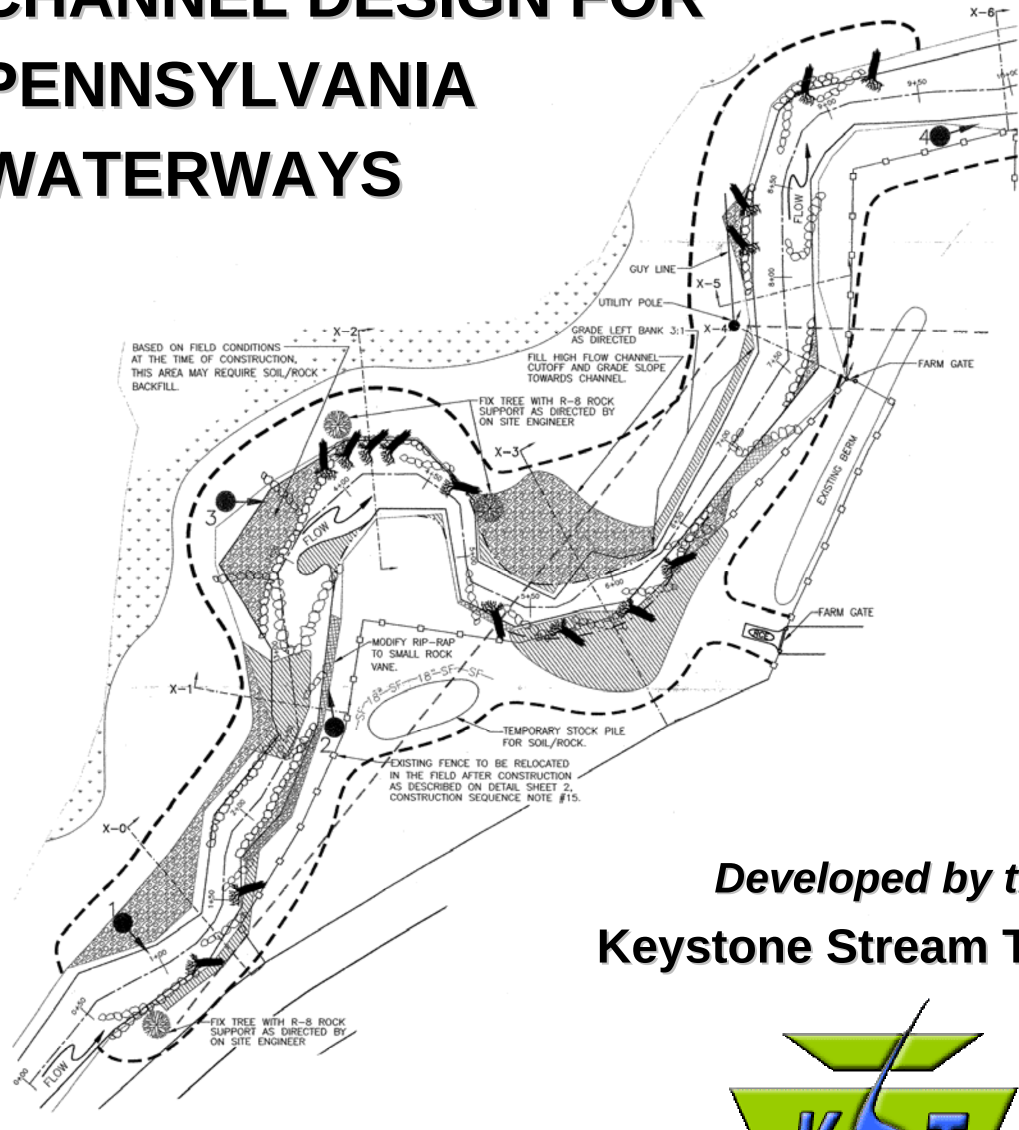
GUIDELINES FOR NATURAL STREAM CHANNEL DESIGN FOR PENNSYLVANIA WATERWAYS



Developed by the

Keystone Stream Team

March 2007

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The Keystone Stream Team welcomes comments on these guidelines.
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Chapter 1
INTRODUCTION

Why Develop Guidelines for Natural Stream Channel Design?

Our understanding of what works best to restore a channel's natural equilibrium is still evolving, particularly across a state as diverse in geography and land use as Pennsylvania. The knowledge and skills required of professionals engaged in natural stream channel design constantly change as experiences are shared about how to work with, not against, a stream's natural form and function. It is the purpose of these guidelines to provide a common process for planning, designing, and evaluating natural stream channel restoration projects.

These guidelines will assist watershed organizations with the planning and implementation of stream restoration projects and professionals with stream restoration design, construction, and permitting. The guidelines are intended to open communication, facilitate the exchange of information, and build consistency across natural stream channel design projects. They will undoubtedly change over time to reflect both new-found successes and failures of design methods, as well as changes to permitting programs at both the state and federal levels. This document is not intended to provide a cookbook approach to natural stream channel design nor serve as a how-to manual.

The guidelines were developed by the Keystone Stream Team, an informal group comprised of government and environmental resource agencies, university researchers, sportsmen, citizen-based watershed groups, and private companies. As a result of the first Natural Stream Design Summit held in February 2000, a list of challenges was developed with regard to stream restoration permitting, data management, design and implementation, problem identification, success criteria, and education. The Keystone Stream Team categorized and prioritized this list of challenges. At the top of the list was the need to develop design guidelines for professionals engaged in natural stream channel restoration projects.

What is Natural Stream Channel Design?

A stream is a complex ecosystem and not simply a storm water conveyance. Its channel exhibits a dimension, pattern, and profile dependent on the characteristics of its watershed, as well as on the volume and timing of the water supplied to it. Proper stream function also includes the transport of water and sediment produced by the stream's watershed.

Natural stream channel design addresses the entire stream system including its biological and chemical attributes. It is based on fluvial geomorphology, or FGM, which is the study of a stream's interactions with the local climate, geology, topography, vegetation, and land use. The underlying concept of natural stream channel design is to stabilize impaired stream reaches by considering channel form and function in conjunction with "soft" engineering treatments, as opposed to traditional "hard" engineering that often ignores channel function. Reference reaches, empirical relationships, and analytical models can be useful in deriving the appropriate channel dimension, pattern and profile. Project design must also address the stream's ability to transport water and sediment.

In addition to providing a stable condition, natural stream channel design promotes a biologically diverse system. Many of the structures employed "buy time" until riparian vegetation becomes established and matures. The establishment of a vegetated buffer that provides long-term protection is a keystone of natural channel design and will provide a number of aquatic and terrestrial benefits. These benefits include root-mass that stabilizes the bank, shade that lowers stream temperature, leaves that provide energy, food and shelter for wildlife, wildlife travel corridors, added roughness to the floodplain which reduces stream energy, and the uptake of nutrients from the soil.

Restoration of the proper channel dimension will insure that the stream is connected to the floodplain so that riparian vegetation and other components that roughen the channel will mitigate damage from flood-flows, in addition to maintaining stability. Structures used in natural stream channel design such as vanes, cross-vanes, and root-wads maintain pool habitat, which is often limited in degraded channels. In other words, they maintain the dimension, pattern and profile (or slope) of the stream. Restored streams also provide for sediment transport and the sorting of bed material that results in greater habitat diversity.

Successful natural stream channel designs achieve sediment transport, habitat enhancement, and bank and channel stabilization. The degree to which a project attains these goals depends on the project's specific objectives. Ultimately, a stream considered stable or "in equilibrium" will carry the sediment load supplied by the watershed without changing its dimension, pattern, or profile, and without aggrading or degrading.

What Makes a Successful Natural Stream Channel Design Project?

Professionals engaged in successful natural stream channel design often:

1) Assess the stability of a stream and its ecological functions.
2) Determine the appropriate level of intervention.
3) Accommodate a range of flows in the final design.
4) Derive stable channel geometry based on reference reach data, regional curve data, and/or analytical models.
5) Validate the final design using hydraulic and sediment transport models.
6) Select channel stabilization techniques that incorporate natural or native materials that provide for vertical and lateral stability.
7) Conduct monitoring to evaluate the success of a restoration project.

Successful stream corridor restoration depends on an understanding of how water and sediment are related to channel form and function, and on an understanding of the processes that are involved in channel evolution. This is particularly important in the context of Pennsylvania's diverse geology. What works in the lowlands of southcentral Pennsylvania may not work in the glacial till streams of north-eastern and north-central Pennsylvania or in streams impacted by coal mining. There can be no "one size fits all" design package for natural stream restoration. Data from the impaired stream reach and data from reference reaches, regional curves, and analytical modeling are critical to designing a channel that will remain stable over a range of flows.

Successful projects usually involve teams that include biologists, hydrologists, and engineers who understand natural stream functions. Successful teams make the effort to evaluate reference streams in planning and designing restoration projects, and they consider multiple alternatives before deciding on the best approach for a given stream project. Most importantly, successful stream restoration requires that we all learn from past mistakes and avoid repeating them.

Natural stream channel design must allow for the integration of "hard" engineering treatments on sites where adjacent land uses restrict efforts to work with a new or existing floodplain. Natural channel design places great emphasis on connecting a stream with its floodplain, but design options may be limited in developed areas where floodplain access is restricted. For more guidance on natural stream channel design options, *see* Chapter 3.

Scope of the Guidelines

These guidelines are intended for *stream restoration* work only. For purposes of this guide, *stream restoration* is defined as:

> "*the process of converting an unstable, altered, or degraded stream corridor, including adjacent riparian zone and flood-prone areas to a stable condition considering recent and future watershed conditions. This process also includes restoring: 1) a stable dimension, pattern, and profile, 2) biological and chemical integrity, and 3) the ability to transport water and sediment in a dynamic equilibrium.*"

Professional judgment is imperative in making the distinction between *stream restoration* projects and *stream enhancement* or *stream stabilization* projects. For purposes of this guide, *stream enhancement* is defined as:

> "*the process of implementing certain stream rehabilitation practices in order to improve water quality and/or ecological function.*"

Stream enhancement practices are typically conducted on the stream bank or in the floodplain but may also include the placement of instream habitat structures. They should only be attempted on a stream reach that is not experiencing severe aggradation or erosion. Care must be taken to ensure that the placement of instream structures will not affect the overall dimension, pattern, or profile of a stable stream.

For purposes of this guide, *stream stabilization* is defined as:

> *"the in-place stabilization of a severely eroding streambank and/or stream bed."*

Stream stabilization techniques that include "soft" methods or natural materials such as root wads, rock vanes, vegetated crib walls may be considered part of a restoration design. Stream stabilization techniques that consist primarily of "hard" engineering, such as concrete lined channels, rip rap, or gabions, while providing bank stabilization, will not be considered restoration or enhancement in most cases.

Some techniques provide both *stabilization* and *enhancement*. These include the placement of appropriate instream grade control structures and the establishment of appropriate stream bank vegetation. Alone, *stabilization* and *enhancement* techniques will not restore morphological or ecological stability to an unstable stream reach.

All situations should be evaluated on a case-by-case basis using the best professional judgment available. Meetings with the watershed community (*see* Chapter 3) will help answer the question of what type of project you have. Regardless of scale, it remains critical to consider a site's larger watershed conditions and to have field-verified data to support even smaller stream restoration projects. Permit conditions (*see* Chapter 5), provide further qualifications for projects that would fall under enhancement or stabilization categories.

Specifically, these guidelines provide direction on the following topics as they apply to natural stream channel design:

- Problem Identification
- Working with the Watershed Community
- Data Collection and Analysis
- Evaluation of Design Options
- Creating the Right Design
- Permitting Guidance
- Selecting a Qualified Consultant
- Construction Considerations
- Pre- and Post-Construction Monitoring

These guidelines are not an endorsement of one methodology or tool to the exclusion of others due to the fact that the design of natural channels is an evolving field. The Keystone Stream Team recognizes the need to address the strengths and limitations of all restoration methodologies and attempts to explain some of these observations in Chapter 4.

Where approval has been granted, the reader is referred to various tools and methodologies and credits the originators of these tools. Included in this document are sets of tables, charts, and other forms (*see* Appendix I) that the Keystone Stream Team believes are most helpful in data collection and analysis.

It is also important to note that the *Guidelines* suggest a sequence of steps to take you from project planning to project implementation. However, the exact sequence may vary depending on the person or group that has initiated the project and what type of information is already available. More important than the sequence is the attempt to cover the elements presented under each step so as not to overlook something altogether.

Finally, it is important to stress that this is an evolving document and the result of collective experience by a wide variety of professionals. Content is based on what members of the Keystone Stream Team have learned about natural stream channel design since it's inception in Pennsylvania. It is the team's intention that these guidelines will save practitioners time and money by avoiding mistakes in design and implementation.

Chapter 2

ASSESSMENT – “READING THE RIVER”

Two questions are critical to determining what approach to take in design. First, is the stream’s condition a reflection of a locally unstable situation or of a larger, watershed-wide problem? Secondly, how far from a “stable” form is the reach of stream you’re proposing to remedy?

In order to answer these questions, it’s important to properly “read the river” in its current state. This involves assessing the big picture (watershed assessment) as well as the local project area. Before attempting a solution, you must thoroughly identify and understand all causes of the observed problems.

Streams tend to evolve toward a state of equilibrium with their current flow and sediment load characteristics. We usually choose to intervene for a variety of reasons. To determine the degree of intervention needed, it’s important to know the evolution of the stream -- at what evolutionary stage is a particular stream or river in relative to its potential equilibrium regime? Designs must be compatible with the stream’s natural tendency to evolve into a particular channel form.

Channel evolution models and stream classification systems can help predict future upstream or downstream changes in habitat and stream morphology. Channel evolution models are based on adjustment processes and include Rosgen’s evolution scenarios (*see* Appendix I) and Simon’s channel evolution stages. Based on morphological parameters, stream classification systems include:

- Schumm’s (relates straight, meandering and braided channels to sediment load)
- Montgomery & Buffington’s (relates six classes of alluvial channels to sediment and bed load)
- Rosgen’s (defines eight major stream classes with about 100 individual stream types using six morphological measurements)

At the heart of each sequence in Rosgen’s scenario is the stream type -- when morphological changes exceed a “geomorphic threshold,” stream type changes and there are new quantitative values of dimension, pattern, and profile.

The only way to be certain of a stream’s evolutionary stage is to quantitatively assess the degree to which the stream’s existing conditions differ from its full range of operating potential. Assessment includes comparing data for existing stream conditions to that of a similar, but unimpaired stream reach, or by comparing data collected for a stream reach at different points in time.

Designs must also consider man-made watershed influences, such as upstream storm water management, agricultural activity, urban development, coal mining, road and bridge construction, dams, and timber harvesting. Does your project consider these influences as potential contributors to your problem? Think "big picture" here. Can your ideas fit into a larger watershed vision being developed for your area?

Another critical element of stream detective work is to think through monitoring needs early in the planning process. A monitoring plan should include pre-construction and post-construction monitoring to show success in meeting project objectives. Since funding for monitoring is often overlooked or not permitted in many government-funded projects, consider ways to use volunteer monitoring programs to measure long term success. Some permitted activities require monitoring components (*see* Chapter 9), so it's important to comply with permit conditions.

In summary, "reading the river" involves four phases of assessment:

- Watershed Assessment (the entire watershed)
- Preliminary Site Assessment (the project area)
- Data Collection and Analysis (at the project site)
- Monitoring for Success

Watershed Assessment

Any assessment of current stream conditions should include a watershed characterization since watershed properties affect the volume, timing, and routing of water and sediments from upland areas to a stream and along the stream to its outlet. This evaluation includes looking at the current landscape and at historical landscape changes that affect the magnitude and duration of peak and base flows and the yield and character of sediments from bank and bed erosion, roads and construction sites, and surface runoff. The hydrologic response of the watershed to various rainfall amounts is important in determining the appropriate size and shape of the stream channel and its floodplain.

You may not have the financial resources needed to collect information on *all* watershed characteristics. You may choose instead to collect just the information useful for your particular project's mission and goals. For cost savings, some of this information can be collected by watershed association members and other community volunteers.

When completing the watershed assessment, it is essential to include both *current* and *historical* information to establish baseline watershed conditions.

1) Collect *historical* information from sources such as:

Historical/Background Information		
Type of Information	**Information to Look For**	**Where to Find It**
General watershed & stream/river information	watershed size, drainage area	USGS topographic maps, fishing and boating clubs, watershed associations, etc.
	classification of stream types based on valley types and land forms	Simplified stream assessments can be used to help prioritize stream problems. See Appendix II for resource information.
Hydrology	stream flow data	USGS stream gages http://www.pa.water.usgs.gov/pa_hydro.html For location of gages in watershed or for nearby watersheds and later 9-207 data (packet of flow information not available on the web but upon request) which is used for design and when comparing gages
	flood history	residential - anecdotal information can help establish or confirm bankfull; US Geological Survey, Federal Emergency Management Association, PA Emergency Management Association
	stormwater management plans	Stormwater Management Act (Act 167) - county, conservation district, DEP, municipality
Historical information (location/condition/pattern)	historical photos, aerial photos	PA Historical and Museum Commission (PHMC) http://www.phmc.state.pa.us landowners, sportsmen groups, county, PA DEP, USGS, USDA Farm Service Agency, TerraServer. Google EARTH
	past projects (relocations, channelization, flood protection - successes & failures)	US ACE, Conservation District, FEMA
Geological Information	physiographic region (changes in rock structure)	USGS maps http://www.dcnr.state.pa.us/topogeo/indexbig.htm
	soils information	soil survey -- identify hydrologic groups, erodibility potential; county conservation district office, NRCS
Biological Information	fishery management survey reports	PA Fish & Boat Commission http://www.fish.state.pa.us, fishing clubs

Water Quality Information	water quality network stations	PA DEP; Susquehanna River Basin Commission - http://www.srbc.net
	Citizens' Volunteer Monitoring Program	Bureau of Watershed Management, DEP (717) 772-5807 http://www.dep.state.pa.us/dep/deputate/watermgt/wc/subjects/cvmp.htm
	local Total Maximum Daily Load data	PA DEP http://www.dep.state.pa.us/watermanagement_apps/tmdl/
	USGS Water Quality Data Warehouse	http://www.water.usgs.gov/nawqa/data
Land Use and Land Cover	land use maps, aerial photos	county or regional plans, PA DEP
	identify areas that have influence on stormwater runoff, discharge, sediment regimes, channel stability, or overall water quality	SHRP http://orser7.erri.psu.edu/loading/downloads.htm, planning offices, National Land Cover Database (NLCD 2001)
	DEP policy considering land use plans and zoning ordinances in issuing DEP permits	(General Information Forms include land use information as it relates to proposed projects permitted by DEP) http://www.dep.state.pa.us
Geographic Information Systems/ Watershed Assessment Information	coverage from Environmental Resources Research Institute (Penn State University)	http://www.environment.erri.psu.edu
	coverage from PA Spatial Data Access (PASDA)	http://www.pasda.psu.edu/
	Storm Water Management Plans, Water Supply and Wellhead Protections Plans	County planning departments

Key Watershed Contacts	
PA DEP Watershed Managers	Regional DEP Offices
County Watershed Specialists	County Conservation District Offices
Erosion & Sediment Pollution Control Technicians	County Conservation District Offices
Local watershed organizations/ Sportsmen's Clubs	http://www.pawatersheds.org
PA DEP Watershed Notebooks	http://www.dep.state.pa.us
US EPA Surf Your Watershed	http://www.epa.gov/surf
PA Fish and Boat Commission	http://www.fish.state.pa.us
Susquehanna River Basin Commission	http://www.srbc.net
Interstate Commission for the Potomac River Basin	http://www.potomacriver.org
Delaware River Basin Commission	http://www.drbc.net
Chesapeake Bay Program - Watershed Profiles	http://www.chesapeakebay.net

2) Collect *current* watershed information, planning information, and technical data from sources such as:

Watershed management plans - river conservation plans (most are funded by DCNR) - watershed management plans (most are funded by PA DEP)
PA Fish & Boat Commission, Division of Fisheries Management and Division of Environmental Services (Pleasant Gap)
PA DEP water quality network stations
River Network's Clean Water Projects (http://www.rivernetwork.org/library/librivcwastate.intro.cfm) - includes state contacts for water quality standards, NPDES permits, TMDLs, and designated uses)
Greenway plans
Regional curve data to provide bankfulls and channel dimensions (for gage sites only; cross-sections will most likely be upstream of OR downstream of gage) (*see* Appendix II).
Chapter 93 classification (http://www.dep.state.pa.us/dep/deputate/watermgt/Wqp/WQStandards/wqstandards)
Land use projections for the future (contact county or municipality)
FEMA flood map (if available) (contact municipality)
PA Natural Diversity Inventory (http://www.dcnr.state.pa.us/forestry/pndi/pndiweb.htm)
PA Scenic River status www.dcnr.state.pa.us/rivers
National Scenic River status (National Park Service) http://www.nps.gov/rivers/
TMDLs (http://www.dep.state.pa.us/watermanagement_apps/tmdl/)
303(d) listing (Assessed Waters program) (http://www.dep.state.pa.us/dep/deputate/watermgt/Wqp/WQStandards/wqstandards)
Current photos

Preliminary Site Assessment

A preliminary analysis of the proposed project area will help guide discussions about the specific information needed to design a restoration project for a particular watershed. This preliminary analysis is more qualitative than quantitative and relies heavily on visual assessment work and professional judgment. It's an important step to take, however, in identifying a stream's problems, and the results will be beneficial when meeting with the area's stakeholders to discuss the proposed restoration effort.

A preliminary site assessment may include the following evaluations:

- Identify stream reaches within your project area
- Take photos of key stream reaches that show signs of degradation
- Conduct physical and biological assessments of identified stream reaches

Begin by forming a multi-disciplinary team for data collection. To ensure consistency in assessment work, walk the site with the assessment team with data collection forms in hand. Review parameters for healthy stream conditions in your project area. This team approach helps eliminate individual interpretations of a stream's conditions. Where a local watershed organization exists, consider employing its assistance in conducting this preliminary site assessment.

Assessment Methodologies

Select a commonly accepted methodology for the physical and biological condition of your project area. Assessment methodologies include the following among others:

- **Simplified Stream Assessment Form** (bank stability, channel stability, riparian vegetation, and aquatic habitat).
- **Stream Visual Assessment Protocol (SVAP)**, USDA/NRCS, 1998
  An easy-to-use assessment protocol to evaluate the condition of aquatic ecosystems associated with streams; does not require expertise in aquatic biology or extensive training; least-impacted reference sites are used to provide a standard of comparison; states may modify the protocol based on a system of stream classification and a series of reference sites.
  http://www.nhq.nrcs.usda.gov/BCS/aqua/svapfnl.pdf
- **Stream Classification Worksheet** - stream classification worksheet used with Rosgen methods ("*Stream Corridor Restoration: Principles, Processes, and Practices", pp 7-33; 1998)*. http://www.usda.gov/stream_restoration
- **USDA Stream Corridor and Inventory Assessment Techniques** - A guide to site, project and landscape approaches suitable for local conservation programs *(Technical Report, January 2001, revised).*
  http://www.wcc.nrcs.usda.gov/watershed/products.html
- **EPA's RBP** (Rapid Biological Assessment Protocol) – The RBP's are designed to provide basic aquatic life data for water quality management purposes such as problem screening, site ranking, and trend monitoring. *See* Rapid Bioassessment Protocols for Use in Wadeable Stream and Rivers: Periphyton, Benthic Macro-invertebrates, and Fish- 2nd Ed., Office of Water, EPA 841-B-99-002, July 1999.
- **PA Modified RBP** (Rapid Biological Assessment Protocol)
  Quality Assurance Plan: Cause/Effect Survey. PA DEP, Bureau of Water Management, on-line document warehouse, document 391-3200-003 or direct website: http://www.dep.state.pa.us/eps/default.asp?P=fldr200149e0051190%5Cfldr200149e32221af (PLEASE NOTE: This document will be updated in the near future. Use the current plan until update occurs)
- **AVStrEAMS –** A customized interface to ArcView GIS, this specially designed tool enables non-technical users to conduct and enter more than 15 different stream assessment protocols at designated stream monitoring sites. Once entered in GIS, the assessment information can easily be mapped, managed and displayed to illustrate problem or worksite attributes at specific stream segment locations. Contact: Ken Corradini, Penn State Institutes for the Environment, 1 Land and Water Research Bldg., University Park, PA 16802. Phone 814-865-6966 or visit http://www.avstreams.psu.edu

Based on an analysis of both watershed and site-specific information, begin to analyze the causes of impairment and draft a conceptual design of your restoration project. Special consideration should be given to managing *causes* as opposed to treating *symptoms*, as well as determining whether a *passive*, nonstructural alternative is appropriate or whether a more *active* restoration alternative is needed. Identify any gaps in information that may be crucial to a thorough assessment of the causes of impairment.

Chapter 3

MEETING WITH THE WATERSHED COMMUNITY

Prior to developing a final design and submitting a permit application for a natural stream design project, it is important to involve all interested parties and persons who have a stake in the outcome of your proposed restoration. Two meetings are recommended:

- Watershed Community Meeting
- Pre-Application Meeting (to be completed before submitting a permit application; *see* Chapter 5).

These early meetings will help build inter-disciplinary support for your project and broaden the knowledge base for applying FGM principles to stream restoration designs. Hold these meetings as early as possible in the planning process to allow for ample time to discuss all concerns and evaluate all the options.

Watershed Community Meeting

Invite all interested parties and members of the community to a stakeholder meeting to discuss issues and problems and introduce your ideas for a stream restoration project. If a watershed organization is involved, hold this planning meeting before a preliminary site assessment is done to ensure broader participation in this early assessment phase. Professionals engaged in stream restoration work can serve as your technical team in providing advice on data collection and design considerations.

Some points to consider when organizing a meeting with your watershed community:

- Include representatives from county, state and federal agencies, local watershed and sportsmen's groups, and interested landowners to hear different perspectives on the need and degree of intervention.
- Request PA DEP Soils & Waterways representation at the table to help clarify the permitting process. A subsequent pre-application meeting will serve to resolve any permitting issues (*see* Chapter 5).
- Discuss causes of stream failure and conceptual solutions. Include an explanation of different philosophies or approaches to stream correction/restoration/remediation and how they relate to the goals of the watershed community. Be prepared to answer questions by bringing to the table basic stream data as outlined in Chapter 2.
- Use historical and current watershed information to support your ideas for a conceptual restoration plan.
- Meet at the project site or sites, if possible, to see problems first hand.
- Involve conservation district watershed specialists and erosion and sediment technicians in the planning of public meetings.
- Consider regional and local restoration goals, land use conditions and constraints affecting the site, cost and natural site evolution.

Points to Address at the Watershed Community Meeting

- **What are the causes of the observed problems**? Are there relationships between channel stability and watershed changes?

- **How does your project support the overall vision for watershed health?** Is the project compatible with concurrent or planned activities within the watershed? Can priorities be established? Is there a sequence of interventions that make sense?

- **What are the options**? The selection of a preferred restoration approach requires consideration on a site-by-site basis. Openly discuss all options, including bioengineering, fluvial geomorphic and traditional hard-engineering methods. It may be necessary to integrate geomorphology, engineering, biology and botany into the restoration solution. Many stream stabilization measures not only support natural stream geometry objectives but may also provide adequate habitat objectives.

  Natural stream restoration can vary from a relatively simple approach (remove the prior interventions/alterations as feasible and allow the site to restore naturally) to highly complex and structural solutions. It is important to consider regional and local restoration goals, land use conditions and constraints affecting the site, cost, and natural site evolution.

  The goal of natural stream channel design is to develop a resilient system, adaptable within a range of flows. Both "active" and "passive" approaches can achieve this. Passive approaches may involve simply allowing natural erosion and sedimentation processes to gradually restore the geomorphic form and function or undoing prior interventions, such as removing a river levee to allow site inundation during large floods. More active sites may require major earthwork to regrade a channel and floodplain, recreate geomorphic features, create habitat structures, and revegetate riparian areas.

  For example, gravel removal in streambeds changes the slope of a stream. As the stream re-adjusts, erosion of the stream bottom takes place, a process known as head-cutting. Head cuts are incisions or a form of channel degradation that will migrate upstream for potentially great distances, until the slope created by the gravel removal activity hits a natural hard point such as a rock outcrop or bedrock or until the slope of the head cut matches the valley slope. This simple act of removing gravel from a streambed can affect miles of stream and produce tons of excess sediment deposited downstream.

  It must be decided whether time exists to wait for a channel to adjust on its own. During that time, direct economic effects may occur, such as property loss and increased flooding, as well as a reduction in water quality, fisheries, aesthetics, and property values. Streams may heal in one area while adjustments are transferred in an upstream or downstream direction, and those adjustments may take decades to complete.

Channel evolution scenarios can be helpful in deciding whether to target a site for restoration or leave it to heal on its own. As a stream evolves from one form to another, the stream channel pattern, dimension, and plan form within the landscape is continually changing. Each change produces sediment that is transported downstream or head cuts that migrate upstream. Some channel evolutions toward a stable state may take less time and minimally affect the stream so natural healing may be the preferential restoration decision. (For instance, a B3 stream is less sensitive to human disturbance and should recover on its own if the disturbance is removed.) Disturbances that cause the most damage for the longest period should be targeted for stabilization and restoration measures.

Factors that usually prompt a more active or intrusive level of intervention include:

- The system is unstable (stream channel may be actively incising and will do so for the foreseeable future)
- A desire to accelerate the time frame of recovery
- Multiple (and perhaps contradictory) site objectives
- An inability to sufficiently alter the prior interventions (for example, watershed hydrology or sediment regime have been so changed that passive restoration processes will not achieve the project goals)
- The site may evolve along a different trajectory than that desired without intervention
- The consequences or risks to infrastructure on or near the site, resulting from the uncertainty of non-managed restoration are unacceptable
- The desire for special habitat features may provide an ecological basis for the site design which differs from the historical site conditions

For incised streams (vertically contained streams that have generally abandoned their floodplains - typical of stream types A, G, and F), Rosgen has developed a priority system that considers a range of options based on numerous factors (*see* Appendix II for the citation of an article explaining the four priority approach.). Priorities 1 and 2 use methods that reconnect incised channels with either previous or existing floodplains. Priority 3 kicks in where streams are laterally contained and physical constraints limit the use of Priority 1 and 2 techniques. This level converts a stream to a new stream type without an active floodplain, but containing a floodprone area. Priority 4 acknowledges that stabilization is the only approach that can be taken given site constraints, such as adjacent roads, buildings, and historic features.

- **Consider the ecological and economic benefits of the project, as well as all costs associated with different solutions.** Determination of costs and benefits can be useful in permitting and justifying temporary environmental impacts, such as erosion and sedimentation. Weigh any immediate or short-term cost benefits against long-term benefits and maintenance costs.

    - What is the cost/benefit ratio for various alternatives?
    - What kinds of risks are associated with each alternative? What are the environmental impacts of each alternative? Are the net environmental impacts of the project positive?
    - What is the impact of working in an active stream channel as opposed to working in a dry channel? What ecological and economic factors can help you determine if you should construct in the *wet* as opposed to *dry*?
    - What is the expected longevity of the structures and design features being considered? What are the long-term maintenance requirements?

- **Emphasize the FGM approach to natural stream design as it relates to data collection & analysis**. Discuss the scale of intervention and the degree of data collection needed for FGM-based projects. Restoring streams to their "natural" condition requires intensive data collection necessary to determine the design elements critical for a project's success.

    - What types of data are needed to support the objectives of the project?
    - What data exists to support your project and what data gaps exist?
    - What types of monitoring data should be collected and for what duration?

- **What site constraints exist?** Consider restrictions imposed by easements, sanitary sewer lines, gas lines, right-of-ways, railroads, large trees, overhead utility lines, storm drain outfalls, unwilling landowners access, and existing concrete channels.

- **Identify permit requirements and seek permit guidance.**

- **Is the project compatible with existing agency policies and/or other jurisdictional regulations?**

    - Does the project significantly reduce or increase the risk to the public health and safety and/or fish and wildlife resources?
    - Is this an emergency stabilization project? For emergency projects, encourage natural channel design alternatives to hard engineering stabilization; encourage search of existing data..
    - Are there maintenance issues with flood control projects (reduction of sediment transport)? Incorporate bankfull channel to minimize maintenance needs.

- **Will the project be technically feasible?**

- **What contingencies can be developed for safety measures if future land use changes?** Write this into the assessment and make local officials part of the process.

Define and Communicate your Project's Objectives

Based on the results of this early planning meeting, summarize your findings and determine the strongest conceptual approach. Include the following in written form and circulate to those who were in attendance and to any partners or stakeholders in the project:

- ✓ Summary of findings.
- ✓ Listing of priorities.
- ✓ Clear description of your project's objectives and scope of work, including the approach to data collection & analysis and plans to evaluate all proposed alternatives.
- ✓ Identification of partners and stakeholders involved in project.
- ✓ Note that there will be a second meeting before applying for a permit to allow for final stakeholder input. (*see* Chapter 5).
- ✓ Request for feedback to your report within ten days.

Chapter 4
DATA COLLECTION AND ANALYSIS

The intent of the FGM-based approach is to design stream channels that will maintain themselves under various flow regimes and sediment loads. The best way to arrive at a sound design is to quantitatively evaluate the principal morphological features of a stream type and valley type that is in a natural equilibrium condition (the “reference reach”) and restore the natural combination of dimension and form (slope, width, meander, etc.) to the impaired channel.

Reference reaches may be located within your project’s watershed or can be selected from a watershed that’s within the same hydrophysiographic region, has the same general land use as your project area, and has the same stream type and valley form as the proposed stream. The reference reach characterizes the *stable* morphology but does not necessarily require a “pristine” reach; procedures exist to verify the stability of the reference reach and aerial photographs can be used to provide additional evidence of stability over time. For consistency of measurement, a reference reach should contain at least two full meander wavelengths or a length that is 20 times the bankfull channel width.

Collecting the information to make this comparative evaluation requires a system of checks and balances that is integral to natural stream channel design. It is critical to cross-verify data that is collected at the study site and at reference sites with information from gage stations, regional curves, and published reports. Multiple data sources help to justify your final project design.

The following guidelines for data collection will assist with permit approval from the Pennsylvania Department of Environmental Protection. These parameters focus on physical restoration of the stream channel, which should lead to habitat improvements and some chemical improvements. Specific habitat objectives must assimilate other tools in data collection and monitoring.

It is important to avoid applying book values to your specific project. Every site is unique, which is why communication between professionals is critical to reaching an understanding of what depth of data analysis is required. Data collection can be time consuming, but don’t take shortcuts. Complex projects may require advanced surveying techniques such as total station survey and aerial digital mapping.

Many designers are embracing Rosgen’s approach to natural stream channel design (often referred to as his “40-step process”). While this process is not intended to be a cookbook for restoration design, it does a good job of presenting a sequence of steps that provide for the calculation of design specifications. Calculations are based on proposed stream types, verified using reference reach data, regional curve data, gaging station data, and empirical formulas, and checked against the parameters of Rosgen’s stream classification values. The system presents checks and balances for just about every calculation, and model calculations are validated using field data. Trained and experienced designers are encouraged to apply this methodology in the collection and analysis of stream data.

Natural channel restoration designs may encompass three different approaches: 1) “analog” meaning reference or template, 2) “empirical” meaning a reliance on equations derived from dimensionless ratios or universal data sets, and 3) “analytical” which involves using hydraulic models and sediment transport functions to determine equilibrium conditions. Each of these approaches has strengths and weaknesses. In practice, designers usually employ elements of each approach in channel design. Because NSCD is continually evolving, it is important to acknowledge the limitations of an approach while embracing its strengths.

To assist with data collection, Rosgen has developed procedures for collecting data from surveying reaches. Appendix I includes *Field Survey Procedures for Characterization of River Morphology* (Dave Rosgen 1996), which illustrates a process for characterizing the dimension, pattern, and profile of selected stream types. In addition to this tool, Rosgen has also developed a *Procedure for Development and Application of Dimensionless Hydraulic Geometry*. This procedure assists in restoration design by helping to define the shape of the channel based on various stages of flow.

If using alternative methodologies to design, be aware of possible limitations in providing for sediment transport at base or low-flow conditions. Many “traditionally-designed” channels attempt to put all the flows into a common width in order to handle high flows; they are constructed “over-width” which may lead to sediment deposition and bar formation. The width-depth ratio is usually too high, which will not provide for adequate development of in-stream habitat or sediment transport.

Recommendations for Data Collection

Whatever methodology is applied, data collection should include the following information. The number of cross-sections needed depends on the length of the reach, stream types, and the relative length of riffles, pools, and meanders. *See* Appendix I for data collection worksheets.

Project site information:

1) Make an initial assessment of cross-sectional area by locating potential bankfull indicators (break in slope on bank, change in vegetation, scour line or stain marking on abutments or rocks, small bench on streambank, or top of point bar or mid-channel bars for entrenched streams; if not entrenched, bankfull is near or at top of the bank.). Avoid relying on only one indicator, and remember that bankfull is often underestimated. If possible, conduct your assessment in collaboration with other professionals to expand your understanding of significant indicators found in this watershed.

In extremely unstable streams, it will be impossible to identify bankfull by visual indicators. An assessment may be necessary to determine what should be there versus what is there, including application of regional curve and local gage information.

Reference: see *Finding Bankfull Stage in North Carolina Streams.*
http://www.bae.ncsu.edu/programs/extension/wqg/sri/fact_sheets.htm

2) Collect data for the dimension, pattern, profile, and bed materials as outlined in the Morph Chart in Appendix I.

3) Determine stream type based on the above information.

4) Fulfill other data requirements as dictated by applicable permit.

Reference reach information: Sufficient cross-sections need to be surveyed to provide a range of pool and riffle characteristics.

1) Collect data for the reference reach dimension, pattern, profile, and bed materials as outlined in the Morph Chart in Appendix I.

2) Determine stream type based on above information. Articulate what the stream condition should be in the impacted area.

3) Convert the morphological measurements into dimensionless ratios by dividing the dimension, pattern, and profile variables by the bankfull values of the same feature. The purpose of the dimensionless ratios is to convert design values to scale for the project area. Ratios are used to calculate actual design measurements for width, depth, meander length, radius of curvature, pool depth, pool slope, cross-sectional area of riffles and pools, riffle slope, maximum riffle depth and many other channel properties. As many as 19 ratios can be computed from the parameters measured or computed using the table of morphological characteristics in Appendix I.

Gage site information:

1) Validate your field observations for bankfull discharge by calibrating your findings against known USGS stream flow data**.** If a gaged site is not located within your site's watershed, locate several gages representative of your project site in nearby watersheds within the same hydro-physiographic region.

Field data collected at the gage site should include bankfull width, depth, cross-section, entrenchment ratio, channel gradient, sinuosity, and the particle size distribution of the bed and bank material. Use the same worksheet as used for project site and reference reach information.

2) Classify the stream type at the stream gage location.

Regional curve information:

Regional curves show the relationship between drainage area and discharge and channel characteristics. The primary purpose of a regional curve is to aid in the identification of bankfull stage and dimension in ungaged watersheds and to help estimate the bankfull dimension and discharge needed for natural stream channel design.

In ungaged watersheds, regional curves and regression equations developed at USGS gaging stations can be used to validate field observations of bankfull discharge. These curves are also used to assist in bankfull determinations in highly unstable systems where field evidence of bankfull is extremely difficult to detect (particularly in the case of incised streams). Use only those regional curves developed for your area.

The USGS has developed regional curves for Pennsylvania (Chaplin, 2005). These curves apply only to watersheds with 20% or less "urban" land use. Separate curves were identified for watersheds underlain with 30% or less carbonate bedrock, and for watersheds underlain with greater than 30% carbonate bedrock. Other than the distinction between carbonate and non-carbonate bedrock, runoff characteristics between Pennsylvania's eco-regions were found to be statistically similar. In using these regional curves, the following criteria should be followed:

- only apply them to watersheds with similar runoff characteristics;
- don't use them where stream flow is regulated by more than 20 percent (i.e., dams);
- there should be at least ten years of records at a gage site; and
- do not use gage site data if the site was abandoned before1985.

Use of hydrology models, such as TR-20 and PSU-4, can be used to estimate flows; however, they must be calibrated to bankfull. Exercise caution in using runoff models and use field-collected data. Accurate field observation and gage record analysis is required to accurately calibrate and corroborate modeling output.

Data Collection Worksheet(s) (*see* Appendix I)

- *Watershed Assessment: Stream Reach Prioritization*
- *Morph Chart* (Rosgen 1996)
- *Field Survey Procedures for Characterization of River Morphology (Rosgen* (1996)
- *Stream Classification Worksheet* - Chapter 7, Page 33 of *Stream Corridor Restoration: Principles, Processes, and Practices* (1998); (not included in Appendix I but available at http://www.usda.gov/stream_restoration)

Data Collection and Analysis References (*see* Appendix II)

- *The Reference Reach Field Book* (Wildland Hydrology 1998)
- *The River Field Book* (Western Hydrology)
- *Procedure for Development and Application of Dimensionless Hydraulic Geometry* (Dave Rosgen, Wildland Hydrology)
- *Stream Channel Reference Sites: An Illustrated Guide to Field Technique*, USDA Forest Service, General Technical Report RM-245

Bankfull and its Role in Stream Classification

Regardless of project size and scope, the linchpin of natural stream channel design is the bankfull discharge of the watershed. Bankfull discharge is closely correlated with effective discharge -- the flow generally doing the work that results in the average morphological characteristics of the channel. Bankfull discharge has also been defined as the discharge that fills a stable alluvial channel to the elevation of the active floodplain. Bankfull discharge nearly always corresponds to a discharge with a recurrence interval between 1 and 2 years.

Bankfull discharge is key to proper stream classification. From bankfull, one can then determine stream type, which can then be used to characterize stream channel cross sections, profile, and plan geometry. Over the past 100 years, there have been about twenty published stream classification systems, including those designed by Schumm, Montgomery & Buffington, and Rosgen.

Because Rosgen's classification system uses quantitative measurements to predict how a river or stream will respond to certain variables, its usefulness continues to gain acceptance among professionals working to restore the biological function and stability of degraded streams. In Pennsylvania, it is the preferred method of stream classification and its use is encouraged on stream restoration projects funded by the Commonwealth.

Bankfull stage is the basis for measuring the cross-sectional area, width/depth ratio and entrenchment ratio, the most important delineative criteria. Therefore, it is critical to correctly identify bankfull stage when classifying streams and designing stream restoration measures.

The Keystone Stream Team advises caution in identifying and verifying bankfull. There is no substitute for field identification and validation of bankfull using the USGS regional curve and local gage data. It is important to learn the value and limitations of other tools (e.g., rating curves, frequency distribution plots, & database calculations). Also, do not ignore the effect of vegetation on a stream's hydrology.

Preliminary Conceptual Design

Collected data will help you most accurately evaluate your design alternatives and answer questions raised at earlier planning meetings with the watershed community. This detailed data will be used to justify the environmental impact of the activity, as well as the associated economic costs (funding). The problems have been qualified and quantified, and the solutions have been evaluated in terms of economic and environmental benefits.

Using the reference reach as a template, regime data from regional sources, and hydraulic modeling, develop a preliminary design for the cross-section, planform, and profile of the project reach. This preliminary design will be less detailed than the final design but will provide sufficient detail for everyone to understand the project. It's also a good idea to share preliminary work plans with local planning, zoning, or building authorities to learn of any local ordinances or applicable state and federal requirements.

The next step is to meet with representatives of the permitting authorities to determine which permits are necessary and to initiate the application process (*see* Chapter 5).

Chapter 5
PERMITTING

Pre-Application Meetings

Prior to developing a final design and submitting a permit application, a pre-application meeting should be held to review a preliminary or conceptual design, its costs, impacts, management, etc. Consider holding an office meeting and a meeting in-the-field to view problems first-hand. Data collected and analyzed up to this point will help answer questions and justify your design approach. Pre-application meetings can go a long way toward speeding up the permitting and approval process. They can also help build interdisciplinary support for the project and broaden the knowledge base for applying FGM principles to stream restoration designs.

Regulators will want to know about the existing aquatic resources. Using Chapter 93, Title 25, determine how the stream is classified. Is it a cold water (CWF), warm water (WWF), High Quality (HQ) or Exceptional Value (EV) fisheries? Using Chapter 105 determine whether EV wetlands are involved or adjacent to the project.

Conduct an on-line PNDI search to determine whether species of special concern (including threatened and endangered) are involved. Send a Notice of Determination to the PA Historic and Museum Commission to determine if special resources may be located in the project area. This information must be obtained as part of the permit process and can be conducted at this time at little extra cost. It is best to address such issues early-on with the regulatory community in order to avoid additional delays later.

Send your proposal, plan outline, sketch of plan and the above information to a pre-application team, which should include the Commonwealth's Department of Environmental Protection's Regional Permitting and Technical Services (formally Soils & Waterways Section), U.S. Army Corps of Engineers, U.S. Fish & Wildlife Service, PA Fish & Boat Commission, and county conservation district. It may also be beneficial to invite the county watershed specialist, DEP regional watershed manager and the Department of Conservation Natural Resources or the PA Game Commission, if these agencies are involved with PNDI issues. Regarding the latter, a simple letter describing the project and its location should be sent to the county and the municipality (Act 14 notification), preferably before the meeting. At this time, also discuss the role of the pre-construction meeting, including who should attend and whether a pre-construction conference should be a condition of the permit.

Record all comments during field visits and office meetings, and provide a written summary to all participants after meetings for review and concurrence. Share this feedback with all project sponsors.

The following guidelines provide general advice on the types of permits that apply to natural stream channel designs. All stream restoration projects require federal authorization whether issued through a Pennsylvania State Programmatic General Permit (PASPGP-3, based on a PA-DEP 105 Permit), Nationwide Permit 27, or Department of the Army Individual Permit.

State Permits: Phased Watershed Permitting

There are Permit Guidelines for Phased NPDES Stormwater Discharges Associated with Construction Activity Permits, Chapter 102 Erosion and Sediment Control Permits, and Chapter 105 Waterway Restoration Permits, otherwise known as the Phased Watershed Permits. The purpose of this guidance is to provide flexibility in the permitting process to minimize the administrative burden on applicants and DEP permit processors, provide an effective public review and notice process for projects, and ensure projects meet the public health, safety, and environmental requirements of the commonwealth. Details of this permit and its requirements can be found in Appendix IV of this document.

Federal Permits

Projects that involve the discharge of dredged or fill material (33 CFR 323) into areas subject to Federal jurisdiction (wetlands or below the ordinary high water mark (OHWM) of a stream) will require Federal authorization[1]. Federal authorization can be issued by the following permits:

A.) *Pennsylvania State Programmatic General Permit 2* (PASPGP-3). DEP includes the federal permit (one-stop shopping) and the U.S. Army Corps of Engineers (USACE) is not directly involved. This applies to most of Commonwealth general permits, waivers and some individual permits:

- Can be utilized for impacts up to 1 acre (depending on specific impacts and the permit type).
- A project less than 250 linear feet (<500feet for bank stabilization) does not require notification to USACE (provided that there are no Section 106 or Section 9 concerns).
- Projects over 250 linear feet are reported to the USACE. After reviewing the project and determining that the project meets the terms and conditions of the PASPGP-2, USACE either notifies PADEP that issuance of PASPGP-3 is appropriate or the USACE can issue PASPGP-3 directly from their office.
- For complete terms, conditions and project applicability please download the PASPGP-3 worksheet <http://www.keystonestreamteam.org/docs/PASPGP-3_FactSheet.pdf>

[1]Note: Be advised that Federal authorizations are not valid until the Commonwealth issues or waives the 401 WQC. This acknowledges that the project is in compliance with Commonwealth standards and regulations.

B.) *Nationwide Permit 27* (NP27) – Stream and Wetland Restoration Activities (not generally used in PA):

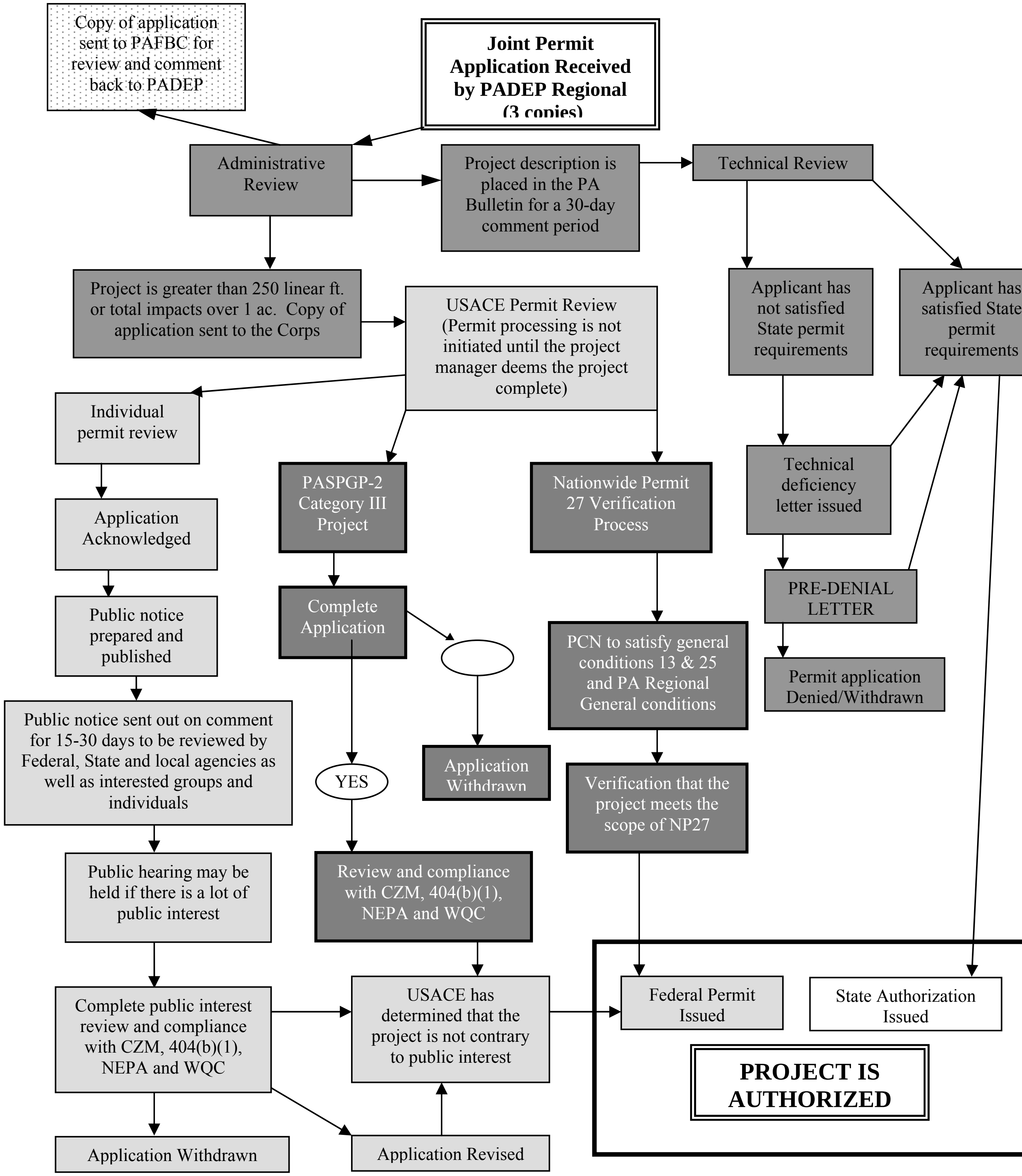
- Covers activities in waters of the United States associated with the restoration of former waters, the enhancement of degraded tidal and non-tidal wetlands and riparian areas, the creation of tidal and non-tidal wetlands and riparian areas, and the restoration and enhancement of non-tidal streams and non-tidal open water areas. *See* 33 CFR 320-330 for Nationwide Permits and General Conditions <http://www.usace.army.mil/cw/cecwo/reg/33cfr320.htm>
- Utilized for projects with limited public involvement
- No impact acreage limitation
- Requires Corps notification as per General Condition 13.
- Project must comply with Pennsylvania Regional Conditions; See Regional Conditions applicable to NP 27.

C.) *Department of the Army Individual Permit* (IP):

- Issued for activities with greater than 1 acre of impact or in special circumstances (*see* Section B above)
- Public Notice issued with 15/30 day comment period
- Public Notice issued to resource agencies (PAFBC, PAGC, NMFS, PHMC, EPA and USFWS), adjacent property owners, municipalities, post offices, newspapers, and other interest groups
- Review not usually less than 60 days
- Alternative analysis required for impacts to special aquatic site (40 CFR 230 Subpart E)

The flow chart below describes the process that a joint permit application will follow once the application is received by the DEP Regional Office.

PERMIT PROCESS FOR NSCD/FGM PROJECTS



NPDES Permits for Discharges of Stormwater Associated With Construction Activities

All construction activities proposing to disturb 5 acres or more of land must be authorized by a National Pollutant Discharge Elimination System (NPDES) Permit. In 1999, EPA promulgated new regulations that require NPDES coverage for small construction activities of 1 to less than 5 acres where a point source exists.

Other than agricultural plowing or tilling, timber harvest activities or road maintenance activities, an NPDES permit is required for:

- Any earth disturbance activity that involves 5 acres or more of earth disturbance, or an earth disturbance on any portion, part, or during any stage of, a larger common plan of development or sale that involves 5 acres or more of earth disturbance over the life of the project; and,

- Any earth disturbance activity that involves 1 acre to less than 5 acres of earth disturbance and has a point source discharge to surface waters of the Commonwealth, or an earth disturbance on any portion, part, or during any stage of, a larger common plan of development or sale that involves 1 acre to less than 5 acres of earth disturbance and has a point source discharge to surface waters of the Commonwealth over the life of the project.

A *point source* is defined as:

> "*any discernable, confined and discrete conveyance, including, but not limited to, any pipe, ditch, channel, well, discrete fissure, container, rolling stock, CAFO, landfill leachate collection system, or vessel or other floating craft, from which pollutants are or may be discharged*."

Normally, restoration activities would be designed to avoid the creation of a point source.

Effective December 8, 2002, a post-construction storm water management (PCSM) plan must be prepared. All general and individual NPDES permit applications must be submitted with an attached PCSM plan that identifies the BMP's that will manage and treat the post-construction stormwater discharge to protect water quality. The BMP's must be designed to maximize groundwater infiltration, to protect the structural integrity of streams, and to protect and maintain the existing and designated uses of surface waters.

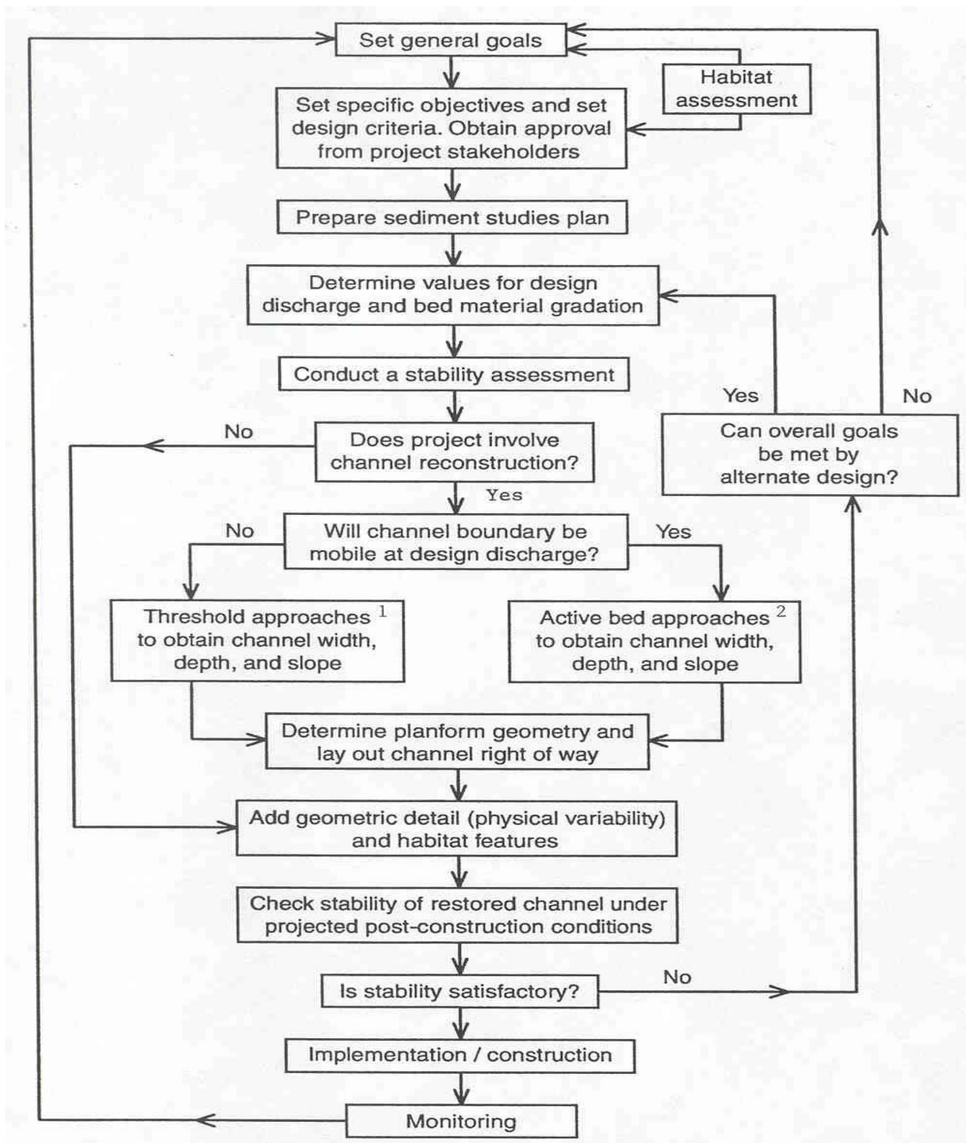
Normally, restoration activities will be designed so that PCSM is not required.

The Keystone Stream Team offers the following additional guidance in issues related to ensuring a good project:

- If federal assistance is provided, the federal agency must comply with:
  - National Environmental Policy Act
  - Clean Water Act (Section 401, 402, 404)
  - Endangered Species Act
  - Rivers and Harbors Act of 1899 (Section 10)
  - executive orders for floodplain management and wetland protection
- Any work in floodplains delineated for the National Flood Insurance Program might require participating communities to adhere to local ordinances and obtain special permits.
- Remember to notify PA's One-Call System to identify underground utility lines. Call three days before you dig (1-800-242-1776).
- Remember to run a search with PNDI to determine if the site is home to any protected plant or animal species (*see* DEP encroachment permit package).
- Check with the State Historical Preservation office (Section 106 of Historical Preservation Act) for known preservation sites (*see* DEP encroachment permit package).
- It is the ultimate responsibility of the permitting agency to decide who must sign-off on design plans. Be aware that projects involving public health or safety issues may require that registered engineers and/or geologists sign-off, if work involves engineering and geological calculations. This guidance document encourages professional peer reviews of design plans and the use of professionals who are trained and experienced in FGM design work.

Chapter 6
CREATING THE FINAL DESIGN

The actual steps taken to design specific projects can be as different as the streams involved. However, the flow chart below outlines a general procedure that can be followed from planning to post-construction monitoring. As can be seen, each step can affect the design.



Excerpt from *Design for Stream Restoration* (Shields, Copeland, Klingeman, Doyle, & Simon, 2003)

[1] Threshold approaches include:
- Allowable velocity
- Tractive stress
- Tractive power
- Regime

[2] Active bed approaches include:
- Analog (reference reach)
- Empirical (regression equations)
- Analytical (models)

Once the preliminary design has been prepared based on consideration of project goals/objectives, site constraints, hydrologic analysis and design flows, and design criteria, a detailed design plan can be developed.

Channel Dimension, Pattern and Profile

Having determined design flows, the next step is to generate channel slope and geometry by assigning a channel width derived from a reference reach, empirical equations, or analytical method. Analytical methods may include readily available flow resistance and sediment transport equations. Channel slope, depth and width should be tweaked until the desired flow parameters, sediment transport conditions, and design criteria have been met. This can typically be accomplished using spreadsheets or software programs that apply the Manning's equation. Constant dimensions for channel width, depth, and slope should be avoided and values that are derived should be applied as averages since designs should capture the spatial variability typical of lightly degraded systems (Richards 1978; Hey and Thorne 1986; Knighton 1998; Soar and Thorne 2001).

After the average channel width, depth, and slope have been selected, the channel planform should be laid out based on channel sinuosity which is dictated by valley slope divided by channel slope. Planform geometry can be established using references such as surveyed analog reaches, regime equations, or layout of a non-uniform flow path for the required length of stream using a string cut to scale. Several of these methods should be consulted to verify that proposed planform variables fall within a desired range of values. It is also important to incorporate some degree of natural variability into the curves developed for the proposed channel planform to avoid creating patterns that may appear unnatural. If channel alignment is confined by topography or infrastructure, the desired sinuosity may be higher than allowable based on site constraints. Under these circumstances, flow training structures and/or grade control structures may be necessary to reduce channel migration or bed degradation.

Hydraulic Validation

Average channel width, depth, slope, and planform generated during the design process should be checked and refined through an iterative process to ensure desired flow and sediment transport conditions. In order to proceed from preliminary design to final design, a flow model of the project reach should be created using a hydraulic modeling program such as HEC-RAS. The level of detail incorporated into the model should be dictated by the complexity of the project, including its objectives and constraints. The model acts as a design tool for investigating potential channel responses to proposed hydraulic geometry, in-stream structures, bank stabilization treatments, etc. over a range of design flows. Once the model is assembled, channel adjustments and treatments can be introduced to generate output that will aid in the validation of proposed design measures.

Sediment Transport Validation

Depending on the complexity of the project, if substantial changes are proposed for the channel dimension, pattern and profile that could impact sediment transport, an incipient motion/sediment transport analysis may be warranted. This could be accomplished through the use of incipient motion/ sediment transport calculations or sediment transport models such as SAM or HEC-6. These equations and models can be used to predict the size or volume of substrate material transported by the proposed design over a range of hydrologic events, which can then be checked against what is observed in the field, at the project site or in reference sections. This type of analysis can be used in order to determine if the channel will experience acceptable levels of scour or deposition during discharges greater and less then the design flow (Shields *et al*. 2003). Confirming the competency of the proposed design channel to transport the sediment load generated by its watershed is a critical phase in the design process. If the new channel has too little energy, sediment deposition may occur which can lead to channel migration, bank erosion and further instability. In contrast, too much energy can result in channel down-cutting and/or bank erosion, also resulting in substantial instability in the watershed.

In-Stream Structures

The use of in-stream structures in Natural Stream Channel Design projects can be very effective at meeting a wide range of objectives if they are incorporated into the design properly and designed and constructed correctly. These structures are often designed to: protect newly constructed channels from erosion until vegetation has established; reduce accelerated stream bank erosion; provide grade control; obtain stable flow diversions; enhance fish habitat, including in-stream cover, spawning areas and habitat diversity; re-introduce and stabilize large wood for habitat, stability and aesthetic purposes; protect infrastructure adjacent to streams; protect bridges, culverts and drainage crossings; reduce flood levels; transport sediment; and provide energy dissipation (Rosgen 2006). However, it should also be noted that, structures not in harmony with the geomorphic processes controlling channel form and aquatic habitat are at best a waste of resources, and may cause more damage than benefit to the stream corridor ecosystem (Thompson 2002). Some commonly applied in-stream structures include root wads, boulder clusters, log vanes, rock vanes, J-hook vanes, flow deflectors, check dams, weirs, cross vanes, step pools, and riffle grade control structures. *See* Appendix II for a list of references that pertain to the application, design, and construction of a variety of in-stream structures.

Bank Stabilization

Stream banks should be designed to withstand the tractive forces exerted on them, including those found at the toe of bank. Bank toe protection should be set to the elevation determined as the maximum depth of anticipated bed scour using appropriate scour calculations. Bank stabilization treatments should vary in proportion to the proposed channel geometry since the range of shear stresses along the boundary of the stream channel can vary significantly. Site constraints such as infrastructure may dictate that more permanent stabilization measures be incorporated to protect adjacent facilities. Project reaches void of infrastructure or similar constraints are typically more conducive to bioengineering bank stabilization measures. Some commonly applied bioengineering bank stabilization treatments include live stakes, live fascines, coir bio-logs, fabric encapsulated soil banks, brush layering, brush mattresses, live crib walls, vegetated geogrids, root wads, and toe protection. *See* Appendix II for a list of references that pertain to the application, design, and construction of a variety of bioengineered bank stabilization techniques.

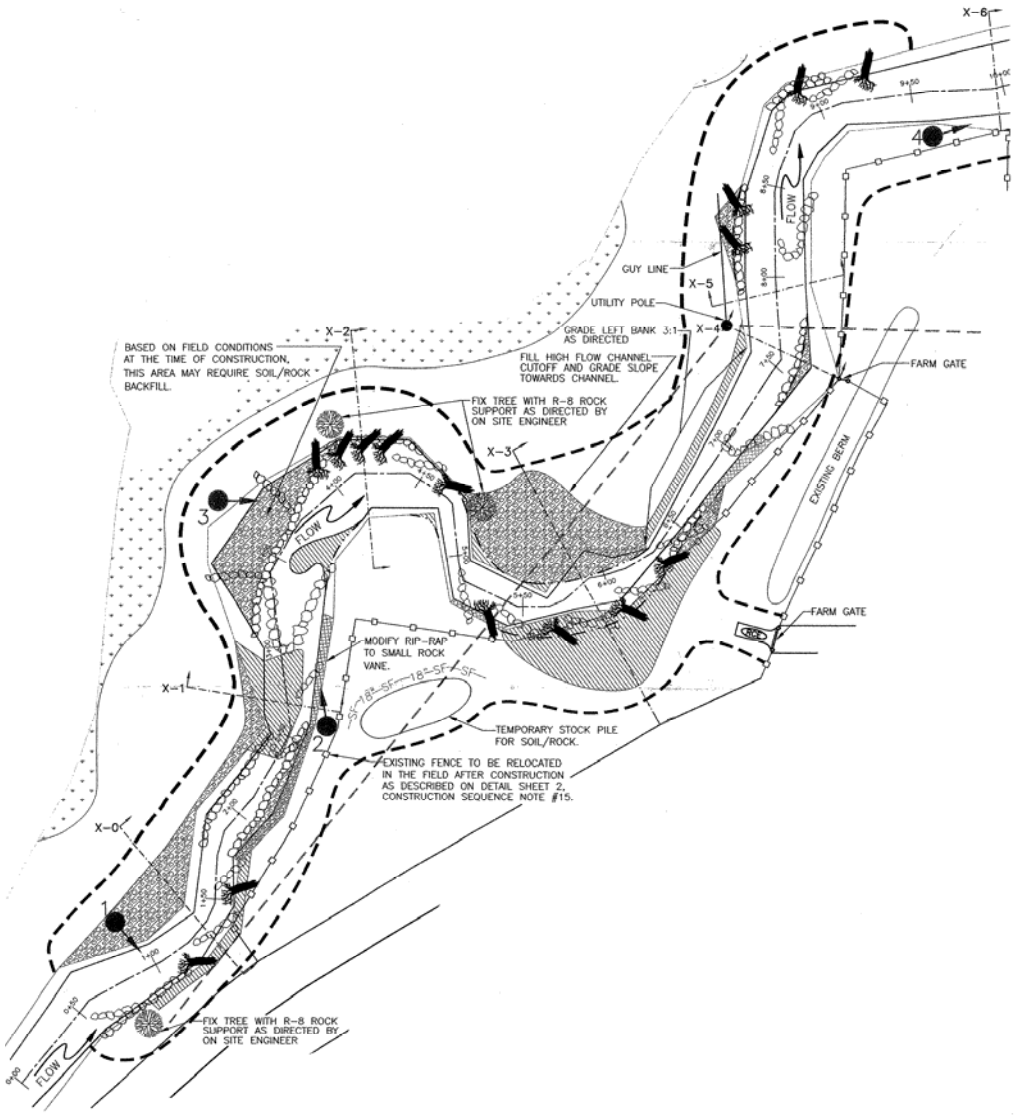
Checking Designs

Checking, and peer review of, final designs is an essential step in ensuring quality assurance and control in the field of Natural Stream Channel Design. Regardless of the design approach(es) used or the design treatments proposed, it is critical for the final design to be checked against accepted analyses and practices. This can typically be accomplished through periodic design reviews held throughout the design phase at critical milestones in the design process. Design checks can be completed beginning with the conceptual design phase and continue through final design and pre-construction. These reviews can be held with a group of designers, both internal and external, resource agency representatives, members of academia, field personnel, construction inspectors, contractors, etc. The more diversified group of practitioners involved in checking designs, the better the likelihood of producing a quality design product. Checking designs allows designers to present their work to other professionals, obtain feedback on proposed treatments, and create a forum for learning from successes and failures experienced by colleagues in a discipline that is continually evolving.

Sample Site Plan

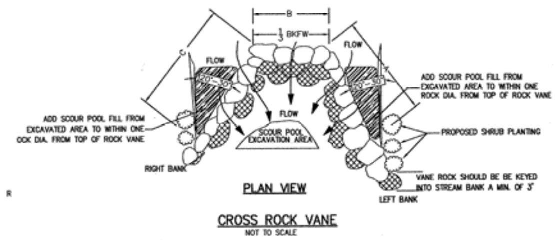
The following site plan is an excellent illustration of design details that should appear in permit application packages. As explained in detail in Chapter 5, applications should include a scaled plan view drawing showing the location and type of structures or activity within the project limits.

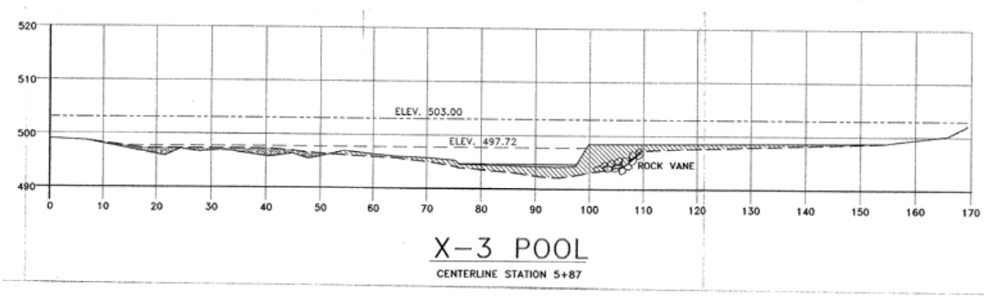
SAMPLE SITE PLAN DRAWING



Source: Site Plan, East Branch Codorus Creek, York County; Izaak Walton League of America - York Chapter #67; Skelly & Loy, Inc.

SAMPLE PLAN VIEW & CROSS-SECTION





Source: Site Plan, East Branch Codorus Creek, York County; Izaak Walton League of America - York Chapter #67; Skelly & Loy, Inc.

Chapter 7
SELECTING A QUALIFIED CONSULTANT

Because natural stream channel design integrates many scientific and engineering disciplines, and requires a combination of field experience and formal education/training, finding competent consultants should require some level of investigative work. Professional engineers, geologists, hydrologists, etc. are not always necessarily qualified to design natural channels, nor are individuals who have completed formal coursework and training without having adequate field, design, and construction experience. Educational background, training record, field experience, design expertise, technical support, knowledge of permitting, construction know-how, professional reputation, references, and successful implementation of similar projects are all critically important factors to be considered.

Establishing the objectives, constraints, complexities, and budget limitations of a specific project can aid in determining which types and levels of expertise will be required to carry out the job. Whether the focus is to hire a consultant for stream assessment, design, or construction work, there are a number of issues that should be considered to assist with selecting a qualified professional or team of professionals for completing a successful project. It is important to conduct background research, investigate into potential options, and evaluate all of the available and feasible alternatives during the selection process. It can be very beneficial to conduct field view of the site with interested candidates. Different scientific backgrounds often provide different perspectives on the sources of stream impairments as well as possible solutions.

Understanding Available Options

Designation as a non-governmental organization (NGO) or governmental agency will determine to a large extent the options that are available when procuring services for a project. In general, local governmental agencies must adhere to local regulations in the awarding of subcontracts, while non-governmental organizations have more flexibility in the process. However, both governmental agencies and NGO's should be aware of state and/or federal subcontract conditions when both applying for and awarding grants. When planning a project and developing a grant proposal, NGOs should learn as much as possible about fiscal agents' rules and construct their proposals accordingly. Each grant program has its own set of requirements. Under state-funded projects, for instance, subcontractors must be presented to the Commonwealth for review and approval. In some cases, the Pennsylvania Prevailing Wage Act applies (*see* Appendix II for listing of helpful websites).

NGO's that do not hold 501(c)(3) non-profit status often look to local governmental agencies to receive grant monies for a local project. An alternative to running a grant through a governmental agency would be to run it through a non-profit grant administrator, which, for an administrative fee, can manage the financial matters of the project and sub-contract the management and implementation of the project to a watershed organization and/or private consultants.

Government funding agencies encourage competition in the selection process. The Commonwealth procures services competitively in two ways: Invitation for Bids and Request for Proposals.

1) **Invitation for Bids** (IFB) - IFBs are used when a project is well-defined and the awarding agency can describe precisely what it's looking for in a project. Bids are submitted in response to the IFB solicitation document issued by the governmental agency. The award is made to the lowest responsive and responsible bidder -- in other words, the lowest bidder that is considered responsible in carrying out the work. Cost is generally the overriding factor in evaluating submissions.

2) **Request for Proposals** (RFP) - RFPs are used when the project is less well-defined. The funding agency may be soliciting novel or creative ideas, or the project may be more complex and open to broader interpretations. Proposals are submitted in response to the RFP solicitation document issued by the governmental agency. The award is made to the highest scoring proposal, in accordance with a set of criteria for selection of which cost is just one factor.

Non-competitively, a third option is sole-source procurement. Under sole-source, the funding agency must justify the award being made to one recipient rather than following a competitive process. Chapter 6, Subpart E of the *Commonwealth Procurement Code*, outlines nine circumstances that justify sole-source awards. Sole source procurement may be used when the contracting officer determines that one of the following conditions exists (refer to http://www.dgs.state.pa.us/comod/handbook/Part1.pdf):

1) Only a single contractor is capable of providing supplies, services, or construction.
2) A state or federal statute or regulation exempts supplies, services, or construction from a competitive procedure.
3) It is clearly not feasible to award the contract for supplies or services on a competitive basis.
4) The services are to be provided by attorneys or litigation consultants selected by the Office of General Counsel, Office of Attorney General, Department of Auditor General, or the Treasury Department.
5) The services are to be provided by expert witnesses.
6) The total cost for services involving the repair, modification, maintenance, or calibration of equipment and are to be performed by the manufacturer of the equipment or by the manufacturer's authorized dealer, is more than $10,000, and the purchasing agency head or designee determines bidding not be appropriate under the circumstances.
7) The contract is for investment advisors or managers selected by the Public School Employees' Retirement System, the State Employee's Retirement System or a state-affiliated entity.
8) The contract is for supplies or services that are in the best interest of the Commonwealth.

The funding source for a particular project may specify which approach should be taken in awarding subcontracts. The three options noted above are simply guidance based on part of the Commonwealth's procurement protocol.

Disclosing Project Information

Establishing the objectives, constraints, complexities, and budget limitations of a specific project will assist in evaluating the capabilities of prospective consultants. This can be initiated by making a public announcement that explains the nature and details of a specific project and what services are expected from a consultant or construction contractor. It is important to be specific with regard to what tasks must be completed as part of the assessment, design, and/or construction and monitoring. This can be incorporated in the form of a RFP or IFB as explained above.

Some invitations for work might be extremely detailed if the individuals preparing the document are experienced in NSCD and know exactly what procedures need to be followed in order to carry out a specific project. Others may request conceptual design plans based on preliminary assessment work or request that up front assessment work be completed. The level of detail presented in an invitation for work will be largely dictated by the complexity of the proposed project and the level of knowledge and experience of those initiating the project.

Instructions to Prospective Consultants/Contractors

Consultants and contractors should clearly articulate any specific procedures they are obligated to follow. The following list of items may need to be specified to prospective design consultants and construction contractors, as applicable:

1) Process for submitting proposals.
2) Process for evaluating proposals, including selection timeframe and notification of final selection.
3) Timeframe for work, including when work should begin, when it should be completed, and contingency plans for seasonal delays.
4) Process and schedule for payment of work, including payment conditions for unsatisfactory installation. It may be necessary to include a provision explaining that payment will be made within a specified number of days after reimbursement is made to the project sponsor from a government grant source. This will help avoid cash flow problems for those watershed organizations that cannot pay a subcontractor until grant monies are reimbursed.
5) Inspection and certification of work
6) Special permit conditions
7) Design plans, specifications, and estimate (PS&E), which may include:
    - Project location map
    - General notes
    - Property line/owner information
    - Survey control information
    - Typical cross sections

- Grading plan sheets illustrating existing and proposed contours as well as in-stream structures, stream bank treatments, and other proposed features
- Profile sheets showing existing and proposed stream bed/bank profiles as well as other stream bed/bank treatments
- Detail drawings for in-stream structures, stream bank treatments and other proposed features
- Cross sections depicting existing and proposed channel dimensions as well as in-stream structures, stream bank treatments and other proposed features
- Erosion and Sediment (E&S) Pollution Control plans showing construction entrances/access, limits of construction/disturbance, staging/stockpile areas, sequence of construction, maintenance of stream flow, and locations of E&S Best Management Practices (BMP's)
- E&S details for proposed E&S BMP's
- Landscape/planting plans illustrating proposed stream bank and riparian plantings/planting zones/seeding areas as well as a list of species, spacing/density, and quantities
- Landscape details for proposed bioengineering, shrub/tree planting, and seeding treatments
- Tabulation of quantities including earthwork, in-stream structures, stream bank treatments, E&S devices, landscape materials, and miscellaneous construction items
- Specifications detailing proposed construction items including excavation, in-stream structures, stream bank treatments, E&S BMP's, landscape treatments, and miscellaneous items
- Cost estimate providing a list of pay items, units of measure, quantities, unit prices, prices per item, and total cost and/or total cost with contingency

8) Change Order and Delays - Additional work or changes to scope of work may be made through a written change order, which should be approved by both the contractor and project administrator.
9) A rate schedule furnished by the contractor can often be used for the determination of costs related to required change orders. Categories typically included in the rate schedule might include laborer, project management, excavator with thumb, wheel loader, dozer, per diem, survey crew, mobilization, and other anticipated categories. The bid documents should contain instructions that explain the following specifics regarding change orders:
   - individual(s) authorized to make/approve changes in the field
   - set dollar amount not to be exceeded for agreed-to changes
   - set per diem cost rates charged to the contractor if the contractor is delayed in starting or completing the work due to causes within their control;
   - set per diem cost rates charged to the project administrator if the contractor is delayed in starting or completing the work due to causes within the project administrator's control;
   - Acts of God - if the project is delayed due to adverse weather or stream conditions, an Act of God, or other conditions beyond the control of the contractor or project administrator, then the contract completion date should

typically be adjusted to reflect the new completion date without additional cost to either party. Reserve the right, to determine when weather or other unforeseen circumstances warrant a delay or suspension, for the project administrator. Contractors should typically not be held responsible for any damage to portions of the project that have already been completed and approved by the project inspector. Consider language that calls for a written change order if significant project delays create more than a 10% increase or decrease in the amount of work.

10) Deliverables – It is imperative to specify what submittals/products are expected or required at each phase of a project. Deliverables might include field data sheets, regional curve data, photo log, conceptual design plans, design report, hydrologic and hydraulic (H&H) report, E&S plans and report, permit applications, final design PS&E, as-built plans, and/or all supporting documentation for all of these, as well as any assessment, management or restoration plans.

11) Proprietary Rights – It is critical to be clear about who owns the data, reports, designs, and any other products produced for the project in both the grant contracts and the contract with the hired consultant. A general guideline to follow is: Any information pertaining to those projects funded in whole or in part with public money and/or conducted on public property will become public property, if it is: (A) Submitted as a part of the permitting process; or (B) Specifically described in the grant contract. Any information not described in the grant contract and not essential to the permitting process does not belong to the funding organization or contractee. Therefore, it remains private property to the contractor. However, this does not preclude the contractee from writing into the contract with the hired consultant that they wish to have ownership of the stated items. Information pertaining to privately financed projects implemented on private property will become public property if it is submitted as part of the permitting process.

Interviews

After receiving proposals, an in-depth interview process should be conducted to screen prospective consultants. The following items should be covered during the interviews, as applicable:

- Credentials, including resume, educational background, training record, and project history of personnel
- Track record, including project write-ups, photos, reports, drawings, and/or client and sub-contractor references for applicable, completed projects
- Rates and work schedule, including estimate of time a consultant would expect to devote to the described assessment, design, and/or construction work
- Proof of insurance coverage, including workers compensation, public liability and property damage, automobile, bodily injury, and property damage)
- Performance bonds for construction work, which could potentially add to project costs.

Chapter 8
CONSTRUCTION CONSIDERATIONS

This chapter presents information to enhance planning of the construction phase of Natural Stream Channel Design (NSCD) projects. It will assist in determining appropriate methods, planning the pre-construction meeting, selecting construction periods and locations, choosing construction equipment, reducing erosion & sedimentation during construction, and the need for on-site supervision.

Background Information

The concepts of NSCD directly address the sediment transport rates of the stream, its load carrying capacity and the sources/amounts of sediment load. NSCD projects use as a reference (or template) a stable stream of the same type, slope, bed and bank materials, valley type, and valley slope as the degraded stream.

Erosion and sedimentation rates in a stable stream channel are in dynamic equilibrium, a natural balance that allows the stream channel to maintain its pattern, profile, and dimension over time without aggrading or degrading. While some channel adjustment and re-alignment is a natural result of sediment transport, stable streams make geomorphic channel adjustments at a rate appropriate to the local climate, geology, topography, vegetation, and land use; these slow changes are not readily apparent and can only be measured by a detailed survey. Stress induced acceleration of erosion and deposition rates results in rapid channel alterations that are more easily observed and measured.

Accelerated bed and bank erosion has been identified as a significant source of sediment loading and stream habitat impairment. This problem is a major concern of watershed groups attempting to address stream channel impairment. Therefore, enabling a stream to return to its proper form and function (through NSCD), is considered an effective restoration tool and best management practice (BMP).

Pre-Construction Meetings

A pre-construction meeting should be held on-site to ensure that the contractor and construction crew understands all aspects of the plan. Include the designer, contractor, construction crew, construction inspector (if different than the designer), landowner, conservation district, and agency representatives, including the Corps of Engineers.

Points to consider at the pre-construction meeting:
- Identify areas most sensitive to disturbance
- Review sequence and schedule of implementing control measures
- Note any changes to the erosion and sediment (E&S) control plan
- Review any changes made to final copies of plans and permits
- Review the right of entry agreements on private properties
- Review any public utility locations and related concerns

- Review the staging and transportation plan (consider access to project site in terms of landowner concerns and how to transport materials and equipment)
- Review records and reports that will be needed to provide necessary documentation for progress on-site
- Review mechanisms for emergency response

Selecting Construction Periods and Locations

Identify specific windows for construction:

- In-channel construction activities should take place during low-flow periods.
- Solidly-frozen ground is an asset for access to a stream. Thaw periods or partially frozen ground should be avoided in order to prevent the formation of deep ruts during heavy equipment operation.
- With regard to fish spawning and stocked trout constraints, no work should be done in wild trout streams between 10/1 and 12/31; stocked trout streams between 3/1 and 6/15; Lake Erie tributaries between 9/1 and 4/30; and warm water streams between 4/15 and 6/15. Consult with the PA Fish & Boat Commission for specifics and to verify restrictions.

Identify starting point, staging areas, and sensitive areas:

- Carefully select staging and access areas for equipment and materials. When selecting these areas, consider minimizing environmental impact by placing access BMPs in an optimal location and optimizing sequencing considerations. Stockpile an adequate amount of materials on-site prior to construction to avoid project delays and additional hauling while under construction. Control and protect ingress and egress to public roadways.
- Identify any soil disposal areas which may be required. Soil requiring disposal should be "feathered out" in thin layers (less than 3 inches) across the floodplain in the work area, especially in pastures. This soil should be seeded and mulched immediately after grading. Soil must not be disposed of in a floodway or wetland.
- For most projects, stream restoration work should begin upstream and then proceed downstream. The installation of in-stream structures will change flow patterns within the channel and, therefore, any required adjustments to restoration activities can be made downstream as needed. However, site conditions, design constraints, and access issues may favor work beginning downstream then proceeding upstream.
- Avoid impacts to existing woody vegetation and their root masses along stream banks. It may be necessary to move equipment or work within the stream with minimal movement to avoid destroying sensitive riparian areas or mature forests. Streams can restore themselves faster than a riparian forest.

- Using natural stream channel design and fluvial geomorphic principles, it is advantageous to construct in-stream structures with normal to low-flow in the channel to observe the reaction of channel flow to the installed structures. When placing structures, be sure to use the appropriate BMPs. In certain cases where in-stream conditions are deemed sensitive or are especially vulnerable to disturbance, a “No Action” alternative may be the preferred alternative when work cannot be done without cofferdams or the temporary diversion of flow.
- For newly constructed channels or stream channel relocations, consideration should be given to constructing the new rough channel geometry in dry conditions. Construction of a new stream channel in dry conditions is easier and can be completed in a shorter time frame. However, it may be necessary to release some water into the new channel before placing structures.
- Wetlands within the limits of disturbance must be clearly identified on project drawings and flagged at the work site prior to start up. Disturbance of wetland areas must be avoided unless work in these areas is permitted. Consult with the DEP Regional Office for any activity that may impact wetlands. If necessary, a GP-8, Temporary Crossing, may be issued to allow minor impacts in wetlands and small streams. Contractors must adhere to all permit conditions.
- Abandoned mine reclamation projects: An impervious liner should be properly placed to prevent stream flow loss to abandoned underground mines or fill areas. It is essential to place the liner and construct the stream channel in the dry.

TIP: *Ensure that the contractor has liability insurance.*

Choice of Equipment

- Match the size of construction equipment to the size of project and materials. Undersized equipment can mean staying in the stream longer and creating more of a disturbance, which can ultimately mean more time and money. Larger equipment can handle working from bank if mandated to do so. However, where useable, smaller equipment may disturb less area.
- Excavation equipment with thumb attachment can greatly improve the handling of large material such as root wads and vane rocks. For wheel loaders, a four yard bucket is best for moving large rocks.
- Prepare for and use the right equipment for wet conditions.
- Encourage the use of biodegradable fluids in construction equipment.

TIP: *Have a spill kit on-site to handle accidental spills of hazardous materials.*

Erosion and Sediment Control

Long-term soil loss from an unstable stream far exceeds the amount of sediment or soil discharged into the stream during NSCD construction. Nonetheless, it is important to minimize all construction impacts. Thus, to minimize erosion and resulting sediment impacts associated with construction, the duration of construction and the degree of disturbance to the stream and riparian corridor should be minimized. Refer to the

Erosion & Sediment (E & S) Pollution Control Plan and the E & S Plan Adequacy letter from the Conservation District (part of the 105 permit application) for analysis of various alternatives to confirm justification of work planned in the stream or from its banks. Reference the cost/benefit ratio and the "No Action" alternative before proceeding.

Erosion and Sediment BMPs:

- Implement the E&S plan, a copy of which must be kept on-site.
- All work should be done from the bank where practicable. Minimize the amount of time and extent of disturbance in the channel as much as possible.
- When fording a stream, select areas with a stable bottom and where the channel is not entrenched to minimize the amount of disturbance.
- Working from within the active stream channel with excavating equipment can be the most effective and least disruptive way to install structures such as rock vanes or cross rock vanes. Working from within a stream will reduce bank damage and maintain established riparian vegetation. Depending on the stream characteristics, allow equipment in the stream as needed and then retreat up the bank slope to properly key structures into the stream bank. Equipment should work from the side of the stream where in-stream structures are being installed. Avoid working from an opposing stream bank if construction equipment is likely to pull soil into the active channel.
- In situations where a new channel is constructed in the dry, consideration should be given to preventing downstream sedimentation. All excavated and filled areas should include rock protection to at least one-third bankfull in order to stabilize the new bank and prevent scour and erosion. Soil removed from a newly-excavated stream channel must be stockpiled and stabilized until the old channel is ready for backfilling.
- Once stabilized, slowly introduce water into the new channel, allowing some flow to remain in the old channel temporarily. Place rock or staked straw bales or other protective barrier across the old channel to divert the remaining flow into the new channel. Once all flow has been diverted, the abandoned channel may be left as is (for its ecological value) or backfilled (if it's hydraulically critical), vegetated, and stabilized. Always begin backfilling of the old channel at the upstream end (behind protective barrier) then proceed downstream. Stabilize all channel fills and other disturbed areas immediately.
- Seed and mulch/mat areas from bankfull to the water's edge (active stream channel) concurrently with restoration activities. Seed and mulch completed areas daily. The addition of live stakes and plants can be concurrent or at a later date.
- Point bars should be stabilized by seeding annual cover crop (rye grass) if there is adequate medium for growth. Where appropriate, re-seed the area for an added measure of stabilization until native vegetation can grow.
- Consider using erosion blankets especially on soils that are more prone to accelerated erosion and along meanders.
- Avoid the use of silt fence along the immediate stream bank area during construction. It will be in the way and is not practical. The installation of silt fence may also disturb the bank area during installation. In most situations where limited disturbance occurs, silt fence is not necessary.

- Everything above the design bankfull elevation should be permanently stabilized.
- Collect pre- and post-construction information on bank erosion.
- Consider the streams' environment. Limitations may differ from one stream to another due to differences in geology. The type, degree, effectiveness and appropriateness of each BMP need to be adjusted to the region where it is applied.

Supervising Construction

The Keystone Stream Team strongly recommends that a project designer or a person knowledgeable and accountable for the project be on-site during crucial construction periods. A contact number for the project designer (or alternate) should be readily available when he/she is not physically on-site to answer questions concerning design. Experience in natural stream channel design is limited among construction contractors, so it's critical to provide direct oversight by someone who understands the project and has knowledge of the structures being installed. The key is to work with contractors so that experience and competency will grow in this evolving field. Where possible, encourage peer-learning opportunities.

Tip*: To avoid delays and ensure proper construction, allocate money for the cost of having the project designer on-site to oversee installation of channel structures.*

Communication between the designer, contractor, and landowners is critical to the success of the construction phase. Walk the site together and discuss access, local availability of rock materials, and use of fill. Assure landowners that the site will be adequately cleaned up after construction is completed. If the work is completed in a professional and satisfactory manner, then landowners will be more receptive to future construction projects.

Chapter 9
MONITORING: PRE- AND POST- CONSTRUCTION

Monitoring is conducted to measure success, and success in the field of natural stream channel restoration can be two-fold: 1) to meet permit conditions and measure the attainment of a project's specific objectives, and 2) to measure the performance of a natural stream channel design over time. Monitoring also documents baseline conditions and measures changes.

A natural stream channel develops its particular dimension, pattern and profile over a long period of time. It makes continual adjustments (sometimes referred to as *Natural* or *Dynamic Equilibrium*) as it reacts to a wide range of flow conditions. A newly restored reach is rarely in perfect equilibrium immediately after construction. Monitoring over a period of at least five years is recommended to allow time for the stream channel to achieve its final form and for riparian vegetation to become fully established.

Monitoring objectives expressed as measurable stream conditions provide the basis for determining the success of a project. Defining monitoring parameters to match your project objectives makes sure that your objectives are both measurable and achievable.

It is important to build monitoring components into the assessment phase of the project. Establish pre-construction monitoring components and locations. Monitor the poorest sections early on -- document conditions before and after construction at the worst sections of the impacted stream reach.

Three objectives of almost any natural stream channel design are adequate sediment transport, habitat optimization, and stabilization of the bed and banks. Determine ways to monitor for each, keeping in mind that the importance of each objective will vary from project to project. Identify your main objectives and monitor accordingly.

Remember also that the reference site establishes baseline conditions that provide a standard against which to measure improvement.

The plan should include documentation of as-built conditions in addition to pre- and post-construction monitoring. The plan should define monitoring parameters, sampling frequency, sampling locations and analytical procedures. Documentation of structures (their size, length, slope, rock size, etc.) should also be part of the monitoring strategy. It's a good idea to involve the project designer in the selection of monitoring parameters.

Reference Worksheets:

- Morph Chart (*see* Appendix I) includes a column for as-built conditions.
- Field Survey Procedures for Characterization of River Morphology (*see* Appendix I)

Take an adaptive management approach -- monitoring and evaluation teaches us new things in natural stream channel design. Unforeseen problems may require midcourse corrections either during or shortly after implementation.

Volunteers from watershed organizations, sportsman clubs, and senior volunteer organizations, such as the Environmental Alliance for Senior Involvement (EASI) may be able to assist with short and long term monitoring tasks.

Monitoring Recommendations

- Duration of monitoring period: a minimum of five years

- As Built Surveys: (now required by DEP) should be done within 60 days post-construction. An as-built site plan should show:
  1) Any field adjustments in plan -- additions/deletions
  2) Post-construction cross-sections (monumented) and longitudinal profile
  3) Elevations and placement of structures
  4) Constructability -- discuss access to project, utilities, selection of equipment
  5) Breakdown of costs (optional: materials, construction, design, construction management)
  6) Photos: take at monitoring stations and cross-section areas, upstream and downstream of project.

  Reference Worksheets:
  - Morph Chart (*see* Appendix I) includes a column for as-built conditions.
  - Field Survey Procedures for Characterization of River Morphology (*see* Appendix I)

- Frequency of monitoring: During first year post-construction, a minimum of twice plus immediately after a bankfull event (as-built survey plus one additional if there is no bankfull event). For 2-5 years post-construction, a minimum of once per year plus as many post-bankfull events as possible.

- Monitoring reports: Long term monitoring reports should include comments on structures (erosion at structures, narrative on any tweaking done), survivorship or percent cover of riparian vegetation or wetlands (this is often specified in the 404 permit special condition), and an evaluation of whether goals/objectives have been met. Note any monitoring requirements as part of required permits.

- Monitoring components: Parameters should reflect those measures needed to meet the project's objectives. It's also important to consider the capability and dedication of people who will be involved in conducting the monitoring activities.

  Channel characteristics:
  - Monumented cross-sections (required by PA DEP)
  - Longitudinal profile
    - slope
    - riffle/pool characteristics
  - Pebble Count
    - bed particle size distribution
  - Pattern
    - sinuosity, meander lengths, radius of curvature
  - Bank stability (optional)
    - bank pins
    - scour chains for measuring aggrading or degrading streambed
    - BEHI (bank erodibility hazard index)
    - overall channel stability and habitat assessment (Pfankuch Stability Rating)

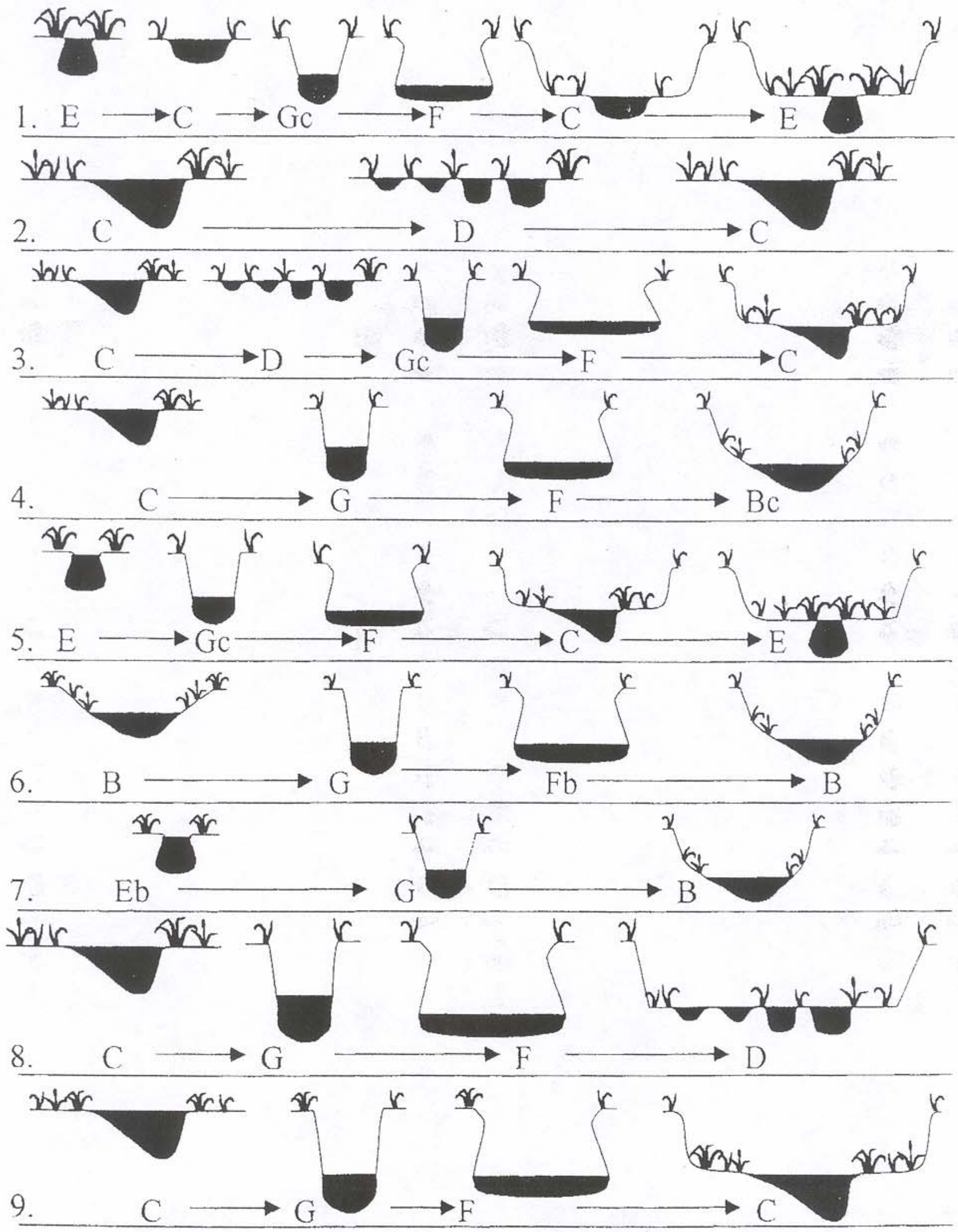
  Biological characteristics:
  - EPA's RBP (Rapid Biological Assessment Protocol) assessment form
  - PA Modified RBP (Rapid Biological Assessment Protocol) assessment form
  - Penn State University's AVStrEAMS (*see* Appendix II)

Currently, DEP's Citizen Volunteer Monitoring Program is developing monitoring guidance for natural stream channel restoration projects. For an update, visit <http://www.dep.state.pa.us/dep/deputate/watermgt/wc/Subjects/cvmp/default.htm>

APPENDIX I

HELPFUL TOOLS AND FORMS

Various Stream Type Evolution Scenarios



Watershed Assessment
Stream Reach Prioritization

Date: ________________ **Overall Score: __________**

Assessed by: ___________ **Priority Ranking:** **1** (4 to 8) **2** (9 to 12) **3** (13 to 16)

Stream Identification:

Watershed ID: ____________ Reach ID: _____________ Stream Type: _____________

Predominant Land Use: *(Circle):* Agricultural, Rural Open, Residential, Commercial, Industrial, Forested

Cause of Impairment: *(Circle all that apply)*: Not impaired, stormwater runoff, pasture impacts, unstable conditions upstream, channel downcutting, floodplain alteration, lack of riparian vegetation, high sediment loads (in-stream or overland)

Stream Assessment: *(Circle descriptive elements that apply to overall stream reach)*

Bank Stability

Priority
1__ Severe (Banks sloughing, undercut or vertical, exposed soils, evidence of property damage)
2__ Moderate (Banks unstable, some bank sloughing, bank slopes 60 to 80 degrees)
3__ Minor (Some bank erosion, slopes < 60 degrees)
4__ Stable (Well vegetated, gently sloping or low banks)

Channel Stability

Priority
1__ Severe (Numerous or large unvegetated channel bars, channel dredged, straightened or bermed, no active floodplain, downcutting and/or widening)
2__ Moderate (Degradation or aggradation noticeable, some evidence of over-bank overflow)
3__ Minor (Some channel scouring or sediment buildup, migration appears minor, floodplain feature present)
4__ Stable (Channel appears natural with no evident migration, point bars well vegetated, active floodplain)

Riparian Vegetation

Priority
1__ Severe (No woody vegetation with high banks, predominately grasses, buffer < 10’, canopy < 20% closed)
2__ Moderate (Sparsely vegetated banks, buffer 10’ to 20’ wide, canopy 20% to 40% closed)
3__ Minor (Some woody diversity and density, buffer 20’ to 60’, canopy 40% to 60% closed)
4__ Good (Good density and diversity of woody species, or low banks with grasses, buffer > 60’, canopy > 80%)

Aquatic Habitat (Features = riffles, runs and pools) (Cover = woody debris, large boulders, roots)

Priority
1__ Severe (No habitat present, uniform substrate or silt, no in-stream cover, uniform stream features)
2__ Moderate (Limited aquatic habitat, some substrate particle gradation, limited mix of stream features/cover)
3__ Minor (Aquatic habitat noticeable throughout reach, some mix of stream features and cover but not optimal)
4__ Good (Good in-stream cover, good mix of features, high variability of substrate particle size)

COMMENTS:____

SOURCE: Aquatic Resource Restoration Company

MORPH CHART

In order to collect the data in a consistent way that can be used to build a Pennsylvania database, please complete this chart and return it to your DEP project advisor. If you have questions please contact Fran Koch 717-783-2289 or email fkoch@state.pa.us

MORPHOLOGICAL CHARACTERISTICS OF THE EXISTING AND PROPOSED CHANNEL WITH GAGE STATION, REFERENCE REACH AND AS BUILT DATA*
(Rosgen, 1996)

Restoration site (Name of stream & location):
USGS Station (No. & location):
Reference Reach (Name of stream & location):

VARIABLES	EXISTING CHANNEL	PROPOSED REACH	USGS STATION	REFERENCE REACH	AS BUILT
1. Stream type					
2. Drainage area (sq. mile)					
3. Bankfull width (W_{bkf})		Mean: Range:		Mean: Range:	Mean: Range:
4. Bankfull mean depth (d_{bkf})		Mean: Range:		Mean Range:	Mean: Range:
5. Width/depth ratio (W_{bkf}/d_{bkf})		Mean: Range:		Mean: Range:	Mean: Range:
6. Bankfull cross-Sectional area (A_{bkf})		Mean: Range:		Mean: Range:	Mean: Range:
7. Bankfull mean velocity (V_{bkf})					
8. Bankfull discharge, cfs (Q_{bkf})					

9. Bankfull Maximum depth (d_{max})		Mean: Range:		Mean Range:	Mean: Range:
10. Max d_{riff}/d_{bkf} ratio		Mean: Range:		Mean: Range:	Mean: Range:
11. Low bank Height to max. d_{bkf} ratio		Mean: Range:		Mean: Range:	Mean: Range:
12. Width of flood prone area (W_{fpa})		Mean: Range:		Mean: Range:	Mean: Range:
13. Entrenchment ratio (W_{fpa}/W_{bkf})		Mean: Range:		Mean: Range:	Mean: Range:
14. Meander length (L_m)		Mean: Range:		Mean: Range:	Mean: Range:
15. Ratio of meander length to bankfull width (L_m/W_{bkf})		Mean: Range:		Mean: Range:	Mean: Range:
16. Radius of curvature (R_c)		Mean: Range:		Mean: Range:	Mean: Range:
17 Ratio of radius of curvature to bankfull width (R_c/W_{bkf})		Mean: Range:		Mean: Range	Mean: Range:
18. Belt Width (W_{blt})		Mean: Range:		Mean: Range:	Mean: Range:

19. Meander width ratio (W_{blt}/W_{bkf})		Mean: Range:		Mean: Range:	Mean: Range:
20. Sinuosity (stream length/valley distance) (k)					
21. Valley slope (ft/ft)				.	
22. Average slope (S_{avg})=(S_{valley}/k)				.	
23. Pool Slope (S_{pool})		Mean: Range:		Mean: Range:	Mean: Range:
24. Ratio of pool slope to average slope (S_{pool}/S_{bkf})		Mean: Range:		Mean: Range:	Mean: Range:
25. Maximum pool depth (d_{pool})		Mean: Range:		Mean Range:	Mean: Range:
26 Ratio of pool depth to average bankfull depth (d_{pool}/d_{bkf})		Mean: Range:		Mean: Range:	Mean: Range:
27. Pool width (W_{pool})		Mean: Range:		Mean: Range:	Mean: Range:
28. Ratio of pool width to bankfull width (W_{pool}/W_{bkf})		Mean: Range:		Mean: Range:	Mean: Range:
29. Ratio of pool area to bankfull area		Mean: Range:		Mean: Range:	Mean: Range:

30. Pool to pool spacing (p-p)		Mean: Range:		Mean: Range:	Mean: Range:
31. Ratio of p-p spacing to bankfull width (p-p/W_{bkf})		Mean: Range:		Mean: Range:	Mean: Range:
MATERIALS:					
1. Particle Size distribution of channel material					
D_{16}					
D_{35}					
D_{50}					
D_{84}					
D_{95}					
2. Particle Size distribution of bar material					
D_{16}					
D_{35}					
D_{50}					
D_{84}					

D_{95}					
Largest size particle at the toe (lower third) of bar					

SEDIMENT TRANSPORT VALIDATION (Based on Bankfull shear Stress	**Existing**	**Proposed**
Calculated value (mm) from curve		
Value from Shield Diagram (lb/ft^2)		
Critical dimensionless shear stress		
Minimum mean d_{bkf} calculated using critical dimensionless shear stress equations		

Remarks: using bedload data adjusted shields relation
***Modified for Pennsylvania with Dave Rosgen's permission. If you have any questions contact Fran Koch email fkoch@state.pa.us.**

Please follow this procedure to establish monumented cross sections that can be used for follow up monitoring of your project. If you have questions/suggestions please contact Fran Koch 717-783-2289 or email fkoch@state.pa.us

Field Survey Procedures for Characterization of River Morphology

by

Dave Rosgen

9/96

- Locate a reach for a minimum of 20 channel widths (Two Meander Wavelengths).

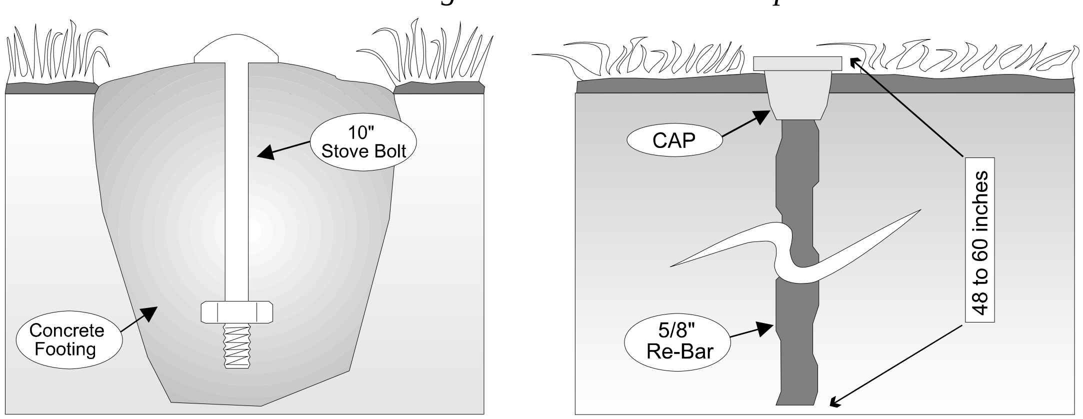
- This reach should characterize or represent the dimension, Pattern, Profile, and materials of the stream type you select.

- Select the reach starting point for the survey at the upstream location. Locate reach on aerial photo and map.

A. Dimension

1) Establish a cross-section at the start of the survey reach.
Establish a Permanent Benchmark to tie Both Cross-Section and longitudinal profile to an elevational control for future comparison. The Benchmark should be located a sufficient distance from the edge of the bank to prevent loss of the reference elevation by lateral erosion. The benchmark should be of a permanent installation using Sackrete with Stove Bolt into a “cone hole”. Another alternative is to drive 5/8" rebar 4' into the ground and place a cap over the rebar, flush with the ground surface (Figure 1).

Figure 1. Benchmark Examples



2) The cross-section needs to show:
-Benchmark elevation and location
-Terraces and floodplain
-Flood prone area width and depth

-Bankfull stage (Both left and right banks)
-Existing left and right edge of water
-Variability in shape of cross-section
-Thalweg

3) Start Cross-Section with the zero end of tape on <u>left</u> bank (looking downstream)

4) The following information is obtained from the cross-section (Figure 2):
   a. Bankfull width (W_{bkf})
   b. Mean Bankfull depth (d_{bkf}) (cross sectional area (A_{bkf})/(W_{bkf})
   c. Width/depth ratio W_{bkf} /d $_{bkf}$
   d. Entrenchment ratio = W_{FPA}/ W_{bkf}
      [Flood prone Area width (W_{FPA}) = (width at an elevation2x maximum bankfull depth)]
   e. Cross-sectional area at the bankfull stage (A_{bkf})
      Cross-sectional area is obtained by computing the sum of the products of the intervals of width times depth across the section.
      Wetted perimeter @ the bankfull stage
   f. Wetted perimeter @ the bankfull stage (WP)
      a) measure from plotted cross section or;
      b) approximate by computation:

$$WP = \left(2d_{bkf}\right) + \overline{W}_{bkf}$$

$$Where: \overline{W} = \frac{\left(W_{top} + W_{bottom}\right)}{2}$$

OR:

$$WP = W_{bottom} + 2\sqrt{\overline{d}^{2}_{bkf} + \left(\overline{W}_{bkf} - W_{bottom}\right)^{2}}$$

$$Where: \overline{W} = \frac{\left(W_{top} + W_{bottom}\right)}{2}$$

   g. Compute bankfull hydraulic radius (R_{bkf} = mean hydraulic depth):

$$R_{bkf} = \frac{A_{bkf}}{WP}$$

   h. Estimate mean bankfull velocity (U_{bkf}) in ft/sec.
   i. Estimate bankfull discharge (Q_{bkf}) = A_{bkf} x U_{bkf}.
   j. Obtain drainage area (mi^2) from topographic map. Compare regional curves at the bankfull stage for; cross-sectional area, width, depth, velocity and discharge by drainage area.

<u>B. PROFILE</u>

1) Start the longitudinal profile from first cross-section and tie-into a permanent elevation control for replicate measurements (Figure 3).

2) Obtain the following elevations on the longitudinal profile:
   * Bed surface
   * water surface
   * Bankfull stage

* Bank height (note left and /or right bank) (Optional)

3) Measure Thalweg position, stationing and distance, i.e. maximum depth. Make sure to measure changes in elevation that indicate the shape, depth, and length of pools and other features to accurately define the bed features along the profile.

4) Locate other cross-sections with longitudinal stationing as reach identifiers i.e. cross-section 3+50 is located 350 feet down from start of profile.

5) The number of points (elevations) obtained along the profile should be sufficient to describe the show the length and depth of pools and well as other bed features such as runs and glides.

6). The following data is obtained from the longitudinal profile.

*average slope (S) (using water surface)
*Bankfull slope (S_{bkf}) (for certain hydraulic and sediment computations.)
*Maximum riffle depth
*Ratio of maximum riffle depth/average depth (d_{maxrif} / d_{bkf})
*Riffle slope
*Ratio of riffle slope to average water surface slope (S_{riff} /S)
*Pool slope
*Ratio of pool slope to average water surface slope (S_{pool} / S)
*Maximum pool depth (d_{pool})
*Ratio pool depth to average bankfull depth (d_{pool} / d_{bkf})
* Riffle/pool spacing or pool to pool distance (r-p / W_{bkf})

C. Pattern

From aerial photos or from field survey obtain the following information:

1) Radius of curvature (R_c) Obtain for minimum, maximum and average values. Besides measuring on aerial photo or in field, another technique for field measurement is the Chord length/mid-ordinate method where $R_c = C^2/8M + M/2$ (Figure 4).
2) Meander wavelength (Lm) Obtain minimum maximum and average values (Figure 4).
3) Ratio of meander wavelength to bankfull width (L_m / W_{bkf}).
4) Meander width ratio (belt width/ bankfull width, or lateral containment) (W_{BLT} /W_{bkf}) Measure minimum, maximum and average meander width ratios (Figure 4).
5) Arc length (L_{arc}).
6) Sinuosity (Stream length/ Valley distance, or valley slope/ channel slope) (Figure 5).

D. General Information

1) The location, elevation, and type of each cross section is tied to the longitudinal profile as shown in Figure 6.

Figure 2. Channel Cross Section

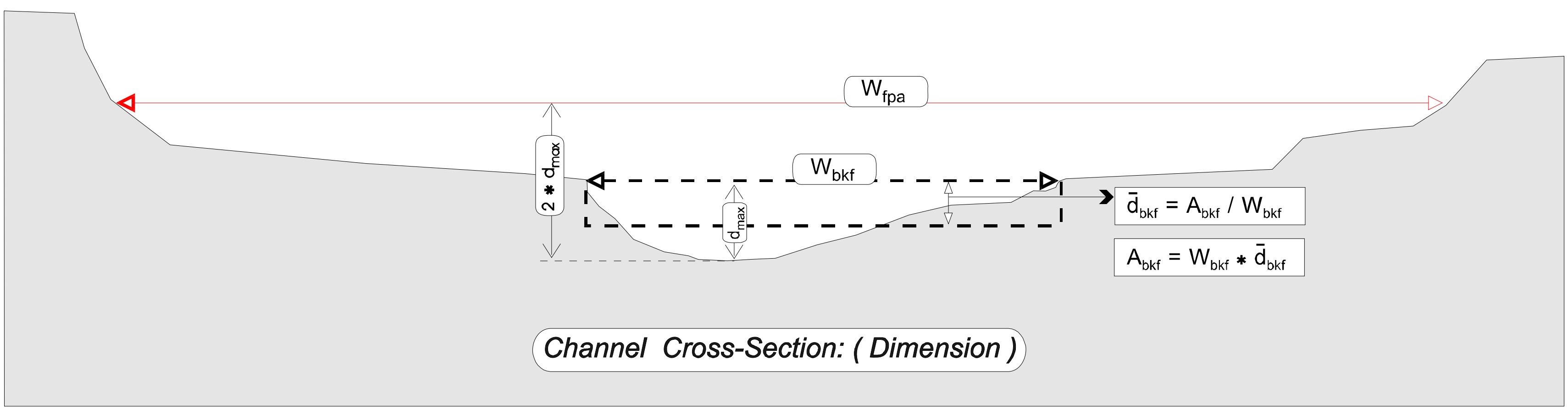


Figure 3. Longitudinal Profile

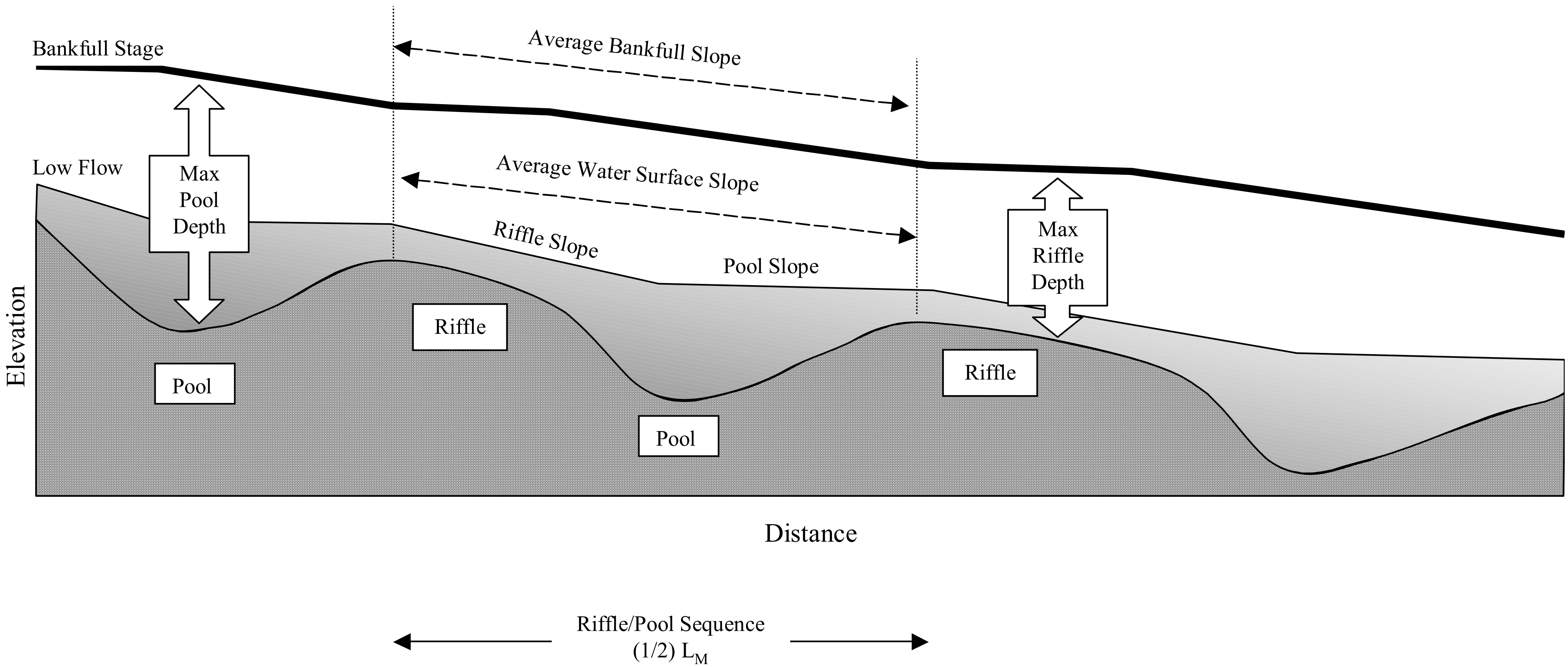
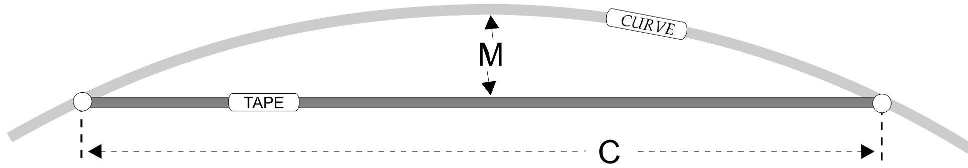


Figure 4. Pattern

Determining RADIUS of CURVATURE (R_c) for a Existing Curve

Extend a known length of tape between two points on a curve, to form a chord (C).

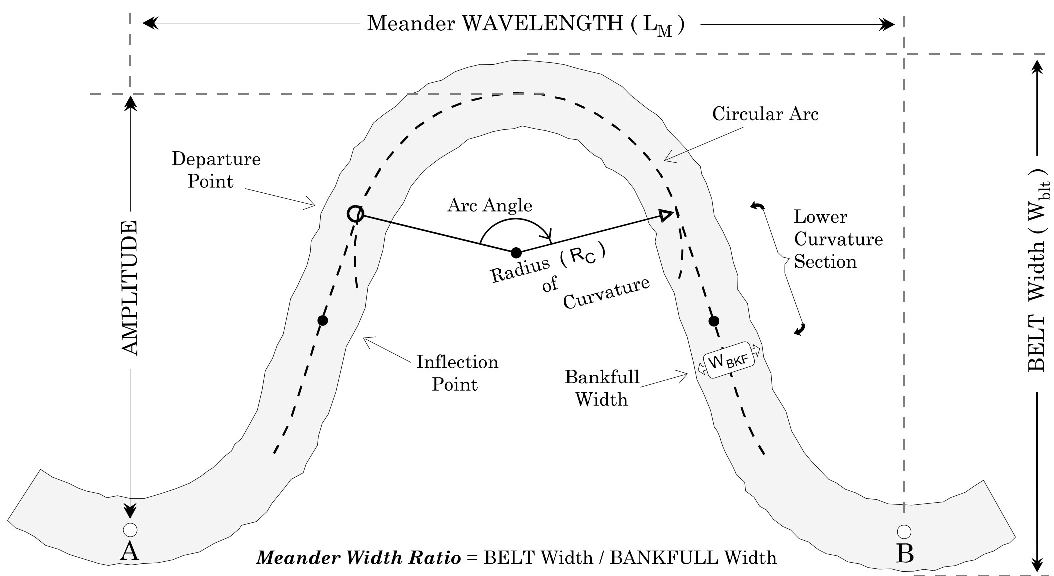
Determine the mid-point of the chord, and measure the length of the perpendicular middle ordinate (M).



Where: C = CHORD length, and M = Middle Ordinate distance,...then:

$$R_c = C^2/8M + M/2$$

Curve RADIUS Ft.	Table of MIDDLE ORDINATES.....with Data in Feet (to nearest tenth) CHORD LENGTH.....FEET 20	25	30	40	50	60	70	80	90	100
20.........	2.7	4.4	6.8							
30.........	1.7	2.8	4.0							
40.........	1.3	2.0	2.9	5.4	8.8	13.5	20.6			
50.........	1.0	1.6	2.3	4.2	6.7	10.0	14.3	20.0	28.2	
70.........	.7	1.1	1.6	2.9	4.6	6.8	9.4	12.6	16.4	21.0
80.........	.6	1.0	1.4	2.5	4.0	5.8	8.1	10.7	13.9	17.6
90.........	.6	.9	1.3	2.3	3.5	5.1	7.1	9.4	12.1	15.2
100.........	.5	.8	1.1	2.1	3.2	4.6	6.3	8.4	10.7	13.4
110.........	.5	.7	1.0	1.8	2.9	4.2	5.7	7.5	9.6	12.0
130.........	.4	.6	.9	1.6	2.4	3.5	4.8	6.1	8.0	10.0
140.........	.4	.6	.8	1.4	2.3	3.3	4.5	5.9	7.4	9.2
150.........	.3	.5	.8	1.3	2.1	3.0	4.1	5.4	6.9	8.6
160.........	.3	.5	.7	1.3	2.0	2.8	3.9	5.1	6.5	8.0
180.........	.3	.4	.6	1.1	1.7	2.5	3.4	4.5	5.7	7.1
200.........	.3	.4	.6	1.0	1.6	2.3	3.1	4.0	5.1	6.4
250.........	.2	.3	.5	.8	1.3	1.8	2.5	3.2	4.1	5.1
300.........	.2	.3	.4	.7	1.1	1.5	2.1	2.7	3.4	4.2



Meander Width Ratio = BELT Width / BANKFULL Width

M W R = W_{BLT} / W_{BKF}

Figure 5. Sinuosity

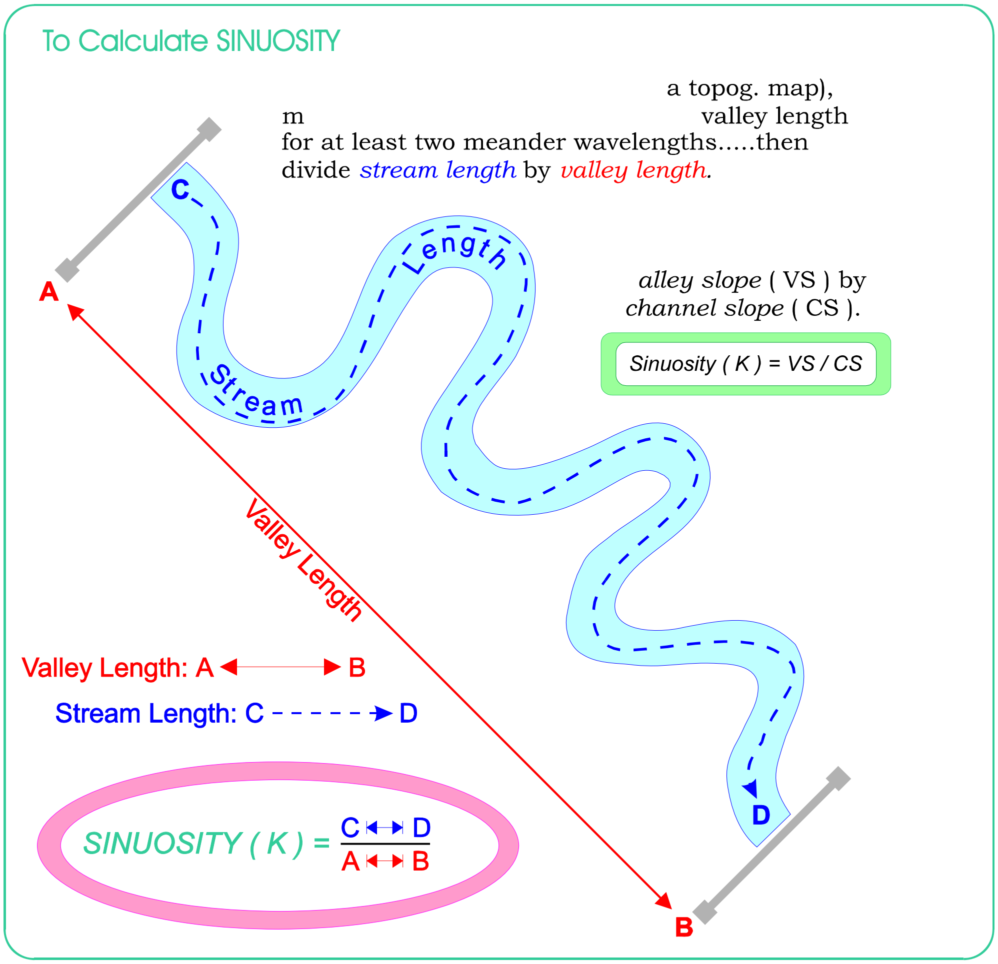
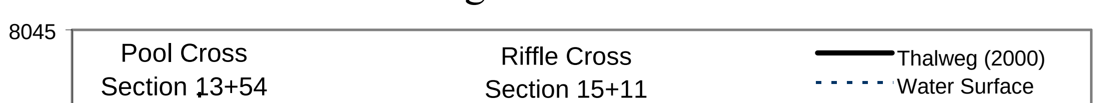


Figure 6. Profile, Dimension, and Plan View

Longitudinal Profile



APPENDIX II

RESOURCE INFORMATION ON NATURAL STREAM CHANNEL DESIGN

Guidebooks, Manuals and Software

- The Reference Reach Field Book
  Wildland Hydrology, Inc. Research and Educational Center for River Studies, Pagosa Springs, CO 81147; 970-731-6100; www.wildlandhydrology.com
- The River Field Book
  Available from Lee Silvey, Western Hydrology; 303-986-9200; email at hlsilvey@msn.com
- River Restoration and Natural Channel Design Field Book
  (only available through Rosgen training coursework)
- Stream Corridor Restoration Principles, Processes, and Practices
  Federal Interagency Stream Restoration Working Group; 10/09
  www.usda.gov/stream_restoration
- Maryland's Guidelines to Waterway Construction
  www.mde.state.md.us/wetlands/guide/html
- Channel Restoration Design for Meandering Rivers
  (US Army Corps of Engineers)
  Philip J. Soar and Colin R. Thorne
  http://libweb.wes.army.mil/uhtbin/hyperion/CHL-CR-01-1.pdf
- Hydraulic Design of Stream Restoration Projects
  (US Army Corps of Engineers)
  Ronald R. Copeland, Dinah N. McComas, Colin R. Thorne, Philip J. Soar
  http://libweb.wes.army.mil/uhtbin/hyperion/CHL-TR-01-28.pdf
- River Engineering for Highway Encroachments
  - *a major rewrite of Highways in the River Environment*

  HDS 6, FHWA-NHI-01-004
  www.fhwa.dot.gov/bridge/hydpub/htm
- Maryland's Streams - Take A Closer Look
  Maryland Department of Natural Resources, Watershed Restoration Division,
  Tawes Building, E2, Annapolis, MD 21401; 410-260-8799
- Restoring Streams in Cities: A Guide for Planners, Policy Makers, and Citizens
  Ann L. Riley, Island Press, 1998
- Montana Stream Management Guide for Landowners, Managers and Stream Users
  - a 33-page, full-color document that provides basic information on stream characteristics, stream types, and steps to stream restoration.
  Department of Environmental Quality, PO Box 200901, Helena, MT 59620-0901; 406-444-2406
- Stream Restoration in Pennsylvania: Ten Case Studies
  Delaware Riverkeeper Network, 2001; 215-369-1188
- Penn State University's AVStrEAMS
  Kenneth Corradini, 814-865-6966, kjc139@psu.edu
- RIVERMorph: Stream Restoration Software, *George Athanasakes,*
  1901 Nelson Miller Pkwy, Louisville, KY 40223. 502-212-5061 *www.rivermorph.com*

Helpful Websites

- North Carolina Stream Restoration Institute
  www5.bae.ncsu.edu/bae/programs/extension/wqg
- Greene County Soil & Water Conservation District, NY www.gcswcd.com/stream
- Wildland Hydrology, Inc., 1481 Stevens Lake Road, Pagosa Springs, CO 81147; (970)264-7120;
  www.wildlandhydrology.com
- Urban Stream Restoration Video
  - highlights six urban stream restoration sites; order at
    http://www.noltemedia.com/nm/urbanstream/index2_nf.html
- FGM Projects in Pennsylvania
  www.dep.state.pa.us
- Pennsylvania Prevailing Wages and PA Prevailing Wage Act
  www.dli.state.pa.us
  www.dli.state.pa.us/landi/CWP/view.asp?a=185&Q=58229
  (Davis-Bacon Act) www.dol.gov/dol/esa/public/programs/dbra/index.html
- NRCS Watershed Science Institute
  - Stream Corridor Inventory & Assessment Techniques
    www.wcc.nrcs.usda.gov/watershed/products.html >> Planning Tools
- NRCS National Water & Climate Center
  - Stream Visual Assessment Protocol
    www.wcc.nrcs.usda.gov >> Water Quality & Quantity Sciences >> Water Quality Assessment & Monitoring >> Guidance Documents
- American Rivers
  - River Restoration in our Nation: A Scientific Synthesis to Inform Policy, Grassroots Actions, and Future Research
    http://www.americanrivers.org/feature/riverrestoration1.htm
- US Fish and Wildlife-Chesapeake Bay Office-Stream Restoration
  - Bankfull Discharge and Channel Characteristics of Streams in the Piedmont Hydrologic Region is available for download. Download a copy of the Maryland Stream Survey in .pdf format (8.8 megabytes). You will need a copy of Adobe's Acrobat Reader in order to view and print this document. The second report of the Maryland Stream Survey is available: Bankfull Discharge and Channel Characteristics of Streams in the Allegheny Plateau and Valley and Ridge Hydrologic Regions (10.3 megabytes). The Coast Plain report is out to the Advisory Panel for review.
    http://www.fws.gov/r5cbfo/stream.htm
- USGS PA Water Resource
  -Development of Regional Curves of Bankfull-Channel Geometry and Discharge for Streams in the Non-Urban, Piedmont Physiographic Province, Pennslyvania and Maryland, Water Resources Investigations Report 03-4014
  http://pa.water.usgs.gov/reports/wrir03-4014.pdf
- USDA-NRCS National Water Management Center-Regional Hydraulic Geometry Curves
  http://wmc.ar.nrcs.usda.gov/proj.dir/geomorph/index.html

Articles / Publications of Interest

- *A Geomorphological Approach to the Restoration of Incised Rivers* (provides an overview of Dave Rosgen's four levels of priorities for incised river restoration)
  David L. Rosgen, Director, Wildland Hydrology, 1481 Stevens Lake Road, Pagosa Springs, CO 81147
- *A Classification of Natural Rivers*
  David L. Rosgen, Wildland Hydrology, Inc. 1481 Stevens Lake Road, Pagosa Springs, CO, 81147; 970-731-6100 (http://www.wildlandhydrology.com/html/references_.html)
- *Regional Curve Development and Selection of a Reference Reach in the Non-Urban, Lowland Sections of the Piedmont Physiographic Province, Pennsylvania and Maryland* (USGS in cooperation with PA DEP)
  Water Resources Investigations Report 01-4146; USGS Branch of Information Services, Box 25286, Denver, CO 80225-0286; 1-888-ASK-USGS
- *The Impact of Afforestation on Stream Bank Erosion and Channel Form*
  A.L. Murgatroyd, J.L. Ternan, 1983, Earth Surface Processes and Landforms, Vol. 8, 357-369.
- *Streamside Forests and the Physical, Chemical, and Trophic Characteristics of Piedmont Streams in North America*
  Bernard W. Sweeney, 1992, Wat.Sci.Tech. Vol. 26, No. 12, pp 2653-2673.
- *Natural Channel Design: How Does Rosgen Classification-Based Design Compare with Other Methods?*
  Dale E. Miller and Peter B. Skidmore, Inter-Fluve, Inc., 2001 ASCE River Restoration Conference, Reno, NV, (Dale Miller - 406-586-6926)
- *Urban Stream Restoration Practices: An Initial Assessment*
  Kenneth Brown, Center for Watershed Protection, 8391 Main Street, Ellicott City, MD 21043, October 2000
- *The Cross-Vane, W-Weir and J-Hook Vane Structure: Their Description, Design and Application for Stream Stabilization and River Restoration*
  David L. Rosgen, 2001, In proceedings of ASCE Conference, August 2001, Reno, Nevada. (http://www.wildlandhydrology.com/html/references_.html)
- *The Reference Reach – A Blueprint for Natural Channel Design*
  David L. Rosgen, ASCE Conference March 1998. (http://www.wildlandhydrology.com/html/references_.html)
- *A Practical Method of Computing Streambank Erosion Rate*
  David L. Rosgen, Proceedings of the Seventh Federal Interagency Sedimentation Conference, Vol. 2, pp.II – 9-15, March 25-29, 2001, Reno, NV (http://www.wildlandhydrology.com/html/references_.html)
- *A Stream Channel Stability Assessment Methodology*
  David L. Rosgen, Proceedings of the Seventh Federal Interagency Sedimentation Conference, Vol. 2, pp.II – 18-26, March 25-29, 2001, Reno, NV (http://www.wildlandhydrology.com/html/references_.html)
- *A Hierarchical River Stability/Watershed-Based Sediment Assessment Methodology*
  David L. Rosgen, Proceedings of the Seventh Federal Interagency Sedimentation Conference, Vol. 2, pp.II – 97-106, March 25-29, 2001, Reno, NV (http://www.wildlandhydrology.com/html/references_.html)

APPENDIX III

COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF ENVIRONMENTAL PROTECTION

PERMIT GUIDELINES FOR PHASED NPDES STORMWATER DISCHARGES ASSOCIATED WITH CONSTRUCTION ACTIVITY PERMITS, CHAPTER 102 EROSION AND SEDIMENT CONTROL PERMITS AND CHAPTER 105 WATERWAY RESTORATION PROJECT PERMITS

March 29, 2003

TITLE: Permit Guidelines For Phased NPDES Stormwater Discharges Associated with Construction Activity Permits, Chapter 102 Erosion and Sediment Control Permits, and Chapter 105 Waterway Restoration Project Permits

DOCUMENT NUMBER: 363-2134-013

EFFECTIVE DATE: March 29, 2003

AUTHORITY:

Pennsylvania Clean Streams Law (35 P.S. §§ 691.1-691.1001); Dam Safety and Encroachments Act (32 P.S. §§ 693.1-693.28); Federal Clean Water Act (33 U.S.C.A § 1342 and 40 CFR 122.26).

POLICY:

It is the policy of the Department of Environmental Protection to ensure projects requiring DEP permits are reviewed as single and complete projects and meet all public health, safety and environmental requirements. The Department is also committed to the implementation of an effective, efficient, and flexible permit application and review process that eliminates redundant processing procedures and ensures public notice, while meeting its commitment to the public interest and the environment.

PURPOSE:

The Department's approach to permit phased construction and waterway restoration activities uses existing authority to promote the development of comprehensive project plans, provide for a single and complete project review, ensure impacts from construction and waterway restoration activities are minimized, allow for more efficient use of grant money, provide implementation flexibility for long range planning, and minimize delays in project implementation.

APPLICABILITY:

This policy applies to the individual Chapter 102 Erosion and Sediment Control Permits, individual and general NPDES Stormwater Discharges from Construction Activity Permits processed by the Department or a delegated Conservation District, and individual Chapter 105 Water Obstruction and Encroachments Permit Applications for waterway restoration as defined herein and processed by the Department.

DISCLAIMER:

The policies and procedures outlined in this guidance document are intended to supplement existing requirements. Nothing in the policies or procedures shall affect regulatory requirements. The policies and procedures herein are not adjudications or regulations. There is no intent on the part of DEP to give the rules in these policies that weight or deference. This document establishes the framework, within which DEP will exercise its administrative discretion in the future. DEP reserves the discretion to deviate from this policy statement if circumstances warrant.

PAGE LENGTH: 15

LOCATION: Volume 34, Tab10

EXECUTIVE SUMMARY

Some projects that require DEP permits are long term or large scale projects that may take several years to complete. These projects are commonly referred to as *phased projects* and are funded, planned, or designed in phases or stages to facilitate project implementation. Phased projects are often dependent upon available financial and staff resources, technical support, design or construction grants, and other factors. Traditional permitting approaches to these types of projects can result in high costs for detailed up front data collection, analysis and project design for projects that may not come into fruition for a number of years.

Traditional front-loaded permitting approaches can also be a disincentive for watershed organizations involved in developing and implementing waterway restoration projects. These watershed organizations, typically funded by private donations, or grants such as Growing Greener, often have limited funds and staff resources. A phased approach to these projects allows those limited resources to be targeted towards immediate stream restoration within the context of a broad based project goal.

The purpose of this guidance is to provide flexibility in the permitting process to minimize the administrative burden on applicants and DEP permit processors, provide an effective public review and notice process for projects, and ensure projects meet the public health, safety, and environmental requirements of the Commonwealth.

A phased project approach promotes the development of comprehensive project plans, provides for a single and complete project review, allows for the efficient use of grant money, reduces permit processing time, and provides implementation flexibility for long term projects. Under the phased project approach, a permit application can be submitted that explains the goals and scope of the project, and the general types and locations of anticipated activities for the entire project site without detailed construction plans and drawings for all phases of the project but in sufficient detail to assess the environmental impacts of the project.

Permit applicants will provide detailed construction drawings, plans, Erosion and Sediment Control Plans, and other required information for review and approval for the initial phase of the project that will be constructed, along with more generalized plans for the subsequent phases under consideration. Notice of the permit application for the entire project area, initial phase along with subsequent phases, is published in the *Pennsylvania Bulletin* to provide landowners, municipalities, and other interested persons with an opportunity to comment on the overall goal and scope of the project and proposed activities. Implementation of the first phase may not commence until the public comment period closes, all required information is received, reviewed, approved, and the permit is issued. Prior to the implementation of subsequent phases, detailed construction drawings, plans, Erosion and Sediment Control Plans, and other required information as described in this policy must be submitted to the Department for review and approval prior to commencing work. The approval of a subsequent phase will be published in the *Pennsylvania Bulletin* as an approved action under the previously issued permit.

This phased permit approach may not be appropriate for all projects. If the Department believes specific circumstances preclude the use of a phased approach, or applicants believe it will not suit their needs, a standard permit application review process will be utilized.

TABLE OF CONTENTS

OVERVIEW

A phased project approach promotes the development of comprehensive project plans, provides for a single and complete project review, allows for the efficient use of grant money, minimizes delays in project implementation and provides flexibility for long term projects. Under the phased project approach, the permit application is submitted with the scope, locations and types of anticipated activities for the entire project site. The activities proposed are evaluated to ensure environmental impacts are minimized and that environmental, public health, and safety issues are satisfied.

For the initial phase of the project, applicants will provide detailed construction drawings, plans, Erosion and Sediment Control Plans, and other required information for review and approval. Implementation of the first phase may not commence until all required information is received, reviewed, approved, and the permit is issued. Prior to the implementation of subsequent phases, detailed construction drawings, plans, Erosion and Sediment Control Plans, and other required information must be submitted to the Department or Conservation District for review and approval prior to commencing work.

This phased approach is not mandatory and may not be appropriate for all projects. If the Department believes specific circumstances preclude the use of a phased approach or the applicants believe it will not suit their needs, a standard permit application review process will be utilized.

DEFINITIONS

Conservation District – *For purposes of this policy, Conservation District shall generally mean the local County Conservation District that has entered into a delegation agreement with the Department to administer the NPDES Program for Stormwater Discharges Associated with Construction Activities. The Department retains program administration and enforcement if the local County Conservation District is not delegated.*

Erosion and Sediment Control (E&S) Permit - A permit required for earth disturbance activities of 25 acres (10 hectares) or more where the earth disturbance is associated with timber harvesting or road maintenance activities.

Erosion and Sediment Control (E&S) Plan - A site-specific plan identifying BMPs to minimize accelerated erosion and sedimentation.

Initial Phase - The first phase of a project site for which implementation approval is being requested in the permit application.

NPDES Permit for Stormwater Discharges Associated With Construction Activities (NPDES Stormwater Construction Permit) - This permit applies to earth disturbance activities, that disturb five (5) or more acres, or an earth disturbance on any portion, part, or during any stage of, a larger common plan of development or sale that involves five (5) or more acres of earth disturbance, AND, earth disturbance activities with a point source discharging to surface waters of the Commonwealth that disturb from one (1) to less than five (5) acres, or an earth disturbance on any portion, part, or during any stage of, a larger common plan of development or sale that involves one (1) to less than five (5) acres of disturbance.

Phased Project - A project site that is divided into different stages to facilitate efficient project development and implementation.

Post-Construction Stormwater Management Plan (PCSM Plan) - A site specific plan identifying Best Management Practices (BMPs) to manage stormwater runoff after construction activities have ended and the project site has been permanently stabilized to protect and maintain existing and designated uses. The PCSM Plan must contain a written narrative, including calculations or measurements, and justifications for each BMP. The BMPs should be designed to maximize infiltration technologies, minimize point source discharges to surface waters, preserve the integrity of stream channels, and protect the physical, biological, and chemical qualities of the receiving water.

Project Site – the entire area of activity, development or sale including:

- the area of an earth disturbance activity;
- the area planned for an earth disturbance activity; and
- other areas which are not subject to an earth disturbance activity.

*Subsequent Phas*e(s) - All other phases after the initial phase that are generally identified in location and scope in the permit application, but not specifically designed and not approved for construction under the initial phase of the project. Subsequent Phase(s) will be approved only after detailed construction plan drawings, Erosion and Sediment Control Plans, PCSM Plans, and other required information is submitted and approved by the Department.

Chapter 105 Waterway Restoration Permit - An individual Chapter 105 water obstruction and encroachment permit, typically issued to a watershed organization for a project with a primary purpose of waterway restoration, using standard protocols, assessment procedures, and designs to support the re-establishment of natural stream flow, dynamics, and environmental conditions.

PHASED NPDES STORMWATER CONSTRUCTION AND E&S PERMIT PROCESS

• <u>Applications</u>

To the extent that a regulatory requirement found in Chapters 92 and 102 is not listed below, the appropriate supporting documentation should be included in the initial permit application submission for the project site. Nothing in this policy relieves the applicant from meeting the requirements of Chapters 92 and 102.

I. General NPDES Permits - For coverage by a NPDES General Permit for Stormwater Discharges Associated with Construction Activities involving a Phased Project an applicant must submit:

A. For The Entire Project Site

1. Completed Notice of Intent (NOI) for General Permit.

2. The Application must be accompanied by a check in the amount of $500.00 for an Individual Permit or $250.00 for a General Permit, payable to the "Commonwealth of Pennsylvania Clean Water Fund" or "___________ County Conservation District Clean Water Fund." This is a one-time fee. There is no permit fee for additional phases. Certain County Conservation Districts may charge plan review fees for initial and subsequent phase plan reviews.

3. Municipal notifications to the county(ies) and municipality(ies) and proof of receipt.

4. Completed PNDI form and search receipt(s) for all phases of the project site.

5. Erosion and Sediment Control Plan (E&S Plan) and Post Construction Stormwater Management Plan (PCSM Plan) containing the following information:

   a) The existing topographic features for the Project Site and immediate surrounding area.

   b) The types, depth, slope, locations and limitations of the soils.

   c) A narrative description and plan drawings showing the locations and the characteristics of the earth disturbance activity including past, present, and proposed land uses, and a description of the planned physical alterations, earth disturbances, and other construction activities, as well as a general description and location of anticipated BMPs, including BMPs for special protection waters.

   d) The location of all surface waters, which may receive runoff within or from the project site, and their classification pursuant to Chapter 93.

   e) Procedures to ensure the proper handling, storage, control, disposal and recycling of wastes or other materials that have a potential to cause pollution.

   f) A narrative description and a map (USGS topographic quadrangle or equivalent) of the project area that identifies the location and characteristics of sensitive areas or areas of environmental concern for the Project Site. Sensitive areas or areas of environmental concern include but are not limited to: wetlands, special protection waters, historic or cultural resource areas and areas where threatened or endangered species or critical habitat may be present.

B. For the Initial Phase Of The Project:

1. A detailed description identifying the specific BMPs that will be used, plan details, drawings, specifications, and a sequence of BMP installation.

2. The amount of projected runoff and supporting calculations for each BMP.

3. E&S Plan drawings identifying the location and boundaries of the phase, the locations of BMPs that will be used, construction details, specifications, and a legend. Typical sketches may be used but must provide sufficient detail to illustrate critical dimensions and construction requirements.

4. Maintenance program including the inspection of BMPs on a weekly basis and after each measurable rainfall event, and the type of maintenance required for each BMP to ensure effectiveness.

5. Post Construction Stormwater Management (PCSM) Plan. The PCSM Plan identifies BMPs that will treat the rate, volume, and quality of stormwater runoff after construction. The applicant is required to identify post-construction stormwater BMPs as part of the Individual NPDES Stormwater Construction Permit application or Notice of Intent for the General NPDES Stormwater Construction Permit. In addition, both the Individual and General NPDES Stormwater Construction Permits require compliance with local ordinances developed under an Act 167 Stormwater Management Plan that incorporates measures to protect and maintain existing uses and protect and maintain water quality to maintain those existing uses. Permanent stormwater management BMPs must be operated and maintained in accordance with a written maintenance plan.

II. Individual NPDES or E&S Permit - Individual NPDES or E&S Permit applications must include all of the information identified for General Permit NOIs and provided in Section I above, plus the following:

A. Completed and Signed General Information Form (GIF).

B. Cultural Resource Notice(s) and the Pennsylvania Historic and Museum Commission (PHMC) response letter for all phases of the when project site is 10 acres or more.

- **<u>Permit Processing Guidelines</u>**

<u>General NPDES Permit</u> **-** General Permit NOIs are reviewed for administrative and technical completeness. Upon approval of the Initial Phase E&S Plan, a notice is published in the *Pennsylvania Bulletin* authorizing the use of the general permit. Notice of Approval of Subsequent Phase(s) will be published in the *Pennsylvania Bulletin* and will identify the specific phase of a project being approved for construction. Earth disturbance activities associated with the Initial Phase and Subsequent Phase(s) may commence when the permittee receives written authorization from the Department for that phase.

<u>Individual NPDES Permit or Chapter 102 E&S Permit</u> - Individual permit applications are reviewed for completeness. A public notice of the individual permit application will be published in the *Pennsylvania Bulletin* for a 30-day comment period after the application is deemed administratively complete. Upon the approval of the individual permit application and Initial Phase E&S and PCSM Plan, the Department will publish a second notice in the *Pennsylvania Bulletin* informing the public of its decision. Notice of Approval of Subsequent Phase(s) will be published in the *Pennsylvania Bulletin* and will identify the specific phase of a project being approved for construction. Earth disturbance activities associated with the Initial Phase and Subsequent Phase(s) may commence when the permittee receives written authorization from the Department for that phase.

- <u>Subsequent Phase Approvals for General and Individual NPDES Permits</u>

<u>Before initiating any earth disturbance activities on Subsequent Phases, the permittee or co-permittee must submit the following information for review before implementation of that subsequent phase:</u>

1. A detailed description identifying the specific BMPs that will be used, plan details, drawings, specifications, and a sequence of BMP installation.

2. The amount of projected runoff and supporting calculations for each BMP.

3. E&S and PCSM Plan drawings identifying the location and boundaries of the phase(s), the locations of construction and post construction BMPs that will be used, construction details, specifications, and a legend. Typical sketches may be used but must provide sufficient detail to illustrate critical dimensions and construction requirements.

4. Maintenance program including the inspection of BMPs on a weekly basis and after each measurable rainfall event, and the type of maintenance required for each BMP to ensure effectiveness.

Upon approval of the subsequent phase submission the Department will publish a notice, in the *Pennsylvania Bulletin*, of approval for the Subsequent Phase(s) as an action under the previously authorized permit. Approval of a Subsequent Phase is not considered a permit modification.

PERMIT, E&S PLAN, AND PCSM PLAN, MODIFICATIONS FOR NPDES STORMWATER CONSTRUCTION PERMIT OR E&S CONTROL PERMIT

- **<u>Minor Permit and Plan Modifications</u>**

  The Department or Conservation District may approve minor modifications or corrections to the NPDES or E&S Permit to allow for minor changes. These minor modifications may be used to correct typographical errors, require more frequent monitoring or reporting by the permittee or co-permittee, change in an interim compliance schedule, allow for change in ownership, address unforeseen site circumstances, or delete a point source outfall from which a discharge is terminated. The Department or Conservation District may approve minor modifications to the E&S Plan or PCSM Plan, including adjustments to BMPs and locations to improve environmental performance so long as, the modifications are within the scope of the approved plan and do not constitute a major modification of the permitted activity. Minor modifications may also include field adjustments on-site such as the addition or deletion of BMPs to address unforeseen circumstances. All minor modifications to the E&S Plan and PCSM Plan shall be noted on the plan that is available at the site and initialed by the Department or Conservation District staff. The Department or Conservation District may also request the review of proposed revisions and supporting calculation. Minor permit and plan modifications do not require a new permit or a public notice and comment period.

- **<u>Major Permit and Plan Modifications</u>**

  A new NPDES or E&S Permit shall be obtained for a new or increased discharge, or a change of the waste stream, including any new or increased pollutant not identified in a previous permit application. Major modifications require a new permit application that meets all procedural E&S Plan requirements, and PCSM Plan requirements identified above for either General or Individual Permit Applications, including the publication of a notice in the *Pennsylvania Bulletin*.

  Examples of changes that require a major permit and plan modification include but are not limited to: adding an industrial waste discharge, adding a point source discharge, and expanding the project site beyond the area approved in the original permit.

CHAPTER 105 WATERWAY RESTORATION PERMIT PROCESS

- **Applications**

To the extent that a regulatory requirement found in Chapter 105 is not listed below, the appropriate supporting documentation should be included in the initial permit application submission for the project site. Nothing in this policy relieves the applicant from meeting the requirements of Chapter 105.

General Information - Before beginning the application process, and in accordance with 105.13(a) a pre-application meeting between the project sponsors (applicant), designers and permitting agencies is recommended to familiarize everyone with the project scope and goals, exchange ideas, and discuss the permitting process. This pre-application meeting should include appropriate staff from the DEP regional office, US Army Corps of Engineers (USACOE), Pennsylvania Fish and Boat Commission (PF&BC), County Conservation District, US Fish and Wildlife Service (USFWS), as well as representatives of the watershed group, project designers, and others involved with the project. The regional DEP Soils and Waterways Section normally serves as the initial point of contact for permit applicants.

At the pre-application meeting, the project designers should have preliminary plans available that depict the overall project goal and planned phases of the project, including an estimate of the total length of stream to be affected, sequence of phases, scope and length of each phase, anticipated BMPs to be used, and anticipated channel modifications or realignments necessary for each phase. Detailed drawings and supporting documentation is not required for the pre-application meeting, however there should be a sufficient level of detail in order for everyone to understand the project and provide technical comments and specific recommendations.

After the pre-application meeting, the project sponsor will commence with the detailed analysis, design, and work plan, supported by written documentation and analysis, for the initial phase of the project. In order for a permit to be processed in a timely fashion it is important that the application reflect the results of the pre-application process, and provide the appropriate level of environmental and engineering information necessary to ensure a sound project and facilitate effective and efficient permit decisions. Construction activity under a phased permit may be authorized for time periods greater than the normal three construction seasons for standard projects. The specific construction window and other terms of the permit will be based on the scope of the project.

Waterway Restoration Permit Requirements - The following information must be provided for all individual permit applications for phased waterway restoration projects:

1. For The Entire Project Site:

    a. Completed and signed GIF and Chapter 105 Water Obstruction and Encroachments Permit Application form.

    b. The Application must be accompanied by a check in the amount of $300.00, payable to the “Commonwealth of Pennsylvania”. This is a one-time fee. There is no Chapter 105 permit fee for additional phases.

c. Municipal notifications to the county(ies) and municipality(ies) and proof of receipt.

d. Completed PNDI form and search receipt(s) for all phases of the project site.

e. Cultural Resource Notice(s) and PHMC response letter(s) for all phases of the project site.

f. A location map of a scale factor of 1:24000 (standard USGS Topographic Map). The location map shall show:

   1) The entire project limits, including the identification of the initial phase and all subsequent phases.

   2) All natural features including the names and boundaries of regulated waters of this Commonwealth, natural areas, wildlife sanctuaries, and natural landmarks.

   3) Political boundaries.

   4) Locations of public water supplies.

   5) The contributory drainage area.

   6) Other geographical or physical features including cultural, archeological and historical landmarks within 1 mile of the site.

g. Project description. A narrative of the project shall be provided which includes:

   1) The project purpose.

   2) A written narrative that clearly identifies the stream's problems and describes the scope and objectives of the project.

   3) Alternatives analysis – A detailed analysis of alternatives to the proposed action, including alternative locations, routings or designs to avoid or minimize adverse environmental impacts.

   4) The upper and lower limits of the project using standard latitude and longitude reference coordinates.

   5) A written description of the activities, structures, BMPs and implementation methods, including a rationale for selected alternatives, that will be utilized throughout all phases of the project.

   6) The effect the project will have on public health, safety or the environment.

   7) A statement on water dependency. A project is water dependent when the project requires access or proximity to or siting within water to fulfill the basic purposes of

the project. For purposes of waterway restoration activities, it is presumed the activities are water dependent.

8) A detailed impact analysis of the potential impacts, to the extent applicable, of the proposed project on water quality, stream flow, fish and wildlife, aquatic habitat, Federal and State forests, parks, recreation, instream and downstream water uses, prime farmlands, areas or structures of historic significance, streams which are identified candidates for or are included within the Federal or State wild and scenic river systems and other relevant significant environmental factors. If a project will affect wetlands, the project description shall also include:

    a) A narrative of the delineation process supported by the appropriate data sheets and copies of appropriate soil maps and descriptions from soil conservation service soil surveys. Soil Conservation Service soil surveys may be obtained from the County Conservation District Offices.

    b) An analysis of whether the wetland is exceptional value as classified in § 105.17 (relating to wetlands).

    c) A statement on water dependency. A project is water dependent when the project requires access or proximity to or siting within water to fulfill the basic purposes of the project.

9) An application for a project which will affect less than 1 acre of wetland where the wetland is not exceptional value wetland shall also include a description of functions and values of the existing wetlands to be impacted by the project, as defined in § 105.1 (relating to definitions).

10) An application for a project which may have an affect on an exceptional value wetland or on 1 or more acres of wetland shall also include an assessment of the wetland functions and values using a methodology accepted by the Department and a survey, conducted by a licensed professional land surveyor, of the wetland boundary as delineated and of the property lines of the parcel where the project is located.

11) A mitigation plan to mitigate any adverse impacts to wetlands that are incidental to the waterway restoration project.

h. Stormwater management analysis. If a stormwater management plan has been prepared or adopted under the Stormwater Management Act (32 P.S. §§ 680.1-680.17), an analysis of the project's impact on the Stormwater Management Plan and a letter from the county or municipality commenting on the analysis shall be included.

i. Floodplain management analysis. If the proposed dam, water obstruction or encroachment is located within a floodway delineated on a FEMA map, include an analysis of the project's impact on the floodway delineation and water surface profiles and a letter from the municipality commenting on the analysis.

j. Risk assessment. If the stormwater or the floodplain management analysis conducted in subparagraphs (h) and (i) indicates increases in peak rates of runoff or flood elevations, include a description of property and land uses which may be affected and an analysis of the degree of increased risk to life, property and the environment.

k. For projects that incorporate fluvial geomorphology methodology (FGM) principals, a reference stream reach or regional curve data must be provided.

l. Environmental Assessment Form, Part 1 items 1-7, Part 2 and Part 3 for the entire project including the initial phase and all subsequent phases included with the Chapter 105 Water Obstruction and Encroachments permit application.

m. Limits of project disturbance should be clearly shown on the drawings. Wetlands within the limits of disturbance must be clearly identified on the drawings and flagged at the project site prior to start up.

n. A monitoring plan.

2. For the initial phase:

a. Photographs of the initial phase of work and a photo location map depicting the area where work will be accomplished.

b. Detailed restoration plans and construction drawings that include:

1) A plan view at a scale of 1" = 30' or larger showing the location and type of structure or activity within the initial phase of the project, depicting at least 100 feet upstream and downstream and the immediate area of the stream and the adjacent floodway. Details such as roads, utilities, buildings, and other man-made structures and natural features such as contours and drainage patterns must be identified.

2) A complete demarcation of the floodplains and regulated waters of this Commonwealth on the site. The wetlands shall be identified and delineated in accordance with the Department's Wetland Delineation Policy as published at § 105.451 (relating to identification and delineation of wetlands – statement of policy).

3) A north arrow.

4) A scaled longitudinal profile of existing and proposed stream channel conditions for the initial phase of the project area, depicting at least 100 feet upstream and downstream and the immediate area of the stream and the adjacent floodway.

5) Detailed cross sections showing the existing and proposed conditions of the initial phase of the project. These cross sections should be taken where the more extensive cuts and fills are proposed. Drawings should have a legend that clearly identifies the cut and fill areas.

6) Cross sections upstream and downstream of work area. The supporting hydraulic information at these sections must clearly indicate that there will be no change of water surface elevations and velocities at bankfull flow and the flow related to the flood prone area.

7) If the project is being designed using the principles of FGM or Natural Stream Channel Design (NSCD), a completed morphological chart for the project that includes the sections of the stream that have been surveyed, stream type, stream sinuosity, bankfull flow width, flood prone areas, belt width and other relevant information.

8) Engineering calculations that prove the competency of the designed channel.

c. Verification by the applicant that landowner consent and permission have been obtained to conduct activities on private property.

d. In FEMA study areas where a detailed floodway has been identified, include an analysis of the Q_{100} flood elevations in both existing and proposed conditions, using the Q_{100} flood flow identified in the narrative of the flood insurance study. This step will help justify that the design can handle all flows.

e. The name of the person who prepared the restoration plan, and the date and name of the applicants.

f. Proof of an application for a NPDES Stormwater Discharge From Construction Activity Permit application or an approved Erosion and Sediment Control Plan, whichever is applicable.

- **Permit Processing Guidelines**

Permit applications are reviewed for administrative and technical completeness. A public notice of the permit application will be published in the *Pennsylvania Bulletin* for a 30-day comment period. Upon the approval of the permit application for the Initial Phase, the Department will publish a second notice in the *Pennsylvania Bulletin* informing the public of its decision. Notice of Approval of Subsequent Phase(s) will be published in the *Pennsylvania Bulletin* as an approved action under the previously issued permit, and will identify the specific phase(s) of a project being approved for construction.

- **Subsequent Phase Approvals**

Before initiating any earth disturbance activities on subsequent phases, the permittee must submit the following information for review and approval before project implementation:

1. Photographs of the subsequent phase of work and a photo location map depicting the area where work will be accomplished.

2. Detailed restoration plans and construction drawings that include:

a. A plan view at a scale of 1" = 30' or larger showing the location and type of structure or activity within the subsequent phase of the project, depicting at least 100 feet upstream and downstream and the immediate area of the stream and the adjacent floodway. Details such as roads, utilities, buildings, and other man-made structures and natural features such as contours and drainage patterns must be identified.

b. A scaled longitudinal profile of existing and proposed stream channel conditions for the subsequent phase of the project area, depicting at least 100 feet upstream and downstream and the immediate area of the stream and the adjacent floodway.

c. Detailed cross sections showing the existing and proposed conditions of the subsequent phase of the project. These cross sections should be taken where the more extensive cuts and fills are proposed. Drawings should have a legend that clearly identifies the cut and fill areas.

d. Cross sections upstream and downstream of work area. The supporting hydraulic information at these sections must clearly indicate that there will be no change of water surface elevations and velocities at bankfull flow and the flow related to the flood prone area.

e. If the project is being designed using the principles of FGM or Natural Stream Channel Design (NSCD), a completed morphological chart that includes the sections of the stream that have been surveyed, stream type, stream sinuosity, bankfull flow width, flood prone areas, belt width and other relevant information.

f. Engineering calculations that prove the competency of the designed channel.

3. Verification by the applicant that landowner consent and permission have been obtained to conduct activities on private property.

4. In FEMA study areas where a detailed floodway has been identified, include an analysis of the Q_{100} flood elevations in both existing and proposed conditions, using the Q_{100} flood flow identified in the narrative of the flood insurance study. This step will help justify that your design can handle all flows.

5. The name of the person who prepared the restoration plan, and the date and name of the applicants.

6. A current PNDI search form and search receipt for the phase proposed for construction.

7. Proof of an application for a NPDES Stormwater Discharge From Construction Activity Permit application or an approved Erosion and Sediment Pollution Control Plan, whichever is applicable.

MODIFICATIONS FOR WATERWAY RESTORATION PERMITS

- **<u>Minor Project Modifications</u>**

The Department may approve minor modifications or corrections to the Chapter 105 permit to allow for minor changes to the project to improve environmental performance so long as the approved changes are within the scope of the approved plan and do not constitute a major modification of the permitted activity, by noting and initialing changes on the project site plan. Minor modifications shall be reflected in the post construction as-built plans. Minor modifications also include correction of typographical errors and other administrative corrections to the plans or permit. Minor modifications do not require a new permit, or a public notice and comment period.

- **Major Project Modifications**

An amended or new Chapter 105 permit shall be obtained for new additions to the project area, a change in project scope, change in the nature of restoration activities, new discharges, any new direct or indirect impacts to wetlands, or any other change to the project beyond those activities identified in the initially approved permit. Major modifications require a new permit application that meets all procedural requirements identified under Waterway Restoration Permit Applications, including the publication of a notice in the *Pennsylvania Bulletin*.

APPENDIX IV

Guidelines for Developing Cost Ranges of a Natural Stream Channel Design Project

Developed by:
The Keystone Stream Team
Cost Ranges Workgroup

Revised 01-24-05

Phases of NCSD Projects

The main purpose of this project was to develop cost ranges for phases of a NSCD project based on the amount of work and types of tasks that need to be done for a successful NSCD project. Many of the terms used within the document that may not be common knowledge will be defined as they appear in italic in the document. The uses for these cost ranges can serve several purposes such as assisting groups interested in sponsoring a project to understand what is involved with the project. The cost ranges should give individuals preparing RFP's for projects a general guide for what to include and how much to expect to pay for certain phases and tasks of the project. The cost ranges should help individuals reviewing and scoring grant proposals to determine if a project is on target with what is being proposed. WARNING-It is important to realize that this is only a guide and should not be taken as the end all be all for every project. Each project is unique due to the nature of stream dynamics and site constraints imposed on projects. We have tried to give enough information to be useful, but not force you down the wrong path. It is important to understand your specific situation and constraints.

To accomplish the goals of this project the Cost Ranges Workgroup has made a many assumptions for a generic project, every phase and related tasks and costs associated with them is based upon the same parameters. If an assumption differs from the standard assumptions listed here the details in the outline will state those differences. The generic project characterization assumes a 50 sq mi watershed, a 1000 foot stream length for the project, with a 50 foot bankfull width, 30 foot wide riparian buffers established on both sides of the creek for the whole length of the project, and 2.5 acres of disturbed area. Unless otherwise note, this exercise assumes an average pay rate of $65/hour, representing the range of disciplines and experience levels needed for completion of all tasks.

This outline is broken up into four different funding phases. Funding Phase One and Funding Phase Two could be combined into one grant if it is clear that channel stability is a major concern for the watershed.

I. Funding Phase One-Watershed-wide Problem Identification

A. Initial Assessment

1. Hold group planning meeting
2. Conduct a windshield survey-prep and field
3. Review current aerial photos

4. Conduct stream walk of representative segments
5. Meet with Conservation District and DEP Watershed Manager
6. Seek assistance to develop a technical plan of action with next steps

Deliverables – Technical plan of action with next steps, photo documentation and study area map

*****Tasks in this phase can be accomplished by a watershed organization, watershed specialist, interns or some combination of those folks. A consultant and/or agency personnel should be part of this process, but not necessarily perform the tasks. They could also help with putting together an estimate for the next phase.***

B. Watershed-wide Stream Inventory

1. Collect historical data
2. Identify USGS stream gages
3. Choose an assessment tool to identify geomorphic issues (A*ssessment Tools-survey form)*
4. Conduct preliminary stream walk survey
5. Document stream conditions (including identified unstable problem areas as well as stable "model" stream reaches potentially suitable for reference reach sites in future restoration design phases) using GPS, digital photos, ArcView and/or other appropriate mapping tools

Deliverables—Completed survey forms, map with all the erosion areas, gravel bars, culverts, riprap, obstructions, etc. labeled, digital photos with map location and a final report with narrative for grant.

EXTRAS-Performing bank profiles under the direction of an FGM Specialist or experienced Field Technician would give real data to gage measurable results.

*****If this part is completed by the sponsoring group, it will build their capacity and that of the watershed specialist as well as gives them ownership of the project and the process involved when using the NSCD approach.***

$$ Parts A and B can be completed by volunteers for $161-321 per mile based upon several projects completed in the NC Region.

II. Funding Phase Two-Developing a Restoration Plan

A. Watershed-wide Forensic Analysis (*Forensic Analysis-identify cause of problem*)

1. Verification of information in Funding Phase One-Watershed-wide Problem Identification
    a. Include an investigation of the identified problem area sites to determine contributing causes and related issues required to be addressed prior to undertaking restoration efforts.
2. Assess applicability of available regional curves (*Regional Curve-representative plot of average channel dimensions for a stable channel based upon drainage area*)
3. Develop a regional curve
4. Perform field data collection
    a. Conduct BeHI measurements (*Bank Erosion Hazard Index-quantifies bank erosion potential*)
    b. Measure hydraulic geometry (*Hydraulic Geometry-existing dimensions for pattern and profile of a stream at representative locations-tabular and mapped*)
    c. Determine stream classification according to Rosgen stream types using regional curve data (*Stream types*-A, B, C, D, E, F, G)
    d. Develop a map of stream features and points of analysis (*Points of analysis- areas measured for hydraulic geometry and BeHI)*
5. Analyze collected field data, prioritize problems, and develop a preliminary restoration plan.

<u>Deliverables</u> – Regional curve plot with data, map identifying stream classifications (*map can be hand drawn or CAD-Computer Aided Drafting*), location map of stream features and points of analysis, map with stability ratings, identification of potential reference reach candidate, identification of usable stream gages, project priority listing, watershed-wide restoration plan, and narrative, and final report for grant.

*****In the case where a watershed group has already identified the target project area, the analysis can be confined to the upstream contributing watershed area.***

<u>SCALEABLE</u>-Based upon the increased size of the watershed and for rural versus urban watersheds.

III. Funding Phase Three-Design and Permitting

A. Conceptual Design Phase

1. Project start up field meeting

~16-40 hours

2. Verify stream gage (*Verify Stream Gage-correlates bankfull stage to flow records that occur on a 1 to 2 year return frequency*)

   ~30-40 hours on project stream or next closest gage with similar watershed characteristics

3. Survey existing conditions of restoration project reach

   ~24-80 hours highly dependent upon site complexity for measuring

4. Develop base map (*Base Map-existing conditions topo map suitable for overlaying design*)

   ~70-120 hours which includes topo survey and base map development <u>CAVEAT</u>- The lower limit of this range is based upon having the site flown, aerial photos and computer design software mapping done. The upper limits based upon total station field surveying for mapping. Vegetative cover and time of the year will have influence on which option is chosen.

   ~$100-150/acre for flight survey and contour mapping (for lower range)

5. Develop conceptual design plan

   ~64-104 hours

6. Identification and survey reference reach (*Reference Reach-stable stream reach of the same stream type as your project design reach*)

   ~56-120 hours is highly dependent upon how hard it is in finding a reference reach

7. Complete morphological chart (*Morphological Chart-chart that compares and documents reference reach, existing conditions, as-built and design data*)

   ~64-96 hours

8. Obtain formal landowner agreement

   Watershed organizations should do this, but may still need 4-20 hours of Q/A from consultant. <u>SCALEABLE</u> -Based upon how many landowners involved in the project. <u>CAVEAT</u>-Landowner agreement might be contingent on detailed designs

<u>Deliverables</u>— Completed morphological chart, summary of findings, conceptual design drawings for the project site, narrative, project base map, and landowner agreements, cross sections, survey data.

<u>Extra Deliverables</u> may include comparison of predicted vs. measured findings, stream rating curve, sediment rating curve (Both curves are studies developed over longer periods of time)

EXTRAS-

Additional verification tasks not required, but ensure better data and design – Level 3 survey-site specific. This should be up to the discretion of the consultant on the project, but should be justifiable and demonstrate benefit.

9. Bed and bank stability verification
   a. Install bank pins, scour chains

      ~ 4 hours for bank pins / location and $50 materials, 4 hours/chain and $250 materials, this task includes monumenting of a cross section

10. Collect and analyze data for Rosgen empirical sediment transport analysis e.g. – what size particles are moving at bankfull and other flows. Field data includes grain size distribution analysis on sediment samples collected from either a point bar or the pavement/subpavement in a riffle. ~ 6 hrs per site

11. Conduct detailed sediment transport analysis: ~ Cost Range of $30,000 - $150,000
    a. Install continuous flow data logger to develop average daily flow records

       ~instrumentation $1000/data logger

    b. Collect bed and suspended sediment samples from an estimated 20 flow events and develop a sediment rating curve.
    c. Estimate annual sediment yield generated from the watershed using average daily flow records and sediment rating curve.

B. **Final Design Phase**

1. Develop design drawing package

   ~140-192 hours which includes: Topo survey, base map with design overlay, long profile with proposed thalweg (*longitudinal line of maximum depth*) and bankfull elevations, existing topo with ground surface elevations, cross sections with proposed channel slope and existing ground surface, detailed sheets for structures, techniques for stabilization, narrative with construction schedule and miscellaneous specifications and instructions, and planting plan.

2. Complete HEC RAS (*HEC RAS-100 year flood frequency analysis at the project location*)

   ~60-80 hours, CAVEAT-If required for consistency with local floodplain ordinances.

3. Write up of narrative report including all data collected and analysis for project

   ~40-90 hours, which includes all data collected and analysis for the project

4. Develop erosion and sediment control plan

   ~80-132 hours, which includes application, plan, drawings, narrative

5. Prepare and submit joint permit application

   ~140-200 hours, which includes data and documentation in accordance with the checklist in the permit package application and construction specifications (when applicable)

6. Develop project construction cost estimates

   ~30-40 hours

Deliverables-Cut and fill estimates, cost estimates for construction, final design package, permit package, and final report for the grant

IV. Funding Phase Four –Construction and Monitoring

SCALEABLE-Every task in this phase is scaleable except Construction Contracting Assistance and Mobilization and Demobilization

CAVEAT-Weather is a major influence on the timeframe of this phase

A. Construction

1. Provide construction contracting assistance

   ~40-80 hours, which includes developing a bid list, advertising, Request for Bids (*Request for Bids-document developed describing the project to which contractor develop their bid*), interviews and selection of contractor.

2. Provide construction oversight-Engineering assistance post-contract award

   pre-construction meeting, overseeing construction activities, checking deliveries/pay schedule, mark up of original plans or as-builts, photos, and other permit/funding requirements

   ~ one person for 5 hours/day to 10 hours/day

3. Mobilization/Demobilization of equipment

~$5000

4. Lay out the construction site for excavation

   ~ $3000 to Set grade stakes, establish construction baseline and offsets, local bench marks, etc.…

5. Construct erosion and sedimentation controls

   ~ $2000-3000, includes the basic requirements such as silt fence @ $3.00 per linear foot, access roads and staging areas and does not include any in-stream water management which is addressed in item #9, SCALEABLE-Based upon the requirements of the permit

6. Clearing and grubbing vegetation

   ~ $1000 /acre for basic removal of vegetation

7. Construct access points/haul roads/staging areas

   ~ $2000-10,000 CAVEAT- Depending upon site conditions with wet situations carrying higher costs

8. Obtain materials

   ~$14-50/ton, average of 1 ton of stone / linear foot of structure (based upon a 3x2xL rock size) CAVEAT-Dependent upon distance for hauling and rock size, going to the quarry and marking your own rocks limits the amount of junk rock received.

9. In-stream water management, (*In-stream Water Management, to divert water around the construction site, if necessary*)

   ~$10/linear foot

   CAVEAT-Pump arounds significantly increase the cost of a project dependent upon streamflow-recommend not using these unless absolutely necessary or when relocating a channel due to the importance of testing the structures with normal water flow

10. Complete construction-excavation

    ~$5.00-10.00/cubic yard, SCALEABLE-Dependent upon project size and CAVEAT-Dependent upon working on the bank or in the water

11. Construct in-stream structures

    ~ $1200-1800/structure based upon a 10 hour day, $180-290/hour for a wheel loader and excavator and two operators' time, this range allows for time differences between experience and inexperienced operators and reworking of structures. (typically in this situation the more experience the higher the cost, but better structure in the end) CAVEATS-Bonding *(In effect, an "insurance policy" which can be used in the event the contractor fails to perform properly or within the terms of the construction contract)* if a contractor is require to bond the project you can expect a 1.5 to 3% increase in total cost of project, Prevailing Wages -if prevailing wage is required you can expect a 25-40% increase in the labor charges, if the contractor is not local you can expect higher rates to cover lodging and per diem. Structures built out of logs rather than stone tend to be cheaper in material costs, but have a shorter life span.

12. Stabilize site

    ~$3000/acre for seeding and mulching, $10/linear foot for bankfull stabilization materials such as matting, $1-10/linear foot for hay bales or coir logs (*coir logs-coconut fiber logs used for bank stabilization*) or $36-40/linear foot for rock and installation CAVEAT-This is an area where money could be saved if volunteers complete the labor of spreading seed/fertilize/lime/mulch/install matting. CAVEAT-Bioengineering *(generally plant materials combined with other materials such as rocks, logs or brush and natural fabrics. Examples would include brush mattresses, live fascine bundles, vegetated geogrids, etc.)* and Toe revetment using large rocks or boulders at the base of a stream bank-this is done in constrained sites such as urban areas where you can't restore the appropriate natural channel meander geometry or flood plain width.

13. Plant riparian buffer

    ~$3-4/plant in containers up to one gallon in size-recognize you would use different plants from water level to bankfull from those planted from bankfull to end of area of disturbance, and $14,000 for installation labor, This is where major cost saving could occur if labor and/or plants were donated, or plants could be live stakes from the site or nearby. SCALEABLE-Based upon project size and disturbance area and the type of plants installed such as bareroot, balled and burlap, or containerized.

14. Install monumented cross sections for monitoring-initial survey

~$2600 based upon 5 person days x 8 hours/day x $65/hour, assumes rebar monuments.

CAVEAT-There will be costs to train the watershed organization to do the monitoring, most permits require 5 years of monitoring

Deliverables- Final report with narrative, as-builts and cross sections. CAVEAT-Assumes that the DEP region will accept marked up plans rather than a new survey for the as-built drawings.

B. Post-construction monitoring

1. Train volunteers to do monitoring tasks
    a. ~ 24 - 40 hours, with field supplies ranging from $600 to $4,000 if a laser level is purchased for the volunteers to use.
2. Obtain additional funding as needed to provide long-term monitoring
3. Annual monitoring will typically be required for a duration of five years. An ideal time to complete the monitoring measurements is during low flow conditions following a significant (≥ bankfull) flow event. At least two monumented cross sections should be measured at some time over the course of the year following the completion of the project and submission of the as-built drawings, or following the submission of the previous monitoring report, to provide an early indication of excessive changes in the channel geometry. At minimum, one subjective inspection of the entire project reach should be made concurrent with the measurement of the monumented cross sections to evaluate whether the project objectives continue to be met, and to identify any problem areas demonstrating signs of instability. Photo documentation should also be provided at the photo documentation stations identified on the as-built drawings submitted at the project completion. A monitoring report should be submitted with the monitoring data, analyses results, and a narrative that also summarizes any high flow events observed during the monitoring period. It is assumed that the watershed association, or other volunteer organizations will perform the annual monitoring. Should problems be indicated, personnel trained in fluvial geomorphology should be brought in to evaluate the magnitude and significance of the problem, and to formulate a strategy for remediation.

<u>Mini Case Study for Costs for Assessment, Design and Permitting</u>

This project assumes a 1000 foot stream length for the project, with a 50 foot bankfull width, 30 foot wide riparian buffers established on both sides of the creek for the whole length of the project, and 2.5 acres of disturbed area.

<u>Task Low Range (Hrs) High Range (Hrs)</u>

I. Funding Phase One-Watershed-wide Problem Identification

A. Initial Assessment

B. Watershed-wide Stream Inventory

**$161-$321 per mile for 25 mi

(based upon several projects completed in the N. Central PA Region). **Total Costs**

$4,025 **$8,025**

Cost Per Lineal Foot

$40.25 **$80.25**

II. Funding Phase Two-Developing a Restoration Plan

A. Watershed-wide Forensic Analysis

1. Verification of information in Funding Phase One-Watershed-wide Problem Identification 160 360
   - based upon an average watershed size of 50 sq/mi
2. Assess applicability of available regional curves 20 30
   - <u>assumes a regional curve exists</u> for the area and there are 3-4 gages for the regional curve
3. Develop a regional curve (NOT REQUIRED IF ONE ALREADY EXISTS) 80 600
4. Perform field data collection 160 555
   - Conduct BeHI measurements
   - Measure hydraulic geometry
   - Determine stream classification
   - Develop a map of stream features and points of analysis

5. Analyze collected field data, prioritize problems, and develop preliminary restoration plan 120

440

Totals Hours (low range without step 3)

460 1,985

DIRECT EXPENSES (travel, repro, field supplies) $5,000

$21,000

Total Costs @ avg of $65/hour

$34,900 $150,025

Cost Per Linear Foot $34.90

$150.03

III. Funding Phase Three-Design and Permitting

A. Conceptual Design Phase

1. Project start up field meeting 16

   40

2. Verify stream gage 30

   40

   - if a stream gage exists on project stream

3. Survey existing conditions of restoration project reach 24

   80

   - highly dependent upon site complexity for measuring

4. Develop base map

   70 120

5. Develop conceptual design plan

   64 104

6. Identification and survey reference reach

   56 120

   - highly dependent upon how hard it is in finding a reference reach

7. Complete morphological chart 64

96

8. Obtain formal landowner agreements 4

20

- Watershed Organizations should do this, but may still need Q/A from consultant

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III. A. Extra Verification Tasks [Not included in Phase III or Project Totals]

9. Bed and bank stability verification (bank pins and scour chains) [per location] 4

8

Direct Costs: field supplies for bank pins (low range), pins +chains (high range) $50

$250

10. Collect & analyze sediment transport data (sediment grab samples) [per location] 6

6

11. Conduct sediment transport analyses (bedload sediment sampling, rating curves, etc.) $30,000

$150,000

III. B. Final Design Phase

1. Develop design drawing package

140 192

2. Complete HEC RAS 60

80

3. Write up of narrative report 40

90

4. Erosion and sediment control plan 80

132

5. Prepare and submit joint permit application 140

200

6. Develop project construction cost estimates 30

40

Totals Hours

818 1354

DIRECT EXPENSES†

$11,000 $8,000

Total Costs

$64,170 $96,010

- **Avg $65/hour**

Cost Per Linear Foot $64.17

$96.01

†: Includes aerial topo survey flight (low range) of II.A.4,

Mini Case Study for Costs for Construction

This project assumes a 1000 foot stream length for the project, with a 50 foot bankfull width, 30 foot wide riparian buffers established on both sides of the creek for the whole length of the project, and 2.5 acres of disturbed area.

Task	Low Range	High Range

IV. Funding Phase Four-Construction and Monitoring

A. Construction Phase

1. Provide construction contracting assistance
   - 40 Hours

     $2600
   - 80 Hours

     $5200
2. Provide construction oversight
   - 1 person x 5 hours/day x 5 days/week x 6 weeks x $65/hour

     $9750
   - 1 person x 10 hours/day x 5 days/week x 6 weeks x $65/hour

     $19,500

3. Mobilization/demobilization of equipment $5000

$5000

4. Lay out construction site for excavation $3000

$3000

5. Construct erosion and sedimentation controls $2000

$3000

6. Clearing and grubbing vegetation
   - $1000/acre x 2.5 arces of disturbed area

   $2500 $2500

7. Construct access points/haul roads/staging areas
   - Dry conditions-minimal prep

   $2000

   - Wet conditions-stone road based

   $10,000

8. Obtain Materials
   - (Avg total vane length of 175 ft including sills x $14/ton = $2450)
     - Assume 5 Structures = 650 linear feet of rock

     $12,250

   - (Avg total vane length of 175 ft including sills x $50/ton = $8750)
     - Assume 8 Structures = 1025 linear feet of rock

     $70,000

9. In-stream water management
   - Avg $10/linear foot of stream

   $10,000 $10,000

10. Complete construction-excavation
    - Best case scenario-need to establish dimension of the existing channel with not much excavation
      - 1000' x 50 wide stream x 2 ft avg depth of rock moved = 100,000 cubic feet
      - 100,000 cubic ft ÷ 27 yds= 3703 cubic yards of soil x $5/cubic yard

      $18,515

- Priority One Restoration-build a new channel and reattach to floodplain
    - 8’ excavation x 100 ‘ floodplain (50’ each side) x 1000’ length = 800,000 cubic yards

      (Price adjusted) $150,000

11. Complete in-stream structures
    - 5 Structures x $1200/structure

      $6000
    - 8 Structures x $1800/structure

      $14,400
12. Stabilize site-required by the permits
    - Seed and Mulch only 1000’ x 30’ each side = 60,000 sq ft = 1.5 acres
        - 1.5 acres + 1 acre staging area = 2.5acres x $3000

          $7500 $7500
    - Bankfull Stabilization materials 1000’ x from $1 - $10/linear foot

      $1,000 $10,000
13. Plant riparian buffer
    - $3.00/plant x 60’ wide buffer (30’ each side) x 1000’
        - plant at 3 sq yd = 2200 plants

          $6700
    - $4.00/plant x 60’ wide buffer (30’ each side) x 1000’
        - plant at 3 sq yd = 2200 plants

          $9000
    - Labor-assumes contracted installation

      $14,000 $14,000
14. Install monumented cross sections for monitoring
    - 5 person days x 8 hours x $65/hour

      $2600 $2600

B. Post Construction Monitoring:

- Training volunteers to do the required field measurements and evaluations

  $1,560 $2,600

- Field supplies for the volunteer organization to do the monitoring

  $600 $4000

- **Total Costs**

  $107,575 $342,300

Cost Per Linear Foot

$107.58 $342.30

Summary-Combined Project Costs

Funding Phase One-Watershed-wide Problem Identification $4,025

$8,025

Funding Phase Two-Watershed-wide Forensic Analysis

$34,900 $150,025

Funding Phase Three-Design and Permitting

$64,170 $96,010

Funding Phase Four-Construction and Monitoring

$107,575 $342,300

Total Project Costs

$210,670 **$596,360**

Cost per lineal foot for 1000-ft project

$210.67 **$596.36**

These estimates do not include:

- PNDI surveys if hits are received
- PHMC surveys, if hits are received
- Land Development Plans
- Zoning Variances
- Changing FEMA Maps
- Wetland Mitigation

APPENDIX V

Glossary

Aggradation -- the excessive accumulation of sediment that results in raising the streambed elevation

Bankfull discharge - the stream flow that transports the majority of a stream's sediment load over time and thereby forms the channel; the discharge that fills a stable alluvial channel to the elevation of the active floodplain; bankfull discharge is the basis for measuring width/depth ratio and entrenchment ratio

Cross vanes -- rock structures that extend across a stream from bank to bank; they are keyed into the bankfull elevation in order to control the channel carving flow.

Dimension - a stream's width, mean depth, width/depth ratio, maximum depth, floodprone area width, and entrenchment ratio

Degradation -- the lowering of a streambed by scour and erosion

Entrenchment -- the degree to which a channel is incised

Incised stream - a stream in which scouring causes the channel to degrade or down cut to a point where the stream is no longer connected to its floodplain

Fluvial Geomorphology (FGM) - the study of a stream's interactions with the local climate, geology, topography, vegetation, and land use; the study of how a river carves its channel within its landscape

Head cuts -- incisions or forms of channel degradation that migrate upstream for potentially great distances; head cuts are created when materials are removed from the streambed at a depth sufficient to cause the stream to adjust its slope in an upstream direction

Pattern - a stream's sinuosity, meander wavelength, belt width, meander width ratio, & radius of curvature

Profile - the mean water surface slope, pool/pool spacing, pool slope, & riffle slope

Natural stream channel design - a fluvial, geomorphic-based restoration method that uses data collection, modeling techniques, and stable or reference channels in the design of ideal channel configurations

Reference reach - a section of a stream that provides a target for a river restoration project; a reference reach must be located within the same hydro-physiographic region, have the same general land use, and the same stream type and valley form as the proposed stream.

Regional curve -- hydraulic geometry relationships that relate bankfull channel dimensions to a stream's drainage area; regional curves aid in identifying bankfull stage and dimension in ungaged watersheds and to help estimate the bankfull dimension and discharge for natural channel designs

Rip Rap -- loose rock generally about 6 to 10 inches in diameter

Rock Vanes -- rock structures used in FGM-based restoration projects; slope and shape of the rock vane reduces the velocity of the water as it flows up the vane and accelerates the flow as it rolls water away from the bank towards the center of the stream; the net effect is to protect the bank from erosion and to direct the force of the water into the center of the stream for sediment transport.

Root wads -- used to control erosion on outside bends; involves tree trunk embedded in a trench in the streambank and angled upstream with the root mass facing the flow; serves to dissipate energy by receiving the brunt of the stream energy.

Stream enhancement -- the process of implementing certain stream rehabilitation practices in order to improve water quality and/or ecological function; typically conducted on the stream bank or in the flood prone area but may also include the placement of instream habitat structures; however, they should only be attempted on a stream reach that is not experiencing severe aggradation or erosion.

Stream restoration -- the process of converting an unstable, altered, or degraded stream corridor, including adjacent riparian zone and flood-prone areas to its natural or referenced, stable conditions considering recent and future watershed conditions. This process also includes restoring the geomorphic dimension, pattern, and profile as well as biological and chemical integrity, including transport of water and sediment produced by the stream's watershed in order to achieve dynamic equilibrium.

Stream stabilization -- the in-place stabilization of a severely eroding streambank and stream bed. Stabilization techniques which include "soft" methods or natural materials (such as root wads, rock vanes, vegetated crib walls) may be considered part of a restoration design. However, stream stabilization techniques that consist primarily of "hard" engineering, such as concrete lined channels, rip rap, or gabions, while providing bank stabilization, will not be considered restoration or enhancement in most cases.