Designing Sustainable Stream Restoration Projects within the Chesapeake Bay Watershed

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Table of Contents

Executive Summary

The Chesapeake Bay Program's (CBP) Habitat Goal Implementation Team (GIT) convened this workshop to discuss the facilitation of effective stream restoration projects within the Bay watershed that can create the functional lift needed to restore Bay health, and not focus solely on nutrient and sediment reductions. Key to this successful outcome is generating an understanding and agreement on the major elements of stream functions that will allow stream restoration practitioners, researchers, and the regulatory community to implement sustainable stream restoration projects. The workshop proposed a Function-based Stream Restoration Project Process to generate discussion that formed the basis for the key workshop findings and recommendations.

The workshop brought together sixty invited researchers, federal, state and local agency representatives, non-governmental organization staff, and practitioners to identify a standard process that can be used by designers, managers, scientists, and permitting agencies to assure stream restoration projects are implemented in a way to add functional lift to the elements of the stream ecosystem. The main outcome of the workshop was to create recommendations for the development of a function-based process to implement sustainable stream restoration projects.

The workshop provided presentations and facilitated discussions to address the following:

1. How to create a common understanding and common language among restoration practitioners, regulators, and scientists;
2. How to establish a uniform process for characterizing the degree of functional lift and/or loss of biological, chemical, and physical processes associated with the various stream restoration approaches; and
3. How to engage the stream restoration community within the Chesapeake Bay watershed and to develop a document from which to continue to build a consensus and guidance on stream restoration that will help to facilitate the implementation of the Total Maximum Daily Load (TMDL) Watershed Implementation Plan (WIP) strategies.

Major Findings

1. Overall, there was general agreement that the identification of stream functions should guide the restoration process and that the design and implementation of projects should include well-articulated goals, design objectives, and measurement parameters that can be used to answer the question – *have the defined functions of a stream been improved and to what degree?* It was debated whether the science is available to answer this question given the disparate datasets that currently exist to assess stream restoration projects. In part, the inconclusive answer to this question in most studies results from the lack of a function-based project process that limits stream restoration stakeholders to assess the effectiveness of projects. Although the two-day workshop limited the opportunity for participants to reach consensus on a unified function-based set of procedures, there was general agreement to adopt

a function-based stream restoration project design process and the proposed approach may be a useful starting point for future discussions.

Workshop participants identified benefits that a function-based process could have for designing and implementing stream restoration projects including its potential to document the increase, or uplift in stream functions and as a valuable communication tool that can help managers and the public understand restoration potential and set realistic restoration objectives (e.g., set short and long-term monitoring needs to effectively evaluate outcomes).

2. Baywide, there is a significant investment being made by the States and District of Columbia for stream restoration to meet numerous restoration goals and objectives such as total nitrogen, total phosphorus, and sediment reductions to achieve the TMDL targets. While the TMDL may be a programmatic goal or driver to implement a stream restoration project, workshop participants discussed the need for a baseline list of critical functions and assessment parameters that would support and make this programmatic goal more sustainable. Further work to define critical functions, metrics, and methods of assessment are needed but were not the objectives of the workshop.

   Workshop presentations and discussions presented a number of functional and structural assessment parameters to assess stream functions. Many of the critical stressors (e.g., flow regime and water quality) are attributed to watershed activities and are accounted for in the watershed assessment phase of the stream restoration project design. However, to further elucidate the interconnectedness of stream functions controlled by the watershed and by those within the riparian corridor (e.g., effect of low impact development on hydrology), additional well-defined research is needed to generate data that can relate design techniques (i.e., stream manipulation and other manipulations) that are implemented to restore stream functions with watershed processes. Furthermore, since one objective of the function-based stream project design process is to promote better communication among all restoration stakeholders, workshop participants agreed that providing better descriptions of the interconnectivity of watershed and stream processes is essential (i.e., what is the context of the stream reach within the watershed?).

3. The monitoring requirements for stream restoration projects should be identified through approaches that link a science-based understanding of stream processes and functions with project goals and objectives to measurement parameters. Monitoring data for stream restoration projects could then better evaluate the effectiveness of projects to restore the identified functions through pre- and post- implementation monitoring. If the project goal is to reduce in-stream sediment loadings downstream, rather than to restore biological function, , then the generation of data such as the Index of Biotic Integrity (IBI) would not be necessary to evaluate the success of such a project. However, as sediment is a leading cause of biological impairments for local TMDLs, the reduction in sediment may lead to an improvement in biological communities in the longer term, post-implementation, providing

that other critical functions to support stream biological functions have been restored. For many permits, it is typical that monitoring requirements focus largely on channel stability and/or biological metrics without making connections to stream functions, or overall project goals and objectives. However, stream stability monitoring may only be required if there are no aquatic resource function trade-offs as a result of the project.

While functional parameters are preferable, participants agreed that the selection of function-based parameters may be limited by scientific capabilities, or the ability to define performance standards. Therefore, the use of structural parameters or indices may be needed as surrogates for stream functions if scientifically justified. An example set of critical functions provided by workshop participants for which monitoring data may be generated to evaluate stream functions include:

a) Carbon retention;
b) Nutrient and sediment retention;
c) Floodplain and hydrologic connectivity;
d) Lateral stability;
e) Bedform diversity; and
f) Riparian corridor coverage.

4. There is an imperfect knowledge and understanding of stream restoration science and the inherent risk that any given project implementation may not achieve its restoration objectives. As stream restoration science and design continues to evolve, the desired ecological endpoint for any given project may also evolve throughout the project life, and through feedback from monitoring of the relevant function-based parameters. In short, the understanding of stream process functions and the interrelationship with a watershed will advance with implementation in the field and not in a laboratory or through simulation models.

   Workshop participants agreed that in most cases, there is sufficient information (e.g., assessment parameters and measurement methods) to assess lower level restoration potential (i.e., hydrology, hydraulics, and geomorphology), while greater uncertainty accompanies the predictive capability of restoration techniques aimed to achieve higher functional uplift (i.e., physiochemical and biological improvements). The fact that longer time periods may be needed to show sustainable biological uplift for an individual project should not necessarily be a reason to reject a permit application during the review process. Participants supported efforts to monitor a full range of stream restoration projects in all relevant physiographic regions to continue to build datasets to evaluate long term stream restoration project outcomes.

<u>Recommendations</u>

1. Resoundingly, workshop participants stressed the need for stream restoration projects to be part of an overall watershed strategy for the Chesapeake Bay. The context of the watershed

occurs at two different stages of stream restoration projects. First, a broad-scale watershed planning effort provides a prioritized set of recommended upland and in-stream projects for restoration, or assessments used for alternative site analysis. Examples of watershed plans include: EPA 319 watershed planning guidance (EPA 2008), TMDL implementation plans, and watershed implementation plans (WIPs). The second type of watershed assessment determines watershed characteristics and limiting factors that may influence the proposed project area after the stream project site is selected, and will play a significant role in determining the restoration potential of the stream reach. This can be accomplished by establishing the overall health of the watershed and identifying constraints to establishing the cause and effect relationship between the watershed and the proposed restoration site. Specifically, determining whether the link between watershed health and contributing factors to the proposed site are degradation issues. Results of the reach-level function-based assessment will be used in combination with the watershed assessment to assist in the development of restoration plan alternatives.

2. An interested party, such as the CBP's Stream Health Workgroup, should adopt the proposed Function-based Stream Restoration Project Process outlined in this report as a starting point to develop a unified process and work with the Partnership to facilitate development of the proposed guidance. The guidance documents and checklists developed by the U.S. Fish and Wildlife Service (USFWS) under contract with Maryland Department of the Environment (MDE) may serve as a template to begin these discussions since these documents follow the Function-based Stream Restoration Project Process presented and discussed at the workshop. In addition, the Pennsylvania Department of Environmental Protection (PADEP) has developed similar methodologies to integrate stream functions into their approval process. The organization that advances the adoption of a function-based process should coordinate with these existing efforts.

   There was general agreement from workshop participants that a science-based, methodological process is needed to clearly define project goals and objectives that lead to the identification of measurement parameters to evaluate the restoration of stream functions. The function-based process would include a watershed assessment (previously described) to identify the limits and opportunities to restore identified stream functions.

3. Workshop participants identified areas for which monitoring efforts may enhance stream restoration science and implementation. For example, there is a need to develop a baseline list of critical stream functions and assessment parameters to monitor the effectiveness of stream restoration to support the programmatic goal of the Chesapeake Bay TMDL, which is the driver for many stream restoration projects in the watershed.

   Participants recommended developing a monitoring consortium or framework that would pool monitoring resources and address key research issues such as critical stream functions, intermediate functional standards, continuum of risk, and at-risk or non-functioning performance standards, among others. The adoption of a pooled monitoring approach would allow researchers, practitioners, and the regulatory agencies to collaboratively review monitoring needs to evaluate restored or enhanced stream functions. During the summer and fall of 2014, an *ad-hoc* committee represented by regulatory agencies (U.S. Army Corp of Engineers [USACE], MDE, USFWS), state and resource agencies (Maryland State Highway Administration [SHA]), and stream organizations ([Maryland Stream Restoration Association (MSRA]) was coordinated and lead by the Chesapeake Bay Trust to explore and begin development of a pooled monitoring approach. Data generated from Big Spring Run, PA (PADEP 2013) may also advance the development of performance levels for stream geomorphic functions.

Overall, monitoring data generated from stream restoration projects should provide the potential to demonstrate restored steam functions. Participants agreed that the existing monitoring needs required by permits were not necessarily sufficiently robust to assess the full breadth of stream functions (e.g., current monitoring focus on stream stability; how well is this rock vane performing?). It was also acknowledged that permit monitoring requirements are prescribed based on the presence/absence of aquatic resource tradeoffs and may not require monitoring data beyond stream stability. Pooled monitoring to address specific research questions should be pursued.

4. It is recommended that the Urban Stormwater Workgroup and Stream Health Workgroup coordinate efforts to develop guidance (e.g., via an expert panel) to align how the restoration/enhancement of stream functions translates to nitrogen, phosphorus, and sediment 'credit'. The CBP recently approved recommendations to credit stream restoration projects along with guidance to verify and report stream restoration as a best management practice (BMP). This guidance would discuss how stream restoration BMP protocols[1] fit within a functional framework for stream restoration project design, as well as verification guidance[2] such that post-construction assessments can verify that the project is meeting minimum performance standards to warrant use of either the general interim pollutant reduction rates or the reduction rates related to one of the four specific protocols approved by the expert panel.

In addition to the key findings and recommendations from the workshop, there were ideas shared by workshop participants deemed necessary, actionable steps to further sustainable stream restoration projects. For example, participants suggested that data generated from pooled monitoring efforts may be compiled into case study examples based on design approaches, watershed characteristics, and physiographic provinces. These set of case studies should define reference sites and conditions for urban stream restoration. It was noted during the breakout

[1] The Chesapeake Bay Program Water Quality GIT approved the Stream Restoration Expert Panel Report Recommendations September 8, 2014

[2] Chesapeake Bay Program approved, "Strengthening Verification of Best Management Practices Implemented in the
[2] Chesapeake Bay Program approved, "Strengthening Verification of Best Management Practices Implemented in the
Chesapeake Bay Watershed: A Basinwide Framework" August 14, 2014

sessions that the restoration potential in urban areas, as well as agricultural, provide a number of constraints that may limit restoration potential to restore to natural or historical states. However, participants were hesitant to limit the restoration potential or functional uplift in urban areas given the site-specific watershed conditions and evolution of design techniques. Further, workshop participants stated that there is a continued need to convene a workshop or other forums to address site selection and alternatives (site/approach/design) analysis with the practitioners, academics, regulators, WIP developers, and funding organizations. The purpose of such a workshop would be to generate a common understanding and baseline of information to present in permit applications and how to encourage high quality proposals.

Designing Sustainable Stream Restoration Projects within the Chesapeake Bay Watershed

There are over 3.5 million miles of rivers and streams in the United States, covering an enormous and diverse landscape with headwater streams (i.e., zero to third-order) comprising 53% of those total stream miles. A recent national assessment found that 55% of the nation's river and stream miles do not support healthy populations of aquatic life, with nutrients and poor habitat the most widespread problems (US EPA 2013). Despite the significant increase in activities in recent decades to restore streams, the field of stream restoration science is relatively young with disparate datasets and studies documenting a project's effect at the reach- or watershed-scale. As the practice of stream restoration is quickly evolving with new design approaches, there is a need to develop a process that allows practitioners to learn from successes and adaptively manage practices to ensure the best chance of success for sustainable stream restoration projects. Harman et al. (2012) suggests this begins in part with a common language and agreed upon protocols to measure the resultant functional lift, and/or loss associated with design features (e.g., pool riffle spacing).

The need for a common language is highlighted by differences in how researchers, practitioners, and regulators define stream restoration. For the purposes of this report, stream restoration is used in general terms to include activities that improve/restore lost or impaired stream functions that may or may not result in an increase in aquatic resource area or net functional gain to meet one of the regulatory definitions for stream enhancement, restoration, or rehabilitation. A discussion of the regulatory definitions associated with stream restoration can be found in Sections I and III of this report.

Approximately 700 miles of stream restoration projects are expected to be implemented to achieve the nutrient and sediment load reductions defined by the Chesapeake Bay total maximum daily load (TMDL) (Table 1). As a result, the projected implementation rate of stream restoration projects to meet the 2017 and 2025 timelines with the Bay watershed is unprecedented. Based on the planned 2025 Phase II Watershed Implementation Plans (WIPs), the Chesapeake Bay Program (CBP) reported that 37% of planned stream restoration projects were implemented based on the 2013 progress reported by the Chesapeake Bay jurisdictions (NY, PA, MD, WV, VA, DE, DC), with those projects including 92% 2025 projected non-urban land use (Table 2). While stream restoration is an approved best management practice (BMP) by the CBP Partnership and it provides nutrient and sediment load reductions, there is a need to have a process to evaluate the overall improvement in stream functions associated with these practices to support the health of the Chesapeake Bay watershed (CBW).

Table 1. Jurisdictional stream restoration projects identified in the Phase II Watershed Implementation Plans (in feet) for 2025.

Land Use	NY	PA	MD	VA	WV	DE	DC	CBW
Non-urban	337,999	529,435	73,975	104,528	19,618	63,202	0	1,128,757
Urban	26,500	55,000	2,527,626	116,399	0	200	42,240	2,332,664
Total	364,499	584,435	2,601,601	220,927	19,618	63,402	42,240	3,461,421

Table 2. CBW stream restoration project implementation for progress periods (2009-2013).

Land Use	2009 Progress	2011 Progress	2013 Progress	% Achieved of 2025 WIP
Non-urban	191,638	501,120	1,041,259	92
Urban	165,375	208,509	385,188	14
Total	548,651	709,629	1,426,477	37

The workshop brought together 60 invited researchers, federal, state, and local agency representatives, non-governmental organizations and practitioners to identify a standard process that can be used by designers, managers, scientists, and permitting agencies to assure stream restoration projects are implemented in a way to add functional lift to the elements of the stream ecosystem. The main outcome of the workshop was to develop recommendations for the development of a function-based process to implement sustainable stream restoration projects.

The workshop provided presentations and facilitated discussions to address the following:

1. Creating a common understanding and common language among restoration practitioners, regulators, and scientists;
2. Establishing a uniform process for characterizing the degree of functional lift and/or loss of biological, chemical, and physical processes associated with the various stream restoration approaches; and
3. Engaging the stream restoration community within the CBW and to develop a document from which to continue to build a consensus and guidance on stream restoration that will help to facilitate the implementation of the TMDL WIP strategies.

The emphasis of the workshop was placed on developing recommendations for the critical components of the stream restoration project process that could be used for improving the functional elements of a stream. The adoption of a common language and agreement on the major elements of stream function will provide a basis for stream restoration practitioners to communicate functional lift within the potential of a project site by addressing the water quality, climatological impacts, as well as physical and biological components within the stream and adjacent riparian zone. The proposed common language, methods, and major elements of stream function-based design process are also intended to assist the regulatory community to ensure that efforts undertaken are consistent with the implementation of the Clean Water Act (CWA).

While prioritization of site locations and other non-stream restoration activities are critical in the success of restoring a watershed, these were not the focus of the workshop: The primary focus was at the stream reach, site level. The workshop was designed to solicit input and develop recommendations on what should happen at a stream restoration site, after it has gone through a prioritization process at the watershed scale.

This report summarizes the presentations and discussions from the workshop that provided input to develop recommendations for refining a Function-based Stream Restoration Project Process to implement sustainable stream restoration projects. The workshop report is organized in the following sections:

I. The Regulatory Context for Stream Restoration
II. Evaluation of Stream Restoration Projects
III. Application of a Stream Functions Framework
IV. A Function-Based Project Process
V. Summary of Breakout Group Discussions
    a. Goals and Objectives
    b. Selection of Function-based Assessment Parameters
    c. Restoration Potential
VI. Findings and Recommendations

I. The Regulatory Context for Stream Restoration

Presentation summaries by Jack Dinne (USACE), Bill Seiger (MDE), Dave Goerman (PADEP)

Regulators from the Maryland Department of the Environment (MDE), Pennsylvania Department of Environmental Protection (PADEP), and the Baltimore District of the Army Corps of Engineers (USACE) were invited to participate in the workshop due to the fact that they are responsible for assuring that stream restoration projects comply with federal and state regulatory requirements. Since regulatory reviews of stream restoration projects typically request documentation to demonstrate the effect on stream functions, it is critical that regulatory agencies have the opportunity to provide input on the recommendations. Furthermore, if the recommendations are not supported by the regulatory requirements, then it is necessary to understand why and whether the requirements are in need of modification to support the recommendations or if the recommendations are not sufficient to address regulatory requirements and necessitate further efforts.

The presentations focused on general state and federal regulatory requirements for stream restoration. Since many of the application requirements are duplicative, Maryland and Pennsylvania have developed operating procedures with the USACE to establish joint applications and permitting procedures to ensure both state and federal requirements are met.

The USACE oversees Section 404 of the CWA that regulates the discharge of dredged or fill material into waters of the United States. The Nationwide 27 permit (NWP 27) is the primary means to authorize stream restoration projects pursuant to the CWA. NWP 27 applies to *"…activities in waters of the United States associated with the* ***restoration****,* ***enhancement****, and* ***establishment*** *of tidal and non-tidal wetlands and riparian areas, the restoration and enhancement of non-tidal streams and other non-tidal open waters, and the* ***rehabilitation*** *or enhancement of tidal streams, tidal wetlands, and tidal open waters,* ***provided*** *those activities result in* ***net increases in aquatic resource functions and services****"* (emphasis in bold added).

To help streamline the permitting process, the USACE established State Programmatic General Permits (SPGP) in Pennsylvania and Maryland for restoration activities that meet certain threshold criteria (e.g., less than 1 acre of permanent or temporary impacts). In addition, the use of regional general permits by the USACE to address specific categories of activities has been implemented in various jurisdictions. The Baltimore District of the USACE is proposing to issue a modified Regional General Permit (RGP) specifically to facilitate meeting Chesapeake Bay TMDL (TMDL Regional General Permit[3]) for activities in waters of the U.S., including jurisdictional wetlands. The project must be part of an overall watershed strategy (e.g., Chesapeake Bay TMDL WIP) to meet nutrient and sediment load reduction targets for existing development under the Chesapeake Bay TMDL.

All of the regulatory agencies provide some degree of direction to applicants. For instance, the PADEP developed and proposed guidelines for utilizing rapid condition assessments and defined resource functional groups for establishing a project's potential effect on the respective groups for the applicable resource category. For example, riverine resource functions based on Fischenich (2006) are grouped into four basic functional groups: hydrologic, biogeochemical, habitat, and recreation/resource support. This recently adopted methodology assists applicants in identifying and documenting causes of degradation and its effect on stream function to ensure that resource/functional equivalency is provided as compensation for project mitigation. The NWP 27 provides a general outline in the form of a checklist for what to include in permit submittals. For instance, requirements include a clearly stated project purpose and objectives, description of baseline conditions from which the proposed project will be compared to evaluate the net functional lift, and potential conflicts and compatibility with watershed management plans.

While these guidelines are available, the greatest challenge for all stream restoration permit applications is to demonstrate that the project will result in ***net increases in aquatic resource***

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[3] A draft general permit was released May 16, 2014 for public comment http://www.chesapeakebay.net/channel_files/21783/draft_rgp_dtd-05_16_14_final_1.pdf

functions and services. This is an issue when stream restoration projects use new and innovative methods that are not familiar to permit reviewers, nor have a breadth of research results to support a project's intended outcome. Although an applicant may include a familiar project design, there still may be disagreement on measurement methods and criteria used to determine trade-offs, or beneficial functions that may be restored. Furthermore, because the field of stream restoration is still accompanied by relatively limited data demonstrating the effect in improving certain stream functions, there is an element of risk associated with innovative projects that the permit process has a difficult time reconciling.

An issue that is continuously over-looked is the identification of the underlying causes of resource degradation at a location (i.e., reach scale). There is a current trend of over reliance upon land use as a definitive causal source when there is not necessarily a direct linkage at the local scale. When the proposed identification of the degradation is addressed and associated with a stream function, this will facilitate addressing the net benefit analysis in a fairly straight forward and concise manner for a stream restoration project.

The regulatory perspective presenters agreed that developing a guidance document may help further streamline the permit process. They highlighted the need for integrating project goals into a watershed management framework as part of an evaluation of alternatives if called for by the permit. For many projects, the alternatives analysis has been an issue because of disagreements on whether the applicant has demonstrated the project will "avoid, minimize, or compensate" impacts and different interpretations of the effect of watershed BMPs on the stream system as a viable alternative to meet project outcomes. This is one of the central issues that will drive complications within the regulatory approval process. That is, modifying aquatic resources to selectively improve stream functions to address larger scale degradation problems is not restoring the aquatic resources at the local scale. The challenge is to have a process to identify and apportion the causes of impaired or lost stream functions between the proposed local project activity (e.g., grading stream channel) and pre-existing watershed scale factors (e.g., hydrologic modification). Furthermore, it is critical to demonstrate that the project will compensate for these lost or impaired project-related activities (i.e., what are the stressors at the watershed and site-scale and what stressors may be addressed by stream restoration to improve or restore stream functions). Broader watershed improvements (i.e., watershed quality) should be the beneficiary of local scale restoration efforts, which must be predicated on the causes of degradation at the local scale and designed to address them accordingly, and not the concerns at a broader watershed scale. While the focus of this workshop was limited to developing a systematic design process for stream restoration projects that clearly shows the linkages between the stream reach and upstream watershed, workshop participants strongly recognized the continued need for watershed-wide restoration as the focus of singular causes of degradation or restoration actions that will have limited effect on stream health.

II. Evaluation of Stream Restoration Projects

Summary of presentation by Dr. Margaret Palmer, UMCES

Palmer provided highlights from a synthesis of 644 stream restoration projects throughout the United States, Europe, and Australia for which quantifiable data were available to evaluate outcomes (Palmer et al. 2014). For each restoration project, the research synthesis determined the project goals, the assessment metrics the evaluators used to identify project outcomes that were most relevant to the stated goals, and whether the assessment data indicated any improvement toward meeting the goal. Outcome results varied depending on the type of method used to restore a stream reach and the particular metric evaluated (Palmer et al. 2014). Palmer emphasized that evaluations using well-developed assessment processes are critical to the major phases of restoration projects including assessment to: 1) identify goals take into account not only local conditions, but the status of the stream in the context of watershed; 2) list site-specific objectives to identify limiting factors (stressors causing degradation) as these determine the methods needed for project design; and 3) evaluate outcomes that best reflect the objectives and goals to determine what will be monitored over the short- and long-term. A project process that links a science-based understanding of stream processes with project goals and objectives to measurement parameters is critical to identify how the stream restoration project will address the local problem (at the stream reach) within the broader context of the watershed. The workshop steering committee proposed that the restoration project design process discussed at the workshop be presented as a starting point for researchers, practitioners, and regulators to adapt and modify.

The synthesis research found that for many projects, the terms 'project goals', 'objectives', and 'measurement parameters' are confused, which led projects to apply them differently across the studies reviewed. For example, while many stream restoration projects identify land use change as the stressor contributing to stream impairments, the defined project goal, or why the restoration project is needed in the context of watershed and local conditions, is often unrelated to that stressor. In turn, these led to the selection of parameters to measure and generate monitoring data that were unable to demonstrate the effect of a stream restoration project, or that the goal of the project was achieved.

Table 3 lists the major types of goals identified in the 644 stream restoration projects evaluated. While each of these goals may be applicable to stream restoration, the implementation of individual projects did not necessarily align with the specified goals. For example, channel stability is commonly aligned with a local design objective to reduce erosion and transport of bank sediments downstream, yet a stated overall project goal is often to improve the stream's biological status. A stream restoration project to stabilize stream banks may also be implemented to protect infrastructure (roads, storm, or sanitary sewer lines). Design for stability may accomplish the latter but rarely is bank stability the local stressor causing biological impairment. Consequently, a stream project design with channel stability as a goal would likely not achieve biological improvement if supporting functions were not a part of the project design process. However, given monitoring requirements for mitigation or other permits, biological conditions are often included in the project process. Furthermore, the selection of a design approach without first assessing which techniques would be most efficient or beneficial to restore stream functions often limits project success. The studies also identified riparian and in-stream habitat as project goals; these were typically to support the broader goal of biodiversity, based on the project's description.

Table 3. Results of research synthesis goal identification (Palmer et al. 2014).

Major stream restoration project goal	% of studies (n= 644)
Recovery of stream biodiversity (fish, macroinvertebates)	33%
Chanel stability	22%
Riparian habitat	18%
Water quality	14%
In-stream habitat	11%

To advance the practice of stream restoration project designs, an agreed upon approach to effectively translate and test the science of stream restoration to quantify the effect on stream functions is needed to narrow the uncertainty of expected outcomes. Ongoing monitoring of pre- and post-monitoring stream restoration projects is paramount to fulfill this need. The Stream Functions Pyramid Framework (SFPF) (Harman et al. 2012) provides examples of stream functions with measurement parameters that need to be modified to address project-specific goals and objectives. For example, as additional research on stream processes emerges, the ability to integrate the role of organic carbon could be better defined as a function-based parameter incorporated into the SFPF assessment given its critical role to regulate processing of nutrients and other ecosystem processes.

III. Application of a stream functions framework

Summary of presentation by Will Harman, Stream Mechanics PLLC

Stream restoration has many definitions, ranging from a catchall term as defined by Simon et al. (2011) to a more explicit definition provided by the 2008 Federal Mitigation Rule (*33 C.F.R. § 332/40 C.F.R. § 230)*: to return natural/historic functions to a former or degraded stream. However, depending on the outcome of the restoration activities, stream restoration may be defined as enhancement, restoration, or rehabilitation as defined in the Federal Registry for the NWP 27 (see box below for full definitions). A broad definition for stream restoration may fail to have the desired effect as the outcomes are unspecified, while focusing it on known ecological targets may improve the potential for meaningful outcomes. Further, these definitions do not define the endpoints regarding restoration to natural or historic functions, nor what parameters or methods are required to characterize the physical, chemical, or biological functions of streams. The Mitigation Rule is focused on protecting ''functions'' (the physical, chemical, and biological processes that occur in aquatic resources) and ‘‘services’’ (the benefits to humans that result from these functions). The Rule does not prescribe the appropriate functional assessments or define the specific type of functions because of its intent for general applicability. The Mitigation Rule gives authority to district engineers to determine appropriate functional assessments to use for particular permitting situations. District and state permitting offices have established their own process and procedures for identifying critical functions and functional assessments to identify the extent to which they are functioning, and the factors affecting them. Harman provided an overview of the SFPF (Harman et al. 2012) as a function-based approach to design and evaluate stream restoration projects, since the key outcome of the SFPF is to improve stream functions and is common to the four regulatory definitions presented. The framework provides an approach to: 1) identify which functions are possible to be restored (for a given reference condition), 2) define how each function relates and supports each other, and 3) identify parameters or metrics that quantify each function. The development of the SFPF was guided by the Federal Mitigation Rule to quantify lost functions of a proposed impact site and the functional lift that may be gained at a proposed mitigation site. The application of this function-based approach allows the difference between the existing and restored stream to be quantified and credited through the mitigation process. While mitigation is a current regulatory driver for stream restoration projects, the Chesapeake Bay TMDL is another driver that may benefit from a functions-based approach to evaluate the implementation of projects. Some of the techniques described in the SFPF can be useful for regulatory agencies to better link the functions lost at a permitted impact site to the functions gained at a mitigation site.

From 2008 Federal Mitigation Rule: 33 C.F.R. § 332/40 C.F.R. § 230

Restoration means the manipulation of the physical, chemical, or biological characteristics of a site with the goal of returning natural/historic functions to a former or degraded aquatic resource

From Simon et al. 2011,

Stream restoration is a catchall term used to describe a wide range of management actions and as such is difficult to define. The definition of stream restoration can vary with the perspective or discipline of the practitioner or with the temporal and spatial scale under consideration

From Federal Register/Vol. 77, No. 34/February 21, 2012. Effective Date: March 19, 2012.

Expiration Date: March 18, 2017.

Definition of enhancement is "The manipulation of the physical, chemical, or biological characteristics of an aquatic resource to heighten, intensify, or improve a specific aquatic resource function(s). Enhancement results in the gain of selected aquatic resource function(s), but may also lead to a decline in other aquatic resource function(s). Enhancement does not result in a gain in aquatic resource area."

Definition of Restoration is "The manipulation of the physical, chemical, or biological characteristics of a site with the goal of returning natural/historic functions to a former or degraded aquatic resource. For the purpose of tracking net gains in aquatic resource area, restoration is divided into two categories: re-establishment and rehabilitation."

Definition of Rehabilitation is, "The manipulation of the physical, chemical, or biological characteristics of a site with the goal of repairing natural/historic functions to a degraded aquatic resource. Rehabilitation results in a gain in aquatic resource function, but does not result in a gain in aquatic resource area."

The SFPF is used to identify the dominant stream functions and to determine how they may be affected by a stream restoration project. The framework is not designed to explain all of the ecological interrelationships and exchanges of energy and matter between stream functions. However, the practice and advancement of stream restoration will rely upon the ability of scientists and practitioners to engage in discussions that apply ecological theory to better understand stream functions and to translate them into design elements for sustainable stream restoration. The SFPF does provide a process to identify key assessment parameters (Harman et al. 2012) that describe stream functions. However, the parameters list is not comprehensive and requires further development. For example, a measurement metric to describe the function of a stream to transport and store large woody materials is currently under development by Will Harman with Stream Mechanics.

The five functional levels of the SFPF include: hydrology, hydraulics, geomorphology, physicochemical conditions, and biology (Figure 1). The premise of the SFPF is that all of the major stream functions as described by Fischenich (2006) can fit into these basic levels. The

SFPF is hierarchical, and similar to a pyramid, with higher-level functions are supported by lower-level functions. The flow or cause-effect relationship between and among the five levels are influenced by a region's geology and climate, as well as by anthropogenic actions. The general concept of the SFPF is to identify what stream functions are needed to achieve a stream restoration goal. That is, if the purpose of a restoration project is to restore trout in a stream, the project needs to identify what supporting physical, chemical, and biological functions are needed to support and sustain trout populations (i.e., Levels 1-5). A description of each function is provided below which were developed with perennial streams as an example. Therefore, in different environments (i.e., ephemeral channels), the functional statements may be modified as well as the function-based assessment parameters.

- Hydrology: Transport of water from the watershed to the channel;
- Hydraulics: Transport of water in the channel, on the floodplain, and through sediments;
- Geomorphology: Transport and deposition of wood and sediment to create diverse bed forms and dynamic equilibrium;
- Physicochemical: Temperature and oxygen regulation; processing of organic matter and nutrients; and
- Biology: Biodiversity and the life histories of aquatic and riparian life.

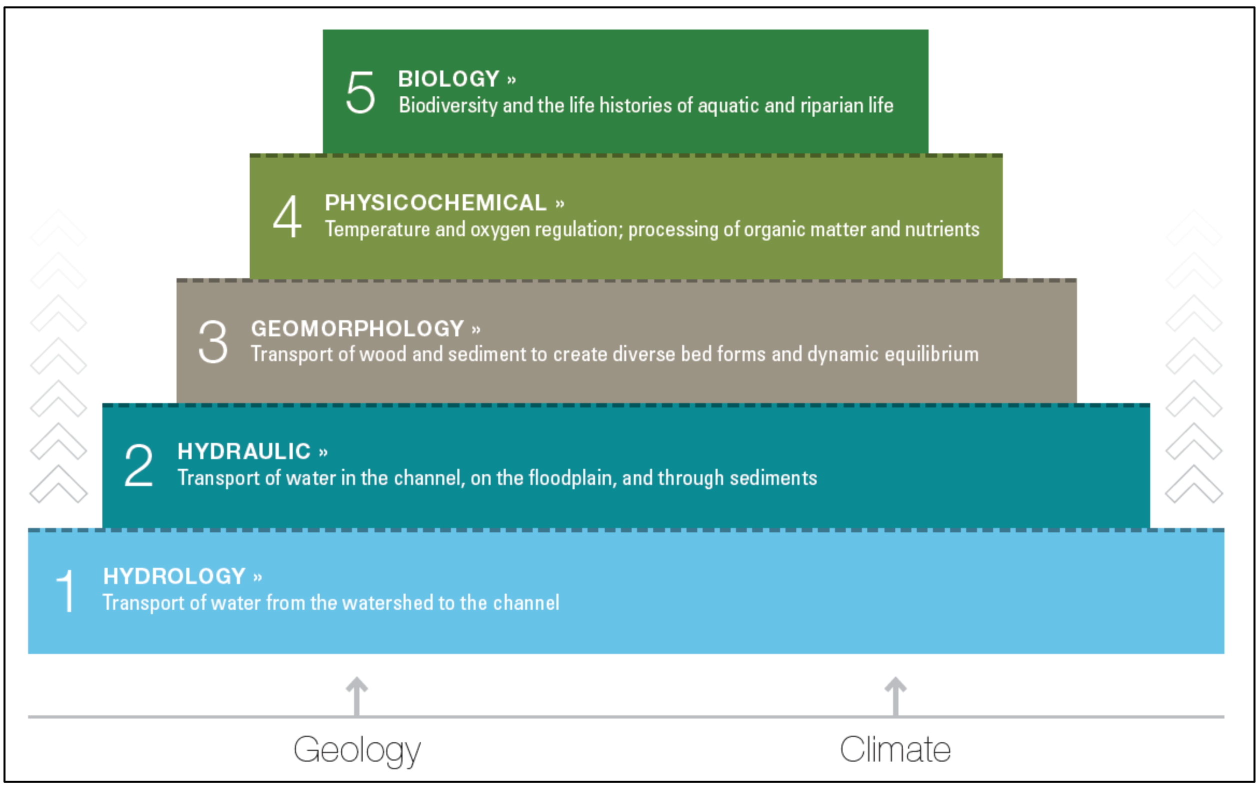

Figure 1. Stream Functions Pyramid Framework (SFPF) (Harman et al. 2012)

Hydrology (Level 1) is the basis of the SFPF and supports all categories above it. Hydrology as a stream function is generally an independent variable where the project reach is small relative to the drainage area. That is, runoff and groundwater flows enter a stream as a function of drainage area characteristics, both surface and subsurface, that cannot be directly manipulated by stream restoration except through broad-scale projects that affect land use, land cover, and percent imperviousness. However, in smaller headwater streams the ability to affect hydrological functions may be greater given the influence of the contributing drainage area.

Hydraulics and geomorphology (Levels 2 and 3) represent manipulation of the stream channel at the reach, most commonly affected by stream restoration activity. In practice, this relates back to the regulatory definition of stream restoration to manipulate physical, chemical, and biological functions of a stream. Improving these functions can directly benefit the physicochemical and biological functions of a stream through restoration activities, if the limiting factors are specifically related to hydraulic or geomorphic factors. However, more often than not projects may have specific hydraulic or geomorphic goals (e.g., stability), without necessarily benefiting physicochemical or biological functions because the factors causing impairment are watershed related (e.g., impervious cover) and outside the stream reach.

Physicochemical and biological functions (Levels 4 and 5) can be directly affected by factors within the stream reach, such as temperature and stream bank erosion rates. However, determining which functions within the lower levels of the pyramid are causing impairment is critical. For projects whose goals are Levels 4 and 5, it is important to think carefully about site selection in relationship to the watershed, for example, how healthy is the upstream watershed in relation to the reach? Will work done in the reach be able to address the impairments that inhibit healthy biological and physiochemical functions?

The SFPF can be used for any type of restoration approach. While the stream restoration approach is determined following the selection of assessment parameters, the measurement methods and performance standards may change from one restoration approach to another. Further, parameters within one functional level cannot be used to describe functions at different functional levels. For example, bed form diversity (Level 3) cannot be used to predict macroinvertebrate health (Level 5), even though it does support macroinvertebrate health. When following the SFPF, direct measures are used to describe a particular function. So for macroinvertebrate health, you would need to actually measure macroinvertebrates (i.e., densities, tolerances, etc.). Bed form diversity is used to understand, not predict, macroinvertebrate health through cause and effect. If the macroinvertebrate survey indicates poor macroinvertebrate health, you would then ask the question why. It could be lack of habitat (bed form diversity), it could be poor water quality, or both. You would have to measure those parameters as well to answer that question.

IV. A Function-based Stream Restoration Project Process

Summary of presentation provided by Rich Starr, US FWS

A restoration design process was proposed in concert with the SFPF as an example function-based assessment to provide a science-based, methodological process to evaluate stream restoration projects. While the SFPF is only one example of a function-based approach, its potential application to the Chesapeake Bay is relevant based on current and proposed regulatory efforts. For example, MDE has recently contracted with the USFWS to develop a guidance checklist for stream restoration design that will be based on the SFPF and the stream restoration design process described at this workshop. Following the workshop, the release of a draft RGP references the SFPF with the following language *"Stream restoration and enhancement project design must be developed through a functional assessment process, such as the stream functions pyramid (Harman et al. 2012) or functional equivalent."* These examples, along with the most recent rules and regulations issued in the 2008 Compensatory Mitigation for Losses of Aquatic Resources by the USACE and EPA stress that stream restoration projects be function-based.

The USFWS developed a Function-based Stream Restoration Project Process to design and evaluate stream restoration projects to document the increase, or uplift, in stream functions. Again, stream restoration for the purpose of this report is being used in the general sense to describe actions that improve or restore lost or impaired stream functions. The USFWS developed this process in response to the emphasis being placed on implementing function-based stream restoration projects by regulatory agencies.

The Function-based Stream Restoration Project Process is comprised of eight sequential steps (described below) that create a transparent process which directly links project goals with design elements to support stream functions. The process can be monitored to evaluate a project's outcome, which in this case is the functional uplift. This process was developed so that the SFPF or other similar frameworks can be easily integrated. *It is important to note that this process utilizes the SFPF but is distinct and separate from the actual SFPF*. The information generated from this project process should reflect the complexity of the project. Each project is unique such that the level of assessment should be proportional to the complexity and size of the site. Key elements (steps 1, 3, and 4) of this process provided the foundation for the workshop break-out group discussions.

Separate from, and prior to this project process, is a watershed-wide assessment of pollutant sources and impacts affecting watershed health. This assessment typically results in a set of recommended upland and stream restoration projects that considers impact, issues, and opportunities for restoration at the sub-watershed, neighborhood, and even site-specific scale. In many cases, local jurisdictions throughout the CBW have WIPs with an inventory of priority projects for implementation. The function-based process is then applied after a site is identified as a candidate or priority stream restoration project and does not have a design approach predetermined.

1. Programmatic and Design Goals – A successful stream restoration project must first have clearly articulated goals. The programmatic goal(s) is the 'big-picture' funding driver for a program or agency. Examples of programmatic goals include: TMDL pollutant load allocations, stream mitigation credits, restoration of listed or candidate species, addressing watershed needs based on a watershed management plan, species restoration for recreation (e.g., trout), and others. Programmatic goals can be linked to regulatory requirements, but can

be initiatives developed through voluntary efforts as well. The purpose of design goals are to document why the project is being proposed, while design objectives describe how it will be completed. The terms goals and objectives are often used interchangeably; however, there is a distinct difference when considering stream restoration. Goals are statements about *why* the project or effort is needed and are typically general intentions that often cannot be validated. Objectives are more specific and follow a functional assessment of the project reach as described below. The first use of established objectives determines which watershed parameters and stream functions will be assessed as part of the functional assessment.

2. Watershed Assessment – The purpose of this step is to determine watershed characteristics and limiting factors that may influence the proposed project area. The watershed assessment is separate from the broad-scale watershed planning process that recommends a set of priority upland and in-stream projects for restoration, or assessments used for alternative site analysis. It is critical that this broad assessment identify the historical root causes of degradation which are often overlooked. For instance, assuming stream incision is due solely to urbanization without considering the historical influences of mill ponds or dams could lead to design approaches that might not be appropriate. Typical watershed assessment parameters include: geology, soils, current and future land uses, land cover types, percent impervious surfaces, site and reach hydrology, etc. The project goals will determine which specific parameters will be assessed. For example, if the programmatic and design goals are to reduce nitrogen loadings to meet load reduction targets as part of the Chesapeake Bay TMDL, the watershed assessment would identify parameters affecting the delivery and processing of nutrients in the watershed. However, there will always be some parameters, such as hydrology, that will be assessed regardless of the project goals and objectives because of their importance in influencing watershed and stream health. This assessment will play a significant role in determining the restoration potential of the proposed stream project. This is accomplished by determining the watershed health and identifying constraints in establishing the cause and effect relationship between the watershed and the proposed restoration site. Specifically, how much do the watershed health and constraints contribute to the proposed site degradation issues and what functions can and cannot be restored at the reach level? For instance, in an ultra-urban environment salt from road clearing and excessive sediment from stream bank erosion may be co-limiting to aquatic life. Site level restoration might be able to address the sediment issue through floodplain reconnection. However, it would be unrealistic to expect improvements to aquatic life unless the chlorides were addressed. Results of the reach-level functional assessment should be used in combination with the watershed assessments to assist in the development of restoration plan alternatives.

3. Reach-Scale Functional Assessment – The purpose of this step is to establish the existing functional condition, determine stressors, and identify constraints at the project reach 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. A function-based parameter describes or quantifies the physical, chemical, and biological processes in a stream ecosystem. While assessment of a functional parameter is almost always preferred, a structural parameter may be used in its place to measure a function if it has been scientifically validated as a rigorous indicator. A functional parameter may not always be feasible due to project costs and timeframe constraints. The SFPF (Harman et al. 2012) provides examples of functional assessments and is described in Section 3 of this report. Expertise and technical understanding is required from multiple disciplines to complete the functional assessment. Measurement parameters and methods are listed to characterize an individual stream function and to assess if each is functioning, functioning-at-risk, or not functioning. The determination of these categories are typically based on local or regional thresholds developed for the measurement parameters, either drawn from research, local or regional reference[4], or in combination with professional judgment where data gaps are present. The project objectives will determine which specific function-based parameters will be assessed at the project site. However, in many cases, there are some parameters that will be assessed regardless of the project goals and objectives because of their importance in influencing stream functional condition. Four examples include: floodplain connectivity, bedform diversity, lateral stability, and riparian vegetation. Appendix A provides an example of a functional assessment table that displays the function-based assessment results.

4. Restoration Potential – The restoration potential, quantified through the functional-based project process, determines whether a project outcome is viable given the watershed conditions, the results of the function-based assessments, and the identification of constraints on recovery potential. This step determines the highest level of restoration that can be achieved and can also result in a shift in perspective or expectations for a project outcome. At this point in the process, the actual amount of functional lift will be determined. For example, the assessment may indicate that a stream reach has severely incised, extreme bank erosion, low bed form diversity, and no riparian vegetation. If this site is in a rural setting (low lateral constraints) within a healthy watershed, then the restoration potential is high because functional lift can likely be achieved for water quality and biological functions. However, if this same site is in an urban area or a setting with lateral constraints, like a road or in an agricultural area where cropland cannot be removed from production, then the restoration potential is lower because the functional lift may only occur for fluvial geomorphologic functions and not physicochemical and biological functions. The degree of functional loss or gain can be determined through this process to demonstrate if the project meets the "net gain" requirement of NWP 27 or to determine the degree of mitigation required.

5. Design Objectives – The purpose of this step is to establish design objectives based on the design goals, results of the functional assessment, and the actual determined functional lift.

[4] See Section V, Break-out Session 3 for a discussion on reference conditions as endpoints and their application to stream restoration projects.

Well-articulated goals and objectives establish a foundation for project success and will be used throughout the entire project process. The design objectives reflect the project goals but state specifically *how* the project will be completed. Thus, design objectives are quantifiable and measureable. For example, the project design goal may be to increase brook trout populations (i.e., SFPF Level 5), but the functional assessment showed that water temperatures were too high to support brook trout and the site was 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. The design approach could then be to plant riparian vegetation to shade the stream and reduce water temperatures. In an urban watershed, the design objective to plant a riparian buffer may be a viable solution to restore lost functions associated with excessive bank erosion. This same design objective may support design goals for nutrient reduction by attempting to explicitly link restoration activities to stream functions controlling nutrient processing by: 1) reducing nutrients from surface flows through infiltration to shallow groundwater or sedimentation of particulate P along flowpaths; 2) reducing nutrients from groundwater – hyporheic zone; or 3) increasing organic matter input to streams to support biological communities. In these examples, a functional-based assessment would be completed to identify the watershed stressor contributing to excessive nutrients and evaluate the critical functions necessary to support the project goals and objectives (e.g., reduce nitrate loading by 15%) and the extent to which restoring the riparian corridor alone can achieve them. It may be that adding design objectives for restoring floodplain connectivity needs to occur as well.

6. Restoration Design Approach & Design Alternatives Analysis – The purpose of this step is to determine the best restoration design approach that meets the project goals and objectives and the highest possible functional lift determined for the site. The Design Alternative Analysis should not be confused with the broad-scale watershed planning process described in the Watershed Assessment section described above. The focus should be on how a design approach could influence stream functions with a level of detail corresponding to the complexity and scale of the project. For example, given a well-articulated set of project goals and objectives, an alternative analysis may compare different design approaches or techniques with expected post-restoration conditions and simply include a narrative of why different alternatives were not used. The narrative or a more detailed analysis would document the highest functional lift that may be achieved for each design alternative, including impacts to existing function, 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.

7. Design Development – 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. A typical design set may

include: title sheet, existing conditions, proposed condition, longitudinal profile, structure details, erosion and sediment control, planting plan, grading, and existing and proposed cross sections.

8. Monitoring – The purpose of this step is to determine if the quantifiable project objectives are achieved and that existing functioning parameters remain functioning (i.e., implementation of a project does not cause further harm). It is critical that monitoring data be converted into information so that it can easily be used to demonstrate whether the project has met the project goals and objectives. This can be simply done by adding additional columns to the example functional assessment table mentioned in the Reach Scale Function Assessment section showing the monitoring results (as shown in Appendix A).

V. Summary of Breakout Group Discussions

One of the major outcomes of the workshop was to present issues associated with the stream restoration project process that have been identified in the scientific literature (See Section II) and local permitting issues identified by the regulatory agencies, and to offer tools (e.g., *Function-based Stream Restoration Project Process and SFPF* and/or similar frameworks) that can help address these problems. The workshop dedicated the second day to hearing feedback from the attendees on how these tools can be improved, modified, or if other tools were available that could be useful in developing a universally accepted Function-based Stream Restoration Project Process for sustainable stream restoration design.

Due to time limitations, breakout groups were asked to focus on three key elements (steps 1, 3, and 4) of the Stream Restoration Project Process. The breakout discussions focused on terminology and basic definitions associated with design goals, functional assessment parameter and restoration potential, along with their application for identifying stream functions relevant to urban and non-urban stream restoration projects.

Case study examples are provided in Appendix B for the programmatic and design goals, objectives, and measurement parameters and how they would align with the restoration of stream functions as defined by the Function-based Stream Restoration Project Process. ***However, it should be noted that the functions provided are examples and that other function-based assessment parameters may be used.*** This may be particularly important for biological functions such as nutrient processing, energy input (amount of sunlight or shading on the reach which determines food base), and biotic dispersal potential (arrival of colonists determined by connectivity to unimpaired waters). Ultimately, the use of a function-based process is to enable practitioners, researchers, and regulators to understand and articulate the explicit link between the purpose of the stream restoration project and the measurable outcomes that can demonstrate a change in the desired stream function.

Breakout Session 1 – Setting goals and objectives

Programmatic Goal – typically describes the funding driver for a program or agency.

Design Goal – describes the purpose of the project and does not need to be quantitative.

Design Objective – describes how the project goals are achieved and must be quantifiable.

Definitions for goals and objectives are provided in the box above. For the Function-based Stream Restoration Project Process, these goals and objectives are used once the proposed restoration site has been selected as an appropriate restoration site through some level of watershed-scale and reach-scale assessments. A common programmatic goal identified by workshop participants was the Chesapeake Bay TMDL, with a design goal to reduce nutrient and sediment loadings. With this goal, a manager would likely consider the most cost effective watershed-based or stream-based BMP to implement. In many situations, especially the urban built environment, a cost effective evaluation might favor a stream-based BMP, although most managers prefer a balanced approach. Since the driver is sediment and nutrient loadings, the degree of expected biological uplift would be limited since watershed-based limiting factors (e.g., chlorides) would not necessarily be addressed. However, improving stream functions associated with sediment and nutrient transport might be possible with site level interventions (e.g., floodplain reconnection). It is important to note that design goals are set after the reach-scale assessment has been completed and are based on the results of that assessment. Local TMDLs were also discussed as a programmatic goal, where a stream restoration project could be used to partially address the biological impairments of the 303(d) impaired waters, in cases where sediment had been identified as the main source of the impairment. Using a Function-based Stream Restoration Project Process, reductions in sediment is a subordinate objective to achieving the design goal of improving stream biological conditions. Further, as discussed later in this report, the selection of measurement parameters to measure the response of stream functions will be based in part by the identified stressors (e.g., legacy sediment vs. adjacent land use).

In urban areas, there are often multiple programs at work to secure funding, or to engage stakeholders that challenge the definition of project goals. For example, a TMDL may or may not be the local issue or program that identified the need for stream restoration, but may be the impetus to secure funding. Flooding issues or damaged infrastructure may engage local leaders and the public to support a stream restoration project that protects infrastructure and property. These driving factors may not align with the regulatory process to support permit approval without compensatory mitigation. Further, a goal to address the Chesapeake Bay TMDL versus the protection of natural resources or a stream restoration permit requirement of 'no net loss of habitat' can at times be in conflict with stream restoration projects. That is, the construction of a stream restoration project with a goal to specifically reduce stream bank erosion may temporarily remove riparian habitat. While the riparian corridor will be replanted as part of the stream restoration project, there may be a net loss in total habitat from the site as evaluated for permit approval. Beginning with the programmatic and design goal definitions to provide a rationale for stream restoration projects, the following steps in the Stream Restoration Project Process may help to articulate and communicate the specific trade-offs that may occur as an outcome of stream restoration. As a result, the Project Process should be used as a communication tool to articulate these different issues with stakeholders and to reach agreement on the need for the project, and its goals and objectives.

There were several discussions regarding how to translate goals into measurable objectives and examples were provided using reference conditions. The Maryland Biological Stream Survey (MBSS) scoring criteria for stream biological health is based on the reference condition approach where the criteria for "healthy biological communities" are based on biological sampling of relatively "pristine" streams. A conditional assessment of these pristine stream reaches can provide criteria for setting thresholds for critical stream functions. David Rosgen (Rosgen 1994) developed an entire design process based on the reference condition concept where the design objectives for unstable stream reaches are based on the probable evolutionary trajectory leading to a "stable" reach. Measurable design objectives are taken from stable reference reaches that are in similar valley types and have other similar hydrological and morphological characteristics. It was noted that reference conditions used for design objectives do not have to be based on idealized pristine conditions. For instance, Baltimore City developed an urban reference index (Mayhew 2001) based on the highest MBSS scores in urbanized areas. The restoration of valley bottom wetlands, as in the case of Big Spring Run in PA, is another example of a design objective where research is emerging that may inform the identification of key parameters and measurement methods to evaluate its success (PA DEP 2013).

Breakout Session 2 - Selection of function-based assessment parameters

A *functional assessment parameter* [5] expresses a rate that directly relates to a stream process or a structural assessment parameter, is representative of a function, and describes a stream condition at a point in time. The action of a stream restoration design is intended to change the condition or status of the function-based parameter. The selection of a parameter is linked to the design goals and objectives such that the rationale, or reason for generating data, is provided (i.e., answers the question: why are we measuring this stream parameter or function?) and prevents the collection of superfluous or meaningless monitoring data (i.e., data that do not help to evaluate if a stream function is restored or not). A commonly used assessment parameter is the Index of Biotic Integrity (IBI) to measure biological function of a stream reach, as it is a readily accepted and well-founded metric to assess stream health (Karr 1981; Barbour et al. 1999). However, there was some discussion and concern that using IBI or any other functional assessment parameter will not be able to show improvements due to stream restoration, where the functional uplift for the stream reach is limited by watershed conditions or site constraints.

[5] The use of the term "parameter" is specific to the definition provided in Harman et al. (2012) and does not reflect its commonly used definition as a numerical or other measurable factor.

Palmer noted in her presentation that over 300 metrics were identified in the synthesis of over 644 stream restoration projects (Palmer et al. 2014). In many instances, the monitoring data generated to quantify project outcomes were not aligned with project goals and objectives, and therefore could not effectively demonstrate that the project goal was met. While assessment of a functional parameter is almost always preferred, it is not always feasible due to projects costs, timeframe constraints, or even scientific measurement capabilities and indicators. In these cases, other structural parameters may be used as a surrogate. Typically, this refers to features that can be measured at a point in time like channel morphology, a standing stock of biomass compared to functions that capture processes, or changes over time in matter or energy.

Workshop participants discussed various function-based assessment parameters and suggested several that were thought to be critical. There was overwhelming support for the development of function-based parameters to characterize the role of organic carbon. Floodplain connectivity, lateral stability, bedform diversity, and health of riparian vegetation were also considered important functions. Examples of potential assessment parameters are provided in Table 4 and discussed in the breakout session on restoration potential.

A *measurement method* quantifies and describes function-based parameters. The measurement methods need to be tailored to the site conditions, rather than being prescriptive, such as those defined in permits. For example, floodplain connectivity may be measured using bank-height ratio, entrenchment ratio, or stage/discharge relationships. Bankfull measurements are needed to quantify the first two methods and may not be relevant in stream/wetland complexes where floodplain inundation occurs more frequently than a bankfull event. For this stream type, bankfull conditions are not as relevant or informative as the frequency in which flow inundates the floodplain; flood frequency would be a preferred measurement method. Therefore, given the various methods available to measure a stream function such as floodplain connectivity, it would be beneficial if measurement methods could be selected based on site-specific conditions, rather than specified in permits, as not all methods are universally applicable. The breakout sessions identified various function-based parameters, but did not necessarily identify associated measurement methods. Continued research is needed on developing methods to measure critical stream functions reflected by the function-based parameters. Furthermore, there was general concern that surrogate measures used to estimate stream functions (e.g., bank height ratio) need to be scientifically verified as well as the performance standards determining whether the measure is functioning, at risk, or non-functioning.

Table 4. Example design objectives and measurement methods for a stream restoration project goal to reduce nutrients and sediments. Additional examples provided in Table 2, Palmer et al. (2014).

Design Objective	Functional Assessment Parameter	Measurement Method
Increase carbon retention (groundwater, floodplain, in-stream) by a defined percentage.	Rate of organic matter (OM) accumulation (surrogate to measure metabolism).	Photographic documentation, physical habitat/debris counts; ratio of total available C: total C; method for metabolism TBD.
Increase nitrogen and sediment retention.	Flux of total N or TSS over time; decrease in peak discharge during storms is a reasonable surrogate.	Measure both discharge and concentration of N or TSS over time pre- and post-restoration or for surrogate, measure Q over time during multiple storms pre- and post-restoration.
Floodplain access during 1 year storm (function to redistribute materials).	Floodplain inundation recurrence interval, OM retention.	Flow gauging station data; stage recorder; groundwater wells in the floodplain; Hobo loggers for presence/absence of water in the floodplain.
Flow regime objectives can be determined from reference sites but a specific design objective was not given. There is a need to restore stream discharges/flows that would support higher level functions of water quality and biology (and OM accumulation, floodplain connectivity, and redistribution of materials).	Flow dynamics (rather than velocity), seasonal vs. annual, reduce peak discharge. Flow dynamics important to dissipate energy, floodplain connection, retention functions.	Flow gauging station data; stage recorder.
Reconnect groundwater/baseflow (important to address if groundwater is a major N source). It was difficult to find measurable objectives for this although indices of floodplain connectivity (recurrence interval, bank height ratio) could be used as surrogate parameters.	Hyporheic exchange and denitrification potential.	Lysimeters to measure water levels, DO levels to support denitrification.
Increase riparian vegetation (width, diversity) by a defined percentage.	Buffer width, groundwater levels within buffer (per Greg Noe/USGS research on the	Groundwater level, denitrification potential (indirectly, directly) as an

	importance of subsurface flowpaths and nutrient removal function of buffers). Parameter may vary (e.g., closed or open canopy) depending on the restoration (e.g., hardwood forest and wetland meadow). Diversity and quality of carbon source. Vegetation cover as a design objective needs to translate to specific types and forms of vegetation that would deliver the OM to the stream when needed; leaf litter studies have shown differences in deliver of OM to urban streams regarding timing and quality of C that results in less efficient or absolute lower processing rates of C (labile vs. recalcitrant).	indicator of biological processing. Include characterization of the type of C: coarse, fine, particulate, dissolved.

A performance standard refers to a benchmark against which actual performance is measured and is used to determine the status of a specific function (e.g., functioning, function-at-risk, not functioning). Functioning indicates that the measurement method is quantifying or describing one aspect of a function-based parameter in a way that supports a healthy aquatic ecosystem. Currently the Function-based Stream Restoration Project Process has not developed a scoring method for functioning, function at-risk, or not functioning, which participants highlighted as a research need. The lack of a scoring method that shows a continuum of performance levels can restrict the use of the Function-based Stream Restoration Project Process in demonstrating to regulatory agencies that functional lift will occur as a result of the project. However, the North Carolina Ecosystem Enhancement Program (EEP) is in the process of developing a function-based quantification tool in conjunction with Will Harman with Stream Mechanics.

The topic of performance standards was one of the major areas of discussion. The following key issues were brought forward by participants.

1) It needs to be acknowledged that both short- and long-term time frames are necessary to measure the response of a parameter due to restoration activity. Typically, the monitoring duration for permit requirements is 3-5 years and can vary depending on the complexity of the project, with additional requirements for catastrophic damage from extreme flood events. This timeframe may be sufficient to measure the outcomes for some lower level functional parameters, but it may not be sufficient for others. For example, floodplain channel

connectivity may improve as a result of the physical alteration within a year, while the equilibrium to achieve the bedform diversity may take longer, and macroinvertebrate communities even longer. In essence it may likely take multiple years of monitoring to show the intended outcome of a project for higher level goals. The ability to fully evaluate the response of hydrologic functions may also take multiple years depending on the annual precipitation patterns (e.g., evaluate under a range of storm events). To date, biological improvement using some diversity or IBI metric has rarely been found with short-term (1-5 yr) assessments of urban stream restoration projects and thus biological assessments over a longer time period are required.

2) The performance standards or benchmarks should be representative of local reference conditions. However, stream permit reviewers are often looking for commonly accepted performance standards based on benthic biology (a Level 5 function in the SFPF). A project process approach that defines parameters and thresholds on individual site conditions may challenge regulatory processes that do not 'flex with the science', or do not change as quickly. In some cases, if there are no resource tradeoffs or testing of an innovative design approach, monitoring for stream stability may be sufficient to the permitting agency. In other cases where resource tradeoffs may exist, performance standards may be lacking for certain functions because of limited research. Palmer advocated for a way to apply adaptive management in the regulatory arena and stated that this is complicated because the regulatory process generally works on finite endpoints and adjustments to these endpoints take many years. As a step towards an adaptive management approach, the PADEP has advanced the use of reference communities based on 'real-world' conditions to use as potential biological endpoints (PADEP online). The reference communities provide a profile of conditions that allows some adaptive capabilities.

3) The ability to agree upon or define a reference condition is central to identifying and then quantifying the performance standards for the function-based assessment parameters. It is critical that the selection of a reference condition correspond with the resource potential achievable given watershed constraints. While pre-colonial or pre-distributed conditions or functions are typically referred to as restoration endpoints, they may not be the goal of the project. The reference or historical condition for which the restoration is targeted is a debatable issue among scientists, practitioners, and regulators. Central questions to ask to define a reference condition are, "What history is reviewed and what future conditions are evaluated to define a realistic outcome for stream restoration and to what degree do the limiting factors and site-specific stressors impact restoration potential and the project design? In the article "*What is a Natural River?*" Wohl and Merritts (2007) discuss how the current state of a river reflects a long history of human disturbances and how our current understanding of this influence may limit actions taken for stream restoration. While visual indicators of eroded streambanks are far-telling of legacy sediment, to what degree can the current urban, developed watershed be restored to a pre-disturbed era that may or may not be representative of pre-colonial times? While restoring the functions of a pre-colonial stream

may not be possible given the modern environment, is it possible to restore the functions to those of an earlier period? If so, how would those streams be defined?

Breakout Session 3 - The determination of restoration potential/functional lift and constraints/limiting factors

Restoration potential is the highest level of restoration that can be achieved on a given stream reach. Conceivably, this could include enhancing functions above what may have existed "naturally" as in the case of creating floodplain wetlands where none existed previously. This example may align more with the regulatory definition of stream enhancement rather than restoration, as defined in Section 3. For a given function, the process for determining restoration potential starts with project design goals and proceeds through the project process. If the project design goal is only to achieve channel stability, then any restoration potential (e.g., biological) beyond stability need not be determined, nor expected. After the desired level of restoration is set and reference performance conditions are identified, the potential to achieve that level is based on watershed conditions that identify stressors to the stream and how they may be affected by stream restoration, project constraints, and limitations to recovery potential that cannot be overcome.

The determination of realistic restoration objectives by a practitioner, scientist, or a regulator faces the same challenges as determining whether a stream function is healthy or not. As previously described, the Function-based Stream Restoration Project Process uses the categories functioning, functioning at risk, or not functioning. However, participants discussed the need for a continuum of stream functioning categories. Generally, workshop participants agreed that functional uplift in urban areas may be more limited than in rural areas due to encroachment and infrastructure constraints common to urban stream corridors, and because common water quality problems must be addressed at whole watershed scales (Smucker and Detenbeck 2014). However, participants were not in agreement to limit restoration potential just because it is urban, or considering a project a failure because it did not achieve currently accepted standards for biological uplift based on least disturbed sites (e.g., based on MBSS reference sites). This is where having a continuum of performance standards would be useful such as the Urban Reference Index created by Baltimore City (Mayhew 2001). While it was debated if higher level functions are more realistic for stream restoration in agricultural or rural watersheds, participants acknowledged that the biological recovery of streams is a long-term process that may require longer periods of record to identify a positive outcome, compared to lower level geomorphic parameters, for example.

The project design approach to define the restoration potential does not have to conflict with existing permitting requirements to achieve a net increase in aquatic resource function, such as the NWP 27 permit. For example, a biological lift from "very poor" to "poor" is still a lift, and if the potential of the site was only "poor", then the project was still considered successful. A function-based assessment, such as Step 3 described in the Function-based Stream Restoration Project Process, can list the stream functions and assessment methods used to evaluate the physical, chemical, and biological restoration potential of a given stream reach. This approach appears to be consistent with permit application requirements, but may need supporting information on how the terms and conditions of the NWP 27 are met, including how the project will achieve a net increase in aquatic resources functions and services over the existing conditions. This approach, however, will need to be reviewed and acknowledged as acceptable by the permitting authorities, if it is to achieve wide-spread usage by permitees. The challenge outlined by workshop participants is to determine the restoration potential in urban, agricultural, and forested watersheds and how stressors in the watershed may limit functional uplift. The five stream function levels (Table 5) and a set of commonly identified limiting factors would be quantified as part of a function-based assessment for urban and agricultural watersheds. The next step in the design process is to select a design approach that would best address manageable constraints for achieving realistic restoration and/or enhancement.

Table 5. Example functions and constraints that may limit restoration potential in urban and agricultural watersheds.

Urban watershed	Agricultural watershed
Hydrology - Stream flashiness. If a stream is restored, it should be resilient from increased flashiness. The problem is that in an urban stream, there may not be space for floodplain reconnection. Flashiness can blow out a stream restoration project if the large to extreme events are not accounted for in the watershed. **Hydraulics** - Scouring from excessive velocities causing head-cuts and bank erosion. **Geomorphology** - Confinement (physical constraint such as infrastructure), lack of vegetation. **Physicochemical** - Polluted runoff, temperature. **Biology** - Deer, invasive species, inadequate forage fish. **Other** - Projects are more expensive in urban areas, so that may be a constraint. Additional constraints may be public access and visibility, and land ownership and politics.	**Hydrology** - Drainage (tile and drainage ditches), irrigation. **Hydraulics** - Inadequate floodplain connection, risk of flooding neighboring properties. **Geomorphology** - Fencing constraints, inadequate riparian vegetation. **Physicochemical** - Water quality (fertilizer/manure application), legacy nutrients, and cattle access. **Biology -** Non-functioning stream buffer. **Other** - Upland land use affecting the project reach (livestock access), agricultural use of the land vs. stream restoration (economics for the farmer, commodity pricing), ownership (owners vs. rental farmers), duration of protection, land use legacy.

VI. Findings and Recommendations

Stream restoration is an evolving field of study that has the potential to significantly improve (i.e., enhance, restore) the biological, physical, and chemical functions of streams throughout the United States, and specifically the CBW. For the purposes of this report, stream restoration is used in general terms to include activities that improve or restore lost or impaired stream functions, that may or may not result in a gain is aquatic resource area or net functional gain to meet one of the regulatory definitions for stream enhancement, restoration, or rehabilitation. The Habitat Goal Implementation Team of the CBP convened this workshop to provide guidance to the development of stream restoration projects within the Bay watersheds that can create the functional lift needed to restore health at the local level and not solely focus on nutrient and sediment reductions needed at the Bay level. Key to this successful outcome is generating an understanding and agreement on the major elements of stream functions that will allow stream restoration practitioners, researchers, and the regulatory community to implement sustainable stream restoration projects. The workshop proposed a Function-based Stream Restoration Project Process to generate discussion that formed the basis for the key workshop findings and recommendations.

Findings

1. Overall, there was general agreement that the identification of stream functions should guide the restoration process, and that the design and implementation of projects should include well-articulated goals, design objectives, and measurement parameters that can be used to answer the question – *Have the defined functions of a stream been improved and to what degree?* It was debated whether the science is available to answer this question given the disparate datasets that currently exist to assess stream restoration projects. In part, the inconclusive answer to this question in most studies results from the lack of a function-based framework and monitoring that limits stream restoration stakeholders' ability to assess the effectiveness of projects. While the two-day workshop limited the opportunity for participants to reach agreement on a unified function-based process, there was general agreement on the merits of a function-based stream restoration design process, which is a useful starting point for future discussions.

   Workshop participants identified benefits that a function-based process could have for designing and implementing stream restoration projects which included: its potential to document the increase, or uplift, in stream functions and as a valuable communication tool that can help managers and the public understand restoration potential, set realistic restoration objectives accordingly, and plan for short- and long-term monitoring to effectively evaluate outcomes.

2. Baywide, there is a significant investment being made by the Bay States and District for stream restoration and enhancement to meet numerous restoration goals and objectives such as total nitrogen, total phosphorus, and sediment reductions to achieve the TMDL targets.

While the TMDL may be a programmatic goal or driver to implement a stream restoration project, workshop participants discussed the need for a baseline list of critical functions and assessment parameters that would support and make this programmatic goal more sustainable. Further work to define critical functions, metrics, and methods of assessment are needed but were not the objectives of the workshop.

3. Workshop presentations and discussions presented a number of functional and structural assessment parameters to assess stream functions. Many of the critical stressors (e.g., flow regime and water quality) are attributed to watershed activities and are accounted for in the watershed assessment phase of the stream restoration project design process. However, to further elucidate the interconnectedness of stream functions controlled by the watershed to those within the riparian corridor (e.g., effect of low impact development on hydrology), additional well-defined research studies are needed to generate data that can relate techniques (i.e., stream manipulation) that are designed to restore stream functions with watershed processes. Furthermore, since one of the objectives of the function-based stream design process is to promote better communication among all restoration stakeholders, workshop participants agreed that providing better descriptions of the interconnectivity of watershed and stream processes is essential (i.e., what is the context of the stream reach within the watershed?).

4. The monitoring requirements for stream restoration projects should be identified through a framework that links science-based understanding of stream processes and functions with project goals, objectives, and measurement parameters. Monitoring data may be more usable to evaluate the effectiveness of projects to restore the identified stream functions through pre- and post-implementation monitoring. If the project goal is not to restore local biological function, but rather to reduce in-stream sediment loadings downstream, then the generation of data such as the IBI would not be useful in evaluating the success of a project. However, as sediment is a leading cause of biological impairments for local TMDLs, the reduction in sediment may lead to an improvement in biological communities in the longer term after implementation, providing that other critical functions to support stream biological functions have been restored. For many permits, it is typical that the monitoring requirements focus largely on channel stability and/or biological metrics without making connections to stream functions or project goals and objectives. However, stream stability monitoring may only be required if there are no aquatic resource function trade-offs as a result of the project.

   While functional parameters are preferred, participants agreed that the selection of function-based parameters may be limited by scientific capabilities, or the ability to define performance standards for a successful BMP do not always have to match performance standards to meet regulatory requirements. Therefore, the use of structural parameters or even indices may be needed as surrogates for stream functions if scientifically justified. An example set of critical functions provided by workshop participants for which monitoring data may be useful to evaluate stream functions include:

a) Carbon retention;
b) Nutrient and sediment retention;
c) Floodplain and hydrologic connectivity;
d) Lateral stability;
e) Bedform diversity; and
f) Riparian corridor cover.

5. For any given stream restoration project, there are uncertainties in the application of even the best stream restoration science, which includes some level of risk that implementation may not achieve its restoration objectives. Considering that stream restoration science and design continues to evolve, the desired ecological endpoint for any given project may also evolve throughout the project life and through feedback from monitoring of the relevant function-based parameters. In short, the understanding of stream process functions and the interrelationship with the watershed will continue to advance with implementation in the field.

   Workshop participants agreed that in most cases, there is sufficient information (e.g., assessment parameters and measurement methods) to assess lower level restoration potential (i.e., hydrology, hydraulics, geomorphology) while greater uncertainty accompanies the predictive capability of stream restoration techniques to achieve higher functional uplift (i.e., physiochemical and biological attributes). The fact that longer time periods may be needed to show sustainable biological uplift for an individual project should not necessarily be a reason to reject a permit application during the review process. Participants supported efforts to monitor a full range of stream restoration projects in all relevant physiographic regions to continue to build datasets to evaluate long-term stream restoration project outcomes.

<u>Recommendations</u>

1. Stream restoration projects should be part of an overall watershed strategy. The context of the watershed occurs at two different stages of stream restoration projects. First, a broad-scale watershed planning effort provides a set of recommended priority upland and in-stream sites for restoration and/or an assessment to be used for alternative site analysis. Examples of watershed plans include: EPA 319 watershed planning efforts, TMDL implementation plans, and WIPs. The second type of assessment (at the reach level) identifies watershed characteristics and limiting factors that may influence the proposed project area – after the stream project site is selected – and will play a significant role in determining the restoration potential of the stream reach. This is accomplished by identifying constraints to establishing the cause and effect relationship between the watershed and the proposed restoration site. Specifically, are the watershed health and constraints contributing to the proposed site degradation issues? Results of the reach-level, function-based assessment will be used in combination with the watershed assessment to assist in the development of restoration/enhancement plan alternatives.

2. The CBP's Stream Health Workgroup, or another vested party, should adopt the proposed Function-based Stream Restoration Project Process as a starting point to develop a unified process, and work with the Partnership to facilitate the development of proposed guidance. The guidance documents and checklists developed by the USFWS under contract with MDE (Starr and Harman 2015) may serve as a template to begin these discussions because these documents follow the Function-based Stream Restoration Project Process presented and discussed at the workshop. In addition, the PADEP has developed similar methodologies to integrate stream functions into their approval process. The organization that advances the adoption of a function-based process should coordinate with these existing efforts.

   There was general agreement from workshop participants that a science-based, methodological process is needed to clearly define project goals and objectives that lead to the identification of measurement parameters to evaluate the restoration of stream functions. The function-based process would include both watershed- and reach-scale assessment procedures (previously described) to identify the limits and opportunities to restore identified stream functions.

3. Monitoring efforts should be more focused to enhance stream restoration science and implementation. For instance, there is a need to develop a baseline list of critical stream functions and assessment parameters to monitor the effectiveness of stream restoration to support the programmatic goal of the Chesapeake Bay TMDL, which is currently driving many stream restoration/enhancement projects.

   It is recommended that a monitoring consortium or framework be developed that would pool monitoring resources and address key research issues such as critical stream functions, intermediate functional standards, and a continuum of risk, at-risk, or non-functioning performance standards. The adoption of a pooled monitoring approach would work with researchers, practitioners, and the regulatory agencies to review monitoring needs to evaluate restored or enhanced stream functions. During the summer and fall of 2014, an *ad hoc* committee represented by regulatory agencies (USACE, MDE, FWS), state and resource agencies (MDE, SHA) and stream organizations (MSRA) was coordinated and led by the Chesapeake Bay Trust to explore and begin development of a pooled monitoring approach. Data generated from Big Spring Run, PA (PADEP 2013) may also advance the development of performance levels for stream geomorphic functions.

   Overall, monitoring data generated from stream restoration projects should have the potential to demonstrate restored steam functions. The participants agreed that the existing monitoring requirements needed for permits were not necessarily sufficiently robust to assess the full breadth of stream functions (e.g., current monitoring focus on stream stability, how well is this rock vane performing?). It was also acknowledged that permit monitoring requirements are prescribed based on the presence/absence of aquatic resource tradeoffs and may not require monitoring data beyond stream stability. Pooled monitoring to address specific research questions should be pursued.

4. The Urban Stormwater Workgroup and the Stream Health Workgroup should coordinate efforts to develop guidance (e.g., via an expert panel) to align how the restoration/enhancement of stream functions translates to nitrogen, phosphorus, and sediment 'credit'. The CBP recently approved recommendations to credit stream restoration projects along with guidance to verify and report stream restoration as a BMP. The guidance would discuss how stream restoration BMP protocols[6] fit within a functional framework for stream restoration design, as well as verification guidance[7] such that post-construction assessments can verify that the project is meeting minimum performance standards to warrant the interim or full rate reductions.

In addition to the key findings and recommendations from the workshop, there were additional ideas shared by the workshop participants deemed as necessary, actionable steps to achieve sustainable stream restoration projects. For example, participants suggested that data generated from pooled monitoring efforts be compiled into case study examples based on design approaches, watershed characteristics, and physiographic provinces. This set of urban case studies should define reference sites and conditions for stream restoration in highly developed areas. It was noted during the breakout sessions that current and future land uses, in both urban and agricultural watersheds, contribute to a number of constraints that may limit the potential to restore a stream to a natural or historical state. However, participants were hesitant to strictly consider land use as a means of defining the restoration potential for functional uplift in urban areas given the site-specific and watershed conditions and evolution of design techniques. Further, workshop participants stated that there is a continued need for a workshop or other forum to address the site selection and alternatives (site/approach/design) analysis with the practitioners, academics, regulators, WIP developers, and funding organizations. The purpose of the workshop would be to generate a common understanding and baseline of information to present in permit applications and to encourage high quality proposals that would be both consistent with permitting guidance and the function-based framework.

Dissenting Opinions Expressed During the Report Review

1. Although one state agency agreed that the function-based type of process has value and could be developed into a useful tool, it cautioned that the Function-based Stream Restoration Project Process does not address the critical parts of the process that place unrealistic expectations on projects, and are counter to resource protection laws and may do more harm

[6] The Chesapeake Bay Program Water Quality GIT approved the Stream Restoration Expert Panel Report Recommendations September 8, 2014
[7] Chesapeake Bay Program approved, "Strengthening Verification of Best Management Practices Implemented in the Chesapeake Bay Watershed: A Basinwide Framework" August 14, 2014

in the long term than benefit to the resources and broader watershed. Of particular concern that re-occurred throughout the workshop was the haphazard use of terminology that can have very specific meaning in the regulatory programs. First was the use of the term "restoration". STAC members and workshop participants should be reminded that under the 2000 Bay Agreement, all signatories agreed to terminology that was defined by the Federal Geodetic Data Commission (FGDC) and this includes federal agencies except the U.S. Department of Agriculture. The terminology used in the 2008 Mitigation Rule uses the same definitions. What most workshop participants discussed was not restoration but enhancement activities. This document should restate this difference and the community commit to that terminology. This will substantially improve framing the discussion in a common language that will allow further refinement of an acceptable process.

Management Committee's Response: We believe that this criticism of the stream restoration design process might have been misdirected because of the examples of its use and not the process itself. This is especially true in examples where functional assessments may not have adequately addressed historical stressors (which are a major criticism from this same agency). Also, for many of the functions, the performance standards to determine if a function is functional are based on best professional judgment because of limited science. Therefore, the use of this process with imperfect science could lead to unrealistic expectations. Further, we agree that the use of the expression "stream restoration" generated a tremendous amount of controversy as almost every example of "stream restoration" that was discussed in the workshop fits the Mitigation Rule's definition of "enhancement" and not restoration. While this was discussed at the workshop, several references were made to the regulatory definition associated with restoration in this document.

2. Workshop participants agreed that functional approaches should be taken. However, not all of the metrics in Harman et al. (2012) and presented at the workshop are the best way to measure functions or that the performance standards for many of the function-based standards are based on science. The workshop steering committee does not want this report to suggest that the pyramid concept has now reached the level of a protocol for assessment and that this workshop led to a full-scale endorsement by the participants.

Management Committee's Response: The focus of the workshop was to gain consensus on the stream restoration design process which uses the SFPF to show how the process works. One of the workshop goals was to identify other functions and metrics for measuring those functions besides the examples provided in the SFPF document. It is recognized that not all of the participants are in agreement with the metrics that were used (e.g., natural channel design metrics). However, the workshop's intent was to use these metrics as an example of how the design process can be used.

3. Regarding permit requirements, improving water quality should not be the primary goal for a stream restoration/enhancement project. Water quality goals should be the result of many

restoration projects over a broad watershed basis. The primary goal of stream restoration/enhancement should be to restore or enhance a resource by addressing the degradation causes at the reach scale, which would result in a stable, dynamic system performing ecosystem services at levels that are within the natural/optimum ranges of the resource without resulting in degradation to the restored resource. Anything else is enhancement and transformation of a resource to a BMP which may result in long-term resource degradation and violate anti-degradation requirements.

Management Committee's Response: The workshop did not endorse "water quality" as a stand-alone goal of stream restoration. However it recognized that the WIP strategies identified stream restoration as one of the BMPs to meet the TMDL goals along with other watershed-based BMPs. While the use of stream restoration as a "BMP" to help meet TMDL targets can be controversial, the workshop focused on the design process once a decision has been made to move forward with a stream restoration project.

4. The steering committee is not satisfied that the workshop resulted in a final product or process. It highlighted that many practitioners do not understand the full meaning of much of the terminology as it relates to regulatory program requirements. Many do not understand the distinctions and differences between programmatic goals (TMDL) and local reach project development procedures. The lack of discussion, understanding, and unabashed use of current land use to establish degradation highlights why regulatory program evaluations need to remain a rigorous process. This will ultimately drive the advancement in understanding watershed- versus reach-scale degradation, and differences between water chemistry problems versus structural deficiency caused by anthropogenic manipulation of the resources.

Management Committee's Response: We recognize that terminology was one of the biggest challenges faced in the workshop, especially regarding the regulatory definitions of "restoration". The issue regarding the use of current land covers to establish degradation causes is also an excellent point which has been captured in this report. The problem that this causes is not a reflection of the stream restoration design process which was the focus of the workshop. Rather, the issue identifies the misuse of the design process by incorrectly identifying the root cause of the degradation which could result in restoration approaches that are ineffective.

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Appendix A: Example Functional Assessment Table

Column1 (Level and Category) displays the functional category of the parameters being assessed. Column 2 (Parameters) displays the function-based parameters being assessed. Column 3 (Measurement Methods) displays the methods used to quantify the function-based parameters, as well as measurements. The case study examples in Appendix B provide example measurement methods for selected function-based parameters. Columns 4 and 5 (Pre-Restoration Value and Rating) contain the quantitative value of the function-based parameter that was derived from the measurement methods and functional rating. Columns 6 and 7 (Post-Restoration condition Value and Rating) display the predicted function-based parameter value and functional condition. For ease of reading the results, color coding is used to display functional conditions of function-based parameters. Green means the stream is functioning; yellow means functioning at risk; and red means non- functioning.

Table Definitions:

HEC-RAS (Hydrologic Engineering Center, River Analysis System) is the U.S. Army Corps of Engineers hydraulic model which is used to show stage-discharge relationships for a wide range of return intervals.

Belt width is the average width of the meander path of the stream. The belt width is measured from the apex of one meander bend to the next meander bend, measured perpendicular to the stream valley.

W/D is the stream width (W) to depth (D) ratio. $W/D_{proj}/W/D_{ref}$ is the ratio of the project W/D ratio and that from a reference stream.

Stream power is the ability of the stream to do work, where work is defined as the conversion of potential energy (elevation change) to kinetic energy, and is calculated as the product of the specific weight of water, discharge, and slope.

Level and Category	Parameter	Measurement Method/Measurement	Pre-Restoration Condition		Post-Restoration Condition	
			Value	Rating	Value	Rating
1 - Hydrology	Runoff	HEC RAS	Similar to reference watershed	Functioning	Similar to reference watershed	Functioning
	Flow Duration	HEC RAS	Similar to reference watershed	Functioning	Similar to reference watershed	Functioning
2- Hydraulics	Floodplain Connectivity	Bank Height Ratio	1.5	Not Functioning	1.0	Functioning
		Entrenchment Ratio	1.73	Not Functioning	>2.2	Functioning
3 – Geomorphology	Bed Form diversity	Pool-to-pool spacing	1.5 to 9	Not Functioning	4 to 5	Functioning
		Pool Depth Variability	2.0 to 3.0	Functioning	2.0 to 3.0	Functioning
		Riffle Length to Riffle Width	2.9 to 4.3	Functioning	3 to 5	Functioning
		Riffle Slope to Reach Slope	1.2 to 3.9	Functioning at Risk	1 to 2	Functioning
		Pool Slope to Reach Slope	0.3 to 0.6	Functioning at Risk	0.2 to 0.3	Functioning
		Rosgen	F → C → E	Functioning at Risk	E	Functioning
	Channel Evolution	Simon	Not Functional	Not Functioning	Functional	Functioning
	Riparian Vegetation	Buffer Width based on Belt width	0	Not Functioning	300	Functioning
		BEHI/NBS	Mod / Low	Functioning at Risk	Low/Low	Functioning
	Lateral Stability	Lateral Erosion Rate	0.09 yr/ft	Functioning	<0.01	
		Confinement	0.69 to 1.14	Functioning	>1.0	Functioning
		Meander Width Ratio (MWR)	2.4 to 4.0	Functioning	>3.5	Functioning
		W/D_{proj} /W/D_{ref}	1.4	Functioning at Risk	1.0 to 1.2	Functioning
		Wavelength to Riffle Width	9 to 14	Functioning	7 to 14	Functioning
4 – Physicochemical	Temperature	Temperature probe for one year every 15 minutes	Higher than upstream reference reach; does not meet species requirements	Not Functioning	Same as upstream reach and meets species requirements	Functioning
	pH	pH probe for one year every 15 minutes	6.0	Functioning at Risk	6.8	Functioning
5 – Biology	Macroinvertebrate Communities	VDEQ Biological Inventory	Moderate to slightly Impaired	Functioning at Risk	Not Impaired	Functioning
		Maryland Biological Stream Stream (MBSS)	3	Functioning at Risk	5	Functioning
	Fish Communities	MBSS	3	Functioning at Risk	5	Functioning

Appendix B: Case Study Examples

Programmatic Goal: USFWS Trout Species		
Design Goal: Increase Brook Trout Populations		
Watershed Condition: Primarily Forested		
Function-based Assessment Parameter	**Measurement Method**	**SFPF Level**
Floodplain Connectivity	Measure bank height to provide data to define bank height ratio	LVL 2 – Hydraulic
Flow Dynamics	Velocity meter for instantaneous measurements of velocity	LVL 2 - Hydraulic
Flow Dynamics	Measure flow and stream geomorphology (i.e., stream slope) to calculate stream power	LVL 2 - Hydraulic
Lateral Stability	Use of bank pins to estimate bank migration/lateral stability	LVL 3 – Geomorphology
Bedform Diversity	Measurements of pool spacing and depth	LVL 3 - Geomorphology
Riparian Vegetation	Species count to determine species composition and diversity Measure riparian width (e.g., 35' wider beyond required MWR)	LVL 3 – Geomorphology
Water Temperature	Thermometer, 11 – 16°C	LVL 4 – Physicochemical

Programmatic Goal: Channel Stability to protect infrastructure		
Design Goal: Reduce lateral and vertical erosion		
Watershed Condition: Mixed Used (forested, residential, agriculture, commercial)		
Assessment Parameter	**Measurement Method**	**SFPF Level**
Floodplain Connectivity	Flood frequencies	LVL 2 – Hydraulic
Flow Dynamics	Measurement of bank height characteristics to provide an entrenchment ratio	LVL 2 – Hydraulic
Flow Dynamics	Measure flow and stream geomorphology (i.e., stream slope) to calculate stream power	LVL 2 – Hydraulic
Bedform Diversity	Pool Depth Variability	LVL 3 – Geomorphology
Lateral Stability	Bank pins to estimate lateral erosion rate	LVL 3 – Geomorphology
Riparian vegetation	Measure buffer width and species composition	LVL 3 – Geomorphology

Programmatic Goal: TMDL		
Design Goal: Reduce nutrient loads		
Watershed Condition: Mixed Used (forested, residential, agriculture, commercial)		
Assessment Parameter	**Measurement Method**	**SFPF Level**
Floodplain Connectivity	Flood Frequencies	LVL 2 - Hydraulic
Floodplain Connectivity	Entrenchment Ratio	LVL 2 - Hydraulic
Flow Dynamics	Stream Power	LVL 2 - Hydraulic
Bedform Diversity	Pool Depth Variability	LVL 3 - Geomorphology
Lateral Stability	Lateral Erosion Rate	LVL 3 - Geomorphology
Riparian vegetation	Measure buffer width and species composition	LVL 3 - Geomorphology
Suspended Sediment	Collect grab or continuous water samples	LVL 4 - Physicochemical
Nitrogen	Collect grab or continuous water samples	LVL 4 - Physicochemical
Phosphorus	Collect grab or continuous water samples	LVL 4 - Physicochemical

Appendix C: Workshop Agenda

Scientific and Technical Advisory Committee
May 6-7, 2014
Workshop Agenda
Sheraton Hotel, Annapolis, MD

Designing Sustainable Stream Restoration Projects within the Chesapeake Bay Watershed:

Workshop Objective: Create agreement among practitioners, regulators, and scientists on a common language and assessment methods for designing sustainable stream restoration projects that improve the functional elements of stream health to address water quality, climatological impacts, physical, and biological components within the stream and adjacent riparian zone.

Description of Workshop:
There is a need to create understanding and agreement among practitioners on a common language and methods for designing sustainable stream restoration projects that improve the functional elements of stream health to address water quality, climatological impacts, physical, and biological components within the stream and adjacent riparian zone. Understanding and agreeing on the major elements of stream function will allow stream restoration practitioners to create functional lift and sustain the biodiversity of riparian ecosystems and aquatic organisms during stream restoration. This common understanding on language, methods, and major elements of stream function is also intended to assist the regulatory community to better understand restoration efforts undertaken to implement the Clean Water Act.

This workshop will specifically target stream restoration practitioners, regulators, and scientists who are designing, building, permitting or studying stream and riparian ecosystems. The workshop will address:

1) Creating a common understanding and common language among restoration practitioners, regulators, and scientists;
2) Establish a uniform process for characterizing the degree of functional lift and/or loss of biological, chemical, and physical processes associated with the various stream restoration approaches; and
3) Engage the stream restoration community within the Chesapeake Bay watershed and provide a document from which to continue to build a consensus and guidance on stream restoration that will help to facilitate the implementation of the TMDL WIP Strategies.

It is important to note that the focus of the workshop is at the restoration site level. All discussions and recommendations will be on what should happen at a specific restoration site and not how that site was selected or on what other watershed restoration activities should be *undertaken. While prioritization of site locations and restoration activities are critical in the success of restoring a watershed, this workshop will focus on what should happen at a stream restoration site after it has gone through this prioritization process.*

The workshop planning committee has drafted a "straw man" of a stream restoration uniform process. The "straw man" process follows typical stream restoration processes used currently, but focuses on function-based assessments and the use of quantifiable objectives throughout the entire project process, including monitoring. The "straw man" consists of four broad steps: 1) setting goals and objectives, 2) selecting function-based assessment parameters, 3) determining restoration potential, and 4) translate into design objectives and monitoring performance standards. A brief description of this process along with additional steps as described in the attachment, entitled "Function-based Stream Restoration Project Process." The workshop is centered on receiving feedback from workshop participants on this "straw man" process. The first part of the workshop will be presentations that provide background information and definitions of the common terms used in the "straw man" process. Then there will be breakout sessions where workshop participants will have the opportunity to discuss each broad step in the "straw man" process. Each group will then report out the results of their discussions to all workshop participants. The workshop will close by discussing research needs and next steps. Ultimately, all of the information gathered from the workshop will be made into recommendations on what and how a uniform stream restoration process should be developed.

AGENDA AT A GLANCE	
9:00 to 9:15	Welcome and Introduction
9:15 to 11:15	T-1: Setting the Stage - The Need for Stream Function Assessments
11:15 to 11:30	Break
11:30 to 12:30	T-2: Organization of Stream Functions into a Framework - Assessment Parameters, Measurement Methods, and Performance Standards
12:30 to 1:30	Lunch
1:30 to 2:30	T-3: Application of Stream Functions Pyramid Framework
2:30 to 2:45	Break
2:45 to 4:45	T-4: "Straw man" Function-based Stream Restoration Project Process
4:45 to 5:00	Recap
8:30 to 9:00	Day 2 Overview and Instructions
9:00 to 10:00	T-5: Setting Goals and Objectives and Identifying Problems
10:15 to 10:30	Reconvene for T-5 Report Out
10:30 to 10:45	Break
10:45 to 12:30 Lunch 1:30 to 2:30	T-6: Selecting Function-based Assessment Parameters, Measurement Methods, and Performance Standards
2:30 to 2:45	Reconvene for T-6 Report Out
2:45 to 3:45	T-7: Determining Restoration Potential and Functional Uplift
3:45 to 4:00	Reconvene for T-7 Report Out
4:00 to 5:00	T-8: Synthesis Session. Research need and Next Steps

DETAILED AGENDA
DAY 1

Welcome and Introduction (15 minutes)
Nick DiPasquale (Director, Chesapeake Bay Program) and Bill Stack (CWP/CBPO)

Track 1: Setting the Stage - Stream Functions - Margaret Palmer (SESYNC), Jack Dinne (ACE), Bill Seiger (MDE), Dave Goerman (PADEP)
Track Recorder: S. Drescher (CWP)
Track Length: 2 hours

Track Purpose and Outcome: Demonstrate and educate on the need for common language and assessment methods for designing sustainable stream restoration projects

1. Overview from synthesis of stream restoration projects. (Margaret Palmer) (50 min)
    a. What does it mean to restore a stream?
    b. Case studies and link to goals, requirement (as applicable), methods of assessment, and outcomes.
    c. Overview of assessment approaches

2. Regulatory Issues associated with stream restoration (Jack Dinne, Bill Seiger, and David Goerman) (70 min)
    a. Federal
    b. State

Track 2: Organization of Functions into a Framework, Objectives, Assessment Parameters, Measurement Methods, and Performance Standards - Will Harman (Stream Mechanics)
Track Recorder: Lisa Fraley-McNeal (CWP)
Track Length: 1 hour

Track Purpose and Outcome: Introduce Stream Functions Pyramid Framework and define common terms within framework

1. Organization of stream functions into a hierarchical order: Hydrology, Hydraulics, Geomorphology, Physicochemical, and Biological
2. Assessment parameters
3. Measurement methods
4. Performance standards

Track 3: Application of Stream Functions Pyramid Framework - Will Harman (Stream Mechanics)
Track Recorder: Lisa Fraley-McNeal (CWP)
Track Length: 1 hour

Track Purpose and Outcome: Provide a stream restoration process following the Stream Functions Pyramid Framework.

1. How to apply stream functions and goals and objective setting to stream restoration projects.

Track 4: "Straw man" Function-based Stream Restoration Project Process

Track Facilitator: Rich Starr (USFWS)

Track Recorder: Reid Christianson (CWP)

Track Length: 2 hours

Track Purpose and Outcome: Introduce the "straw man" Function-based Stream Restoration Project Process and obtain feedback

1. Introduce "straw man"
    a. Programmatic/Project Goals and Objectives
    b. Watershed Assessment
    c. Site Level Functional
    d. Restoration Potential
    e. Design Objectives
    f. Restoration Design Approach & Design Alternative Analysis
    g. Design
    h. Monitoring
2. Break out to discuss "straw man"
3. Report out

Recap from Day One and what will happen on Day 2 Bill Stack - (15 minutes)

DAY 2

Day 2 Overview and Instructions - Rich Starr (30 minutes)

Track Facilitators: J. Berg, L. Craig, R. Christianson, R. Klauda, N. Law, S. Lowe, G. Yagow
Track Recorders: R. Christianson, S. Drescher M. Ellis, L. Fraley-McNeal, N. Gardner, S. Kemp

Track 5: Setting Goals and Objectives and Identifying Problems

Track Length: 1 hour 15 minutes

Track Purpose and Outcome: Discuss typical stream problems and identify typical stream restoration programmatic goals, design goals, and design objectives that address stream problems (e.g., TMDLs, stabilization, biological, Non-TMDL WQ, etc.)

Definitions:
Programmatic Goal – typically describes the funding driver for a program or agency
Design Goal – describes the purpose of the project and does not need to be quantitative
Design Objective – describes how the project goals are achieved and must be quantifiable

1. Break out groups
2. Report out

Track 6: Selection of Function-based Assessment Parameters

Track Length: 2 hours and 30 minutes

Track Purpose and Outcome: Define and identify commonalities on what are assessment parameters and identify function-based assessment parameters (by functional category and project goals), and their potential measurement methods and performance standards.

Definitions:
Function-based Assessment Parameter – a functional assessment parameter expresses a rate that directly relates to a stream process and a structural assessment parameter describes a stream condition at a point in time and should be representative of a function. While assessment of a functional parameter is almost always preferred, it is not always feasible due to projects costs and timeframe constraints. Since the focus of this workshop is on developing guidelines for stream restoration project implementation and these constraints are common for stream restoration projects, function-based assessment parameters, which includes both functional and structural measurements, will be discussed.
Measurement Method – quantifies and describes function-based parameters
Performance Standard – refers to benchmarks against which actual performance is measured

1. Break out groups

2. Report out

Track 7: The Determination of Restoration Potential/Functional Uplift and Constraints/Limiting factors

Track Length: 1 hour and 15 minutes

Track Purpose and Outcome: Define and identify commonalities on what is restoration potential and functional uplift based on differing watershed conditions (e.g., forested, rural, agricultural, and urban).

Definitions:

Restoration Potential – Highest level of restoration that can be achieved on a given stream reach. The process for determining restoration potential starts with project design goals. If the project design goal is only to achieve channel stability, then any restoration potential (e.g., biological) beyond stability need not be determined. After the desired level of restoration is set, the potential to achieve that level is based on watershed conditions, results of the function-based assessment, project constraints, stressors reference performance standards and ("cause and effect" analysis) and which stressors are constraints to recovery potential that cannot be overcome.

Functional uplift – the amount of change (in a positive direction) to a stream function as a result of restoration activities.

1. Break out groups
2. Report out

Track 8: Synthesis Session: Research Needs and Next Steps

Track Facilitators: Bill Stack and Rich Starr

Track Recorder: Natalie Gardner, CRC

Track Length: 1 hour

Track Purpose and Outcome: Develop list of next steps and research needs.

Next Steps in the Process for Designing Sustainable Stream Restoration Projects: The final interactive session will feature a facilitated discussion to identify critical research needs and the development of a document from which to continue to build consensus and guidance for a comprehensive scientific design process that allows practitioners to communicate to managers, regulators, and other stakeholders on how the stream restoration design approach will meet project goals and objectives given watershed and site constraints.