Maintaining Forests in Stream Corridor Restoration Best Practices Guide

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<u>Notes on this draft:</u>

This draft is not yet formatted in a manner suitable for distribution. The intention for the draft is to compile the content for review and discussion by the stakeholder team. After the content is completely developed, this guide will be formatted by a professional graphic designer.

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1 Introduction and Purpose

This guidance document includes best practices for local and state governments in the Chesapeake Bay watershed to consider when planning for stream restoration projects to minimize unintended impacts to riparian forests and ecosystems. It was developed collaboratively between the Center for Watershed Protection, Inc. (CWP), Chesapeake Bay Program (CBP), and stakeholders based on findings from a recent study (*Include reference or link to the final project report here*) that consisted of a survey of regulators, practitioners, and local governments in the Chesapeake Bay watershed; a literature review of guidance documents and policies; interviews with individuals considered experts in stream restoration and/or forest buffers; case study evaluations of stream restoration projects; and state-specific webcasts to discuss study findings.

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Stream restoration for the purposes of this guidance document is defined according to the Chesapeake Bay Program (CBP) stream restoration expert panel recommendations[1,2] as "any natural channel design, regenerative stormwater conveyance, legacy sediment removal or other restoration project that meets the qualifying conditions for credits, including environmental limitations and stream functional improvements."[3]

This document is designed to be a reference guide that provides an overview of the best practices and available resources and tools. It consists of the following sections:

- Background: Context for the need for riparian buffer considerations as part of stream restoration projects.
- Regulation Summary and Jurisdiction-Specific Considerations: Summary of state-specific stream restoration considerations and federal, state, and local regulations.
- General Best Practices: Overview of best practices for considering forests as part of stream restoration and a compilation of associated resources and tools.
- Design-Specific Best Practices: Description of the main approaches to stream restoration design and their associated unique considerations and best practices.

2 Background

Forest buffers are critical for stream health. They improve the stability of stream banks, provide shade, filter nutrients and sediments, and contribute organic material for aquatic food webs. It is generally acknowledged that restoration project construction often exerts short-term adverse environmental impacts. Depending on the pre-restoration condition and level of construction disturbance, years of ecosystem maturation may be needed before a project fully meets its long-term restoration objectives and realizes its full environmental benefits.

In 2003, CBP partners set a goal to restore 900 miles of riparian forests in the watershed each year. This goal was renewed in the 2014 Chesapeake Bay Watershed Agreement (CBP, 2014), which was signed by all six Bay states and the District of Columbia. The agreement also calls for the conservation of existing buffers until at least 70 percent of riparian areas throughout the watershed are forested. With growing interest and implementation of stream restoration in the Chesapeake Bay Watershed, there is an increasing need for research about how to protect riparian buffers and minimize

[1] Schueler, T. & B. Stack. 2014. Recommendations of the Expert Panel to Define Removal Rates for Individual Stream Restoration Projects. Approved by the Water Quality Goal Implementation Team of the Chesapeake Bay Program September 8, 2014.
[2] Wood, D., Schueler, T., & B. Stack. 2021. A Unified Guide for Crediting Stream and Floodplain Restoration Projects in the Chesapeake Bay Watershed.
[3] It's important to note that the term "restoration" can be misleading because it has the connotation that the stream will be returned to a historical condition, which is often not possible due to changes in hydrology, soils, flow and general pattern and profile. In these cases, the result would be rehabilitation instead of restoration. However, for simplicity and to remain consistent with existing CBP stream restoration guidance, the term restoration will be used throughout this document.

their impact during stream restoration construction. The CBP Stream Restoration Expert Panel Report[4] and recent work group updates[5] intended for the stream restoration crediting protocols to be part of a holistic watershed approach and included qualifying conditions that offer some protection for riparian vegetation. However, stream restoration projects are commonly implemented with the main goal of obtaining TMDL credits and the qualifying conditions for riparian vegetation have not been consistently met. Because stream restoration and expanding forest buffers are a large component of state Watershed Implementation Plans (WIPs) and the 2014 Chesapeake Bay Agreement, it is imperative to better synergize efforts and investments to minimize negative trade-offs impacts/outcomes.

3 Regulation Summary and Jurisdiction-Specific Considerations

The ways in which riparian vegetation is considered during stream restoration projects varies between Pennsylvania, Maryland, and Virginia in terms of regulations and state-specific guidance. The variability between the states' definition of stream restoration, primary types of restoration implemented, and acceptable riparian vegetation outcomes are summarized below. There are federal regulations and permit requirements that pertain to stream restoration in all three states (Pennsylvania, Maryland, and Virginia). This includes Army Corp of Engineers nationwide permits, regional permits, and joint permits with all three states. This regulatory power comes from the Clean Water Act and the mandate to protect water quality. Key federal regulations focused on stream restoration are summarized in Table 1. State-specific regulations and examples of local government regulations are summarized in the subsequent sections below.

Table 1. Summary of federal regulations that correspond to riparian forest buffers and stream restoration

Regulation	Where it Applies	Description	Key Requirements
Nationwide Permit 27 – Aquatic Habitat Restoration, Enhancement, and Establishment Activities	Waters of the United States (WOTUS)	Authorizes activities in waters of the United States associated with (i) the restoration, enhancement, and establishment of tidal and non-tidal wetlands and riparian areas, (ii) the restoration and enhancement of non-tidal streams and other non-tidal open waters, and (iii) the rehabilitation or enhancement of tidal streams, tidal wetlands, and tidal open waters, provided those activities result in net increases in aquatic resource functions and services.	• Restoration or enhancement, maintenance, and legal protection of riparian areas next to open waters (typically 25-50ft on either side of a stream). • Post-construction monitoring (typically 5 years). • Requires riparian areas be restored with native species
Regional General Permit for Chesapeake Bay TMDL Activities	Nontidal WOTUS in the watershed within the State of Maryland (with some exceptions), the District of Columbia, Fort Belvoir, Fort Myer, and the Pentagon in Virginia	This permit is for projects undertaken to meet TMDL goals for a five-year period on September 1, 2020. The TMDL RGP is applicable to non-tidal wetlands and streams within the State of Maryland, the District of Columbia, and Fort Belvoir, Fort Myer, and the Pentagon in Virginia under regulatory control of the Baltimore District.	• 3-year monitoring requirement following construction completion which may be extended based on monitoring • Permanent impacts may not exceed 3 acres of nontidal wetlands and/or nontidal streams, or 5,000 linear feet of nontidal streams
Maryland State Programmatic General Permit-6 Joint Permit	Maryland	Federal joint permit from USACE with the appropriate state agency for environmental policy. The permit covers activities on US waters associated with the restoration, enhancement, and establishment of tidal and non-tidal	• Impacts limited to 10,000 square feet and/or 200 linear feet of streams • Compensatory mitigation at a minimum one-for-one ratio required for permanent losses of streams or other open waters

[4] Schueler, T. & B. Stack. 2014. Recommendations of the Expert Panel to Define Removal Rates for Individual Stream Restoration Projects. Approved by the Water Quality Goal Implementation Team of the Chesapeake Bay Program September 8, 2014.
[5] Wood, D., Schueler, T., & B. Stack. 2021. A Unified Guide for Crediting Stream and Floodplain Restoration Projects in the Chesapeake Bay Watershed.

Table 1. Summary of federal regulations that correspond to riparian forest buffers and stream restoration

Regulation	Where it Applies	Description	Key Requirements
Pennsylvania State Programmatic General Permit-6	Pennsylvania	wetlands and riparian areas, the restoration and enhancement of non-tidal streams and other non-tidal open waters, and the rehabilitation or enhancement of tidal streams, tidal wetlands, and tidal open waters. The permit provides information on reporting procedures, water quality certification details, nationwide conditions regional, and general conditions which are required to qualify for NWP authorization.	• Reporting requirement for activities with permanent impact on more than 500 linear feet of stream
Virginia State Programmatic General Permit Standard Joint Permit Application	Virginia		• Requires use of Natural Channel Design Review Checklist and Selected Morphological Characteristics form

3.1 Pennsylvania Regulations

In Pennsylvania, emphasis is primarily placed on identifying and correcting the underlying cause of degradation. The Pennsylvania Department of Environmental Protection (PA DEP) describes two approaches to stream restoration: evidence-based and triage. The evidence-based evaluates the causes of degradation and proposes appropriate designs to correct them. The triage approach involves identifying an urgent stream problem with a willing landowner and being able to secure funding. State representatives, local government representatives, and Pennsylvania-based practitioners are also specific about how to define stream restoration and how to apply that definition in the context of measuring project success. A 2018 PA DEP document defined stream restoration in the context of eligibility for MS4 crediting as "any natural channel design, wet channel regenerative stormwater conveyance, legacy sediment removal or other stream modifications intended to restore natural forms and processes that reduce streambank or streambed erosion and capture pollutants"[6]. For PA DEP, stream projects that target symptoms of degradation rather than the underlying cause(s) would not be considered stream restoration. Legacy sediment removal projects are commonly implemented in Pennsylvania and can involve the removal of relatively substantial amounts of riparian vegetation. However, PA DEP does not consider the loss of riparian trees negatively if the historic condition of the site did not include riparian forests. Key Pennsylvania regulations related to stream restoration can be found in Table 2.

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Table 2. Summary of Pennsylvania regulations that correspond to riparian forest buffers and stream restoration

State	Regulation	Where it Applies	Description	Key Requirements
PA	PA Code Chapter 105 Dam Safety and Waterway Management	Statewide	Chapter 105 provides for the comprehensive regulation and supervision of dams, reservoirs, water obstructions and encroachments in the Commonwealth and is the primary regulations for stream restoration projects in Pennsylvania.	• Require an impacts analysis for a proposed water quality project on the following: stream flow, fish and wildlife, aquatic habitat, Federal and State forests, parks, recreation • 3- to 5-year monitoring period for most restoration projects
PA	PA Code Chapter 102 Erosion and Sediment Control	Statewide	State regulations for requiring persons proposing or conducting earth disturbance activities to develop, implement and maintain BMPs to minimize the potential for accelerated erosion and sedimentation and to manage post construction stormwater	• Affords protection to riparian buffers being used for post-construction management

[6] Pennsylvania Department of Environment Protection (PA DEP). 2018. Considerations of Stream Restoration Projects in Pennsylvania for Eligibility as an MS4 Best Management Practice.

Table 2. Summary of Pennsylvania regulations that correspond to riparian forest buffers and stream restoration				
State	**Regulation**	**Where it Applies**	**Description**	**Key Requirements**
PA	Act 394 PA Clean Streams Law	Statewide	The Clean Streams Law is the main law designed to protect freshwater resources. The Clean Streams Law creates the legal framework to "preserve and improve the purity of the waters of the Commonwealth."	• It is the objective of the Clean Streams Law not only to prevent further pollution of the waters of the Commonwealth, but also to reclaim and restore to a clean, unpolluted condition every stream in Pennsylvania that is presently polluted;
PA	Act 247 PA Municipalities Planning Code	Statewide	The state law enabling local municipalities to enact comprehensive plan and zoning, subdivision & land development, and official map regulations.	• Language allows zoning ordinances to permit, prohibit, regulate, restrict and determine the uses of land, watercourses and other bodies of water and protect and preserve natural and historic resources and prime agricultural land and activities.

3.2 Maryland Regulations

In Maryland, stream restoration prioritizes the creation of stream-wetland complexes and healthy floodplains. There is more emphasis on evaluating projects based on the value of their current conditions as opposed to achieving historic or predevelopment conditions. The type of restoration design is selected based on site-specific factors, but the most commonly implemented types of stream restoration projects are Natural Channel Design (NCD), followed by Regenerative Stormwater Conveyance (RSC) projects. The Maryland Department of the Environment (MDE) recently developed stream restoration guidance (refer to Section 4) that includes best practices for minimizing forest loss during stream restoration. MDE is also conducting new research on ecological restoration and permitting, which aims to produce an operational definition of ecological restoration, revise applicable permits/processes as appropriate, and integrate these findings into MDE's existing work. Key Maryland regulations related to stream restoration can be found in Table 3.

Table 3. Summary of Maryland regulations that correspond to riparian forest buffers and stream restoration				
State	**Regulation**	**Where it Applies**	**Description**	**Key Requirements**
MD	Forest Conservation Act	Statewide	Requires units of local government with planning and zoning authority to establish and implement local forest conservation programs. It also provides for the Department's administration of forest conservation requirements, in the absence of a local forest conservation program. The guidance included establishes standards performance required in forest stand delineations and forest conservation plans and assists in the developing of required forest stand delineations and conservation plans.	• Any activity requiring an application for a subdivision, grading permit or sediment control permit on areas 40,000 square feet (approximately 1 acre) or greater is subject to the Forest Conservation Act and will require a Forest Conservation Plan
MD	Critical Areas Law	All land within 1,000 feet of MD's tidal waters	Comprehensive program to protect the natural resources of the Chesapeake Bay and its tidal shorelines.	• Provides for stream buffers in critical areas of a minimum of 100 ft which can be expanded. • The cutting or removal of natural vegetation in the Buffer is not allowed

Table 3. Summary of Maryland regulations that correspond to riparian forest buffers and stream restoration				
State	**Regulation**	**Where it Applies**	**Description**	**Key Requirements**
		and tidal wetlands		without an approved Buffer Management Plan • Replanting is typically required for the removal of vegetation and use of native plant species is called for to enhance wildlife habitat.
MD	Nontidal Wetlands	Statewide	Provides the permits required for activities which alter nontidal wetlands. Also contains the activities which are exempt from permit requirements as well as the delegation of authority within the nontidal wetlands protection program. Contains the regulations for nontidal wetland buffer expansions.	• Calls for a minimum 25-foot buffer area. • Nontidal wetland permit application does require applicants to indicate if there will be temporary or permanent tree clearing (upland or wetland) occurring on the overall project site and the total estimated acres of tree clearing.
MD	Construction on Nontidal Waters and Floodplains	Statewide	Provides the regulations for governing construction, reconstruction, repair, or alteration of a dam, reservoir, or waterway obstruction or any change of the course, current, or cross section of a stream or body of water within Maryland. Contains permit requirements, permit application requirements as well as the regulations and criteria for a variety of construction of various water and floodplain structures.	• Requires a person who proposes to construct, reconstruct, repair, or alter a dam, reservoir, or waterway obstruction, or change in any manner the course, current, or cross section of a stream or body of water within the State except tidal waters, including any changes to the 100-year frequency floodplain of free-flowing streams shall obtain a permit from the Administration before commencing any work
MD	Maryland Water Quality standards	Statewide	This chapter of the code includes the framework for water quality criteria to protect given designated uses for water resources.	• States that it is the policy of the State that riparian forest buffer adjacent to natural trout waters or recreational trout waters shall be retained whenever possible to maintain the temperatures essential to meeting this criterion.
MD	Annotated Code - Natural Resources	Statewide	Details the afforestation and reforestation requirements for compliance with the state Forest Conservation Act	• Establishes requirements for forest buffers and corridors along intermittent and perennial streams and coastal bays • Details forest conservation thresholds for all land use categories covered by the Act

3.3 Virginia Regulations

In Virginia, stream restoration is defined as, "modifications to a stream that make its morphologic structure and fluvial function more consistent with that of a dynamically stable, natural stream"[7]. Efforts to improve stream structure and function that are consistent with this definition are referred to as natural channel design. Design approaches are

[7] Virginia Department of Conservation and Natural Resources (VA DCR). 2004. The Virginia Stream Restoration & Stabilization Best Management Practice Guide. Prepared with assistance from KCI Technologies, Inc. and the Center for Environmental Studies at Virginia Commonwealth University.

generally categorized by the four NCD priority types[8]. Most implemented projects fall under Priority I, which involves raising the channel to connect to the floodplain and is commonly considered the most preferable restoration design type. However, many Priority II projects, which involve creating a new channel and lowering the floodplain, are also implemented. Key Virginia regulations related to stream restoration can be found in Table 4.

Table 4. Summary of Virginia state regulations that correspond to riparian forest buffers and stream restoration

State	Regulation	Where it Applies	Description	Key Requirements
VA	Chesapeake Bay Preservation Act	Chesapeake Bay counties in VA	The goal of the Act is to protect and improve water quality in the Chesapeake Bay by requiring the implementation of land use management practices including an ordinance to reduce pollution during development and redevelopment and identification of Chesapeake Bay Preservation Areas (CBPAs).	• Establishes Resource Protection Areas (RPAs) criteria that requires a vegetated buffer on streams no less than 100 feet wide • Documents the criteria for RPA buffers including allowed uses • Calls for comprehensive plans to include elements on shoreline and streambank erosion problems
VA	Virginia Water Protection Permit	Statewide	This regulation requires a Virginia Water Protection permit unless otherwise excluded for certain wetland activities and makes it unlawful to alter the physical, chemical, or biological properties of state waters and make them detrimental to the public health, animal, or aquatic life;	• Protects wetlands from excavation or new activities that may cause draining that significantly alters or degrades existing wetland acreage or functions. • Permits must contain requirements for compensating impacts on wetlands sufficient to achieve no net loss of existing wetland acreage and functions
VA	Virginia Water Protection General Permit for Impacts Less Than One-Half Acre	Statewide	The purpose is to establish a VWP General Permit to govern permanent and temporary impacts to less than one-half acre of nontidal wetlands or open water and up to 300 linear feet of nontidal stream bed.	• All temporarily impacted streams and streambanks shall be restored to their preconstruction elevations and contours with topsoil from the impact area where practicable within 30 days following the construction at that stream segment. • Streambanks shall be seeded or planted with the same vegetation cover type originally present, including any necessary, supplemental erosion control grasses. • Invasive species identified on the Department of Conservation and Recreation's Virginia Invasive Plant Species List shall not be used to the maximum extent practicable or without prior approval from the Department of Environmental Quality
VA	Fisheries and Habitat of the Tidal Waters	State-owned submerged lands, tidal wetlands, and dunes/ beaches	Details the Virginia Marine Resources Commission and the jurisdiction and powers of the commission over tidal waters of the state of Virginia.	• Creates standards for use and development of wetlands

[8] Rosgen, D. 1997. A Geomorphological Approach to Restoration of Incised Rivers. In: Proceedings of the Conference on Management of Landscapes Disturbed by Channel Incision, S.S.Y. Wang, E.J. Langendoen, & F.D. Shields (Editors). University of Mississippi, Oxford, MS.

3.4 Examples of Local Government Regulations

Examples of local government regulations corresponding to counties included in the case study analysis of the Maintaining Forests in Stream Corridor Restoration case study analysis are provided in Table 5. There are no local level regulations for the Pennsylvania case study.

Table 5. Example local government regulations that correspond to riparian forest buffers and stream restoration

State	Regulation	Where it Applies	Description	Key Requirements
VA	Fairfax County Chesapeake Bay Preservation Ordinance	All lands designated as part of the RPA or RMA in Fairfax County	County ordinance that codifies requirements for Resource Protection Areas ("RPAs") and Resource Management Areas ("RMAs") that are subject to the criteria and requirements as described by the state Code.	• Water Quality Impact Assessment for any proposed land disturbance, development, or redevelopment within an RPA that is not exempt. • Tree Canopy target goals should be met by preservation of existing trees preferentially • 100-foot buffers in RPA
VA	Fairfax County Public Facilities Manual	Countywide	The purpose and intent of Chapter 12 is to provide plan submission requirements, technical specifications and on-site practices that support the administration, implementation, and enforcement of the tree conservation requirements of the Code.	• 10 Year Tree Canopy requirement to provide for the conservation of trees so that the minimum tree canopy for the site reaches a projected canopy percentage. • Tree Conservation Plan Requirements
VA	Fairfax Tree Conservation Ordinance	Countywide	This ordinance was designed to control the destruction of trees and established the Office of Urban Forest Management to administer the ordinance. The code establishes tree preservation and planting requirements for private property.	• Allows the Director of Land Development Services to require periodic inspections of tree conservation activities • Addresses 10-year tree canopy requirements for different land uses, • Tee preservation and planting requirements • The code provides for periodic monitoring and inspections,
MD	Anne Arundel Subdivision and Development	Countywide	Subtitle 3 on Forest Conservation provides the general development provisions. on forest stand delineations, forest conservation plans, afforestation and reforestation methods, forest conservation funds, and violations of the subtitle. Subtitle 4 on Natural Features lists the development provisions for nontidal wetlands, streams, steep slopes, nontidal floodplains, and for environmental site design.	• Establishes priority retention areas including trees, shrubs, and plants located in sensitive areas, including the 100-year floodplain, intermittent and perennial streams and their buffers, steep slopes, non-tidal wetlands, and all associated buffers • Sets afforestation and reforestation policies including the preferential sequencing and the use of native species • Requires 100-foot buffers on streams

4 General Best Practices

The cost-benefit for stream restoration projects in the context of the Chesapeake Bay TMDL has made the practice a "go-to" for many municipalities and credit/nutrient bankers, and this leads inevitably to poorly sited projects. The CBP Stream Restoration Expert Panel report[9] and recent work group updates[10] recommended that all stream restoration projects adopt a holistic watershed approach and improve the functional uplift of the riparian ecosystem. This section describes the general best practices for minimizing forest and riparian vegetation impacts and helping to ensure functional uplift is obtained.

Table 6 includes helpful guidance documents that contain information related to the best practices. Weblinks are provided to each document, as well as the jurisdictional application for each resource. There is also an annotated bibliography in Section 8 that provides a short description of each resource and the best practices they address.

Table 6. Guidance documents and resources to minimize riparian forest impacts

Citation	Title	Jurisdiction	General Best Practices Addressed					
			Site Selection	Establishing Goals and Objectives	Design and Permitting	Stakeholder Engagement	Construction	Maintenance and Monitoring
Baird & Wetmore (2003)	Riparian Buffers Modification & Mitigation Guidance Manual	VA			X	X		X
Berger et al. (2021)	Recommended Stream Restoration Best Practices: Voluntary Guidance for Stormwater Program Managers in the COG Region on Best Practices for Implementing Stream Restoration Projects	DC MD VA	X	X	X	X	X	X
Harman et al. (2012)	A Function-Based Framework for Stream Assessment & Restoration Projects	US	X	X				
Keystone Stream Team (2007)	Guidelines For Natural Stream Channel Design for Pennsylvania Waterways	PA				X	X	X
Schueler & Stack (2014)	Stream Restoration Expert Panel Report	Bay[1]	X	X	X			X
Wood et al. (2021)	Unified Crediting Guidance	Bay[1]	X	X	X		X	X
Burch et al. (2019)	CBP Stream Restoration Verification Guidance	Bay[1]						X
Law et al. (2015)	Designing Sustainable Stream Restoration Projects within the Chesapeake Bay Watershed	Bay[1]		X	X			X

[9] Schueler, T. & B. Stack. 2014. Recommendations of the Expert Panel to Define Removal Rates for Individual Stream Restoration Projects. Approved by the Water Quality Goal Implementation Team of the Chesapeake Bay Program September 8, 2014.
[10] Wood, D., Schueler, T., & B. Stack. 2021. A Unified Guide for Crediting Stream and Floodplain Restoration Projects in the Chesapeake Bay Watershed.

Citation	Title	Jurisdiction	General Best Practices Addressed: Site Selection	Establishing Goals and Objectives	Design and Permitting	Stakeholder Engagement	Construction	Maintenance and Monitoring
MD DNR (2018)	Regenerative Stream Conveyance Construction Guidance	MD			X		X	X
MDE (2022)	Guidance for Stream Restoration Based on Key Wildlife Habitats: Upper Coastal Plain Stream-associated Wetlands	MD	X	X	X		X	X
MDE (n.d.)	MS4/Chesapeake Bay TMDL/Trust Fund Restoration Project Wetlands & Waterways Permit Package Checklist	MD	X		X	X	X	
PA DEP (2022)	Pennsylvania Function-Based Aquatic Resource Compensation Protocol	PA	X	X	X	X		
Palone & Todd (1998)	Chesapeake Bay Riparian Handbook: A Guide for Maintaining Riparian Forest Buffers	DC MD VA				X	X	
RRC (2011)	Practical river restoration appraisal guidance for monitoring options (PRAGMO)	UK[2]		X		X		
USBR & ERDC (2016)	National Large Wood Manual—Assessment, Planning, Design, and Maintenance of Large Wood in Fluvial Ecosystems: Restoring Process, Function, and Structure	US		X	X		X	
USDA NRCS (2007)	Stream Restoration Design (National Engineering Handbook 654)	US		X	X	X	X	
USNVC (2022)	U.S. National Vegetation Classification	US	X					
VA DCR (2004)	The Virginia Stream Restoration & Stabilization Best Management Practices Guide	VA	X		X			
VA DEQ (1992)	Virginia Erosion and Sediment Control Handbook	VA			X		X	
Yochum (2018)	Guidance for Stream Restoration	US		X			X	

Table 6. Guidance documents and resources to minimize riparian forest impacts

1. Chesapeake Bay
2. Also applicable in the US

4.1 Site Selection

Proper siting of restoration projects relates very closely to goal setting, covered in the next subsection. Proper siting is critical to assure a good, positive return on investment in terms of ecological and water quality benefits, as well as minimizing impacts to riparian vegetation. The stream restoration expert panel[11] recommended a watershed-based approach for screening and prioritizing stream restoration projects to focus restoration efforts at locations that will provide the most benefit in terms of sediment and nutrient reduction, as well as improvement to stream function. Stream restoration should be directed to areas of severe stream impairment and avoid areas such as stable stream

[11] Schueler, T. & B. Stack. 2014. Recommendations of the Expert Panel to Define Removal Rates for Individual Stream Restoration Projects. Approved by the Water Quality Goal Implementation Team of the Chesapeake Bay Program September 8, 2014.

reaches, wetlands, seeps, good quality vegetative communities, rare or sensitive species, important cultural features, or specimen trees, etc.

Stream restoration itself, no matter how well executed, cannot successfully restore the stream and riparian forest systems without complementary upland work. Options for combining stream and floodplain restoration with stormwater, forestry and agricultural BMPs in the contributing watershed area should be evaluated when screening and prioritizing projects. It is generally accepted that individual stream restoration projects are more effective when pollutant loads and flow from the contributing watershed also are reduced.

4.2 Establishing Goals and Objectives

Many stream restoration projects are implemented solely to meet nutrient and sediment load reduction goals for TMDL purposes. However, the CBP Stream Restoration Expert Panel Report, recent work groups, and CBP partners and stakeholders suggest that the full spectrum of water quality goals (e.g., temperature, dissolved oxygen, etc.) be taken into consideration. Establishing achievable goals and objectives is one of the most important steps in a stream restoration project that determine not only the design, but the data collection effort and methodologies for assessments. Goals are general, while objectives are measurable and in support of the stated goals[12,13]. Figure 1 provides an example of how to develop specific goals and objectives using the SMART approach (Specific, Measurable, Attainable, Relevant, and Time-bound) described by the River Restoration Centre[14], which is a tool for designing useful and achievable restoration goals. When restoration-related goals are too broad (e.g., "restore the habitat"), they are more difficult to map out and less likely to be achieved. Developing SMART goals can help to ensure that restoration outcomes meet the goals set by practitioners and stakeholders.

[12] Yochum, S. E. 2018. Guidance for Stream Restoration. U.S. Department of Agriculture, Forest Service (USDA FS), National Stream & Aquatic Ecology Center. Technical Note TN-102.4. Fort Collins, CO.
[13] United States Department of Agriculture, Natural Resources Conservation Service (USDA NRCS). 2007. Stream Restoration Design Part 654 National Engineering Handbook.
[14] River Restoration Centre (RCC). 2011. Practical River Restoration Appraisal Guidance for Monitoring Options (PRAGMO). Guidance document on suitable monitoring for river and floodplain restoration projects. Cranfield, UK. 320 pp.

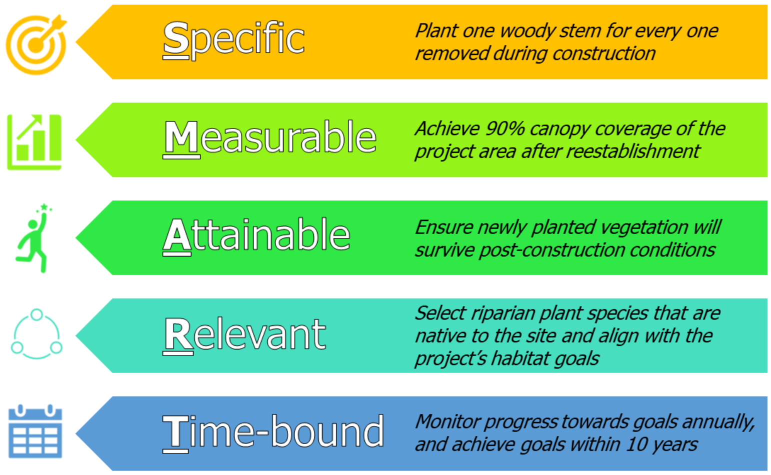


Figure 1. Example of a SMART goal for maintaining riparian vegetation in stream restoration projects. SMART goals are Specific, Measurable, Attainable, Relevant, and Time-bound[15].

To determine appropriate goals and objectives, it is necessary to identify the cause of stream degradation by comparing the current condition of a stream to historical conditions, and then projecting its future conditions under different restoration scenarios. This important step is often abbreviated or overlooked, resulting in many failed or poorly performing restorations. When restoring streams to a given historical condition is an objective, care must be taken to ensure that physical or biological changes in the watershed have not prohibited a return to that historical condition. In many cases, restoration projects are actually rehabilitations since not all ecologically self-sustaining functions and values can be restored to the stream[16].

The CBP stream restoration expert panel and subsequent work groups recommended that proposed stream restoration projects be developed through a functional assessment process, such as the Stream Functions Pyramid[17] (Figure 2) or functional equivalent. It is important to note that stream evolution theory is still evolving with widely divergent opinions and views, which should be considered in any functional assessment. The Stream Functions Pyramid Framework can be used to determine the restoration potential at a proposed project site. Restoration potential is the highest level of restoration or functional lift that can be achieved given the site constraints and health of the watershed. Once the restoration potential is known, specific design goals and objectives can be established, or original goals and objectives may need to be refined.

[15] River Restoration Centre (RCC). 2011. Practical River Restoration Appraisal Guidance for Monitoring Options (PRAGMO). Guidance document on suitable monitoring for river and floodplain restoration projects. Cranfield, UK. 320 pp.

[16] United States Department of Agriculture, Natural Resources Conservation Service (USDA NRCS). 2007. Stream Restoration Design Part 654 National Engineering Handbook.

[17] Harman, W., Starr, R., Carter, M., Tweedy, K., Clemmons, M., Suggs, K., & C. Miller. 2012. A Function-Based Framework for Stream Assessment and Restoration Projects. US Environmental Protection Agency (US EPA), Office of Wetlands, Oceans, and Watersheds. Washington, DC. EPA 843-K-12-006.

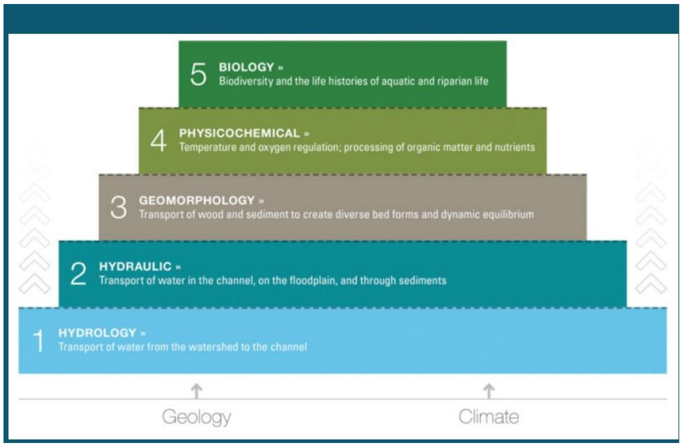


Figure 2. Stream Functional Pyramid (Harman et al., 2012), which is a widely used functional assessment process.

Establishing or maintaining a mature riparian forest may or may not be an appropriate and/or achievable goal for all sites or projects. Depending on current, historic, and projected future conditions, some stream restoration designs will not naturally evolve to become forested. In addition, some currently forested sites will evolve to conditions that do not include forest, often due to increased inundation and saturation of the floodplain. The project goals should be carefully considered by all stakeholders to determine if forested riparian conditions are appropriate.

4.3 Design and Permitting

The design of a stream restoration project should take into account the site conditions and restoration goals and objectives. Designs should also consider whether a forested riparian area is appropriate, and practitioners should be familiar with differing goals and priorities in the various jurisdictions over riparian forest management. General best practices for design are provided below and Section 5 provides guidance on best practices applicable to specific stream restoration design.

Guidance should be followed from the appropriate federal, state or local regulatory authorities regarding assessment and incorporation of existing high-quality habitat and ecosystem functions into project design. The following are considerations that may be required:

- Assess existing habitat characteristics and functions across the project during project planning and design phases and compare with predicted post-construction conditions to evaluate uplift. Revise design to address undesirable resource tradeoffs.
- Conduct a comparative analysis of different restoration approaches to evaluate the impacts of temporary construction landscaping relative to the creation of a long-term sustainable system. This comparative analysis of restoration approaches should also consider the level of risk a client or landowner is willing to accept for both routine and restorative maintenance.
- Conduct intensive surveys when high quality stream or wetland resources are identified within or immediately downstream of the project reach to assess potential impacts to these resources.
- Carefully survey existing forests to minimize tree clearing during construction and identify individual trees that should be saved. Plan access routes to retain marked desired trees.

It is critical to determine the restoration potential of the riparian forest and get community input that would involve walking the existing sites, marking trees that will be removed, and artistic renderings of the revegetation plan not just during full revegetation but at different periods after construction. Trees should be ranked during the planning process based on factors such as tree health, location, size, value, bank proximity, root mass erosion status, and amount of shade cast. Planting plans for the project design should consider:

- plant species selection and quality
- species selection based on seed dispersal potential to encourage regeneration
- local source material, and local phenotypes
- a planting strategy/plan with input from a plant ecologist or natural resource specialist that is suitable for the entire LOD and include a selection of approved trees, shrubs, and herbaceous materials, in addition to planting densities and planting zones in the construction plan set.
- Ensuring that the planting plan and proposed species are reviewed and approved by the appropriate authority prior to installation, and any plant substitutions are approved before the substitute species are installed.
- site modifications to accommodate and foster existing and new plants
- super clumps, and nucleation (small clumps)
- predator- and pest-resistant planting and/or landform design
- techniques that provide higher degrees of canopy coverage in shorter amounts of time
- consideration of invasive species impacts
- post-construction monitoring and remediation (refer to Section 4.6)

Figure 3. Nursery plantings

Ground-truthing is crucial for most projects at various stages of implementation, including initial assessment, and at any significant change points in the process. Sometimes survey data is inaccurate, incomplete, or otherwise corrupt. Also, the time across which many stream and riparian area projects take place is sufficient that it becomes important to for designers to refresh their memory of the site.

Early feedback from regulators is also important before a design is undertaken. Pre-application meetings with federal and state permitting agencies help the applicant design a project that will minimize environmental impacts, including existing riparian resources, before a final design is committed to and a great deal of money is spent. This early feedback also helps to identify aspects of the proposed project that may affect permit approval and possible alternatives to streamline the approval process.

Figure 4. Design meeting with MD DNR during the concept development phase for a stream restoration project.

4.4 Stakeholder Engagement

Stakeholders include a range of individuals from internal and external groups. Internal stakeholders may include outreach managers, reviewers and permitting agencies, staff from various government departments and agencies, and elected officials. External stakeholders may include local residents and landowners near the site, community groups, non-profit organizations, others in the planning and design process, and schools. Stakeholder goals and objectives should be clearly defined and prioritized. Risks also need to be mutually understood by the community, planners, and designers for implementing any successful project[18].

The social context of the restoration needs to be accounted for as part of stream restoration[19]. An often overlooked and misunderstood risk associated with stream restoration projects is the acceptance of the project by those who live near the stream and its floodplain. While a stream restoration project may be technically sound from a biophysical perspective, if it is not in harmony with community objectives, it may also be considered a failure[20].

Community outreach and input on the project design is key to avoid surprises and complaints. Impacts need to be understood, including what the project site will look like during and after construction. Some stream restoration projects are initially very high impact, potentially removing a large number of trees, and changing the general shape of the

[18] United States Department of Agriculture, Natural Resources Conservation Service (USDA NRCS). 2007. Stream Restoration Design Part 654 National Engineering Handbook.
[19] Wohl, E., Lane, S. N., & A. C. Wilcox. 2015. The Science and Practice of River Restoration. *Water Resources Research, 51*(8): 5974 – 5997. DOI: 10.1002/2014WR016874.
[20] United States Department of Agriculture, Natural Resources Conservation Service (USDA NRCS). 2007. Stream Restoration Design Part 654 National Engineering Handbook.

stream channel and corridor. Some sites have been described by the community as looking like "warzones." Plantings done for revegetation can take many years, before the vegetative community is reestablished, and decades for reforestation. During and immediately following construction, the project sites look so different than the familiar state of the site and "natural" areas, that many people in the community complain to local officials. Giving the community a thorough understanding about the projects and incorporating their input into the design can help to avoid social distress.

4.5 Construction

Impact to the riparian forest from the construction process is an important consideration for stream restoration projects. Geomorphic restoration work inherently involves site impacts, some of which are unavoidable, but should be minimized to the extent possible. Site conditions may also vary between the time the design is finalized and the permit is issued and therefore it is critical for the designer and contractor to walk the site prior to construction to identify challenges that may need revision and further coordination with regulatory agencies. Likewise unforeseen conditions arise during the construction process (e.g., large rock deposits) that require modifications to the design approach. It is critical to have the designers on-site periodically during the construction process so they can make "change orders" if necessary. "As-Built Designs" are typically required post-construction to account for any changes that occur because of unforeseen site conditions, which should also include the riparian vegetation. An independent environmental monitor or inspector may be needed in sensitive areas to oversee construction and coordinate any changes with regulatory agencies.

Construction of stream restoration projects can lead to local destruction of riparian cover within the project reach. Machine access, construction material transport, laydown and staging, and other components of the work introduce clearing, soil and root compaction, possible accidental direct damage to trees, often significant grading, and possibly even rerouting of the stream channel itself through established vegetation. The proper selection of design and construction practices can help to minimize these adverse impacts. A list of best practices for construction is provided below.

- Minimize the removal of mature trees
- Identify tree protection for specimen trees to be saved during construction on the ESC Plan.
- Include measures that prevent the spread of invasive species in construction plans.
- Delineate the Limit of Disturbance (LOD) to avoid mature trees and other critical resources. Organize construction sequence to prevent from repeating trips over the same area many times.
- Construct access roads with mulch and/or timber mats to distribute heavy equipment pressure and reduce compaction of soils and roots. Use rubber-tired equipment to minimize compaction.
- Utilize the existing channel as the primary access road to the extent practicable to minimize disturbance, particularly for sites adjacent to mature forest or other high-quality resources.
- Utilize trunk planking (strapping vertical lumber boards to the trunks) to avoid accidental impact damage from heavy machinery.
- Avoid backfilling and compacting soils over tree roots.
- Carefully prune tree roots in areas where excavation is necessary within the critical root zone (CRZ) to help reduce stress to the tree. Minimize pruning to 30% of the CRZ or less.
- Install water gators (bags of water attached to the tree that slowly drip down) and mulch applications to keep the underlying soil moist. Feed and water impacted trees post-construction to support healing and reestablishment.
- Leave the remaining stump and root mat for trees that must be cut.
- Leave cut trees in the floodplain to serve as coarse woody debris to help restore habitat features and serve as a source of carbon.

Figure 5. Stream restoration construction

4.6 Monitoring and Maintenance

After construction, monitoring should be performed to assess if the project is fulfilling the goals and objectives. If not, project remediation may be needed through adaptive management. In any case, documentation of project performance should be maintained, for communication with stakeholders and adding to the knowledge base of the individual professional and the restoration community as a whole.

Fairfax County has developed a "Restoration Recovery Wheel," which is a framework that helps define success across multiple metrics of pre-design, design specification, and post-construction success. The higher a project scores on a variety of different metrics and measurements determines whether the project is considered successful. Figure 6 below shows an example of the Fairfax County Restoration Recovery Wheel for measuring the 3-year post-construction success of the Flatlick Branch project, which was an NCD project constructed in 2018.

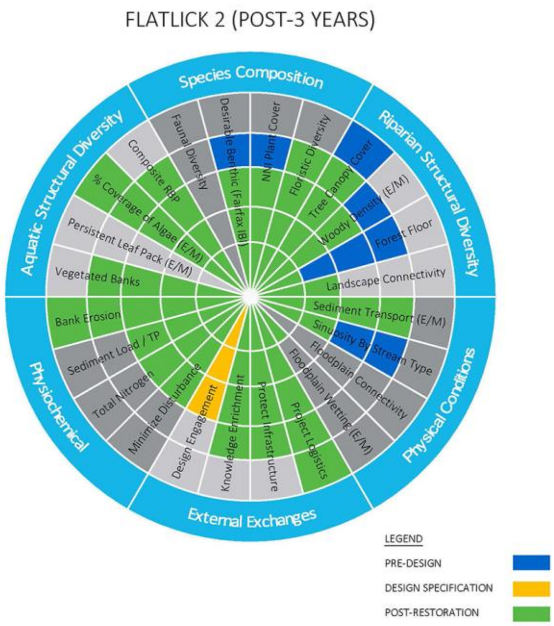


Figure 6. Fairfax County's Restoration Recovery Wheel for the Flatlick Branch NCD project (constructed 2018).

Most restoration projects undergo monitoring for 2 – 5 years after construction, based on required state and federal permit conditions. Once the original permit expires, responsibility shifts to the installing agency to meet CBP stream restoration verification requirements[21] for visual inspections once every 5 years. These inspections are designed to eliminate projects that fail or no longer meet their restoration objectives and to reduce or eliminate their sediment and nutrient reduction credit. Verification inspection also generates useful data on real world projects that can refine future restoration methods and practices.

While permit and CBP verification related monitoring is valuable, it typically does not include monitoring of the riparian ecosystem, which is needed to guarantee success of the project. Long-term monitoring of riparian benefits and total ecosystem benefits done by professionals/scientists with consideration of a pooled monitoring approach is recommended. Monitoring can also include local watershed organizations or citizens that have gone through training, such as Master Naturalists. Project sponsors may need to have long-term resources available to better ensure that the stream and riparian area are restored as projected.

Best practices for monitoring and maintenance include:

- Allocate a minimum of 10% of the total project budget for sufficient post-construction monitoring and maintenance.
- Monitor beyond the LOD, and include a site's undisturbed areas, and adjacent upstream and downstream areas.
- Utilize performance-based contracting and warranty monitoring for plant survival and contractual requirements.

[21] Burch, J., Cox, S., Davis, S., Fellows, M., Hoverman, K., Law, N., Mumaw, K., Rauhofer, J., Schueler, T., & R. Starr. 2019. Recommended Methods to Verify Stream Restoration Practices Built for Pollutant Crediting in the Chesapeake Bay Watershed. CBP Approved Memo submitted by Stream Restoration Group 1: Verification and approved by the Urban Stormwater Work Group of the Chesapeake Bay Program.

- Develop clear monitoring metrics as a way of evaluating goals and objectives and the degree of project success (See Section 4.2 Establishing Goals and Objectives)
- Implement both a short and long-term vegetation management plan to maintain the post-restoration vegetation target for the banks and floodplain that includes invasive species management, climate change impact management, deer predation protection, and other predation and pest control measures.
- Maintain a designated maintenance trail on projects, to allow practitioners to monitor and maintain constructed projects without contributing additional disturbance.

5 Design-Specific Best Practices

This section describes the main approaches to stream restoration design and their associated unique considerations and best practices. Note that all design approaches should follow the general best practices in Section 4 to minimize impacts and assure sustainability of the riparian vegetation.

5.1 Floodplain Restoration

Floodplain restoration is the practice of increasing the hydrologic connection of rivers and streams to their floodplains. It can be included as a component of all the stream restoration design types described in the remainder of this section, including natural channel design, legacy sediment removal, regenerative stormwater conveyance, and beaver dam analogs. Note that not every project can reconnect to the historical floodplain because of encroachment from adjacent urbanization and farm fields. In many cases only part of the floodplain can be reconnected, and, in some cases, reconnection may not be possible, such as in ultra-urban areas.

Figure 7 shows pre- and post-construction photos of the Furnace Creek floodplain reconnection project that was constructed in Anne Arundel County, MD in 2020.

Preconstruction

PHOTO 4: LOWER PROJECT SUBREACH

PHOTO 7: CONCRETE CHANNEL IN UPPER PROJECT SUBREACH

Post-construction

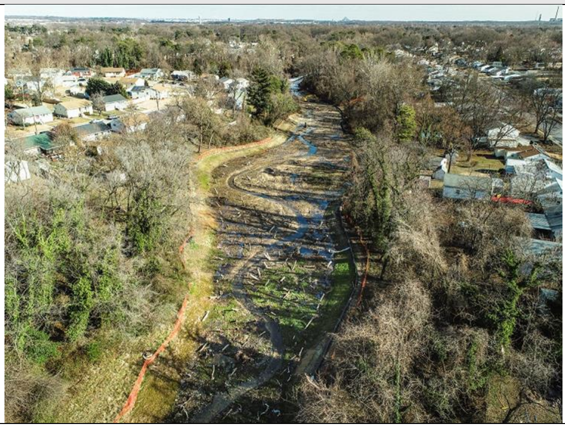
Preconstruction


Figure 7. Pre- and post-construction photos of the Furnace Creek floodplain reconnection project in Anne Arundel County, MD.

Unintended consequences identified by the Protocols 2 and 3 work group[22] include:

- Riparian/floodplain forest losses are common due to clearing for design and construction access and increased inundation.
- Field and lab studies show that too much long-term soil inundation results in mortality and morphological changes in tree species.
- Construction disturbance and frequent inundation of the floodplain can serve as vectors for invasive species along restored and unrestored streams.
- Changes in vascular plant communities as a result of floodplain inundation are expected and may be desirable or undesirable depending on the goals for the habitat outcome.

Several recent assessment tools developed by Starr & Harman[23,24] may be useful for measuring functional uplift at floodplain restoration projects, possibly in combination with traditional wetland functional assessment methods such as FHWA, HGM, WET and others. The group agreed that basic research to define and test new metrics to effectively measure functional uplift in floodplains was an urgent management priority.

5.2 Natural Channel Design / Channel Reconfiguration

According to Lammers[25], "One of the more intensive and expensive stream restoration strategies is channel reconfiguration that may entail reconnection of a historically abandoned channel, partial channel realignment, or complete construction of a new channel." Historically, channel reconfiguration has been the subject of a great deal of controversy among researchers and practitioners, primarily regarding the use of template-based restoration approaches

[22] Wood, D., & T. Schueler. 2020. Consensus Recommendations to Improve Protocols 2 and 3 for Defining Stream Restoration Pollutant Removal Credits. Approved by WQGIT October 26, 2020.
[23] Starr, R., & W. Harman. 2015. Valley Restoration Design Review Checklist Version 3. U.S. Fish and Wildlife Service, Chesapeake Bay Field Office. Annapolis, MD. CBFO-S15-05.
[24] Starr, R., & W. Harman. 2016. Function-Based Stream Restoration Project Process Guidelines. U.S. Fish and Wildlife Service, Chesapeake Bay Field Office. Annapolis, MD. CBPO-S16-03.
[25] Lammers, R. 2015. Stream Restoration as a Nutrient BMP—A Review. Report prepared for the Water Environment Research Foundation (WERF). Alexandria, VA.

over more process-based approaches[26,27]. The primary argument centers on the use of the industry standard for stream restoration design, the Natural Channel Design (NCD) method[28], which many argue is a “template-based” approach. The NCD method uses a Channel Evolution Model similar to Schumm et al.[29] to predict channel trajectory for determining appropriate stable reference reaches to provide channel dimension, pattern and profile for design. Stream designers today are using more sophisticated approaches combining the NCD approach with sediment transport models and two-dimensional hydraulic modeling.

NCD guidance includes forest preservation and restoration, and a checklist has been developed for this purpose[30] that references the preservation of mature trees as part of permitting. Many state- and municipal-level agencies will have their own forest conservation plan requirements (refer to Table 1, Table 2, Table 3, and Table 4) that prevent unnecessary removal of trees, especially large/mature trees, but NCD itself does not focus as much on trees and forest areas as some believe it should. This may be partly due to the geographic region in which a lot of this work was done.

Preconstruction	Post-Construction
	

Figure 8. Pre- and post-construction photos of the Pohick Creek NCD project in Fairfax County, VA.

5.3 Legacy Sediment Removal

Legacy sediment removal (LSR) involves careful modifications to valley bottoms that contain legacy sediments to increase the interaction of the stream with its floodplain and the hyporheic aquifer. This usually involves restoring smaller baseflow channel(s) and removing legacy sediments to effectively lower the floodplain to promote interaction of surface flows with the underlying hyporheic aquifer, which produces riparian wetland conditions over much of the floodplain. In some cases, not all the legacy sediment area can be removed because of restrictions in the floodplain. LSR projects restore a vegetative community that includes a diverse mosaic of herbaceous plants, shrubs and water-loving trees and less continuous and drier floodplain forest cover. The restored vegetative community seeks to mimic the natural reference condition for the valley bottom that is supported by historical accounts.

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[26] Simon, A., Doyle, M.W., Kondolf, M., Shields Jr, F.D., Rhoads, B., & M. McPhillips. 2007. Critical Evaluation of How the Rosgen Classification and Associated “Natural Channel Design” Methods Fail to Integrate and Quantify Fluvial Processes and Channel Responses. *Journal of the American Water Resources Association, 43:* 1117 – 1131. DOI: 10.1111/j.l752-1688.2007.00091.x.
[27] Lave, R., 2009. The Controversy Over Natural Channel Design: Substantive Explanations and Potential Avenues for Resolution. *Journal of the American Water Resources Association, 45*(6): 1519 – 1532. DOI: 10.1111/j.17521688.2009.00385.x.
[28] Rosgen, D.L. 1996. Applied River Morphology. Wildland Hydrology, Colorado.
[29] Schumm, S. A., Harvey, M. D., & C. C. Watson. 1984. Incised Channels: Morphology, Dynamics, and Control. Water Resources Publications. ISBN: 09-183-34535. Littleton, CO.
[30] Harman, W., & R. Starr. 2011. Natural Channel Design Review Checklist. U.S. Fish and Wildlife Service, Chesapeake Bay Field Office. Annapolis, MD. US Environmental Protection Agency, Office of Wetlands, Oceans, and Watersheds, Wetlands Division. Washington, D.C. EPA 843-B-12-005.

Preconstruction

Post-Construction

Figure 9. Pre-restoration (top) and post-restoration (bottom) photos of the Big Spring Run legacy sediment removal project in Lancaster, PA (Source: LandStudies, Inc. and http://www.bsr-project.org/photos.html)

The CBP legacy sediment removal workgroup[31] noted the following considerations related to riparian forests/trees and LSR projects:

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[31] Altland et al. 2020. Consensus Recommendations for Crediting Floodplain Restoration Projects Involving Legacy Sediments. Appendix C of Consensus Recommendations to Improve Protocols 2 and 3 for Defining Stream Restoration Pollutant Removal Credits.

- Depending on the site location, upland trees growing on legacy sediments may not be endemic to the riparian wetland community. The tree community may need to shift from upland/dry to wet/floodplain-adapted species in the valley bottom.
- Existing tree mortality can occur due to more frequent inundation/higher water table in the restored floodplain, but these are intended to shift from upland to wetland community of herbs, shrubs and trees.
- Project monitoring indicates that construction disturbance is a vector for invasive plant species in any stream restoration project. Risk may be lower for connected vs. disconnected floodplains. Post-construction invasive management is critical to establish a sustainable wetland plant community.
- Some degradation of excavated "toe of slope" or perched wetlands has been observed, but these are replaced by more extensive wetland complexes in the stream corridor that generally increase wetland functions.

5.4 Regenerative Stormwater Conveyance

Regenerative stormwater conveyance (RSC), also known as step pool stormwater conveyance systems (SPSCs) refers to two specific classes of stream restoration as defined in the technical guidance developed by Anne Arundel County DPW[32] and Flores[33]. The RSC approach has also been referred to as coastal plain outfalls, regenerative step pool storm conveyance, base flow channel design, and other biofiltration conveyance.

- Dry channel RSC involves restoration of ephemeral streams or eroding gullies using a combination of step pools, sand seepage wetlands, and native plants. These applications are often located at the end of storm drain outfalls or channels. The receiving channels are dry in that they are located above the water table and carry water only during and immediately after a storm event. The CBP stream restoration expert panel[34] concluded that dry channel RSC should be classified as a stormwater retrofit practice rather than a stream restoration practice.
- Wet channel RSCs can be located in intermittent streams but are more typically located farther down the perennial stream network and use instream weirs to spread storm flows across the floodplain at minor increases in the stream stage for events much smaller than the 1.5-year storm event, which has traditionally been assumed to govern stream geomorphology and channel capacity. Wet channel RSC may also include sand seepage wetlands or other wetland types in the floodplain that increase floodplain connection, reconnection, or interactions with the stream.

5.5 Beaver Dam Analogs

Beaver dam analogs (BDAs) are channel-spanning structures that mimic or reinforce natural beaver dams and can be used to raise the bed of the stream channel to connect to the floodplain. The Beaver Restoration Guidebook: Working with Beaver to Restore Streams, Wetlands, and Floodplains[35] provides an excellent overview to the types of beaver dam analogs, design considerations, and the risks involved in their use. Research has shown that beaver colonization after

[32] Anne Arundel County Department of Public Works. 2022. Design Guidelines for Step Pool Storm Conveyance Systems. Prepared by the Anne Arundel County Department of Public Works, Bureau of Watershed Protection and Restoration, Annapolis, MD. 64 pp, plus Appendices.
[33] Flores, H. 2011. Design Guidelines for Regenerative Step Pool Storm Conveyance. Revision 3. Anne Arundel County Department of Public Works. Annapolis, MD.
[34] Schueler, T. & B. Stack. 2014. Recommendations of the Expert Panel to Define Removal Rates for Individual Stream Restoration Projects. Approved by the Water Quality Goal Implementation Team of the Chesapeake Bay Program September 8, 2014.
[35] Pollock, M. M., Lewallen, G., Woodruff, K., Jordan, C. E., & J. M. Castro (Editors). 2015. The Beaver Restoration Guidebook: Working with Beaver to Restore Streams, Wetlands, and Floodplains. Version 1.02. United States Fish and Wildlife Service (USFWS). Portland, OR. 189 pp.

BDA installation can help combat stream channel erosion and entrenchment by promoting sediment deposition. Beaver dams have also been shown to improve floodplain connectivity, attenuate flows, and increase habitat complexity[36,37].

Figure 10. Two examples of beaver dams and their influence on the surrounding environment (Source: Ecotone, Inc.)

Although wood from the riparian buffer can be used as construction materials for BDAs, Bennett et al.[38] strongly recommends acquiring waste products from timber harvesting to minimize riparian tree loss and integrate forestry management with stream restoration. Woody material for BDAs may be obtained by yard waste facilities and local landowners, but it is important to avoid material that has been contaminated by pesticides, herbicides, and/or fertilizers. This is aligned with insights from practitioners who were interviewed as a part of this project, who explained that utilizing trees that were already identified for removal, either on-site or off-site, is an effective way to reduce both material/transport costs and on-site riparian impacts. In terms of best practices for transporting woody materials to a

[36] Shahverdian, S. M., Wheaton, J. M., Bennett, S. N., Bouwes, N., Camp, R., Jordan, C. E., Portugal, E., & N. Weber. 2019. Chapter 4 – Mimicking and Promoting Wood Accumulation and Beaver Dam Activity with Post-Assisted Log Structures and Beaver Dam Analogues. In: J. M. Wheaton, S. N. Bennet, N. Bouwes, J. D. Maestas, & S. M. Shahverdian (Editors). "Low-Tech Process-Based Restoration of Riverscapes: Design Manual." Utah State University Restoration Consortium. Logan, UT. 66 pp.

[37] Polvi, L. E., & E. Wohl. 2013. Biotic Drivers of Stream Planform: Implications for Understanding the Past and Restoring the Future. BioScience, 63(6): 439 – 452. DOI: 10.1525/bio.2013.63.6.6.

[38] Bennett, S. N., Wheaton, J. M., Bouwes, N., Camp, R., Jordan, C. E., Macfarlane, W. W., Maestas, J. D., Shahverdian, S., & N. Weber. 2019. Chapter 6 – Low-Tech Restoration Project Implementation. In: J. M. Wheaton, S. N. Bennet, N. Bouwes, J. D. Maestas, & S. M. Shahverdian (Editors). "Low-Tech Process-Based Restoration of Riverscapes: Design Manual." Utah State University Restoration Consortium. Logan, UT. 38 pp.

project location, Bennett et al. (2019) recommends the use of ATVs, handcarts, and/or boats, as appropriate, in order to navigate access constraints and minimize construction disturbance.

6 Examples of Successful and Unsuccessful Projects

Placeholder for examples from state agencies if provided.

7 Summary

The complexities of stream restoration and riparian cover, varying information in the scientific literature, limited information about riparian cover in the CBP stream restoration expert panel report and work group documents, variations in state and local government regulations, and the experiences of practitioners and researchers have resulted in varying viewpoints of how forests and riparian areas should be considered as part of stream restoration projects. This guidance document includes a compilation of the best practices for local and state governments in the Chesapeake Bay watershed to consider when planning for stream restoration projects to minimize unintended impacts to riparian forests and ecosystems. This guidance document is based on the best available knowledge at the time of development. Our current understanding of best practice is always evolving as new science sheds light on how aquatic ecosystems respond to restoration interventions along the stream and its floodplain. As such, the guidance should be updated on a regular basis as new information becomes available.

8 Annotated Bibliography

Baird, A. R. T., & D. G. Wetmore. 2003. Riparian Buffers Modification & Mitigation Guidance Manual. Prepared for Virginia Department of Conservation and Natural Resources (VA DCR).

Riparian Buffers Modification & Mitigation Guidance Manual

The guidelines are intended to aid local governments in helping a property owner with questions regarding riparian buffer activities, Resource Protection Areas, and potential conflicts with the intent of the Bay Act and regulations. This manual provides information on permitted buffer modification guidance, as well as buffer management recommendations and plant species guidance.

Berger, K., Howard, C., Bonnaffon, H., Trieu, P. & A. Maynard (Editors). 2021. Recommended Stream Restoration Best Practices: Voluntary Guidance for Stormwater Program Managers in the COG Region on Best Practices for Implementing Stream Restoration Projects. Metropolitan Washington Council of Governments. (MWCOG)

Recommended Stream Restoration Best Practices: Voluntary Guidance for Stormwater Program Managers in the COG Region on Best Practices for Implementing Stream Restoration Projects

This guidance provides details on specific practices local governments can use to best implement stream restoration projects and builds on the recommendations from the CBP expert panel. Best practices include creating a road map and the contents of that product, setting priorities and metrics for success, and planning for inspection and monitoring. The guidance provides information on development of a road map for the site selection process that documents how a decision to pursue a stream or outfall and gully stabilization project will be reached and what its goals are. This includes enumeration of specific project goals, including primary programmatic goals such as stream stability and pollution reduction, and secondary goals such as habitat improvement and minimization of impact to existing high-quality forest ecosystems. The guidance also includes tips on defining stakeholders, elements of a public outreach process, and communication needs to promote public engagement. There is also construction best practices to reduce impacts from tree loss, quality control practices for restoration planting, and tips on making adjustments during construction.

Burch, J., Cox, S., Davis, S., Fellows, M., Hoverman, K., Law, N., Mumaw, K., Rauhofer, J., Schueler, T., & R. Starr. 2019. Recommended Methods to Verify Stream Restoration Practices Built for Pollutant Crediting in the Chesapeake Bay Watershed. Submitted by Restoration Group 1: Verification and Approved by the Urban Stormwater Work Group of the Chesapeake Bay Program.

Recommended Methods to Verify Stream Restoration Practices

A group of stream restoration experts provided recommended methods for verifying the pollutant reduction performance of individual stream restoration projects built to meet the Chesapeake Bay TMDL goals. The memo highlights general guidance on how to verify stream restoration projects in the Chesapeake Bay watershed. This includes; defining what constitutes an adequate post-construction document for stream restoration projects, determining the quantitative data collected during the project necessary to assist in future verification efforts, identifying visual indicators that can determine whether an individual stream restoration project is still performing its designed water quality functions, and the specific thresholds for project failure that trigger the need loss of pollutant reduction credits and remedies.

Harman, W., R. Starr, M. Carter, K. Tweedy, M. Clemmons, K. Suggs, C. Miller. 2012. A Function-Based Framework for Stream Assessment and Restoration Projects. US Environmental Protection Agency, Office of Wetlands, Oceans, and Watersheds, Washington, DC. EPA 843-K-12-006.

A Function-Based Framework for Stream Assessment & Restoration Projects

The document provides a framework for approaching stream assessment and restoration using a function-based perspective. The document highlights the importance of site selection in river restoration and provides site selection criteria for reference reaches based on project goals and objectives and the stream's impaired functions. The document also covers the application of the Stream Functions Pyramid to help establish project goals and objectives.

Keystone Stream Team. 2007. Guidelines for Natural Stream Channel Design for Pennsylvania Waterways.

Guidelines For Natural Stream Channel Design for Pennsylvania Waterways

These guidelines are intended to help watershed organizations with the planning and implementation of stream restoration projects and professionals with stream restoration design, construction, and permitting and build consistency across natural stream channel design projects. The guidelines outline a general procedure for project design from planning to post-construction monitoring and reviews the importance of involving all interested parties and persons who have a stake in the outcome of the proposed restoration, recommending a watershed community meeting and pre-application meetings.

Law, N., B. Stack, R. Starr and E. Yagow. 2015. Designing sustainable stream restoration projects within the Chesapeake Bay watershed. CBP. STAC Publication No. 15-003. Edgewater, MD. 50 pp.

Designing Sustainable Stream Restoration Projects within the Chesapeake Bay Watershed

A Scientific and Technical Advisory Committee (STAC) workshop report that includes a general framework for defining how functional uplift may be assessed for stream projects implemented for the Chesapeake Bay TMDL.

Maryland Department of Natural Resources (MD DNR). 2018. Regenerative Stream Conveyance Construction Guidance: First Edition.

Regenerative Stream Conveyance Construction Guidance

This guidance presents conceptual information on constructing regenerative projects and implementation techniques for common features. This includes a focus on assessment of wetland or upland floodplain conditions, constructing regenerative projects, and implementation techniques for common features.

Maryland Department of the Environment (MDE). 2022. Guidance for Stream Restoration Based on Key Wildlife Habitats: Upper Coastal Plain Stream-associated Wetlands. MDE, Baltimore, MD. 46 pages

Guidance for Stream Restoration Based on Key Wildlife Habitats: Upper Coastal Plain Stream-associated Wetlands

This guidance presents an approach to recommendations for restoration based on the extent of degradation and condition of the Key Wildlife Habitat riparian wetland resources. This includes a Watershed Resources Registry (WRR) to identify sensitive species resources, nontidal wetlands of special State concern, and check for other designations (e.g., forest interior bird habitat) and other features which may be potential constraints on design or need specialized construction practices. The WRR also has identified priority areas for restoration and protection. The guide also includes information on identification of stream degradation sources, assessment of existing stream and wetland/riparian conditions, and assessment of Key Wildlife Habitat (KWH) conditions.

Maryland Department of the Environment (MDE). n.d. MDE, MS4/Chesapeake Bay TMDL/Trust Fund Restoration Project Wetlands & Waterways Permit Package Checklist.

MS4/Chesapeake Bay TMDL/Trust Fund Restoration Project Wetlands & Waterways Permit Package Checklist

The checklist and other documents outline steps to demonstrate functional impairment of a site, or aquatic resources which include biological function-based parameters and geomorphology/hydraulic function-based parameters for perennial or intermittent streams, description of biological degradation and geomorphology/hydraulic function degradation. It also advises assessment of wetland or upland floodplain conditions before restoration design choice, as well as preparing a Forest Stand Delineation and identifying all trees to be removed in the LOD.

Palone, R.S. and A.H. Todd (editors.) 1997. Chesapeake Bay riparian handbook: a guide for establishing and maintaining riparian forest buffers. USDA Forest Service. NA-TP-02-97. Radnor, PA.

Chesapeake Bay Riparian Handbook: A Guide for Maintaining Riparian Forest Buffers

This handbook addresses the design of buffer systems for nonpoint source pollution reduction, determination of buffer width. Site evaluation, planning, and establishment; streamside stabilization components and techniques along with aspects of agricultural/rural, silvicultural/Forest management, and Urban/Suburban considerations. The guide includes a Chapter (13) with information and education strategies from professional training to landowners, volunteers, and the media. This includes tips on holding meetings, working with the media, and working with volunteers.

Pennsylvania Department of Environmental Protection (PA DEP). 2022. Pennsylvania Function-Based Aquatic Resource Compensation Protocol. Document Number: 310-2137-001.

Pennsylvania Function-Based Aquatic Resource Compensation Protocol

The protocol outlines how aquatic resource compensatory mitigation evaluations should be conducted using this methodology and the factors to consider when doing so. Specifically, the protocol; covers how Aquatic Resource Condition Level 2 Rapid Assessment Protocols and Intensive Assessments are used in site selection.

Schueler, T. and Stack, B. 2014. Recommendations of the Expert Panel to Define Removal Rates for Individual Stream Restoration Projects. Approved by the Water Quality Goal Implementation Team of the Chesapeake Bay Program September 8, 2014.

[Stream_Panel_Report_Final]

This report reviews research on the impact of stream restoration projects in reducing the delivery of sediments and nutrients to the Chesapeake Bay. It also provides recommendation from an expert panel on methods to credit projects to account for pollutant reductions due to project implementation. The recommendations include four general protocols defining the pollutant load reductions and examples for calculating total loads for various project implementation scenarios.

The River Restoration Centre (RRC). 2011. Practical River Restoration Appraisal Guidance for Monitoring Options (PRAGMO)

Practical river restoration appraisal guidance for monitoring options (PRAGMO)

This document is intended as a living guidance document on suitable monitoring for river and floodplain restoration projects. There is discussion on the importance of good goal setting for river restoration projects that involves SMART goals: **S**pecific, **M**easurable, **A**ttainable, **R**elevant and **T**ime-bound.

U.S. National Vegetation Classification (USNVC). 2022.

U.S. National Vegetation Classification

This database provides a comprehensive classification system for all vegetation types in the United States. The system is a central organizing framework for documentation, inventory, monitoring, and study of vegetation on scales ranging from forests to plant communities that can help to avoid restoration site selection in areas with existing good quality communities and rare species.

United States Bureau of Reclamation and United States Army Engineer Research and Development Center (USBR & ERDC). 2016. National Large Wood Manual—Assessment, Planning, Design, and Maintenance of Large Wood in Fluvial Ecosystems: Restoring Process, Function, and Structure. 628 pp.

National Large Wood Manual—Assessment, Planning, Design, and Maintenance of Large Wood in Fluvial Ecosystems: Restoring Process, Function, and Structure

The manual describes the application of using a structured process as well as decision support tools for making informed restoration decisions. It also discusses the interdisciplinary design needs to address biological, physical, and social factors specific to the engineering challenges of large wood restoration projects. Methods of public outreach that can be used during large wood projects are also reviewed. This includes public notices, stakeholder engagement, and continued outreach. It also examines legal issues, project failures, and construction-related risks.

United States Department of Agriculture, Natural Resources Conservation Service (USDA NRCS). 2007. Stream Restoration Design Part 654 National Engineering Handbook.

Part 654 Stream Restoration Design National Engineering Handbook; Chapter 2 Goals, Objectives, and Risk

The handbook includes detailed description of the need and approach for selecting stream restoration project goals and objectives. This includes a discussion of the importance of community engagement.

Virginia Department of Conservation and Natural Resources (VA DCR). 2004. The Virginia Stream Restoration & Stabilization Best Management Practice Guide. Prepared with assistance from KCI Technologies, Inc. and the Center for Environmental Studies at Virginia Commonwealth University.

The Virginia Stream Restoration & Stabilization Best Management Practices Guide

The guide presents an overview of stream channel design through guiding principles and methods. It also describes the possible legal aspects involved in permitting work within the stream channel. The guide also outlines three steps for a site selection study that includes the assessment of degraded stream functions and values, stream reach rankings, and prioritization.

Virginia Department of Environmental Quality (VA DEQ). 1992. Virginia Erosion and Sediment Control Handbook.

Virginia Erosion and Sediment Control Handbook

A technical guide to meet requirements dictated by the VA Erosion and Sediment Control Law and the VA Erosion and Sediment Control Regulations. Includes the designated standards as well as guidelines and support materials to assist users in the implementation of the technical standards in accordance with the provisions of the law and regulations.

Wood, D., Schueler, T., and B. Stack. 2021. A Unified Guide for Crediting Stream and Floodplain Restoration Projects in the Chesapeake Bay Watershed.

Master Stream Restoration Crediting Guide

This guide provides a single source for stream practitioners and Bay managers to answer their questions on crediting stream restoration projects. The guide is organized to provide the most essential details that Bay managers and stream practitioners need to know on the current protocols to credit stream restoration projects. This includes types of stream restoration practices and the methodologies for calculating pollutant credits. The guide also includes information on qualifying conditions, construction best practices and post-construction project verification.

Yochum, S. E. 2018. Guidance for Stream Restoration. U.S. Department of Agriculture, Forest Service (USDA FS), National Stream & Aquatic Ecology Center. Technical Note TN-102.4. Fort Collins, CO.

Guidance for Stream Restoration

This guidance looks at fundamental principles of preliminary field assessments along with design approaches and analyses for stream restoration as well as specific planning and design features relevant when developing stream restoration projects. The guide includes an overview of establishing goals and objectives and conducting existing condition assessments (including riparian vegetation) with links to additional resources and information.