U.S. Fish and Wild Service

DRAFT FINAL Function-Based Stream Restoration Project Process Guidelines

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FUNCTION-BASED STREAM RESTORATION PROJECT PROCESS GUIDELINES

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I. INTRODUCTION

The Maryland Department of Environment (MDE), Maryland State Highway Administration (SHA) and the U.S. Fish and Wildlife Service (Service) - Chesapeake Bay Field Office (CBFO) have entered into a partnership to assist MDE in meeting its goals for restoring and enhancing the quality of Maryland's water and floodplain resources. As part of this partnership, the Service has developed six stream assessment and design review documents. This document is one of the six. The other five documents include: *1) Function-based Rapid Stream Assessment Methodology, 2) Analytical Design Review Checklist, 3) Natural Channel Design Review Checklist, 4) Regenerative Storm Conveyance Design Review Checklist* and *5) Valley Restoration Design Review Checklist*. All documents can be downloaded from the following website: **www.fws.gov/chesapeakebay/stream/protocols.html**.

All of these documents have been developed to assist MDE regulators in the review of stream restoration permit applications. However, they can also be used by stream restoration practitioners and managers in implementing stream restoration projects. The documents are based on the Stream Functions Pyramid Framework (SFPF) (Harman et al., 2012) and were developed to be used together throughout the stream restoration project process. Additionally, they were tailored for the Maryland nontidal wetland and waterway regulatory process and requirements.

This document provides guidance on how to apply the SFPF to the stream restoration project process. The function-based rapid stream assessment protocol is a rapid assessment protocol that can be used to assist in the selection of restoration sites, evaluate stream systems for prioritization purposes and validate detailed stream assessment results. The four design review checklists are used to review stream restoration designs for completeness and potential for success. Each document has a checklist to assist in the use of the guidelines. While these documents are based on several existing and proven stream restoration project processes, they do differ since they are based on the SFPF. Therefore, all six documents have been released as draft finals. The Service and MDE requests feedback from users. The Service and MDE will then revisit and potentially revise the documents based on feedback.

II. PURPOSE OF FUNCTION-BASED STREAM PROJECT PROCESS GUIDELINES

The primary purposes of these guidelines are to provide a standardized science-based and function-based stream restoration project process that can quantify the degree of functional uplift and/or loss of biological, chemical and physical processes, and promote better communication among all restoration stakeholders (e.g., restoration practitioners, regulators and scientists). The function-based project process is also intended to assist the regulatory community in ensuring that stream restoration efforts undertaken are consistent with the requirements of MDE and implementation of the Clean Water Act (CWA). The document will guide users through the stream restoration process from developing well-articulated goals and objectives, selecting watershed and reach-level assessment parameters and measurement methods, conducting design

alternatives analysis, developing restoration designs and establishing quantifiable and measureable monitoring performance standards. The goal of the guidelines is to assist applicants in selecting and implementing the best project restoration solution based on watershed health, stressors, constraints, reach-level conditions, restoration potential, goals and objectives and other regulatory requirements.

These guidelines may also support recommendations made in the: Designing Sustainable Stream Restoration Projects within the Chesapeake Bay Watershed - STAC Publication 15-003; Chesapeake Bay – Stream Health Outcome Management Strategy – June 2015; Regional General Permit for Chesapeake Bay TMDL, July 2015 - Baltimore District Corps of Engineers; and 2008 Compensatory Mitigation for Losses of Aquatic Resources – US Army Corps of Engineers (USACE) and Environmental Protection Agency (EPA). All of which recommend the development and/or use of a function-based stream restoration project process.

III. PROJECT PROCESS GUIDELINES OVERVIEW

A. OVERVIEW

The stream restoration project process is well established in the literature (EPA, 1995; Palmer et al., 2005; Kondolf, 1995; Kondolf & Micheli, 1995; Ehrenfeld, 2000; Thorne et al., 2014). The guidelines within this document are an extension of these processes. They are based on *A Function-Based Framework for Stream Assessment and Restoration Projects* (Harman et al., 2012), commonly referred to as the Stream Functions Pyramid Framework (SFPF). The SFPF illustrates the hierarchal relationship of stream functions where lower-level functions support higher-level functions, and they are all influenced by local geology and climate, which underlie the Pyramid (Figure 1). This hierarchal relationship has been applied to the project process described within this report. Furthermore, the SFPF has been used to develop other stream restoration methodologies within Maryland, as described above, and this document aligns with them.

The Pyramid consists of five critical categories that evaluate stream functions. The framework of the Stream Functions Pyramid is shown below in Figure 2. The Broad-Level View of the framework is the Stream Functions Pyramid graphic shown in Figure 1. The remainder of the framework is a “drilling down” approach that provides more detailed forms of analysis and quantification of functions. The function-based parameters describe and support the functional statements within each functional category. The term “function-based” is used instead of functional because the measurement methods include a combination of functional and structural measures. A functional measurement measures a function as a rate over time, whereas a structural measurement measures a function at one point in time. However, this combination is considered function-based because the parameters and measurement methods are used to quantify or qualitatively describe the overall functional condition for a given assessment parameter. The “measurement methods” are specific tools, equations, assessment methods, etc. that are used to quantify the function-based parameter.

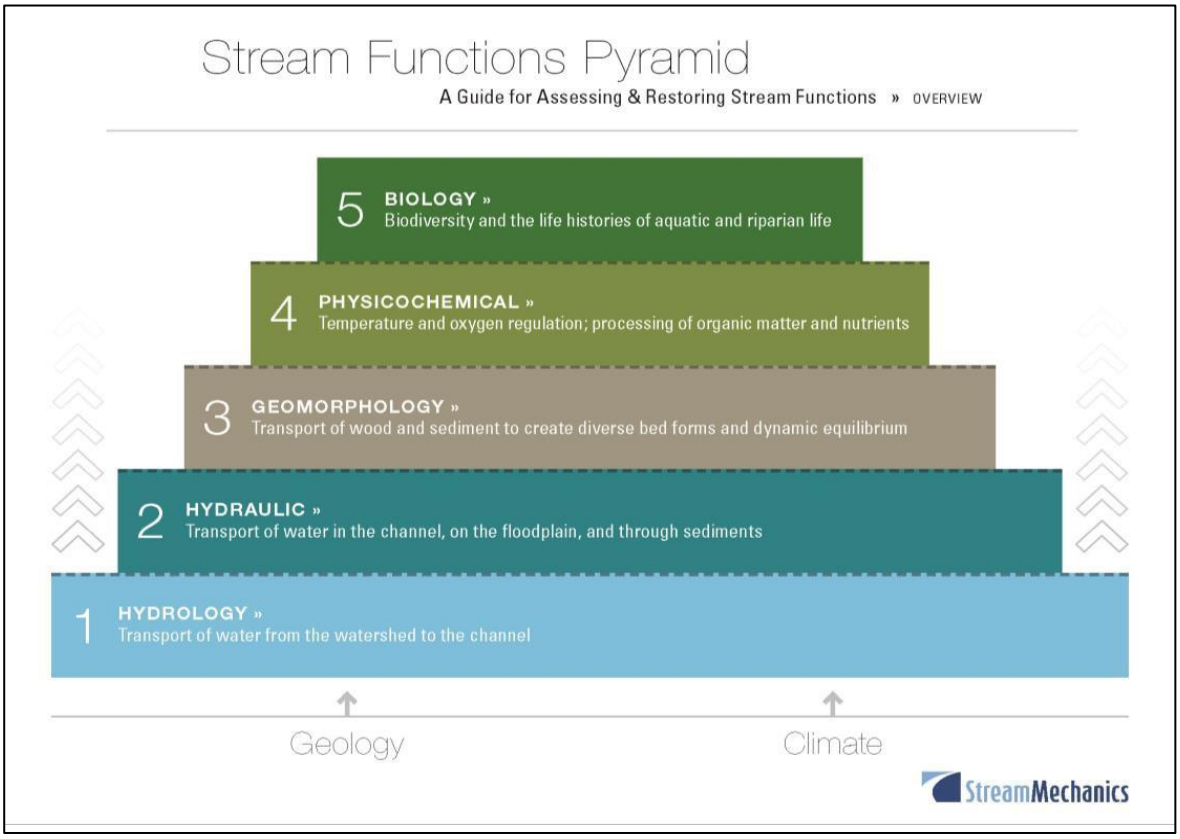


Figure 1. Stream Functions Pyramid (Harman et al., 2012)

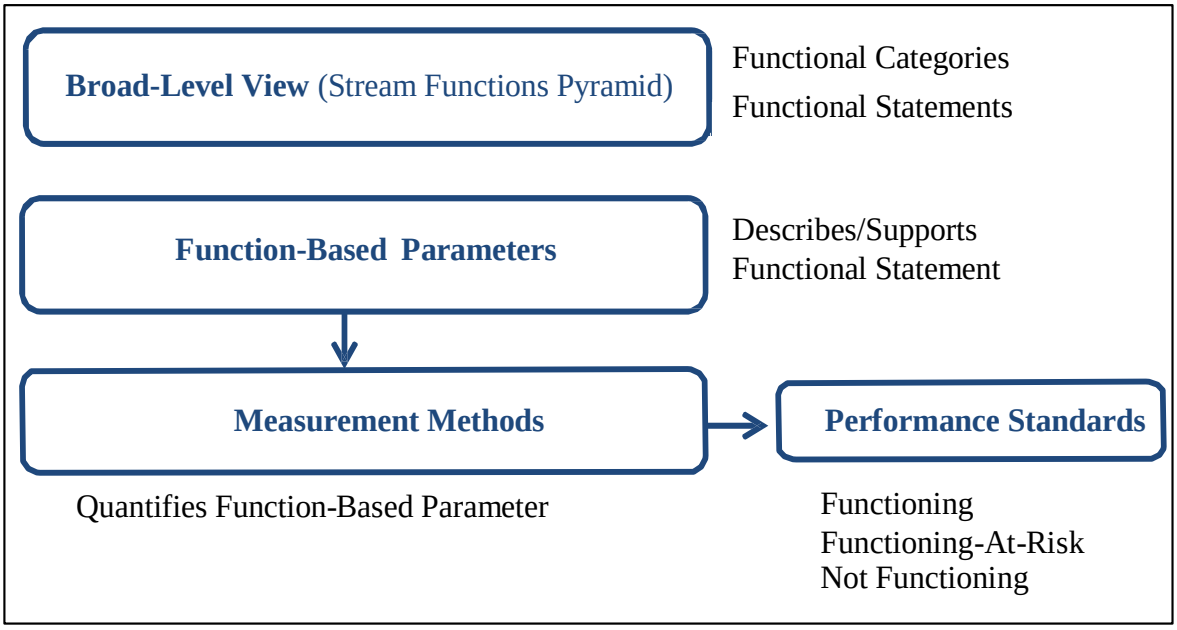


Figure 2. Stream Functions Pyramid Framework (Harman et al., 2012)

The Function-based Stream Restoration Project Process is comprised of nine sequential steps (Figure 3) that create a transparent process which directly links programmatic goals with design elements to support stream functions. Each step builds upon the previous step and at each step, programmatic goals and design goals and objectives are re-evaluated to ensure they can still be achieved. While each step builds upon the previous step, some steps can be repeated. For example, as part of the site selection step, it is recommended that rapid watershed and reach level assessments be conducted. A basic understanding of existing watershed health and reach level function-based conditions is critical in determining whether a proposed project site is suitable for restoration. Once the proposed site is deemed suitable for restoration (typically after a pre-application meeting with regulators), detailed watershed and reach level assessments might be necessary to properly develop and evaluate potential restoration solutions. The level of detail for each step should be proportional to the complexity and size of the project site.

It is important to note that while all of these steps are necessary to complete a function-based approach to a stream restoration project, they do not have to be completed concurrently with review of a permit application. Watershed studies and assessments may be done in advance of application submittal, as part of an MS-4 permit requirement, or as part of a comprehensive watershed implementation plan to meet TMDL requirements. The existing supporting field information generated during watershed plan development, plus the watershed plan itself, may be submitted as part of the permit application.

Function-based Stream Restoration Project Process:

Step 1 Programmatic and Design Goals – Program goals document why the project is being proposed as typically stated by the owner, regulatory requirement or funding source (e.g., stream mitigation, TMDL). Design goals are general statements that describe why the project is needed (e.g., reduce streambank erosion, improve brook trout habitat). This information is generally included in the "project purpose" section of State/federal permit application.

Step 2 Site Selection - Determines if the site restoration potential can meet programmatic and design goals as part of a site suitability decision making process. During this step in the process, a pre-application meeting is recommended.

Step 3 Watershed Assessment – Determines the health of the drainage area contributing water to the project reach and its influence on a project's restoration potential.

Step 4 Reach-Scale Function-based Assessment – Establishes the existing function-based condition, identifies constraints and determines channel evolution.

Step 5 Restoration Potential – Determines the highest level of restoration that can be achieved given the watershed conditions, function-based assessment results, stressors and constraints. Also, it is at this point that the amount of potential functional lift will be determined.

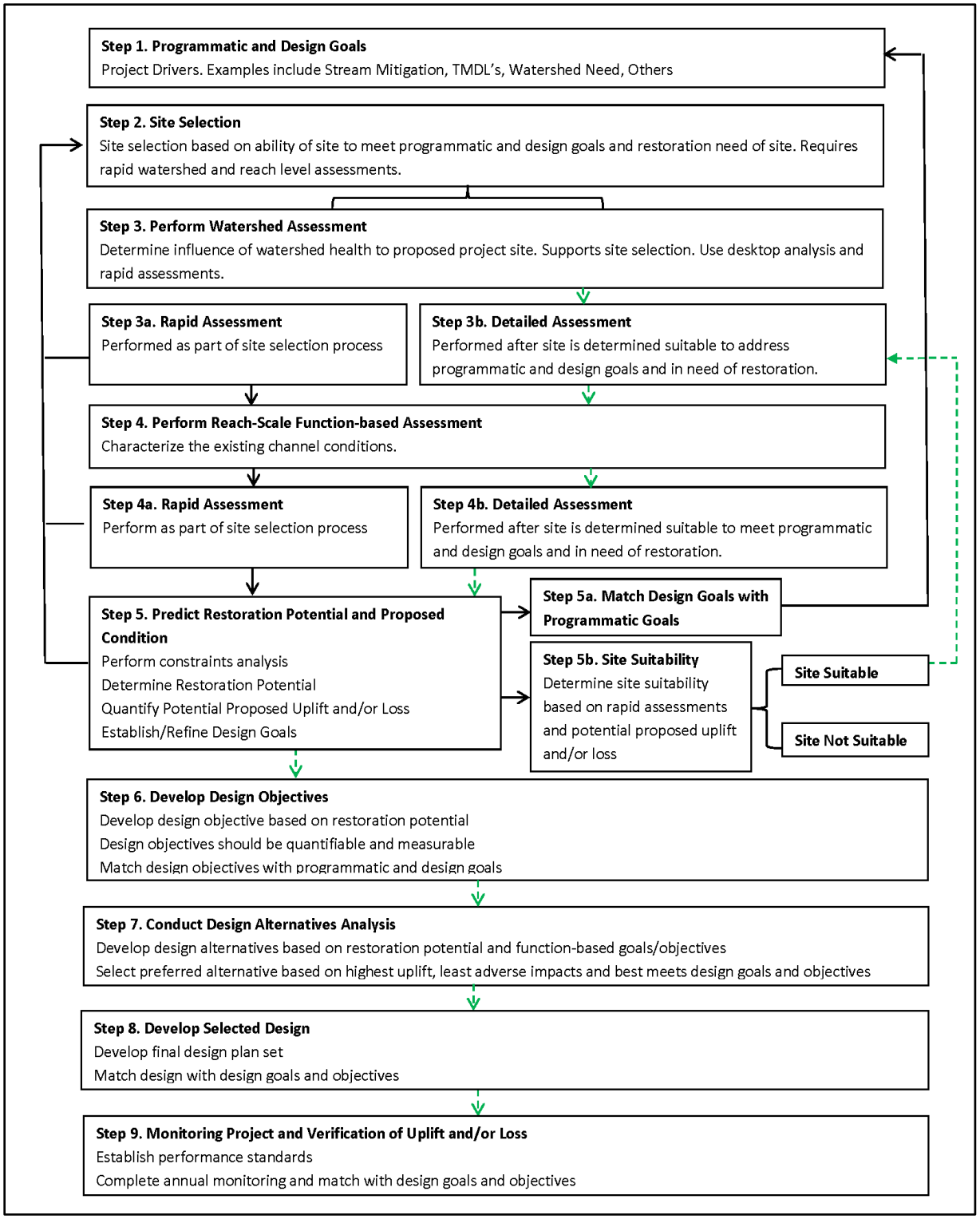
Step 6 Design Objectives – Establishes design objectives based on the programmatic and design goals, results of the watershed and reach-scale function-based assessment, constraints and restoration potential. Design objectives are specific and tangible statements that define how the project is to be completed (e.g., reduce streambank erosion to less than 0.01 ft/yr).

Step 7 Design Alternatives Analysis – Determines the restoration design approach that best meets the project goals, objectives and restoration potential of the site. The focus is on how a design approach can change function-based parameters. During this step, further coordination with regulatory agencies is recommended to ensure that there is general agreement on the design solution, so the application review can be completed in a timely manner.

Step 8 Design Development – Documents the design development process, ensures project feasibility, determines project implementation costs and produces a constructible design set along with specifications and materials. Upon completion of this step, an application should be submitted to regulatory agencies.

Step 9 Monitoring - The monitoring plan should determine if the quantifiable project objectives are achieved.

This document contains a description of each step in the project process; guidance on how to conduct each step; brief examples; project process review checklist; and examples of the project process applied to a variety of programmatic and design goals. Description will be brief and focus on how it relates to the SFPF. The document is intended to be a guide in applying the SPFP to stream restoration projects and not a detailed methods protocol. Examples of how the SFPF project process has been applied can be found on the U.S. Fish and Wildlife Service – Chesapeake Bay Field Office website at: http://www.fws.gov/chesapeakebay/stream/projects.html. Additionally, a template report format can be found in Appendix C.



Note: Non-dashed flow lines are tasks completed as part of site selection step and dashed flow lines are tasks completed after the site selection step.

Figure 3. Function-based Stream Restoration Project Process

B. LIMITATIONS

Even though one of the purposes of this document is to ensure that stream restoration efforts undertaken are consistent with the implementation of Maryland permit requirements and the Clean Water Act, it does not address every permit application requirement. It does address project purpose and need, objectives, existing conditions assessment, potential functional uplift, potential impacts, design alternatives analysis and monitoring. It does not address other permit requirements such as Section 7 Endangered Species Act, Section 6 Historic Resources, mitigation requirements, design plan set requirements or any other special permit requirements. Permit applicants should refer to MDE's (*http://mde.maryland.gov/programs/Water/WetlandsandWaterways/Pages/Programs/WaterPrograms/wetlands_waterways/index.aspx*) and COE's (*http://www.nab.usace.army.mil/Missions/Regulatory.aspx*) websites for specific permit application requirements. However, some information related to permit requirements is presented in Appendix F.

Another limitation to these guidelines is that they have been specifically developed to address stream functions. It does not address other ecological resources which can exist within a stream corridor (e.g., wetlands). It is common for stream restoration sites to have opportunities to restore other stream corridor functions. If other ecological functions exist or are being proposed, permit applicants should conduct appropriate assessments to document these ecological functions so that they can be used during the design alternatives analysis.

C. APPLICABILITY

The applicability of the function-based stream restoration project process guidelines is influenced by the type, size, location and complexity of a restoration effort. Stream restoration projects that involve physical manipulation to intermittent and perennial stream channels can benefit from these guidelines (Harman et al., 2012). However, restoration activities in ephemeral channels and uplands may benefit less from using these guidelines. Implementation of upland stormwater BMPs, Low Impact Development and other practices typically have goals to reduce flow energy, reduce nutrients and remove other inorganic and organic compounds. These project types would rely more on conventional approaches to stormwater treatment rather than the SFPF.

Water quality solutions like treating point source discharges and lime dosing may not need the SFPF guidelines as well to set design goals or develop assessment methods. However, even in these cases, it is always appropriate to ask, "What are the supporting functions and conditions that are required to meet the desired result?" This is important because other problems may exist in addition to the obvious impairment. For example, low pH is a commonly known problem in some Maryland trout streams. If streams with low pH where dosed with lime and improvements in trout populations were variable, then the actual cause of changes in populations could not be determined. This is because only one parameter that influences trout populations was addressed. Therefore, an understanding of key functions in all five levels is needed in order to find a solution. Reducing pH may be the most important part of the solution, but other function-based

parameters may also need to be addressed, e.g. improved bed form diversity, to recover trout populations.

While the purpose of these guidelines is to provide guidance on how to apply a function-based approach to stream restoration projects, the SFPF has broader applications to stream related efforts. As stated above, the SFPF is a framework that is intended to show the hierarchical relationship among stream functions. Understanding how stream functions influence and are influenced by each other allows those involved in stream related work to understand and predict how functions could be influenced by in-stream and/or watershed changes. Even though many stream restoration efforts consist of multi-discipline teams, they can still struggle in understanding how individual functions interact and influence one another as well as support the project goal(s). The SPFP provides a means for these different stream disciplines to effectively communicate and see how lower-level functions support higher-level functions.

The SPFP can be applied to a variety of stream efforts including *watershed assessments and stressor identification, strategic planning and prioritization, on-the-ground implementation (well-established and innovative approaches), management decisions, monitoring* and *research*. For example, a stream restoration manager would like to determine the best locations to achieve the highest stream functional uplift within a particular watershed. The *Function-based Rapid Stream Assessment Protocol* (Starr et al., 2015) could be used to assess all stream reaches within the watershed. That data then could be used to show existing function-based conditions and the restoration potential for each reach assessed. The reaches that are most degraded and have the highest restoration potential would be the preferred stream restoration sites for the stream restoration manager.

IV. FUNCTION-BASED STREAM RESTORATION PROJECT PROCESS

This section contains a description of each step in the function-based project process, guidance on how to conduct each step and brief examples.

A. STEP 1 – PROGRAMMATIC AND DESIGN GOALS

1. Purpose

Developing goals and objectives is important for projects of all sizes. Well-articulated goals and objectives establish a foundation for project success. Vague, too broad or poorly articulated goals and objectives often lead to project failure at worst, and misunderstandings at best. This is directly related to project uncertainty and risk. As described in Section IV. G. Design Alternatives Analysis, poor or inappropriate design goals and objectives increase project uncertainty and risk.

The terms goals and objectives are often used interchangeably; however, there is a difference. Goals are statements about why the project or effort is needed. They are general intentions and

often cannot be validated. The goal should relate to the primary function(s) of interest, e.g. life history of some type of aquatic life. Objectives can also be used to identify the supporting functions needed to meet the goal and should help explain how the functional improvement will occur. Objectives are more specific. They are tangible and can be validated, typically by the performance standard (Harman et al., 2012). A detailed description of objectives is presented below in Section IV. F. Design Objectives.

Goals are divided into two categories: programmatic and design. Programmatic goals are created from agency and organization funding programs or regulatory requirements. Examples include: Total Maximum Daily Load (TMDL) allocations, providing stream mitigation credits, restoring listed or candidate species, addressing watershed needs based on a watershed management plan and others. They can be linked to regulatory requirements, but can also be initiatives developed through voluntary efforts.

Design goals are general statements that describe why the project is needed (e.g., reduce sediment loads coming from streambank erosion) and should align with the programmatic goals. For example, if the programmatic goal is to implement stream restoration projects for a TMDL associated with sediment and nutrient pollution, a design goal may be to reduce sediment and nutrient loading from adjacent cropland. The process of matching the programmatic goal to the project's design goal can help ensure that a project is providing the intended functional benefit. Furthermore, design goals must be based on the restoration potential at the proposed project site (Refer to Section IV. E. Restoration Potential). Ensuring that design goals can be achieved based on the restoration potential ensures that any proposed functional uplift can be supported by the health of the contributing watershed and existing functional condition of the proposed project site.

Since design goals are based on restoration potential, some general knowledge of the proposed project site must exist. This information can come from watershed assessment and prioritization documents or rapid reach level assessments. Refer to Section IV. B. Site Selection on how to develop or refine design goals. If existing data are not available, then developing design goals may have to wait until the proposed project site is assessed.

Programmatic and design goals are also part of the permit application. This information is generally included in the "project purpose" (i.e., What is the need for the project?) section of state/Federal joint permit application. Regulatory agencies have the authority to independently define "project purpose." This is more likely to happen when a project purpose is too broad or too narrow or when a project may have other mandate considerations. Restoration practitioners may find it beneficial and efficient to coordinate with regulatory agencies to arrive at a mutual decision regarding the most appropriate goals for a proposed project site.

2. Programmatic and Design Goal Development Process

Establishing programmatic and design goals is a relatively easy process as long as they are not mixed with objectives. It starts by identifying the driver(s) that is funding the stream restoration

project. It is common to have more than one programmatic goal since stream restoration can be expensive and require more than one funding source and several stakeholders. Next, establish at least one design goal for each programmatic goal. Then, identify the highest level on the Pyramid that relates to each design goal and is supported by the restoration potential. Refer to Figure 4 for examples of matching programmatic and design goals. This is needed because the programmatic and design goals will be used initially to assist in site selection and identification of appropriate watershed and reach level assessment parameters. Details of how this is done are described below in Section IV. C. Watershed Assessment and Section IV. D. Reach Level Function-based Assessment.

Other sources for developing stream restoration related goals and objectives include: SFPF (Harman et al., 2012), NRCS Stream Restoration Design Manual, Part 654, Chapter 2 (USDA NRCS, 2007) and the USACE Technical Note, Ecosystem Restoration Objectives and Metrics (McKay et al., 2012).

PROGRAMMATIC and DESIGN GOALS

Programmatic Goal: TMDL and/or Water Quality requirements
Design Goal: Reduce sediment and nutrient loads coming from streambanks

Programmatic Goal: Species recovery
Design Goal: Create habitat for American Eel

Programmatic Goal: Recreational Fisheries
Design Goal: Create habitat for trout

Programmatic Goal: Watershed Implementation Plans
Design Goal: Identify and prioritize potential stream restoration sites to meet water quality improvement requirements

Figure 4 Example Programmatic and Design Goals

3. Programmatic and Project Goals Development Step-wise Process

- Identify drivers for the restoration effort.
- Develop programmatic goals based on the drivers.
- Develop at least one design goal, if possible, for each programmatic goal based on the SFPF.
- Compare the design goals to the restoration potential of the proposed project site.

B. STEP 2 – SITE SELECTION

1. Purpose

The purpose of the site selection is to document existing function-based conditions and determine whether the restoration potential of the site can meet the programmatic goal(s) and develop or refine design goals. It is not to determine whether there is another potential site that would better address the programmatic and design goals. The prioritization of potential restoration sites is typically done through a broad-scale watershed assessment and is a different process than what is described within this section. However, the results of such a study can be used to assist in the identification of sites that could potentially meet the programmatic goal(s) and to develop design goals. Study results should be included with a permit application. Additionally, if there is a proposed restoration solution, the potential uplift and adverse impacts to stream functions can be determined as part of the site selection assessment.

2. Site Selection Process

The site selection process begins by collecting readily available and relevant watershed and reach level information (e.g., watershed assessments, management plans, reach level assessments, water quality data, species data, etc.) related to a proposed project site. The existing data should describe, at least qualitatively, the current functional condition of critical stream and other ecological functions (e.g., wetlands, mature forest). This is important because the evaluation of potential effects to ***all*** existing ecological functions from proposed design solutions is a permit requirement. Refer to Section IV. C. Watershed Assessment and IV. D. Reach Level Function-based Assessment on how to determine appropriate assessment parameters.

If data does not exist, some level of watershed and reach level assessment needs to occur. Even if data does exist, field verification of the data should occur. The field verification assessment can be rapid and qualitative, but must address critical functions on all levels of the Pyramid. Refer to the *Function-based Rapid Stream Assessment Methodology* (Starr et al., 2015) for examples of rapid watershed and reach level assessments. If other critical ecological resources exist, assessments for these ecological resources need to be conducted. The reach level assessment should also determine the channel evolution sequence (Refer to Section IV. D. Reach Level Function-based Assessment). Lastly, identify any constraints that may influence reach level functional uplift. Refer to Section IV. C. 2. Watershed Assessment Process for further detail on identifying constraints.

Based on all the data collected, determine the highest restoration potential and the associated Pyramid level. Refer to Section IV. F. Restoration Potential for a detailed description on how to determine restoration potential. Also, if there is a proposed plan of action, identify any potential uplift and/or adverse impacts to existing stream and other ecological functions. Note that a full design alternatives analysis must occur later in the project process (Refer to Section IV. G. Design Alternatives Analysis) before a preferred plan of action can be selected.

If design goals are not yet established, develop the goals based on the collected data and in line with the programmatic goals. Compare the restoration potential to the programmatic and design goals. Determine if there are potentially significant adverse impacts to existing functions. If the restoration potential is at least as high as the programmatic and design goals and there are no potential adverse impacts to existing functions, then the site is suitable for restoration. If the programmatic and/or design goals cannot be achieved at the proposed project site and/or potential adverse impacts are significant, then the site is not suitable for restoration for those particular programmatic and/or design goals. If the site is not suitable for a certain type of restoration, consider revising design goals and/or potential restoration solutions. If the site is not suitable and the design goals and/or potential restoration solutions cannot be revised, then the site should be eliminated from further consideration as a potential site to meet the programmatic goal(s).

Lastly, describe how the proposed project supports existing and current larger-scale (Statewide, regional, watershed) plans or policies, if applicable. Furthermore, describe how the programmatic and design goals for the proposed project site cannot be achieved at other potential sites. An example of how the site selection process can be applied to a proposed project site is provided in Appendix E.

Pre-application consultation with regulatory agencies to determine their concurrence on goals and suitability of the site for restoration is highly recommended at this step.

3. Site Selection Step-wise Process

- Obtain readily available and relevant information (e.g., watershed assessments, management plans, reach level assessments, water quality data, species data, etc.) related to a proposed project site or study area. Some of this information may already be included in Watershed Implementation Plans or watershed plans required for MS-4 permits.
- Review the data to: determine the existing function-based conditions of the proposed project site; identify constraints; establish restoration potential; if there is a proposed design solution, predict potential functional uplift and/or loss; and develop or refine design goals.
- To validate existing information or if existing data is not available, conduct rapid watershed and reach level assessments. The assessment should assess parameters that support the programmatic and design goals. Refer to the *Function-based Rapid Stream Assessment Methodology* (Starr et al., 2015) for an example of a rapid watershed assessment.
- Conduct a “windshield” tour of the watershed to validate the findings of the existing data and/or rapid watershed assessment and focus on identifying stressors that may influence reach level functional uplift.
- Visit the proposed project site and conduct a rapid assessment to determine the existing function-based conditions. Refer to the *Function-based Rapid Stream Assessment Methodology* (Starr et al., 2015) for an example of a rapid reach level assessment.
- Conduct other assessments necessary to document other ecological functions (e.g., wetlands, mature forests) occurring within the project site.

- Determine the channel evolution sequence. Refer to Section IV. D. Reach Level Function-based Assessment.
- Identify any constraints that may influence reach level functional uplift.
- Determine the highest restoration potential and the associated Pyramid level of the proposed project site based on the watershed health (i.e., stressors), constraints and reach level function-based conditions. Refer to Section IV. F. Restoration Potential for a detailed description on how to determine restoration potential.
- If there is a proposed plan of action, identify any potential uplift and/or adverse impacts to existing stream and other ecological (e.g., wetlands) functions.
- Develop design goals, if not already established.
- Compare the restoration potential to the programmatic and design goals.
- Determine if there are potentially significant adverse impacts to existing functions.
- If the restoration potential is at least as high as the programmatic and design goals and there are no potential adverse impacts to existing functions, then the site is suitable for restoration. If the programmatic and/or design goals cannot be achieved at the proposed project site and/or potential adverse impacts are significant, then the site is not suitable for restoration to meet those goals.
- If the site is not suitable for restoration, consider revising design goals and/or potential restoration solutions.
- If the site is not suitable and the design goals and/or potential restoration solutions cannot be revised, then the site should be eliminated from further consideration as a potential site to meet the programmatic goal(s).
- Describe how the proposed project supports existing and current larger-scale (Statewide, regional, watershed) plans or policies, if applicable.
- Describe how the programmatic and design goals for the proposed project site cannot be achieved at another potential site. Note: This determination may have already been documented in a comprehensive watershed plan, MS-4 restoration plan; or Watershed Implementation Plan.
- Consider a pre-permit application meeting with regulatory agencies to discuss results of site selection assessment.

C. STEP 3 – WATERSHED ASSESSMENT

1. Purpose

The purpose of the watershed assessment is to determine the health of the watershed and its influence on the proposed project site. The watershed assessment is separate from the broad-scale watershed planning process that recommends priority upland and in-stream restoration projects. It focuses on identifying stressors, causes of stressors and the effects of stressors on the existing function-based condition of a proposed project site. The process involves selecting watershed assessment parameters, following the Pyramid, that support the programmatic goals and using that information to determine if programmatic goals are achievable, as well as establish the restoration potential of the proposed project site.

Two levels of watershed assessment typically occur during the stream restoration process. One is a brief or rapid assessment used during the site selection process, as described above in Section IV. B. Site Selection. The other is a more detailed assessment, if necessary, used in the development and evaluation of design solutions.

This section focuses on describing how to apply the SFPF to a watershed assessment and is not a "step-wise" description of how to conduct a watershed assessment.

2. Watershed Assessment Process

The watershed assessment process begins by selecting watershed assessment parameters. Parameters on all levels of the Pyramid must be assessed, at least to some degree, to determine the influence of the watershed health on the proposed project area. This is important because the evaluation of potential effects to existing stream functions from proposed design solutions is a permit requirement.

The level of detail associated with the watershed assessment is determined by programmatic and design goals and when in the study process the assessment occurs (i.e., site selection versus design alternative analysis). If it is during the site selection, a rapid assessment would, in most cases, be appropriate. The rapid watershed assessment methodology described in the *Function-based Rapid Assessment Methodology* (Starr et al., 2015) is a rapid assessment protocol that assesses all levels of the Pyramid. Other protocols can be used; however, they should address all levels of the Pyramid. To determine whether a protocol contains appropriate assessment parameters, refer to Section IV. C. 3. Typical Watershed Assessment Parameters.

If the watershed assessment is used during the design alternative analysis, a more detailed watershed assessment, in most cases, is required. The level of detail is based on the programmatic and design goal. Enough information should be collected in order to determine whether the watershed health could support the programmatic goal(s). This process starts by determining what level of the Pyramid is targeted by the programmatic goal(s). For example, if the programmatic goal is to reduce nutrients, then detailed watershed data will need to be collected through Pyramid Level 4 – Physicochemical. The amount of nutrients being delivered to the proposed project area needs to be quantified in order to determine if the proposed design solution could reduce nutrient levels. However, if the programmatic goal is to reduce lateral erosion (Pyramid Level 3 – Geomorphology), water quality still needs to be evaluated for permitting requirements but can be qualitative based, such as based on watershed land uses and observations. In this case, the level of information collected should be enough to determine whether the existing biological condition of the proposed project site is more influenced by the watershed health or existing reach level conditions, or possibly both. Lastly, the level of detail is also influenced by project budget and watershed size and complexity.

Once the assessment is complete, the data needs to be related to functional processes. For example, a watershed could have a percent impervious surface of 15 percent. This data point in

itself does not describe how it affects the watershed and stream functions. Therefore, a description of how it influences watershed processes is needed. In this particular case, research (Schueler et al., 2009) has shown that 15 percent imperviousness can increase flow regime (i.e., precipitation time and concentration) and adversely impact water quality, both of which affect biology. Now the impervious surface data has meaning to the proposed project site and can be used to determine restoration potential and develop restoration solutions.

Along with identifying natural watershed stressors, constraints must be identified. Constraints are natural or man-made and limit potential restoration alternatives, which then influences restoration potential. Typical man-made constraints include such things as roads, bridges, utility lines, reservoirs, flood control structures, buildings, property boundaries and policies and regulations. As stated in MDE COMAR 26.23.02.05B(2)e, natural features can also be considered constraints. A natural constraint could be existing high-functioning or sensitive natural or water resources and soil properties.

The final step in determining how the health of the watershed influences the proposed project site is to describe all of the individual watershed data together. The description should include how all of the watershed data relate (i.e., support and rely upon) to one another and influence the potential project site. Furthermore, this description should state whether the watershed health can support the project goals. The following example is an excerpt from the *Little Tuscarora Stream Restoration Project Assessment and Design Report* (Hutzell et al., 2015):

> *"The Little Tuscarora Creek watershed is an actively developing watershed. It is unique, in part, by the fact that it consists of two physiographic regions and is underlain by 41 percent karst topography. These things alone are known to alter flow volumes and duration. Additionally, decades of poor agriculture practices have compromised much of the physical integrity of the channel and riparian corridor. The more recent land use changes, including increased development, has led to higher percentages of impervious surface, which contributes to higher flows and thermal loading. While the flows have increased, they have not increased to an amount to be considered flashy, therefore, the flow regime is considered non-flashy. This means that the proposed project will have a ground water recharge source and flood flows will not be as elevated as similar sized watershed with higher runoff rates. However, these higher flows, coupled with poor riparian buffers and erosive soils, have led to widespread lateral instability throughout the watershed. Therefore, the proposed project area will have a sediment supply that must be addressed in the proposed design. Lastly, the increased impervious surfaces and poor riparian vegetation will increase water temperatures. This adversely affects the ability of the proposed project area to support brook trout. However, as noted by Frederick County's CAMBI report (Moore, 2011), the Little Tuscarora Creek watershed is dominated by coldwater springs which is a positive effect on water temperatures.*

> *Collectively, these "stressors" impact the restoration potential of the proposed project area. While these stressors cannot currently be addressed at the watershed level as part of this project, they can be addressed at the reach-level with the appropriate design approach. As mention earlier, the Frederick County Division of Public Works, Eastern Brook Trout Joint Venture and Maryland Brook Trout Alliance has identified this watershed as a high priority for brook trout restoration in their working draft CAMBI report (Moore, 2011). Additionally, the upper, less impacted, portion of the watershed still holds and nourishes an intact brook trout population. This, along with Frederick County efforts, is enough to support the project goal of creating a habitat suitable for seasonal brook trout usage."*

By understanding watershed conditions we are able to determine if programmatic and design goals are achievable, as well as determine the restoration potential of the project reach.

3. Watershed Assessment Step-wise Process

- Select watershed assessment parameters based on permit requirements and programmatic and design goals. All levels of the Pyramid should be assessed.
- Determine level of assessment and measurement methods based on when assessment occurs during the study process, programmatic goals, project budget and watershed size and complexity.
- Determine if the measurement methods need to be adapted based on unique regional characteristics (e.g. karst topography and location of endangered species).
- Determine how to relate watershed data to functions so that it can be used to understand how the watershed health influences the proposed project site.
- Implement the appropriate level of watershed assessment, evaluate its effectiveness in assessing watershed processes, and adapt method as necessary.
- Identify stressors and constraints.
- Combine all watershed data and determine if the watershed health will support the programmatic and design goals. If the success of restoration depends on other actions taking place in the watershed, note this information as well.

4. Typical Watershed Assessment Parameters

Watershed assessments typically assess such watershed characteristics as geology, soils, current and future land uses, land cover types, percent impervious surfaces, hydrology, etc. to describe watershed characteristics and processes and to identify stressors. However, these data by themselves do not help us understand how they might influence the proposed project site and support the programmatic and design goals. Therefore, a description of how watershed characteristics influence watershed processes is needed. For stream restoration projects, watershed data is typically collected to describe four watershed processes: hydrology (i.e., flow regime) (Pyramid Level 1), sediment supply (i.e., sources and amount) (Pyramid Level 3), water

quality (i.e., types and sources) (Pyramid Level 4) and landscape connectivity (i.e., upstream and downstream biological health) (Pyramid Level 5).

An understanding of flow regime is needed to determine how much and how quickly precipitation runoff reaches a stream, typically referred to as time and concentration. The amount and rate of precipitation runoff influences many stream processes (e.g., stream energy, bedform diversity, based flows, etc.) (Knighton, 1998) which in turn influences stream restoration solutions. Typical watershed characteristics used to understand flow regime include precipitation, geology, soils, basin shape and relief, road systems, reservoirs and land uses.

Sediment transport is a critical stream function because it significantly influences the creation and maintenance of stream channel dimensions (i.e., cross section and profile) (Yang, 2003). Sediment transport is a product of sediment supply and hydrology/flow regime. A stream typically must be able to transport the sediment supply being delivered by the watershed or degradation and/or aggradation could occur. Assessment of sediment supply, at the watershed level, focuses on identifying sources and estimating, qualitatively, the amount of sediment supply. Typical watershed characteristics assessed for determining sediment supply include land uses, riparian vegetation, percent impervious surfaces, stream stability, landscape topology, depositional patterns, road systems, soils and geology.

Water quality is significant because it influences biological health (Schueler et al., 2009). If a stream restoration project has biological uplift goals, then water quality must be assessed. There are numerous water quality parameters and which ones are assessed is highly variable depending upon programmatic goals and watershed characteristics. Additionally, assessment of water quality involves identifying point source and non-point source pollution sources. Typical watershed characteristics assessed for determining water quality include land uses, percent impervious surfaces, soils and geology.

Landscape connectivity also influences biological health because it can be a source of macroinvertebrates and fish that can populate a newly restored stream reach. If stream reaches upstream and downstream are impaired and do not have healthy macroinvertebrates and fish, then it is unlikely that a newly restored stream reach would have biological uplift. The determination of landscape connectivity is mostly based on the health and condition of upstream and downstream stream reaches and involves using the data collected as part of the watershed assessment and a field visit inspection to determine the presence of macroinvertebrates and fish. If there are biological programmatic goals, a detailed biological assessment, such as methods used in the Maryland Biological Stream Survey, may be required.

D. STEP 4 - REACH LEVEL FUNCTION-BASED ASSESSMENT

1. Purpose

The purpose of the reach level function-based assessment is to establish the existing functional condition, determine stressors and identify constraints at the proposed project site. This information will be used to describe the hierarchical influences of existing functions and to develop a cause and effect relationship between these functions and the stressors and constraints at both the watershed and reach-level. Just like the watershed assessment, this process involves selecting appropriate stream assessment parameters that support the design goals and establish the restoration potential of the proposed project site.

This section focuses on describing how to apply the SFPF to a reach level function-based assessment and is not a "step-wise" description of how to conduct a reach level function-based assessment.

2. Reach Level Function-based Assessment Process

The reach level function-based assessment process generally follows the same process as the watershed assessment. There are two levels of reach assessment that typically occur during the stream restoration process. One is a brief or rapid assessment used during the site selection process, as described above in Section IV. B. Site Selection. The other is a more detailed assessment used in the development and evaluation of design solutions.

In both cases, appropriate parameters must be assessed. There are two factors that influence the selection of assessment parameters. The first is programmatic and design goals. Parameters must be selected that allow decision makers to determine if the goals can be achieved. The second is permit requirements. Permit regulations require that applicants document potential effects to physical, chemical and biological functions and resources. Therefore, parameters on all levels of the Pyramid, which may be influenced by the proposed project, must be assessed to some degree.

An example of an appropriate rapid reach level assessment methodology is described in the *Function-based Rapid Assessment Methodology* (Starr et al., 2015). Other protocols can be used; however, they should address all levels of the Pyramid. To determine whether a protocol contains appropriate assessment parameters, refer to Section IV. D. 3. Typical Reach Level Assessment Parameters.

For detailed reach level assessment guidance, use the Pyramid as a guide to select specific assessment parameters. Identify the highest Pyramid level that corresponds to the programmatic and design goals. Then select assessment parameters at that level and all other lower levels that can be used to determine whether the goals can be achieved. For example, if the programmatic goals are to provide lateral and vertical stability, then the highest Pyramid level associated with these goals would be Level 3 – Geomorphology. Parameters that influence lateral and vertical

stability with Level 3 – Geomorphology, as well as the lower levels (i.e., Level 2 – Hydraulics and Level 1 – Hydrology) should be identified and assessed. Next, if there are Pyramid levels higher than that of the Pyramid level that corresponds to the goals, select assessment parameters for the remaining Pyramid levels to address regulatory requirements. Following the same example above, Pyramid Levels 4 – Physicochemical and 5 - Biology would need parameters identified and assessed.

For each selected assessment parameter, select at least one measurement method and a corresponding performance standard for each measurement method. The level of effort of the measurement methods is influenced by the proposed project length, functional complexity and project budget. Table 1 is an example of potential assessment parameters and measurement methods by Pyramid level. Examples of typical assessment parameters by programmatic and design goals are in Appendix D. Additional examples can also be found in the SFPF (Harman et al., 2012) and at the U.S. Fish and Wildlife Service – Chesapeake Bay Field Office website: **www.fws.gov/chesapeakebay/stream/projects.html**.

Once the assessment parameters and measurement methods are selected, conduct the reach level function-based assessment. The data then needs to be related to a functional rating. Table 1 provides an example demonstration. Data are rated at three levels: 1) measurement method, 2) Pyramid level and 3) overall reach. There are many ways to rate data. The example shown in Table 1 uses *Functioning, Functioning-at-Risk* and *Not Functioning* along with color coding. What is most important is that the data be described somehow so that the functional condition of the proposed project site is known and can be used to determine whether the project goals are achievable. In addition, data forms, modeling results and photographs are useful in supporting the functional rating determinations. Another tool that can be used to display assessment results is the *Functional Lift Quantification Tool.* The tool was developed by Stream Mechanics for the Environmental Defense Fund and NC Division of Mitigation Services. It is similar to Table 1 but instead of functional ratings, it uses numeral values (Table 2). It also can summarize the functional lift, numerically (Table 3). The tool can be downloaded from: **http://stream-mechanics.com/stream-functions-pyramid.**

Level and Category	Parameter	Measurement Method	Pre-Restoration Condition				
			Value	Rating	Parameter Rating	Level Rating	Overall Reach Rating
1 - Hydrology	Runoff	Flashiness	Non-flashy	F	**F**	**F**	**FAR**
		Concentrated Flow	No concentrated flow	F			
2 - Hydraulics	Floodplain Connectivity	Bank Height Ratio	1.3	FAR	FAR	**FAR**	
		Entrenchment Ratio	2.2	F			
	Floodplain Complexity	FWS Rapid Assessment	N/A	FAR	FAR		
3 - Geomorphology	Riparian Vegetation	Composition	Mostly Invasive	NF	NF	**NF**	
		Density	<40ft2/ac	NF			
	Bedform Diversity	Pool-to-pool Spacing	2	NF	FAR	**FAR**	
		Pool Depth Variability	1.4	FAR			
		Depositional Pattern	B1	F			
	Lateral Stability	Lateral Erosion Rate -ft/yr	1.1	NF	FAR		
		Meander Width Ratio (C and E Stream Types)	3.1	FAR			
		Meander Pattern	M1	F			
4 - Physicochemical	Temperature	Temperature Probe	20°C	NF	NF	**NF**	
	pH	pH Probe	6.4	F	F		
5 - Biology	Macroinvertebrates	MBSS	2.5	FAR	FAR	**NF**	
	Fish	MBSS	1.5	NF	NF		

Table 1. Example of Assessment Parameters, Measurement Methods, and Performance Standards

After the parameters have been rated, site constraints must be identified. As described in Section VI. C. 2. Watershed Assessment Process, constraints may be natural or man-made and limit and/or restrict restoration alternatives, thus influencing restoration potential.

The final step is to determine the channel evolution trend. The channel evolutionary stage conveys important information about how a stream channel responds to changes in watershed processes. Understanding channel evolution is helpful for setting design objectives. If the stream is trending towards stability and/or recovery (late stage of evolution), then the restoration objectives can be more passive. These passive approaches often include land use management changes or simply re-establishing a wide riparian buffer. If the stream is stable but is showing signs of instability (early stage of channel evolution), like the early signs of a headcut, then the objective may be to simply stabilize the headcut to prevent further upstream damage. Full-scale restoration objectives are often needed for streams that have been disturbed and are evolving towards increasingly unstable conditions or reaches that will require many years of adjustment before reaching equilibrium.

EXISTING CONDITION ASSESSMENT						
Functional Category	Function-Based Parameters	Roll Up Scoring				
		Parameter	Category	Category	Overall	Overall
Hydrology	Catchment Hydrology	0.8	0.80	Functioning	0.67	Functioning
Hydrology	Runoff					
Hydrology	Flow Duration					
Hydraulics	Floodplain Connectivity	0.80	0.80	Functioning		
Geomorphology	Large Woody Debris	0.00	0.36	Functioning At Risk		
Geomorphology	Lateral Stability	0.50				
Geomorphology	Riparian Vegetation	0.50				
Geomorphology	Bed Form Diversity	0.43				
Geomorphology	Sinuosity					
Physicochemical	Temperature	0.30	0.50	Functioning At Risk		
Physicochemical	Specific Conductance					
Physicochemical	Stream Metabolism					
Physicochemical	Organic Matter	0.70				
Physicochemical	Nitrogen					
Physicochemical	Phosphorus					
Biology	Macros	0.90	0.90	Functioning		
Biology	Fish					

EXISTING CONDITION SUMMARY	
Existing Condition Score	0.67
Functional Foot Score	924

Table 2. Example Quantification Tool Assessment Display

Existing Condition Score	0.67
Proposed Condition Score	0.88
Functional Lift Score	0.21
Existing Stream Length (ft)	1375
Proposed Stream Length (ft)	1375
Additional Stream Length (ft)	0
Existing Functional Foot Score	924
Proposed Functional Foot Score	1211
Proposed Functional Foot Score - Existing Functional Foot Score	288
Functional Lift (%)	31.1

Table 3. Example Quantification Tool Functional Lift Summary Display

3. Reach Level Function-based Assessment Step-wise Process

- Select parameters from the Pyramid and/or other sources of information about parameters that describe stream functions relevant to the programmatic and design goals and permit requirements.
- Select other assessments necessary to document other ecological functions (e.g., wetlands, mature forests) occurring within the proposed project site.
- Determine the appropriate methods for measuring the parameters, e.g. rapid versus intensive and simple versus complex. This selection will also be dependent on the budget and purpose of the assessment.
- Determine if the measurement methods need to be adapted based on unique regional characteristics, e.g. karst topography and location of endangered species.
- Review the performance standards that are associated with the methods of measurement and determine if they are appropriate based on local environmental conditions and the purpose of the assessment. If possible, update performance standards with information from local reference streams.
- If deemed necessary by the purpose, develop a scoring method to determine the overall functionality of the stream reach, i.e., Overall Functioning, Functioning-at-Risk, or Not Functioning score. Consider having an overall score per functional category as well, e.g. Geomorphology, to help show where functional problems may exist as well as an overall score for the entire proposed project area.
- Establish the length of the assessment period.
- Implement function-based stream assessment and other ecological resource assessments (when appropriate), evaluate its effectiveness in assessing stream functions, and adapt method as necessary.
- Describe the functional condition rating of the proposed project site based on the results of the assessment data.
- Identify site constraints.
- Determine the channel evolution.
- If the reach level assessment is part of the site selection process, determine if the proposed project site is in need of restoration and whether restoration will support the programmatic and design goals. If the success of restoration depends on other actions taking place in the watershed, note this information as well.

4. Key Function-based Stream Assessment Parameters

As stated above, goals and permit requirements will determine which specific parameters will be assessed. However, there are four key parameters that should be assessed for almost every stream restoration because of their influence on stream functions. The key parameters include: floodplain connectivity, riparian vegetation, lateral stability and bed form diversity (Harman et al., 2012).

Floodplain Connectivity

Floodplain connectivity describes how often stream flows access the adjacent floodplain and how much floodplain area is available for stream flows. In high functioning alluvial valleys, all flows greater than the bankfull discharge spread across a wide floodplain (Leopold et al., 1992). In humid environments, streams that are well connected to the floodplain also have relatively high water tables, encouraging the development of riparian wetlands. In these systems, the channel is just deep enough to maintain sediment transport equilibrium and to create diverse bed forms and habitats. Channelization is the primary reason streams disconnect from their adjacent floodplain. Additionally, indirect impacts, like urbanization and increases to impervious cover, also contribute to channel enlargement and incision through increased runoff. The extra runoff often causes an increase in stream power, which leads to headcuts and incision. The combination of increased runoff and channelization can lead to rapid destabilization and adjustment of stream channels. Floodplain connectivity is a lower level supporting function in the SFPF and therefore, once a stream becomes disconnected from its floodplain many other higher level functions are adversely affected.

It should be noted that streams located in colluvial valleys typically do not have floodplains but instead have floodprone areas. Floodprone areas are still important for these streams because they provide the needed area to carry only the amount of water necessary for sediment transport requirements.

Riparian Vegetation

Riparian vegetation zones are the vegetated region adjacent to streams that provide multiple benefits (Gordon et al, 1992). A functioning riparian vegetation corridor contains diverse plant communities and a variety of habitat conditions for terrestrial and aquatic species. It provides a wide range of benefits but it is considered a key assessment parameter because of the role it provides in lateral stability. The roots of riparian vegetation assist streambanks in resisting the erosive forces associated with stream flows. Riparian areas often include wetlands.

Lateral Stability

Lateral stream migration commonly occurs on rivers that flow through alluvial valleys. A channel migrates within the floodplain through lateral erosion on the outside of meander bends and deposition on the interior bend, or point bar. Streams and rivers are open systems, which have a continual source of potential energy supplied by topographic elevation and precipitation. The potential energy supplied by the rain and elevation is transformed to kinetic energy as water flows downhill. Kinetic energy carries sediment downstream (sediment transport) and causes some erosion from turbulence and friction along the channel boundary. In an alluvial valley where the boundary conditions (bank materials) are erodible, meanders will form and continue to erode until the stream achieves a plan form, where energy is expended uniformly and the least amount of work possible is accomplished (Leopold, 1994). Once this equilibrium is achieved, a

stream may continue to migrate but will deposit materials in point bars to maintain a stable cross-sectional area.

Bedform Diversity

Natural streams rarely have flat uniform beds (Knighton, 1998). Instead, hydraulic and sediment transport processes shape the stream bed into a myriad of forms, depending on channel slope, type of bed material (sand, gravel, cobble, boulder, bedrock) and other factors. These bed forms are symptomatic of local variations in the sediment transport rate and represent vertical fluctuations in the stream bed (Knighton, 1998) and dissipating energy. These vertical fluctuations are essentially a form of meandering, but in the vertical direction rather than horizontal (like sinuosity).

Bed forms are also important because they provide the environmental conditions that a variety of aquatic organisms need for survival. For example, macroinvertebrates often colonize in riffle habitats and fish tend to stay in pools. Without the diversity of riffles and pools, there is also a loss of diversity in macroinvertebrates and fish species. Additionally, highly mobile bed features that adjust frequently after storm events adversely affect aquatic species by disrupting their cover, forage and nesting areas. The mobility of bed features is directly related to stream stability.

5. Other Ecological Function-based Assessments

Many stream corridors provide more than just stream functions. Stream corridors can include ecological resources such as wetlands, bogs, terrestrial forests and meadows that provide a multitude of ecological functions. Appropriate assessments need to be conducted for any other functions occurring within the stream corridor, which might be influenced by the proposed project, to be considered during the design alternatives analysis. Refer to Section IV. F. Design Alternatives Analysis for further information regarding design alternatives analysis and refer to Appendix E for information regarding assessment of existing conditions.

E. STEP 5 - RESTORATION POTENTIAL

1. Purpose

Restoration potential is the highest level of restoration that can be achieved, given the watershed and reach level conditions, stressors and constraints. Also, it is at this point the actual amount of potential functional uplift will be determined. For example, the assessment results may indicate that a stream reach is severely incised, has extreme bank erosion, low bed form diversity and no riparian vegetation. If this site is in a rural setting (low lateral constraints) with a healthy watershed, then the restoration potential is high because functional uplift can likely be achieved for water quality and biological functions (Pyramid Levels 4 and 5). However, if this same site is in an urban area or a setting with lateral constraints like a road or even cropland that cannot be

removed from production, then the restoration potential is lower because the functional uplift may only occur for hydraulic and geomorphic functions (Pyramid Levels 2 and 3). Once the restoration potential is known, specific design objectives can be established or original design goals may need to be refined.

2. Restoration Potential Process

Determining the restoration potential involves using the results of the watershed and reach level assessments. Watershed stressors, reach level impaired stream functions and constraints are listed based on the assessment results. A cause and effect relationship between these data is developed to understand how they interact and influence each other, by Pyramid level. It should clearly show which functions support other functions and which ones are supported by others. For example, the watershed assessment may have shown that there is a high percentage of agricultural activities and the reach level assessment showed that the water quality had high levels of nutrients. A conclusion can be drawn that the agricultural activities are the cause of the high nutrient levels. Additionally, the reach level assessment may have shown that there is active bank erosion and poor riparian vegetation. The conclusion can be drawn that the poor riparian vegetation has caused the active bank erosion.

An understanding of the cause and effect relationship is critical in the development of restoration solutions. Restoration activities may or may not need to occur at both the watershed and reach levels to achieve design goals. Following the agricultural example provided above, watershed level restoration activities to address the nutrient sources would have to occur in order to meet reach level nutrient reduction design goals. However, following the bank erosion example provided above, planting of riparian vegetation could address the bank erosion issues without implementing any watershed level restoration activities. Ultimately, the level and success of restoration is directly related to how well the cause and effect relationship is documented.

Next, a determination needs to be performed on whether the degraded reach level functions can be restored and how much functional uplift could occur. Watershed and reach level constraints should be considered during this process since they can limit restoration solutions. Table 4 builds on Table 1 – Example of Assessment Parameters, Measurement Methods, and Performance Standards shown earlier and illustrates proposed functional uplift of baseline functions. The table is an example that shows how the function-based parameters, measurement methods, and performance standards can be used to demonstrate functional uplift using the SFPF. It is important to note that only partial functional uplift could occur for some degraded functions. Partial functional uplift is typically associated with functions occurring at Pyramid Levels 4 – Physicochemical and 5 – Biology because these functions are significantly supported by reach level functions and influenced by watershed health. For example, aquatic habitat (Pyramid Level 3) can be a limiting factor influencing aquatic species health, and poor water quality (Pyramid Level 4) can be a watershed stressor. The most feasible restoration solution may only be to address the reach level issues and not the watershed level issues. Therefore, habitat is improved, but only for tolerant aquatic species. This example also stresses the critical role that the watershed health plays in restoration potential. ***If there are watershed stressors***

adversely affecting reach level stream functions that cannot be addressed, then fully restoring reach level stream functions to Pyramid Level 5 is unlikely. Furthermore, research has shown (Orzetti et al, 2010) that water quality and biological uplift response is typically not immediate. Time is required for these functions to improve, up to 5 to 15 years.

The overall reach level restoration potential is then established. Restoration potential is described by Pyramid level based on the potential functional uplift of the individual functional parameters. Based on the example shown in Table 4, Pyramid Levels 1– Hydrology, 2 – Hydraulics and 3 – Geomorphology would have a restoration potential of full functional uplift and Pyramid Levels 4 – Physicochemical and 5 - Biology would have a restoration potential of partial functional uplift.

Once the reach level restoration potential is established, then it is compared to the programmatic and design goals. For the proposed project site to meet design goals, the highest restoration potential must be at least as high as the design goal. For example, if there is a design goal of floodplain connectivity, the highest restoration potential must be at least through Pyramid Level 3 – Geomorphology or higher. Furthermore, the highest potential restoration level can never be lower than the design goals. For example, if the highest restoration potential stops at Pyramid Level 3 – Geomorphology, then the site is not suitable to meet the design goals that go up to Pyramid Level 4 – Physicochemical. ***At this point, project stakeholders must decide to revise/refine their design goals to reflect the restoration potential of the proposed project site or to not restore the site.***

Level and Category	Assessment Parameter	Pre Restoration Rating	Proposed Condition Rating
1 - Hydrology	Runoff	**F**	**F**
2 - Hydraulics	Floodplain Complexity	**FAR**	**F**
3 - Geomorphology	Bedform Diversity	**FAR**	**F**
	Riparian Vegetation	**FAR**	**F**
	Lateral Stability	**NF**	**F**
4 - Physicochemical	Temperature	**NF**	**FAR**
5 - Biology	Macroinvertebrate Communities	**NF**	**FAR**
	Fish Communities	**FAR**	**FAR***
Note : "*" represents partial uplift			

Table 4. Restoration Potential Example

3. Restoration Potential Step-wise Process

1. List watershed stressors and constraints and reach level constraints to determine those that impact achieving design goals.
2. Develop a list of degraded and healthy stream functions.
3. Identify which degraded stream functions can be restored (i.e., fully or partially).
4. Establish restoration potential by Pyramid level and state the highest overall Pyramid level achievable.
5. Compare the restoration potential to the design goals using the Pyramid (i.e., both achievable functions and highest overall Pyramid level). If the restoration potential cannot achieve the design goals, revise/refine the design goals or do not restore the proposed project site.

F. STEP 6 - DESIGN OBJECTIVES

1. Purpose

Design objectives state how the design goals will be achieved. This step is critical because it connects design goals to the development of restoration solutions and assists in the establishment of monitoring performance standards. For example, a design goal may be to increase brook trout populations (i.e., Pyramid Level 5), but the functional assessment showed that water temperatures were too high to support brook trout and the site is devoid of riparian vegetation. A design objective for this project would be to have average water temperatures less than 16°C in any given year. A design solution to achieve this objective could be to plant riparian vegetation to shade the stream and reduce water temperatures. The monitoring performance standard would be to not exceed water temperatures greater than 16°C in any given year.

2. Design Objectives Development Process

The development of design objectives start with using the watershed stressors and reach level impaired stream functions identified as part of the restoration potential as well as the interrelationship and/or “cause and effect” developed as part of the restoration potential. The interrelationship plays a critical role in the development of design objectives. It is needed to identify the stressors and impaired functions that are critical to meeting design goals. Not every stressor or impaired stream function identified in the assessment process needs a design objective. This is because some degraded functions will be restored through the restoration of lower-level, supporting functions. For example, planting riparian vegetation (Level 3) could stabilize lateral erosion (Level 3), reduce stream temperatures (Level 4) and increase food supply for macroinvertebrates, which could increase macroinvertebrate populations (Level 5). Or, it is possible that some degraded functions cannot be restored. For example, there may be degraded water quality functions as a result of upstream land use activities that cannot be addressed as part of the stream restoration project. Therefore, degraded water quality cannot be restored through restoration activities within the proposed project site.

Next, develop at least one quantifiable and measureable design objective for each selected reach level impaired stream function. Start at the highest Pyramid level and then work down through each level. Lastly, explain how the functional improvement will occur and how design goals are achieved. Table 5 is an example of design objectives organized by Pyramid level.

The level of detail and the ability to quantitatively measure each design objective influences project uncertainty and risk (Refer to Section IV. G. Design Alternatives Analysis for further information regarding uncertainty and risk). Design objectives with specific, measurable performance standards will have lower project uncertainty and risk because expected outcomes are well defined. For example, a floodplain connectivity design objective of creating a bank height ratio (BHR) of 1.0 is specific and measurable. If a BHR of 1.0 is achieved, then the design objective has been met and risk is low. However, if the floodplain connectivity design objective was to reconnect the stream to the floodplain, the success would be uncertain because floodplain connectivity was not quantitatively defined and the risk is high.

Design Objectives		
Level and Category	**Parameters**	**Design Objectives**
Level 1- Hydrology	1. Flow Regime 2. Concentrated Flows	1. Reduce hydrograph peaks and increase duration compared to existing conditions (*Reach 2)* 2. Eliminate Concentrated Flows
Level 2 - Hydraulics	1. Floodplain Connectivity 2. Floodplain Storage	1a. Create floodplain connection at no greater than 1 year storm event (*Reach 2)*. 1b. Create floodplain connection by BHR of 1.0 to 1.2 and ER of 1.4 to 2.2. (*Reach 1*) 2. Store flood flows up to a 5 year storm event (*Reach 2)*
Level 3 - Geomorphology	1. Lateral Stability 2. Sediment/Reduction and Trapping 3. Riparian Buffer	1. Reduce stream bank erosion rates to match reference erosion rates (bank migration/lateral stability) 2. Decrease sediment loads leaving the project to loads less than entering loads entering the project 3. Create native riparian buffer for Eastern Wood-Peewee, Red-Shoulder Hawk, and Acadian Flycatcher
Level 4 - Physicochemical	1. Nutrient Levels	1. Reduce nutrient levels compared to existing conditions

Table 5. Design Objectives Example

3. Design Objectives Development Step-wise Process Steps

- Use watershed stressors and reach level degraded stream functions identified as part of the restoration potential.

- Select only the reach level degraded stream function that are related to the design goals and can be restored.
- Organize the stressors and functions by Pyramid levels to show the interrelationship of the stressors and stream functions.
- Develop at least one quantifiable and measureable design objective for each reach level degraded stream function starting at the highest Pyramid level and then work down through each level.
- Determine the uncertainty and risk of each design objective.
- Provide a description of how the functional improvement will occur and design goals are achieved.

G. STEP 7 - DESIGN ALTERNATIVES ANALYSIS

1. Purpose

The purpose of this step is to determine the best restoration design approach that meets the design goals and objectives, has the highest possible functional uplift and is suitable for the site. The Design Alternatives Analysis should not be confused with the broad-scale watershed planning process described in the Watershed Assessment section above. The focus should be on how a design approach could influence stream functions with a level of detail corresponding to the complexity, existing functional conditions (of all stream corridor resources) and scale of the project. For example, given a well-articulated set of design goals and objectives, an alternatives analysis may compare different design approaches or techniques with expected post-restoration conditions (uplift and loss) by simply including a narrative of why different alternatives were not used. A detailed alternatives analysis is not always required, especially for smaller and less complex project sites. The alternatives analysis would document the highest functional uplift that may be achieved for each design alternative, including impacts to existing stream and other ecological functions, costs, etc. At the end of the alternatives analysis, detailed design criteria should be developed. A few examples of the design criteria metrics may include: floodplain and channel velocities, frequency of floodplain inundation, radius of curvature ratio, meander width ratio, bank height ratio, maximum slopes, pool to pool spacing, pool max depth ratio and width to depth ratio.

The intent of the design alternatives analysis is to allow the watershed and reach level existing conditions to guide stakeholders to the best design approach that meets design goals and objectives and any other pertinent screening criteria. A design alternatives analysis should not attempt to force a particular design approach in a landscape that would not naturally evolve and be self-maintaining overtime.

This section focuses on describing the critical components and other considerations of the design alternatives analysis and is not a "step-wise" description of how to conduct a design alternatives analysis.

2. Design Alternatives Analysis Process

The design alternatives analysis described in this document includes two different perspectives. There are five major elements to consider during the alternatives analysis as identified by Pastorok et al., 1997; Yozzo et al., 1996: 1) goals and objectives, 2) ecological model and key parameters, 3) uncertainty and risk, 4) restoration design, feasibility analysis and experimentation and 5) implementation, monitoring and adaptive management. Based on MDE requirements, the regulatory perspective regarding alternatives analysis is to avoid and minimize adverse impacts to existing water resources and other natural resources. When there are nontidal wetlands affected by the project, there may be requirements to evaluate other sites where the basic purpose of the project can be accomplished with fewer adverse impacts. In many cases the documentation that this requirement has been met may be found in comprehensive watershed plans. In addition, there are requirements to demonstrate to MDE's satisfaction that alternative designs with fewer adverse impacts that would accomplish the basic project purpose have been considered on the selected project site; and were found not to be practicable. (Environment Article, Annotated Code of Maryland 5-907; COMAR 26.23.02.04D; 26.23.02.05A; 26.23.02.05B; 26.23.03.02A.) Minimization measures may also be required under Maryland Waterway Construction regulations for adverse impacts to aquatic or terrestrial habitat. (COMAR 26.17.04.04D; 26.17.04.07B(8); 26.17.04.11B.

The design alternatives analysis begins by the review of design goals and objectives, watershed and reach level assessment results and restoration potential, all of which were completed earlier in the project process. These are needed to assist in the development and comparison of design alternatives. Only design alternatives that have the potential to meet design goals and objectives should be considered. Furthermore, the design goals and objectives and existing resource conditions will be used when determining uncertainty and risk. Increases in uncertainty and risk can occur with poorly defined and/or overly ambitious design goals and objectives as well as limited or inaccurate documentation of existing resource conditions. This is described in further detail below.

Next is to document historic stream conditions and determine what stream conditions would naturally form and be self-maintaining by current day watershed and reach level existing conditions. Understanding how historic stream conditions have evolved to present day conditions begins to describe what stream condition can be maintained over time. This understanding can be drawn from the channel evolution evaluation conducted as part of the reach level function-based assessment. The channel evolution evaluation not only describes what stream condition could be maintained but it also describes what evolution must occur before quasi-equilibrium can be achieved. This is important because it influences the level of restoration required, as well as determining uncertainty and risk. A stream that is near quasi-equilibrium may only require some localized restoration activities to meet design goals and objective versus a stream that is highly unstable. A highly unstable stream would most likely need to undertake significant restoration activities to meet design goals and objectives. A design solution that is implemented at a site that would not naturally form or drastically changes existing stream and other ecological functions

could be considered high risk and long-term sustainability uncertain versus a design solution that would naturally form over time.

Additional information that can assist in determining what stream functions may be self-maintaining include stream energy and sediment supply. *Specifically, does the stream have low stream energy and a low sediment supply or does it have moderate to high stream energy and a moderate to higher sediment supply?* Stream energy and sediment supply significantly influence the size and shape of a stream channel. A stream with low energy (typically valley slopes with less than 1 percent) and a low sediment supply allows for a larger number of design alternatives because potential for the stream to degrade or aggrade is limited.

A stream with moderate to high energy and moderate to high sediment supply has potential to degrade or aggrade and could potentially limit design alternatives, but will certainly influence design complexity and project uncertainty and risk. If a particular design approach cannot transport sediment, it could have positive or adverse effects. If the sediment deposition occurs at a rate that vegetation can establish, then the sediment is held in place. This is a positive effect, especially for watersheds with excessive sediment supply. However, if the sediment deposition occurs at a rate that vegetation cannot establish and hold the sediment in place, it could induce bed and bank instability. This means that the stream channel and floodplain are in a constant state of flux, adversely affecting water quality and biology.

After it is determined which stream functions would naturally form under existing watershed and reach level conditions, design alternatives should be developed. Design alternatives should be technically and economically feasible designs that could potentially meet design goals and objectives and would result in the least amount of disturbance practical. The range of feasible alternatives should allow for meaningful and informed decision making and include the "no action" plan. Furthermore, the range of alternatives should not only be those considered desirable from the standpoint of project stakeholders. Potential alternatives that fail to meet design goals and objectives; do not avoid significant environmental impacts; and have high uncertainty and risk can be eliminated from the range of design alternatives, but a narrative should be provided explaining specifically why they were eliminated.

Alternatives to be evaluated should be developed to a comparable level of detail to allow for a comparable level of analysis. The alternatives analysis should initially determine potential uplift and/or loss of existing stream functions and other ecological functions. As stated above, this can be done in a narrative form or for more complex projects, in table form. Table 6 is one summary example of how an alternatives analysis can display potential functional uplift and/or loss, and builds on Tables 1, 3, and 4 shown early in the document. ***However, a table with quantitative scores alone is often not adequate to depict all pre-and post-construction outcomes.*** Narrative information on other resources which are affected, such as wetlands, should be included with functional assessment results as well as acreage changes in extent or type. Other requirements, the regulatory decision process, and broader agency goals may also have to be considered. Then spatial and temporal impacts and functional response time and longevity should be addressed.

Lastly, potential impacts from differing construction methods should be documented. Additional screening criteria used in selecting the preferred design alternative is discussed below.

Uncertainty and risk of the potential uplift and/or loss in functions need to be discussed next. Uncertainty describes situations where answers are not absolutely true and risk describes the chance of something bad happening (Yoe, 1996). There are three classes of uncertainty: 1) uncertainty of knowledge, 2) uncertainty about quantities and 3) uncertainty about models (Yoe, 1996). There are two parts of risk: 1) risk evaluation (i.e., How risky is a situation?) and 2) risk management (i.e., What should be done about the risk?) (Yoe, 1996). The uncertainty classes and parts of risk should be considered when evaluating the potential uplift and/or loss in functions of the design alternatives. In general terms, uncertainty and risk can be expressed by basic questions: What is the likelihood that this project will be able to successfully sustain itself over time? What are the consequences of failure?

Uncertainty is first introduced when considering the level of detail in design goals and objectives and the existing conditions assessments, as discussed above. Site suitability is another influential uncertainty and risk factor. Stream functions that would naturally form and be maintained given the existing watershed and reach level conditions would have low uncertainty and risk versus functions that would not naturally form and be maintained. Unpredicted natural or anthropogenic disturbances also affect uncertainty. Stakeholders can use planning documents to predict potential future anthropogenic disturbances and even possibly modify design solutions that can address the future changes. Stakeholders can also predict how some potential episodic natural events (e.g., extreme storm events) could impact project effectiveness and again, even possibly modify design solutions that can address the future episodic natural events. However, it is impossible to predict all potential future actions that could affect the restoration project, but risk management is a way to address the uncertainty of future disturbances. Risk management can be incorporated in the maintenance/adaptive management and monitoring plans. If a particular design alternative is expected to require maintenance/adaptive management, the alternatives analysis should state how uncertainty and risk will be reduced through the maintenance/adaptive management.

The final step of the alternatives analysis is to select the preferred design alternative. This is based on which design alternative has the highest functional uplift, the least adverse impacts, best meets design goals and design objectives, lowest uncertainty and risk and meets other critical screen criteria (e.g., costs, level of effort, unique stakeholder needs, other regulatory requirements, constraints, etc.). For more complex projects, stakeholders should consider meeting with regulators to discuss the results of the design alternatives analysis before proceeding to design development.

Level and Category	Parameter	Measurement Method	Pre-Restoration Condition				Restoration Alternative 1				Restoration Alternative 2			
			Value	Rating	Para-meter Rating	Level Rating	Value	Rating	Para-meter Rating	Level Rating	Value	Rating	Para-meter Rating	Level Rating
1 - Hydrology	Runoff	Flashiness	Non-flashy	F	**F**	**F**	Non-flashy	F	**F**	**F**	Non-flashy	F	**F**	**F**
		Concentrated Flow	No concentrated flow	F			No concentrated flow	F			No concentrated flow	F		
2 - Hydraulics	Floodplain Connectivity	Bank Height Ratio	1.3	FAR	FAR	**FAR**	1	F	F	**F**	1	F	F	**F**
		Entrenchment Ratio	2.2	F			2.2	F			2.2	F		
	Floodplain Complexity	FWS Rapid Assessment	N/A	FAR	FAR		N/A	F	F		N/A	F	F	
3 - Geomorphology	Riparian Vegetation	Composition	Mostly Invasive	NF	**NF**	**NF**	All Natives	F	**F**	**F**	All Natives	F	**F**	**F**
		Density	<40ft2/ac	NF			>60sqft/ac	F			>60sqft/ac	F		
	Bedform Diversity	Pool-to-pool Spacing	2	NF	FAR	**FAR**	4	F	F	**F**	3	FAR	FAR	**FAR**
		Pool Depth Variability	1.4	FAR			2.5	F			1.2	FAR		
		Depositional Pattern	B1	F			B1	F			B6	NF		
	Lateral Stability	Lateral Erosion Rate -ft/yr	1.1	NF	FAR		0.01	F	F		0.01	F	FAR	
		Meander Width Ratio (C and E Stream Types)	3.1	FAR			4.6	F			1.5	NF		
		Sinuosity	1.24	F			1.4	F			1.15	FAR		
4 - Physicochemical	Temperature	Temperature Probe	20°C	NF	NF	**NF**	15°C	F	F	**F**	17°C	FAR	FAR	**FAR**
	pH	pH Probe	6.4	F	F		6.4	F	F		6.4	F	F	
5 - Biology	Macroinverte-brates	MBSS	2.5	FAR	FAR	**NF**	4.2	FAR*	FAR*	**FAR***	2.5	FAR*	FAR*	**FAR***
	Fish	MBSS	1.5	NF	NF		3.7	FAR	FAR*		2	NF	NF	

Note: "*" represents partial uplift

Table 6. Design Alternatives Analysis Example (Showing Only Quantitative Changes to Stream Functions; Other factors not included in example).

3. Design Alternatives Analysis Step-Wise Process

- Review design goals and design objectives.
- Review watershed and reach level assessment results.
- Review restoration potential.
- Determine historic stream condition.
- Determine stream functions that would naturally form and be maintained over time given existing watershed and reach level conditions.
- If valley slope is greater than 1 percent, consider only those design approaches based on channel forming flows. If other design approaches are considered, the designer must demonstrate how high shear stress conditions will be addressed.

- If there is a sediment supply, consider only those design approaches based on channel forming flows. If other design approaches are considered, the designer must demonstrate how sediment supply will be addressed.
- Develop a range of technically and economically feasible (practicable) design alternatives that could potentially meet design goals and objectives and would result in the least amount of disturbance practicable. Include the "no action" plan.
- Predict the potential functional uplift and/or loss associated with each design alternative. Potential functional uplift and/or loss should be determined for all existing critical stream corridor functions (e.g., streams, wetlands, floodplain vegetation, etc.).
- Consider spatial and temporal impacts; functional response time and longevity; and construction impacts.
- Predict the potential uncertainty and risk associated with each design alternative.
- Select the alternative based on: the highest functional uplift, the least adverse impacts, best meets project goals and design objectives, lowest uncertainty and risk and meets other critical screening and regulatory criteria.
- For more complex projects, consider having a meeting with regulators to discuss the results of the design alternatives analysis before proceeding to design development.

H. STEP 8 - DESIGN DEVELOPMENT

1. Purpose

The purpose of this step is to document the design development approach, ensure project feasibility, determine project implementation costs and to produce a constructible design set along with specifications and materials. At the end of the process, the design is compared to the design objectives to ensure the programmatic and design goals will be achieved by the proposed design. ***This section is not a "step-wise" design description, but rather describes certain design milestones/products that should be produced to ensure design goals and objectives are met.***

2. Design Development Process

First select the appropriate design review checklist (Starr et al., 2015) based on the preferred plan selected during the alternatives analysis process. This step is not necessary; however, MDE will use these checklists to review stream restoration projects submitted for permits. The checklists are not a "step-wise" design procedure, but rather intended to provide a reviewer with a method for determining if a project design contains an appropriate level of information and for identifying major design shortcomings. Using the checklist as a guide through the design development process will assist in ensuring critical design questions are addressed.

The next step is to develop design criteria that support the design objectives. Some design objectives can also be used as design criteria. The design criteria should include, at the minimum, floodplain dimensions, stream channel dimensions, planform and profile, stream bed material and riparian vegetation. These criteria are important because they significantly

influence stream energy and sediment transport and ultimately, long term stability. They are also important if there are aquatic species design goals. Aquatic species have specific habitat requirements that are typically addressed through bedform diversity such as large woody debris, pool to riffle ratio, pool depths and stream bed materials (Pyramid Level 3 – Geomorphology). Examples of design criteria are provided in the design review checklists (Starr et al., 2015).

From the design criteria, a concept plan should be developed. The focus of the concept plan should be on the location of the stream (e.g., channel alignment and dimensions) within the stream corridor and the connection with the floodplain (e.g., banks height ratio, storm flow return interval, etc.). It should also address any unique or critical aspects and/or resources (e.g., constraints, wetlands, cultural resources, threaten and endangered species, etc.) associated with the proposed project site. The concept design should then be reviewed to ensure that it meets the design goals and objectives; has the least amount of disturbance practical; and minimizes adverse impacts to all critical existing stream corridor functions. At this point, project stakeholders should consider having a pre permit application meeting with regulators to receive initial feedback on the proposed concept design.

Once a concept plan has been developed that addresses the design goals and objectives, a draft final plan should be developed. The draft final plan should be developed to a level where feasibility (i.e., stability) analysis can be completed. The feasibility analyses should include, at the minimum, stage/discharge shear stress analysis, sediment transport analysis (i.e., competency and capacity) and in-stream structure stability analysis. It should demonstrate that the proposed design will not degrade or aggrade over time. If sediment aggradation is part of the proposed design, then analyses (location, amount and rate) need to be completed to document that the aggradation will not result in adverse impacts to stream corridor functions. Then the draft final design should be reviewed again to ensure it meets the design goals and objectives.

Lastly, the final design and specifications should be reviewed one more time to ensure project design goals and objectives were met, and that questions within the design review checklist were adequately addressed.

3. Design Development Step-wise Process

- Select the appropriate design review checklist and use as guide to develop design.
- Develop design criteria.
- Develop concept plan and review to ensure design objectives are met; has the least amount of disturbance practical; and minimizes adverse impacts to all critical existing stream corridor functions.
- Consider having a pre permit application meeting with regulators to receive initial feedback on the proposed concept design.
- Develop draft final design; complete a feasibility analysis to demonstrate stability over time; and review to ensure design objectives are met.
- Develop final design and specifications and review to ensure design objectives are met.
- Review design review checklist and ensure each question has been addressed.

I. STEP 9 - MONITORING

1. Purpose

The purpose of monitoring is to determine if the project achieved the design goals and objectives. Additionally, monitoring is typically needed to demonstrate long-term restoration integrity and stability. This section focuses on a process that can be used to develop monitoring plans. Ultimately, regulators (COE and MDE) will set the monitoring requirements (Refer to Appendix F for additional information).

The type, level of effort and period of monitoring should be based on the type and complexity of the project. Additionally, monitoring plans should consider the time required for predicted functional uplift to establish or a trajectory to establish. For example, if project goals include geomorphic and biological objectives, a monitoring plan could conduct more detailed geomorphic monitoring for the first 3 years and then less detailed monitoring for the following 2 years since stream restoration projects can typically reach stability within 3 to 5 years post construction. However, biological monitoring would occur in years 5, 7 and 10 since it typically takes a much longer period for biological uplift to occur (Orzetti et al., 2010). A monitoring plan should also recognize that function-based conditions can fluctuate over time for many reasons. Some years there may be uplift, and other years there may be no change or even loss. The intent of the monitoring is to determine if function-based conditions are trending towards functioning.

The monitoring plan should consist of quantifiable and measureable assessment parameters, measurement methods, performance standards, period, timing and frequency of monitoring and who will conduct the monitoring and make repairs, if necessary.

There are many existing monitoring methods available. ***This section focuses on describing the critical components and other considerations of a monitoring plan, and is not an all-inclusive description of monitoring methods.*** Readers should refer to other sources for detailed information regarding monitoring methods.

2. Monitoring Plan Development Process

The development of a monitoring plan begins with selecting assessment parameters that will demonstrate whether the project has achieved the project goals. The assessment parameters should be quantifiable, measureable and at a level commensurate with the complexity of the stream restoration project. The assessment parameters should address the design objectives established earlier in the restoration process and include any other assessment parameters needed to demonstrate project success. Additional assessment parameters may be needed in order to monitor any existing stream corridor functions that may be adversely impacted by the proposed project. Next, organize the assessment parameters by Pyramid level to determine if any other lower-level, supporting parameters are needed to determine project success. Use the “cause and effect” relationship developed as part of the restoration potential to assist in selecting additional

assessment parameters. Select at least one measurement method for each assessment parameter along with a performance standard. Table 7 is an example of how assessment parameters, measurement methods and performance standards can be displayed following the SFPF and is a continuation of the tables used to display existing function-based conditions, restoration potential, and alternatives analysis. Figure 5 is another example of how data can be converted into functional ratings.

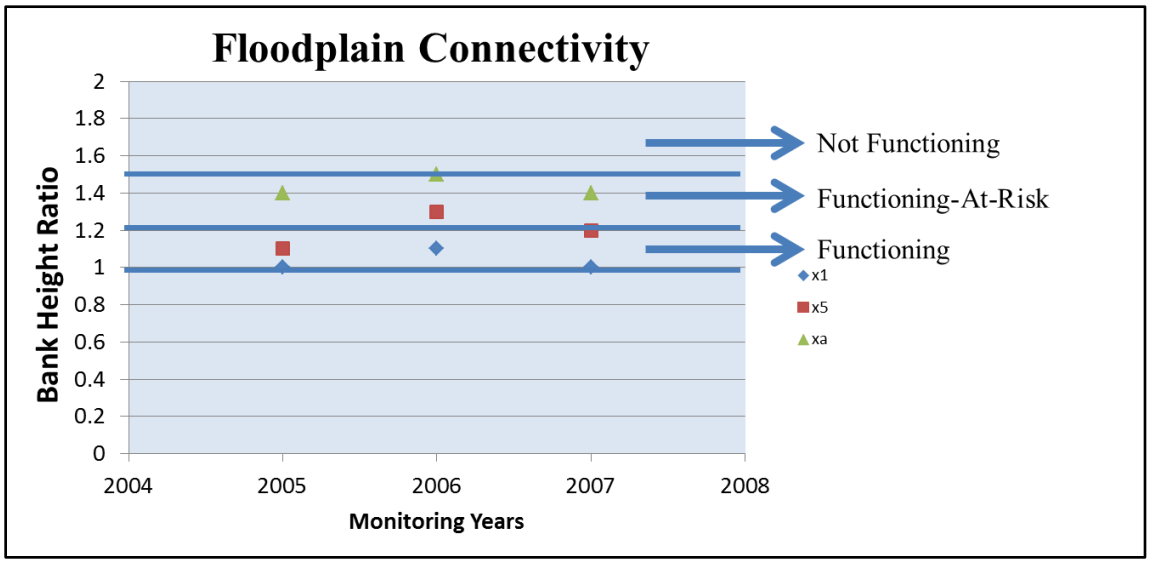


Figure 5. Monitor Information Example

Once all of the assessment parameters and measurement methods have been selected, the period, timing and frequency of each measurement method needs to be set. When setting the period of monitoring, keep in mind the potential time required for targeted functions to fully establish. As stated above, the assessment parameters associated with Pyramid Levels 2 and 3 should be fully functional immediately after construction while assessment parameters associated with Pyramid Levels 4 and 5 will most likely take longer to fully recover.

Next describe how monitoring data will be reported. The focus should be on converting monitoring data to functional ratings, as described above in Section IV. D. Reach Level Function-based Assessment. Table 7 shows one way of doing this where the monitoring data is described as Functioning, Functioning-at-Risk or Not Functioning. The monitoring report should also state the recovery direction of the assessment parameters in a qualitative description, and state any potential adverse impacts that may exist. Remember, as stated above, the recovery of function-based conditions can fluctuate over time for many reasons and could be positive, neutral or even negative. Therefore, assessment parameters should be analyzed over the course of the monitoring period and not just based on one year's data before adaptive management or repairs occur. However, extreme changes, such as vegetation death, excessive vertical and/or lateral instability or failed structures which may pose a hazard to upstream and/or downstream life, human safety or infrastructure should be addressed as quickly as practical. The last

component of the monitoring plan should clearly state who is responsible for conducting the monitoring and for making repairs when necessary.

Level and Category	Parameter	Measurement Method	Pre-Restoration Condition				Monitoring Year 1				Monitoring Year 2			
			Value	Rating	Para-meter Rating	Level Rating	Value	Rating	Para-meter Rating	Level Rating	Value	Rating	Para-meter Rating	Level Rating
1 - Hydrology	Runoff	Flashiness	Non-flashy	F	**F**	**F**	Non-flashy	F	**F**	**F**	Non-flashy	F	**F**	**F**
		Concentrated Flow	No concentrated flow	F			No concentrated flow	F			No concentrated flow	F		
2 - Hydraulics	Floodplain Connectivity	Bank Height Ratio	1.3	FAR	FAR	**FAR**	1	F	F	**F**	1	F	F	**F**
		Entrenchment Ratio	2.2	F			12	F			12	F		
	Floodplain Complexity	FWS Rapid Assessment	N/A	FAR	FAR		N/A	F	F		N/A	F	F	
3 - Geomorphology	Riparian Vegetation	Composition	Mostly Invasive	NF	**NF**	**FAR**	All Natives	F	**F**	**F**	Mostly Native and some Invasive	FAR	**FAR**	**FAR**
		Density	<40ft2/ac	NF			>80sqft/ac	F			>75sqft/ac	F		
	Bedform Diversity	Pool-to-pool Spacing	2	NF	FAR		4	F	F	**F**	5	F	F	**F**
		Pool Depth Variability	1.4	FAR			2.5	F			3	F		
		Depositional Pattern	B1	F			B1	F			B6	F		
	Lateral Stability	Lateral Erosion Rate -ft/yr	1.1	NF	FAR		0.025	F	F		0.01	F	F	
		Meander Width Ratio (C and E Stream Types)	3.1	FAR			4.6	F			4.7	F		
		Sinuosity	1.24	F			1.4	F			1.45	F		
4 - Physicochemical	Temperature	Temperature Probe	20°C	NF	NF	**NF**	18°C	FAR	FAR	**FAR**	17°C	FAR	FAR	**FAR**
	pH	pH Probe	6.4	F	F		6.4	F	F		6.4	F	F	
5 - Biology	Macroinverte-brates	MBSS	2.5	FAR	FAR	**NF**	2.7	FAR*	FAR*	**FAR***	3	FAR*	FAR*	**FAR**
	Fish	MBSS	1.5	NF	NF		2	FAR*	FAR*		2.5	FAR*	FAR*	

Note: "*" represent partial uplift

Table 7. Monitoring Example

3. Monitoring Plan Development Step-wise Process

- Develop a list of assessment parameters to monitor that are quantifiable and measureable. List should include parameters that address design goals and objectives and any existing functions that may be adversely impacted by the proposed project.
- Organize assessment parameters by Pyramid level and determine if any other lower-level, supporting parameters are needed to determine project success.
- Select measurement methods and performance standards for each assessment parameter.
- Describe the period, timing and frequency of each measurement method.
- Describe how monitoring data will be reported.
- Convert monitoring data to functional rating (e.g., Functioning, Functioning-at-Risk or Not Functioning).
- State who is responsible for monitoring and repairs, if necessary.

4. USFWS Rapid Stream Restoration Monitoring Protocol

The Service has developed a rapid stream restoration monitoring protocol that promotes consistency and reproducible results (Davis et al., 2014). The protocol is based on the SFPF (Harman et al., 2012) and addresses stream hydraulics, geomorphic functions and in-stream structures. It does not address physicochemical and biological stream functions or other stream corridor ecological functions such as wetlands.

V. FUNCTION-BASED STREAM RESTORATION PROJECT REVIEW CHECK LIST

A Function-based Stream Restoration Project Process Review Checklist has been developed to assist regulators in reviewing stream restoration project permit applications and for practitioners in conducting stream restoration projects (Appendix A). Just like the design review checklists, the project process review checklist is not a “step-wise” assessment procedure. Rather, it is intended to provide a regulator and/or practitioner with a method for ensuring the stream restoration project process contains an appropriate level of information and for identifying and/or avoiding major assessment shortcomings. For ease of use, the format of the review checklist follows the Function-based Stream Restoration Project Process described in this document. The checklist includes the following sections: programmatic and design goals, site selection, watershed assessment, reach level function-based assessment, restoration potential, design objectives, design alternatives analysis, design development, monitoring plan and overall project process review.

The structure of the project process review checklist is the same as the design review checklists (Starr et al., 2015). There are four columns for most questions, which include Submitted, Acceptable, Page Number and Comments (Figure 6). The reviewer answers “yes”, “no” or “partially” for Submitted and Acceptable and provides a reason/explanation for Comments. A column is also provided to cite the page number where the information is discussed in the report. This format is straightforward for some questions, like “3.0a – Was the watershed assessment

methodology described?" Under the Submitted column, the reviewer would respond with "yes" if the designer submitted a methodology description. If the description was missing or inadequate, then the reviewer would respond with "no" under the Acceptable column and then describe why under Comments.

Function-based Stream Restoration Project Process Review Checklist	**Reviewer:**				
	Date:				
Project:					
Assessor:					
Item	**Submitted (Y/P/N)**	**Acceptable (Y/P/N)**	**Page #**	**Comments**	
1.0 Programmatic Goals					
1.0a Are the project purpose and need(s) described?					
1.0b Does the project have clear programmatic and design goals?					

Figure 6. Review Checklist Structure

Other questions are not as straightforward in terms of fitting the checklist structure. For example, under Section 5.0 Restoration Potential, question 5.0a asks, "Was the restoration potential based on the results of the watershed and reach level assessments and constraints analysis?" For questions that seem to warrant an indirect answer, the reviewer should still follow the two-step process: (1) Determine if the designer *Submitted* information that answers this question, even if it is more implicit in the report than explicit; and (2) Decide if the information is *Acceptable* and *Comment* on their reason.

Finally, there are places in the checklist where the reviewer can provide overall comments and impressions about the project process. These sections do not require a "yes" or "no" for Submitted or Acceptable.

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APPENDIX A

DRAFT FINAL Function-based Stream Restoration Project Process Review Checklist

Function-based Stream Restoration Project Process Review Checklist

Reviewer: _____

Date: _____

Project: _____

Assessor: _____

Item	Submitted (Y/P/N)	Acceptable (Y/P/N)	Page #	Comments
1.0 Programmatic Goals				
1.0a Are the project purpose and need(s) described?				
1.0b Does the project have clear programmatic and design goals?				
2.0 Site Selection				
2.0a Was a description/rationale provided stating how the site was selected?				
2.0b Was some level of assessment completed to justify the site selection?				
2.0c Did the assessment(s) accurately document watershed and reach level conditions?				
2.0d Were assessment(s) of other existing stream corridor functions (e.g., wetlands floodplain vegetation, etc.) conducted?				
2.0e Did the assessment(s) accurately document other existing stream corridor functions?				
2.0f Were potential constraints identified?				
2.0g Was the restoration potential determined?				
2.0h Is the proposed site suitable for restoration?				
2.0i Have design goals been developed based on the site selection assessment?				
2.0j Are the project goals appropriate for the site and support the programmatic goal(s)?				
2.0k If a concept plan was available, were potential functional uplift and losses determined?				
2.0l Are there any potential adverse impacts associated with the concept plan to existing stream corridor functions?				
2.0m Overall site selection comments.				

DRAFT FINAL Function-based Stream Restoration Project Process Review Checklist

Item	Submitted (Y/P/N)	Acceptable (Y/P/N)	Page #	Comments
3.0 Watershed Assessment				
3.0a Was the watershed assessment methodology described?				
3.0b Did the watershed assessment accurately document the existing and potential future health of the watershed?				
3.0cWere watershed stressors identified and accurately described?				
3.0d Did the watershed assessment accurately describe the existing and potential future influence of the watershed on the proposed site?				
3.0e Will the watershed health support the programmatic and design goal(s)?				
3.0f Overall watershed assessment comments.				
4.0 Reach Level Function-based Assessment				
4.0a Was the reach level assessment methodology described?				
4.0b Were the measurement methods appropriate to document existing conditions?				
4.0c Did the reach level assessment accurately document the existing function-based conditions?				
4.0d Were assessment(s) of other existing stream corridor functions (e.g., wetlands floodplain vegetation, etc.) conducted?				
4.0e Did the assessment(s) accurately document other existing stream corridor functions?				
4.0f Were potential constraints identified?				
4.0g Did the constraints analysis accurately identify constraints?				
4.0h Did the reach level assessment determine channel evolution?				
4.0i Overall reach level assessment comments.				

DRAFT FINAL Function-based Stream Restoration Project Process Review Checklist

Item	Submitted (Y/P/N)	Acceptable (Y/P/N)	Page #	Comments
5.0 Restoration Potential				
5.0a Was the "cause and effect" relationship(s) described and based on the watershed and reach level assessments?				
5.0b Was the description of the "cause and effect" relationship(s) accurate?				
5.0c Was the restoration potential described?				
5.0d Was the restoration potential based on the "cause and effect" relationship(s) and constraints and stressors analyses?				
5.0e Did the restoration potential accurately identify which impaired functions can be restored and not restored?				
5.0f Did the restoration potential determine whether the site can still meet the programmatic and design goals and if not, describe how the project will proceed?				
5.0g Overall restoration potential comments.				
6.0 Design Objectives				
6.0a Were design objectives provided?				
6.0b Were design objectives developed based on the restoration potential?				
6.0c Are the design objectives quantifiable and measurable?				
6.0d Are the design objectives appropriate and achievable for the site?				
6.0e Do the design objectives meet the project goals and if not, is it described how the project will proceed?				
6.0f Overall design objectives comments.				
7.0 Design Alternatives Analysis				
7.0a Was a design alternatives analysis performed?				
7.0b Were the alternatives analysis screening criteria provided and based on the results of the restoration potential and design goals and objectives?				
7.0c Did the alternatives analysis evaluate appropriate design solutions that could meet design goals and objectives and minimize adverse impacts?				

DRAFT FINAL Function-based Stream Restoration Project Process Review Checklist

Item	Submitted (Y/P/N)	Acceptable (Y/P/N)	Page #	Comments
7.0d Did the alternatives analysis accurately document potential uplift and adverse impacts to stream functions and other critical stream corridor functions (e.g., wetlands, floddplain vegetation, etc.)?				
7.0e If there are potential project adverse impacts, was a description provided on how the impacts will be addressed?				
7.0f Were uncertainty and risk analyses conducted and were they accurate?				
7.0h Was the most appropriate alternative selected based on the screening criteria?				
7.0i Overall design alternatives analysis comments.				
8.0 Design Development				
8.0a Were design criteria provided and explained in relation to the project goals and design objectives?				
8.0b Does the final plan set met the design goals and objectives				
9.0 Monitoring Plan				
9.0a Was a monitoring plan provided?				
9.0b Does it state who is required to conduct the monitoring?				
9.0c Does it have measurable and quantifiable performance standards?				
9.0c Are the performance standards based on the design goals and objectives and any potential adverse impacts?				
9.0d Is the monitoring period, timing and frequency appropriate based on the time required for uplift to occur?				
10.0 Overall Assessment Review				
10.0a Does the project assessment address the design goals and objectives?				
10.0b Are there any assessment components that are missing or could adversely affect the success of the project?				
10.0c Does the project have a high potential for success?				

APPENDIX B

"Step-wise" Function-based Project Process

Step 1. Programmatic and Project Goals Development Step-wise Process

- Identify drivers for the restoration effort.
- Develop programmatic goals based on the drivers.
- Develop at least one design goal, if possible, for each programmatic goal based on the SFPF.
- Compare the design goals to the restoration potential of the proposed project site.

Step 2. Site Selection Step-wise Process

- Obtain readily available and relevant information (e.g., watershed assessments, management plans, reach level assessments, water quality data, species data, etc.) related to a proposed project site or study area. Some of this information may already be included in Watershed Implementation Plans or watershed plans required for MS-4 permits.
- Review the data to: determine the existing function-based conditions of the proposed project site; identify constraints; establish restoration potential; if there is a proposed design solution, predict potential functional uplift and/or loss; and develop or refine design goals.
- To validate existing information or if existing data is not available, conduct rapid watershed and reach level assessments. The assessment should assess parameters that support the programmatic and design goals. Refer to the Function-based Rapid Stream Assessment Methodology (Starr et al., 2015) for an example of a rapid watershed assessment.
- Conduct a "windshield" tour of the watershed to validate the findings of the existing data and/or rapid watershed assessment and focus on identifying stressors that may influence reach level functional uplift.
- Visit the proposed project site and conduct a rapid assessment to determine the existing function-based conditions. Refer to the Function-based Rapid Stream Assessment Methodology (Starr et al., 2015) for an example of a rapid reach level assessment.
- Conduct other assessments necessary to document other ecological functions (e.g., wetlands, mature forests) occurring within the project site.
- Determine the channel evolution sequence. Refer to Section IV. D. Reach Level Function-based Assessment.
- Identify any constraints that may influence reach level functional uplift.
- Determine the highest restoration potential and the associated Pyramid level of the proposed project site based on the watershed health (i.e., stressors), constraints and reach level function-based conditions. Refer to Section IV. F. Restoration Potential for a detailed description on how to determine restoration potential.
- If there is a proposed plan of action, identify any potential uplift and/or adverse impacts to existing stream and other ecological (e.g., wetlands) functions.
- Develop design goals, if not already established.
- Compare the restoration potential to the programmatic and design goals.
- Determine if there are potentially significant adverse impacts to existing functions.

- If the restoration potential is at least as high as the programmatic and design goals and there are no potential adverse impacts to existing functions, then the site is suitable for restoration. If the programmatic and/or design goals cannot be achieved at the proposed project site and/or potential adverse impacts are significant, then the site is not suitable for restoration to meet those goals.
- If the site is not suitable for restoration, consider revising design goals and/or potential restoration solutions.
- If the site is not suitable and the design goals and/or potential restoration solutions cannot be revised, then the site should be eliminated from further consideration as a potential site to meet the programmatic goal(s).
- Describe how the proposed project supports existing and current larger-scale (Statewide, regional, watershed) plans or policies, if applicable.
- Describe how the programmatic and design goals for the proposed project site cannot be achieved at another potential site. Note: This determination may have already been documented in a comprehensive watershed plan, MS-4 restoration plan; or Watershed Implementation Plan.
- Consider a pre-permit application meeting with regulatory agencies to discuss results of site selection assessment.

Step 3. Watershed assessment step-wise process

- Select watershed assessment parameters based on permit requirements and programmatic and design goals. All levels of the Pyramid should be assessed.
- Determine level of assessment and measurement methods based on when assessment occurs during the study process, programmatic goals, project budget and watershed size and complexity.
- Determine if the measurement methods need to be adapted based on unique regional characteristics (e.g. karst topography and location of endangered species).
- Determine how to relate watershed data to functions so that it can be used to understand how the watershed health influences the proposed project site.
- Implement the appropriate level of watershed assessment, evaluate its effectiveness in assessing watershed processes, and adapt method as necessary.
- Identify stressors and constraints.
- Combine all watershed data and determine if the watershed health will support the programmatic and design goals. If the success of restoration depends on other actions taking place in the watershed, note this information as well.

Step 4. Reach level function-based assessment step-wise process

- Select parameters from the Pyramid and/or other sources of information about parameters that describe stream functions relevant to the programmatic and design goals and permit requirements.
- Select other assessments necessary to document other ecological functions (e.g., wetlands, mature forests) occurring within the proposed project site.

- Determine the appropriate methods for measuring the parameters, e.g. rapid versus intensive and simple versus complex. This selection will also be dependent on the budget and purpose of the assessment.
- Determine if the measurement methods need to be adapted based on unique regional characteristics, e.g. karst topography and location of endangered species.
- Review the performance standards that are associated with the methods of measurement and determine if they are appropriate based on local environmental conditions and the purpose of the assessment. If possible, update performance standards with information from local reference streams.
- If deemed necessary by the purpose, develop a scoring method to determine the overall functionality of the stream reach, i.e., Overall Functioning, Functioning-at-Risk, or Not Functioning score. Consider having an overall score per functional category as well, e.g. Geomorphology, to help show where functional problems may exist as well as an overall score for the entire proposed project area.
- Establish the length of the assessment period.
- Implement function-based stream assessment and other resource assessments (when appropriate), evaluate its effectiveness in assessing stream functions, and adapt method as necessary.
- Describe the functional condition rating of the proposed project site based on the results of the assessment data.
- Identify site constraints.
- Determine the channel evolution.
- If the reach level assessment is part of the site selection process, determine if the proposed project site is in need of restoration and whether restoration will support the programmatic and design goals. If the success of restoration depends on other actions taking place in the watershed, note this information as well.

Step 5. Restoration Potential Step-wise Process

- List watershed stressors and constraints and reach level constraints to determine those that impact achieving design goals.
- Develop a list of degraded and healthy stream functions.
- Identify which degraded stream functions can be restored (i.e., fully or partially).
- Establish restoration potential by Pyramid level and state the highest overall Pyramid level achievable.
- Compare the restoration potential to the design goals using the Pyramid (i.e., both achievable functions and highest overall Pyramid level). If the restoration potential cannot not achieve the design goals, revise/refine the design goals or do not restore the proposed project site.

Step 6. Design Objectives Development Step-wise Process Steps

- Use watershed stressors and reach level degraded stream functions identified as part of the restoration potential.
- Select only the reach level degraded stream function that are related to the design goals and can be restored.

- Organize the stressors and functions by Pyramid levels to show the interrelationship of the stressors and stream functions.
- Develop at least one quantifiable and measureable design objective for each reach level degraded stream function starting at the highest Pyramid level and then work down through each level.
- Determine the uncertainty and risk of each design objective.
- Provide a description of how the functional improvement will occur and design goals are achieved.

Step 7. Design Alternatives Analysis Step-Wise Process

- Review design goals and design objectives.
- Review watershed and reach level assessment results.
- Review restoration potential.
- Determine historic stream condition.
- Determine stream functions that would naturally form and be maintained over time given existing watershed and reach level conditions.
- If valley slope is greater than 1 percent, consider only those design approaches based on channel forming flows. If other design approaches are considered, the designer must demonstrate how high shear stress conditions will be addressed.
- If there is a sediment supply, consider only those design approaches based on channel forming flows. If other design approaches are considered, the designer must demonstrate how sediment supply will be addressed.
- Develop a range of technically and economically feasible (practicable) design alternatives that could potentially meet design goals and objectives and would result in the least amount of disturbance practicable. Include the "no action" plan.
- Predict the potential functional uplift and/or loss associated with each design alternative. Potential functional uplift and/or loss should be determined for all existing critical stream corridor functions (e.g., streams, wetlands, floodplain vegetation, etc.).
- Consider spatial and temporal impacts; functional response time and longevity; and construction impacts.
- Predict the potential uncertainty and risk associated with each design alternative.
- Select the alternative based on: the highest functional uplift, the least adverse impacts, best meets project goals and design objectives, lowest uncertainty and risk and meets other critical screening and regulatory criteria.
- For more complex projects, consider having a meeting with regulators to discuss the results of the design alternatives analysis before proceeding to design development.

Step 8. Design Development Step-wise Process

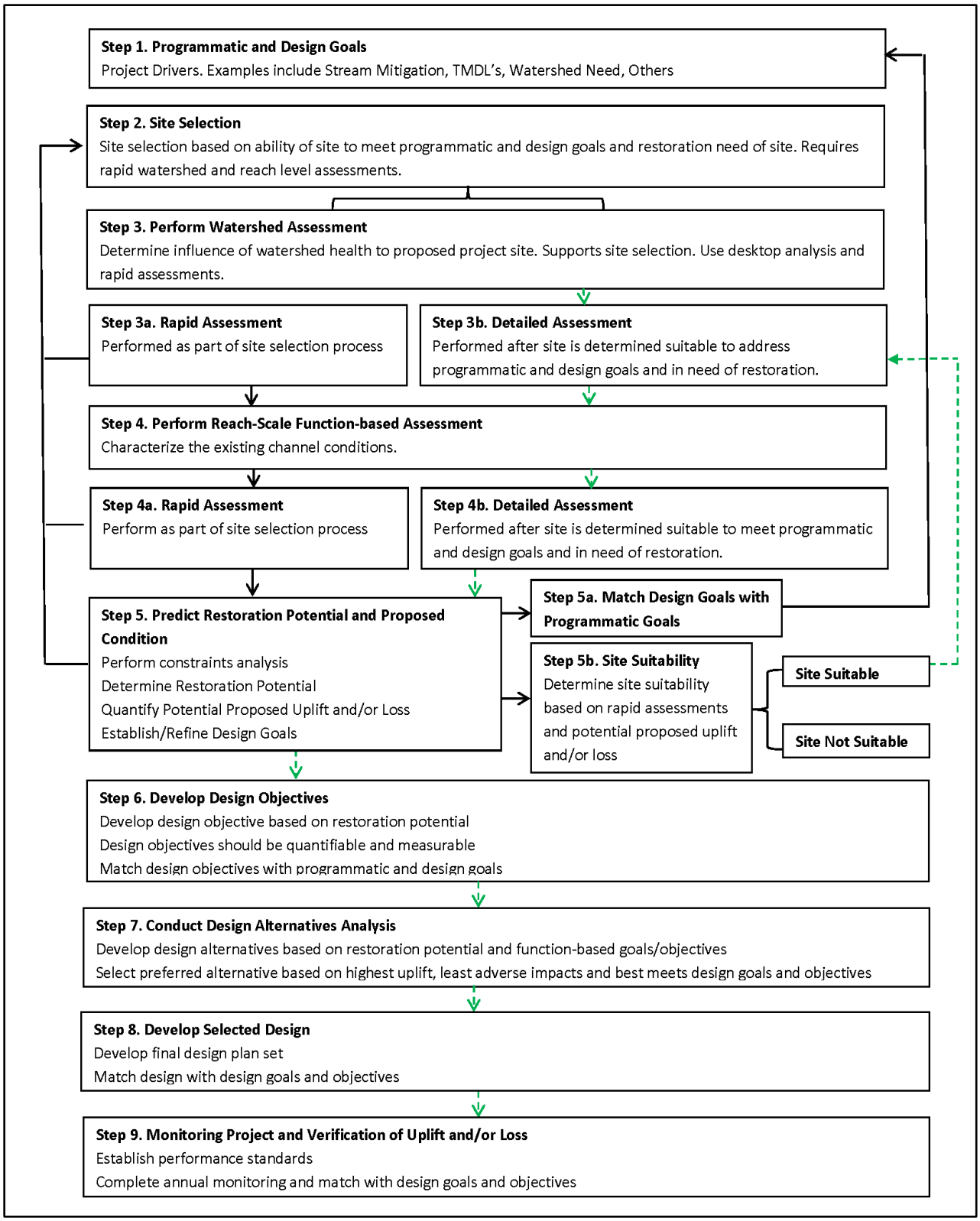
- Select the appropriate design review checklist and use as guide to develop design.
- Develop design criteria.
- Develop concept plan and review to ensure design objectives are met; has the least amount of disturbance practical; and minimizes adverse impacts to all critical existing stream corridor functions.
- Consider having a pre permit application meeting with regulators to receive initial feedback on the proposed concept design.

- Develop draft final design; complete a feasibility analysis to demonstrate stability over time; and review to ensure design objectives are met.
- Develop final design and specifications and review to ensure design objectives are met.
- Review design review checklist and ensure each question has been addressed.

Step 9. Monitoring Plan Development Step-wise Process

- Develop a list of assessment parameters to monitor that are quantifiable and measureable. List should include parameters that address design goals and objectives and any existing functions that may be adversely impacted by the proposed project.
- Organize assessment parameters by Pyramid level and determine if any other lower-level, supporting parameters are needed to determine project success.
- Select measurement methods and performance standards for each assessment parameter.
- Describe the period, timing and frequency of each measurement method.
- Describe how monitoring data will be reported.
- Convert monitoring data to functional rating (e.g., Functioning, Functioning-at-Risk or Not Functioning).
- State who is responsible for monitoring and repairs, if necessary.

Function-based Stream Restoration Project Process



Note: Non-dashed flow lines are tasks completed as part of site selection step and dashed flow lines are tasks completed after the site selection step.

APPENDIX C

EXAMPLE FUNCTION-BASED STREAM RESTORATION PROJECT PROCESS - TABLE OF CONTENTS

I. INTRODUCTION.....

II. SITE SELECTION.....

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C. Reach Level Assessment.....

IV. PROGRAMMATIC/PROJECT GOALS.....

V. WATERSHED AND REACH ASSESSMENT.....

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B. Base Mapping.....
C. Reach Level Function-Based Assessment.....
1. Reach 1.....
2. Reach 2.....**Error! Bookmark not defined.**
3. Channel Evolution.....
D. Other Ecological Resource Assessments.....

VI. PRELIMINARY DESIGN.....

A. Constraints.....**Error! Bookmark not defined.**
B. Restoration Potential.....
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c. Cobble Weir.....
d. Rock Sill.....
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a. Bankfull Validation.....
b. Geomorphic Indicators.....
c. Resistance Relationships.....
d. Regional Relationships.....

e. Bankfull Validation.....
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VII. MAINTENANCE AND MONITORING PLANS.....

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B. Monitoring Plan .....

VIII. PERMIT REQUIREMENTS.....

IX. LITERATURE CITED .....

APPENDIX D

Example Goals, Objectives, Assessment Parameters based on Drivers

This appendix provides examples of typical stream restoration design goals and objectives and assessment parameters based on typical restoration drivers following the SFPF. Three driver examples are provided: TMDL sediment reduction, TMDL nutrient and sediment reduction and aquatic species population improvement. Each example lists the driver(s) first. Then design goals and objectives that would typically be associated with the drivers are listed. The design objectives are displayed in a table format following the SFPF. The design goals and objectives can be modified or others can be added. Assessment parameters that would typically be assessed based on the drivers are also provided. The assessment parameters are also displayed in a table format following the SFPF. It shows the Pyramid level, assessment parameter, measurement method, value, rating, parameter level rating, Pyramid level rating and overall reach rating. Users can highlight the rating cells with color to further illustrate rating conditions, as shown in the main report. The assessment parameters are the minimum parameters that should be assessed. Other assessment parameters can be added. The measurement methods provided are only suggestions. Other measurement methods can be used instead as long as they are quantitative and have performance standards. For the nutrient and sediment examples, assessment parameters are shown for Pyramid Levels 4 – Physicochemical and 5 – Biology to meet permit requirements.

The tables shown in the example are in a separate Excel file and can be downloaded from http://www.fws.gov/chesapeakebay/stream/protocols.html.

SPECIES DRIVER EXAMPLE

Programmatic Goal: Native Brook Trout

Design Goal:

- Improve brook trout biomass of all age classes

Design Objectives:

Table 1 – Typical Species Brook Trout – Design Objectives

Category Level	Parameters	Design Objectives
Level 1- Hydrology	1. Concentrated Flows	1. Eliminate Concentrated Flows
Level 2 - Hydraulics	1. Floodplain Connectivity 2. Velocity Variability 3. Hyporheic Zone	1. Create floodplain connection at levels associated with 1.2 to 1.5 year return interval 2. Create velocities of 2.8 to 4.3 ft/sec 3. Reconnect riffles with hyporheic zones
Level 3 - Geomorphology	1. Riparian Vegetation 2. Lateral Stability 3. Bedform diversity	1. Create native riparian buffer >/= 150 ft 2. Reduce stream bank erosion rates to match reference erosion rates (bank migration/lateral stability) 3. Create 60:40 riffle/pool ratio
Level 4 - Physicochemical	1. Water Temperature	1. Reduce water temperature to 11 to 16° C
Level 5 - Biology	1. Macro 2. Fish	1. Increase MBSS macro cold water score to “good”. 2. Increase brook trout biomass compared to existing conditions.

Assessment Parameters:

Table 2 – Typical Species Brook Trout – Assessment Parameters							
Category Level	**Parameter**	**Measurement Method**	**Pre-Restoration Condition**				
			Value	**Rating**	**Parameter Level**	**Pyramid Level**	**Overall Reach**
1 - Hydrology	Concentrated Flow	Visual Observation of number of concentrated flows					
2 - Hydraulics	Floodplain Connectivity	BHR					
	Velocities	HEC-RAS					
	Hyporheic Zone	Water table wells					
3 - Geomorphology	Riparian Vegetation	Species Diversity and Composition					
		Buffer Width (left)					
		Buffer Width (right)					
	Lateral Stability	BANCs					
	Bedform Diversity	Pool-to-pool Spacing					
		Pool Depth Variability					
		Riffle to pool percentage					
4 - Physicochemical	Water Temperature	Temp Probe					
5 - Biology	Macroinvertebrate	MBSS					
	Fish	Brook Trout Populations					

TMDL NUTRIENT and SEDIMENT DRIVER EXAMPLE

Programmatic Goal: TMDL Nutrient and Sediment Reduction

Design Goals:

- Reduce sediment loads from eroding stream banks (Lvl 3)
- Capture sediment loads from upstream sources (Lvl 3)
- Reduce nutrients concentrations (Lvl 4)

Design Objectives:

Table 1 – Typical Nutrient and Sediment TMDL – Design Objectives

Category Level	Parameters	Design Objectives
Level 1- Hydrology	1. Flow Regime 2. Concentrated Flows	1. Reduce hydrograph peaks and increase duration compared to existing conditions 2. Eliminate Concentrated Flows
Level 2 - Hydraulics	1. Floodplain Connectivity 2. Floodplain Storage 3. Groundwater 4. Base flow	1. Create floodplain connection at levels associated with specified design storm event (e.g., return interval, storm event intensity, etc) 2. Store flood flows in the floodplain associated with a specified design discharge 3. Raise groundwater levels to (insert design depth) 4. Increase base flow levels to (insert design depths or annual duration of base flows)
Level 3 - Geomorphology	1. Lateral Stability 2. Sediment Reduction and Trapping 3. Bedform Diversity 4. Riparian Buffer	1. Reduce stream bank erosion rates to match reference erosion rates (bank migration/lateral stability) 2. Decrease sediment loads leaving the project to loads less than entering loads entering the project 3. Increase Bedform Diversity – Create (insert design bed ratio) riffle/pool ratio 4. Create native riparian buffer >/= 150 ft
Level 4 - Physicochemical	1. Nutrient Levels	1. Reduce nutrient concentration compared to existing conditions

Assessment Parameters:

Table 2 – Typical Nutrient and Sediment TMDL – Assessment Parameters							
Category Level	**Parameter**	**Measurement Method**	**Pre-Restoration Condition**				
			Value	**Rating**	**Parameter Level**	**Pyramid Level**	**Overall Reach**
1 - Hydrology	Concentrated Flow	Visual Observation					
2 - Hydraulics	Floodplain Connectivity	HEC-RAS or BHR					
	Floodplain Storage	HEC-RAS					
3 - Geomorphology	Riparian Vegetation	Species Diversity and Composition					
		Buffer Width (left)					
		Buffer Width (right)					
	Lateral Stability	Lateral Erosion Rate or BANCs					
		MWR					
	Bedform Diversity	Pool-to-pool Spacing					
		Pool Depth Variability					
	Sediment Supply	Sediment Load or BANCS					
4 - Physicochemical	Nutrient Level	Water Samples					
For Permit Requirements **5 - Biology**	Macroinvertebrate	Visual Observation					
	Fish	Visual Observation					

TMDL SEDIMENT DRIVER EXAMPLE

Programmatic Goal: TMDL Sediment Reduction

Design Goals:

- Reduce sediment loads from eroding stream banks (Lvl 3)
- Capture sediment loads from upstream sources (Lvl 3)

Design Objectives:

Table 1 – Typical Sediment TMDL – Design Objectives

Category Level	Parameters	Design Objectives
Level 1- Hydrology	1. Concentrated Flows	1. Eliminate Concentrated Flows
Level 2 - Hydraulics	1. Floodplain Connectivity 2. Floodplain Storage	1. Create floodplain connection at levels associated with specified design storm event (e.g., return interval, storm event intensity, etc) 2. Storage flood flows in the floodplain associated with a specified design discharge
Level 3 - Geomorphology	1. Lateral Stability 2. Bedform Diversity 3. Riparian Buffer	1. Reduce stream bank erosion rates to match reference erosion rates (bank migration/lateral stability) 2. Increase Bedform Diversity – Create (insert design bed ratio) riffle/pool ratio 3. Create native riparian buffer based on MWR, plus 30 ft.

Assessment Parameters:

Table 2 – Typical Sediment TMDL – Assessment Parameters							
Category Level	**Parameter**	**Measurement Method**	**Pre-Restoration Condition**				
			Value	**Rating**	**Parameter Level**	**Pyramid Level**	**Overall Reach**
1 - Hydrology	Concentrated Flow	Visual Observation					
2 - Hydraulics	Floodplain Connectivity	HEC-RAS or BHR					
	Floodplain Storage	HEC-RAS					
3 - Geomorphology	Riparian Vegetation	Species Diversity and Composition					
		Buffer Width (left)					
		Buffer Width (right)					
	Lateral Stability	Lateral Erosion Rate or BANCs					
		MWR					
	Bedform Diversity	Pool-to-pool Spacing					
		Pool Depth Variability					
	Sediment Supply	Sediment Load or BANCS					
For Permit Requirements **4 - Physicochemical**	Overall Water Quality	Visual Observation					
For Permit Requirements **5 - Biology**	Macroinvertebrate	Visual Observation					
	Fish	Visual Observation					

APPENDIX E

EXAMPLE SITE SELECTION

Youngs Branch, Fairfax, VA
Reach 1

A. **Programmatic Goal** TMDL Nutrient and Sediment Reduction

B. Design Goals

- Reduce sediment loads from eroding stream banks (Lvl 3)
- Capture sediment loads from upstream sources (Lvl 3)
- Reduce nutrients concentrations (Lvl 4)

C. Rapid Assessment Results

1. Watershed Assessment

Overall Watershed Condition	Fair

WATERSHED ASSESSMENT

	Category / Parameter / Measurement Method	Description of Watershed Condition			Rating (G/F/P)
		Good	Fair	Poor	
1	Hydrology / Runoff / Watershed Impoundments	No impoundment upstream of project area	No impoundment within 1 mile upstream of project area OR impoundment does not adversely affect hydrology or fish passage	Impoundment(s) located within 1 mile upstream of project area and/or has an adverse effect on hydrology and/or fish passage	P
2	Hydrology / Runoff / Concentrated Flow	No potential for concentrated flow/impairments from adjacent land use	Some potential for concentrated flow/impairments to reach restoration site, however, measures are in place to protect resources	Potential for concentrated flow/impairments to reach restoration site and no treatments are in place	P
3	Hydrology / Runoff / Land Use Change	Rural communities/slow growth or primarily forested (>70%)	Single family homes/suburban development occurring or active agricultural practices occurring, or commercial and/or industrial development starting, forested area 20 - 70%	Rapidly urbanizing/urban or primarily active agricultural practices (> 70%), forested area <20%	G
4	Hydrology / Runoff / Distance to Roads	No roads in or adjacent to site. No proposed major roads in or adjacent to site in 10 year DOT plans	No roads in or adjacent to site. No more than one major road proposed in 10 year DOT plans	Roads located in or adjacent to site boundary and/or major roads proposed in 10 year DOT plans	G
5	Hydrology / Runoff / Flashiness	Non-flashy flow regime as a result of rainfall patterns, geology, and soils, impervious cover less than 6%	Semi-flashy flow regime as a result of rainfall patterns, geology, and soils, impervious cover 7%- 15%	Flashy flow regime as a result of rainfall patterns, geology, and soils, impervious cover greater than 15%	F
6	Geomorphology / Riparian Vegetation	>80% of contributing stream length has >25 ft corridor width	50 - 80% of contributing stream length has >25 ft corridor width	<50% of contributing stream length has >25 ft corridor width	G
7	Geomorphology / Sediment Supply	Low sediment supply. Upstream bank erosion and bed load supply is minimal. There are few bars present in the channel	Moderate sediment supply from upstream bank erosion and bed load supply. There are some point bars and small lateral bars	High sediment supply from upstream bank erosion and bed load supply. There are numerous alternating point bars, transverse bars and/or mid-channel bars	G
8	Physicochemical / Water Quality / 303(d) List	Very clear, or clear but tea-colored; objects visible at depth 3 to 6 ft (less if slightly colored); no oil sheen on surface; no noticeable film on submerged objects or rocks. Clear water along entire reach; diverse aquatic plant community includes low quantities of many species of macrophytes; little algal growth present. Not on 303d list	Considerable cloudiness most of the time; objects visible to depth 0.5 to 1.5 ft; slow sections may appear pea-green; bottom rocks or submerged objects covered with green or olive-green film; or moderate odor of ammonia or rotten eggs. Greenish water along entire reach; overabundance of lush green macrophytes; abundant algal growth, especially during warmer months. On or downstream of 303d list and TMDL/WS Mgmt plan addressing deficiencies	Very turbid or muddy appearance most of the time; objects visible at depth< 0.5 ft; slow moving water maybe bright green; other obvious water pollutants; floating algal mats, surface scum, sheen or heavy coat of foam on surface; or strong odor of chemicals, oil, sewage, or other pollutants. Pea-green, gray, or brown water along entire reach; dense stands of macrophytes clogging stream; severe algal blooms creating thick algal mats in stream. On or downstream of 303d list and no TMDL/WS mgmt plan to address deficiencies	F
9	Biology / Landscape Connectivity	Channel upstream and downstream of project area has native bed and bank materials and is not impaired	Channel upstream and downstream of project area has native bed and bank materials but is impaired	Channel upstream and downstream of project area is concrete piped, or hardened	P

2. Reach Level Assessment

Youngs Branch, Fairfax, VA: YB-R1

Level and Category	Parameter	Measurement Method	Pre-Restoration Condition				Proposed Condition			
			Rating	Parameter Rating	Level Rating	Overall Reach Rating	Rating	Parameter Rating	Level Rating	Overall Reach
1 - Hydrology	Runoff	Flashiness	FAR	FAR	FAR	FAR	FAR*	FAR	FAR*	FAR*
		Concentrated Flow	NF				F			
2 - Hydraulics	Floodplain Connectivity	Bank Height Ratio	NF	NF	NF		F	F	F	
		Entrenchment Ratio	NF				F			
	Floodplain Drainage	FWS Rapid Assessment	NF	NF			F	F		
	Vertical Stability Extent	FWS Rapid Assessment	NF				F			
3 - Geomorphology	Riparain Vegetation	FWS Rapid Assessment	FAR	FAR	FAR		F	F	F	
	Lateral Stability	Dominant Bank Ersoion Rate	NF	NF			F	F		
	Bedform Diversity	Shelter for Fish	FAR	FAR			F			
		Pool-to-pool Spacing	NF				F			
		Pool Depth Variability	F				F			
	Lateral Stability Extent	FWS Rapid Assessment	NF	NF			F	F		
4 - Physicochemical	Water Appearance and Nutrients	FWS Rapid Assessment	FAR	FAR	FAR		FAR*	FAR*	FAR*	
	Detritus	FWS Rapid Assessment	FAR	FAR			F	F		
5 - Biology	Macro	Presence	FAR	FAR	FAR		FAR*	FAR*	FAR*	
		Tolerance	NF				NF			
	Fish	Presence	FAR	FAR			FAR*	FAR*		

Note: "*" indicates partial uplift

	Rating	Comment
Channel Evolution	FAR	Trending towards functioning. Bedrock downstream and pond upstream of reach. So no longer downcutting but stream is incised and entrenched. Widespread lateral instability. Will be decades before equilibrium is met.

Constraints	Inline pond at upstream end.

3. Overall Reach Summary

Youngs Branch, Fairfax, VA: Overall Function-based Reach Assessment Summary				
Reach	**Reach Length (ft)**	**Rosgen Stream Type**	**Channel Evolution**	**Reach Level Function-based Rating**
1	~ 683 ft	F4	E -> C -> F	FAR
2	~ 760 ft	B4c	E -> C -> F -> Bc	FAR
3	~ 1075 ft	F4	E -> C -> F	FAR
4	~ 570 ft	C4	E -> C -> F -> C	FAR

D. Restoration Potential

- Fully functioning up to Level 3 – Geomorphology
- Partial functional uplift for Levels 4 – Physicochemical and 5 – Biology. Actual uplift dependent upon ability to address water quality issues. Additional water quality sampling needed to identify limiting factors.

E. Design Objectives

Table 1 – Example Nutrient and Sediment TMDL – Design Objectives		
Category Level	**Parameters**	**Design Objectives**
Level 1- Hydrology	1. Flow Regime 2. Concentrated Flows	1. Reduce hydrograph peaks and increase duration compared to existing conditions 2. Eliminate Concentrated Flows
Level 2 - Hydraulics	1. Floodplain Connectivity 2. Floodplain Storage	***Primary Objectives*** 1. Create floodplain connection at levels associated with specified design storm event (e.g., return interval, storm event intensity, etc) 2. Storage flood flows in the floodplain associated with a specified design discharge ***Secondary Objectives*** 3. Raise groundwater levels to (insert design depth) 4. Increase base flow levels to (insert design depths or annual duration of base flows)
Level 3 - Geomorphology	1. Lateral Stability 2. Sediment/Reduction and Trapping 3. Riparian Buffer	1. Reduce stream bank erosion rates to match reference erosion rates (bank migration/lateral stability) 2. Decrease sediment loads leaving the project to loads less than entering loads entering the project 3. Increase Bedform Diversity – Create (insert design bed ratio) pool / riffle ratio 4. Create native riparian buffer for Eastern Wood-Peewee, Red-Shoulder Hawk, and Acadian Flycatcher
Level 4 - Physicochemical	1. Nutrient Levels	1. Reduce nutrient levels compared to existing conditions
Level 5 - Biology	1. Macro 2. Fish	***Secondary Objectives*** 1. Increase macroinvertebrate diversity and density compared to existing conditions. 2. Increase fish diversity and density compared to existing conditions.

F. Potential Design Solutions

1. Overall Project Length:
   - The possibly exists to build a Priority 1 stream restoration. The farthest upstream end of the project would most likely be a Priority 3. As the stream moves downstream, a Priority 2 could be built. At the lower end of the project area, a Priority 1 could be built along or near the existing stream alignment or completely separate of the existing alignment. The possibility of this approach is mostly depended upon the overall grade drop of the project area. Enough grade drop has to occur to avoid any significant backwater affects. However, a portion of the upstream project area could be specifically designed to be a backwater area so that a Priority 1 stream could be constructed as far upstream as possible. Flood stages typically increase when building a Priority 1 project. However, the stream flows through a valley that has high, steep valley walls and there are no structures on the valley floor. Therefore, there would be no flooding impacts. There are though, sewer lines that are parallel and perpendicular to the stream that might be affected by elevated flood flows.

2. Reach Specific:
   - Rosgen Priority 2 but significant grading and tree removal will be required since the stream is significantly incised and entrenched (Rosgen F4). To reduce grading a Priority 3 could be built. USGS shows that percent imperviousness is 1.15%. However, based on a visual observation of the watershed, the percent imperviousness could actually be higher. The correct percent imperviousness needs to be determined because it could significantly influence the design channel dimensions. Also there is an inline storm water pond at the upstream end of this reach. This is most likely controlling sediment supply and possibly the effects of percent imperviousness. H&H modelling will be required to determine the effects of the pond. If pond does control storm flows, a nested channel may not be required. If it does not, a nested channel should be considered. If a nested channel is built, the low flow channel would be based on a rural regional curve and the next channel, which would connect with the floodplain, would be based on a more urban regional curve.
   - Modified valley restoration is also an option. Potential greater WQ uplift with valley restoration. Approach could use riffle grade controls to reconnect to floodplain with flows less than a bankfull flow. However, sediment supply being delivered to the project area must be determined. If sediment supply is low, then a modified valley restoration approach could be used.

3. Other Ecological Functions
   - Wetlands – wetlands are located throughout the project area floodplain. Hydrology source appears to be from valley toe seeps. Wetlands have the potential to be enhanced as part of the proposed stream restoration project.
   - Riparian vegetation – while there is a mature forest stand within the project area floodplain, it consists primarily of canopy tree. Trees will have to be removed as part of the restoration but they will be used as instream structures. Additionally, a planting plant will be installed within the floodplain to enhance the existing vegetation.

4. Other Implementation Considerations
    - Property Ownership – Fairfax County owned
    - Accessibility – will have to access through private property
    - Construction Impacts – while there is a mature forest stand within the project floodplain, it consists primarily of canopy trees. So a construction road can be utilized with minimal impacts to existing trees. As stated above, the existing riparian will be enhanced
    - Implementation Costs – potential costs could be feasible because there are few constraints and grading can be minimalized.
    - Contaminant – none observed
    - Cultural Resources – none observed
    - Permitting Requirements – no unique permit requirements

G. <u>Site Suitability</u>

- Site is degraded
- Potential for uplift exists
- Minimal adverse impacts
- No unreasonable implementation issues
- Uncertainty and risk low
- Design goals and objectives can be met
- Suitable site for restoration

H. Proposed Detailed Assessment Parameters:

Youngs Branch - Function-based Assessment Existing Conditions							
Level and Category	Parameter	Measurement Method	Collection Method	Pre-Restoration Condition			
				Value	Rating	Overall by Level	Overall Reach
1 - Hydrology	Flashiness	FWS Function-based Rapid Assessment	Visual Observation		F	FAR	NF
	Concentrated Flow	FWS Function-based Rapid Assessment	Visual Observation				
2 - Hydraulics	Floodplain Connectivity	Bank Height Ratio	Long Pro				
		Entrenchment Ratio	Cross sections				
	Floodplain Complexity	FWS Rapid Assessment	Visual Observation				
3 - Geomorphology	Riparian Vegetation	FWS Function-based Rapid Assessment	Visual Observation				
		Rosgen Riparian Vegetation Assessment	Visual Observation				
	Lateral Stability	Dominant BEHI/NBS	BANCs				
		Lateral Erosion Rate	BANCs				
		Meander Width Ratio (C and E Stream Types)	Geometry				
		Radius of Curvature	Geometry				
		Confinement	Geometry				
		Wave length	Geometry				
		Meander Pattern	Rosgen				
	Bedform Diversity	Pool-to-pool Spacing Ratio	Long Pro				
		Pool Depth Ratio Variability	Long Pro				
		Large Woody Debris (LWD)	USFS				
		Pfankuck	Pfankuck Assessment form				
		Depositional Pattern	Rosgen				
	Sediment Transport	Sediment Compentence	Bar samples and riffle pebble counts				
		Sediment Capacity	Sediment rating curve/ Visual Observation/ Rosgen Deposition Pattern				
4 - Physicochemical	Nutrients	Laboratory Analysis	Grab Sample/Sampler				
	Organic Carbon	Laboratory Analysis	Grab Sample				
	Detritius						
	Turbidity	Probe	Probe				
	Temp	Probe	Probe				
	pH	Probe	Probe				
	DO	Probe	Probe				
	Conductivity	Probe	Probe				
5 - Biology	Macro Community	MBSS	MBSS Protocol				
	Fish Community	MBSS	MBSS Protocol				

APPENDIX F

(Under review by MDE. Will be added once approved)