 8 requires access to a microwave.

(5) **Weigh and Record Sample**

- Weigh the soil sample in its bag. [If the sample is too heavy for the scale, transfer about half of the sample to another plastic bag. The weights of the two sample bags will need to be added together. Enter the weight (sum of two bags, if applicable) on the Soil Data worksheet.

- Weigh an empty plastic bag to account for the weight of the bag. Enter the weight (sum of two bags, if applicable) on the Soil Data worksheet.

(6) **Extract Subsample to Determine Water Content and Dry Soil Weight**

- Mix sample thoroughly in the bag by kneading it with your fingers.

- Take a 1/8-cup level scoop subsample of loose soil (not packed down) from the plastic bag and place it in a paper cup (a glass or ceramic cup may be used).

(7) **Weigh and Record Subsample**

- Weigh the soil subsample in its paper cup. Enter the weight on the Soil Data worksheet.

- Weigh an empty paper cup to account for its weight. Enter the weight on the Soil Data worksheet.

(8) **Dry Subsample**

Place the paper cup containing the subsample in a microwave and dry for two or more four-minute cycles at full power. Open the microwave door for one minute between cycles to allow venting. Weigh the dry subsample in its paper cup and enter the weight on the Soil Data worksheet.

NOTE: To determine if the soil is dry, weigh the sample and record its weight after each 4-minute cycle. When its weight does not change after a drying cycle, then it is dry.

CALCULATIONS (See page 13)

Bulk Density Test for Gravelly and Rocky Soils

This method is to be used when rocks or gravels prevent sampling bulk density by the core method described in the first part of this Chapter. This excavation method will require the user to sieve out the coarse material greater than 2 mm in size.

Materials needed to measure bulk density:

- **Plastic wrap**
- **140-cc syringe**
- **water**
- **garden trowel**
- **sealable bags and marker pen**
- **2-mm sieve**
- s**cale (0.1 g precision)**
- **1/8-cup (30 mL) measuring scoop**
- **paper cup or bowl**
- **access to a microwave oven**

Considerations: Choose a spot that is as level as possible to allow water to fill the hole evenly. If the soil is too wet to sieve, ignore the part in Step 2 about replacing rocks, and proceed to Step 3. Soil will have to be dried and sieved later. The volume of gravel will need to be determined and subtracted from the total volume of the soil sample taken in the field.

1 Dig Hole

- Dig a bowl shaped hole three inches deep and approximately five inches in diameter using the trowel (**Figure 4.3)**. Avoid compacting the soil in the hole while digging. Place **all** of the soil and gravel removed from the hole in a plastic bag.

- Using the 2-mm sieve, sieve the soil in the plastic bag to separate the gravel. Collect the soil in a plastic sealable bag. Put the gravel aside to be used in Step 2. Seal and label the plastic bag. **[Note: See Considerations above if soil is wet.]**

Figure 4.3

2 **Line the Hole**

Line the hole with plastic wrap as shown in **Figure 4.4**. Leave some excess plastic wrap around the edge of the hole. Place the sieved rocks and gravel carefully in the center of the hole on top of the plastic wrap. Assure that the pile of rocks **do not** protrude above the level of the soil surface.

Figure 4.4

3 **Add Water to Hole**

- Use the 140 cc syringe to keep track of how much water is needed to fill the lined hole. The level of the water should be even with the soil surface.

- The amount of water represents the volume of soil removed. Record the total amount of water in cubic centimeters (1 cc = 1 cm^3) on the Soil Data worksheet.

NOTE: Steps 4-6 can be done in a lab or office if a scale is not available in the field. Step 7 requires access to a microwave.

4 **Weigh and Record Sample**

- Weigh the soil sample in its bag. [If the sample is too heavy for the scale, transfer about half of the sample to another plastic bag. The weights of the two sample bags will need to be added together. Enter the weight (sum of two bags, if applicable) on the Soil Data worksheet.

- Weigh an empty plastic bag to account for the weight of the bag. Enter the weight (sum of two bags, if applicable) on the Soil Data worksheet.

5 **Extract Subsample to Determine Water Content and Dry Soil Weight**

- Mix sample thoroughly in the bag by kneading it with your fingers.

- Take a 1/8-cup level scoop subsample of loose soil (not packed down) from the plastic bag and place it in a paper cup (a glass or ceramic cup may be used).

6 **Weigh and Record Subsample**

- Weigh the soil subsample in its paper cup. Enter the weight on the Soil Data worksheet.

- Weigh an empty paper cup to account for its weight. Enter the weight on the Soil Data worksheet.

7 **Dry Subsample**

Place the paper cup containing the subsample in a microwave and dry for two or more four-minute cycles at full power. Open the microwave door for one minute between cycles to allow venting. Weigh the dry subsample in its paper cup and enter the weight on the Soil Data worksheet.

NOTE: To determine if the soil is dry, weigh the sample and record its weight after each 4-minute cycle. When its weight does not change after a drying cycle, then it is dry.

CALCULATIONS (for both bulk density methods):

Soil water content (g/g) = $\frac{\text{(weight of moist soil - weight of oven dry soil)}}{\text{weight of oven dry soil}}$

Soil bulk density (g/cm^3) = $\frac{\text{oven dry weight of soil}}{\text{volume of soil}}$

Soil water-filled pore space (%) = $\frac{\text{volumetric water content} \times 100}{\text{soil porosity}}$

Volumetric water content (g/cm^3) = soil water content (g/g) x bulk density (g/cm^3)

Soil porosity (%) = $1 - \left(\frac{\text{soil bulk density}}{2.65}\right)$

Volume of Rocks (cm^3) = Fill 1/3 of a graduated cylinder with water, and record the amount. Add the rocks to the cylinder and record the change in the water level. The difference is the volume of rocks (1 mL = 1 cm^3).

Volume of Soil (cm^3) = Total soil volume - volume of rocks

Contents

Launching equipment

Software requirement:

- HOBOware Pro

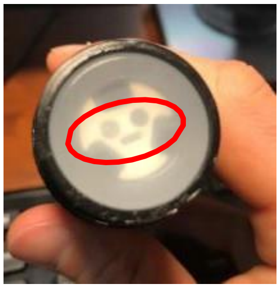
Hardware:

- Pressure transducer(s) and/or rain gage
- Waterproof shuttle with attachments
- Macro USB cable

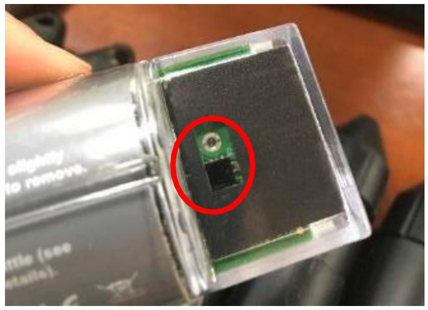
Steps:

1. Unscrew the cap off the waterproof shuttle and plug it into the computer
2. Attach the appropriate coupler to the waterproof shuttle for the device you are launching
   a. The purpose of the coupler is to align the sensor on the shuttle with the sensor on the monitoring device. The images below show the sensors meant to be coupled.

Data transmission sensor on waterproof shuttle and on pressure transducer



Data transmission sensor on waterproof shuttle and tipping bucket logger

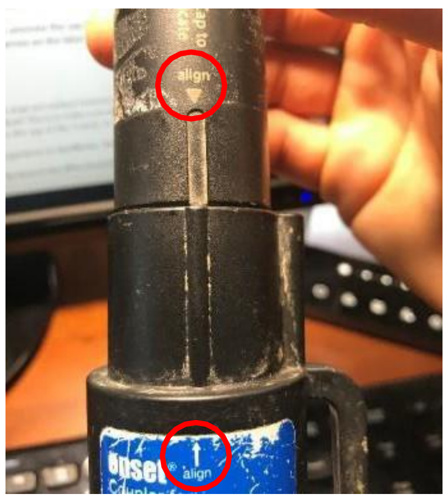


b. The rain gage coupler and pressure transducer coupler are shown below.

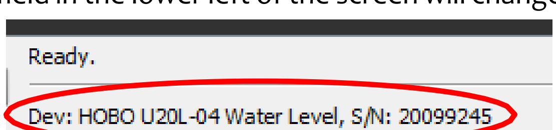
Pressure transducer coupler

Rain Gage Coupler

3. Slide the logger into the coupler
   a. For a pressure transducer, unscrew the cap and align the arrows on the logger and coupler

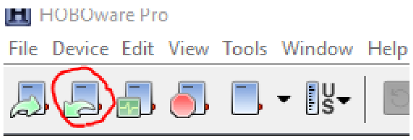


   b. For a rain data logger, anticipate difficulty aligning the sensors sufficiently to read the device. You may have to press it on very tightly and it might still be finicky.
4. Open HOBOware
5. Depress the plastic lever on the coupler to connect the logger
   a. The OK light should light up and remain lit. If connection fails, make sure the logger is snuggly in the coupler and try again. If it still fails, try to shove the coupler further onto the waterproof shuttle. This will probably be the solution.
   b. It may take a couple minutes for the device to set up on your computer. When it has been connected, device field in the lower left of the screen will change accordingly.

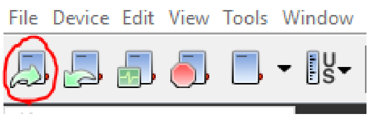


6. Check to make sure the device has been read out (i.e. any data it contained has been uploaded to the server)

   a. Click the readout device icon. If there is data, follow the how-to linked above for offloading and processing monitoring well data



7. Click the launch device icon



8. Name the device according to the following format: [Logger ID]_[Project No.]_[Data type and Gage/Well ID]
   a. The [Logger ID] is a consecutive series for loggers we have used. The Monitoring Equipment Spreadsheet has a table of Logger IDs that can be added to if using new equipment.
   b. [Data type and Gage/Well ID] will be relevant if there are multiple water level gages at a site. This ID should correspond to identifiers in the monitoring plan for which there should be an .mxd. Be sure to keep the transducers distinguishable by either placing a piece of tape on them and labeling it or labeling a box or bag that contains it.

9. Take note of the battery level. If it seems low, contact the PM to see if the budget will allow the use of new equipment. Typically, replacing the batteries is costly enough to warrant using new equipment.

10. Depending on the type of data you are collecting, the remaining steps will be different.
   a. **For rain data:**
      i. Uncheck Temperature as a sensor to log. This is useless and burns up precious memory. If we want ambient air temperature, we can use the pressure transducer recording barometric pressure.
      ii. Start logging at a Date/Time after you are certain you will be finished with installation.
      iii. Double check each entry
      iv. Click "Delayed Start" and uncouple the logger
   b. **For a pressure transducer:**
      i. Make sure absolute pressure and temperature are both checked
      ii. Set the logging interval to 5 minutes unless otherwise informed
      iii. Start logging at a date/time that you will be confident you will be finished installing the equipment
      iv. Double check each entry
      v. Press Delayed Start
11. Open up the Monitoring Equipment spreadsheet linked above and add a copy/paste the project template. Fill out the relevant fields for your project, including the look-up cell that will update with he logger fill-up date.

Stream Gage

Placement Considerations

Context:

Most often, stream gage data will be used in the calibration process of hydrologic modeling. The goal of calibration is to determine the rainfall-runoff relationship of the watershed, and stage data is the basis for developing the "runoff" portion of that relationship. In determining the location of the stream gage, there are two primary placement goals: best representing watershed drainage patterns and suitability for solving manning's equation. Of secondary concern is convenience and limiting visibility to prevent vandalism or theft.

Transforming stage data into flowrates requires the application of Manning's equation which, in addition to stage data, requires channel geometry, a roughness coefficient, and slope. Channel geometry can be measured directly in the field and **must** use the same datum as the stage data because we need to know the associated flow area for each stage measurement. The upstream and downstream slope can also be measured directly in the field. The roughness coefficient cannot be measured directly but it can be determined by taking flow measurements at various stages to develop a stage-discharge relationship. Manning's can be assumed based on bed and bank material but collecting flow measurements is ideal. Finally, because manning's equation assumes the flow vectors in the channel are all going in the same direction, it is important to choose a location where this assumption is most true. This will typically be in a straight run/glide section well away from features that may cause backwatering or significant turbulence such as confluences and bridges. It is not uncommon that we are unable to install the gage in a riffle section because of rocks, but if we install it just upstream or downstream of the riffle, we can extrapolate our stage measurements based on the hydraulic grade line to the riffle cross section for which we are solving for Manning's equation. Upstream of the target riffle is preferred because we can input the stage hydrograph into GeoHECRAS directly without having to extrapolate the stage data.

To best represent watershed drainage patterns, it is useful to do perform a GIS watershed assessment to identify potential installation locations that drain portions of the watershed that are most representative of the project reach. If there are significantly different watershed conditions draining to distinct stream sections, it may be a good idea to install more than one stream gage. For example, if you are restoring 1000 feet of stream and the watershed of the upstream portion is mostly agricultural and the downstream portion is receiving runoff from urban landuses, you may want to install 2 gages OR install 1 gage close to the downstream end, which would likely result in a more conservative calibrated model (i.e. a model that would generate more runoff per unit rainfall throughout the reach).

Consult with the PM and designer on stream gage placement prior to field work, then adjust the placement based on field conditions.

Construction and Installation

Construction

- Generally, the more work that can be done in the office the better
- Stream gages and wells should be made from a section of slotted 2" PVC 'screen', available from well drilling supply companies (with a section of normal 2" PVC for structure and to reduce sedimentation in groundwater wells).
- Use a threaded PVC "clean out" type cap. This prevents the cap from being pulled off the stream gage and makes it easier to download the logger.
- Drill a hole in the threaded PVC cap and feed the cord from the logger through the cap, then tie it off with a stopper knot. Using this method dramatically reduced instances of the logger being dislodged from the bottom of the stream gage.
- Use a standard 2" PVC cap for the bottom of the stream gage.
- Use PVC primer and cement to assemble the pieces of the stream gage. It's best to assemble the stream gage in the office rather than the field.
- Put filter material over the slotted section of PVC on the gage to reduce the amount of sediment that accumulates inside the gage. This is also available at well drilling supply stores.
- Make the wells as short as possible (e.g. use a 5' T-post driven 3' into the ground and construct the PVC housing so that the cap is just barely above the top of the post)
  - Keep the overall gage length short, but not so short that the gage will be submerged during downloads unless you want cold hands.

Installation

- Use a t-type fence post driven into the stream T-post rather that U-posts, as U-posts are not nearly as durable.
- Use a post driver to drive the t-post into the stream bed. Depending on the substrate, I typically try to get the post in at least two feet. **Wear ear and eye protection.**

- Try to keep the post as level as possible to ensure accurate measurements
- Ideally, the t-post will be just shorter than the stream gage, with the top high enough to not be submerged, but not so tall as to create extra leverage on the gage during flood events.
- Secure the stream gage PVC to the T-post using metal hose clamps. These eventually do rust, but are more secure than plastic zip ties, rope, or cable, in my experience
- Bring an extra U-post during gage install in case the first one gets bent
- All water elevations will be relative to the top of the PVC so the top of this must be measured with a total station or GPS at some point
- Since it takes some time for the temperature to equilibrate, the logger should be set to start recording several hours after it has been installed
- Take pictures
- Schedule a download in outlook and in the monitoring spreadsheet (linked above)
- At minimum, measure a cross section at the location for which you are solving for manning's, at the location of the gage, and the slope through the riffle cross section.
- If monitoring head in a pond, place the gage in an inlet or outlet. The purpose is to calibrate the rain-runoff relationship, not the change in storage. It WOULD be useful, however, to record both inflow or outflow AND change in storage, or inflow and outflow.
- Should be installed firmly; the top of PVC will likely be the reference elevation and we don't want this to shift
- Consider whether there is a risk of the gage being knocked loose or vandalized
- Take note of the final installed geometry of the well including the total height of the PVC housing, the distance between the top of the PVC housing and the top of the T-post, and the height of the T-post.

Wetland Monitoring Well

Installation:

- It should be installed plumb, so bring a level. This is to make sure reference water level measurements are accurate
- A U-post shall be installed if visibility or mobility is a concern but is not necessary
- The top of the PVC should serve as the reference elevation and should be measured with the RTK GPS or with the total station
- Pictures should be taken of each well
- Schedule first download in outlook and add to monitoring equipment spreadsheet
- Conduct soil boring at least down to hydric soils and preferably to the first confining layer and record the elevation of each strata; this will be used as a line of evidence for groundwater readings that we'd expect which is particularly useful if the monitoring wells happen to be installed before a dry spell.
- Should be an exploratory process
    - Do transects with soil borings perpendicular to adjacent channels
        - Use river width as distance between borings
- When deciding to add another well:
    - Is the vegetation or soils significantly different?
- Consider history
    - Was there an underdrain?
    - Could an adjacent channel deposited lateral barriers
- Install well in analog wetland
- Landscape position, soils, plants, and hydrology determine location of wells

- Install a filter sock if there is any risk of the well silting in; the two drain holes at the bottom of the logger must remain free of debris. If these are clogged up they can cause unpredictably anomalous readings.

- Always check for blockages in in-line conduits (upstream and downstream)
- Should be installed firmly; the top of PVC will likely be the reference elevation and we don't want this to shift
- Consider well configuration; if cattle are around, it is a good idea to make the wells low to the ground so the cattle aren't tempted to rub against it. A configuration with 3 T-post wrapped in chicken wire surrounding the gage can be useful too.

Placement:

- When the purpose of the monitoring wells includes calibrating a hydrologic model, consider having one monitoring well for each modeled subcatchment.
    - Install it at the low point of the catchment (if there is a channel, install it at the downstream end in the thalweg)
- From a modeling perspective, we want to detect inflows, outflows, and anomalies
    - Inflows could be springs, toe of slope, channels, upward seepage
    - Outflows could be karst features or channels
    - Anomalies can be detected by:

        - Comparing existing well hydrographs to determine whether clusters of wells seem to be responding to the same inflows and outflows (the shapes will look similar if so)
        - Conducting soil borings in transects to identify variability in confining layer depths or hydric soils
- Conduct soil borings in transects and record ground elevation
    - Important variables: surface texture of strata
    - Depth to confining layer
    - Depth to water table (i.e. hydric soils)
    - Depth to water, if struck (allow water level to stabilize before taking measurement ~10min)
- If part of the project is on cultivated land, be sure to install the rain gage well away from where the farmer will be working. Consider that the equipment they tow is much wider than the tractor.

Rain Gage

- The rain gage when recording rain only (i.e. not recording temperature) has enough memory to record between 160 and 230 inches per rain. For comparison, Charlottesville gets an average of about 48 inches of rain per year.
- Schedule the next download in outlook

Placement:

- Types of interference:
    - Hit with farm or construction equipment, vandalism/theft, bird poop, curious/itchy livestock, blockage of rain by trees and buildings
- Strategies for avoiding interference:
    - Sufficiently far from any obstructions to rainfall (buildings, trees)
    - Inconspicuous from perspective of pedestrians
    - If part of the project is on cultivated land, try to install out of the way of equipment. Otherwise, install with a very tall brightly colored flag.
    - Install wire around the rim of the rain gage to prevent birds from landing
    - Install where livestock cannot reach

LARGE WOODY DEBRIS FIELD FORM

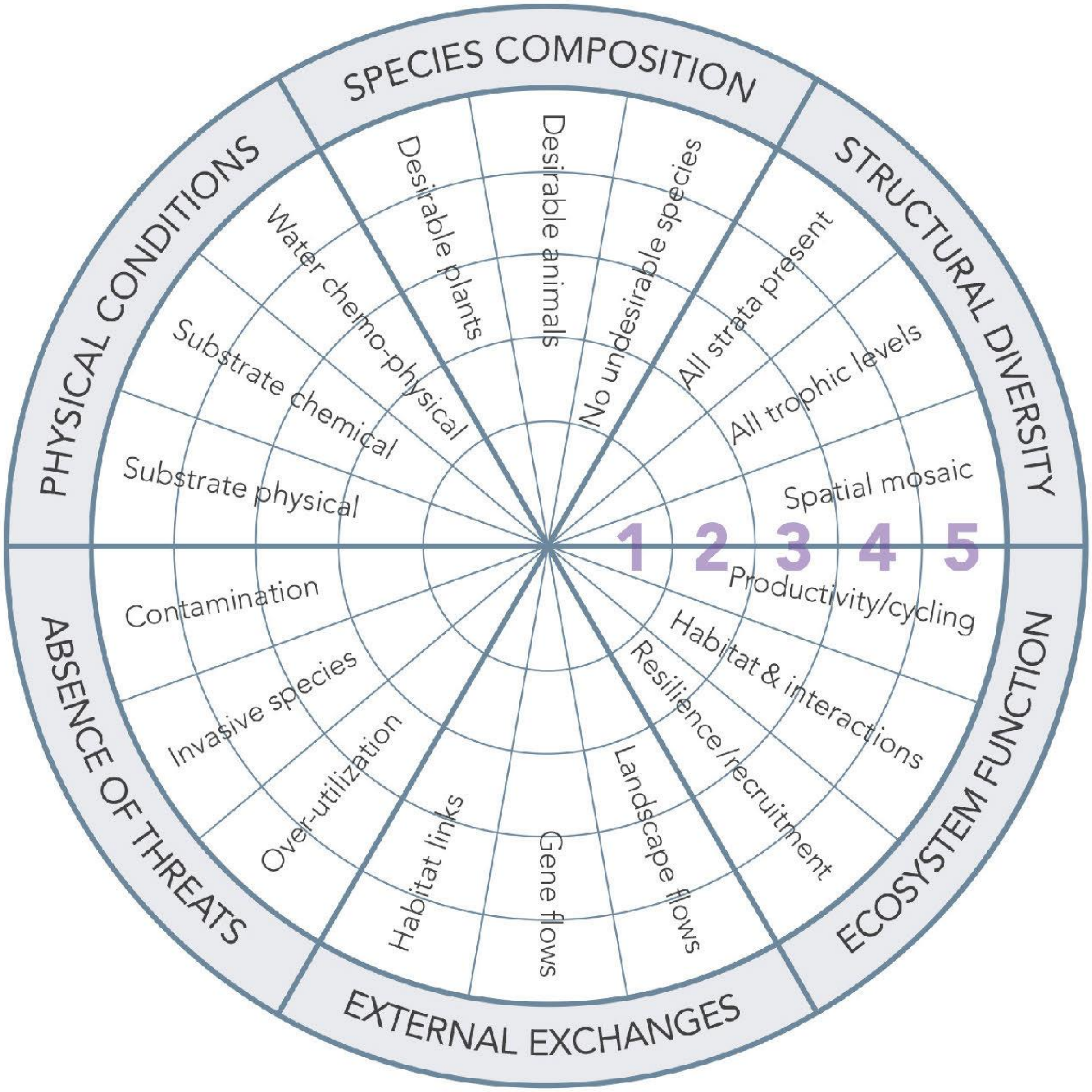
Date Revised: 10/19/2016

Investigator(s)		State		Forest Type	Deciduous Evergreen Mixed Other
Date		County		Forest Age (yrs)	
Stream Name		Phys. Province		Latitude (dd)	
Reach ID		Drainage Area (mi^2)		Longitude (dd)	
Watershed Name		Dominant Species			
Survey Length (ft)	328 — Survey Length = 328 ft/100 m	BKF Width (ft)		Slope (ft/ft)	
Stream Classification	Ephemeral Intermittent Perennial	BKF Mean Depth (ft)		Bed material	
Stream Condition	Degraded Restored Reference Managed	Floodprone Width (ft)		Rosgen Type	
Field Notes:					

SCORE	1	2	3	4	5	
CATEGORY			*** PIECES ***			**TOTAL PIECES**
Length/BKF Width	0 to 0.4	0.4 to 0.6	0.6 to 0.8	0.8 to 1.0	> 1.0	
Diameter (cm)	10 to 20	20 to 30	30 to 40	40 to 50	>50	
Location	**Zone 4** (Above BKF/Extending into Channel)		**Zone 3** (Above BKF/Within Streambanks)	**Zone 2** (Above WS/Below BKF)	**Zone 1** (Below WS)	
Type	Bridge		Ramp	Submersed	Buried	
Structure	Plain	Plain/Int	Intermediate	Int/Sticky	Sticky	
Stability	Moveable	Mov/Int	Intermediate	Int/Sec	Secured	
Orientation (deg)	0 to 20	20 to 40	40 to 60	60 to 80	80 to 90	
CATEGORY			**** DEBRIS DAMS ****			**TOTAL DAMS**
Length (% of BKF Width)	0 to 20	20 to 40	40 to 60	60 to 80	80 to 100	
Height (% of BKF Depth)	0 to 20	20 to 40	40 to 60	60 to 80	80 to 100	
Structure	Coarse	Coarse/Int	Intermediate	Int/Fine	Fine	
Location	Partially high flow	In high flow	Partially low flow	Mid low flow	In low flow	
Stability	Moveable	Mov/Int	Intermediate	Int/Sec	Secured	

* Pieces - Non-living wood that has a large end diameter ≥ 10 cm and has a length ≥ 1 m. ** Debris Dams - Three (3) or more pieces touching.

APPENDIX 2: BLANK PROJECT EVALUATION TEMPLATES (for practitioner use)



Recovery wheel template

EVALUATION OF ECOSYSTEM RECOVERY

Site ______________________________

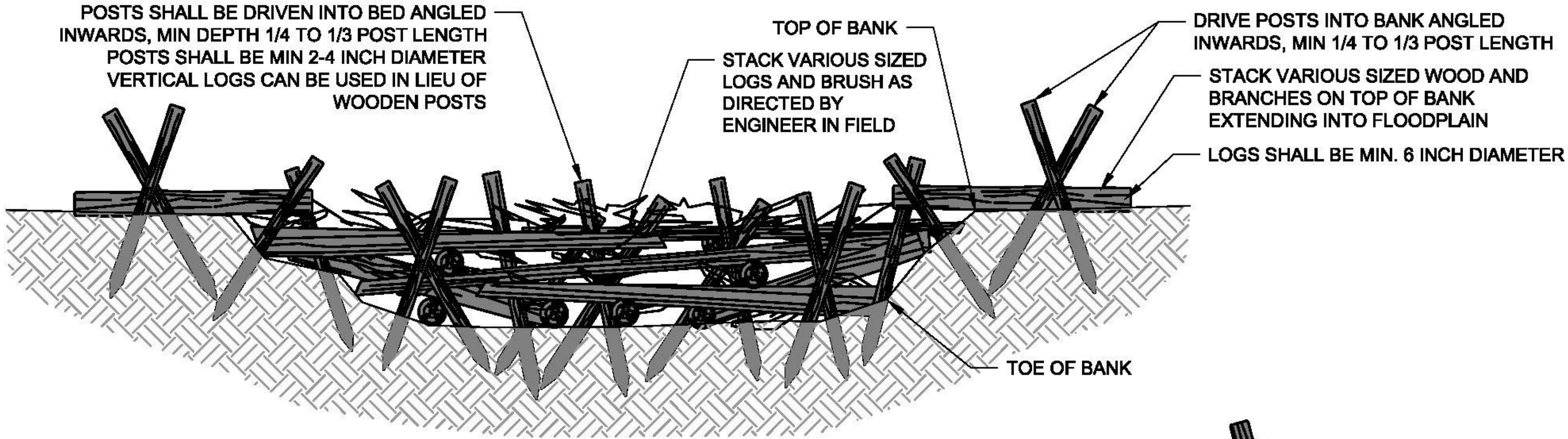
Assessor ______________________________

Date ______________________________

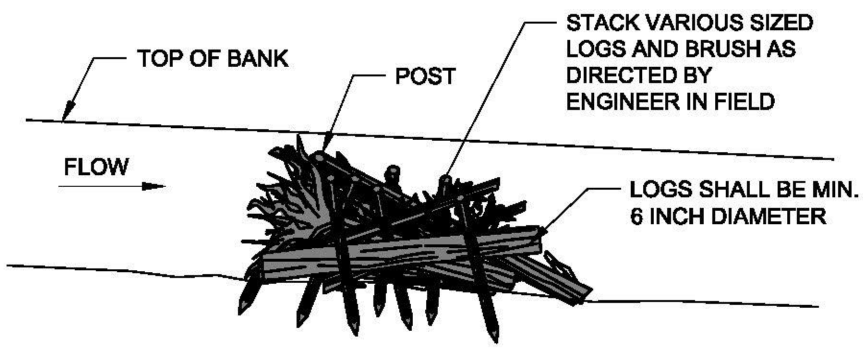
Reference Ecosystem:

ATTRIBUTE CATEGORY	REOCOVERY LEVEL (1-5)	EVIDENCE FOR RECOVERY LEVEL
ATTRIBUTE 1. Absence of threats		
Over-utilization		
Invasive species		
Contamination		
ATTRIBUTE 2. Physical conditions		
Substrate physical		
Substrate chemical		
Water chemo-physical		
ATTRIBUTE 3. Species composition		
Desirable plants		
Desirable animals		
No undesirable species		
ATTRIBUTE 4. Structural diversity		
All strata present		
All trophic levels		
Spatial mosaic		
ATTRIBUTE 5. Ecosystem function		
Productivity, cycling		
Habitat & interactions		
Resilience, recruitment		
ATTRIBUTE 6. External exchanges		
Landscape flows		
Gene flows		
Habitat links		

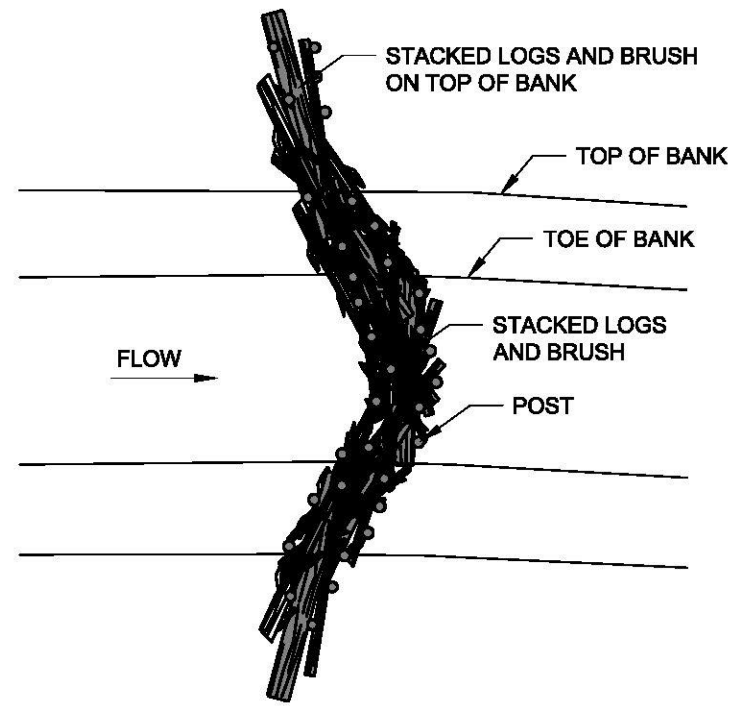
Appendix E. Common Low-Tech Design Details



SECTION VIEW



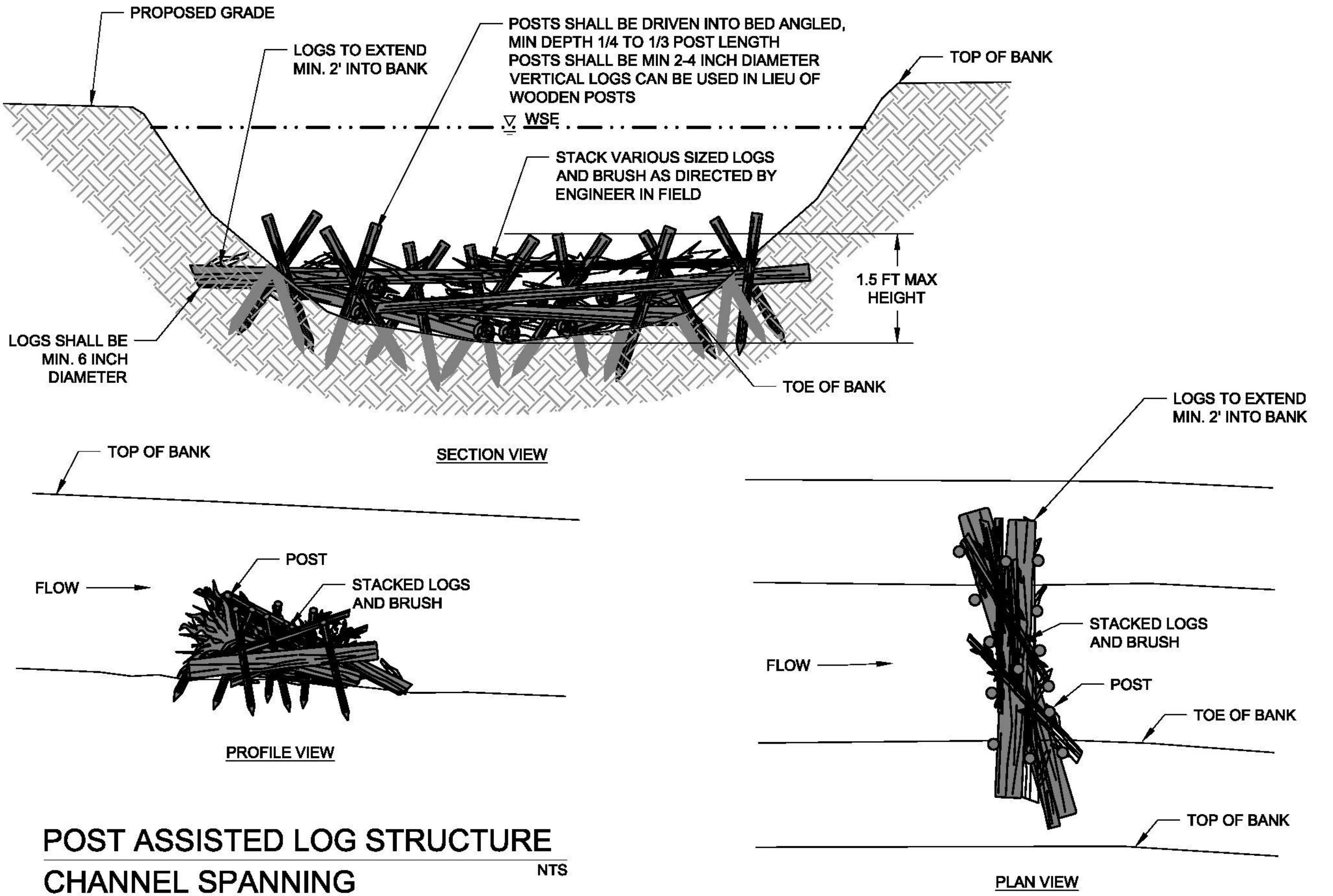
PROFILE VIEW



PLAN VIEW

BEAVER DAM ANALOG (BDA)

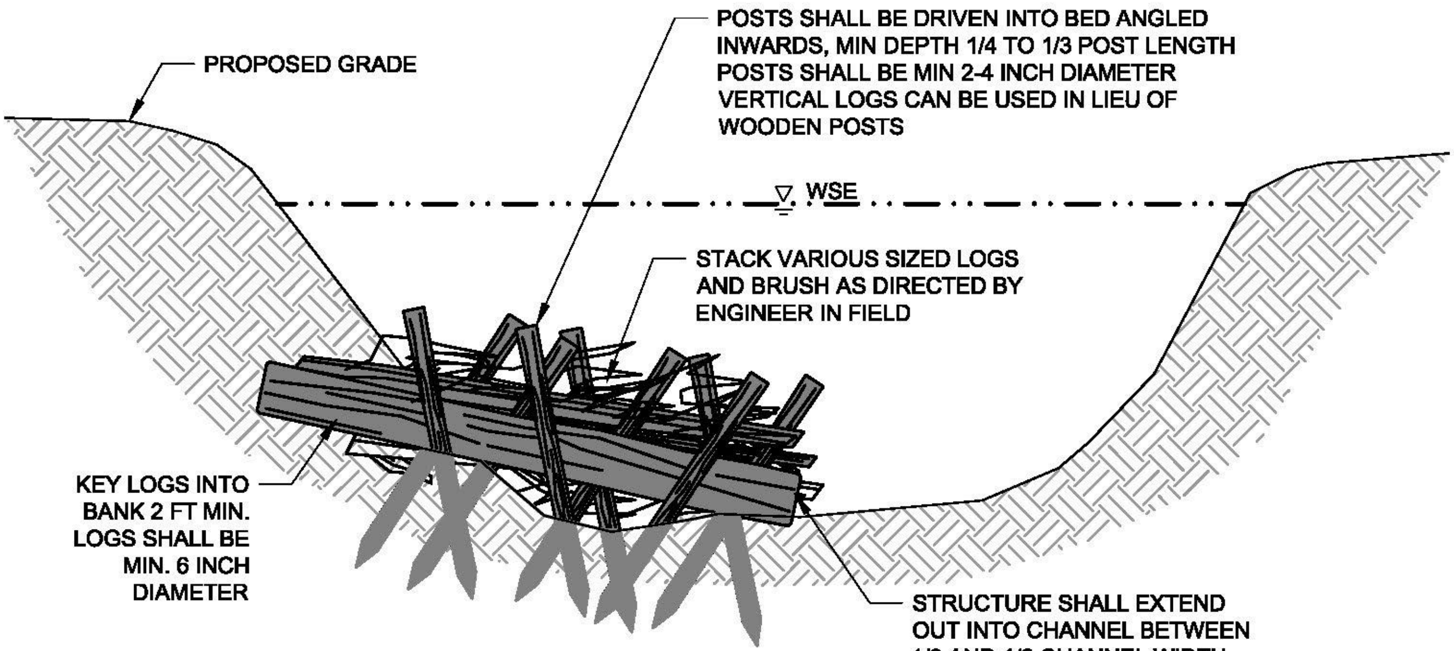
NTS



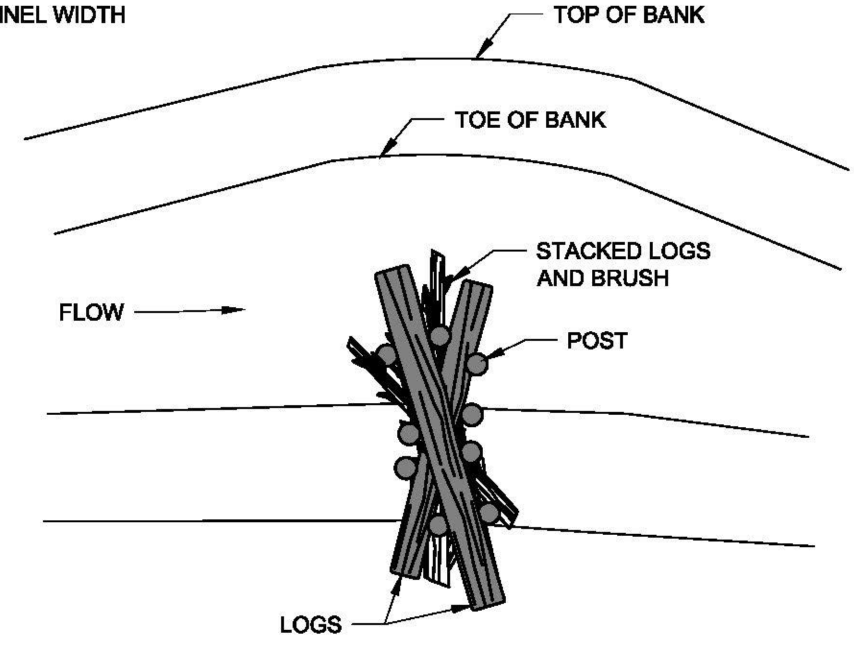
POST ASSISTED LOG STRUCTURE

CHANNEL SPANNING

NTS



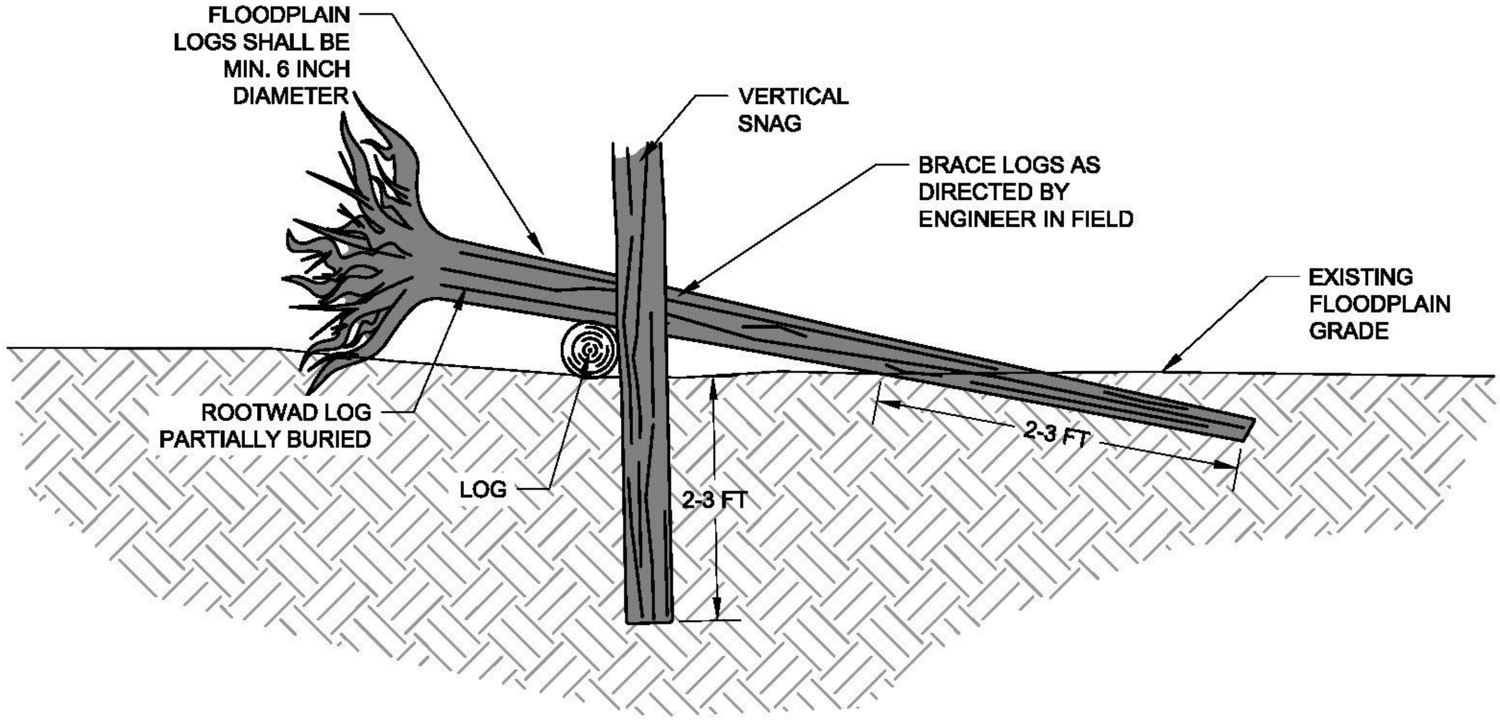
SECTION VIEW



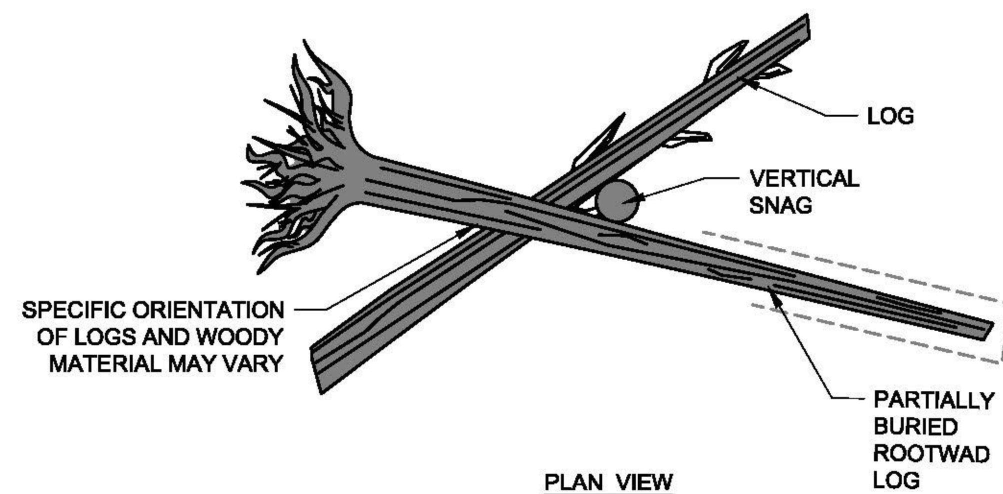
PLAN VIEW

POST ASSISTED LOG STRUCTURE
BANK ATTACHED

NTS



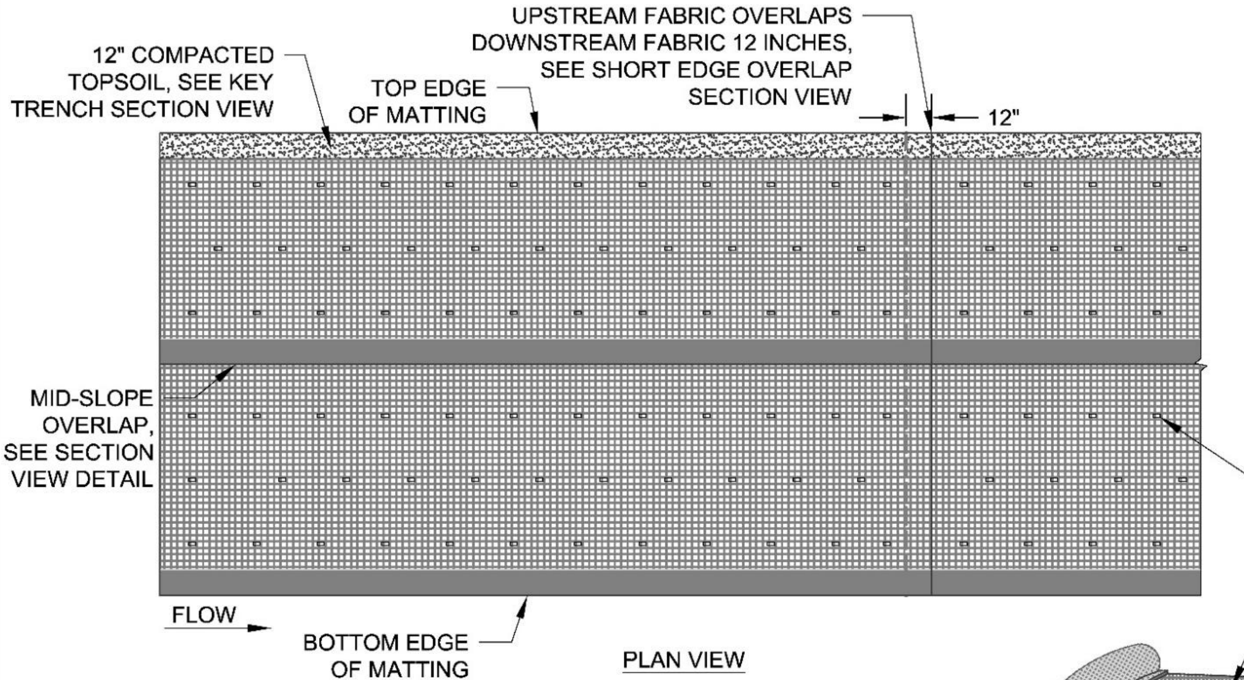
SECTION VIEW



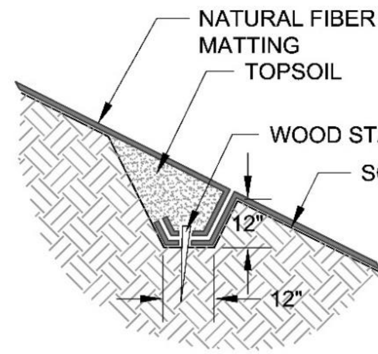
PLAN VIEW

FLOODPLAIN ROUGHNESS

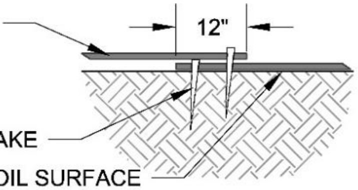
NTS



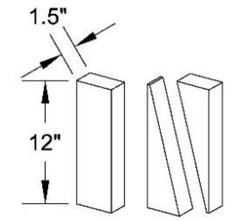
PLAN VIEW



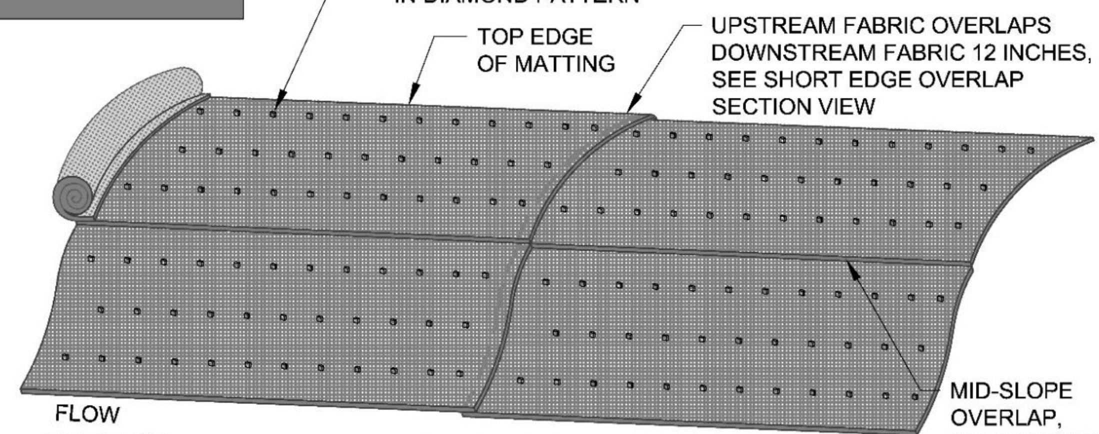
MID-SLOPE OVERLAP SECTION VIEW



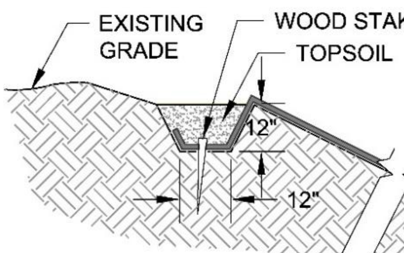
SHORT EDGE OVERLAP SECTION VIEW



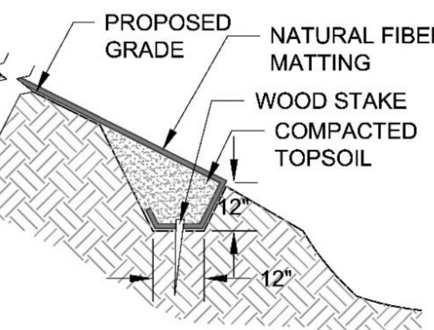
2x4 WOOD STAKE DETAIL (OR EQUIV.)



ISOMETRIC VIEW



KEY TRENCH SECTION VIEW



BOTTOM EDGE TRENCH SECTION VIEW

STREAMBANK MATTING

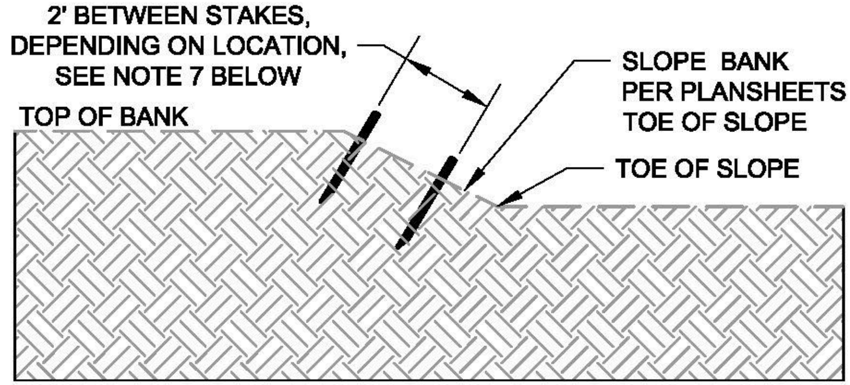
NTS

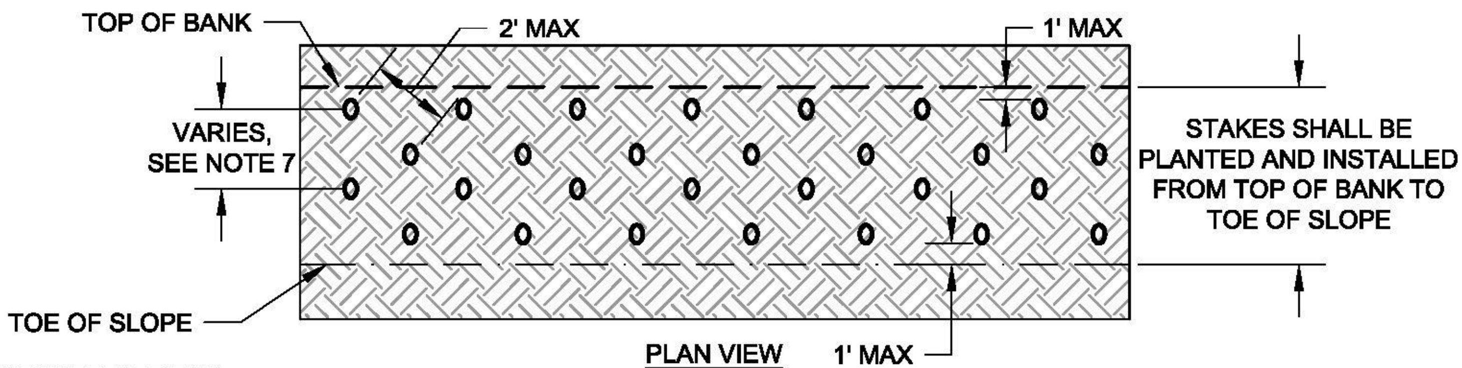
STREAMBANK MATTING NOTES:

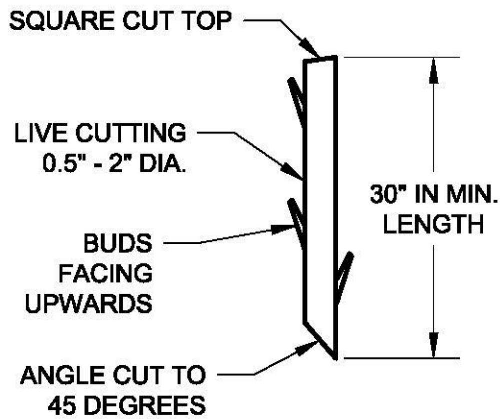
1. STREAMBANK MATTING TO BE PLACED ON ALL PROPOSED STREAMBANKS.
2. NATURAL FIBER MATTING SPECIFICATION ALIGNS WITH 700 GRAM COIR FABRIC. EQUIVALENTS ARE ACCEPTABLE.

Natural Fiber Matting Specifications

Properties	Test Method	Specifications
Material		Woven matting made of high strength natural fiber
Color		Natural tone
Thickness	ASTM D 5199	0.35 in
Weight	ASTM D 3776	20.3 oz/sqyd
Maximum Elongation Wet MD x CD	ASTM D 4595	69% x 34%
Maximum Elongation Dry MD x CD	ASTM D 4595	40% x 33%
Wide width tensile strength Wet MD x CD	ASTM D 4595	924 x 684 lbs/ft
Wide width tensile strength Dry MD x CD	ASTM D 4595	1512 x 1032 lbs/ft
Slope (Recommended)	Observed	>1 : 1
Shear Stress (Recommended)	Flume Test	4.5 psf
Water Velocity (Recommended)	Flume Test	12 ft/sec
Water Absorption	ASTM D 1117	146%
"C" Factor		0.002
Open Area	Measured	50% or 0.5 in x 0.5 in





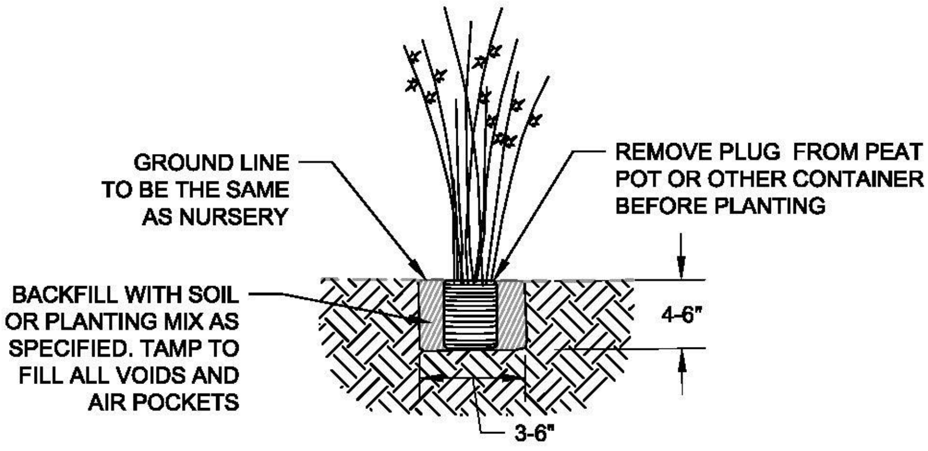


LIVE STAKE INSTALLATION NOTES:

1. STAKES SHALL BE CUT AND INSTALLED ON THE SAME DAY.
2. STAKES THAT HAVE BEEN SPLIT SHALL BE REJECTED AND NOT USED FOR CONSTRUCTION.
3. STAKES SHALL BE INSTALLED WITH BUDS POINTING UPWARD.
4. STAKES SHALL BE INSTALLED PERPENDICULAR TO BANK.
5. STAKES SHALL BE 0.5" - 2" IN DIAMETER AND 30" IN MINIMUM LENGTH.
6. STAKES SHALL BE INSTALLED WITH APPROXIMATELY 3" OF STAKE REMAINING ABOVE GROUND.
7. STAKE SPACING SHALL BE NO MORE THAN 2' ON CENTER.

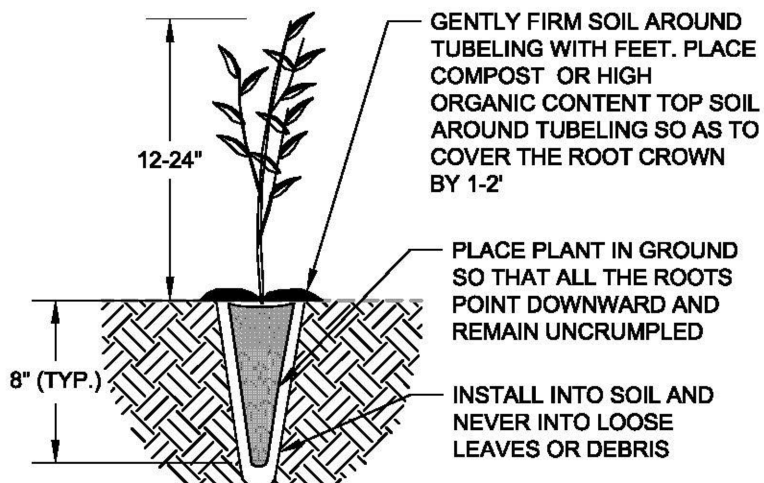
LIVE STAKE INSTALLATION

NTS



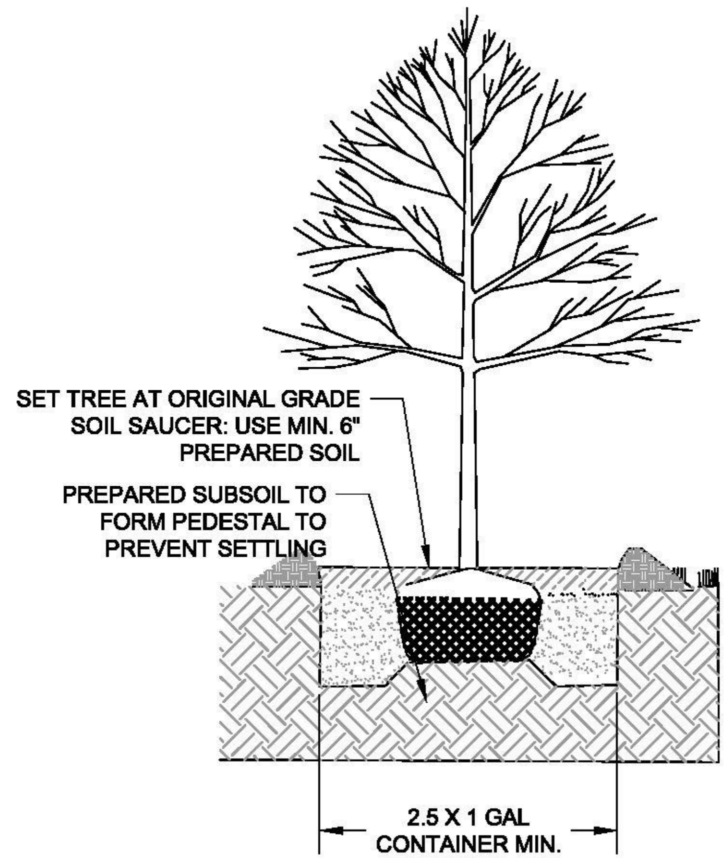
HERBACEOUS PLUG PLANTING

NTS



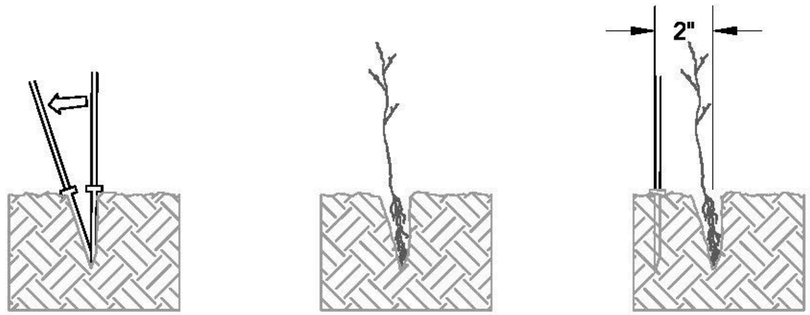
TREE/SHRUB TUBELING PLANTING

NTS



TREE/SHRUB TUBELING PLANTING

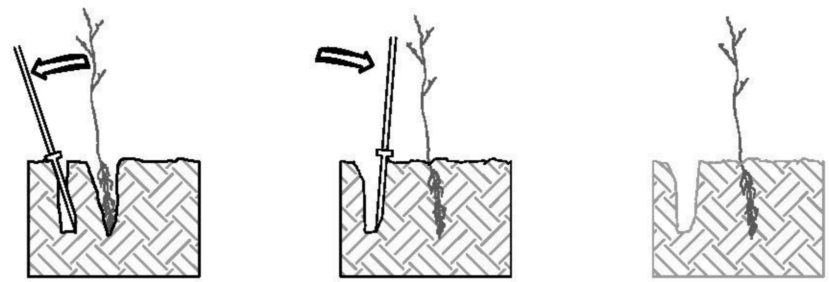
NTS



1. INSERT PLANTING BAR AS SHOWN AND PULL HANDLE TOWARD PLANTER.

2. REMOVE PLANTING BAR AND PLACE SEEDLING AT CORRECT DEPTH.

3. INSERT PLANTING BAR 2IN. TOWARD PLANTER FROM SEEDLING.



4. PULL HANDLE OF BAR TOWARD PLANTER, FIRMING SOIL AT BOTTOM.

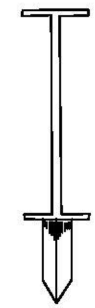
5. PUSH HANDLE FORWARD FIRMING SOIL AT TOP.

6. LEAVE COMPACTION HOLE OPEN. WATER THOROUGHLY.

DIBBLE PLANTING METHOD

PLANTING BAG
DURING PLANTING, SEEDLINGS SHALL BE KEPT IN A MOIST CANVAS BAG OR SIMILAR CONTAINER TO PREVENT THE ROOT SYSTEMS FROM DRYING.

KBC PLANTING BAR
PLANTING BAR SHALL HAVE A BLADE WITH A TRIANGULAR CROSS SECTION, AND SHALL BE 12IN. LONG, 4IN. WIDE AND 1IN. THICK AT CENTER.



ROOT PRUNING
ALL SEEDLINGS SHALL BE ROOT PRUNED, IF NECESSARY, SO THAT NO ROOTS EXTEND MORE THAN 10 INCHES (10IN.) BELOW THE ROOT COLLAR.

BARE ROOT SEEDLING PLANTING NOTES:

1. DIBBLE METHOD IS PREFERRED. OTHER BARE ROOT PLANTING METHODS CAN BE USED WITH THE PERMISSION OF THE PLANTING SUPERVISOR.
2. CONTRACTOR TO USE KBC PLANTING BAR OR EQUIVALENT.
3. PLANTING BAR SHALL HAVE A BLADE WITH A TRIANGULAR CROSS-SECTION, AND SHALL BE 12" IN LENGTH, 4" IN WIDTH, AND 1" IN CENTER.
4. METHOD TO BE IMPLEMENT IN AREAS WHERE BARE ROOT PLANTS ARE TO BE INSTALLED
5. BEFORE PLANTING, SEEDLINGS SHALL BE UNPACKED AND SOAKED IN WATER FOR 1-4 HOURS TO ALLOW FOR REHYDRATION.
6. DURING PLANTING, SEEDLINGS SHALL BE KEPT IN A MOIST CANVAS BAG OR SIMILAR CONTAINER TO PREVENT THE ROOT SYSTEMS FROM DRYING.
7. ALL SEEDLINGS SHALL BE ROOT PRUNED, IF NECESSARY, SO THAT NO ROOTS EXTEND MORE THAN 10" BELOW THE ROOT COLLAR.

BARE ROOT SEEDLING PLANTING

NTS

ECOSYSTEM SERVICES

ENGINEERING | ECOLOGICAL RESTORATION | CONSULTING