Flood Hazard Area Technical Manual
Section 8
Bank Stabilization and Stream Restoration

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Stream Restoration Committee

FHA Subcommittee

Submitted to NJDEP November 2007

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Channel Restoration

1.1 Introduction

This section of the Flood Hazard Area Control Act Rules (N.J.A.C. 7:13) Technical Manual provides guidance to Applicants proposing a channel restoration project in complying with the project assessment, design, and justification requirements outlined in N.J.A.C. 7:13-11.14.

Channel restoration projects as defined in N.J.A.C. 7:13-11.14 refer to proposed modifications to waterbodies with jurisdiction under the Flood Hazard Area rules. Channel restoration projects can be grouped into four major categories:

1. Bank stabilization,
2. Natural channel design,
3. Riparian buffer restoration, and
4. In-stream habitat enhancement.

In the past, common channel restoration solutions have often relied heavily upon engineered structures consisting of concrete, gabions or rip-rap stone. While these solutions provide immediate stabilization, and may be appropriate in some situations, they typically have not taken into account the complexity of stream systems or provide habitat value for aquatic organisms, and in certain circumstances exacerbate degradation of channel conditions. To address existing problems and to enhance degraded stream channels, an integrated design and analysis approach should be used. This approach should document the cause of the channel instability and craft a solution that addresses the cause of the problem, not just the symptom. Projects submitted under this section require that the science of stream geomorphology be correctly applied. An applicant shall evaluate the hydraulic, hydrologic and geomorphic processes that form stream channels, drainage patterns, floodplains, terraces, and explain sediment erosion, transport and deposition.

Specific goals, objectives, and level of effort associated with channel restoration projects vary greatly based on the existing need or problem. Channel restoration designs must reflect and account for site specific conditions and often require the use of innovative construction methods and restoration technologies.

The permit requirements set forth at N.J.A.C. 7:13-11.14 require Applicants to:

- Clearly define the need and approach for proposed channel restoration projects,
- Demonstrate sound science and engineering for proposed restoration activities, and to
- Document a clear purpose for activities that impact stream channels.

This section of the technical manual sets forth methods for project assessment, goal setting, design, and monitoring that Applicants should follow in meeting the requirements of N.J.A.C. 7:13-11.14. The goal of the assessment and design process for channel restoration projects is to assess and understand the natural stream system to the greatest extent practicable, to evaluate and select the most appropriate design solution to achieve the project goal(s), and to maximize use of natural materials and low-impact construction methods.

Full ecosystem recovery is rarely achievable, due to the impacts of human activities in the watershed. In such systems, rehabilitation (producing a state of ecological productivity and useful structure) or enhancement (an improvement in habitat structure or function) may be the only achievable goals. In some situations, the goal of the project may simply be to protect existing infrastructure.

Due to the complexity of drainage systems and the natural environment, it is recommended that a multidisciplinary team of scientists and engineers (soil and plant scientists, geologists, hydrologists, civil engineers, wetland scientists, fisheries biologists, etc.) as well as technical experts in stream and river systems be consulted throughout the design process. The complexity of the design team should be commensurate with the complexity of the project.

There are many valuable reference documents available to the applicant; the attached reference list provides some of them. It should be noted that this is not an exhaustive list.

1.1.1 Introduction to Channel Restoration

Streams and floodplains are a valued natural resource throughout the State, providing important ecological, economic, recreational, and aesthetic benefits to our communities. Due to development and landscape changes, ever-increasing pressures are placed on our streams and flood plains. Streams and floodplains are dynamic systems that naturally move horizontally and vertically over time. Normally this process slowly forms a path through the surrounding landscape. But, watershed-wide activities and development pressures along streams and floodplains often causes changes to this normally slow forming natural process.

When a stream is in disequilibrium, the balance between erosion and deposition has been disrupted. This may be the result of major land disturbance in the watershed, changes to riparian vegetation, or to the supply of water, sediment or structural elements. Disequilibrium can also be caused by local disturbance or channel manipulation. If the changes or disturbance are temporary, the stream will often recover its former characteristics. If the changes are chronic, the stream will eventually reach a new equilibrium.

Successful restoration projects strive to balance rates of erosion and deposition, so the natural processes of forming individual channel and floodplain features can occur and overall channel characteristics such as sinuosity, gradient, width/depth relationships, and pool and riffle frequency are maintained. Effective restoration depends upon reestablishing watershed and stream processes to a range of variability that maintains a complex channel/floodplain system in dynamic equilibrium. In some cases, an action as simple as improving the riparian buffer will help achieve this equilibrium. In other cases, more complex actions are required.

Channel restoration projects typically address one of two issues:

1. Channel instability: erosion problems, streambank failures, and other physical characteristics within a stream channel causing structural changes that threaten life and/or property, or
2. Ecological degradation: threats to in-stream habitat, loss of stream form and function, and impacts to riparian vegetation.

The Department encourages the Applicant to take a watershed approach to analyzing and characterizing the physical and ecological processes that affect the stream corridor. Stream ecosystems extend well beyond the channel, encompassing the entire stream corridor. All aspects of the stream corridor must be considered when identifying the limits of the restoration project site and identifying all the opportunities for restoration. By considering processes beyond the immediate project site, the Applicant can factor those processes into the design process and decrease the chance of those processes negatively impacting the restoration project.

Without adequate consideration and knowledge of watershed and ecosystem processes and conditions, any measure will be prone to failure, may provide only short-term benefits, and is likely to have unintended adverse effects.

1.1.2 The Channel Restoration Process

This section of the Technical Manual sets forth a recommended approach for Applicants proposing a channel restoration project. It is recommended that the project justification be provided in the form of an alternatives analysis that follows the decision framework specified in N.J.A.C. 7:13-11.14 c(1)-c(5) and outlined here. Per this framework, the Department will generally look for the Applicant to justify why less invasive methods (e.g., bioengineering, planting) would be unsuitable to achieve the project's goals and objectives before considering more invasive methods (e.g., structural bank stabilization, natural channel design).

The hierarchy of channel restoration projects to address channel instability or ecological degradation as defined in N.J.A.C. 7:13-11.14 c(1)-c(5) includes:

1. Bank Stabilization Projects (Design Option 1, N.J.A.C. 7:13-11.14(c)2 and (c)4): As outlined in this section of the regulations, the applicant shall first consider stabilizing the streambank by grading and planting the eroded area.
2. Soil Bioengineering Projects (Design Option 2, N.J.A.C. 7:13-11.14(c)4): If grading and planting cannot fully prevent further channel instability or ecological degradation due to excessive channel velocity, or if cutting the bank would destroy an excessive number of existing trees or other vegetation, soil bioengineering shall be used to stabilize the eroded channel. The applicant must demonstrate why less invasive techniques are not appropriate.
3. Other Design Strategies (Natural Channel Design, Structural Stabilization, Floodplain Terracing, Design Option 3, N.J.A.C. 7:13-11.14(c)4): If less invasive techniques (Design Options 1 and 2) are not appropriate, a project that modifies the plan, form, dimension, or profile of a stream and flood plain system to a stable form and function appropriate to the existing site conditions and watershed drainage area may be proposed. The Applicant must demonstrate that conditions on the site make the use of less invasive techniques alone inadequate. This is intended to ensure the proper use of more extensive techniques, and to ensure that the adverse impacts of such techniques are minimized.
4. Riparian Buffer Restoration (Optional Design Element: Applicants may incorporate a riparian buffer restoration component into their project. This component may include clearing, invasive-exotic species removal and planting of native species in the riparian zone to re-establish a native vegetated corridor along a stream or floodplain. It should be noted that the riparian buffer may or may not correspond with the regulated riparian zone.

   Note: Riparian buffer projects which do not involve disturbance or modification of the regulated riparian zone, are not considered channel restoration projects and are thus not regulated under N.J.A.C. 7:13-11.14.
5. In-stream Habitat Enhancement Projects (Optional Design Component): Applicants may propose installation of natural materials and plantings within the stream channel to provide habitat enhancement beyond under the Permit-by-rule defined at N.J.A.C.7:13-7.2(a)7. Projects which include only this component are not subject to the requirements of this section; applicants should refer to N.J.A.C. 7:13-11.14 b(2). Projects beyond what is permitted by rule shall follow the requirements of this section of the technical manual.

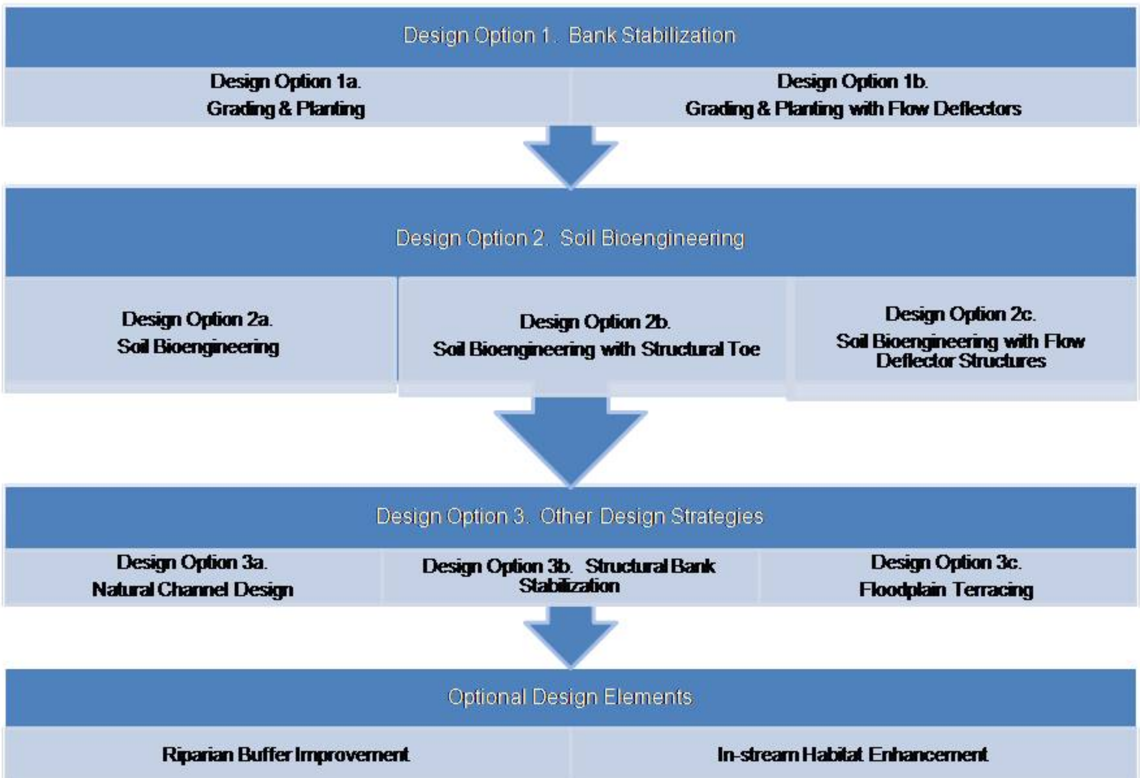


Figure 1. Design Decision Framework

This section of the Technical Manual provides guidance to the Applicant regarding:

- Project identification,
- Evaluation of existing conditions,
- Project development – selection of design options and development of design data
- Development of monitoring, maintenance and adaptive management plans.

The following steps can assist Applicants considering channel restoration projects and developing design approaches to be considered under the requirements for bank stabilization and channel restoration.

Restoration Project Development Process (also see Figure 2):

Step 1. Identify location and extent of restoration project site.

Step 2. Develop project team.

Step 3. Evaluate existing stream corridor conditions.

Step 4. Identify and characterize reference sites; analyze departure of the existing condition from the desired condition.

Step 5. Define project goals and objectives.

Step 6. Develop conceptual design and alternatives for channel restoration activities.

Step 7. Develop restoration design data.

Step 8. Develop restoration design.

Step 9. Develop monitoring plan.

Step 10. Develop maintenance plan.

Step 11. Identify adaptive management options.

Step 12. Implement restoration project.

Step 13. Initiate post-project monitoring and maintenance

Step 14. Evaluate project success.

Step 15. Respond to monitoring results – maintenance or adaptive management if needed.

Step 16. Documentation and reporting

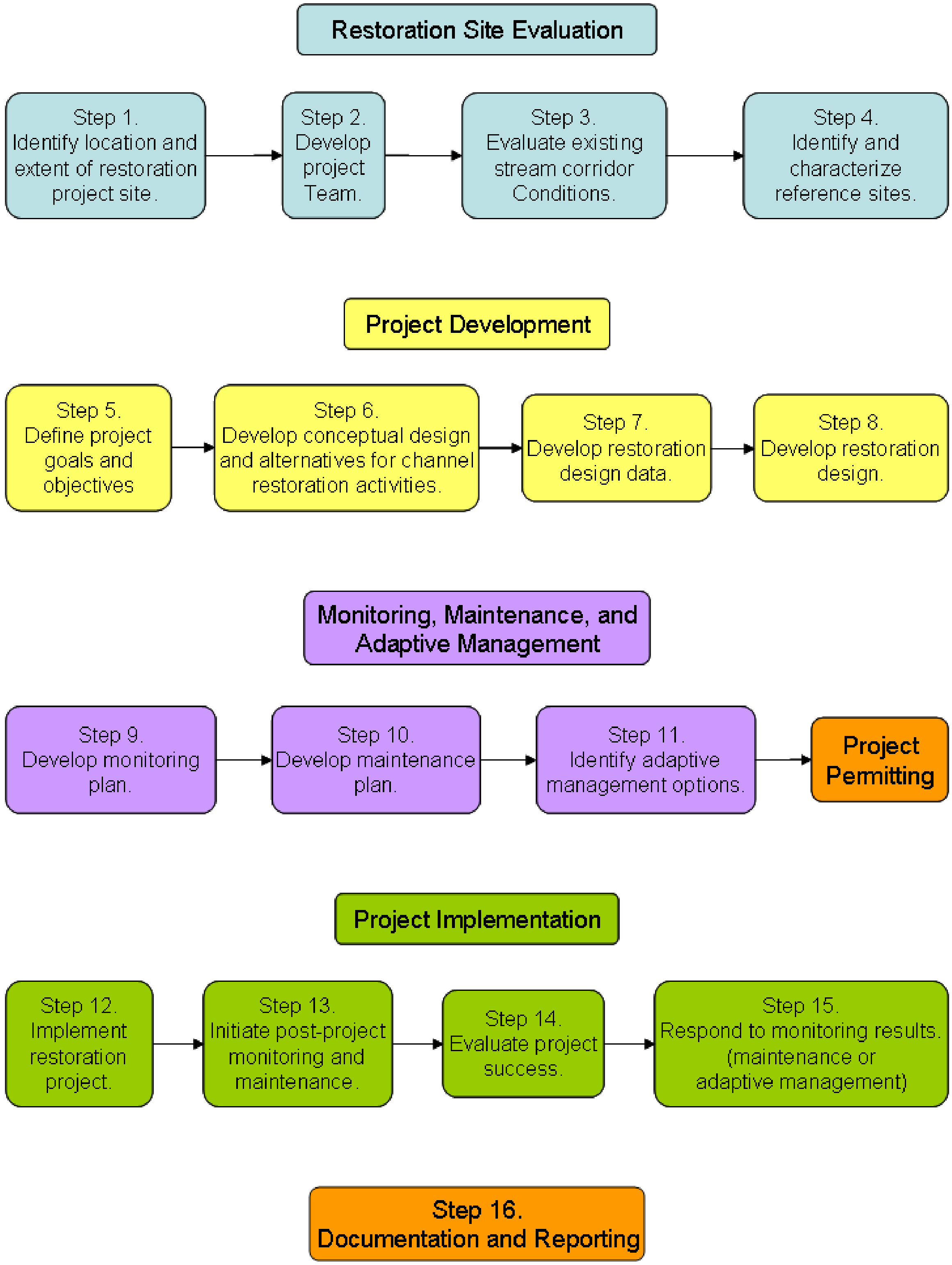


Figure 2
Restoration Project Development Process
Flow Diagram

1.1.1 Compliance with Other Relevant Regulations

Many channel restoration projects may involve ancillary or related work that is not specifically covered under N.J.A.C. 7:13-11-14 but that is regulated under other sections of N.J.A.C. 7:13. These activities include but are not limited to dam removal (N.J.A.C. 7:13-11.11), bridge/culvert modification/replacement (N.J.A.C. 7:13-11.7), utility line crossing (N.J.A.C 7:13-11.9), and outfall structure upgrade/replacement (N.J.A.C. 7:13-11.10). Channel restoration projects must also comply with, among other applicable sections, standards for excavation, fill, and grading activities (N.J.A.C. 7:13-11.3) and revegetation (N.J.A.C. 7:13-10.2). If a retaining wall or bulkhead is proposed in connection with a channel restoration project, Applicants must also comply with N.J.A.C. 7:13-11.13. Certain channel restoration projects are permitted by rule and may thus be eligible for coverage under a General Permit (see N.J.A.C. 7:13-8 for additional information). Projects not eligible for coverage under a General Permit will require an Individual Permit (N.J.A.C. 7:13-9).

Channel restoration projects typically also require separate approval under the Freshwater Wetlands Protection Act Rules (N.J.A.C. 7:7A). Channel restoration projects occurring in the Coastal Zone may require approval under the Coastal Permit Program Rules (N.J.A.C. 7:7). Applicants proposing projects in the Highlands, Pinelands, or Tidelands Special Planning Areas are advised that special approvals and permits may be required. Channel restoration projects proposed within or adjacent to Category 1 Waters as defined under N.J.A.C. 7:19B must provide a Special Water Resource Protection Area Functional Value Analysis as required by Administrative Order No. 2007-01.

It should be noted that this is not an exhaustive list of other regulations that may apply to channel restoration projects. The applicant is responsible for identifying the complete list of required permits for their particular project.

1.2 Restoration Site Evaluation

The purpose of this section is to provide Applicants with a comprehensive list of factors and criteria to consider when evaluating a stream and developing goals and objectives for a channel restoration project. The overall process is hereafter referred to as the restoration site evaluation.

The complexity of the restoration site evaluation shall match the complexity of the project goals and objectives. The channel restoration techniques mentioned herein are not meant to limit the design choices. If properly presented and justified, the Department may consider innovative channel restoration techniques and methodologies.

Through field reconnaissance, review of maps and aerial photography, data collection and data analysis, the Applicant shall document the following steps outlined as Project Identification and Assessment of Existing Conditions. For riparian buffer projects, the process should be straightforward. For more complex channel restoration projects, the site evaluation may be an iterative process.

Project Identification and Assessment of Existing Conditions

Step 1. Identify location and extent of restoration project site

Step 2. Develop project team.

Step 3. Evaluate existing stream corridor conditions.

Step 4. Identify and assess reference sites or reference condition, analyze departure of the existing condition from the desired condition.

For a more complete discussion of site evaluation for the purpose of channel restoration, the Applicant is encouraged to consult the reference list.

1.2.1 Step 1: Identify Location and Extent of Restoration Project Site

Potential channel restoration sites are often identified as part of a larger watershed characterization and assessment effort. In other cases, potential restoration sites are identified separate from a complete watershed effort. In either case, the channel restoration site must be considered in the context of watershed-wide characteristics and disturbances. Although the problem may be local in nature, the Department encourages the Applicant to address upstream processes that may be causing the problem and the influence the proposed solution will have downstream of the site.

Once a potential project site is identified, whether through a watershed assessment or not, the Applicant shall first conduct a visual reconnaissance of the project site and the contributing drainage area to identify problem areas and potential stressors. The initial field reconnaissance shall be followed by a review of available maps and aerial photographs.

Following the initial field reconnaissance, the Applicant should be able to identify the limits of the project site and to consider potential goals and objectives. The applicant should also be able to conceptually identify the type of project and its place within the channel restoration hierarchy included in this Manual. This will assist the applicant in determining what level of data collection and analysis is necessary for site evaluation and design development.

1.2.2 Step 2: Develop Project Team

Applicants shall consider the size and complexity of their project when developing their project team. Smaller or less complex projects will not require the variety of project team members that larger projects will. Small projects may only require the participation of a landowner and qualified professional; however, other stakeholders may provide valuable input and resources. Larger, more complex projects shall include a variety of stakeholders to increase the likelihood of project success. Potential project team members may include:

- Local, county and state representatives;
- Government agencies (e.g. county soil conservation district, Fish & Wildlife Service, USDA-NRCS);
- Watershed associations, nature conservancies or other non-profit groups;
- Local utilities (water supply authority or municipal utility authority);
- Qualified professionals in aquatic and terrestrial ecology, hydrologic and hydraulic engineering, soils, wetlands, fisheries and other related disciplines.

The project design team is likely to be a subset of the project team. As with the project team, the size and complexity of the project will determine the composition of the design team. The project design team members shall be listed in the permit application package. A short description of their role in the project, their area of expertise, and their level of experience (if applicable) shall be included. The project design team shall include a member who is experienced in stream geomorphology. Other members of the project design team shall include:

1. For riparian buffer restoration projects that are part of a regulated channel restoration project: A botanist, landscape architect, or individual experienced in the design and implementation of riparian zone projects.
2. For in-stream habitat enhancement projects: A fisheries biologist, stream ecologist, or individual experienced in the design and implementation of in-stream habitat structures.
3. For bank stabilization projects: A botanist and a licensed professional engineer experienced in soil bioengineering techniques and stream mechanics.
4. For natural channel design, structural stabilization and floodplain terracing projects: In addition to those required for bank stabilization projects, the design team must include a stream geomorphologist.

1.2.3 Step 3: Evaluate Existing Conditions

Regardless of the size and complexity of a channel restoration project, an assessment of existing conditions within the project area is critical to documenting the extent, nature and severity of the problem; identifying the causes or ‘stressors’ that are responsible for the problem; and developing an effective design solution. Section 7:13-11.14(b)1 requires the collection of data to characterize the existing problem; however, Applicants should keep in mind that much of this data will be the same information that will be used to provide a justification for the chosen design alternative and also for project design.

The following section outline recommended procedures for existing data collection:

Step 3a. Assess Historic Watershed and Site Conditions

Step 3b. Assess Existing Watershed Conditions

Step 3c. Assess Existing Site Conditions

Step 3d. Identify Causes of Channel Instability/Channel Degradation.

The exact data collection program will depend on the specific project conditions, available data and the preliminary goals and objectives associated with the project. Also, while the project team may have preliminary ideas concerning the type and extent of the proposed project prior to documenting existing conditions, insights into the project area gained through the site evaluation process can often lead to significant changes to the channel restoration approach that is ultimately used to address a given site.

1.2.3.1 Step 3a: Assess Historic Watershed and Site Conditions

Stream corridors change over time in response to natural or human-induced processes and disturbances. The stressors may be local or system-wide, temporary or recurring. By investigating historic conditions at the project site and in the watershed, the Applicant will be better able to identify the causes of channel instability or ecological degradation.

For all projects, the Applicant shall document historic activities that affected the project reach, including:

- Removal of riparian vegetation;
- Land use changes;
- Channel modifications, including channel straightening, channel widening, past stabilization efforts or other activities that affected the stream corridor, the hydraulics of the project reach or the aquatic habitat of the reach.

For larger, or more complex projects, the Applicant shall also document impacts to watershed hydrology, including changes in land use, water diversions or installation of flood control structures;

Potential sources of information on historic site conditions and land use activities include:

Aerial photographs and historic maps

Historic aerial photographs are available from several sources, including:

- the Department
- New Jersey State Department of Transportation,
- U.S. Forest Service,
- U.S. Army Corps of Engineers, and
- USDA-Natural Resources Conservation Service.

The U.S. Geologic Survey Earth Resources Observation and Science Center (http://eros.usgs.gov/products/aerial.html) maintains a list of additional sources of aerial photographs.

Interviews and Photographs: Interviews with long-time residents may provide information on previous riparian corridor conditions, land use and local disturbances. The Applicant should use caution when utilizing anecdotal data.

Field Investigation: An experienced field investigator may be able to identify historic streambanks, terraces or infrastructure which indicate historic stream patterns. Field observations can also indicate the channel's response to previous channel modifications. These findings shall be documented on site sketches.

1.2.3.2 Step 3b. Watershed Assessment

Some channel restoration projects will be undertaken following completion of a watershed restoration or protection plan. Others will be identified as part of more localized efforts. The applicant shall, commensurate with the project complexity, assess factors within the watershed that affect the project site.

The watershed assessment in an important component of the restoration site evaluation. Stressors in the project watershed, beyond the project reach, can have significant impacts on the project reach.

Important factors to consider at the watershed scale include:

- Topography
- Geology
- Soils
- Land use
- Impervious surface
- Surface water hydrology
- Water quality impairments
- Floodplain characteristics
- Hydrologic alteration
- Important habitats and species

As part of the site evaluation report, the following shall be documented:

All restoration projects:

Bank stabilization projects:

- Analysis of current land use in the watershed to identify any watershed-wide stressors and whether or not they can be addressed by the project.

Natural channel design projects:

- Analysis of current land use in the watershed to identify any watershed-wide stressors and whether or not they can be addressed by the project.

1.2.3.3 Step 3c: Existing Stream Corridor Conditions

Describing existing stream corridor conditions requires data that encompasses the existing structure and function of the stream corridor and the associated stressors. Comparing the existing conditions to reference conditions (in Step 4) will demonstrate the need for the project and help define the project goals and objectives. The level of effort for this portion of the evaluation will vary and is dependent upon site conditions and the scope of the project.

Existing conditions shall be characterized with a combination of mapping and field investigation. Mapping and field investigations shall extend both upstream and downstream of the project reach, and both stable and unstable areas with the study reach shall be identified and documented. Consideration should be given to describing the present conditions associated with the following stream corridor components:

- Geomorphological characteristics
- Hydrologic and hydraulic processes
- Sediment transport and channel stability
- Aquatic and riparian species and critical habitats

Some measurable attributes that may be useful for describing these components of a stream corridor are shown below in Table 2.

Table 2

Measurable Attributes for Describing Conditions in the Stream Corridor

Geomorphological characteristics	Hydrology and Hydraulics
Stream classification	*Annual and seasonal discharge*
Channel Slope	*Peak flows*
Channel Shape	*Minimum flows*
Entrenchment Ratio	*Flow regime*
Width/Depth Ratio	*Annual flow durations*
Sinuosity	*Rainfall records*
Valley slope and type	*Channel roughness*
Channel materials	*Control points and channel crossings*
Meander Pattern	*Watershed Cover and soil health*
Bank erosion potential	*Sediment delivery rates*
Channel profile & cross-sections	Water Quality
Riffle-pool or step-pool measurements	*Temperature*
Aggradation/Degradation (stability)	*Suspended sediment*
Depositional features	*Nutrients*
	Dissolved Oxygen
	Other pollutants

Sediment Transport and Stability	Species and Habitats
Bedload sediment	*Riparian vegetation – type, composition*
Suspended sediment	*Aquatic species and habitats present*
Dominant erosion processes	*Aquatic vegetation and habitats present*
Channel erosion processes and rates	*Invasive species*
Sediment transport functions	*Canopy cover*
Sediment storage functions	*Unique habitats*

Stream Classification

The Applicant shall provide a classification of the existing conditions of the stream. The Channel Evolution Model, Rosgen and Montgomery-Buffington classification systems are useful in describing the project sites. This classification can assist in developing project alternatives that are appropriate for the condition of the stream, the valley type and the geomorphic setting.

<u>Classification based on stream flow conditions</u>

- *Perennial* streams
- *Intermittent* streams
- *Interrupted* streams
- *Ephemeral* streams

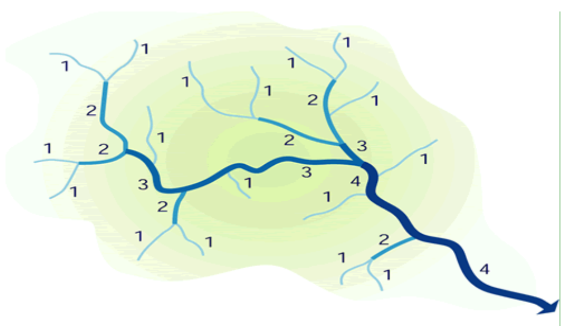


Figure 3. Stream order Courtesy of FISRWG

<u>Classification based on stream order</u> is related to the type and number of tributaries that make up a channel network. A stream's order is its rank, or relative position, within the network.

- *First-order streams* are unbranched channels draining from headwaters;
- *Second-order streams* form when two first-order streams unite;
- *Third-order streams* form when two second-order streams unite, and so on.

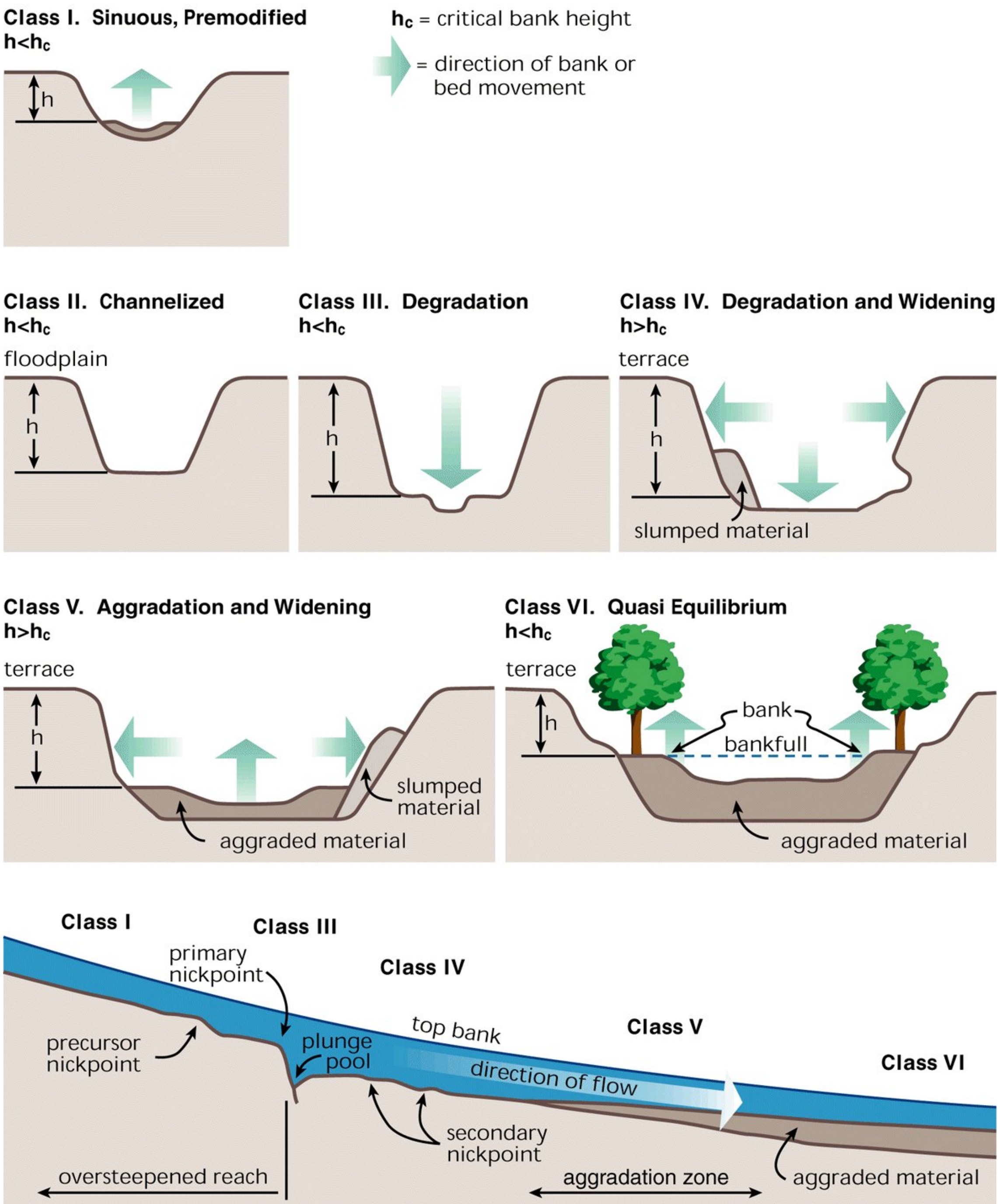
<u>Classification based on stream pattern</u> describes the planform of a channel. The three basic patterns are based on single or multiple thread channels, and the stability of the land between multiple threads.

- *Straight*
- *Meandering*
- *Braided*

<u>Classification based on the Channel Evolution Model</u> describes the channel in terms of the changes that may be expected following a man-made or natural disturbance. The Channel Evolution Model provides a framework for assessing the condition of the stream channel.

Figure 3 contains a schematic of the Channel Evolution Model; the six classes are:

- *Class I:* The waterway is a stable, undisturbed natural channel.
- *Class II:* The channel is disturbed by some drastic change such as forest clearing, urbanization, dam construction, or channel dredging.
- *Class III:* Instability sets in with scouring of the bed, termed channel degradation.
- *Class IV:* Destructive bank erosion and channel widening occur by collapse of bank sections.
- *Class V:* Bed aggradation (stabilizing) - The banks continue to cave into the stream, widening the channel. The stream also begins to aggrade, or fill in, with sediment from eroding channel sections upstream.
- *Class VI:* Stable channel inside new floodplain terraces - Aggradation continues to fill the channel, re-equilibrium occurs, and bank erosion ceases. Riparian vegetation once again becomes established (Simon, 1989)



Source: Simon, 1989; US Army Corps of Engineers, 1990.
Fig. 7.14 -- Channel evolution model..
In Stream Corridor Restoration: Principles, Processes, and Practices, 10/98.
Interagency Stream Restoration Working Group (FISRWG)(15 Federal agencies of the US).

Figure 4. Channel Evolution Model. Figure courtesy of FISRWG.

Geomorphic Assessment

A geomorphic assessment is a critical component of all channel restoration projects, regardless of the scale or objectives of the project. Geomorphic assessment provides a basic morphological description of the channel; maps the nature, severity, and extent of observed problems within the project reach, and helps to understand the processes at work within the channel that are contributing to the observed problems. The data gathered during the geomorphic assessment will be used with other information, including historical channel analysis and watershed analysis to answer three basic questions:

What is causing the observed problems?

Is the observed problem caused by local stressors or system wide stressors?

Answering these questions is critical to developing and ultimately justifying a design solution.

<u>Extent of geomorphic assessment</u>

A geomorphic assessment is typically performed at the reach scale, such that the longitudinal extent of the survey is typically extends for approximately 25-40 channel widths. Major changes in channel form as would be produced by a sudden change in slope or the entrance of a significant tributary can be used to delineate sensible boundaries for the geomorphic assessment. The lateral extent of the geomorphic assessment typically includes the channel and associated floodplain. The extent of the survey should completely encompass the anticipated extent of the project and should extend upstream and downstream far enough to allow the Applicant to understand how conditions at the project site may or not may be similar to the prevailing conditions within the reach. Also, property boundaries should generally not be used to define geomorphic assessment boundaries.

<u>Geomorphic mapping</u>

A geomorphic assessment typically involves descriptive mapping of the channel and floodplain complex associated with the project including:

1. The *cross-section* is a detailed engineering survey of the shape of the channel and the floodplain. Representative cross-sections shall be chosen throughout the reach to measure low-flow, bankfull, and floodprone channel dimensions. The key geomorphic feature to be identified is bankfull depth, which is used in many subsequent calculations to describe the condition of the stream.

   Each cross-section shall provide a detailed view of the channel bottom, toe of bank, top of bank, bankfull elevation, terrace elevations, and floodplain. Secondary channels should be included with an indication of whether they are contributing to flow during bankfull conditions.

   Cross-section data is used to calculate the width to depth ratio at bankfull and the entrenchment ratio, both important classification parameters. Repeated measurement of the cross-section over time allows comparison of changes in the stream's cross-sectional area (aggradation and/or degradation) and movement of bed and bank material.

2. The *longitudinal profile* documents the overall profile of the stream by surveying the stream at each stream feature. The reach should extend through two full meanders. Profile survey points area taken of the thalweg and the water surface at each bed feature along the channel. The longitudinal profile also surveys the bankfull depth and low bank

elevations along the survey reach. Bankfull elevations are only taken at points along the stream where indicators are reliable. Low bank elevations are taken if the low bank is lower than bankfull.

When the profile is plotted, the water surface profile is used to calculate the channel slope, which is needed in many subsequent calculations. The profile of bankfull depth is used in many dimensionless parameters to compare existing conditions to reference conditions. The distance between pools, the lengths of riffles and the depths of pools are all used in natural channel design to evaluate the stability of the stream channel.

3. *Planform features*, most notably sinuosity, are typically measured from recent, high resolution aerial photographs.
4. *Channel materials* are quantified using a pebble count methodology to generate a particle size distribution of the stream bed and bank materials. The average particle size (bedrock, boulder, cobble, gravel, sand, or silt/clay) further aids in the classification of the stream. The Applicant shall provide a substrate analysis to the level of accuracy required by the sediment transport model. Pebble count procedures such as the 100-point Wolman pebble count or the more statistically defensible 400-point grid sample, are acceptable for coarse-grained substrates.

   A thorough description of field techniques can be found in "*Stream Channel Reference Sites: An Illustrated Guide to Field Technique*" (Harrelson, et al, date). Important issues regarding the identification of bankfull indicators are addressed in several references listed in Section 9.7.

This mapping is then used to develop morphological variables and ratios such as:

- Channel bed and water surface slope, the vertical difference in the elevation over the study reach divided by the stream length between the two morphologically similar points; i.e. top of riffle to top of riffle.
- Sinuosity, or the ratio of stream length at the bankfull stage to valley length.
- Meander amplitude and wavelength
- Width to depth ratio defines the shape of the channel
- Entrenchment ratio (or channel incision) is a basic geomorphic principle. Rosgen's definition is empirical that infers the degree of vertical containment of the channel. Entrenchment may be defined as the flood prone width divided by the channel width at bankfull.

The longitudinal profile, cross-sections, and substrate data and plots are to be clearly documented and provided to the Department. Data can be documented and plotted by hand or by computer. Software is available from several sources including RIVERMorph (http://www.Rivermorph.com) and the Ohio Department of Natural Resources, Division of Soil & Water Conservation (http://www.dnr.state.oh.us/soilandwater/streammorphology.htm).

It is important to understand not only the mean values of these variables and ratios, but the variability of values around the mean. Table 3 provides examples of the relationship of the field data to the morphological ratios.

Table 3. Level II Stream Classification Based on Fluvial Geomorphology			
Field Function	**Field Data**	**Data Obtained**	**Significance**
Field survey of stream cross-section	• Channel shape • Floodplain shape • Bankfull depth • Water surface	• Width/Depth ratio • Entrenchment ratio	• Shape of the channel and indicator of channel stability • Degree of vertical containment in the valley
Field survey of longitudinal profile	• Thalweg elevations at each stream feature • Water surface profile • Bankfull depth profile	• Water surface slope • Configuration of step/pools, riffle/pools, cascades.	• Used in hydraulics and sediment transport • Used to compare to reference conditions
Planform features (from maps)	• Valley length or slope • Belt width	• Sinuosity • Meander width ratio	• Describes meander geometry • Indicates energy dissipation
Channel materials (pebble count)	• Pebble size & number	• Average particle size • Particle size distribution	• Indicator of sediment transport, hydraulic resistance, and biologic function

Channel classification

Classification systems generalize field observations and are useful communication tools. Classification systems include characteristics of flow (e.g. perennial or ephemeral), planform (e.g. straight or meandering), boundary (threshold or alluvial) and other physical variables (e.g. slope, sinuosity, channel width). Many of these classification systems focus on stream form (how streams look) rather than process (how streams behave). The applicant should be sure to consider process variables as well as form variables during the existing data collection and design development.

The two most common classification systems were developed by Rosgen (1996) and Montgomery-Buffington (1993). The applicant is referred to USDA-NRCS Stream Restoration Design section of the National Engineering Handbook (2007) for a more thorough discussion of different classification systems.

The summarized morphological variables and ratios to can be used to classify the stream channel using various geomorphic classifications systems such as proposed by Rosgen or Montgomery and Buffington. Geomorphic classification systems are based on the assertion that certain ranges of morphological variables commonly co-ocur and thus form regular and predictable channel types.

The Rosgen classification system, the most commonly used system, divides channels into seven major types (A-G) based on channel slope, shape (width/depth ratio), and degree of confinement (expressed by an entrenchment ratio).

Geomorphic condition assessment

Geomorphic survey is typically accompanied by a geomorphic condition assessment. While the geomorphic survey is primarily descriptive, the condition assessment is diagnostic. The condition assessment typically does involve some mapping of physical features that are either diagnostic of stable streams or unstable or adjusting streams. For instance:

- Bank height, angle, and erosion mapping
- Location of nick points or headcuts
- Presence of multiple or rapidly migrating channels
- Large, recently deposited sediment bars
- Exposed or buried infrastructure

Many of these features are both problems, in that they represent potential physical locations where active channel restoration may be warranted, as well as diagnostic indicator that assist the investigator in better understanding the condition of the channel in terms of its stability.

Many existing protocols can be used to structure the collection of geomorphic condition data including Rosgen's Level III analysis, and Vermont DEC's Rapid Geomorphic Assessment Protocols.

Geomorphic stressor assessment

Stressor assessment involves the mapping of physical features that may be partially or fully responsible for any observed areas where geomorphic conditions are less than ideal or specific problems (e.g. bank erosion) have been observed. Features that are typically mapped during the stressor assessment include:

- Dams and impoundments
- Bridges and culverts
- Stormwater outfalls
- Revetments
- Removed or denuded riparian vegetation
- Accelerated bank erosion (bank erosion can be both a stressor and an indicator of geomorphic condition

The spatial location of observed stressors in relation to observed problems may help the investigator infer suspected cause and effect relationships that will ultimately aid in the selection and justification of design measures.

Other methods

Most common geomorphic assessment methods involve assessment of conditions, stressors, and morphology at a single point in time. However, for certain projects, particularly those potentially involving natural channel design or channel realignment, the use of repeated measures techniques to direct measure geomorphic process rates may be appropriate. These methods include the use of scour chains and bank pins to measure erosion rates and repeated cross-section and longitudinal profile surveys to quantify rates of channel adjustment.

<u>Integrated assessment</u>

Typically, the Geomorphic Survey, Condition Assessment, and Stressor Assessment are conducted simultaneously.

<u>Assessment Requirements for Project Types</u>

All successful channel restoration projects incorporate an understanding of geomorphic processes. Thus, a geomorphic assessment should be performed for any project, even small bank stabilization projects. The spatial extent, complexity, and nature of the assessment should, however, be commensurate with the scale of the problem and the project. Importantly, however, the geomorphic assessment is a critical aspect of understanding the nature and scale of the problem and as a result the applicant's understanding of the problem and potential restoration solutions may evolve considerably during the course of the assessment.

Combined with other aspects of the existing conditions assessment, the geomorphic assessment should allow the Applicant to define the extent, nature, and cause of the observed problem. The most critical aspect of this determination is distinguishing between problems and associated stressors that are local in nature and those that are part of a system-wide set of adjustments to changes in major driving variables n the system (e.g., land use change, dam removal or construction, downstream channelization, etc.). Determining this requires that the reach-scale geomorphic assessment be combined with watershed-scale analysis and historical analysis.

If the applicant is working in an area for which a comprehensive watershed assessment that includes a geomorphic assessment has not been performed, it is advisable to perform a screening level geomorphic survey of the project site and the upstream watershed. This screening level analysis, then, will inform the scope of work for a more detailed geomorphic assessment.

As part of the site evaluation report, the following shall be documented:

All restoration projects:

- Classification based on stream flow conditions
- Classification based on stream order
- Classification based on stream pattern

All bank stabilization projects < 300 feet:

- Classification based on Channel Evolution Model
- Comprehensive geomorphic survey (Level I Rosgen or equivalent)

All bank stabilization projects >300 feet:

- Classification based on Channel Evolution Model

- Comprehensive geomorphic survey (Level II Rosgen or equivalent)

All Natural Channel Design Projects:

- Comprehensive geomorphic survey (Level III Rosgen or equivalent)

Hydrology and Hydraulic Processes

As part of the existing conditions assessment, the applicant shall provide a description of hydrologic and hydraulic conditions within the project area. During the site evaluation phase, the hydrologic and hydraulic analyses are preliminary in nature. Particular attention should be given to determining the extent to which hydrology and hydraulics have been altered by human activity and the extent to which these changes may be contributing to the observed problems.

Stream hydrology quantifies the rate, timing and frequency of water delivered to a particular stream as well as the rate at which it moves through the stream system. An adequate understanding of stream hydrology is important both in characterizing the existing conditions and selecting potential channel restoration measures. Hydrologic data include rates of precipitation and patterns of stream flow (frequency and duration).

Hydraulics are the set of laws that govern the movement of water and the forces generated by that movement. With respect to channel restoration, hydraulic processes govern the flow of water in the channel and ultimately the ability of moving water to erode, transport and deposit sediment throughout the system. During the stream classification phase, the applicant will collect data that will be valuable in the hydrologic and hydraulic analyses required in the design phase.

Precipitation data are readily available for most areas. Stream flow data may be obtained from the United States Geological Survey (USGS); many streams throughout the state are gaged. Gage data should be used to verify bankfull discharge wherever possible. If gage data is not available, the Applicant should attempt to identify a gage on a hydrologically similar stream. There are also several other methods to estimate stream flow, including Manning's equation, hydraulic models and regional curves.

The Department encourages the use of models prepared by others in the evaluation phase of project planning. Municipal, county, federal and private sources may have previously prepared hydrologic and hydraulic models that can assist in defining the scope of the project and keep planning and design costs down. Hydrologic models may assist in the identification of bankfull depth.

As part of the site evaluation report, the following shall be documented:

All projects:

- Watershed delineation of the contributing drainage area to the downstream limits of the project site on a topographic map at a scale of 1:24000 or less.

Riparian buffer projects:

- Base flow and bankfull flow information to assist in planning the lowest extent of perennial vegetation.
- Location of secondary flow channels and other areas where planting may be avoided.

May be documented on a plan view or sketch.

- Note concentrated flow channels through the buffer area. Observe overall stability and determine whether or not treatment is required to repair or prevent erosion.

In-stream habitat enhancement projects:

- Cross-section, slope, flow velocity, depth, and/or resistance data if planned structures require a stability analysis such as cover stones or boulder clusters.
- Low flow and base flow water surface elevations to assist in planning location and extent of devices.

Bank stabilization projects:

- Hydrology and hydraulic analyses will be conducted during the final design phase. Certain features can be taken into consideration during the site evaluation phase.
- Cross-section, slope and resistance data to be used in design calculations.
- Preliminary analysis of stream gage data.

Natural channel design projects:

- Preliminary analysis of stream gage data.
- For projects with a stream gage in close proximity to the project site, the longitudinal profile should extend through the gage and be calibrated to bankfull indicators.
- For projects with a stream gage within the watershed, separate longitudinal profile and cross-section at the gage location may be useful in identifying bankfull depth at the project site.
- For projects where no stream gage data is available within the project watershed, gage data of a reference reach or from a hydraulically similar stream may be useful.

Sediment Transport and Channel Stability

At the site evaluation phase, sediment transport analyses are preliminary in nature.   Field investigations shall determine which method of sediment transport analysis will be applicable in the final design phase. For instance, a sand bed channel will be analyzed differently from a gravel bed channel. The site evaluation phase may also be the opportunity to collect the field data required for final design and analysis.

Sediment transport analysis is most critical for natural channel design projects. For site evaluation purposes, the Level III classification analysis is sufficient. The Applicant is encouraged, however, to be fully aware of sediment transport issues whenever working in the stream at any level.

Biologic Conditions

The applicant shall collect information on the project site’s physical habitat, plants and animals during the site evaluation phase. The analysis of habitats and species present will vary in scale depending on the complexity of the project and the planned activities.

The biological condition of the stream can be measured by looking at particular species present or by looking at indicators. If the project is designed to target a particular species, information on that species' life cycle requirements, distribution and current population will be required. For other projects, species such as aquatic macroinvertebrates may be used as indicators of stream channel condition. Macroinvertebrate species present and diversity can provide a great deal of information regarding the condition of the stream and the stressors impacting the stream.

An assessment of the habitat present for a particular species may be performed rather than looking at the species or diversity present. For example, if the project goal is to increase fish habitat, then measuring the existing habitat will be useful. Certain fish species reproduce on clean sands and gravels in the glide section of a riffle-pool stream. Therefore, an project to re-establish riffles and pools in a reach will provide the necessary habitat. Similarly, if a project goal is to increase riparian habitat for birds and amphibians, an evaluation of the current habitat that is present will be useful.

The USEPA's Rapid Bioassessment Protocol contains procedures for measuring several biological indicators, including habitat, fish and macroinvertebrates. The Department's Landscape Project and Natural Heritage Program can provide information on habitat and species that may be present at the project site.

As part of the site evaluation report, the following shall be documented:

All restoration projects:

- Plan view, aerial photo or site sketch showing location and extent of riparian vegetation. Scale to be 1:1200 or less. All specimen trees and vegetation that is to be protected shall be clearly indicated.
- A description of threatened and endangered species as contained in the Department's Natural Heritage Database and the Landscape Project.

Riparian buffer projects that are part of a regulated restoration project, bank stabilization projects (greater than 300 feet) and natural channel design projects:

- Inventory of native tree, shrub, and grass species in the project area or immediately upstream or downstream.
- Inventory of invasive tree, shrub, and other perennial vegetation in the project area or immediately upstream or downstream.

In-stream habitat enhancement projects:

- An analysis of biological conditions shall be conducted.

Bank stabilization projects (< 300 feet):

- A description of the soil types within the project area to be graded or planted and any features that will restrict planned excavations, foundations, or planting practices.
- A description of the moisture regime of all areas to be planted.

1.2.3.4 Step 3d. Identify Causes of Channel Instability or Ecological Degradation

Before identifying potential channel restoration measures, the Applicant must identify the stressors that are causing the need for channel restoration. A thorough analysis of the cause(s) of these alterations or impairments is fundamental to identifying management opportunities and constraints and to defining realistic and attainable restoration goals and objectives.

Some of the potential causes of channel instability and ecological degradation include:

- Increased discharge resulting from watershed changes;
- Increased flow velocities caused by reduction in channel roughness or increased gradients;
- Removal or loss of bank vegetation;
- Accelerated velocity around obstacles or constrictions, such as debris or fallen trees;
- Excessive velocities due to channel modifications;
- Catastrophic flooding;
- Wave or wake action.

Channel instability can occur as a result of system-wide (e.g., land use change, etc.) or local (e.g., removal of riparian vegetation, undersized bridge or culvert) stressors. The system's response to stressors includes changes in the movement of water and sediment, channel aggradation or degradation and changes in the rate of erosion or deposition.

The Applicant shall demonstrate how existing local and /or system-wide stressors have caused the channel instability or ecological degradation. and identify whether the stressors are local, system-wide or both. This analysis shall be performed within a fluvial geomorphic context; that is, the discussion of bank erosion shall be conducted within the overall context of the stream's form and behavior.

If the channel instability is occurring because of a localized stressor, the Applicant is encouraged to directly remediate/eliminate the stressor as part of the stabilization project. The locations and types of existing stressors, both in the upstream and downstream direction shall be documented as required in N.J.A.C. 7:13-11.14 b(1)..

Excessive erosion is also commonly associated with channels that are actively adjusting in response to large-scale channel disturbances or land use changes. These system-wide stressors shall be identified as part of the existing conditions analysis in N.J.A.C. 7:13-11.14 b(1) and shall be further discussed in N.J.A.C. 7:13-11.14 b(2) in terms of the selection of restoration techniques.

1.2.4 Step 4: The Reference Condition

The fourth step in the watershed assessment and restoration evaluation is to define the reference conditions for the project site. Reference sites should be identified and characterized early in the planning and design process for more complex projects. The use of reference sites is important to the development of a channel restoration project for several reasons:

- To provide a model for developing restoration actions;
- To provide target standards for performance criteria and evaluation; and

- To provide a control against which to assess natural changes.

By comparing the existing conditions of the project site to the reference characteristics, the Applicant can define the departure from the reference condition and develop the restoration project to bring the project site to the reference condition. By documenting the channel pattern and profile at reference sites, the Applicant can determine what appropriate dimensions for the project site should be. Restoration efforts can be targeted to physical features in the stream or floodplain.

Reference site characteristics may be developed based on predisturbed channel conditions, if sufficient historical data is available. This method is appropriate if hydrology and bed materials are very similar to historic conditions. The watershed must also be carefully analyzed for any significant changes that could affect the hydrology of the stream. Caution is advised when using predisturbed conditions, as those conditions may not be appropriate for the existing watershed conditions.

Reference sites are typically stable (in equilibrium) stream reaches within the same watershed, or non-impacted reaches. For natural channel design projects, the reference reach may be used as a template for the geometry of the restored channel. The width, depth, slope and planform characteristics of the reference reach are transferred to the design reach. Analytical and empirical techniques are used to scale dimensionless ratios to fit the different characteristics of the project reach, such as drainage area. However, the Department acknowledges that it is difficult to identify such reaches in many areas of New Jersey. For that reason, the use of reference sites in other watersheds with similar properties (e.g. similar physiographic settings, geologic setting) is permitted.

The selection of reference reaches shall be based on a screening of reference reaches during which the Applicant identifies through desktop and field reconnaissance several potential reference reach candidate sites that are similar to the restoration area (or the expected final condition) with respect to bank vegetation, watershed size, land use, lithology, and valley form. A rapid geomorphic survey or field-based channel stability analysis (e.g., Pfankuch Stability Analysis, Vermont Phase II Rapid Geomorphic Survey, etc.) should be performed on reference reach sites before confirming their use in a restoration design.

Alternatively, channel planform can be determined using hydraulic geometry techniques (e.g. Leopold and Wolman, 1975; Thorne and Abt, 1993; Cherry, Wilcock and Wolman, 1996). When uncertain about the appropriate technique, many practitioners use both analogy and hydraulic geometry and look for points of convergence in the recommendations. The desired planform may be limited by riparian features, infrastructure, land use or other restrictions. These factors may preclude the use of meanders with the amplitudes suggested from the described analogy or hydraulic geometry methods.

A reference reach may also be used to described desired biological conditions. For example, a primary concern at a particular project site may be to conserve a particular species. If the species has been documented at another site, the features of that site can be used to design the physical features of the project reach. The most common use of biological and ecological reference conditions is when a disturbed channel is compared to a nearby less impacted watershed to indicate what type of aquatic and riparian community might be possible in the project reach.

1.3 Project Development

Project Development

- Step 5. Develop project goals and objectives.
- Step 6. Develop conceptual design and alternatives for channel restoration activities.
- Step 7. Develop restoration design data.
- Step 8. Develop restoration project design.

N.J.A.C. 7:13-11.14 b(2) requires that the Applicant provide a justification of the proposed restoration project. This justification shall reference the site evaluation required in N.J.A.C. 7:13-11.14 b(1) and shall be framed within explicitly stated goals and objectives for the project. Further, it is recommended that the justification be provided in the form of an alternatives analysis that follows the design decision framework specified in N.J.A.C. 7:13-11.14 c(1)-c(5).

The Department has outlined a design decision framework for evaluating channel restoration options. This framework is described in N.J.A.C. 7:13-11.14(c) and discussed in this manual. The purpose of the design decision framework is to ensure that the Applicant first considers and subsequently rejects simpler, less invasive restoration methods before considering more complex and invasive methods. Bank stabilization (as opposed to more extensive channel modifications) are generally the first approaches that could be considered by the Applicant. Grading and planting shall first be considered as specified in N.J.A.C. 7:13-11.14 c(2). If grading and planting is insufficient, soil bioengineering can be considered. If soil bioengineering is also insufficient, several other options, including structural bank stabilization and natural channel design can be considered. The following sections provide guidance on the application of the design decision framework.

Tidal streams

Due to the two-directional flow of water and sediment and the diurnal stage changes associated with tidal cycles, channel restoration methods in tidally-influenced channels differ substantially from those appropriate for non-tidal systems. The methods and design guidance presented in this manual are generally applicable to non-tidal systems and applicants should use extreme caution when applying these methods to tidal channel restoration. The following guidance is intended to raise key issues associated with designing channel restoration measures in tidal systems, but is not intended to provide detailed design guidance. Applicants proposing natural channel design projects in tidal systems should meet with the Department to discuss and determine appropriate design methodology on a case-by-case basis.

Applicants proposing channel restoration projects in tidally-influenced streams should account for the influence of tidal exchange and diurnal stage fluctuation in their designs. For instance, bank stabilization project treatments should extend vertically from low flow, low tide elevation to high flow, high tide elevation. Due to the variation in water stage, the use of bioengineering treatments between low and high tide elevation must be used with extreme caution. When sizing bank treatments, tractive force associated with both high flows and tidal exchange should be computed. Where applicable, the influence of wave action and run-up should also be accounted for in sizing and specifying bank treatments. Applicants are advised that scour depths may be deep in sand-bedded tidal channels and bank toe treatments should extend below the anticipated scour depth.

Also, due to the two-directional flow of water and sediment in tidal channels, methodology and modeling techniques developed for uni-directional water flow and sediment transport in non-tidal systems may not be appropriate for designing channel geometry for natural channel designs in tidal systems.

1.3.1 Step 5. Develop Project Goals and Objectives

Project goals express the overall desired outcome of the project, or provide a clear statement of the project targets. The project objectives are the desired physical, hydrological, chemical or biological environmental changes from the project. They are more detailed, focused outcomes that achieve the project goals, and must be quantifiable.

Specific goals and objectives for the project shall be developed and included in the permit application package. The proposed channel restoration methods shall be justified in terms of the project goals and objectives. Table 4 contains example goals and objectives.

Table 4.

Example Goals and Objectives

Example Goals	Example Objective
• Improve channel dimension, pattern, profile. • Reconstruct natural channel geometry scaled to current bankfull flows. • Allow stream channel ability to migrate within the restored floodplain.	• Modify stream to a X channel type. • Establish a channel slope of X%. • Establish a bankfull width of X. • Establish a width/depth ratio of X. • Establish an entrenchment ratio of X. • Establish a sinuosity of X. • Establish a meander width of X, belt width of X. • Create a specified hydrologic condition.
• Protect bank from erosion. • Increase stream stability by reducing stream power at erodible surfaces. • Increase stream stability by protecting erodible surfaces, e.g. with bioengineering.	• Protect X linear feet of bank. • Install X practices to protect the bank and channel.
• Improve riparian habitat. • Establish a native riparian plant community. • Control invasive plants. • Increase biological diversity.	• Plant X feet/acres of riparian zone. • Increase species diversity by X species. • Reduce cover by invasive species by X%.
• Improve aquatic habitat. • Restore fish passage.	• Increase fish habitat (e.g. rearing, cover, spawning) by X percent.

	• Increase macroinvertebrate habitat by X%. • Establish a pool/riffle spacing of X, based on reference site data. • Increase large woody debris by X.
• Improve water quality.	• Specific water quality targets, such as: • Decrease water temperature by X; or • Increase dissolved oxygen concentrations by X.
Note: Targets specified in the objectives may be ranges based on stream classification and reference conditions. For example: Establish a sinuosity of 1.0 – 1.2.	

1.3.2 Steps 6, 7 and 8. Develop Conceptual and Final Restoration Site Design and Supporting Design Data

In this section, the project moves from the assessment phase (figuring out what's wrong and what's causing it) to the design phase (developing a solution to the problem). In this phase, the Applicant will be called upon to provide a compelling justification for the design approach chosen. Importantly, this justification shall relate specifically back to the findings of the existing conditions assessment performed in Step 3. Regardless of the ultimate scope of the project and the approach chosen, the Applicant's ability to demonstrate that the design approach reflects an understanding of the root causes of the observed problems is critical. As a result, much of the assessment data that was collected in Step 3 (Existing Conditions) and Step 4 (Reference Condition) will also be used to select a design approach and to develop the specific parameters of the design approach. In most cases, however, the Applicant will need to collect additional site data during this phase to:

1. Justify the use of a particular design strategy, and
2. To size and specify particular design elements.

Whereas the data collected during Step 3 is primarily *diagnostic* (this is, it helps understand the nature and causes of a problem), the data required in Steps 6, 7, and 8 will assist the Applicant in deciding among the available design options and ultimately to develop a design from an initial concept to a set of detailed design drawings and specifications.

The formal selection and justification of channel restoration activities is required by N.J.A.C. 7:13-11.14 b(2). N.J.A.C. 7:13-11.14 c(1)-c(5) set forth a decision framework. In following this framework, the Applicant must first consider simpler methods, before deciding to employ more complex solutions. Per this framework, Applicants shall consider design approaches in the following order:

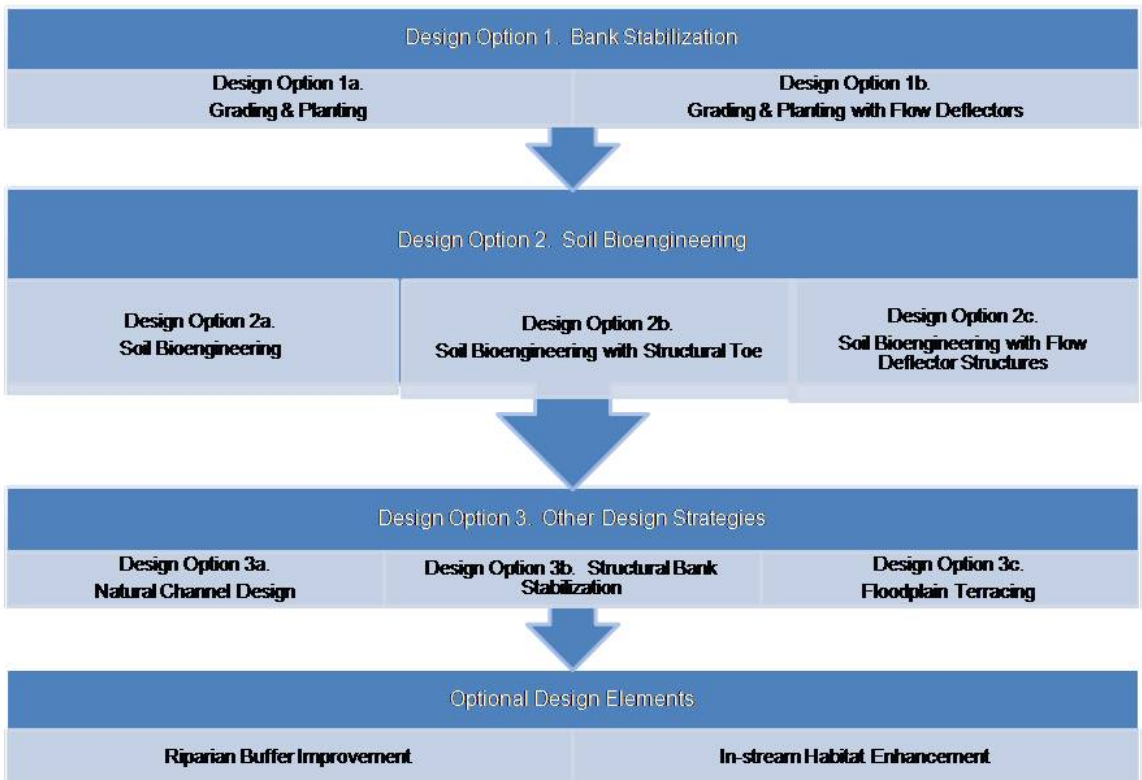


Figure 4. Design Decision Framework

The following sections of the technical manual guide the Applicant through the selection of channel restoration techniques and provide recommendations concerning data collection and design methodologies applicable to various techniques.

1.3.3 Design Guidelines for Bank Stabilization and Soil Bioengineering (Design Options 1 and 2)

The Department requires an Applicant to consider grading the bank and planting vegetation suitable for bank stabilization first in the hierarchy of channel restoration options (Design Option 1). The cause of the erosion shall be specifically attributed to a particular disturbance factor. In addition, the stream corridor itself should be relatively stable in planform and profile and neither aggrading or degrading. If regrading the bank and planting suitable vegetation cannot adequately meet the project goals, soil bioengineering techniques (Design Option 2)may be proposed.

The Applicant shall demonstrate the need for the proposed bank stabilization in terms of the project goals and objectives. The Applicant is reminded that streambank erosion is a naturally-occurring process that does not always require corrective action. Rapid erosion rates are commonly observed in natural river channels with tortuously meandering channels and low gradients. The need for bank stabilization can be justified if anthropogenic stressors have produced erosion that is in excess of what is expected in a natural, undisturbed system or if the proposed bank stabilization is required to protect life or property.

Bank stabilization projects should start and stop along stable points in the stream corridor. Disturbance of relatively stable sections should be avoided, and only those areas with documented erosion problems treated. Effects to adjacent properties must be considered.

1.3.3.1 Project Justification

If excessive erosion rates are used to justify the need for the project, the Applicant shall identify the causes of the excessive erosion as part of the project justification. See Section XX for further discussion. The Applicant shall demonstrate how existing local and /or system-wide stressors have caused the excessive erosion problem and shall identify whether the stressors are local, system-wide or both. This analysis shall be performed within a fluvial geomorphic context; that is, the discussion of bank erosion shall be conducted within the overall context of the stream's form and behavior. The Department strongly discourages bank stabilization project designs that are not clearly based on an explicit understanding and analysis of the fluvial processes within the project area.

To address N.J.A.C. 7:13-11.14 b(2), the Applicant shall discuss how the proposed approach specifically accounts for and remediates the existing stressors. If the proposed work does not remove or otherwise remediate the existing stressors, the application shall provide justification for why such an approach is not feasible and why the proposed stabilization measures will be sufficient to protect the bank from excessive erosion despite the persistence of the observed stressors. For example, if the erosion problem is occurring as a result of accelerated flow from a culvert, the Applicant is encouraged to implement practices (e.g., energy dissipation structures, etc.) to mitigate the flow in addition to the proposed bank stabilization measures.

Excessive erosion is also commonly associated with channels that are actively adjusting in response to large scale channel disturbances or land use changes. These system-wide stressors shall be identified as part of the existing conditions analysis in N.J.A.C. 7:13-11.14 b(1) and shall be further discussed in N.J.A.C. 7:13-11.14 b(2) in terms of the selection of restoration techniques. Generally, the presence of any of factors that indicate instability should cause the Applicant to specifically consider the role of the channel adjustment processes in the observed bank erosion problem.

Bank stabilization projects constructed to prevent damage to infrastructure are frequently necessary despite the presence of channel instability. However, bank stabilization projects proposed for sediment reduction or ecological benefits are generally not recommended in actively adjusting channels. If active channel adjustment has been documented, the Department will look for specific evidence that the proposed design has accounted for the ultimate endpoint of the adjustment process. For instance, if the channel is incising, the

Applicant should install footers for any structures that will be sufficiently deep to resist undermining due to the lowering of the channel bed over time.

1.3.3.2 Design Option 1a – Bank Stabilization using Grading and Planting

The Applicant shall consider grading and planting the bank as a first option for channel restoration as specified in N.J.A.C. 7:13-11.14 c(2). Grading and planting a bank may be a suitable technique for addressing mild to moderate streambank erosion problems where geomorphic channel instability is not present, and where expected shear stress and velocity are low.

Grading and planting may not be suitable for a variety of reasons. For instance, the presence of infrastructure, buildings, or bedrock may inhibit grading operations. Environmental conditions, including poor soil quality, extreme shading, or high stream velocities or shear stress may create conditions in which vegetative cover will be difficult to establish or will be insufficient to protect the bank against expected shear stress and/or velocity. The presence of a geotechnically unstable bank may also preclude the use of grading and planting. If a geotechnically unstable bank is suspected, a stability analysis shall be conducted by a geotechnical engineer and shall be included as part of the project justification provided in N.J.A.C. 7:13-11.14 b(2). Construction access or the presence of wetlands may also restrict grading operations. In this case, the Applicant shall provide a detailed justification including mapping, photographs, and narrative elements, of the full range of construction access options that were considered to be unsuitable.

Soil amendments, proper plant selection, and extended-life erosion blankets may be effective strategies for stabilizing eroding banks using grading and planting.

If sensitive wetland or riparian habitats will be impacted by grading operations, mapping of these areas and the approximately limits of grading shall be provided. The environmental disturbance required to stockpile and remove soil material may also provide justification for using more intensive stabilization methods that reduce the net cut associated with the project. In this case, the Department will look for specific evidence (e.g., cut/fill volumes, evidence that the Applicant has exhausted soil disposal options proximate to the project site) to document the excessive hardship associated with material disposal.

1.3.3.3 Design Option 1b – Bank Stabilization using Grading and Planting with Flow Deflector Structures

If shear stress or stream velocity is a primary concern, the Applicant shall consider the use of flow deflector structures as a possible means for reducing near bank hydraulic stress before considering more structural bank stabilization measures. Flow deflectors refer to rock or wood devices installed in a stream channel for the purpose of altering the trajectory of streamflow. These and other techniques shall be fully considered prior to considering soil bioengineering options.

1.3.3.4 Design Option 2a –Soil Bioengineering

If the project goals and objectives or existing conditions are not suitable for grading and planting, the Applicant shall provide documentation, including (where applicable) supporting literature, case studies, environmental testing data and/or calculations, demonstrating why the conditions are not suitable and shall next consider a soil bioengineering solution (N.J.A.C. 7:13-11.14 c(3)). Soil bioengineering encompasses a wide variety of techniques including vegetated geogrids, root wads, live stakes, live fascines, brush mattressing, willow posts, tree revetments, and brush layering. Soil bioengineering techniques are discussed in detail in Chapter 16 of the NRCS Field Engineering Handbook and in Gray and Sotir (1996).

The Applicant shall discuss how the selection of bioengineering techniques relates to and accommodates existing site conditions including soil moisture and texture; light availability expected shear stress and velocity; and bank height, slope and stratigraphy.

1.3.3.5 Design Option 2b – Soil Bioengineering With Structural Toe

Soil bioengineering approaches may require the use of stone or natural boulder placements to provide resistance at the bank toe. If a stone or boulder footer is proposed, a scour depth calculation shall be provided demonstrating that the proposed footer depths will exceed the anticipated scour depths at the design discharge. Although most bioengineering treatments require bank grading at a 2(H):1(V) profile to produce a suitably flat surface for planting, certain techniques, including vegetative geogrids, allow the reconstruction of a steep bank profile where extensive grading is not possible. Use of a “self-launching” toe treatment may also be considered.

1.3.3.6 Design Option 2c – Soil Bioengineering with Flow Deflector Structures

Flow deflectors refer to rock or wood devices installed in a stream channel for the purpose of altering the trajectory of streamflow. Flow deflector structures are often used in conjunction with soil bioengineering projects and to increase the ecological benefit of the project and may help to reduce sheer stress in the near bank region. If hydraulic modeling suggests that soil bioengineering treatments may not withstand hydraulic forces at the design discharge, the applicant is advised to first consider the use of flow deflector structures as a means to reduce the hydraulic stress along the bank before rejecting a soil bioengineering approach in favor of a more structural approach.

Flow deflector structures should generally not be placed into high gradient streams (bed slope > 3%) and should be suitably keyed to the bank and channel bed to prevent undermining or flanking. If flow deflectors are small structures (e.g., single-wing, double-wing deflectors) designed primarily for the purposes of enhancing low flow habitat, Applicants need not submit detailed design calculations. If more substantive measures are proposed (e.g., rock vanes, bendway weirs, or stream barbs), the Applicant shall provide applicable supporting design calculations. A scour depth analysis shall be provided to justify the footer depths. If rock structures are used (e.g., rock vanes), the Applicant shall provide quantitative evidence that the proposed rock will resist motion at the design discharge.

1.3.3.7 Hydraulic Design Considerations

Bank stabilization project designs shall explicitly identify a proposed design-life and shall provide a quantitative demonstration of stability over the course of the design life. All proposed bank stabilization projects shall identify a design storm event and associated design discharge and shall provide quantitative computations of maximum channel shear stress and expected velocity within the project area at the design discharge. The applicant should further demonstrate that the proposed treatments can withstand the expected velocity and shear-stress associated with the design discharge.

For most projects, the recommended design-life and corresponding design discharge is the 100-year recurrence interval. However, the applicant is urged to select and justify a design discharge that is appropriate for a specific project. If the 100-year recurrence interval discharge is used for those projects for which a detailed flood study exists, the design discharge can be obtained from the flood study. For small projects (<300 ft. of bank), the design discharge can also be determined using a regional regression analysis. For larger projects, the Applicant shall determine the design discharge using accepted hydrologic modeling (e.g., TR-55, TR20). The rational method may be used for small, homogenous drainage areas, but is generally not recommended for larger, heterogeneous areas. Applicants should refer to "Hydraulic Design of Channel Restoration Projects" (U.S. Army Corps of Engineers,2001) and other references listed in this manual for a more complete discussion of appropriate hydraulic design procedures.

If the proposed bank stabilization area is small (<300 ft.) and the corresponding channel section is relatively short and uniform, shear stress and velocity calculations can be performed at a single cross-section using a uniform flow resistance equation (e.g., Manning's equation). If the project occurs in a channel bend, the uniform flow computation should be performed at a nearby cross-section that meets uniform flow assumptions and a correction should be applied to account for the bend shear stress. Generally maximum shear stress calculations should be performed in which the maximum channel depth (not the mean channel depth) at the design discharge should be used in the computation. If energy dissipation devices or flow deflector structures are proposed, the Applicant shall provide a qualitative analysis referencing appropriate cases studies or literature of the effects of these measures on expected shear stress and velocity.

For large projects (>300 linear feet of stream channel) or those with rapidly changing conditions, shear stress and velocity calculations shall be performed for a minimum of one cross-section every 300 feet and/or at each substantial channel change. For such cases, the use of a 1-dimensional gradually-varied, steady-state flow analysis (e.g. HEC-RAS) is recommended. Corrections for shear stress around meander bends (e.g., FHA HEC-15) should also be performed as HEC-RAS does not explicitly account for these effects. If energy dissipation devices or flow deflector structures are proposed, the Applicant shall provide a quantitative analysis of the effects of these measures on expected shear stress and velocity.

1.3.3.8 Species and Habitat Considerations

As discussed in the site evaluation section, the applicant shall provide a description of the habitats present and the species that will be affected by the project. The applicant shall provide justification for any disturbance caused to riparian vegetation. The design should include discussion of factors such as the depth to seasonal high water table, depth to bedrock, and the moisture regime at the site.

1.3.3.9 General Considerations

Proposed bank stabilization projects should be tied in to stable upstream and downstream bank areas. Plantings shall consist of exclusively of native vegetation.

Applicants proposing bank stabilization projects shall prepare and submit a maintenance and monitoring plan that provides a means for evaluating a successful project outcome (in terms of explicitly stated project goals and objectives) and that provides a plan for both routine maintenance and inspection as well as addressing emergency repairs. Funding sources, schedules, and responsible parties shall be identified in the plan.

1.3.4 Design Guidelines for Other Restoration Alternatives (Design Option 3)

1.3.4.1 Project Justification

If grading and planting or soil bioengineering approaches are insufficient to meet the project's goals and objectives and existing conditions, other design alternatives may be considered. These methods include natural channel design, structural bank stabilization and floodplain terracing.

The Applicant shall provide field assessment data, regional curve analysis, historical photograph interpretation, or other substantial evidence to suggest that the stream channel is geomorphically unstable or has otherwise been significantly altered from its probable natural state. If the Applicant is proposing to realign or move an existing natural channel to accommodate, for instance, an infrastructure project, the Applicant shall justify the proposed channel modification by first considering and subsequently rejecting other design alternatives that would not require the modification of the existing channel.

If geomorphic instability is being used as the primary justification for the project, the Applicant shall provide a detailed and quantitative analysis of the local and system-wide stressors that have resulted in the observed unstable channel form. This information may be adapted from the existing conditions analysis required in N.J.A.C. 7:13-11.14 b(1), but should be presented here in the context of the justification for the proposed design approach. This analysis shall employ conceptual frameworks such as channel evolution models (CEMs) or stream classification; particularly if the channel response is the result of an indirect stressor (e.g., land use change, upstream impoundments etc.) and shall be based on a detailed field survey of reach level geomorphology (dimension, planform, profile, and channel materials) as well as an analysis of the context or setting of the project site within the fluvial network.

1.3.4.2 Natural Channel Design

Projects that propose significant changes to the planform, dimension, or profile of a perennial stream channel that mimic the form and/or processes of natural river channels are termed natural channel design projects and are specifically authorized under N.J.A.C. 7:13-11.14 c(5). Natural channel design projects will be permitted by the Department under an individual permit if regrading and soil bioengineering cannot mitigate the channel instability or ecological degradation.

To justify a natural channel design approach, the Applicant shall provide field assessment data, regional curve analysis, historical photograph interpretation, or other substantial evidence to suggest that the stream channel is geomorphically unstable or has otherwise been significantly altered from its probable natural state.

In providing justification for the natural channel design project, the Applicant should juxtapose the expected and measurable environmental benefits of the proposed natural channel design project against the short and long-term environmental impacts of the proposed work. For instance, the restoration of incised river channels often involves the lowering of the floodplain surface, a process that can result in the removal of significant number of mature canopy trees. If such an approach is proposed, the Applicant should address why the channel bottom cannot be raised in order to reconnect the channel to the floodplain, how removal of vegetation meets the boundary conditions of a stable reach, and how the proposed environmental benefit would offset the loss of riparian cover. The Applicant should also provide an aggressive plan to redress the loss of trees in the riparian zone.

Natural channel design incorporates a combined empirical/analytical/analog design approach to restoration. The Department encourages the use of regional curves and reference reach data to generate initial design parameters. However, regional curve analysis, regime equations, or hydraulic geometry data should not be used as the sole basis for establishing initial design parameters. The Applicant is advised that bankfull hydraulic geometry can vary significantly according to a number of factors including precipitation patterns and bedrock geology. Therefore, if regional curve data or hydraulic geometry relationships are used, the Applicant should provide copies of the original report or study from which the relationships were taken and should specifically comment on the applicability of the referenced curves to the proposed project site in terms of physiography, lithology, land use, rainfall and boundary conditions. Applicants are advised to use regional curves that incorporate urban land use as a specific term in the prediction equation as these curves may predict widened, incised non-equilibrium channels that are still adjusting to land use changes; equilibrium channels may be significantly smaller. Also, planform geometry in particular has been shown to vary widely from curve predictions. Applicants are encouraged to use reference reach data and/or historical planform analysis to develop initial planform geometry and to accordingly limit the use of empirical relationships as the sole or primary basis for the development of meander geometry.

Natural channel design projects should consider the location of channel control structures (e.g. dams, culverts), tributary locations, changes in channel evolution type and other significant hydrologic or geomorphic features. The project design shall take into consideration headcuts that could migrate through the treated reach. Subsurface borings should be collected with sufficient depth, frequency and aerial extent to properly characterize subsurface conditions within the project area. Boring logs and a corresponding location map shall be submitted with the permit application. Further, the Applicant shall provide design details and construction specifications for the proposed channel substrate. If existing substrate is to be used to line the proposed channel substrate, evidence documenting that the existing substrate at the proposed channel depths is of sufficient composition and caliber to line the proposed channel shall be provided.

1.3.4.3 Floodplain Terracing

Floodplain terracing is considered to be a specialized type of natural channel design. Where floodplain grading is proposed, the floodplain should be sized to convey the 100-year recurrence interval flow. Applicants are advised that natural channel design projects are subject to the net fill provisions of the Flood Hazard Area rules. Also, as indicated in N.J.A.C. 7:14 c(6), if nuisance flooding is a problem, terracing of the floodplain should be used as a technique to increase flood storage (as opposed to increasing the conveyance of the main channel). Floodplain terracing is considered a natural channel design project. Thus, if floodplain terracing is proposed, Applicants should size the main channel and floodplain areas according to methods recommended in Section 3.6.2.3..

1.3.4.4 Other Design Elements

Design of bank stabilization treatments and in-stream structures (e.g., root wads, cross-vanes, Newbury rock riffles, J-hooks, bendway weirs, etc.) associated with natural channel design projects shall follow the guidelines given for bank stabilization projects. Where possible, structural practices including boulder toe, shall be restricted to outer meander bends and areas immediately upstream and downstream of critical infrastructure (e.g., bridges, culverts, outfalls, etc.) The design of bridge replacements, culvert replacements, outfall modifications and other related project elements associated with natural channel design projects are not covered in this section. See Section 1.1 for a discussion of the sections of the Flood Hazard Area rules that cover these items. Floodplain revegetation shall conform to the guidance for riparian zone projects contained in this manual.

1.3.4.1 Structural Bank Stabilization

Structural bank stabilization includes techniques such as rock rip-rap, gabion baskets, bulkheading and imbricated stone walls. Structural methods can be justified if damage to life or property cannot be prevented using grading and planting or soil bioengineering. Generally, structural stabilization is strongly discouraged where life or property is not a primary concern (e.g., ecological restoration projects). If structural bank stabilization measures are proposed (e.g., bulk heading) the Applicant shall provide scour depth and stability calculations. Stability calculations are not required for boulder or rip rap toe stabilization treatments or for walls <4 ft. in height. If bank rip-rap or gabions are proposed, standard design methodology (e.g., FHA HEC-11) shall be provided.

1.3.4.2 General Considerations

Hydraulic Design Considerations

As with bank stabilization projects, designers of natural channel design projects shall define a design storm and associated design discharge. For alluvial (mobile bed) channels, the most common design flow will be bankfull discharge, which commonly has a recurrence interval of 1.3 – 1.5 years. Bankfull discharge in urban streams, however, may correspond to a 1.1 year return period or less. The recurrence interval should be similar to a reference reach in the physiographic region, or a gauged stream in the area. The adjacent floodplain should be designed to convey larger flows. Generally, the designed channel should not be sized to carry larger recurrence interval flows. In such cases, the designer should specify that an alluvial design will be used for which the larger particles in the streambed will be assumed to be at the threshold of motion at the design discharge. The Applicant is advised, however, that steeply sloping channels that assume a cascade or threshold morphology may be principally formed and reformed by design discharges that are of significantly higher recurrence interval than those commonly associated with bankfull discharge. Typical bankfull indicators may be extremely difficult to identify or absent in channels with step pool or cascade-like bed morphology. Bankfull discharge is nearly impossible to identify in gullied stream channels in which case, use of regional curves or reference reach data may be the only alternatives. In such cases, the Applicant shall provide an alternative method of determining an appropriate design discharge such as a flood frequency analysis, modeled discharge, or effective discharge computation. For conditions where the upstream sediment load is unlikely to provide the amount and caliber of material required to replace transported material, the Applicant is advised to consider a design methodology for which the channel bed is fixed at bankfull discharge (so called threshold or fixed bed design). The Applicant is referred to Shields et al. (2003) for a more complete discussion of fixed and mobile bed designs.

Field Assessment of Bankfull Discharge

Field assessment methods predicated on field identification of bankfull as a surrogate for the channel-forming, dominant or effective discharge are subject to error, particularly if experienced personnel are not materially involved in the assessment. A professional restoration practitioner with documented field training in the identification of bankfull stage in the Eastern U.S. should verify that the bankfull identification associated with the existing conditions survey and any reference reach survey is accurate. Regional curve analysis, flood frequency analysis, hydraulic modeling or hydrologic modeling should be conducted to verify bankfull stage, channel dimensions, and discharge. Verification is particularly important in actively incising channels or in non-alluvial channels (e.g., step pool channels, Rosgen G-type streams, and flood control channels) for which bankfull indicators are poorly defined or absent. Specifically, if a the site is located near a USGS flow gauge, the Applicant should perform a flood frequency analysis to determine the discharge associated with the 1-, 1.3-, 1.5-, and 2-year recurrence interval storms. Interpolation of USGS Log Pearson Type III regression equations can also be used as a method for verifying or cross-checking field estimates of bankfull discharge.

Sediment Transport and Channel Stability Considerations

Design parameters developed from regional curve and reference reach data shall be validated and further refined in an iterative design environment that incorporates hydraulic and sediment transport analysis. This analysis shall demonstrate that the designed channel will convey the sediment load efficiently, with ample capacity and competence, without aggrading or degrading over time. Applicants are advised to understand the limitations and high degree of uncertainty associated with sediment transport modeling and are referred to Wilcock, 2001 for a discussion of sediment transport analysis for restoration. Incipient motion analysis, while useful, should be combined with and complemented by an analysis of sediment load transport. Sufficient channel pavement, subpavement, and bar samples should be obtained to provide estimates of bedload transport.

Where available, regional bedload relations should be used for sediment transport computations. In many alluvial channels, the channel pavement is significant coarser than the load being transported at bankfull discharge. Therefore, the Applicant shall carefully document the selection of sediment transport relations and the assumption under which initial sediment loads are derived from channel material samples. Generally a 1-D gradually-varied flow steady state model should be developed for the existing and proposed conditions and should be used as the basis for sediment transport model development. Models available for sediment transport computations include HEC-6, HEC-RAS (US Army Corps); GSTRA2.1 (Bureau of Reclamation) and; EFDC-1D (Tetra Tec and EPA).

Species and Habitat Considerations

As discussed in the site evaluation section, the applicant shall provide a description of the habitats present and the species that will be affected by the project. The applicant shall provide justification for any disturbance caused to riparian vegetation. The design should include discussion of factors such as the depth to seasonal high water table, depth to bedrock, and the moisture regime at the site.

General Considerations

Applicants proposing natural channel design projects shall prepare and submit a maintenance and monitoring plan that provides a means for evaluating a successful project outcome (in terms of explicitly stated project goals and objectives) and that provides a plan for both routine maintenance and inspection as well as addressing emergency repairs. Funding sources, schedules, and responsible parties shall be identified in the plan.

1.3.1 Design Guidelines for Riparian Buffer Projects (Optional Design Component)

Riparian buffer restoration may be proposed to restore a natural riparian buffer to improve the ecological health of, improve stabilization of or reduce pollutant loading to a particular stream segment. If the riparian buffer planting is associated with a larger restoration effort (e.g., replanting of a new floodplain surface created by a natural channel design project), the buffer activities are considered part of the larger project and shall thus be included in the Applicant's project justification as required in N.J.A.C. 7:13-11.14(b) and (c). Justification for a proposed riparian buffer restoration shall be provided by explaining why the buffer restoration work is a necessary component of the proposed channel restoration.

It should be noted that the riparian buffer referred to here may not exactly correlate with the regulated riparian zone defined by the flood hazard area rules. If the riparian buffer project is not associated with a larger restoration effort that involves a specifically regulated activity as defined in N.J.A.C. 7:13-11.14, or does not involve the removal of existing vegetation, the project is not regulated under N.J.A.C. 7:13 – 11.14. Applicants are, however, advised to comply with the requirements for vegetation removal set forth in N.J.A.C. 7:13-10.2.

Riparian buffer restoration project designs shall provide evidence that the selected plants will perform as intended given the environmental conditions associated with the site. Mapping or other narrative information concerning environmental factors influencing plant growth (e.g., soil texture, moisture zones, shading, etc.) shall be provided.

Riparian buffer project should have a goal of creating a contiguous vegetated corridor. The Applicant is encouraged to use a zoned planting approach, in which species lists are specified for unique environmental zones (e.g., high-light, upland, etc.). Applicants are strongly encouraged to utilize a combination of herbaceous and woody native plants in their designs. A cover crop should be provided to provide early cover. Applicants are generally discouraged from using fertilizers or other soil amendments, which typically accelerate weed growth. Consideration should be given to removal of invasive or exotic species within and beyond the project limits that could interfere with the establishment of existing vegetation.

Existing vegetation does not have to be completely removed if it is not invasive in nature. Interseeding techniques that retain existing vegetative cover are encouraged. Measures for protecting newly planted areas from nuisance wildlife and or trampling by people shall be specified.

Applicants proposing riparian buffer restoration projects shall prepare and submit a maintenance and monitoring plan that provides a means for evaluating a successful project outcome (in terms of explicitly stated project goals and objectives) and that provides a plan for both routine maintenance, including invasive species removal, and inspection as well as addressing emergency repairs. Funding sources, schedules, and responsible parties shall be identified in the plan.

1.3.2 Design Guidelines for In-stream Habitat Enhancement (Optional Design Component)

In-stream habitat enhancement projects include the placement of wood and stone structures into the stream channel for the purposes of enhancing habitats for fish and other aquatic life. Such structures should be installed where aquatic habitat features are lacking. Several in-stream habitat enhancement structures are permitted by rule under N.J.A.C. 7:13-7.2-7. This section applies to structures that are not permitted by rule.

Low flow deflector structures that extend above base-flow elevations, including bendway weirs, j-hook rock vanes and cross-vanes are not considered in-stream habitat structures and cannot be permitted by rule. Those structures must be permitted through an individual permit.

The narrative for in-stream habitat enhancement projects that are not permitted by rule shall describe why the existing habitat is deficient, explain the intended result of the habitat structures in terms of improved habitat conditions, and provide documentation justifying the specific criteria or methodology used to design the structures. The applicant shall consult with the Department to determine the level of complexity required for the site evaluation and design data documentation.

Applicants proposing in-stream habitat enhancement structures shall prepare and submit a maintenance and monitoring plan that provides a means for evaluating a successful project outcome (in terms of explicitly stated project goals and objectives) and that provides a plan for both routine maintenance and inspection as well as addressing emergency repairs. Funding sources, schedules, and responsible parties shall be identified in the plan.

1.4 Monitoring, Maintenance & Adaptive Management

Monitoring, Maintenance and Adaptive Management

Step 9. Develop monitoring plan.

- Determine monitoring plan design.
- Define performance and success criteria.
- Select monitoring parameters and methods.
- Establish QA/QC control.
- Establish timing, frequency and duration of post-project monitoring.
- Define roles and responsibilities of project partners for project monitoring.

Step 10. Develop project maintenance plan.

Step 11. Identify adaptive management options.

Step 12. Implement channel restoration project.

Step 13. Initiate post-project monitoring and maintenance.

Step 14. Evaluate project success.

Step 15. Respond to monitoring results.

Step 16. Documentation and reporting.

Channel restoration projects include a level of uncertainty due to the complex nature of stream systems. Historically, channel restoration projects have not been adequately monitored or maintained due to lack of funding; however, monitoring and maintenance are critical to project success. Monitoring, maintenance and adaptive management plans, developed in conjunction with the restoration design, will increase the likelihood of the project meeting its goals and objectives. A well-designed monitoring plan will enable the project team to assess progress and determine when or if additional maintenance or adaptive management is required.

It is imperative that these plans be developed in conjunction with the pre-project data collection and restoration design to ensure that the appropriate pre-project data are collected.

Monitoring is defined as the collection and assessment of repeated observations and/or measurements over time to evaluate the effectiveness of restoration actions. It is intended to:

- Ensure the project is performing as intended;
- Help identify maintenance and adaptive management needs
- Measure the effectiveness of project through time and under range of changing environmental conditions relative to project goals
- Provide information on ways to improve and refine restoration techniques
- Provide information on why projects succeed and fail

The monitoring plan discussion contained here assumes that adequate existing conditions data was collected as identified in the previous sections of this manual. Baseline data is essential for a successful channel restoration project, both to assist in developing project alternatives, and to provide comparison for post-project monitoring. The Applicant must consider what data will be needed to measure project success based on the project objectives when designing the site evaluation and project design data collection program.

Three types of monitoring are recommended for channel restoration projects. The first is addressed in Section 2 – Restoration Site Evaluation; the second and third are addressed in this section.

1. *Baseline* – Characterize existing conditions pre-project. See Section 2 for further discussion.
2. *Implementation*- Assess whether project was carried out as planned. Assess whether the restoration measures were installed or constructed correctly. This monitoring is typically conducted during and immediately after implementation.
3. *Effectiveness* – Evaluate whether the project had the desired effect on resource indicators. Assess whether the restoration achieved the desired result. The monitoring variables used shall focus on indicators that document the desired conditions. This type of monitoring is conducted post-implementation, and may continue for several years.

A fourth type of monitoring should be considered by any organization implementing channel restoration projects, although it is not a requirement of the Flood Hazard Area rules. *Validation monitoring* establishes the cause and effect relationship between project and biological indicators. For example: Did an increase in large woody debris result in changes to fish population density?.

1.4.1 Step 9 - Develop Monitoring Plan

1.4.1.1 Step 9a. Determine Monitoring Plan Design

There are several monitoring plan designs the Applicant shall consider when designing a monitoring plan :

- Project site only evaluation,
- BA – before-after evaluation, and
- BACI – before-after-control-impact evaluation.

For very simple projects, such as riparian zone establishment, monitoring the project site may be sufficient. For most projects, a BA (before-after) monitoring plan design is appropriate. In the BA design, the project site is monitored both pre- and post-treatment, while the reference site is assessed pre-treatment.

In the BACI design, both the project site and the reference site are monitored simultaneously pre- and post-treatment. By monitoring the reference site as well as the project site, natural variability can be considered when assessing changes in the project site over time. If funding and staff are available, this type of monitoring design can provide valuable information.

1.4.1.2 Step 9b. Define Performance Criteria

Performance criteria are specific, predetermined standards of performance for measurable attributes. The criteria define acceptable performance levels for each parameter being measured, beyond which maintenance or adaptive management is triggered. The criteria are standards used to evaluate measurable or observable aspects of the restored system and indicate progress of the system toward meeting the established project goals. The criteria must be relevant to the goals and objectives, and shall be measurable and quantifiable.

The three key aspects of developing performance criteria include:

- Linking the criteria to the project goals and objectives;
- Linking the criteria to the actual measurement parameters; and
- Specifying the boundary conditions or thresholds for each criterion (Thom & Wellman, 1996).

Performance criteria for stream restoration projects typically fall into several categories, including:

- physical (geomorphic and topographic features),
- hydrologic,
- biological (communities and structural components and processes that reflect the biological functions of the stream),
- vegetation, and
- water quality.

1.4.1.3 Step 9c. Select Monitoring Parameters and Methods

The monitoring parameters consist of what is being measured in the system. The hierarchy of monitoring parameters recommended in this manual reflects the level of complexity of various channel restoration projects. The basic parameters are measured at all sites, while more detailed measurements are completed for more complex projects.

The monitoring methods are essentially standard operating procedures. When selecting methods, the Applicant shall consider:

- Does the method provide accurate data regarding the parameter?
- Does the method provide replicable data? and
- Is the method feasible within time and cost constraints?

Any method designated for use in the monitoring plan shall be documented. Harrelson, et. al., (1994), for example, contains basic stream survey techniques. The USEPA Rapid Bioassessment Protocols contain habitat assessment protocols, macroinvertebrate sampling protocols, and several other types of protocols.

Implementation Monitoring

An as-built survey shall be completed for any channel restoration project. The level of detail for the survey shall match the complexity of the project. For simpler projects, a sketch of the project reach may be sufficient. For more complex projects, an engineering survey will be required.

This survey will ensure that the project was constructed as designed. For example:

- Were the structures installed at the correct elevation and angle?
- Does the constructed cross-sectional area match what was specified on the plans?
- Were the species specified on the plan actually planted?
- Was vegetation planted in the correct manner?

If discrepancies are identified, the project team should determine why there are discrepancies and if they must be modified to meet the original design parameters.

Effectiveness Monitoring

Following completion of the project, monitoring shall be conducted to determine whether the project is meeting the objectives that were defined.

Table 5.

Example Monitoring Parameters and Performance Criteria

General Goal	**Example Parameters**	**Example Performance Criteria**
Improve channel condition Channel morphology and stability	• Characteristics of cross section shape • Channel planform, pattern, profile • Stream classification or channel type • Stage in channel evolution model • Characteristics of longitudinal profile. • Floodplain connectivity	• Stream falls within specified range for each parameter relative to desired stream type. • Cross-section and profile – Channel geometry did not change beyond the specified design range. • Width/depth ratio did not increase or decrease beyond the specified design range. • The bankfull cross-sectional area did not increase or decrease beyond the specified design range. • The bankfull depth is within X% of the design depth. • The sinuosity did not increase or decrease beyond the specified design range. • The radius of curvature/width ratio did not increase or decrease beyond the specified design range. • The slope did not increase or decrease beyond the specified design range. • The bed elevation has not aggraded or

		degraded beyond the specified design range. • Entrenchment ratio is within X% of the design ratio. • Dominant substrate material is within design criteria. • Habitat spacing – define criteria based on reference site
Increase bank stability Decrease bank erosion	• Condition of structures • Cross section shape • Pattern • Profile • Channel planform • Integrity of rip rap or other protection • Channel cross section stability • Upstream and downstream bank condition • Rate of erosion	• Scour chains or Bank pins – set maximum allowable erosion rate, after which action is required. • Bank erosion hazard index (BEHI) is within specified range. • Slope and angle of structures relative to bank are within specified range. • Pfankuch stability rating • Structure is protecting bank as designed and there is no erosion associated with the structure. • Linear feet actively eroding. • Scour chain or bank pin measurements.
Improve riparian habitat	• Plant survival rate • Percent vegetative cover • Plant diversity – species composition • Width of buffer • Natural recruitment • Wildlife presence • Percent cover • Species composition and density • Size distribution • Age/class distribution • Indices of ecological diversity • Overall health and growth • Habitat structure	• Set minimum survival rate for new vegetation (e.g. 85%) and threshold for replacement. • Set acceptable thresholds for damage to plants at which replacement is required. • Set minimum cover by vegetation per year. • Criteria for success = 85% survival of initial stock. • Relative abundance of invasive species decreased. • Relative abundance of native species increased. • Composition of canopy, understory and ground cover
Improve	• Habitat mapping (Pool/riffle	• Define frequency, spacing, length and

aquatic habitat Fish and biological habitat[1]	spacing and composition, cover or spawning or rearing habitat quantity and quality) • Stream temperature • Substrate/Bed material composition • Water depth and velocity • Indices of macroinvertebrate ecological diversity • Macroinvertebrate population assessments	depth of pools, riffles, etc. (amount of habitat available) • Number of cover types present and extent of each. • Substrate – dominant size, or % embeddedness • Large woody debris – amount and distribution. • Stream water temperature is within range specified for a particular species, or water temperature shows a trend toward the specified range. • Number or diversity of macroinvertebrate species. • Macroinvertebrate ecological indices within acceptable range for region.
Improve water quality	• Temperature • PH • Dissolved oxygen • Turbidity, dissolved or suspended solids • Nutrients	• Specified water quality values for the SWQS of the stream. Also consider approved TMDL values, regional stormwater management plan standards and target species requirements.

1.4.2 Monitoring Hierarchy

The level of monitoring required will be dependent on the type and complexity of the project. Monitoring may require assessment of physical (geomorphic and topographic) features, hydrology, vegetation, biological features (fish and macroinvertebrate populations) and water quality parameters. Table 6 details the monitoring required for different types of projects.

Table 6. **Monitoring Requirements**

[1] While macroinvertebrate populations show improvement relatively rapidly following channel restoration projects, many studies have shown that measuring abundance or population changes in fish requires many years of monitoring. For this reason, monitoring fish populations is not recommended. Indicators, such as habitat quality and extent are recommended as surrogates for fish populations.
Fish response to habitat alteration can be quite difficult to assess (Bisson et al 1997; Minns et al. 1996; Korman and Higgins, 1997; Ham and Pearsons, 2000, Roni et al., 2003). Ham and Pearsons (2000) estimated that "detecting changes in abundance and population size less than 19% would not e detectable over a short time frame (<5 years)" (Roni). Other studies showed that 20 to 30 years of monitoring could be required to detect a change of 50% or more. WA Salmon – A wide variety of results in ability to associate changes with changes in fish abundance. Some studies unable to detect statistical changes in abundance after several years. CA PtII Validation Monitoring – algae and macroinvertebrates may show responses in weeks or months after project, but fish (e.g. salmon/steelhead/trout) may take years or decades.

	As-built Survey	Photo- Documentation	Dimension/Pattern/Profile (longitudinal profile and cross-section)	Bank erosion	Aquatic Habitat – mapping (pool/riffle spacing, etc.)	Aquatic Habitat – macro-invertebrate surveys	Riparian Habitat – Vegetation Survey	Water Quality	Qualitative report on the project's progress toward meeting performance criteria.
Design Option 1a.Grading & planting	Req.[2]	Req.	May be req.**[3]	Req.	Opt	Opt	Req.*[4]	Opt	Req.
Design Option 1b. Grading & planting w/deflectors	Req.	Req.	May be req.**	Req.	Opt.	Opt.	Req.*	Opt.	Req.
Design Option 2a. Soil Bioengineering	Req.	Req.	May be req. **	Req.	Recom	Opt	Req.	Opt	Req.
Design Option 2b. Soil Bioeng w/Structural Toe	Req.	Req.	May be req.**	Req.	Recom	Opt	Req.*	Opt	Req.
Design Option 2c. Soil Bioeng w/Deflector Structures	Req.	Req.	Req.	Req.	Req.	Opt	Req.*	Opt	Req.
Design Option 3a. Natural Channel Design	Req.	Req.	Req.	Req.	Req.	Req.	Req.	Opt	Req.
Design Option 3b. Structural Bank Stabiliz.	Req.	Req.	Req.	Req.	Req.	Req.	Req.	Opt	Req.
Design Option 3c. Floodplain Terracing	Req.	Req.	Req.	Req.	Req.	Req.	Req.	Opt	Req.
In-Stream Habitat	Req.	Req.	Opt	Opt	Req.	Req.	Req.*	Opt	Req.
Riparian zone Restoration	Req.	Req.	Not req	Opt	Opt	Opt	Req.	Opt	Req.

1.4.2.1 Step 9d. Establish QA/QC Control

[2] Req. = required, Opt. = optional, Recom. = Recommended
[3] **depending on extent of project

[4] * Required in areas of disturbance.

The level of quality assurance/quality control for a particular project will be dependent on the complexity of the project and the level of monitoring. The Department may require preparation of a quality assurance project plan (QAPP) for certain types of monitoring or for monitoring performed through certain grant programs. At a minimum, the monitoring plan shall include a review of the monitoring plan and data by a third party to ensure that the plan meets the project goals. Guidance is available from a number of sources regarding development of QAPPs.

1.4.2.2 Step 9e. Select Post- Project Monitoring Schedule

The monitoring duration shall be a minimum of three years, which should allow the project to be exposed to a range of flows. Five years or more will be appropriate for some project. The monitoring shall extend to a point somewhere after the period of most rapid change and into the period of stability, when the project has developed a natural range of ecological services and can be shown to meet the performance criteria.

If success criteria are not met at the end of the designated monitoring period, a monitoring report shall be required each year until two annual reports indicate that the criteria have been satisfied.

If the Applicant is utilizing grant funding to conduct a channel restoration project, they should ensure that the grant contract period extends through the monitoring period.

The frequency of monitoring, particularly of channel conditions, may be based on the occurrence of specific flow events and length of growing season. New systems change more rapidly and shall be monitored more often than established systems.

- Photodocumentation (using established photo points) shall be performed at least quarterly and after significant flow events. If possible, photodocumentation during high flow events may also be helpful.
- Visual inspection (condition of structures, bank protection and vegetation) shall be performed at least quarterly and after significant flow events. Structures shall be inspected for undermining, areas of bare soil, movement of rock or other indications of potential failure.
- Vegetation monitoring shall be performed once per year between July and September, during the growing season.
- Macroinvertebrate sampling shall be performed at least twice per year, April-June and July-October.
- Channel conditions – The channel shall be surveyed (Longitudinal profile and cross sections and pebble counts) at least once per year and after significant flow events.

1.4.2.3 Step 9f. Define roles and responsibilities of project partners

It is important that the Applicant define the roles and responsibilities of each member of the project team for monitoring. Appropriate budget shall be allocated at the beginning of the project.

1.4.3 Step 10. Develop Maintenance Plan

Maintenance, including repair or replacement of components of the project due to design flaws, installation flaws or lack of maintenance, will be necessary for most channel restoration projects. Appropriate maintenance activities will ensure that the various components of the project continue to function as designed.

Ideally, the project will be self sustaining following implementation; however, in reality most projects require some level of maintenance and adaptive management. Funding resources must be allocated for these tasks early in the project planning phase.

There are three types of maintenance that shall be included in the maintenance plan:

1. *Scheduled maintenance/Preventative maintenance*: Routine activities that are performed at intervals specified during design phase. This may include clearing culverts, removing invasive vegetation, irrigation.
2. *Corrective or remedial maintenance*: Repair after damage or failure to meet success criteria. Triggered by results of monitoring or inspections.
3. *Emergency maintenance*: Requires immediate action to repair or prevent damage.

As part of the maintenance and monitoring plan, the Applicant shall:

- Establish maintenance objectives for the project.
- Set a maintenance schedule.
- Assign maintenance responsibilities to project team members.

Table 7 provides examples of typical maintenance actions.

Table 7. **Example Maintenance Actions**
• Repair structures • Maintain bank toe stabilization – rock or vegetation • Repair bank stabilization structures – revetments, riprap, etc. • Repair, replacement of rocks and structures • Removal of nuisance aquatic vegetation • Modify bank grading • Address encroachments • Replant vegetation • Irrigation • Removal of invasive species

- Replacement of vegetation
- Reseeding
- Mulching
- Maintain, repair and replace fencing
- Maintain protection used to prevent deer damage
- Re-establish boundaries if encroachments occur
- Prevention of mowing
- Mowing where required

1.4.4 Step 11. Develop Adaptive Management Plan

There are many definitions or understandings of adaptive management. These understandings, for the most part, fall into two groups: learning from how the system reacts to the project and making necessary modifications, or testing a specific hypothesis. All definitions of adaptive management emphasize the need for specific objectives, followed by monitoring and feedback regarding success in achieving those objectives.

Adaptive management is a continuous and cyclic process that is meant to recognize that natural systems are not completely predictable. It allows for modification of the project design to react to this unpredictability and to new information. These modifications are made to improve the overall project success. In addition, adaptive management can only be successful if the project objectives are clearly stated during the project planning and the monitoring program is properly executed.

As with the monitoring plan, the adaptive management plan shall be developed during the project planning phase. Adaptive management must be included in the project budget. For preliminary estimate purposes, the Applicant shall consider 10% of the project cost for adaptive management. Responsibilities for executing the plan must also be established during the project planning phase.

The adaptive management plan shall include actions to direct the project back within the specified criteria if monitoring or inspections indicate deviation from the defined performance/success criteria. A maintenance and monitoring plan that incorporates adaptive management views a restoration project as a continuous, cyclic process, where the monitoring data trigger feedback mechanisms and are incorporated into future decisions.

As with design data and the monitoring plan, the level of complexity of the adaptive management plan should match the complexity of the project. For example, a riparian zone project may have a very simple adaptive management plan ; for example, replant vegetation if X% survival is not achieved. Natural channel design projects will have a much more complex adaptive management plan.

1.4.5 Project Implementation

- Step 12. Implement channel restoration project.

- Step 13. Initiate post-project monitoring and maintenance
- Step 14. Evaluate project success
- Step 15. Respond to monitoring results (maintenance or adaptive management)

1.4.6 Step 16. Documentation and Reporting

Documentation of monitoring and maintenance is necessary to justify adaptive management recommendations, to provide a record from which to evaluate project success and to provide information to others who may undertake similar projects. Depending on the complexity of the project, the documentation may range from submittal of photographs and narrative descriptions, to submittal of longitudinal survey and cross-section data.

Interim reports shall be submitted yearly with the monitoring results for the year. The report shall include a discussion of the overall project status and progress toward meeting the project objectives. The report shall also discuss the maintenance performed in the past year and plans for the next year, any revisions to the project or the monitoring program and shall include photographs of the project site.

The final report at the end of the monitoring period shall include a description of the project and the project objectives, a description of the final condition of the site, a summary of the monitoring results and a discussion of whether or not the project was a success. If the project does not meet the objectives at the end of the monitoring period, the Applicant must continue monitoring and submit a plan to revise the project. The report shall include a discussion of lessons learned from the project.

1.5 Summary of Required Submissions

The complexity of the site evaluation report shall be commensurate with the scope of the project. The written analysis shall adequately describe the cause of the instability and the need for restoration. The following sections provide guidance regarding the site evaluation report; the first section contains guidance for all projects and the following sections detail additional information to be provided for different types of projects.

1.5.1 All Projects - Site Evaluation Report

1. General Information
   - Narrative description of site
   - Goals and objectives of the project
   - List of project design team members and their qualifications.
   - List of stakeholders and their involvement with the project.
   - Current aerial photograph(s) of the project site and drainage area.
   - Historical aerial photographs or other maps documenting changes to the stream corridor that will be addressed by the project.
   - Site sketch showing channel, floodplain, terrace, erosion, deposition, large woody debris, existing vegetation, points of access, proposed staging area(s), location of known utilities and other site features that would affect the proposed project.
   - Photographs of the project site showing indications of the current conditions being addressed by the proposed project.

2. Stream Classification:
   - Classification based on stream flow conditions
   - Classification based on stream order
   - Classification based on stream pattern

3. Hydrology and Hydraulics
   - Watershed delineation of the contributing drainage area to the downstream limits of the project site on a topographic map at a scale of 1:24000 or less.

4. Species and Habitat
   - Plan view, aerial photo or site sketch showing location and extent of riparian vegetation. Scale to be 1:1200 or less. All specimen trees and vegetation that is to be protected is to be clearly indicated.
   - A description of threatened and endangered species as identified by the New Jersey Natural Heritage Program and the Landscape Project.

5. Maintenance, Monitoring and Adaptive Management Plan

1.5.2 Summary of Required Submissions – Riparian Buffer Projects

1. General Information
   - Justification of the need for riparian restoration,
   - Justification of proposed species selections in terms of mapped environmental conditions, and
   - Summary of planting approach.

2. Stream Classification – no additional information.

3. Hydrology and Hydraulics
   - Base flow and bankfull flow information to assist in planning the lowest extent of perennial vegetation.
   - Location of secondary flow channels and other areas where planting may be avoided. May be documented on a plan view or sketch.
   - Note concentrated flow channels through the buffer area. Observe overall stability and determine whether or not treatment is required to repair or prevent erosion.

4. Species and Habitat
   - Inventory of native tree, shrub, and grass species in the project area or immediately upstream or downstream.
   - Inventory of invasive tree, shrub, and other perennial vegetation in the project area or immediately upstream or downstream.

1.5.3 Summary of Required Submissions – In Stream Habitat Enhancement

1. General Information
   - Narrative describing the observed habitat deficiencies and providing justification for the selection of specific techniques.

2. Hydrology and Hydraulics
   - Cross-section, slope, flow velocity, depth, and/or resistance data if planned structures require a stability analysis such as cover stones or boulder clusters.

     Low flow and base flow water surface elevations to assist in planning location and extent of devices.

3. Stream Classification – no additional information

4. Species and Habitat:
   - An analysis of biological conditions shall be conducted.

1.5.4 Summary of Required Submissions – Bank Stabilization

1.5.4.1 Bank Stabilization <300 feet

1. General Information
   - Narrative justifying the need for a bank stabilization project and providing supporting documentation justifying the specific techniques used.
   - Project goals and objectives
   - Proposed design-life and associated design discharge and supporting hydrologic modeling, documentation or regression analysis
   - Expected channel shear stress and velocity calculations
   - Scour depth calculations (if flow deflectors or structural toe treatments are proposed)
   - Flow deflector calculations (if deflector structures are proposed)
   - Design calculations for structural measures (for measures such as rip-rap gabions)
   - Stability calculations (if vertical walls in excess of 4 ft. in height are provided)
   - Explain how the project will address future channel changes.
   - Historic aerial photos or photographs showing local or regional disturbances.
   - Discussion of the history of the channel, the history of the watershed, and the cause of channel instability or ecological degradation. This shall include an analysis of current land use in the watershed to identify any watershed-wide stressors and whether or not they can be addressed by the project.
   - Design drawings

2. Stream Classification
   - Classification based on Channel Evolution Model
   - Comprehensive geomorphic survey (Level I Rosgen or equivalent)

3. Hydrology and Hydraulics:
   - Cross-section, slope, and resistance data to be used in design calculation.
   - Analysis of stream gage data.

4. Species and Habitat Data:
   - No additional information is required.

1.5.4.2 Bank Stabilization >300 feet

1. General Information

- Narrative justifying the need for a bank stabilization project and providing supporting documentation justifying the specific techniques used
- Project goals and objectives
- Proposed design-life and associated design discharge and supporting hydrologic modeling, documentation or regression analysis
- Expected channel shear stress and velocity calculations
- Scour depth calculations (if flow deflectors or structural toe treatments are proposed)
- Flow deflector calculations (if deflector structures are proposed)
- Design calculations for structural measures (for measures such as rip-rap gabions)
- Stability calculations (if vertical walls in excess of 4 ft. in height are provided)
- Explanation of how the project will address future channel changes.
- Historic aerial photos or photographs showing local or regional disturbances.
- Discussion of the history of the channel, the history of the watershed, and the cause of channel instability or ecological degradation. This shall include an analysis of current land use in the watershed to identify any watershed-wide stressors and whether or not they can be addressed by the project.
- Design drawings

2. Stream Classification

- Classification based on Channel Evolution Model
- Comprehensive geomorphic survey (Level II Rosgen or equivalent)

3. Hydrology and Hydraulics

- Cross-section, slope, and resistance data to be used in design calculation.
- Analysis of stream gage data.

4. Species and Habitat Data

- Inventory of native tree, shrub, and grass species in the project area or immediately upstream or downstream.
- Inventory of invasive tree, shrub, and other perennial vegetation in the project area or immediately upstream or downstream.
- A description of all soil types within the project area to be planted and any features that will restrict planned excavations, foundations or planting practices.

- A description of the moisture regime of all areas to be planted.

1.5.5 Summary of Required Submissions - Natural Channel Design Projects

1. General Information

- A narrative description of the existing channel morphology and the direct and indirect stressors that have modified the channel from its probable stable form
- Reference reach data and reference reach selection methodology and assessment forms
- A table providing a comparison between existing, reference reach, regional curve, and proposed morphological data
- Explain how the project will address future anticipated changes.
- Historic aerial photos or photographs showing local or regional disturbances.
- Discussion of the history of the channel, the history of the watershed, and the cause of channel instability or ecological degradation. This shall include an analysis of current land use in the watershed to identify any watershed-wide stressors and whether or not they can be addressed by the project.
- Documentation justifying the selection of the design procedure, design flow, and channel type (e.g., fixed bed, mobile bed)
- Boring logs
- Sediment transport validation
- Hydraulic analysis

2. Stream Classification

- Complete geomorphic survey (Level III Rosgen or equivalent)

3. Hydrology and Hydraulics

- Analyze current land use in the watershed to identify any watershed-wide stressors and whether or not they can be addressed by the project.
- Preliminary analysis of stream gage data.
- For projects with a stream gage in close proximity to the project site, the longitudinal profile should extend through the gage and be calibrated to bankfull indicators.
- For projects with a stream gage within the watershed, separate longitudinal profile and cross-section at the gage location may be useful in identifying bankfull depth at the project site.
- For projects where no stream gage data is available, gage data from a reference reach or from a hydraulically similar stream may be useful.

4. Species and Habitat

- Inventory of native tree, shrub, and grass species in the project area or immediately upstream or downstream.
- Inventory of invasive tree, shrub, and other perennial vegetation in the project area or immediately upstream or downstream.
- A description of all soil types within the project area to be planted and a map showing the aerial extent. Map scale to 1:1200 or less. Description to include:
    a) Depth and condition of planting horizon to determine if soil amendments are advisable;
    b) Depth to seasonal high water table to assist in the evaluation of the moisture regime;
    c) Depth to bedrock or fractured bedrock that may restrict planned excavations or foundations;
    d) Identification of gravel or cobble layers that will restrict planting, staking, or anchoring operations.
- A description of the moisture regime of all areas to be planted.
- A description of the current shade conditions at the site.

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