US Army Corps of Engineers

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Washington, D.C. 20314

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SEP 15 2004

MEMORANDUM TO THE FIELD

SUBJECT: Stream Mitigation Compendium

We are pleased to enclose, as part of the implementation of the National Wetlands Mitigation Action Plan, a technical resource document to assist with stream mitigation entitled: *Physical Stream Assessment: A Review of Selected Protocols for use in the Clean Water Act (CWA) Section 404 Program* (Stream Mitigation Compendium).

As noted in the U.S. Army Corps of Engineers Regulatory Guidance Letter 02-2, authorized impacts to streams require appropriate and practicable compensatory mitigation to replace lost or degraded stream functions (40 CFR §230.10 (d)). In support of RGL 02-2, the Stream Mitigation Compendium is intended as a reference that can be consulted by regulatory agencies, resource managers, and restoration ecologists in order to select, adapt, or devise stream assessment methods appropriate for impact assessment and mitigation of fluvial resources in the CWA Section 404 Program.

The physical, chemical, and biological properties of streams vary both within and among regions, thus stream assessment/mitigation protocols must be tailored to address this variability. However, all protocols used in the CWA Section 404 program should have the following characteristics:

1. Classification: Stream assessment should be preceded by classification to narrow the natural variability of physical stream variables.

2. Objectivity: The assessment procedure should remove as much observer bias as possible by providing well-defined procedures for objective measures of explicitly defined stream variables.

3. Quantitative Methods: The assessment procedure should utilize quantitative measures of stream variables to the maximum extent practicable.

4. Fluvial Geomorphological Emphasis: Stream assessments undertaken to prioritize watersheds or stream reaches for management or evaluate the design of stream mitigation projects (e.g., stream enhancement or restoration) should be based on fluvial geomorphic principles.

5. Data Management: The assessment procedure should utilize available stream data to the maximum extent practicable. Many state agencies maintain databases for ambient monitoring and designated use allocations. Such data should be effectively utilized as it is useful for calibrating stream quality indices, understanding local reference conditions, and developing performance standards to evaluate stream restoration and enhancement efforts.

In its review of 51 selected complete or draft stream assessment protocols, the Stream Mitigation Compendium highlights examples of existing stream assessment/mitigation protocols that include these characteristics and may serve as sound models for other regions of the United States.

We encourage you to use this technical resource document to improve the scientific foundation for compensatory mitigation decisions, and to make its availability known to the mitigation planning and design community and to agencies with which we cooperate in decisions affecting stream resources. We are grateful to the Federal Interagency Mitigation Workgroup, including staff from the Departments of Agriculture, Commerce, Interior, and Transportation, in addition to our members, for their important work to improve the regulatory program and to achieve better environmental outcomes. Thanks also to all who submitted information for the compendium and who provided insights and comments as it was developed.

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PHYSICAL STREAM ASSESSMENT:

A Review of Selected Protocols for Use in the Clean Water Act Section 404 Program

September 2004

DISCLAIMER

This review of physical stream assessment methods was funded wholly by the U.S. Environmental Protection Agency (EPA) and the U.S. Army Corps of Engineers (USACE) and conducted in support of the National Mitigation Action Plan. It has been subjected to review by the Federal Interagency Mitigation Workgroup and approved for release. Approval does not signify that the contents reflect the views of the Agencies, nor does mention of trade names or commercial products constitute endorsement or recommendation for use. This document is not a regulation itself, nor does it change or substitute for statutory provisions and EPA or USACE regulations. Thus, it does not impose legally binding requirements on EPA, USACE, States, or the regulated community.

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LIST OF ABBREVIATIONS / ACRONYMS

BEHI	Bank Erosion Hazard Index
CFR	Code of Federal Regulations
CWA	Clean Water Act
D50	Median particle size, typically referring to riffle substrate
FEMA	Federal Emergency Management Agency
GIS	Geographic Information System
GPS	Global Positioning System
HUC	Hydrologic Unit Code
IBI	Index of Biotic Integrity
NPDES	National Pollutant Discharge Elimination System
NRCS	U.S.D.A. Natural Resources Conservation Service
PSD	Particle Size Distribution (typically referring to channel substrate)
RBP	Rapid Bioassessment Protocol
SCS	U.S.D.A. Soil Conservation Service (now referred to as NRCS)
TVA	Tennessee Valley Authority
USACE	U.S. Army Corps of Engineers
USBLM	U.S. Bureau of Land Management
USDA	U.S. Department of Agriculture
USDC	U.S. Department of Commerce
USDOD	U.S. Department of Defense
USDHUD	U.S. Department of Housing and Urban Development
USDOI	U.S. Department of the Interior
USEPA	U.S. Environmental Protection Agency
USFS	U.S. Forest Service
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geologic Survey
W/D	Width:Depth Ratio (Bankfull Stream Dimensions)
WQC	Water Quality Certification

1.0 EXECUTIVE SUMMARY

We reviewed stream assessment and mitigation protocols collected from throughout the United States in an effort to identify attributes most pertinent to the Clean Water Act (CWA) Section 404 regulatory program. We also solicited input from practitioners utilizing stream assessment protocols nationwide in an effort to identify common attributes of existing protocols and to seek recommendations for future training and technical needs to enhance stream assessment.

Subjective, visual-based assessment protocols are rapid and relatively easy to use. They may provide an acceptable means of watershed-scale stream assessment or coarse level prioritization. However, they are rarely detailed enough to be used for project design, and their accuracy and precision has been subject to debate.

In contrast, objective, quantitative assessments, often referred to as transect-based or measurement-based assessments, are time consuming and labor intensive. Detailed quantitative assessment is a prerequisite to project design and should be based on comparison to stable reference conditions. However, the precision of even some commonly utilized quantitative stream assessment metrics has been shown to be less than certain.

We suggest that programmatically complete stream assessment protocols for use in the CWA Section 404 regulatory program should have the following characteristics:

1) Classification: Stream assessment should be preceded by classification to narrow the natural variability of physical stream variables.

2) Objectivity: The assessment procedure should remove as much observer bias as possible by providing well-defined procedures for objective measures of explicitly defined stream variables.

3) Quantitative Methods: The assessment procedure should utilize quantitative measures of stream variables to the maximum extent practicable.

4) Fluvial Geomorphological Emphasis: Stream assessments undertaken to prioritize watersheds or stream reaches for management or aid the design of stream enhancement or restoration projects should be based on fluvial geomorphic principles.

5) Data Management: Data from stream assessments should be catalogued by designated entities in each region of the country. This is especially true of reference data.

Stream assessment and mitigation protocols developed specifically for the CWA Section 401/404 regulatory program incorporate technical features of stream assessment, as well as programmatic or policy directives important in the CWA Section 404 program. Notable such protocols include the *Draft Standard Operating Procedure for Calculating Compensatory Mitigation Requirements for Adverse Impacts to Wetlands, Open Waters, and Streams* from the U.S. Army Corps of Engineers (USACE) Savannah District (No. 6), the *Standard Operating Procedure [for] Compensatory Mitigation* from the USACE Charleston District (No. 14), and the *Draft Stream Mitigation Guidelines* from the Kentucky Division of Water (No. 7).

Still other protocols provide unique approaches or particularly useful methods to address aspects of stream assessment and mitigation. The *Eastern Kentucky Stream Assessment Protocol* from the USACE Louisville District (No. 9) incorporates a wealth of biological data into the calibration of the stream assessment method, and is thereby an integration of biotic and abiotic factors of fluvial systems in eastern Kentucky. The *Integrated Streambank Protection Guidelines* from the Washington State Aquatic Habitat Guidelines Program (No. 13) uses a series of sequential or hierarchic matrices to aid practitioners in selection of potentially appropriate mechanisms to abate streambank instability.

Non-regulatory stream assessment protocols lack the policy characteristics important in the administration of the CWA Section 404 regulatory program. However, they are also able to emphasize technical aspects of stream assessment, independent of the often subjective policy considerations. The *Idaho Beneficial Use Reconnaissance Project (BURP) Workplan* (BURP TAC, 1999) (No. 19) and the *Guidelines for Evaluating Fish Habitat in Wisconsin Streams* (Simonson *et al.*, 1994) (No. 24) are notable for relying upon primarily quantitative data to assess physical stream conditions, and both of these protocols also utilize condition indices based on these data.

The *Vermont Stream Geomorphic Assessment Protocol Handbooks* (VANR, 2003) (No. 45) incorporate all five of the above recommended criteria for a programmatically complete stream assessment protocol for use in the CWA Section 404 regulatory program. VANR (2003) utilizes stream and valley classifications to narrow the range of expected conditions and assist in the selection of appropriate reference sites; instructions for measurement or estimation of stream variables are clearly described, and detailed rationale for each variable is provided; quantitative methods are emphasized, yet rapid procedures are also provided to quickly characterize large stream systems or whole watersheds; fluvial geomorphology provides the fundamental basis for assessment, although a habitat assessment component is under development for inclusion in the protocol; and recommendations are provided to aid in the management, interpretation, and dissemination of stream assessment data collected using the protocol.

The number of stream assessment protocols nationwide has risen dramatically in recent years commensurate with the anthropogenic stressors affecting these resources and the public's interest in protecting them. It is incumbent upon the federal, state, and local agencies tasked with regulating and managing streams to utilize the best available means to do so and to base decisions affecting these resources on the most robust scientific data practicable. To this end, we also recommend the following:

1) Convene an interagency technical panel to develop consistent national or regional guidelines for stream assessment and mitigation protocols for the CWA Section 404 regulatory program. Such a panel should include not only regulatory agencies, but also those with extensive resource management responsibilities, such as the U.S. Forest Service and the U.S. Bureau of Land Management.

2) Support a nationwide effort to test various assessment protocols and/or components thereof in a variety of ecoregions or bioregions. Such an effort may shed additional light on both the commonalities and uniquely regional characteristics of streams for which assessment protocols should be designed to capture.

3) Support and encourage training of regulatory personnel in various disciplines including, but not necessarily limited to, aquatic ecology, hydrology, fluvial geomorphology, etc. Emphasis may include such topics as stream stability assessment, stream habitat assessment, development of regional curves, analysis of U.S. Geologic Survey gauging station records, etc.

4) Support and encourage interdisciplinary interaction and coordination among regulatory personnel and professionals in the private sector and academia through meetings, symposia, conferences, and workshops.

2.0 INTRODUCTION

Aquatic resources nationwide are under increasing demands and stressors as population increases and development pressure continues to expand beyond the limits of traditional urban centers. Rivers and streams provide drinking water, recreational opportunities, and support diverse biological communities throughout the stream system, including receiving estuaries. The nation's rivers and streams are subject to direct physical perturbation as result of urbanization and infrastructure improvements, as well as the effects of non-point source discharges, such as run off from agriculture and silviculture lands, mined areas, and impervious surfaces of cities, towns, and transportation facilities.

According to the *National Water Quality Inventory: 2000 Report*, which was compiled pursuant to Section 305(b) of the Federal Water Pollution Control Act (as amended), 39% of the nation's rivers and streams that were assessed for the report were impaired by some form of pollution or habitat degradation (USEPA, 2002a). Siltation (sedimentation) and habitat degradation accounted for 53% of the impaired river and stream miles assessed for the 2000 305(b) report (USEPA, 2002a).

The total number of river and stream miles in the United States is itself an elusive figure (NRC, 1992). Leopold *et al.* (1964) estimated approximately 3.25 million miles of streams and rivers nationwide, but acknowledged excluding tributaries of the smallest streams. A 1982 Nationwide Rivers Inventory (cited in Benke, 1990) estimated 3.12 million miles of streams and rivers, and Echeverria *et al.* (1989) estimated 3.2 million miles of streams nationwide. The National Hydrography Dataset (NHD) maintained by the U.S. Geologic Survey (USGS) estimates approximately 3.4 million miles of rivers and streams nationwide, but this figure excludes Alaska and may not account for many of the nation's smallest streams (American Rivers, 2003). American Rivers reviewed State estimates reported in the biennial National Water Quality Inventory reports and found an estimated 4.1 million miles of rivers and streams nationwide (American Rivers, 2003).

All of these estimates may significantly underestimate the true total number and length of streams nationwide by vastly under representing small, headwater streams. Arguably, it is these small streams that are most at risk of impairment from watershed perturbation due to their intimate connection to the landscape and the relative technical ease with which small streams can be piped, relocated, or otherwise altered. An experimental comparison of stream channel length in a 6.3 mi^2 southern Appalachian watershed in North Carolina found that 0.5 miles of stream were mapped at a scale of 1:500,000, 15.2 miles at a scale of 1:100,000, and 34.8 miles at a scale of 1:7,200 (N. Gardiner pers comm., cited in Meyer and Wallace, 2001). In addition, Hansen (2001) found that only 21% of the total stream channel length in the 446 mi^2 Chatooga River watershed of Georgia, North Carolina, and South Carolina was mapped on 1:24,000 maps, such as the USGS 7.5-minute series topographic quads.

The public's interest in protection and management of stream resources demands that local, state, and federal agencies with mandates to preserve, enhance, manage, and regulate impacts to these resources utilize the best available tools and scientific understanding to do so. The assessment of stream habitat, stream biota, and water quality is a fundamental first step required to make sound, responsible regulatory decisions affecting these resources and to develop management plans, species recovery plans, or habitat restoration plans.

Compensatory mitigation for authorized impacts to federally jurisdictional waters of the United States is a fundamental component of the federal wetlands and other aquatic resources regulatory program. Consistent with the mitigation policies outlined in the Council on Environmental Quality regulations (40 CFR 1508.20) and the Clean Water Act (CWA) Section 404(b)(1) Guidelines (40 CFR 230), mitigation is defined as the creation, restoration, enhancement, or in exceptional circumstances, preservation, of aquatic resources undertaken expressly for the purpose of compensating for authorized impacts to similar resources elsewhere.

Historically, compensatory mitigation for authorized impacts to streams has often consisted of measures to create, restore, enhance, or preserve wetlands. Such an approach does not recognize the fundamentally different functions that these two disparate yet often interacting ecosystems play in the landscape. One of the stated goals in the National Wetlands Mitigation Action Plan (Action Plan) released by the George W. Bush Administration on December 26, 2002, was clarification of considerations for mitigating impacts to streams in the CWA Section 404 program. Nearly concurrent with release of the Action Plan, the U.S. Army Corps of Engineers (USACE) released Regulatory Guidance Letter No. 02-2, *Guidance on Compensatory Mitigation Projects for Aquatic Resource Impacts Under the Corps Regulatory Program Pursuant to Section 404 of the Clean Water Act and Section 10 of the Rivers and Harbors Act of 1899*, which clarifies that authorized impacts to streams should require compensatory mitigation projects to replace lost or degraded stream functions.

2.1 Objectives

There are a number of technical and programmatic considerations paramount to selection of an appropriate stream assessment protocol. For instance, recommended assessment tools may vary based on technical considerations such as project scale, stream size, ecoregion, watershed position, valley type, channel classification, channel gradient, and composition of bed material. In addition, administrative or programmatic considerations, such as logistics, level of effort, time constraints, personnel resources and expertise, and specialized equipment requirements may also affect selection of an appropriate assessment tool.

The objective of this report is to summarize selected stream assessment and mitigation protocols in use throughout the country and recommend pertinent components of assessment protocols to best assess and document physical stream conditions during the CWA Section 404 regulatory process. Background information describes some fundamental components and concepts of physical stream assessment, including a discussion of factors that can limit the ability of physical stream assessment data to adequately support management or restoration decisions. We also compiled and distributed a stream assessment protocol questionnaire to practitioners nationwide in order to solicit information from professionals utilizing these protocols in the field. Summaries of selected physical stream assessment protocols are provided in appendices, and these protocols are compared in the latter sections of this report.

This report is not a guidance manual. It is a summary compilation of practices developed and used by various federal, state, and local entities to assess the physical characteristics of streams. It is intended as a reference that can be consulted by regulatory agencies, resource managers, and restoration ecologists in order to select, adapt, or devise stream assessment methods appropriate for impact assessment and mitigation of fluvial resources based on the desired features and resolution of those assessments.

3.0 BACKGROUND

3.1 Objectives of Stream Assessment

The need for accurate assessment of streams and stream water quality has increased commensurate with the pressures facing these ecosystems. Stream assessments may be undertaken for any number of purposes including, but not necessarily limited to, fisheries management, threatened or endangered species recovery plans, drinking water source assessment, watershed/land use planning, compliance monitoring for State or Federal permits, or for reporting and documenting the status and trends affecting local, regional, or national water quality and stream habitat. Bauer and Ralph (2001) opine that the fundamental goal of the CWA, which is to protect and restore the physical, chemical, and biological integrity of the nation's waters, could be better addressed by explicitly integrating physical stream habitat criteria into water quality standards.

The breadth and scope of stream assessments is as varied as the reasons for undertaking them. They can be rapid, qualitative assessments capable of being initiated by volunteer stream monitoring groups with minimal technical background or training (e.g. Andrews and Townsend, 2000). In contrast, stream assessments can also be comprehensive, quantitative exercises based on rigorous sampling methods executed by trained specialists with carefully controlled quality assurance and quality control plans (e.g. Lazorchak *et al.*, 1998). The type of assessment and the protocols and methods used are influenced by project objectives, available time and resources to perform assessment, and the degree of confidence required of the assessment in order to support the decisions based thereon. As the number and scope of stream restoration projects nationwide expands, it is incumbent upon those responsible for designing, executing, and authorizing these plans to fully understand the intrinsic complexity of stream systems, the interactions and influences among streams and watersheds, and the potential causes and consequences of stream degradation.

3.2 Components of Stream Assessment Protocols

Stream assessment protocols often, but not always, include both biological and physical (geomorphological and habitat) variables. The level of detail for each component is largely dependent on the objective for which the protocol was developed. Variables common to biological assessments often include both benthic macroinvertebrates and fish community assemblages, although they may also include mollusks, periphyton, or other locally important components of stream biota. The use of indicators of biological integrity as evidence of environmental conditions has gained widespread acceptance since USEPA hosted the first national workshop on biological monitoring and assessment in 1987. Sections 303 and 304 of the CWA, as amended in 1987, provide the legal authority for the use of biological assessments and criteria in state and tribal water quality programs. Most states now include biological assessment as part of their water quality programs, including assigning or revising water quality standards (USEPA, 2002b). In fact, in 1998, USEPA made it a national priority for state and tribal water quality standards programs to adopt biocriteria to better protect aquatic life in all waters where biological assessments methods were available (USEPA, 1998).

Whereas biological variables tend to be seasonally variable and labor intensive to sample, physical stream features are relatively stable over short time frames in all but the most perturbed stream environments, are relatively easy to measure in the field, and provide a tangible resource for decision making, management, and restoration plans (Johnson *et al.*, 2001; Roper *et al.*, 2002). Habitat assessment is a nearly ubiquitous component of all stream assessment protocols. The number of stream habitat assessment methods has risen rapidly in recent years (Bain *et al.*, 1999; Johnson *et al.*, 2001; Roper *et al.*, 2002). Johnson *et al.* (2001) note that habitat assessments are now the basis of most impact assessment and resource inventories, species management plans, and mitigation planning and compliance monitoring. However, collection of habitat data may require vastly different levels of effort depending on the protocol.

Geomorphological data may or may not be included in assessment protocols and may range in comprehensiveness from simple observations of stream bank erosion to complete fluvial geomorphic characterization of the stream's hydraulic geometry, plan form, and profile. The National Research Council (NRC) evaluated the status of aquatic ecosystem restoration nationwide, and concluded, in reference to stream restoration, "the principles and analytical tools of hydrology and fluvial geomorphology need to be applied to a much greater extent than in the past to the planning and execution of projects," (NRC, 1992, p.172). Data indicating that biota is impaired is of little use if restoration or enhancement measures are conceptualized in the absence of detailed geomorphological and habitat assessment data. In addition, both biological and physical stream assessments should ideally be augmented with water quality measures to help identify causes of impairment in situations where the physical structure of the stream suggests that biota should be more representative of reference conditions than biological sampling indicates is actually the case.

We have limited our review of assessment protocols to physical stream assessment protocols and methods that emphasize geomorphological variables, stream habitat variables, or both. In addition, we have made no effort to compile and review all physical stream assessment procedures included as part of broader stream bioassessment programs nationwide. We have, however, included some physical stream assessments developed or presented as part of bioassessment programs where we believe these methods hold potential independent utility for the CWA 404 regulatory program. For information regarding bioassessment programs nationwide, the reader is respectfully referred to a USEPA summary of biological assessment programs in all 50 States, the District of Columbia, four territories, six tribes, and four interstate commissions (USEPA, 2002b).

3.3 Accuracy and Precision of Physical Stream Assessment Data

Physical stream assessment protocols can include both subjective and objective criteria, and frequently incorporate both types of measures. Subjective or qualitative habitat assessments or habitat type classifications are often advantageous because they can be executed rapidly (Fitzpatrick *et al.*, 1998) and can often be undertaken by personnel with moderate training or expertise. These are often visual-based assessment protocols where selected stream and riparian zone variables are estimated in the field and rated according to criteria defined in the protocol. Conversely, more rigorous, quantitative measures take more time, are more expensive, and require greater levels of training to execute. Quantitative assessments typically require actual measurement of stream variables from channel cross-sections or transects. These can be referred to as measurement-based or transect-based assessments and require additional equipment and resources relative to visual-based assessments.

There are both proponents and detractors for each type of assessment protocol. However, the ultimate utility of any protocol is in large part dependent on its intended use and objective. There have been a number of investigations comparing the accuracy and precision of visual-based subjective assessments, and similar investigations have evaluated many common variables included in more quantitative assessments.

3.3.1 Evaluations of Visual-Based (Qualitative) Stream Habitat Classification and Assessment Variables

Visual-based stream habitat assessments are often in the form of habitat quality indices, where various stream variables or metrics are scored and summed to generate a single number representing habitat quality. Habitat quality indices allow multiple streams in a given region to be rapidly compared and ordered according to habitat quality. One of the principle concerns with visual-based assessments is that qualitative measures or categorization of habitat types can invite observer bias, and thus adversely affect repeatability and objectivity (Roper and Scarnecchia, 1995; Poole *et al.*, 1997).

Stauffer and Goldstein (1997) compared three commonly used qualitative habitat indices- the Qualitative Habitat Evaluation Index (QHEI) (Rankin, 1989); the USEPA Rapid Bioassessment Protocols (RBP) (Plafkin *et al.*, 1989); and the Riparian, Channel, and Environmental Inventory (RCE) (Petersen, 1992)- among 18 prairie streams in the Red River of the North basin in eastern North Dakota and northwestern Minnesota. Based on their evaluation, the authors concluded the following: 1) Scores for the three indices were highly correlated; 2) QHEI and RBP scores emphasized channel geomorphology variables (accounting for 41% and 42% of the total scores, respectively), while RCE scores emphasized riparian zone variables (32% of total scores); 3) Each index includes redundant (highly correlated) variables that result in an overemphasis of some habitat features and a diminished influence of others; 5) QHEI was the least subjective index, and RBP was the most subjective; and 6) All three indices failed as predictors of the fish community in streams of the Red River of the North basin (Stauffer and Goldstein, 1997). Stauffer and Goldstein (1997) opined that all of the indices may be improved with regionalization to account for conditions typical of prairie streams, such as that proposed by Hayslip (1993) for modification of the USEPA RBP in the Pacific Northwest.

Kaufmann *et al.* (1999) assessed sampling precision of the USEPA RBP habitat quality index. The RBP habitat assessment or regional modifications thereof are common components of many state biological monitoring and assessment protocols. The authors' precision estimates were based on sampling 459 streams in the Mid-Atlantic region and 34 streams in Oregon (Kaufmann *et al.*, 1999). The RBP utilized in these trials consisted of 12 habitat metrics consistent with Barbour and Stribling (1991) and Klemm and Lazorchak (1994). Kaufmann *et al.* (1999) found that seven of the habitat metrics proved rather imprecise as evidenced by "among stream" variation. The authors reported that, especially in the Mid-Atlantic region, the variation of total RBP habitat score between visits to the same stream (measurement variance) was nearly as great as the variance of scores among streams. These findings are consistent with the results of a similar study by Hannaford and Resh (1995) in California. Kaufmann *et al.* (1999) concluded that in both Oregon and the Mid-Atlantic region, either the streams lacked habitat quality variation or the RBP habitat quality assessment was unable to discern habitat quality difference above the "noise" of measurement variability. Hannaford and Resh (1995) suggested that training would reduce observer variability. Hannaford *et al.* (1997) concluded that training did in fact reduce observer variability of the RBP published by Plafkin *et al.* (1989). However, Hannaford *et al.* (1997) also noted that training at one site did not necessarily reduce variability of RBP assessments at a second site.

It should be noted that the current version of the USEPA RBP (Barbour *et al.*, 1999) contains only 10 metrics and has been modified to increase parameter objectivity and incorporate a non-weighted point scoring system. Modifications included suggestions recommended by Barbour and Stribling (1994): 1) Certain criteria were clarified to make scoring more stringent; 2) as noted above, all variables are now weighted evenly; and 3) Barbour *et al.* (1999) recommend that survey teams be trained in the use of the RBP and also conduct calibration exercises as a unit prior to initiation of field surveys.

3.3.2 Evaluations of Measurement-Based (Quantitative) Habitat Classification and Assessment Variables

Effective environmental policy and resource management decisions and habitat restoration projects require stream assessment data that is accurate, precise, and relevant to the project objectives (Kaufmann and Robison, 1998). Projects that include measures to enhance or restore stream corridors require that stream assessments be objective and repeatable. Many well-meaning but unsuccessful stream restoration projects have been caused by inadequate analysis of the physical characteristics and processes that govern stream form and function (NRC, 1992).

Despite the adoption of stream habitat as a prominent component of assessment protocols and the concomitant proliferation of habitat assessment methods, few quantitative investigations related to the accuracy and precision of common habitat assessment variables have been published (Poole *et al.*, 1997). Roper *et al.* (2002) succinctly summarized common concerns cited in literature for using physical stream variables for monitoring, including: 1) lack of repeatability; 2) inconsistent application; 3) lack of consistent training; and 4) a lack of resolution that prohibits detection of changes caused by management activities.

Platts *et al.* (1983) recommended standard methods for measuring physical attributes of streams and riparian areas, and the authors rated the accuracy and precision for many of the stream habitat assessment variables. In summary, the methods described by Platts *et al.* (1983) for measuring stream width, depth, shore water depth, undercut depth, bank angle, and vegetation use by animals rated good to excellent for both accuracy and precision. In contrast, percent-pool, pool quality, percent-riffles, pool:riffle ratio, streambank alteration, streambank vegetation stability, substrate embeddedness, streamside cover type, length of overhanging vegetation, and riparian habitat type rated fair to poor in accuracy and/or precision. Methods to characterize the features that formed or maintain pools, stream discharge, channel gradient, channel sinuosity, subsurface (pavement), cross-sectional surveys, channel debris and sediment storage, stream order, and herbage production and utilization were recommended, but were not evaluated by the authors for precision or accuracy (Platts *et al.*, 1983).

Roper and Scarnecchia (1995) evaluated the ability of observers to independently classify habitat unit types present within stream reaches in southwestern Oregon into primary (pools, riffles, and glides) and secondary (types of pools and types of riffles) habitat types. These kinds of classifications are common components or precursors to stream habitat assessment, and many variables depend on their accurate characterization (e.g., percent-pool, percent-riffle, pool:riffle ratio, pool spacing, etc.). Roper and Scarnecchia (1995) found that experienced observers who also received uniform training differed far less in their habitat type classifications than experienced observers who did not receive consistent training. Variability of secondary habitat types was greater in both trials than variability of estimates of primary habitat units. Roper and Scarnecchia (1995) concluded that variation among observers classifying primary and secondary habitat unit types was related to at least three factors: 1) the classification's level of definition (e.g., pools vs. types of pools); 2) level and uniformity of surveyor training; and 3) characteristics (complexity) of the stream itself.

Similar conclusions were reached by Wang *et al.* (1996) concerning level of definition and stream complexity following their investigation into the accuracy and precision of selected stream habitat attributes in southern Wisconsin. They evaluated estimates or measures of 27 stream habitat variables conducted by surveyors with three levels of experience ranging from: 1) no experience, but recent instruction; 2) one to two field seasons of stream habitat assessment experience; and 3) four or more field seasons of habitat assessment experience. Wang *et al.* (1996) found that the difference in mean values among observers for most variables was small. In contrast to many other investigations documenting observer variability, the authors found little influence of observer training or experience on either the precision or accuracy of habitat estimates for most variables. Exceptions included bank vegetation, land use variables, and embeddedness of stream substrate, all of which displayed high variability among observers. Wang *et al.* (1996) noted that observer variance was directly associated with habitat heterogeneity, where assessment of streams having more complex habitat features resulted in more observer variance for estimates and measures of those features. The authors also observed that well defined variables (e.g., stream width and depth), as well as variables measured along transects, were estimated or measured relatively accurately. The authors attributed the accuracy of fish cover variables to the relatively low occurrence of these features in the study stream reaches (Wang *et al.*, 1996).

Kaufmann *et al.* (1999) evaluated sampling precision of stream habitat assessment methods prescribed in USEPA's Environmental Monitoring and Assessment Program (EMAP). The authors based their evaluation on comparisons of variance among streams with variance between repeat visits to the same stream for hundreds of streams surveyed in Oregon (Herlihy *et al.*, 1997) and the Mid-Atlantic region (Paulsen *et al.*, 1991). Kaufmann *et al.* (1999) reported that quantitative measures of channel morphology and riparian canopy densiometer measurements were precise. Semi-quantitative measures, such as substrate size and visual presence-absence determinations also had moderate to high precision. However, visual estimates of riparian canopy cover and in-stream fish cover tended to have low to moderate precision, and commonly used flow-dependent variables (e.g., riffle:pool ratio, width:depth ratio, etc.) tended to be imprecise (Kaufmann *et al.*, 1999).

Bauer and Ralph (2001) conducted literature reviews and interviews with aquatic habitat scientists to assess the potential utility of some common physical habitat attributes as water quality criteria pursuant to Section 304(a) of the CWA. The authors' primary motive was the loss of habitat for native salmonids in the Pacific Northwest and evaluated habitat attributes as potential water quality criteria based on: 1) the attributes' relevance to biological requirements of salmonids; 2) applicability to landscape processes and the stream network; 3) responsiveness to human-caused stressors; and 4) the accuracy (bias) and precision (variability) of common measurement methods (Bauer and Ralph, 2001). Bauer and Ralph (2001) concluded that most indicators of physical stream habitat do not meet these criteria due in part to the lack of certainty in quantifying physical habitat quality and questionable reliability of assessment techniques.

Roper *et al.* (2002) evaluated observer variability (precision) in measuring or estimating 13 common physical stream attributes in central Idaho. All sampling methods originated from existing protocols, and all participants in the surveys received ten days of training prior to the surveys. The authors reported that observer variability accounted for less than 20% of the total variability for 10 of the 13 attributes. Citing Clark *et al.* (1996), Ramsey *et al.* (1992), and Kaufmann *et al.* (1999), Roper *et al.* (2002) suggest that when sampling variance is equal to or less than 20% of the total variability, then the attribute is likely to be a reliable component of a monitoring protocol. Using this criterion, percent stable banks, percent fines, and percent pools are not reliable stream monitoring variables, even when the scientists collecting the measurements are trained in appropriate methods. However, stream gradient, sinuosity, bank angle, undercut depth, percent of bank undercut, bankfull width, width:depth ratio, D50 (median riffle particle size), percent surface fine sediment in pool tails, and residual pool depth are potentially reliable monitoring variables (Roper *et al.*, 2002). It should be noted that percent surface fine sediment in pool tails and residual pool depth both exhibited an observer variability equal to 20%, and thus, fall exactly on the line demarcating reliable vs. unreliable monitoring variables.

The accuracy and precision of many commonly utilized physical stream habitat variables have been tested in a few ecoregions around the country. While the specific methods and protocols employed in these evaluations have varied, there remains significant uncertainty in the ability of numerous stream attributes to detect changes in stream habitat quality as a result of management actions, and this is exacerbated by questions surrounding the ability for assessment data to be accurately replicated. In general, the presence and degree of unified observer training, complexity of habitat classifications, and geomorphological heterogeneity of the stream (in cross-section, longitudinal section, and planform) all affect accuracy and precision of habitat assessment data. Explicit, well defined, definitions, consistent training, and quantitative methods may minimize observer variability. However, the accuracy and precision of even such commonly assessed variables as bankfull width (Johnson and Heil, 1996; Bauer and Ralph, 2001), pool:riffle ratio (Platts *et al.*, 1983; Roper and Scarnecchia, 1995; Kaufmann *et al.*, 1999; Roper *et al.*, 2002), and substrate embeddedness (Platts *et al.*, 1983; Wang *et al.*, 1996), which are often perceived as quantitative variables, has proven uncertain in many field evaluations.

3.4 The Utility of Stream Classification

The task of describing or monitoring physical stream attributes must be preceded by efforts to minimize the natural variability of these attributes. Gauch (1982) succinctly and simply notes that “classification basically involves grouping similar entities together.” Stream classification reduces the natural variability among streams such that adverse impacts and loss of stream habitat and stream function can more easily be identified and addressed. Classification also allows for professionals in various disciplines to communicate more effectively by being able to assume certain characteristics of an object based on its classification (Newson *et al.*, 1998).

The variety and complexity of stream ecosystems has led to a profusion of fluvial classification schemes (Hawkes, 1975; Mosley, 1987). While regional classification schemes may be most descriptive of a region’s fluvial resources and thereby reduce the variability among stream variables to the maximum extent feasible, Montgomery and Buffington (1997) note that proliferation of regional classifications may impede rather than enhance communication and understanding.

Although there are numerous stream classifications in the United States, those developed by Rosgen (1994) and Montgomery and Buffington (1993; 1997) are perhaps the most widely used. The Rosgen classification is based on channel morphology and uses a hierarchical key to demarcate 94 stream types based on specified ranges of quantitative variables, including entrenchment ratio, bankfull width:depth ratio, channel sinuosity, gradient, and dominant substrate. The Rosgen classification can be used to identify stream types in a wide range of settings, and if utilized concurrent with an understanding of channel evolution models (e.g., Simon, 1989; Rosgen, 1996) can also suggest patterns of channel response to perturbation.

The Montgomery-Buffington classification is also based on channel reach morphology, but is applicable only to high gradient (mountain) drainage basins (Montgomery and Buffington, 1997). Montgomery and Buffington (1997) describe their classification as a “process-based alternative to channel assessments based solely on descriptive typologic classification.” Seven channel types are defined based on qualitative morphological characteristics, principally channel-bed morphology. While the authors include descriptions of “typical” or “dominant” stream variables, such as gradient, valley type, confinement, and width:depth ratios, they do not define stream classes based on defined ranges of these variables. Montgomery and Buffington (1997) stress sediment supply and transport capacity as formative elements to consider when evaluating a channel’s potential response to changes in sediment supply or discharge.

Kondolf (1995) notes that channel classification can be a useful tool in stream restoration programs by 1) providing a framework within which to survey existing conditions and set restoration priorities; 2) defining restoration objectives; and 3) identifying conceptual restoration measures likely to succeed in a given channel. However, he also warns that stream classifications also have limitations in fluvial restoration, especially when poorly trained professionals assume that classifications ascribe rigid values or limits for stream characteristics, and design projects without considering the unique, site-specific factors affecting channel morphology (Kondolf, 1995).

4.0 STREAM ASSESSMENT PROTOCOL QUESTIONNAIRE

4.1 Objective of the Stream Assessment Protocol Questionnaire

We wished to consult practitioners in the field who are actually executing stream assessments in order to ascertain how stream assessments are being used nationwide, what components are most commonly incorporated, and which methods are most popular. We developed a questionnaire based largely on a turbidity questionnaire compiled by Pruitt (2003), that included a brief explanatory introduction to the project and 28 questions in four general categories related to the application of stream assessment protocols or methods in the field (Appendix A). Seven questions addressed the general utility of stream assessments and sought information on such matters as applicable scale, programmatic uses, and targeted objectives. Eight questions concerned assessment technologies, and sought specific information about stream classifications, individual methods being used, use of reference data, etc. Nine questions concerned data reduction and synthesis, including use or development of correlations, efforts to minimize observer bias, and training requirements. The last category of questions asked potential respondents about future needs for either technical, programmatic, or data management issues pertinent to stream assessment.

The questionnaire was delivered electronically to representatives of 11 Federal agencies and all 50 States. A total of 220 individuals were provided the questionnaire, including 120 Federal employees and 100 State employees. However, in many cases, individuals within specific agencies further distributed the questionnaire internally, thus providing a wider and indiscernible distribution. Distribution of the questionnaire includes persons, departments, and agencies whose primary responsibility included ambient monitoring, water quality standards, and/or regulatory matters pursuant to Sections 401 and 404 of the CWA. Our hope was to obtain feedback from as many different programs with as varied a geographic distribution as possible.

4.2 Questionnaire Results

We received 48 responses (22% response rate) to the Stream Assessment Protocol questionnaire from 9 Federal agencies, 20 State agencies in 18 States, and 1 municipality (Table 1). Twenty six respondents (54%) were employees of federal agencies, 21 (44%) were representatives of state agencies, and a single response (2%) was received from the City of Charlotte, North Carolina. The geographic distribution of respondents covered much of the nation. We received somewhat elevated concentrations of responses from the southeastern and mid-Atlantic regions of the country, and relatively few responses were received from the arid Southwest, Upper Mid-West, and Northern Great Plains states (Figure 1).

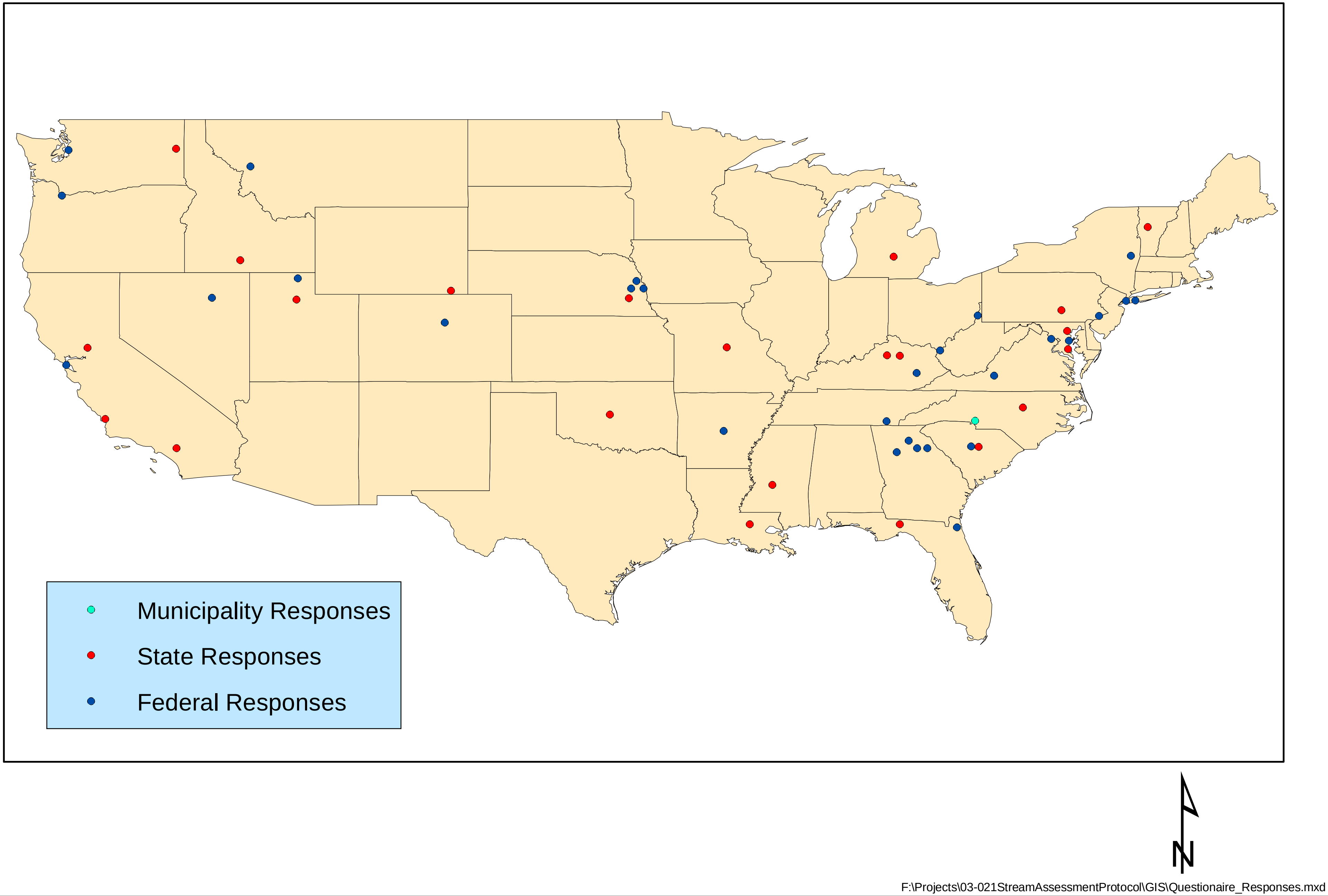

Figure 1. Geographic distribution of respondents to the Stream Assessment Protocol questionnaire.

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4.2.1 General Utility of Stream Assessments

The vast majority of respondents (83%) employ stream assessments on the stream-reach scale. In addition, 60% of respondents said that watershed-scale stream assessments were undertaken by either themselves or their agency, and slightly over 20% indicated that broader regional scale assessments (e.g. ecoregions) were important to their respective agencies.

The range of objectives for stream assessments reported by the questionnaire respondents reflects their wide range of programmatic responsibilities (Table 2). Forty-percent of respondents noted that CWA Section 401/404 regulatory permitting is a potential use of their stream assessment protocols, and eleven respondents (23%) indicated that this was their primary programmatic responsibility. We received a number of responses from persons or agencies with prominent land and resource management roles (e.g., USFS, BLM), and most of the responding state agency representatives work in water quality ambient monitoring programs and/or standards programs. As a result, watershed assessment (69%) and assessment of environmental impacts (66%) were the most frequently cited programmatic uses of stream assessments (Table 2). Approximately 65% of respondents also reported that stream assessments were used to aid prioritization of watersheds for preservation, enhancement, or restoration. Numerous respondents also noted other programmatic uses for stream assessments, including assessment of cumulative impacts, prioritization and design of stream restoration projects, post-construction restoration monitoring, use in floodplain and/or flood hazard programs, and hydraulic design of structures such as bridges.

4.2.2 Overview of Responses to Technical Questions

4.2.2.1 Stream Classification

Classification of inherently complex and variable systems or objects is often used to minimize the natural variability of subjects under study by aggregating them into classes based on similarities. Stream classifications were discussed in Section 2.4 of this report. We asked the respondents which stream classification(s) they presently used. While we were seeking information concerning stream classification as a tool to stratify assessment efforts, the responses suggest that the intent of our question was not entirely clear. Approximately 31% of respondents either failed to answer this question, or did so with an answer that suggests the question was poorly worded or simply misunderstood. Slightly less than one-half of total respondents (48%) reported that stream classification is either a component of or precursor to stream assessment. In contrast, 21% of respondents indicated that no stream classification is used in their programs. Among those respondents reporting the use of classification, 77% utilize the Rosgen stream classification (Rosgen, 1994; 1996), 11% use the classification developed by Montgomery and Buffington (1993; 1997), and the remainder utilize a variety of other classifications, including Strahler (1952) and Cowardin *et al.* (1979).

4.2.2.2 Specific Parameters and Methods

We sought information concerning specific parameters included in stream assessments, as well as the methods used to evaluate those parameters. Physical assessment parameters included geomorphological variables, bank stability variables, etc. We also inquired about physiochemical parameters to see if respondents augment physical and habitat assessments with common water quality parameters. Finally, we specifically asked about habitat classification and assessment emphasizing stream habitat units, such as pools, riffles, over-hanging vegetation, etc.

4.2.2.2.1 Physical Stream Assessment Variables

Respondents noted a number of different physical stream assessment variables and methods. Although a few variables were more common than others and geomorphological parameters outweighed habitat variables, there was no single ubiquitous variable commonly cited by questionnaire respondents (Table 3).

Many variables or methods that were cited are in fact constituent parts of other methods that were also cited. For example, Rosgen assessment methods (Rosgen, 1996; 2001a) (No. 17) were commonly noted by questionnaire respondents (27%). However, the “Rosgen method” includes a number of different methods, and could in this respect perhaps better be considered a protocol. The Rosgen method (Rosgen, 1996; 2001a) is fundamentally a procedure for characterizing and describing stream geomorphological characteristics by incorporating measures of entrenchment, hydraulic geometry (based on channel cross-sections), sinuosity, channel materials (substrate), and channel slope (based on longitudinal profiles).

Rosgen (2001b) reiterates a bank erosion hazard index (BEHI) as a method for estimating the susceptibility for streambank erosion, and Rosgen (2001a) incorporates BEHI into a larger channel stability assessment methodology. Thus, “Rosgen methods” include many of the individual physical stream assessment parameters cited by questionnaire respondents, including those who did not specifically cite Rosgen methods (e.g., BEHI, cross-sectional surveys, pebble counts, etc.) (Table 3).

Channel cross-sectional surveys and longitudinal (thalweg) profiles were also frequently cited by questionnaire respondents (29% and 27%, respectively). However, these are components not only of Rosgen’s assessment methodology, but also numerous other protocols.

4.2.2.2.2 Physiochemical Parameters

Background physiochemical conditions vary across the country for a variety of reasons including, but not limited to, geology, climate, land use, land cover, and disturbance history. This variability may be subtle or quite profound. Background physiochemical conditions may change gradually across relatively large-scale geographic areas, or they may occur quite abruptly with changes in altitude, aspect, or geologic conditions. While physiochemical parameters are most often components of biological sampling protocols, we elected to incorporate them in the questionnaire in recognition that many stream assessment protocols in use nationwide are either used or were developed primarily as biomonitoring tools. In addition, some physiochemical parameters have been incorporated into stream assessment protocols designed explicitly for use in the CWA 401/404 program (e.g. Eastern Kentucky Stream Assessment Protocol (Sparks *et al.*, 2002a,b)) (No. 9).

Six respondents to the questionnaire failed to answer our question regarding physiochemical parameters in stream assessments. Of those respondents who did answer this question, another six (14%) indicated that no such parameters were included in their assessment protocols (Table 4). Water temperature was clearly the most common physiochemical parameter cited by respondents (60%). Additionally, over one-third of respondents also cited turbidity, pH, dissolved oxygen, and specific conductivity as important physiochemical parameters included in their respective stream assessments (Table 4).

4.2.2.2.3 Habitat Classification and Assessment Variables

Habitat classification and assessment is an integral part of most biological and physical stream assessment protocols. However, as described in Section 2.3 of this report, there is some disagreement concerning the accuracy and utility of many habitat classification and assessment methods due in part to the inherent complexity of these stream features, the high potential for observer bias, and the lack of repeatability (precision) for many habitat classification methods. Four respondents failed to answer the question seeking information about habitat classification and assessment in the questionnaire. Of those who did respond, four persons (9%) indicated that such exercises were not applicable to their assessment protocols, and four more respondents (9%) indicated that no habitat classification or assessment method was incorporated into their protocols.

The stream habitat assessment included in the USEPA Rapid Bioassessment Protocols (RBPs), or modifications thereof, was the most widely cited habitat classification and assessment protocol and was noted by 18 respondents (38%). No other single habitat assessment method or protocol was noted by more than two respondents. Fifteen respondents (31%) indicated that their agency or department utilized a habitat classification and assessment method developed in-house to suit its particular objectives. Thus, aside from the prevailing dominance of the RBP habitat assessment method, respondents to our questionnaire suggest that state and federal agencies use a myriad of different habitat classification and assessment methodologies, each tailored to the specific objectives and/or conditions commonly experienced by these entities.

4.2.2.3 Use of Reference Reach Conditions

Twenty-seven of the respondents (56%) reported that reference reaches are incorporated into their stream assessment protocols, and another three respondents (6%) indicated that reference reaches were sometimes, but not always, utilized. Of the 27 respondents who affirmed the consistent use of reference reaches, ten of them did not specify the types of parameters for which reference reaches are utilized. Fourteen of the other 17 respondents indicated that reference reaches were typically used for biological parameters. Only nine respondents incorporate physical/geomorphological reference reaches, and even fewer (three) include chemical reference.

4.2.2.4 Bankfull Stage or Discharge

Twenty respondents (42%) do not incorporate measures of bankfull stage or discharge into their stream assessment protocols. Twenty-one respondents (44%) reported incorporating bankfull stage or discharge regularly, and another seven (15%) indicated that they sometimes collect bankfull information. However, discerning the means by which the respondents obtain bankfull stage or discharge data is in many ways convoluted by the same factors described previously in the summary of responses for physical stream assessment variables.

Specifically, eight respondents (17%) reported utilizing Rosgen methods to determine bankfull stage or discharge. However, Rosgen (1996) lists a number of methods applicable for obtaining bankfull information, including field indicators (cited by another 13% of respondents), gauging station records (cited by 10%), and regional hydraulic curves (cited by 10%). Other methods for determining bankfull stage reported by respondents included the minimum width/depth ratio, NRCS curve numbers, Dunne and Leopold (1978), USFS methods (Harrelson *et al.*, 1994), and EMAP methods (Kaufmann and Robison, 1998). Further confounding efforts to identify the most frequently used methods to assess bankfull stage among respondents is the fact that Dunne and Leopold (1978), Harrelson *et al.* (1994), and Rosgen (1996) all reference many of the same field indicators of bankfull stage, and in some cases outline the same methods for utilizing such tools as stream gauging station records and regional curves.

4.2.3 Overview of Responses Related to Data Reduction and Synthesis

Effective policy decisions and stream restoration planning and implementation must be based on sound objective data collected not only from the proposed project stream, but also from appropriate reference stream reaches (NRC, 1992; Kaufmann *et al.*, 1999). Embedded within this fundamental position are the concepts of accuracy (bias) and precision (variability) in stream assessment, which were discussed in Section 2.3 of this report. We posed a number of questions pertaining to reduction and synthesis of stream assessment data, with particular interest aimed at respondents' perceptions of data quality, utility, accuracy, and level of effort required for their respective stream assessment protocols.

4.2.3.1 Categorization of Stream Assessment Data

Respondents were asked to assess their stream assessment methods as quantitative, semi-quantitative, or qualitative, and to identify which components of their protocols fit into each category if more than one is applicable. As a general matter, we assumed that quantitative measures are generally more accurate (less opportunity for observer bias) and more precise (less variability among practitioners) than subjective assessments, although in hindsight we recognize that this assumption may not always be valid.

Five respondents failed to answer this question on the questionnaire. Most of the 43 respondents who did answer the question indicated that stream assessment protocols generally include elements in all three data categories. Unfortunately, 26 of these respondents (54% total) did not identify specific components of their protocols that they consider applicable to each category. Among the 17 respondents who did identify specific quantitative, semi-quantitative, and qualitative components of their stream assessment protocols, geomorphic surveys and physiochemcial water quality data were almost unanimously considered quantitative data. The only exceptions were two respondents who considered geomorphic surveys semi-quantitative. Pebble counts and macroinvertebrate sampling were evenly divided among those who considered them quantitative and semi-quantitative. Respondents' perceptions of habitat surveys, including the USEPA RBP habitat assessment, were divided. Three respondents considered them quantitative, four respondents considered them semi-quantitative, and five noted that habitat assessments are qualitative. Our data did not allows us to associate a particular respondent's perception of habitat surveys with visual-based habitat assessments versus transect-based habitat assessments.

4.2.3.2 Relationships Among Stream Assessment Variables

Over one-half of respondents (56%) are evaluating correlations or correspondence between physical stream assessment variables and aquatic biota, including 20 respondents who reported having identified such correlations and another 7 who indicated that these analyses were in process. Six respondents(13%) failed to answer this question, and another 15 respondents (31%) indicated that no such correlations or correspondence had been made based on stream assessment data in their respective programs. The correlation most commonly cited by respondents related habitat assessment (e.g., RBP) with benthic macroinvertebrates. Other examples of relationships either developed or being investigated included sediment with fish community assemblages, water quality with benthic macroinvertebrates, riparian zone condition with stream biota, and even habitat quality and benthic macroinvertebrates with land use history.

4.2.3.3 Integration of Riparian Zones and Streams

Following its evaluation of aquatic ecosystem restoration in the United States, the NRC noted that stream and river restoration would be greatly enhanced by assessing, designing, and monitoring such projects as systems integrated with the surrounding landscape. "Chief among conceptual limitations on both management and restoration of fluvial systems is the failure to consider the stream and its riparian zone or the river and its floodplain as components of one ecosystem," (NRC, 1992; p. 231).

We asked questionnaire recipients if stream assessments had been integrated with adjacent wetlands or riparian zones. Five respondents failed to answer this question. Twenty-six of the remaining respondents (54%) indicated that integration of stream and riparian zone conditions was absent from their assessment protocols. Only one-third of respondents (33%) reported that riparian zones were integral to their stream assessment protocols.

4.2.3.4 Seasonal Variability

Variability of stream assessments was discussed in Section 2.3, and is affected by the assessment procedure itself, the person executing the assessment, and the site specific conditions where the assessment is taking place. We asked if questionnaire recipients had observed seasonal variability in stream assessments. Eleven respondents (23%) failed to answer this question, and an additional four respondents indicated that seasonal variability had not been evaluated. Of the remaining 33 respondents, 22 reported that seasonal variation was a concern that was often mitigated by sampling only during certain times of year. Eleven respondents indicated that seasonal variation was not a concern or had not been noticed. Although we did not specifically ask about causes of seasonal variability, some respondents volunteered this information and most of these cited changes in hydrological conditions (discharge) as the primary seasonal factor affecting stream assessment data.

4.2.3.5 Minimizing Observer Bias

Recognizing that observer bias is a frequent source of variation in stream assessment results, we sought information concerning methods to reduce or minimize observer variability. Eight respondents (17%) failed to answer this question.

There were a number of activities cited by respondents to reduce observer variability (Table 5), and most respondents cited more than one. Over one-half of the 40 respondents who answered this question noted that training was integral to their stream assessment programs, and some respondents also offered that this training was undertaken annually. Other common means cited by respondents to reduce observer variability included the use of standardized protocols and the use of teams (often interdisciplinary) to perform the assessments. Using consistent team members or team leaders was cited by six respondents, and repeat visits to re-assess the same site was cited by another five respondents (Table 5).

4.2.3.6 Training

Numerous investigations have illustrated the benefit that observer training as on the precision of stream assessments. We asked questionnaire recipients to subjectively rate the level of training required to properly execute their assessment protocol as high, medium, or low. Eight respondents (17%) failed to answer this question. Three respondents (6%) indicated that no training was necessary, and another three respondents (6%) noted that the level of training was variable, dependant on the objectives of the study, the size of the assessment reach, or the specific methods used (e.g., channel cross-sections vs. RBP).

Fourteen (29%) respondents reported that a high level of training was necessary to properly execute the assessment methodology used by their respective agency or department. Seven respondents (15%) indicated that a medium-high level of training was required, eight (17%) noted that a medium level of training was necessary, and five respondents (10%) considered their protocol’s training needs as low.

More than one respondent opined that subjective, visual-based assessment protocols require a greater level of training to properly execute and interpret than quantitative protocols. In hindsight, we agree with these respondents and regret that we cited examples of quantitative methods to illustrate “high” levels of training required, and “descriptive” methods as exemplifying low-level training requirements in our questionnaire.

4.2.3.7 Level of Effort

We sought information concerning the level of effort required for each protocol by asking for the typical amount of time required to complete the assessment both in the field and in the office. We arbitrarily defined five levels: 1) <15 minutes; 2) <30 minutes; 3) 30-59 minutes; 4) 1-2 hours; and 5) >2 hours. Nine respondents (19%) failed to answer this question, and three additional respondents failed to answer it in its entirety.

Twenty-seven respondents (56%) indicated that stream assessments required at least 1 hour in the field (Table 6), and 13 of these respondents noted that assessment required greater than 2 hours to complete in the field. Six respondents reported that 30-59 minutes in the field was sufficient, and another six respondents indicated that time in the field was variable.

Approximately 33% of respondents reported that over 2 hours of office work was required for each stream assessment. Other respondents were essentially evenly divided among four other categories of office work required: 1) <30 minutes; 2) 30-59 minutes; 3) 1-2 hours; and 4) "variable," (Table 6).

4.2.4 Future Needs for Stream Assessments

Finally, we sought input from professionals in the field to identify desired future needs that would enhance the collection and/or management of stream assessment data. We also solicited opinions regarding the utility of national or regional database warehouses and appropriate entities to manage such compilations of data.

Respondents' opinions on future needs varied considerably. This was not unexpected given the broad cross-section of disciplines to whom the questionnaire was sent. The most common technological need cited by respondents (48%) concerned issues related to fluvial sediment and bedload transport. Specific sediment related concerns included 1) effects of sediment on biota and recovery times following degradation; 2) rapid and accurate means of measuring fluvial sediment; 3) regional turbidity relationships; and 4) availability of sediment rating curves. Expanded availability of regional hydraulic curves was the second most common technical data request cited by respondents (15%). A number of respondents (17%) expressed a desire for continued or expanded data availability from USGS stream gauging stations. Other technical concerns included a desire for better methods and availability of remote sensing tools, assessment techniques for small headwater (intermittent) streams, assessment techniques for large unwadable rivers, and correlations of riparian zone attributes with stream quality.

Approximately 19% of respondents cited a need for standardized protocols to facilitate comparison of data from disparate sources. A few respondents (4%) indicated that any protocol, existing or proposed, should be subject to rigorous testing, and this data should be made widely available to professionals in the field. While some respondents advocated for rapidity of stream assessment protocols (10%), others expressed the need for quantitative measures in order to enhance precision (4%). One respondent suggested incorporating quantitative measures, including variables to assess geomorphology, into the stream habitat assessment component of the USEPA RBP. Some respondents advocated for regionalization of assessment protocols, while still others expressed a desire to have "universal protocols" applicable in a wide range of settings. Regardless of the components of assessment protocols, training was cited by over 10% of questionnaire respondents as a desired future need.

Over 56% of respondents believed that a national stream assessment database would facilitate communication and education. Over 12% of respondents suggested that such a database should be available over the internet, and nearly 30% of respondents opined that USEPA would be the best agency to store and manage a national stream assessment database. Other recommendations for stream assessment database management included USGS (19%), USACE (4%), and USFS (2%). Over 8% of respondents openly questioned the utility of a national stream assessment database.

5.0 STREAM ASSESSMENT PROTOCOLS

5.1 Existing Protocol Reviews

The myriad of influences on stream structure and function and the complexity of physical, biological, and chemical interactions in stream ecosystems has both fostered and confounded efforts to develop stream assessment protocols. Annotated reviews of stream assessment methods and protocols have been compiled by Johnson *et al.* (2001) and NRCS (2001). Johnson *et al.* (2001) reviewed 429 protocols for obtaining field, laboratory, and office-based data relevant to salmonid conservation and habitat restoration in the Pacific Northwest. The authors ultimately recommend 68 of these protocols for use by volunteers and 93 for use by research and resource management professionals. Recommended protocols encompass a range of variables including physiochemical parameters (e.g. temperature, turbidity, etc.), biological parameters (e.g., fish community assemblage, periphyton, etc.), morphological parameters (e.g., bankfull width and depth, bank stability, etc.), and physical habitat parameters (e.g., bank and shoreline cover, substrate embeddedness, etc.) (Johnson *et al.*, 2001).

NRCS (2001) compiled 36 “notable stream corridor inventory and assessment techniques” suitable for local conservation programs to help land managers, stakeholders, and land owners select appropriate techniques to answer questions about stream corridor conditions. This review included not only stream assessment protocols, but also riparian and wetland assessment techniques. NRCS (2001) provides descriptive ratings to indicate the setting, sampling intensity, level of effort, expertise required, type of measure, and need for reference condition assessment for each protocol.

Many, but certainly not all, of the protocols included in the above referenced reviews are also included in this report. Special attention for this review was placed on the potential utility of the assessment procedures in the CWA Section 404 program where the need for rapid yet accurate and repeatable stream assessment must be evaluated alongside the responsibility and potential scrutiny commensurate with federal regulation of public resources. Despite that Johnson *et al.* (2001) and NRCS (2001) do not specifically reference the CWA 404 program, many of the protocols reviewed by the authors could be utilized in this capacity. Both reviews are excellent resources worthy of consultation by regulators, stream assessment and restoration practitioners, and resource managers.

5.2 Protocol Review Procedures

We compiled information pertaining to 51 complete or draft stream assessment protocols via a combination of literature reviews, internet searches, and interviews with personnel from a variety of state and federal agencies nationwide. Sixteen protocols are specifically for use in the CWA Section 401/404 regulatory program. An additional 35 protocols, developed by State, Federal, or municipal agencies throughout the nation, are intended to assess stream conditions for a variety of other purposes.

As referenced previously in this report, we limited our scope to assessment protocols focused primarily on the physical (geomorphological and habitat) assessment of fluvial systems as opposed to biological assessments. We did however, include a few physical stream habitat assessment procedures from primarily bioassessment protocols where we believed that the protocol either included combinations of physical stream variables particularly suited for typical CWA Section 404 project evaluations, and/or exemplified good combinations of rapidity and objective measures of stream habitat.

We reviewed a number of programmatic attributes of the protocols, including their target resource type, geographical applicability, need for reference conditions, and adaptability for use outside of intended target areas. Typically, reference conditions are assessed from a nearby stream that has been relatively free from disturbance. Reference data provides a means to assess the departure of the project stream from “least disturbed,” stable conditions capable of being supported by the watershed given current climatic and land use conditions. However, one should also recognize that the physical and biological characteristics of a stream may be relict conditions indicative of adverse impacts due to past land uses no longer evident in the watershed (Harding *et al.*, 1998). Reference data may also help identify design standards for restoration, success criteria, or monitoring variables.

Some stream assessment protocols that utilize indices of stream quality based on estimated or measured stream variables may be internally calibrated to reference conditions defined by reference streams sampled from throughout a particular region. However, even in such cases, it is advisable to collect reference reach data from one or more nearby streams to account for those variables that the index may not adequately describe.

We also considered a number of technical attributes of each protocol in order to subjectively assess their potential utility in the CWA Section 404 program. We identified whether each assessment was based on qualitative, semi-quantitative, or quantitative data. We also recorded the output of each assessment protocol as either a stream quality index value (e.g. 0 to 1.0), a compilation or tabulation of data, or categorical / descriptive summaries.

We qualitatively ranked the degree to which each protocol documents geomorphological characteristics and physical stream habitat characteristics, including the riparian zone. A ranking of 0 indicates that the protocol does not address the attribute, whereas a ranking of 5 indicates that the protocol results in complete objective documentation of the respective element. This level of documentation should be based on accurate, repeatable measures encompassing the entire fluvial corridor, and if undertaken on a suitable reference reach would also support design of a stream enhancement or restoration project, selection of performance criteria, and identification of the most applicable post-construction monitoring variables.

We similarly ranked the requisite level of effort and level of expertise required to execute an assessment, and the likely precision (repeatability) of assessments completed according to each protocol. These rankings also range from 0 (lowest) to 5 (highest), and were based solely on interpretation of the primary documentation for each protocol. We recognize that there may be additional guidance or instruction developed for some protocols subsequent to publication of the primary document. We also acknowledge that appropriate training for any protocol likely reduces variance among observers. However, in the absence of a licensing program or some other mandatory training requirement, applications for CWA Section 404 permits will continue to be submitted by consultants and permit applicants with a wide range of expertise and background. Similarly, the diligence with which permit applicants seek all available information, instruction, or guidance about any given protocol will vary. Therefore, the degree to which the primary documentation of an assessment protocol provides well defined procedures and objective measures or estimates for target assessment variables is critical in the evaluation of any given protocol's potential utility in the CWA Section 404 program.

Finally, we subjectively rated the overall programmatic suitability of each protocol for use in the CWA Section 404 program. This ranking is based on all of the previously discussed factors, and is therefore a qualitative index that considers the level of geomorphic and habitat data provided, level of effort and expertise required, and objectivity (and presumably precision) of the protocol.

5.3 Clean Water Act Section 404/401 Regulatory Protocols

Stream assessment and mitigation protocols designed specifically for use in the CWA 401/404 regulatory program typically include a number of elements that may not be addressed by other stream assessment protocols. These may include specific requirements for reference reach data, mitigation (restoration) success criteria, and post-construction monitoring criteria. While some of these elements may be addressed by non-regulatory protocols designed for use in fluvial restoration programs, they are equally likely to be absent from protocols intended to be used as inventory or ambient monitoring tools.

Regulatory assessment protocols also often include "value" factors that enable locally important aquatic resource priorities to be preferentially reviewed by permitting agencies who may require greater compensatory mitigation for impacts to these resources and/or allocate greater mitigation credit for projects that restore or enhance them. Examples include impacts or mitigation in water supply watersheds, impaired water bodies (303(d) List; TMDL), or waters with plant or animal species of special concern.

We reviewed 16 stream assessment and mitigation protocols developed specifically for either the CWA Section 401/404 regulatory program or local ordinances with similar permitting and mitigation requirements. Eight of these regulatory protocols come from the southeastern part of the country, two each from the Northeast, Great Plains, and Pacific Northwest, and one protocol each from the Mid-Atlantic and Upper Midwest (Table 7a). Brief summaries of these protocols are contained in Appendix B of this report.

Nine of the above referenced protocols were developed by USACE District offices independently or in conjunction with other local, state, or federal natural resources agencies. Most of the remaining protocols were developed independently by either state agencies or local government. One protocol, Guidelines for Natural Stream Channel Design for Pennsylvania Waterways (No. 12), was compiled by a consortium of government and non-government entities, but is reportedly utilized by state and federal regulatory agencies in Pennsylvania.

The State of Ohio, Environmental Protection Agency (OEPA) is currently developing a stream mitigation rule, which would presumably also include or initiate development of stream mitigation guidelines for Ohio. According to OEPA, several approaches to standardize evaluation of proposed project impacts are being evaluated and the appropriate mitigation steps for those impacts are being determined. To date, initial approaches are being based on a method developed by the USACE Savannah District (No. 6).

The Washington Department of Fish and Wildlife is currently developing stream habitat restoration guidelines that will reportedly include sections devoted to such topics as habitat assessment, problem identification, various in-channel, off-channel, and riparian habitat enhancement and restoration techniques. Appendices will include information pursuant to technical evaluation, regulatory permitting, monitoring. We have no reason to believe that this effort is being undertaken explicitly to support any specific state or federal regulatory program, but as with the ADEQ geomorphology research, the potential utility of this effort in the Section 401/404 program is worthy of review.

5.3.1 Federal Regulatory Protocol Reviews

In Autumn 2003, USEPA and USACE released an undated Memorandum to the Field titled the *Multi-Agency Compensatory Mitigation Plan Checklist,* which was intended "as a technical guide for CWA Section 404 permit applicants preparing compensatory mitigation plans," (USACE and USEPA, undated). The Checklist does not include or reference specific technical methods to assess streams or wetlands, but it does provide brief descriptions of the types of information that should be submitted to the USACE with a CWA Section 404 permit application. The Checklist specifically notes that aquatic resource types and functions should be described and quantified [emphasis added]. The Checklist also indicates that resource classification should be included as part of the documentation of baseline conditions, and it references the Rosgen classification for streams. Existing hydrology (e.g., watershed size, hydroperiod, water quality analysis, etc.), vegetation characteristics (e.g., speciation, percent cover, strata, etc.), soils information, historic and current land use, and watershed context are among the factors to be considered during site assessment.

In addition, on October 29, 2003, USACE released a Memorandum to the Field titled, *Model "Operational Guidelines for Creating or Restoring Wetlands that are Ecologically Self-Sustaining" for Aquatic Resource Impacts Under the Corps Regulatory Program Pursuant to Section 404 of the Clean Water Act and Section 10 of the Rivers and Harbors Act* (USACE, 2003). USACE (2003) included a document titled *Incorporating the National Research Council's Mitigation Guidelines into the Clean Water Act Section 404 Program.* The latter document provides recommendations for incorporating NRC guidelines (NRC, 2001) to improve the planning and implementation of successful aquatic resources mitigation projects. While most of the NRC suggestions target wetland mitigation, USACE (2003) clarifies that they also pertain to restoration or enhancement of other aquatic resources under USACE jurisdiction, including streams.

Three of the nine USACE District protocols we reviewed (Nos. 1, 4, and 5) include only general guidelines such as those found in the Memoranda to the Field referenced above. We could not readily rank these protocols due to the lack of definition and detail provided in them. Without additional guidance, subjective interpretation of these protocols could possibly lead to the use of numerous methods by individual permit applicants and a wide disparity of data quality, completeness, and precision.

The other six federal regulatory protocols rely primarily on stream quality indices based on numerous stream and riparian zone variables (Table 7b). Frequently, these indices must be completed for proposed impact sites, proposed mitigation sites, and sometimes reference sites. Four of these are augmented with additional semi-quantitative or quantitative data ranging from geomorphological characterization to biological data (Table 7b).

Assessment and mitigation protocols from the USACE Savannah District (No. 6) and the USACE Charleston District (No. 14) include criteria representing both programmatic and technical considerations pertinent to the CWA Section 404 regulatory program. Subjective criteria are used to encourage mitigation projects sited in the same 8-digit HUC watershed as the impacted stream, to encourage more robust monitoring plans or levels of long-term protection for mitigation sites, or to assign greater mitigation requirements for projects with greater perceived impact (e.g., filling) relative to those with comparatively minor impact (e.g., shading with non-natural structures). Objective criteria are used to guide the technical design and evaluation of proposed stream mitigation plans. Both protocols (Nos. 6 and 14) rely upon geomorphic assessment methods proposed by Rosgen (1996; 1997) and channel evolution models, principally the model presented by Simon (1989).

Regulatory protocols from the USACE Louisville District (No. 9) and the USACE Norfolk District (No. 15) also utilize indices, but unlike Protocols Nos. 3, 6, and 14, the USACE Louisville and Norfolk District protocols are internally calibrated to reference data collected from throughout their respective regions of applicability. Selection of pertinent variables used for the *Eastern Kentucky Stream Assessment Protocol* (No. 9) was based on the discriminatory efficiency of assessment variables measured from reference streams and degraded (non-reference) streams throughout the Eastern Kentucky Coalfield. The variables used in the USACE Norfolk District *Stream Attributes Analysis* (No. 15) for the Piedmont physiographic region of Virginia were selected based on literature reviews.

The USACE Wilmington District *Stream Mitigation Guidelines* for North Carolina (No. 16), references a number of different methods to assess stream quality ranging from quantitative biological sampling, completion of a stream quality index, or via methods that are currently being developed by the North Carolina Division of Water Quality (NCDWQ) and USACE. The guidelines indicate that state and federal agencies were working on alternative stream quality assessment methods in April 2003. Pending development and adoption of final stream quality assessment methods, stream quality will be determined by the USACE Wilmington District and NCDWQ on a case-by-case basis "based on the best information that is available at the time." The Guidelines mandate that all channel restoration or enhancement work is to be based on Rosgen classification and restoration methods (Rosgen, 1994; 1996) and all stream mitigation requires reference stream reach data.

5.3.2 State and Local Regulatory Protocol Reviews

We reviewed seven regulatory protocols from Washington, Kentucky, Tennessee, Florida, Kansas, Pennsylvania, and King County, Washington. Three of these protocols rely in whole or in part on indices of stream quality (Table 7b). Only protocols from the Kentucky Division of Water (No. 7) and the Keystone Stream Team in Pennsylvania (No. 12) require quantitative assessment of stream or riparian characteristics. The *Draft Stream Mitigation Guidelines* for Kentucky (No. 7) include requirements for a Level II Rosgen geomorphic characterization (Rosgen, 1996), as well as USEPA RBP habitat assessment (Barbour *et al.*, 1999). The Kentucky Division of Water has calibrated the USEPA RBP habitat assessment to resident aquatic macroinvertebrate communities typical of reference conditions in a number Kentucky's ecoregions, and work continues to further the coverage of these assessments. The *Guidelines for Natural Stream Channel Design for Pennsylvania Waterways* (No. 12) emphasize methods of stream assessment and natural channel design proposed by Rosgen (1996), and also discusses such factors as community support, regulatory permitting requirements, and selection of qualified consultants.

We could not assign rank values for the technical aspects described in Section 3.4.1 for either the *Florida Unified Mitigation Assessment Methodology* (FUMAM) (No. 10) or the *Integrated Streambank Protection Guidelines* (ISPG) (No. 13) from the Washington State Aquatic Habitat Guidelines Program. Neither protocol provides definitive procedures for assessing the whole-stream environment. The ISPG discusses mechanisms and causes of streambank failure in great detail and provides a series of useful matrices that can be used to identify potential actions to address bank failure. However, the level and scope of assessment is not stipulated, and we could therefore not ascribe rankings to the protocol.

5.4 Non-Regulatory Protocol Reviews

In addition to the 16 regulatory protocols referenced above, we reviewed 29 non-regulatory stream assessment protocols. Twelve of these protocols are nationwide in scope, and were therefore developed without intrinsic regional stream attributes as targets. Five of the non-regulatory protocols we reviewed were developed in the Mid-Atlantic region, four each from the Upper Mid-West and Pacific Northwest, one each from the Southern Plains, Southwest, and New England, and one non-regulatory protocol from Hawaii (Table 8a). Brief summaries of these protocols are contained in Appendix C of this report.

The Arizona Department of Environmental Quality (ADEQ) is current conducting geomorphology research intended to develop reliable quantitative assessment tools for use in evaluating the functional state of streams and rivers. ADEQ is reportedly primarily evaluating existing protocols, such as those developed by the USBLM, USFS, and Rosgen (1996), for applicability, and if necessary adaptation, to best suit conditions in Arizona streams. Although ADEQ is undertaking this effort primarily in support of its water quality standards program, there may be significant utility for the results of the research in the Section 401/404 program as well.

Non-regulatory procedures typically lack the policy considerations inherent in regulatory protocols. While some may include infrastructure inventories, most focus solely on the specific physical and structural characteristics of channels and riparian zones. Fourteen of these 29 non-regulatory protocols utilize indices to summarize data and present assessment results, and some of these (e.g., Nos. 24, 27, and 41) base these indices on measured data. Twelve of the remaining 15 protocols result solely in compilations or tables of data that require interpretation. Three protocols we reviewed result only in categorical or descriptive summaries of various stream variables (Table 8b).

Two nationwide protocols, the USEPA EMAP *Physical Habitat Characterization* (Kaufmann and Robison, 1998) (No. 20) and *Methods for Evaluating Stream, Riparian, and Biotic Conditions* (Platts *et al.*, 1983) (No. 26) provide fundamentally sound, objective, quantifiable methods for assessment of physical stream conditions. Cumulatively, these procedures may be excessive for many stream assessment and mitigation projects, and the agency or practitioner recommending or utilizing these protocols may have to identify the subset of methods included therein that are most applicable to the specific project. *Stream Channel Reference Sites: An Illustrated Guide to Field Technique* (Harrelson *et al.,* 1994) (No. 38) provides an excellent overview of physical, geomorphological stream variables and their measurement in the field, but it largely lacks consideration of habitat related variables (i.e., large woody debris).

The *Idaho Beneficial Use Reconnaissance Project (BURP) Workplan* (BURP TAC, 1999) (No. 19), *Guidelines for Evaluating Fish Habitat in Wisconsin Streams* (Simonson *et al.*, 1994) (No. 24), and the *Vermont Stream Geomorphic Assessment Protocol Handbooks* (VANR, 2003) (No. 45) stand out among the non-regulatory, local or regional protocols we reviewed. Each of these protocols emphasizes objective, quantitative assessment methods and each of them also incorporates quality or condition indices.

BURP TAC (1999) recommends first stratifying streams based on ecoregion, stream order, and Rosgen stream type (Rosgen, 1994; 1996) in order to aid comparison of streams and simplify sampling procedures and then describes explicit methods for measuring stream assessment variables. Fore and Bollman (2002) propose a stream quality index based on the 10 BURP variables exhibiting the greatest discriminatory power and strong correlations with stream biota while also having minimal measurement error (bias). Simonson *et al.* (1994) incorporates not only quantified data measured from channel transects (cross-sections), but also a stream quality index based in large part on those measurements.

Neither BURP TAC (1998), nor Simonson *et al.* (1994) include requirements or recommendations for detailed geomorphologic stream variables. It is likely that additional data would be necessary in order to properly design either a channel proposed to be relocated from its current position and/or stream enhancement or restoration measures that propose to affect channel dimensions or in-stream habitat.

The Vermont Handbooks (No. 45) utilizes both the USEPA RBP habitat quality index and a rapid geomorphic assessment index to represent an overall condition and sensitivity rating for the stream reach being assessed. In contrast to BURP TAC (1998) and Simonson *et al.* (1994), VANR (2003) includes not only a physical stream assessment protocol, but also a comprehensive, quantitative geomorphic assessment protocol. The Vermont Handbooks include rationale and background information for proposed stream variables to be used for assessment, detailed descriptions of how data should be collected, and even recommends data management protocols. The Vermont Handbooks outlines a phased approach to stream assessment whereby each successive phase becomes more detailed and more data intensive. In this manner, the Vermont Handbooks are organized to first provide a broad overview of stream corridor condition and then to subsequently guide the collection of increasingly more refined data to support restoration design. Many of the geomorphological requirements stipulated in VANR (2003) mirror the methods and protocols in Rosgen (1996) (No. 17) and Harrelson *et al.* (1994) (No. 38).

Rosgen (1996) (No. 17) has become a de facto standard protocol for design of natural stream channels in many parts of the United States, and is included in whole or in part in various other assessment protocols compiled by other parties. Like Harrelson *et al.* (1994), Rosgen (1996) relies nearly exclusively on geomorphic characterization of stream channels. While this type of assessment is consistent with recommendations for stream restoration by the NRC, other prominent stream attributes (e.g., habitat features, important water quality constituents, etc.) are not emphasized. Many of the detailed geomorphological investigations described by Rosgen (1996; 2001a) are extremely labor intensive and might best be preceded by a more rapid stream channel or stream corridor assessment. Numerous stream assessment protocols we reviewed incorporate various components of Rosgen's approach (e.g., stream classification, BEHI, channel evolution sequences, etc.), and responses to the Stream Assessment questionnaire provide further evidence of the popularity of Rosgen methods throughout the nation (see Section 3.3.2).

5.5 Discussion

The expedience with which an assessment can be completed is frequently and justifiably a concern. However, the burden for an accurate characterization of stream conditions usually falls upon the permit applicant proposing to adversely affect jurisdictional waters of the U.S. and not the regulatory agencies themselves. With proper training, representatives of federal, state, or local regulatory agencies should be able to rapidly conduct adequate field review of stream assessment data provided by permit applicants. This review should focus on identifying obvious discrepancies between the data and the conditions in the field, but it need not necessarily recreate the entire suite of assessment data.

Stream assessment and mitigation protocols developed specifically for use in the regulatory program are generally combinations of policy doctrine and technical assessment. Protocols from the USACE Savannah District (No. 6), the USACE Charleston District (No. 14), and the Kentucky Division of Water (No. 7), present admirable combinations of these two facets and may provide good foundations on which to model national programmatic guidelines for stream assessment and mitigation in the CWA Section 404 program. Each of these three protocols assigns base mitigation ratios based in part on the types of activities proposed as mitigation measures. Policy considerations are also included in the designation of mitigation ratios. It should be stressed that these policy issues may not be readily transferrable outside of the respective regions or USACE Districts where they were conceptualized.

An alternative approach to determine mitigation ratios is provided by the USACE Louisville District, *Eastern Kentucky Stream Assessment Protocol* (No. 9). This assessment procedure is based solely on technical stream assessment attributes- that is, there are no policy considerations in the assessment. Stream attributes are used to determine pre-impact and predicted post-impact stream quality index values between 0 and 1.0, the difference of which is multiplied by the linear length of stream impacted to determine a "currency" (Ecological Integrity Units) that compensatory mitigation must replace. A similar exercise is undertaken for pre-mitigation and predicted post-mitigation conditions on the target mitigation site, and the necessary length of stream mitigation is simply the length that offsets (equals or exceeds) the impacts.

Non-regulatory protocols lack consideration of mitigation ratios, subjective priority areas, and most other policy features typical of regulatory protocols. Thus, adaptation or incorporation of some of these elements would be necessary in order to use a non-regulatory protocol in a regulatory context. Non-regulatory protocols from Kaufmann and Robison (1998) (No. 20), Platts *et al.* (1983) (No. 26), BURP TAC (1999) (No. 19), Simonson *et al.* (1994) (No. 24), and VANR (2003) (No. 45) include objective, quantitative measures and would provide excellent foundations from which to build a comprehensive stream assessment and mitigation regulatory protocol for the CWA Section 404 program. Protocols outlining procedures for more robust geomorphological characterization, such as Harrelson *et al.* (1994) or Rosgen (1996; 2001a) provide specific design criteria for major in-stream restoration work or channel relocations, but would perhaps be best utilized after a less intensive assessment of channel and riparian conditions. VANR (2003) presents what may be the optimal approach to physical stream assessment by providing for successively more detailed levels of assessment as one moves through the three phases outlined in the Vermont Handbooks.

We believe that stream quality indices are a useful component of stream assessment protocols for the regulatory program. While a significant proportion of the regulated public may not fully grasp the underlying differences between streams based simply on tabulated data, stream quality indices allow laymen to understand the basis of regulatory decisions that are themselves based in part on stream quality.

The USEPA RBP habitat assessment (Barbour *et al.*, 1999) (No. 30), or adaptations thereof, is arguably among the most widely utilized rapid visual-based stream quality indices in the U.S. While we believe that the RBP has great merit, we suspect that reference conditions for the RBP are not determined or utilized to the extent that Barbour and Stribling (1991) and Barbour *et al.* (1999) intended. Furthermore, like all visual-based assessments, the lack of specified methods to objectively measure and rank the assessment variables can lead to significantly diverging results dependent in part on the competence, training, and bias of the practitioner utilizing the protocol. We contend that incorporation of objective measurement-based variables in the index would improve its overall utility in the CWA Section 404 program and enhance the validity of regulatory decisions based thereon. In addition, incorporating stream classification and measures to assess stream stability into the USEPA RBP would further enhance the capacity of the index to represent as broad a depiction of stream conditions as possible.

No stream quality index can comprehensively include all pertinent stream and riparian corridor variables that warrant consideration during the planning and design of stream enhancement or restoration projects. Reduction of quantitative data to an index score reduces the resolution of that data. Thus, a preferred regulatory protocol might include not only a stream quality index, but also quantified and tabulated data, the level of which should be commensurate with the proposed impact and mitigation project.

6.0 RECOMMENDATIONS

In 1992, the National Research Council concluded that, "The increased use of quantitative descriptions of pre- and post-treatment hydrological conditions is necessary to transform fluvial restoration from an art to a science," (NRC, 1992, p.233). Nearly a decade later, the NRC again stressed that dependence on subjective, best professional judgement in the regulatory program should be minimized or replaced by science-based, rapid assessment procedures (NRC, 2001). We agree that the CWA Section 404 program should be based on the most resolute and objective information possible. To this end, we suggest that programmatically complete stream assessment protocols for use in the CWA Section 404 regulatory program should have the following characteristics:

1) Classification: Stream assessment should be preceded by classification to narrow the natural variability of physical stream variables. Classification should be based on intrinsic resource characteristics affecting the physical, chemical, and biological attributes of streams. Pertinent characteristics may span numerous scales including regional, watershed, stream reach, and site specific factors.

2) Objectivity: The assessment procedure should remove as much observer bias as possible by providing well-defined procedures for objective measures of explicitly defined stream variables.

3) Quantitative Methods: The assessment procedure should utilize quantitative measures of stream variables to the maximum extent practicable. If stream quality indices are used, they should be based on explicit values or narrowly defined ranges of quantifiable stream characteristics.

4) Fluvial Geomorphological Emphasis: Stream assessments undertaken to prioritize watersheds or stream reaches for management or aid the design of stream enhancement or restoration projects should be based on fluvial geomorphic principles. In-stream modifications undertaken in the absence of a firm understanding of hydrology and sediment transport, and the resultant implications on channel form can only lead to haphazard success at best, and may result in gross channel instability and degradation that can adversely affect the entire drainage network.

5) Data Management: Data from stream assessments should be catalogued by designated entities in each region of the country. This is especially true of reference data. Many state agencies maintain databases for ambient monitoring and designated use allocations, but this data may not always be shared or utilized by CWA Section 401/404 personnel even within the same agency. Regional or national compilations of stream assessment data would enhance the science of fluvial restoration by providing a more complete picture

of physical stream characteristics, and would thereby improve design and review of stream enhancement or restoration projects.

The proliferation of stream assessment protocols in recent years is simultaneously a testament to the varied needs of resource managers nationwide and the lack of definitive characteristics available to guide the development of such protocols. The variety of fluvial resources as affected by climatic, geologic, and other innate landscape traits nationwide makes the search for a single definitive procedure capable of serving all needs in the nationwide CWA Section 404 program unlikely and perhaps folly. However, it may be possible to develop regional protocols that capture the intrinsic nuances of stream corridors unique to various parts of the country. There are just as likely to be commonalities among such protocols as there are differences necessary to adequately represent local stream conditions.

Despite that we received very few responses to the questionnaire from the southwestern portion of the country and that we were unable to review a number of pertinent assessment protocols developed exclusively for or with a particular focus on arid to semi-arid conditions, we believe that the above referenced recommendations are applicable regardless of physiographic or climatic conditions. A fundamental emphasis on objective, quantitative methods for characterizing the fluvial geomorphic characteristics of streams provides as firm a foundation upon which to assess and manage stream and riparian resources in the desert as it does in the temperate rain forest of the Pacific Northwest. It is the reference upon which local comparisons are made that provide the foundation for placing a given stream and its habitat into regional context. Similarly, it is the specific success criteria developed on the basis of these local reference conditions that should guide the evaluation of restoration or enhancement efforts.

This is not to say that we believe that streams nationwide are the same. Nor do we contend that the most applicable assessment parameters for streams nationwide are the same. An interdisciplinary, interagency team of nationwide experts in stream assessment and mitigation could begin to identify first the common characteristics necessary of stream assessment protocols, and subsequently the regional characteristics that makes streams in different settings and geographic locations unique. This team should include not only representatives of regulatory agencies, such as USACE and USEPA, but also agencies with vast resource management experience such as USFS and USBLM. This technical committee may also benefit from the participation of representatives from selected state agencies, academia, and private parties and NGO's with experience and interest in stream assessment.

Consistent with recommendations of NRC (2001), we believe funding for and encouragement of technical training for regulatory staff and forums designed to encourage communication among agencies, regions, or districts is paramount to the continued success of the regulatory program. Appropriate training in stream assessment protocols and methods has been cited by numerous investigators as a prominent means of reducing variability as a result of observer bias (Hannaford and Resh, 1995; Roper and Scarnecchia, 1995; Hannaford *et al.*, 1997; Barbour *et al.*, 1999; Roper *et al.*, 2002). Training was also cited as a programmatic need by 44% of respondents to the Stream Assessment Protocol questionnaire.

Interaction among regulatory personnel and professionals of other affiliations and disciplines is paramount to keep the regulatory program abreast of current and emerging trends in stream assessment and restoration. National and regional organizations such as the Southeastern Water Pollution Biologists Association, Pacific Northwest Clean Water Association, American Fisheries Society, North American Benthological Society, and American Society of Civil Engineers hold annual or semi-annual meetings, conduct training courses, and/or sponsor publication of trade journals that are critical disseminators of information that can help make assessment, management, and regulatory decisions rapidly and based on the best science available.

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Table 1. Respondents of the Stream Assessment Protocol questionnaire.

Type	Respondent	Office
State Agencies	California	Regional Water Quality Control Board(s)
		Department for Water Resources
	Florida	Department for Environmental Protection
	Idaho	Department of Environmental Quality
	Kentucky	Division of Water
	Louisiana	Department of Environmental Quality
	Maryland	Department of Environment
		Department of Natural Resources
	Michigan	Department of Environmental Quality
	Mississippi	Department of Environmental Quality
	Missouri	Department of Natural Resources
	Nebraska	Department of Environmental Quality
	North Carolina	Division of Water Quality
	Oklahoma	Conservation Commission
	Pennsylvania	Department for Environmental Protection
	South Carolina	Department of Health and Environmental Control
	Utah	Department of Environmental Quality
	Vermont	Department of Environmental Conservation
	Washington	Department of Ecology
	Wyoming	Game and Fish Department
Municipality	City of Charlotte, North Carolina	

Table 1. Respondents of the Stream Assessment Protocol questionnaire (continued).

Type	Respondent	Office
Federal Agencies	U.S. Army Corps of Engineers	Huntington District
		Jacksonville District
		Little Rock District
		Louisville District
		Omaha District
		New York District
		San Francisco District
	U.S. Environmental Protection Agency	Region 2
		Region 3
		Region 4
		Region 10
	U.S. Fish and Wildlife Service	Chesapeake Bay Field Office
	U.S. Bureau of Land Management	Elko, NV Field Office
	U.S. National Oceanic and Atmospheric Administration - Fisheries	
	U.S. Geologic Survey	
	U.S.D.A. Natural Resources Conservation Service	
	U.S.D.A. Forest Service (GA, MT, SC, TN, UT, VA)	
	Federal Highways Administration	

Table 2. Programmatic uses of stream assessments cited by respondents of the Stream Assessment Protocol questionnaire.

Programmatic Uses of Stream Assessments	Number of Respondents [1]	Percent of Respondents [1]
Water quality standards or criteria	18	38%
CWA Section 401/404 regulatory permitting	19	40%
TMDL's (sediment and habitat)	16	33%
Trend monitoring (CWA 305(b))	24	50%
Watershed assessment	33	69%
Prioritizing watersheds for preservation, enhancement, or restoration	31	65%
Environmental impacts	32	66%
Assessing water resources/uses	25	52%
Correspondence with aquatic resources (habitat, water quality)	27	56%
Comparison/stratification based on stream type or class	20	42%
Other	14	29%

[1] Multiple programmatic uses of stream assessments were reported by most respondents.

Table 3. Components/Methods of physical stream assessments cited by respondents of the Stream Assessment Protocol questionnaire.

Components/Methods of Physical Stream Assessment	**Number of Respondents [1]**	**Percent of Respondents [1]**
Rosgen (Rosgen, 1996; 2001a)	11	23%
Bank Erosion Hazard Index (BEHI)	5	10%
Longitudinal (thalweg) Profile Surveys	11	23%
Channel Cross-Sectional Surveys	12	25%
Pebble Counts (e.g., Wolman, 1954)	7	15%
Stream Habitat Inventory (i.e., % pools, % riffles, etc.)	4	8%
Woody Debris Inventory	1	2%
Pfankuch Channel Stability (Pfankuch, 1975)	7	15%
Channel Evolution Model (Schumm *et al.*, 1984; see also Simon and Hupp, 1986; Simon, 1989)	3	6%
Riffle Stability Index (Kappesser, 2002)	4	8%
V* Pool (Hilton and Lisle, 1993)	2	4%
Bank Pins / Scour Chains	5	10%
USEPA EMAP / REMAP Physical Habitat Characterization (e.g. Kaufmann and Robison, 1998)	4	8%
USEPA RBP (Barbour *et al.*, 1999)	4	8%
Proper Functioning Condition (BLM, Technical Reference 1737-9, rev 1998)	3	6%

[1] Multiple components/methods of physical stream assessments were reported by most respondents. Some respondents failed to answer this question at all (see text).

Table 4. Physiochemical parameters included in stream assessments cited by respondents of the Stream Assessment Protocol questionnaire.

Physiochemical parameters	Number of Respondents [1]	Percent of Respondents [1]
Water Temperature	25	52%
Turbidity	15	31%
pH	15	31%
Dissolved Oxygen (DO)	15	31%
Specific Conductivity	14	29%
Total N	8	17%
Total P	8	17%
Total Suspended Solids (TSS)	6	13%
Total Dissolved Solids (TDS)	3	6%
Fecal Coliform Bacteria	4	8%
Oxidation-Reduction Potential (ORP)	2	4%
Sediment	2	4%
Color	1	2%
NONE (No physiochemical parameters collected.)	6	13%

[1] Multiple physiochemical parameters were reported by most respondents. Some respondents failed to answer this question at all (see text).

Table 5. Methods to reduce observer variability in stream assessment data cited by respondents of the Stream Assessment Protocol questionnaire.

Methods to Reduce Observer Variability	**Number of Respondents** [1]	**Percent of Respondents** [1]
Training (classroom and in the field)	21	44%
Use of Standardized Protocols	9	19%
Presence of Multiple Field Investigators (teams)	9	19%
Consistent Team Members of Team Leader	6	13%
Repeat Visits to the Same Site	5	10%
Use of Objective Methods (measurable parameters)	3	6%
Use of Multiple Protocols on the Same Sample Reach	2	4%
Use of Visual Aids	1	2%
None	5	10%

[1] Multiple methods to reduce observer variability were reported by most respondents. Some respondents failed to answer this question at all (see text).

Table 6. Time required to execute stream assessments in the field and in the office according to respondents of the Stream Assessment Protocol questionnaire.

Approximate Time Frame	Field		Office	
	Number of Respondents [1]	Percent of Total [1]	Number of Respondents [1]	Percent of Total [1]
<15 minutes	0	0%	1	2%
<30 minutes	1	2%	4	8%
30-59 minutes	6	13%	5	10%
1-2 hours	11	23%	4	8%
>2 hours	13	27%	16	33%
Variable	6	13%	5	10%
Other	1	2%	1	2%

[1] Some respondents failed to answer this question (see text), and three additional respondents failed to answer the question in its entirety.

Table 7a. Programmatic summary of regulatory stream assessment and mitigation protocols.

No.	Protocol Title / Author	Target Resource Type	Geographic Applicability	Reference Required	Adaptable for use Elsewhere?	Programmatic Intended Use	Performance Standards Noted (Y/N)
1	Compensatory Mitigation] Plan Review Checklist (April 2002) - USACE New England District	unstated	unstated	No	Yes	CWA 404	No
2	Critical Areas Mitigation Guidelines - King County [WA] Department of Development and Environmental Services	Wetlands, streams, lakes, buffers, steep slopes, etc.	Unincorporated King Co., WA	Yes	Yes	King Co. Code (land disturbance and building permits)	Yes
3	Draft Compensatory Stream Mitigation (Suggested Procedure) July 2002- USACE Mobile District	Perennial, intermittent, & ephemeral streams	Eastern MS; central & southern AL	Yes	Yes	CWA 404	No
4	Draft Mitigation and Monitoring Guidelines (December 2003) - USACE Rock Island District	All aquatic resources	Parts of IA, IL, WI, and MN	No	Yes	CWA 404	No
5	Draft Mitigation and Monitoring Guidelines (December 2003) - USACE Tulsa District	All aquatic resources	OK and northern TX	No	Yes	CWA 404	No
6	Draft Standard Operating Procedure for Calculating Compensatory Mitigation Requirements for Adverse Impacts to Wetlands, Open Waters, and/or Streams (July 2003)- USACE Savannah District	All aquatic resources	GA	Yes	Yes	CWA 404	Required, but not explicitly defined
7	Draft Stream Mitigation Guidelines - KY Division of Water	Intermittent and perennial streams	KY	Yes	Yes	CWA 401	Yes
8	Draft Stream Mitigation Guidelines for the State of Tennessee - TN Division of Water Pollution Control	"Streams," otherwise undefined	TN	Yes	Yes	CWA 401 / TN Water Quality Control Act	Partial
9	Eastern Kentucky Stream Assessment Protocol - USACE Louisville District	Headwater streams (1st -2nd order)	Eastern KY Coalfield physiographic region	Yes (internal calibration)	Yes	CWA 404	No
10	Florida Unified Mitigation Assessment Methodology - FL Department of Environmental Protection	All aquatic resources	FL	No	Yes	CWA 401	No
11	Guidelines for Assessing Development Project Impacts on Wildlife Habitats and Planning Mitigation Measures for Wildlife Habitat - Kansas Department of Wildlife and Parks	All terrestrial and aquatic habitats	KS	No	Yes	CWA 404/401	No
12	Guidelines for Natural Stream Channel Design for Pennsylvania Waterways - Keystone Stream Team (2003)	All streams	PA	Yes	Yes	CWA 404/401	No

Table 7a. Programmatic summary of regulatory stream assessment and mitigation protocols (continued).

No.	Protocol Title / Author	Target Resource Type	Geographic Applicability	Reference Required	Adaptable for use Elsewhere?	Programmatic Intended Use	Performance Standards Noted (Y/N)
13	Integrated Streambank Protection Guidelines - Washington State Aquatic Habitat Guidelines Program (2002)	All streams	WA	No	Yes	CWA 401/404; WA Shoreline Management Act; other State laws	Yes
14	Standard Operating Procedure: Compensatory Mitigation - USACE Charleston District	All aquatic resources	SC	Yes	Yes	CWA 404	Required, but not explicitly defined
15	Stream Attributes Analysis: Impact and Mitigation Assessment - USACE Norfolk District	Perennial and intermittent streams	VA Piedmont physiographic region	unstated (internal calibration)	Yes	CWA 404	No
16	Stream Mitigation Guidelines (April 2003) - USACE Wilmington District, NCDWQ, EPA R4, and NCWRC	Perennial and intermittent non-tidal streams	NC	Yes	Yes	CWA 404/401	Yes

Table 7b. Technical summary of regulatory stream assessment and mitigation protocols.

No.	Protocol Title / Author	Stream Attributes Assessed	Type of Assessment	Output	Morphological Assessment	Habitat Assessment	Level of Effort	Level of Expertise	Precision/ Repeatability	Overall Suitability
1	[Compensatory Mitigation] Plan Review Checklist (April 2002) - USACE New England District	None specified	- -[1]	- -	- -	- -	- -	- -	- -	- -
2	Critical Areas Mitigation Guidelines - King County [WA] Department of Development and Environmental Services	Hydrology and buffer descriptions; includes numerous descriptors for wetlands, but most are only partially applicable to streams.	Qualitative; Semi-Quantitative	Categorical or Descriptive Summaries	0.5	0.5	0.5	0.5	0.5	0.5
3	Draft Compensatory Stream Mitigation (Suggested Procedure) July 2002- USACE Mobile District	Scoring of a variable number of mostly qualitative to semi-quantitative metrics	Qualitative; Semi-Quantitative	Index	1.5	0.5	1.5	1.5	2	1
4	Draft Mitigation and Monitoring Guidelines (December 2003) - USACE Rock Island District	None specified	- -[1]	- -	- -	- -	- -	- -	- -	- -
5	Draft Mitigation and Monitoring Guidelines (December 2003) - USACE Tulsa District	None specified	- -[1]	- -	- -	- -	- -	- -	- -	- -
6	Draft Standard Operating Procedure for Calculating Compensatory Mitigation Requirements for Adverse Impacts to Wetlands, Open Waters, and/or Streams (July 2003)- USACE Savannah District	Scoring of five to six metrics ranging from qualitative ("priority area," based on special use designations) to quantitative Rosgen Level II(III) geomorphic descriptions	Qualitative, Semi-Quantitative, & Quantitative	Index; Data	5	1	3.5	3.5	3	4
7	Draft Stream Mitigation Guidelines - KY Division of Water	Geomorphic descriptions (i.e., Rosgen Level II); riparian surveys; RBP habitat assessments	Semi-Quantitative (visual estimates based on defined ranges); Quantitative	Data; Index	3.5	2.5	3	3.5	2 - 3	3.5
8	Draft Stream Mitigation Guidelines for the State of Tennessee - TN Division of Water Pollution Control	Impact and mitigation classes defined based on activities; Assessment based on RBP habitat assessment and riparian vegetation survey.	Qualitative; Semi-Quantitative	Categorical or Descriptive Summaries; Index	1	2	1.5	1.5	1	1
9	Eastern Kentucky Stream Assessment Protocol - USACE Louisville District	Biological (MBI) and Physical (spec cond & RBP habitat)	Semi-Quantitative; Quantitative	Index; Data	0.5	2	1 - 3	3 - 4	2	2

Table 7b. Technical summary of regulatory stream assessment and mitigation protocols (continued).

No.	Protocol Title / Author	Stream Attributes Assessed	Type of Assessment	Output	Morphological Assessment	Habitat Assessment	Level of Effort	Level of Expertise	Precision/ Repeatability	Overall Suitability
10	Florida Unified Mitigation Assessment Methodology - FL Department of Environmental Protection	None specified; includes only descriptions of broad ecological functions potentially performed by any aquatic resource.	- -[1]	- -	- -	- -	- -	- -	- -	- -
11	Guidelines for Assessing Development Project Impacts on Wildlife Habitats and Planning Mitigation Measures for Wildlife Habitat - Kansas Department of Wildlife and Parks	1) Physical habitat; 2) Riparian/Floodplain; 3) Biological components; and 4) Pollution components	Qualitative (visual estimates) to Semi-Quantitative (estimates, ranges)	Index	1	2	2	1.5	2	2
12	Guidelines for Natural Stream Channel Design for Pennsylvania Waterways - Keystone Stream Team (2003)	Fluvial geomorphic parameters outlined in Rosgen (1996)	Quantitative (cross-sections, profiles, etc.)	Data	5	1	3.5	3.5	3	4
13	Integrated Streambank Protection Guidelines - Washington State Aquatic Habitat Guidelines Program (2002)	Mechansims and causes of streambank failure, which can range from site-specific to stream reach-scale variables.	- -[1]	- -	- -	- -	- -	- -	- -	- -
14	Standard Operating Procedure: Compensatory Mitigation - USACE Charleston District	Scoring of a variable number of metrics ranging from qualitative ("priority category," based on special use designations) to quantitative Rosgen Level II geomorphic descriptions	Qualitative, Semi-Quantitative, & Quantitative	Index; Data	3	0.5	3	3	3	3.5
15	Stream Attributes Analysis: Impact and Mitigation Assessment - USACE Norfolk District	Six metrics scored 0 to 1.0: Riparian width, watershed development, channel incision, bank erosion, channelizarion, & in-stream habitat	Qualitative, Semi-Quantitative, & Quantitative	Index	1	1	2	2	3	2
16	Stream Mitigation Guidelines (April 2003) - USACE Wilmington District, NCDWQ, EPA R4, and NCWRC	Stream quality assessed via 1) NC State biological assessment SOP; 2) Stream Quality Assessment Worksheet; or 3) methods under development. Final determination made by USACE.	Semi-Quantitative; Quantitative	Index; Data	2 - 5	1 - 3	1 - 4	2 - 4	2 - 3	1 - 3

[1] Information provided in the document lacks specificity of assessment methods or provides such a range of potential methods that ranking the protocol is impracticable.

Table 8a. Programmatic summary of non-regulatory stream assessment and mitigation protocols.

No.	Protocol Title / Author	Target Resource Type	Geographic Applicability	Reference Required	Adaptable for Use Elsewhere?	Programmatic Intended Use	Performance Standards Noted (Y/N)
17	Applied River Morphology - (Rosgen, 1996)	All streams	Nationwide	Yes	- -	Classification; Assessment; Restoration	No
18	Basinwide Estimation of Habitat and Fish Populations in Streams - (Dolloff et al., 1993)	All streams	Nationwide	No	- -	Inventory	N/A
19	Beneficial Use Reconnaissance Project: Workplan for Wadeable Streams - Idaho Division of Environmental Quality (BURP TAC, 1999)	Wadeable streams	ID	Yes	Yes	Ambient monitoring; WQ standards	N/A
20	EMAP Physical Habitat Characterization - (Kaufmann and Robison, 1998)	Wadeable streams	Nationwide	No	- -	Ambient monitoring	N/A
21	EMAP Rapid Habitat and Visual Stream Assessments - (Lazorchak et al., 1998)	Wadeable streams	Nationwide	No	- -	Ambient monitoring	N/A
22	Fairfax County Stream Physical Assessment Protocols - Stormwater Management Branch, Fairfax County, VA (Draft, August 2002)	All streams	Fairfax Co., VA	Implied	Yes	Inventory	N/A
23	Field Evaluation Manual for Ohio's Primary Headwater Habitat Streams - OEPA, Division of Surface Water	Ohio headwater streams (<1sq.mi watershed)	OH	No (internal calibration)	No	CWA 402 (NPDES); WQ standards	N/A
24	Guidelines for Evaluating Fish Habitat in Wisconsin Streams - USFS North Central Forest Experiment Station (Simonson et al., 1994)	Perennial wadeable streams	WI and adjacent states	No (internal calibration)	Yes	Ambient monitoring; Inventory; Post-management monitoring	N/A
25	Hawaii Stream Visual Assessment Protocol, Version 1.0 - USDA NRCS Hawaii, 2001	All streams	HI	No	Yes	Inventory	N/A
26	Methods for Evaluating Stream, Riparian, and Biotic Conditions - (Platts et al., 1983)	All streams	Nationwide	No	- -	Inventory; Post-management monitoring	N/A
27	Physical Habitat and Water Chemistry Assessment Protocol for Wadeable Stream Monitoring Sites - Minnesota Pollution Control Agency (rev. 12/2002)	All streams	MN	No	Yes	Ambient monitoring; WQ standards	N/A
28	A Physical Habitat Index for Freshwater Wadeable Streams in Maryland - Maryland Department of Natural Resources (Paul et al., 2002)	Wadeable streams	MD	No (internal calibration)	Yes	Ambient monitoring; WQ standards	N/A

Table 8a. Programmatic summary of non-regulatory stream assessment and mitigation protocols (continued).

No.	Protocol Title / Author	Target Resource Type	Geographic Applicability	Reference Required	Adaptable for Use Elsewhere?	Programmatic Intended Use	Performance Standards Noted (Y/N)
29	The Qualitative Habitat Evaluation Index (QHEI): Rationale, Methods, and Application - Ohio Environmental Protection Agency (Rankin, 1989)	All streams, except the smallest headwaters (See PHHS)	OH	No (internal calibration)	Yes	WQ Standards	N/A
30	Rapid Bioassessment Protocols for Use in Wadeable Streams and Rivers, 2nd Edition - (Barbour et al., 1999)	Wadeable streams	Nationwide	Yes	- -	Ambient monitoring; Inventory	N/A
31	Rapid Stream Assessment Technique (RSAT) - Metropolitan Washington Council of Governments (Galli, 1996)	Streams in watersheds 100-150 sq.mi.	MD Piedmont physiographic region	Yes	Yes	Inventory	N/A
32	The RCE: A Riparian, Channel, and Environmental Inventory for small streams in the agricultural landscape - Petersen (1992)	Small (<3m wide), lowland streams in agricultural settings	Nationwide	No	- -	Inventory	N/A
33	Revised Methods for Characterizing Stream Habitat in the National Water-Quality Assessment Program - (1998) USGS WRI 98-4052	All streams	Nationwide	No	- -	Ambient monitoring	N/A
34	Riparian Area Management: Process for Assessing Proper Functioning Condition - USDOI BLM (Prichard et al., 1993; Prichard et al., 1998)	Streams and riparian-wetland areas	Nationwide	Implied	- -	Ambient monitoring; Resource management	N/A
35	Standard Operating Procedures for Sample Collection and Handling, Section 10.0 Physical Habitat Monitoring - New Mexico Environment Department, Surface Water Quality Bureau	Perennial and intermittent streams	NM	No	Yes	WQ Standards; TMDL; Ambient Monitoring	No
36	Stream*A*Syst: A Tool to Help You Examine Stream Conditions on Your Property - Oregon State University Extension Service (Andrews and Johnson, 2000)	All streams	OR (modified and/or adapted for use elsewhere)	No	Yes	Inventory	N/A
37	Stream and Riparian Habitats Rapid Assessment Protocol - USFWS Chesapeake Bay Field Office (Starr and McCandless, 2001)	All streams on federal lands	Chesapeake Bay watershed (VA, MD, DE, WV, PA, NY)	No	Yes	Inventory; Watershed Management	No
38	Stream Channel Reference Sites: An Illustrated Guide to Field Technique - (Harrelson et al., 1994)	All streams	Nationwide	N/A	- -	Ambient monitoring; Inventory; Post-management monitoring	N/A

Table 8a. Programmatic summary of non-regulatory stream assessment and mitigation protocols (continued).

No.	Protocol Title / Author	Target Resource Type	Geographic Applicability	Reference Required	Adaptable for Use Elsewhere?	Programmatic Intended Use	Performance Standards Noted (Y/N)
39	Stream Corridor Assessment Survey Protocols - Maryland Department of Natural Resources (Yetman, 2001)	All streams	MD	Implied	Yes	Inventory; Watershed management	N/A
40	Stream Corridor Restoration: Principles, Processes, and Practices - Federal Interagency Stream Corridor Restoration Working Group (1998)	All streams	Nationwide	Yes	- -	Restoration	Yes
41	Stream Habitat Assessment Procedures, Chapter 8 in Surface Water Quality Monitoring Procedures Manual - TNRCC (1999)	All streams	TX	No	Yes	Ambient monitoring; WQ standards	N/A
42	Stream Habitat Classification and Inventory Procedures for Northern California - (McCain et al., 1990)	Gravel & boulder bed streams	Northern CA	No	Yes	Inventory; Habitat management monitoring	N/A
43	Stream Survey Report Criteria - King County [WA] Department of Development and Environmental Services	All streams	Unincorporated King Co. WA	No	Yes	King Co. Code; Watershed & Species Management	N/A
44	Stream Visual Assessment Protocol - USDA NRCS (1998)	All streams	Nationwide	Yes	N/A	Inventory	N/A
45	[Vermont] Stream Geomorphic Assessment Protocol Handbooks - Vermont Agency of Natural Resources (May 2003)	All streams	VT	Yes	Yes	Inventory	No

Table 8b. Technical summary of non-regulatory stream assessment and mitigation protocols.

No.	Protocol Title / Author	Stream Attributes Assessed	Type of Assessment	Output	Morphological Assessment	Habitat Assessment	Level of Effort	Level of Expertise	Precision/ Repeatability	Overall Suitability
17	Applied River Morphology - (Rosgen, 1996)	Geomorphic parameters: W/D, entrenchment, sinuoisty, slope, PSD, BEHI, etc.	Quantitative	Data	5	0.5	5	4	4	3
18	Basinwide Estimation of Habitat and Fish Populations in Streams - (Dolloff et al., 1993)	Physical stream habitat units (e.g., riffles, pools, cascades), surface area, maximum depth, dominant substrate, embeddedness, coarse woody debris, etc.	Quantitative (longitudinal profile)	Data	1.5	4	3.5	3	4	2
19	Beneficial Use Reconnaissance Project: Workplan for Wadeable Streams - Idaho Division of Environmental Quality (BURP TAC, 1999)	Flow (discharge), width/depth, shade (canopy cover), bank cover and stability, substrate, habitat types, pool complexity, large woody debris, Rosgen classification, physicochemcial (temperature & conductivity)	Quantitative	Index; Data	3	3.5	4	3.5	4	3.5
20	EMAP Physical Habitat Characterization (Kaufmann and Robison, 1998)	1) Thalweg profile (depth, habitat unit types, wetted width, etc.); 2) Woody debris; 3) Channel and riparian characterization (cross-sectional dimensions, bank height, undercut, angle, channel slope, canopy density, substrate size class, etc); 4) Discharge	Quantitative (cross-sections, longitudinal profiles)	Data	3	3	4	3	4	3.5
21	EMAP Rapid Habitat and Visual Stream Assessments (Lazorchak et al., 1998)	1) Rapid habitat assessment based on USEPA RBP; 2) General stream reach and basin observations	Qualitative (visual estimates)	Categorical or Descriptive Summaries	0.5	2	1	3	1	1
22	Fairfax County Stream Physical Assessment Protocols - Stormwater Management Branch, Fairfax County, VA (Draft, August 2002)	1) Habitat assessment based on USEPA RBP, 2) geomorphic assessment (Rosgen Level I), and 3) infrastructure inventory	Qualitative, Semi-Quantitative, & Quantitative	Index; Data; Categorical or Descriptive Summaries	2	2	2.5	3	2.5	2
23	Field Evaluation Manual for Ohio's Primary Headwater Habitat Streams - OEPA, Division of Surface Water	Three-tiered protocol: 1) Headwater Habitat Evaluation Index; 2) Biological (Family-level); and 3) Biological (Genus, species-level)	Qualitative, Semi-Quantitative, & Quantitative	Index; Data	0.5	1	1 - 4	1 - 4	4.5	1 - 2

Table 8b. Technical summary of non-regulatory stream assessment and mitigation protocols (continued).

No.	Protocol Title / Author	Stream Attributes Assessed	Type of Assessment	Output	Morphological Assessment	Habitat Assessment	Level of Effort	Level of Expertise	Precision/ Repeatability	Overall Suitability
24	Guidelines for Evaluating Fish Habitat in Wisconsin Streams - USFS North Central Forest Experiment Station (Simonson et al., 1994)	Riparian land use, riparian buffer width, bank erosion, shading, habitat units, substrate, embeddedness, sediment depth, cover, width, depth, velocity, discharge, stage, water level, physicochemical parameters	Quantitative (cross-sections, longitudinal profiles)	Index; Data	3	3.5	4	3.5	4.5	3.5
25	Hawaii Stream Visual Assessment Protocol, Version 1.0 - USDA NRCS Hawaii, 2001	Subjective inventory of turbidity, plant growth, channel condition, flow alteration, embeddedness, bank stability, riparian vegetation, shading, trash/litter, etc.	Qualitative (visual estimates)	Index	0.5	1	1	1	1	1
26	Methods for Evaluating Stream, Riparian, and Biotic Conditions - (Platts et al., 1983)	Stream width, depth, discharge, gradient, percent pool, percent riffle, shading, streambank stability, bank angle, bank undercut, sinuosity, cross-sectional surveys, embeddedness, PSD, riparian conditions, and coarse woody debris	Quantitative (cross-sections, longitudinal profiles)	Data	3	4	5	4	4.5	4
27	Physical Habitat and Water Chemistry Assessment Protocol for Wadeable Stream Monitoring Sites - Minnesota Pollution Control Agency (rev. 12/2002)	Stream width, depth, embeddedness, PSD, percent algae, percent macrophytes, percent fish cover, bank erosion, riparian land use, riparian buffer width, shading, pool & riffle spacing and dimensions, physicochemical (DO, turbidity, conductivity, etc.)	Semi-Quantitative (visual estimates based on defined ranges) to Quantitative (transect-based)	Data	2	3	3.5	3	2	2.5
28	A Physical Habitat Index for Freshwater Wadeable Streams in Maryland - Maryland Department of Natural Resources (Paul et al., 2002)	Variable, depending on physiographic region; May include bank stability, in-stream wood, in-stream habitat quality, epibenthic substrate, shading, and remoteness, riffle quality, embeddedness, and/or riparian width	- -[1]	Index	0.5	3	- -	- -	- -	- -
29	The Qualitative Habitat Evaluation Index (QHEI): Rationale, Methods, and Application - Ohio Environmental Protection Agency (Rankin, 1989)	Dominant substrate type, substrate origin, embeddedness, in-stream cover types & percent coverage, channel morphology, riparian width & land use, stream depth, pool & riffle widths, depths, & substrate, current velocity	Qualitative to Semi-Quantitative (visual estimates, rapid measurements)	Index	2	2	2	2	2	2

Table 8b. Technical summary of non-regulatory stream assessment and mitigation protocols (continued).

No.	Protocol Title / Author	Stream Attributes Assessed	Type of Assessment	Output	Morphological Assessment	Habitat Assessment	Level of Effort	Level of Expertise	Precision/ Repeatability	Overall Suitability
30	Rapid Bioassessment Protocols for Use in Wadeable Streams and Rivers, 2nd Edition - (Barbour et al., 1999)	Attributes based on stream gradient (high vs. low): Epifaunal substrate/available cover, embeddedness, [pool substrate, pool variability], velocity/depth regime, sediment deposition, channel flow status, channel alteration, frequency of riffles or bends, [channel sinuosity], bank stability, vegetative bank protection, riparian width	Semi-Quantitative (visual estimates based on defined ranges)	Index	0.5	2	1	3	2	2
31	Rapid Stream Assessment Technique (RSAT) - Metropolitan Washington Council of Governments (Galli, 1996)	Channel stability (streambank erosion, bank mateials, channel shape, etc.); Scouring & Sediment Deposition (embeddedness, number and depth of pools, stability of point bars, etc.); In-stream habitat (riffle substrate, channel alteration, etc.); Water quality (TDS, clarity, etc.); Riparian conditions; Biota	Semi-Quantitative (visual estimates based on defined ranges) to Quantitative (transect-based)	Index	0.5	2	1	2	1.5	1.5
32	The RCE: A Riparian, Channel, and Environmental Inventory for small streams in the agricultural landscape - Petersen (1992)	Riparian land use, riparian buffer width, W/D ratio, large woody debris, streambank stability, occurrence/spacing of pools and riffles, relative substrate PSD	Qualitative (visual estimates)	Index	0.5	1	1	1.5	2	1
33	Revised Methods for Characterizing Stream Habitat in the National Water-Quality Assessment Program - (1998) USGS WRI 98-4052	Four different spatial scales: 1) Basin; 2) Segment; 3) Reach; and 4) Microhabitat. Reach-scale assessment includes measures of channel width, gradient, bank condition, water depth and velocity, substrate, & habitat.	Quantitative (cross-sections, longitudinal profiles)	Data	2.5	2.5	3.5	2-3	3	3
34	Riparian Area Management: Process for Assessing Proper Functioning Condition - USDOI BLM (Prichard et al., 1993; Prichard et al., 1998)	Frequency of floodplain inundation above bankfull; stability of beaver dams (if present); sinuosity, W/D ratio, and gradient; watershed characteristics; species composition, age, and structure or riparian vegetation; streambank cover; horizontal and vertical channel stability	Qualitative (visual estimates) [Quantitative methods are provided, but not required]	Categorical or Descriptive Summaries [Data]	1 - 3	0.5	1 - 3	3	0.5 - 2	1 - 2

Table 8b. Technical summary of non-regulatory stream assessment and mitigation protocols (continued).

No.	Protocol Title / Author	Stream Attributes Assessed	Type of Assessment	Output	Morphological Assessment	Habitat Assessment	Level of Effort	Level of Expertise	Precision/ Repeatability	Overall Suitability
35	Standard Operating Procedures for Sample Collection and Handling, Section 10.0 Physical Habitat Monitoring - New Mexico Environment Department, Surface Water Quality Bureau	Fluvial geomorphic parameters outlined in Rosgen (1996) and Harrelson et al. (1994); BEHI; RBP habitat assessment	Semi-Quantitative (estimates, ranges) to Quantitative	Index; Data	3.5	2	3.5 - 4	3	2	3
36	Stream*A*Syst: A Tool to Help You Examine Stream Conditions on Your Property - Oregon State University Extension Service (Andrews and Johnson, 2000)	Series of yes/no questions pertaining to pollution, algae, water clarity, barriers to fush movement, ditches, water diversion, flood control structures, riparian vegetation, etc.	Qualitative (visual estimates)	Categorical or Descriptive Summaries	0.5	0.5	0.5	0.5	4	0.5
37	Stream and Riparian Habitats Rapid Assessment Protocol - USFWS Chesapeake Bay Field Office (Starr and McCandless, 2001)	Vertical and horizontal channel stability (bank height, bank angle, sediment deposition, etc.); Riparian & in-stream habitat (in-stream cover, epifaunal cover, shading, riparian width, land use, and vegetative community, etc.)	Qualitative, Semi-Quantitative, & Quantitative	Index	1.5	1.5	2	2.5	2	1.5
38	Stream Channel Reference Sites: An Illustrated Guide to Field Technique - (Harrelson et al., 1994)	Longitudinal profile, channel cross-sectional surveys, discharge, substrate PSD, streambank material characterization, erosion rates	Quantitative (cross-sections, longitudinal profiles)	Data	4	0.5	4	2	3.5	3
39	Stream Corridor Assessment Survey Protocols - Maryland Department of Natural Resources (Yetman, 2001)	Subjective inventory of anthropogenic channel or riparian disturbance, including infrastructure; riparian buffer width and landuse; rapid habitat assessment based on USEPA RBP	Qualitative (visual estimates) to Semi-Quantitative (estimates based on ranges)	Index	0.5	2	2	3	1-3	1
40	Stream Corridor Restoration: Principles, Processes, and Practices - Federal Interagency Stream Corridor Restoration Working Group (1998)	Various processes and measurements are discussed, including hydrologic processes (e.g., in-stream flow), geomorphology; water quality (chemistry), and biology.	- -[1]	- -	- -	- -	- -	- -	- -	- -

Table 8b. Technical summary of non-regulatory stream assessment and mitigation protocols (continued).

No.	Protocol Title / Author	Stream Attributes Assessed	Type of Assessment	Output	Morphological Assessment	Habitat Assessment	Level of Effort	Level of Expertise	Precision/ Repeatability	Overall Suitability
41	Stream Habitat Assessment Procedures, Chapter 8 in Surface Water Quality Monitoring Procedures Manual - TNRCC (1999)	Mostly transect based assessments of habitat type, in-stream cover, substrate, channel obstructions, wetted width & depth, riparian vegetation characteristics	Subjective (visual estimates) to Quantitative (transect-based)	Index; Data	2	3.5	3.5	3	3	3
42	Stream Habitat Classification and Inventory Procedures for Northern California - (McCain et al., 1990)	Length, width, and depth of habitat types (22 possible types)	Qualitative (inventory) to Quantitative (measures of dimensions)	Data	1	4	4.5	4	2	2
43	Stream Survey Report Criteria - King County [WA] Department of Development and Environmental Services	Variable depending on designated use and fish utilization: riparian zone land uses, riparian vegetation, channel morphology, bank stability, substrate composition, large woody debris, pool quality, benthos (invertebrates), and fish habitat	Qualitative, Semi-Quantitative, & Quantitative	Index	2 - 3.5	2.5 - 3.5	2.5 - 4	2.5 - 4	3	2 - 3.5
44	Stream Visual Assessment Protocol - USDA NRCS (1998)	Subjective inventory of channel condition, bank stability, riparian vegetation, water appearance, in-stream cover, pools, embeddedness, canopy cover, etc.	Qualitative (visual estimates)	Index	1	1.5	1	2	1.5	1
45	[Vermont] Stream Geomorphic Assessment Protocol Handbooks - Vermont Agency of Natural Resources (May 2003)	Three successive levels of detail: 1) Remote sensing, 2) Basic geomorphology and indices, and 3) detailed comprehensive geomorphological measurements.	Semi-Quantitative to Quantitative	Data; Index	5	2	5	4	4	4.5

[1] Information provided in the document lacks specificity of assessment methods or provides such a range of potential methods that ranking the protocol is impracticable.

[2] Under development.

APPENDIX A

Stream Assessment Protocol Questionnaire

In support of the National Wetlands Mitigation Action Plan, the U.S. Environmental Protection Agency (EPA) and the U.S. Army Corps of Engineers (USACE) have recently contracted with Nutter & Associates, Inc. to compile an annotated summary of extant stream assessment and mitigation protocols nationwide suitable for reference during compilation of national stream mitigation guidance.

The objective of this proposal is to compile and review existing stream assessments currently in use or under development by State and Federal agencies, county and municipal governments, and non-government organizations nationwide. Stream assessment is defined as methods, protocols, standard operating procedures, etc. used to assess the physical condition (e.g., stability) and/or the biological health (e.g., habitat, water quality) of a stream, stream reach, or watershed. Components of this review will include the following:

- Identification of the target scale and objective of each assessment method;
- Identification of specific stream types and/or geographic areas (i.e., ecoregions) for which the assessment method is applicable;
- Identification of the level of effort required and the necessary components to "calibrate" the protocol to local conditions;
- Identification of the complexity or level of effort necessary to execute a site assessment in the field using each method;
- An assessment of the degree to which each method can be utilized evaluate a proposed project's impact, identify/quantify the necessary compensatory mitigation for those impacts, and assess the efficacy of a proposed mitigation plan/site to satisfy the mitigation requirements.

EPA and USACE will be working closely with Nutter & Associates to compile the various State and/or Federal stream assessment methodologies and it is with this cooperation in mind that we seek your assistance to identify stream assessment and stream mitigation methodologies in your respective regions of the country. Your attention and cooperation with this effort will directly enhance the scope of the review, and ultimately the efficacy of stream mitigation efforts.

Please take a few moments (20-25 minutes) to complete the following questionnaire and forward any internet links, electronic copies, or bibliographical citations of methods, protocols, previous reviews, etc. that are applicable to stream assessment and stream mitigation by October 10, 2003 to the attention of either Bruce Pruitt (bpruitt@nutterinc.com)or Eric Somerville (esomerville@nutterinc.com).

NUTTER & ASSOCIATES, INC.
1073 S. Milledge Avenue
Athens, Georgia 30606
(706) 354-7925 tel
(706) 354-7928 fax

Stream Assessment Protocol Questionnaire

Update History:
Pruitt 05Sep2003
Pruitt 03Sep2003
Pruitt 29Aug2003
DES 29Aug2003
DES 27Aug2003
DES 21Aug2003
Pruitt 21Aug2003

Your input is critical in addressing key issues related to stream assessment protocols and methods. Consequently, we are especially interested in how stream assessment methods are presently being used by your agency. In turn, your involvement will ensure that issues of interest to you related to the subject are addressed at a national scale.

Please take no more than 20-25 minutes to fill out the following questionnaire and return it to us via email by September 15, 2003 (bpruitt@nutterinc.com or esomerville@nutterinc.com). The questionnaire is being submitted in both Microsoft™ Word and Corel™ WordPerfect formats. They are otherwise identical.

Contact Information:

Your Name: ______________________________

Title: ______________________________

Educational Background: ______________________________

Years Professional Experience: ______________________________

Agency: ______________________________

Program Element: ______________________________

Address: ______________________________

____

____

Business Voice No. ______________________________

Business Fax No. ______________________________

Email: ______________________________

General:

1. What scale(s) are you presently using stream assessment methods? (Check appropriate)

River-Reach	_____
Watershed	_____
Regional/District	_____
Hydro-Physiography	_____
Other (Please specify)	______________________

2. In what states(s) are you using stream assessment methods?

3. What hydro-physiography(ies) or ecoregions are you applying stream assessments methods? Please be specific.

4. How are the results of stream assessment being used, programmatically? (Check appropriate)

Water quality standards or criteria	___
Section 401/404 permitting	___
Sediment and habitat total maximum daily loads (TMDLs)	___
Trend monitoring (305(b))	___
Watershed assessment	___
Prioritizing watersheds for preservation, enhancement, and/or restoration	___
Environmental impacts	___
Assessing water resources/uses	___
Correspondence with aquatic resources (habitat, water quality)	___
Comparison/stratification based on stream type or class	___
Other (Please specify)	______________________

5. Ultimately, what element are you protecting by using stream assessment methods (e.g., water quality, channel stability, aquatic macroinvertebrate habitat, fisheries)?

6. What programs, regulations, or policies do your stream assessments affect (e.g., water quality standards, beneficial uses, TMDLs)? *If used as water quality standard, please specify below, submit your web page, attach your standard via*

email, or fax to our attention at (706) 354-7928 (narrative and/or numeric criterion as it relates to a beneficial use or use classification).

7. In what database(s) are your stream assessment data being stored?

   If being archived, are there any critical ancillary information included (e.g., hydro-physiography, stream class, habitat assessment)?

Technology:

8. What stream classification are you presently using?

9. What physical methods of stream assessment are you using? (e.g. Schumm CEM, Rosgen BEHI, Pfankuch, Kappesser RSI, V* pool, bank pins/scour chains, cross-sections/ thalweg profiles at monumented cross-sections, etc.). Please specify application to hydro-physiography.

10. What physiochemical parameters are you using during stream assessment? (e.g., temperature, specific conductivity, DO, pH, turbidity, etc.)

11. What aquatic habitat/riparian zone methods are you using? (e.g., rapid bioassessment protocol (RBP), etc.).

12. Have you established regional hydraulic curves? If so, for which hydro-physiography(ies) or ecoregion(s)?

13. Have you established reference-reaches? Physical, Geomorphological, or Biological? How many? Are they permanent? How long have they been monitored? What hydro-physiography(ies) or ecoregion(s)?

14. Do you determine bankfull stage/discharge during stream assessment? If so, what method/criteria of determining bankfull are you using?

15. Are you measuring fluvial sediment? Suspended? Bedload?

Data Reduction/Synthesis:

16. Would you consider your stream assessments to be:

    Quantitative ____
    Semi-quantitative ____
    Qualitative? ____

    If you selected more than one, please specify which elements of your method fall under each category.

17. Have you made correlations or correspondence between physical stream assessments and fluvial sediment? Effective discharge vs. bankfull dimensions? Etc.?

18. Have you made correlations or correspondence between physical stream assessments and aquatic ecology (e.g., biological impairment, fish IBI, MBI (HBI, NCBI, etc. for macroinvertebrates)? If so, please explain.

19. Have you integrated stream assessment results with adjacent wetlands or riparian zones? If so, via what method?

20. Have you noticed seasonal variation in the results of stream assessment methods? Explain.

21. What methods have you used to reduce observer bias (i.e., repeatability among practitioners) in defining stream features, and how have they worked?

22. What degree of training does your assessment method require to properly execute? (e.g., High = quantitative such as surveying cross-sections; Low = descriptive such as Pfankuch)

    High ____
    Medium ____
    Low ____
    Minimal ____

23. How much time does your assessment method require:

(a) In the field?	< 15 minutes	____
	< 30 minutes	____
	30-59 minutes	____
	1-2 hours	____
	> 2 hours	____
(b) In the office?	< 15 minutes	____
	< 30 minutes	____
	30-59 minutes	____
	1-2 hours	____
	> 2 hours	____

24. In general, what methods or procedures do you recommend when time and resources are limited?

    When time and resources are NOT limited?

Future Needs:

25. In your opinion, what improvements should be made to stream assessment technology? Sampling methods and procedures?

26. In the future, what data needs (or data gaps) related to stream assessment protocols and methods do you anticipate (e.g., stream discharge, fluvial sediment)?

27. What means of compiling/storing and sharing information between agencies on a national scale do you recommend (e.g., national databases, internet, etc.)? Who should be the lead agency to maintain this database?

28. May we contact you to seek clarification or additional information?

THANK YOU VERY MUCH FOR YOUR PARTICIPATION!!

APPENDIX B

Regulatory Protocol Reviews

No. 1 - [Compensatory Mitigation] Plan Review Checklist
U.S. Army Corps of Engineers, New England District - April 2002

PRIMARY PURPOSE:

The New England District [Compensatory Mitigation] Plan Review Checklist provides a format for use in reviewing mitigation plans submitted to the USACE New England District pursuant to Section 404 of the Clean Water Act. It is also the intent of the Checklist to provide guidance to the regulated community on the requirements for mitigation plans.

The Checklist is primarily formatted to accommodate the review of applications for permits to impacts wetlands as opposed to streams. There is no technical or programmatic guidance included in the checklist that pertains uniquely to streams.

PROCEDURE SUMMARY:

The Checklist is essentially an administrative document as opposed to a technical guidance manual on impact assessment and mitigation planning. Although it includes some technical considerations (e.g., coarse woody debris, invasive plant species, etc.), the Checklist merely mentions these factors as points to consider during the planning process. The majority of the Checklist is comprised of checklists intended to guide the review of plans, and not necessarily to enable an assessment of the technical competence or potential efficacy of those plans once implemented.

REFERENCE CONDITIONS, PERFORMANCE STANDARDS, & MONITORING:

There is no discussion in the Checklist concerning reference conditions, nor is there any language specifically related to performance standards or success criteria. The Checklist requires that “assessments” of the mitigation area must be conducted by someone other than the person(s) who prepares the annual monitoring reports, thereby suggesting that “assessment” and “monitoring” are not synonymous. However, there is no technical guidance or references provided to indicate how this assessment should be undertaken, other than to state that the same procedure used to determine the functions and values of the impacted wetlands should also be used at the mitigation site.

FOR ADDITIONAL INFORMATION:

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[Compensatory Mitigation] Plan Review Checklist (April 2002) -
U.S. Army Corps of Engineers, New England District
http://www.nae.usace.army.mil/reg/index.htm

No. 2 - Critical Areas Mitigation Guidelines

King County, Washington
Department of Development and Environmental Services (December 29, 2003)

PRIMARY PURPOSE:

The *Critical Areas Mitigation Guidelines* (Guidelines) are intended to assist applicants seeking building or land use permits from the King County Department of Development and Environmental Services (DDES) in unincorporated King County, Washington. Critical areas are referred to as *Environmentally Sensitive Areas* in Chapter 21A.24 of the King County Code (KCC), and include lands that are subject to natural hazards or that support certain unique, fragile or valuable resource areas. Wetlands, streams, and other water bodies, as well as their buffers, are protected by KCC as environmentally sensitive areas. DDES defines streams based on the physical (geomorphic) presence of a defined channel or bed.

The Guidelines are applicable for "minor" projects, which are defined as those that are typically restricted to one single family residential lot and are comprised of buffer enhancements less than $1000ft^2$ or buffer restoration less than $500ft^2$.

PROCEDURE SUMMARY:

The Guidelines outline mitigation plan requirements (maps, site plans, and other drawings), report requirements (project description, construction details, maintenance and monitoring plans), and design requirements, including performance standards. All of the examples in the Guidelines, as well as most of the references provided, are tailored to wetlands and wetland mitigation. For example, the Guidelines include an appendix entitled, Wetland Hydrology Management Guidelines, which details the specific methods for determining pre-development wetland hydrology and designing surface water conveyance systems to maintain this hydrology post-development. However, there is very little similar information provided to assist applicants evaluating stream hydrology, sediment transport, or other critical components of stream relocation or restoration. The Guidelines simply state that hydrologic calculations for both existing and proposed stream [conditions] must be provided.

Data sheets are provided to document basic wetland characteristics, such as location, Cowardin classification (Cowardin *et al.*, 1979), acreage, plant communities and indicator status, etc. However, there are no data sheets provided to readily document stream habitat or geomorphology.

REFERENCE CONDITIONS, PERFORMANCE STANDARDS, & MONITORING:

Quantifiable performance standards must be identified for each project objective and keyed to "thorough reviews of existing area streams...in good condition," (DDES, 2003, p. 5). Project objective themselves must be specifically detailed based on the overall project goals. As-built plans are required for all mitigation projects.

Monitoring methods should assess performance standards and proposals should include specific references to field methods and analyses proposed. However, the Guidelines do not stipulate or mandate specific methods. Monitoring is typically required for a period of five years from installation/construction, but may be extended until performance standards are met.

LITERATURE CITED:

Cowardin, L.M., V. Carter, F.C Golet, and E.T. LaRoe. 1979. *Classification of Wetland and Deepwater Habitats of the United States*. FWS/OBS-79/31, U.S. Fish and Wildlife Service, Washington, D.C. 103 pp.

DDES, 2003. *Critical Areas Mitigation Guidelines*. Department of Development and Environmental Services, King County, Washington, December 29, 2003. 23 pp.

FOR ADDITIONAL INFORMATION:

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Critical Areas Mitigation Guidelines
http://www.metrokc.gov/ddes/sensarea/

No. 3 - Compensatory Stream Mitigation (Suggested Procedure)

U.S. Army Corps of Engineers, Mobile District - Draft July 2002

PRIMARY PURPOSE:

The Mobile District Suggested Procedure is applicable to regulatory actions requiring compensatory mitigation for impacts to perennial, intermittent, or ephemeral streams pursuant to Section 404 of the CWA in the USACE Mobile District, which includes all of central and southern Alabama, as well as eastern Mississippi.

PROCEDURE SUMMARY:

The Mobile District Suggested Procedure for planning and evaluating compensatory mitigation for stream impacts is very similar to the SOP's used in the USACE Charleston and Savannah Districts (see reviews this volume). Worksheets are provided to document various aspects of projects proposing to impact and mitigate stream resources, and include a number of semi-quantitative and qualitative factors. Each worksheet includes a number of metrics that are scored, summed, and then multiplied by the linear feet of stream impacted or mitigated to obtain a total of number of mitigation credits either needed to offset the impacts or that result from the mitigation efforts, respectively. The Mobile District worksheets are based on the worksheets included in the above referenced SOP's, and in some cases use the same metrics and classes, but differ in their scoring. Worksheets include: a) Adverse Impact Factors, b) Stream Channel/Streambank Restoration and Relocation, and c) Riparian Restoration and Preservation.

The Mobile District Suggested Procedure uses six metrics in the Adverse Impact Factors worksheet to determine the number of mitigation credits necessary to satisfactorily compensate for the authorized losses: a) Stream Type Impacted, b) Priority Area, c) Existing Condition, d) Duration [of Impact], e) Dominant [Type of] Impact, and f) Scaling Factor (based on linear feet).

The Stream Channel/Streambank Restoration and Relocation worksheet uses seven metrics to evaluate proposed mitigation plans: a) Stream Type, b) Existing Condition, c) Net Improvement, d) Monitoring / Contingency, e) Priority Category, f) Control, and d) Credits [schedule]. Stream channel restoration and streambank stabilization provides the greatest Net Benefit, and concomitant number of mitigation credits generated, and is based on level of effort or magnitude of the anticipated benefits of the mitigation plan. Although some example criteria are provided to distinguish “Moderate” stream channel restoration actions from “Good” or “Excellent” actions, there is little quantifiable means provided in the Suggested Procedure on which to base these judgements.

Riparian buffer preservation may be utilized to generate up to 70% of the required compensatory mitigation credits for authorized impacts to streams in the USACE Mobile District. Riparian buffer preservation refers to the conservation, in its naturally occurring or present condition, of a riparian buffer that requires planting of deep rooted vegetation in no more than 20% of the area to restore streambank stability and improve wildlife habitat. The Riparian Restoration and Preservation worksheet delineates minimum buffer widths necessary to receive mitigation credit for buffer restoration or preservation based on the presence/absence of livestock and the need for exclusion fencing, as well as the proposed width of the buffer. The worksheet then utilizes six additional metrics to determine the total number of mitigation credits generated by a proposed buffer restoration or preservation plan.

REFERENCE CONDITIONS, PERFORMANCE STANDARDS, & MONITORING:

Reference Reach/Condition is included in the definitions section of the Suggested Procedure, but there is little discussion of reference reach data, its utilization, or requirements as part of the stream restoration design process. The Suggested Procedure does not address or reference performance standards or success criteria.

Monitoring is a required component of all mitigation plans. Monitoring of stream channel restoration and/or streambank stabilization projects includes annual monitoring of water temperature, DO, turbidity, pH, substrate characteristics, streambank erosion patterns, and longitudinal and cross-sectional profiles at sites above, within, and below the restored reach. Incorporation of biological monitoring of stream fauna is optional, but results in a greater allocation of mitigation credit for the proposed project. Biological monitoring includes measures of density and diversity of mammals, birds, reptiles, amphibians, fish, freshwater mussels, other macroinvertebrates and other fauna at sites within the buffer and/or stream. No specific physical, geomorphological, or biological sampling protocols are suggested or referenced, and no additional technical or programmatic monitoring guidance is provided. Initial baseline physical stream data is required for stream channel restoration and/or streambank stabilization projects.

FOR ADDITIONAL INFORMATION:

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Compensatory Stream Mitigation (Suggested Procedure)
Draft- July 2002
USACE Mobile District
https://155.82.160.8/ribits/index.php

No. 4 - Mitigation and Monitoring Guidelines

(December 17, 2003) - U.S. Army Corps of Engineers, Rock Island District

PRIMARY PURPOSE:

In December 2003, the USACE Rock Island District issued a Public Notice seeking comment on its proposed Mitigation and Monitoring Guidelines. The Guidelines are applicable to regulatory actions requiring compensatory mitigation for impacts to all federally jurisdictional waters pursuant to Section 404 of the CWA in the USACE Rock Island District, which includes parts of Iowa, Illinois, Wisconsin, and Minnesota. The Guidelines are intended to summarize major points regarding compensatory mitigation in the Rock Island District, and refer readers to the *Multi-Agency Compensatory Mitigation Plan Checklist,* which was released by USEPA and USACE as an undated Memorandum to the Field in Autumn 2003*.* In addition, the Guidelines also reference and borrow heavily from a documented titled *Incorporating the National Research Council's Mitigation Guidelines into the Clean Water Act Section 404 Program,* which was distributed by USACE Headquarters in an October 29, 2003, Memorandum to the Field titled, *"Model 'Operational Guidelines for Creating or Restoring Wetlands that are Ecologically Self-Sustaining' for Aquatic Resource Impacts Under the Corps Regulatory Program Pursuant to Section 404 of the Clean Water Act and Section 10 of the Rivers and Harbors Act."*

PROCEDURE SUMMARY:

The Rock Island District Mitigation and Monitoring Guidelines is not a technical manual providing recommended methods to assess, design, and execute mitigation projects. Rather, it is essentially an administrative compilation of suggested elements to include in mitigation proposals that will result in efficient and expedited review of those proposals by the Rock Island District. The Guidelines do not include any methods to assess stream conditions or aid in the technical review of proposed plans.

Baseline information on both the project site and the proposed mitigation site is required and should include site descriptions, maps, ownership, land use, etc. This baseline information should also include "information on soils, vegetation, and hydrology" and a description of "functions," although no suggested methods to assess any of these features are provided.

General descriptors for "good site selection" for mitigation are provided, as are recommended components of "good mitigation plans."

REFERENCE CONDITIONS, PERFORMANCE STANDARDS, & MONITORING:

Reference conditions are not addressed in the Rock Island Guidelines.

Performance standards are required to be submitted with proposed mitigation plans and "should be based on practicably measurable quantitative or qualitative characteristics of the mitigation plan." Performance standards for stream mitigation sites must include at a minimum, measures to assess stable stream banks, bed, and structures, as well as successfully vegetated stream banks and buffers.

Monitoring of mitigation sites must take place annually for at least 5 years. The applicant is responsible for submitting a monitoring plan that identifies what will be monitored, methods and tools for monitoring, and the format for reporting monitoring data and assessing mitigation success. An adaptive management plan must also be submitted to the Rock Island District that identifies how potential changes (e.g., drought, flooding, invasive vegetation species, etc.) may alter the mitigation site and what remedial actions may be employed to address such changes.

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Public Notice
Mitigation and Monitoring Guidelines
December 17, 2003
USACE Rock Island District
http://www.mvr.usace.army.mil/Regulatory/RegulatoryDivisionHomePage.htm

No. 5 - Mitigation and Monitoring Guidelines

(Draft December 15, 2003) - U.S. Army Corps of Engineers, Tulsa District

PRIMARY PURPOSE:

In December 2003, the USACE Tulsa District issued a Special Public Notice seeking comment on its proposed Mitigation and Monitoring Guidelines. The Guidelines are applicable to regulatory actions requiring compensatory mitigation for impacts to all federally jurisdictional waters pursuant to Section 404 of the CWA in the USACE Tulsa District, which includes all of Oklahoma, the Texas panhandle, and the Red River watershed in northern Texas. The primary purpose of the Guidelines is to: 1) provide predictability to applicants for CWA 404 permits, 2) improve the success of mitigation projects, 3) increase mitigation compliance through self-reporting, and 4) ultimately meet the goal of “no overall net loss” of wetlands in the regulatory program.

PROCEDURE SUMMARY:

The Tulsa District Mitigation and Monitoring Guidelines is not a technical manual providing recommended methods to assess, design, and execute mitigation projects. Rather, it is essentially an administrative compilation of suggested elements to include in mitigation proposals that will result in efficient and expedited review of those proposals by the Tulsa District. Although the Guidelines discuss a number of elements related to mitigation project planning, such as site selection criteria, mitigation strategies, and resultant compensatory ratios, there are not any methods provided for either permit applicants or project reviewers to quantitatively assess the potential efficacy of a proposed plan.

Preference is given to restoration of previously degraded or destroyed wetlands or streams. Enhancement activities are also encouraged so long as the proposed mitigation activities do not compromise other resource functions (i.e., preferential emphasis of one function at the expense of others). Creation can be a viable mitigation strategy where valuable uplands are not destroyed as a result of the mitigation efforts and the inherent uncertainties regarding hydrology can be overcome. Preservation of existing resources is least preferred, but can account for up to 50% of the required compensatory mitigation when included as part of a multi-faceted plan. All stream mitigation should include a minimum 50-foot buffer on each side of the stream.

Examples of stream mitigation activities are listed in the Guidelines, but no additional discussion or guidance is provided or referenced. Stream mitigation credit may be achieved via the following actions:

1. restoration of a previously channelized or modified stream channel to appropriate channel geometry including sinuosity, gradient, channel shape, and access to flood plain;
2. enhancement of in-stream aquatic habitat or restoration of stream bed diversity (substrate, structure, holes, permanent bars and points, permanent coarse woody debris in stream bed);

3. restoring natural channel features such as riffles and pools appropriate to stream type;
4. restoration, enhancement, establishment, or protection of natural buffers and riparian corridor along a stream;
5. increasing tree canopy and effective shading over a stream;
6. exclusion of livestock from stream corridor;
7. installation of grade control structures in a degrading stream;
8. removal of check dams, weirs, or other man-made structures which block aquatic organism movement or migration, or are contributing to stream bank erosion;
9. removal of impoundments;
10. installation of natural erosion and sediment control measures in eroded areas;
11. reduce or eliminate sediment sources in the immediate watershed;
12. restore the dynamic relationship between a stream and its flood plain.

REFERENCE CONDITIONS, PERFORMANCE STANDARDS, & MONITORING:

There is no discussion or reference made to incorporate reference reach conditions in the design or monitoring of mitigation projects for the Tulsa District. The Guidelines include "assessment of success toward the performance standards or success criteria" as a required component of monitoring reports. However, neither performance standards nor success criteria are otherwise discussed in the document.

Monitoring is a required component of all mitigation plans. Monitoring will be required for no less than 3 years, and more typically 5 years where restoration of a channelized or impaired stream to a historic alignment or condition is proposed. No specific variables or methods for stream monitoring are provided in the Guidelines.

OTHER:

The Guidelines indicate that mitigation plans should include the elements listed in the *Multi-Agency Compensatory Mitigation Plan Checklist*, which was released by EPA and USACE as an undated Memorandum to the Field in Autumn 2003. Also, recommendations in the undated document titled, "*Incorporating the National Research Council's Mitigation Guidelines into the Clean Water Act Section 404 Program*" should be given due consideration during the site selection and design process. Both of these documents provide lists of required or recommended elements to include in mitigation planning documents. However, neither of them includes specific technical recommendations, guidance, or references.

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Special Public Notice
Mitigation and Monitoring Guidelines
Draft- December 15, 2003
USACE Tulsa District
http://www.swt.usace.army.mil/library/libraryDetail.cfm?ID=126

No. 6 - Draft Standard Operating Procedure Compensatory Mitigation Wetlands, Open Water & Streams

U.S. Army Corps of Engineers, Savannah District - July 2003

PRIMARY PURPOSE:

The Savannah District SOP is intended to be used to evaluate projects seeking authorization from the USACE Savannah District pursuant to Section 404 of the CWA to impact up to 10 acres of wetlands or open water and/or up to 5000 linear feet of intermittent and/or perennial stream resources in the State of Georgia. It is the policy of the Savannah District that the SOP may be used as a guide for projects proposing impacts greater than these thresholds, however, greater mitigation may be required.

The SOP addresses impact and mitigation assessment for various types of jurisdictional waters. However, the following discussion will focus solely on aspects of the SOP that are applicable to fluvial resources. This review is based on a July 2003 draft revision of the Savannah SOP. However, on December 23, 2003, the Savannah District issued a public notice announcing a subsequent revision to the SOP.

PROCEDURE SUMMARY:

Worksheets are provided to document various aspects of a project proposing to impact and mitigate stream resources. These include: a) Adverse Impact Factors, b) Stream Channel Restoration, Stream Relocation, and Streambank Restoration, and c) Riparian Restoration and Preservation. Each worksheet includes a number of metrics that are scored, summed, and then multiplied by the linear feet of stream impacted or mitigated to obtain a total of number of mitigation credits either needed to offset the impacts or that result from the mitigation efforts, respectively. As an example, Table 1 summarizes the metrics and the scoring classes for Adverse Impact Factors.

The SOP uses five metrics to evaluate proposed Stream Channel Restoration, Stream Relocation, and Streambank Restoration projects: 1) Net Benefit, 2) Monitoring/ Contingency, 3) Priority Area, 4) Control, and 5) Mitigation Timing. The SOP itself provides detailed definitions and criteria to be used to evaluate each of these metrics. Net Benefit is based on the magnitude of the restoration project (Priorities 1 through 4) as defined by Rosgen (1997), and is thereby related to quantifiable aspects of a proposed project. In contrast, Monitoring/ Contingency, Priority Area, Control, and Mitigation Timing are all subjective criteria that affect the allocation of mitigation credit.

Design of restored or relocated channels is required to be based on a local reference stream reach within the same physiographic region and valley type as the impacted stream, and may only be undertaken on verifiably entrenched, unstable streams (Channel Evolution Stages III-V) (Simon, 1989; see also Schumm et al., 1984; Simon and Hupp, 1986). All such plans are also required to include a complete geomorphic

Table 1. Metrics and classes in the Adverse Impact Factors worksheet in the USACE Savannah District SOP to assess compensatory mitigation requirements for stream impacts.

Metric	**Classes**	**Description / Example**
Stream Type Impacted	Intermittent	Self explanatory
	Perennial > 15' wide	Self explanatory
	Perennial ≤ 15' wide	Self explanatory
Priority Area	Tertiary [a]	Streams not considered Secondary or Primary
	Secondary [a]	303(d), State Heritage Trust Preserves, anadromous spawning habitat, etc.
	Primary [a]	T&E spp., primary trout stream, waters adjacent to approved mitigation sites or banks, etc.
Existing Condition	Fully Impaired [a]	High loss of stream system stability & resilience
	Somewhat Impaired [a]	Stability has been compromised, but has a moderate probability of natural recovery
	Fully Functional [a]	Stable geomorphology & diverse biological community
Duration	Temporary	<1 year
	Recurrent	Repeated impacts of short duration
	Permanent	> 1 year
Dominant Impact	Shade/Clear	Shading of stream (i.e. bridging) or clearing of riparian vegetation when these activities are associated with regulated activities.
	Utility Crossing	Pipeline/utility line that disturbs stream bed
	Bank Armor	Riprap, bulkhead, etc.
	Detention	Temporarily detain (≤ 72 hrs) flows above bankfull discharge
	Crossing (≤ 100')	Pipe, box culvert, etc
	Impound	Conversion of normal flows below bankfull stage to a lentic state
	Morphologic Change	Channelize, dredge, armored ford, etc.
	Pipe > 100'	Pipe, box culvert, etc.
	Fill	Permanent filling of a channel
Scaling Factor (based on length of impact)	Scaling Factor (SF) = 0 for impacts less than 100' in length, and increases to 0.4 per 1000' (rounded to nearest 1000') e.g. 2800' = 0.4 x 3 = SF 1.2	

[a] SOP provides much greater definition, detail, and specific criteria by which to assign classes.

assessment of the impacted stream, the reference stream, and the proposed stream design, consistent with a Rosgen Level II assessment (Rosgen, 1996). The SOP includes a geomorphic assessment table to aid practitioners during collection of pertinent data.

REFERENCE CONDITIONS, PERFORMANCE STANDARDS, & MONITORING:

A complete geomorphic assessment must be documented on a reference stream for proposed stream restoration and/or relocation projects. Specific performance standards are not provided in the SOP due to the variety of physiographic and ecoregions in which the SOP is intended to be applicable. Instead, the SOP makes clear that written performance standards are required, may be developed through interagency coordination, may be based on reference conditions, and will be used for post-construction monitoring. Various degrees of complexity for post-construction monitoring are provided in the SOP, based in part on the complexity of the project itself. More rigid monitoring efforts are allotted higher mitigation credit.

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Simon, A. and C.R. Hupp, 1986. Channel Evolution in Modified Tennessee Streams. In Proceedings of the 4th Federal Inter-Agency Sedimentation Conference, 2:71-82.

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Draft Standard Operating Procedure Compensatory Mitigation Wetlands, Open Water & Streams (July 2003), USACE Savannah District
http://144.3.144.48/permit.htm

No. 7 - Draft Stream Mitigation Guidelines [for Kentucky]

Kentucky Division of Water - December 2002

PRIMARY PURPOSE:

The Draft Stream Mitigation Guidelines developed by the Kentucky Division of Water (KDOW) are intended to provide guidance to applicants for CWA Section 401 Water Quality Certification (WQC) from the Commonwealth of Kentucky for projects proposing to relocate or adversely impact fluvial resources of the Commonwealth. Regulated Waters of the Commonwealth include those streams represented as dashed or solid blue lines on the most recent version of USGS 7.5' topographic maps.

The Guidelines include topical elements addressing data requirements, physical and biological monitoring requirements, acceptable types of mitigation projects, and draft guidance for calculating the credits generated by each type.

PROCEDURE SUMMARY:

Stream mitigation for permanent losses of Waters of the Commonwealth must be provided on a 1:1 ratio of linear feet lost to mitigation credits generated. The Guidelines list various types of mitigation projects and provide example calculations to help plan the appropriate amount of mitigation required to reach the aforementioned ratio (Table 1). For example, if 1000 linear feet of stream is lost, and daylighting plus stream enhancement (0.8 multiplier) is proposed as mitigation, then 1250 linear feet of mitigation work will be required.

1000 l.f. of stream loss	=	Daylighting + Enhancement (0.8 x l.f. of mitigation)
	=	0.8 x 1250 l.f.
	=	1000 l.f.

Data required to support stream relocation and restoration projects includes a number of geomorphic and physical habitat data (Table 2). All stream relocations must adhere to fluvial geomorphological principles and “natural channel design.” There must also be a minimum riparian zone 25' wide on each side of the channel measured from bankfull elevation. All stream and riparian zone work that is proposed as a means of generating mitigation credit requires permanent protection of the area via conservation easements, deed restrictions, etc.

Table 1. Description of stream mitigation types and enumeration of corresponding mitigation ratios in the KDOW Guidelines.

Type of Mitigation	Description	Ratio Calculation
Daylighting + Full Restoration	Removing pipes, culverts, fill, concrete linings, etc. and restoring the stream to natural conditions based on reference.	1.0 x linear feet
Daylighting + Enhancement	Removal of impediments listed above with stream enhancement measures undertaken at the stream's existing location.	0.8 x linear feet
Full-scale Restoration	Converting an unstable, altered, or degraded stream corridor, including riparian and floodprone areas to natural conditions based on reference.	0.8 x linear feet
Enhancement	Improvement of aquatic habitat, channel stability, or flow and sediment transport, usually via riparian zone establishment, bank stabilization, and/or in-stream work.	0.2 to 0.6 x linear feet
Preservation		0.1 x linear feet

Table 2. Data required by KDOW to support stream relocation projects in Kentucky.

Metric	Description / Method
Level II Rosgen stream classification	Rosgen (1996)
Bankfull discharge	
Substrate description	Riffle pebble count and sieve sample from a gravel bar (Rosgen, 1996); Data presented as a sediment particle size curve
Dimensionless critical shear stress and critical shear stress values	
Channel stability	e.g., Alterations, bank erosion, sedimentation, embeddedness, headcutting or downcutting, etc.
Longitudinal profile	Including bankfull stage, channel slope, valley slope, pool and riffle slope, pool and riffle depth (Harrelson *et al.*, 1994)
Planform information	e.g., Sinuosity, belt width, radius of curvature, etc.
Cross-sectional geometry	Collected from meanders and straight reaches (Rosgen, 1996)
Riparian conditions	e.g., Riparian width, dominant species, etc.
Habitat assessment	USEPA RBP (Barbour *et al.*, 1999)

REFERENCE CONDITIONS, PERFORMANCE STANDARDS, & MONITORING:

A complete geomorphic assessment must be documented on a reference stream for proposed stream restoration and/or relocation projects seeking CWA Section 401 WQC from KDOW. The reference stream should be similar to the project stream with regard to watershed size, bankfull discharge, valley slope, and substrate. The Guidelines also refer to Rosgen (1998) for additional information concerning reference reaches.

Performance standards (success criteria) are required as part of project plans, and the Guidelines provide specific success criteria for some elements (e.g., riparian revegetation).

Monitoring plan requirements may include both physical and biological parameters with various degrees of complexity and rigor. Stream relocation and restoration projects require an as-built survey that includes a longitudinal profile survey, a number of channel cross-sections located at defined points within the project reach, and a plan view of the project site. Minimum criteria, including permanent concrete monuments, are stipulated for execution of these surveys. Permanent photography stations must also be established from which semi-annual photographs will be taken throughout the post-construction monitoring period (3 to 8 years). In general, data outlined in Table 1 above must be provided as part of annual monitoring reports, unless a less rigorous monitoring plan is agreed to by KDOW.

Biological monitoring requirements will be determined on a case by case basis and must follow the July 2002 *Methods for Assessing the Biological Integrity of Surface Waters* (KDEP, 2002).

LITERATURE CITED:

Barbour, M.T., J. Gerritsen, B.D. Snyder, and J.B. Stribling. 1999. *Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates, and Fish*, Second Edition. EPA 841-B-99–002. USEPA Office of Water, Washington, D.C.

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Wetlands Engineering and River Restoration Conference, March 1998, Denver, CO.

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Draft Stream Mitigation Guidelines
http://www.water.ky.gov/permitting/wqcert/

No. 8 - Draft Stream Mitigation Guidelines for the State of Tennessee

Tennessee Department of Environment and Conservation - January 31, 2003

PRIMARY PURPOSE:

The Draft Stream Mitigation Guidelines for the State of Tennessee were developed by the Tennessee Department of Environment and Conservation (TDEC), Division of Water Pollution Control in consultation with the USACE, USEPA, USFWS, TVA, and the Tennessee Wildlife Resources Agency. The Guidelines include topics related to activities requiring mitigation, classification of stream alterations, mitigation activities and corresponding mitigation ratios, monitoring requirements, and definitions.

PROCEDURE SUMMARY:

The Guidelines define mitigation ratios based upon classifications of stream impacts (elimination, degradation I, and degradation II) and stream mitigation activities (replacement, restoration, enhancement I, enhancement II, and preservation). Each impact classification is accompanied by a list of activities that fall into each respective category (Table 1). Similarly, stream mitigation activities are summarized and classified as outlined in Table 2. The required compensatory mitigation ratio is determined based on a matrix of impact classifications and mitigation activity classifications as illustrated in Table 3.

Table 1. Stream impact classifications and activities listed in the Draft Stream Mitigation Guidelines for the State of Tennessee.

Impact Classification	Activities
Elimination	Culverts; fill; loss of stream length (relocation); concrete lining (bottom and sides).
Degradation II	Rip-rap lining (bottom and sides); channel modifications to increase cross-sectional area; rip-rap or concrete lined stream banks (both sides); impoundment.
Degradation I	Loss of riparian canopy on channel relocations; channel modifications that deviate from or degrade proper pattern, profile, dimension, and/or in-stream habitat; synthetic channel lining along banks.

Table 2. Stream mitigation classifications and activities listed in the Draft Stream Mitigation Guidelines for the State of Tennessee.

Mitigation Classification	Activities / Treatments
Replacement	Removal of existing culverts and/or concrete lined channels and full restoration based on reference conditions.
Restoration	Returning an unstable, altered, or degraded stream corridor, including riparian and floodprone areas to natural conditions based on reference.
Enhancement II	Significant bank stabilization (>33% of total project length), introduction of in-stream habitat, and re-establishment of vegetated riparian zone along both stream banks for 50' or 3x bankfull width, whichever is greater.
Enhancement I	Any combination of bank stabilization, livestock exclusion, introduction of in-stream habitat, and riparian zone restoration along both stream banks.
Preservation	Preservation of threatened, unique, or ecologically significant streams as a component of a restoration project.

Table 3. Compensatory stream mitigation ratios listed in the Draft Stream Mitigation Guidelines for the State of Tennessee.

	Mitigation Activities / Treatments				
Impact	Replacement	Restoration	Enhancement II	Enhancement I	Preservation
Elimination x 1	0.04236111	1.5:1	0.12569444444	4-6:1	10-60:1
Degradation II x 0.75	0.04236111	1.5:1	0.12569444444	4-6:1	10-60:1
Degradation I x 0.5	0.04236111	1.5:1	0.12569444444	4-6:1	10-60:1

REFERENCE CONDITIONS, PERFORMANCE STANDARDS, & MONITORING:

In order to insure that permit applicants do not use streams already in good condition as mitigation sites, the Draft Guidelines require that a proposed mitigation stream have a USEPA RBP habitat score (Barbour et al., 1999) not greater than 75% of reference conditions. There is no other discussion in the Draft Guidelines concerning reference streams or reference data, nor is there any additional guidance provided to aid selection of an appropriate reference stream (e.g., stream order, stream type, etc.).

The only performance standards (success criteria) noted in the Draft Guidelines pertain to riparian zone vegetation.

Monitoring is required for all stream mitigation projects for a period of 3 to 5 years. The specific components required to be monitored are based on the type of mitigation undertaken. The Draft Guidelines repeatedly mention surveys of channel morphology (pattern, profile, and dimension). However, except for reference to the Riparian Restoration and Streamside Erosion Control Handbook (Hoffman *et al.*, 1998), no specific methodology for morphological assessment is referenced. Channel morphology is required to be monitored for Replacement or Restoration mitigation activities, as defined in Table 2. However, the only morphological parameters that are specifically noted are channel cross-sections and photographs. Other required elements for all monitoring plans include narrative descriptions and photographs to document baseline and annual post-project conditions, pre- and post-project RBP habitat assessments, and annual riparian vegetation surveys.

OTHER:

Mitigation site selection should be located within the same Level III Ecoregion (Griffith et al., 1998) or 8-digit USGS HUC as the impacted stream. Mitigation streams must also be within one stream order of the impacted stream. With all other factors equal, mitigation priority should be given to impaired waters on the State 303(d) List for which mitigation activities may alleviate the causes or sources of water quality and/or habitat impairment.

LITERATURE CITED:

Barbour, M.T., J. Gerritsen, B.D. Snyder, and J.B. Stribling. 1999. Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates, and Fish, Second Edition. EPA 841-B-99–002. USEPA Office of Water, Washington, D.C.

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Hoffman, J.T., D.L. Green, and D.C. Eagar. 1998. Riparian Restoration and Streamside Erosion Control Handbook. Tennessee Department of Agriculture, Nashville, TN.

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Draft Stream Mitigation Guidelines for the State of Tennessee
http://www.state.tn.us/environment/wpc/wpcppo/arap/Draft%20Stream%20Mitigation%20Guidelines.pdf

No. 9 - Eastern Kentucky Stream Assessment Protocol

U.S. Army Corps of Engineers, Louisville District

PRIMARY PURPOSE:

The Eastern Kentucky Stream Assessment Protocol (eKY Protocol) was developed by an interagency team including members from the USACE Louisville District, USEPA R4, USFWS, the Kentucky Division of Water (KDOW), and the Kentucky Department of Fish and Wildlife Resources (KDFWR). The primary motive for the effort was to address the need for a headwater stream assessment procedure that would accommodate the CWA 404 programmatic requirements in the eastern Kentucky Coalfield Region where resource extraction (coal mining) impacted over 430 miles of small, headwater streams between 1985 and 2001 (USEPA *et al.*, 2003).

The eKY Protocol includes the USEPA RBP (Barbour *et al.*, 1999), but was calibrated to local conditions in the Eastern Kentucky Coalfield via an extensive collection of biological and physical habitat data collected by KDOW (Pond and McMurray, 2002). Pond and McMurray (2002) collected macroinvertebrates and physical habitat data during the spring index period (mid-February to late-May) from 58 sites in 2000 and 2001, including both reference streams and degraded streams in various degrees of impairment.

PROCEDURE SUMMARY:

The eKY Protocol is a hierarchical assessment procedure that variably incorporates both biotic and abiotic factors of stream ecosystems based upon the desired degree of confidence for the assessment and the amount of time available for data collection. A Macroinvertebrate Bioassessment Index (MBI) developed specifically for the Eastern Kentucky Coalfield region (Pond and McMurray, 2002) comprises the biological component of the eKY Protocol. Statistical analysis of the physical habitat data collected during development of the MBI revealed that conductivity, riparian width, canopy, embeddedness, and USEPA RBP habitat scores best separated reference (least disturbed) and test (degraded) sites. The RBP habitat assessment includes variables identical to or closely aligned with riparian width, canopy, and embeddedness. Thus, only RBP habitat score and conductivity are required abiotic components in the eKY Protocol.

The most robust form of the eKY Protocol includes both biotic and abiotic variables shown to be statistically significant for headwater streams in the Eastern Kentucky Coalfield and collectively provides the most complete index of ecological integrity. Less robust forms of the Protocol may be used if, for example, biological data is not readily available or when only a preliminary assessment is needed. Analysis of the biological data indicated that the output of the MBI model using family level taxonomy and sampling only the riffle habitats was highly correlated with the output derived from using genus and species level taxonomy and sampling multiple habitats. Thus, the use of only family level taxonomy and the sampling of a single habitat (riffles) can reduce the time and effort required to obtain useful data in certain situations. If only a cursory assessment is desired, only the abiotic components of the stream can be assessed (USEPA RBP habitat score and specific conductivity). Confidence in less robust forms of the assessment is supported by moderately strong correlations between the integrity (quality) of the macroinvertebrate assemblage and the representative physical habitat variables.

Spreadsheets available on the USACE Louisville District web site are used to calculate subindices for Habitat Integrity (RBP habitat score), MBI, and specific conductivity. These are then summed and divided by three in order to obtain an Ecological Integrity Index (EII) ranging between zero (0) and one (1.0) representing the degree of similarity of the assessed stream relative to other headwater streams in the Eastern Kentucky Coalfield region (Sparks *et al.*, 2003a). The EII is then multiplied by the linear stream length affected to obtain Ecological Integrity Units (EIUs), which essentially comprise the currency by which stream impacts and stream mitigation are compared. Additional EII spreadsheets are available to calculate EII's based on less complete data sets.

The difference between EIUs under existing conditions at the proposed impact site and predicted conditions following impact provides the number of EIUs that must be generated during mitigation. The same procedure is applied to the proposed mitigation site [(predicted post-mitigation EIUs - pre-mitigation EIUs) x channel length] to estimate the number of EIUs generated by proposed mitigation actions.

REFERENCE CONDITIONS, PERFORMANCE STANDARDS, & MONITORING:

Reference conditions for stream assessment are essentially internal to the eKY Protocol due to its calibration based on the 58 sample sites. There is little information either included in the calibration data or required as part of the assessment itself that documents the geomorphological conditions in the assessed streams. However, Sparks *et al.* (2003a) stress that mitigation proposing to improve geomorphological conditions in a stream must "not be done in a haphazard fashion," and sound fluvial geomorphological principles (i.e., Leopold *et al.*, 1964) should be adhered to. The authors also clarify that design of the mitigation should be based on reference reaches (Rosgen, 1996; 1998).

Neither performance standards, nor specific monitoring requirements are addressed in the eKY Protocol. However, Sparks *et al.* (2003b) state that the results of the assessment should be applied when conceptualizing and designing both success criteria and the requisite monitoring plan.

OTHER:

Sparks *et al.* (2003a) also present a means by which the eKY Protocol, discount rates, and spreadsheets developed by the USACE Engineer Research and Development Center can be used to generate mitigation ratios that account for risk and temporal losses. Discount rates are commonly used in economic analyses to express the idea that "a benefit to be received in the future is less valuable than the same benefit received today."

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http://www.lrl.usace.army.mil/orf/

No. 10 - [Florida] Uniform Mitigation Assessment Method

Florida Department of Environmental Protection (F.A.C. 62-345) (August 2003)

PRIMARY PURPOSE:

The [Florida] Uniform Mitigation Assessment Method (FUMAM) is intended to provide a standardized procedure for assessing the functions of wetlands and other surface waters in Florida. It is also intended to assess the degree to which those functions may be compromised by authorized impacts and the required compensatory mitigation necessary as a result.

PROCEDURE SUMMARY:

Qualitative and quantitative characterizations are required for both impact areas and proposed mitigation areas. FUMAM provides descriptive summaries of the types of information to be included in qualitative characterizations, such as special Florida water classifications, significant nearby features (e.g., national forests, conservation areas, major industry, commercial airport, etc.), assessment area size, land use or habitat classification, etc. Qualitative characterizations are also expected to identify applicable functions of the area being assessed. Functions to be considered include: 1) Providing cover, substrate, or refuge; 2) Breeding, nesting, denning, and nursery areas; 3) Corridors for wildlife movement; 4) Food chain support; and 5) Natural water storage, natural flow attenuation, and water quality improvement. No technical or programmatic guidelines are provided to guide the evaluation or applicability of these functions.

Quantitative characterizations are intended to identify the degree to which the assessment area performs the functions identified during the qualitative characterization and are also used to determine the amount of function lost or gained by the proposed project. FUMAM outlines three functions for wetlands and other surface waters: 1) Location and Landscape Support, 2) Water Environment, and 3) Community Structure. Location and Landscape Support is essentially a representation of the assessment area's landscape position and its relationship with surrounding land uses that may affect its capacity to provide functions and benefits to fish and wildlife. Water Environment refers to the timing, frequency, depth and duration of inundation or saturation, flow characteristics, and water quality factors that may affect certain functions or the site's capacity to support certain wildlife. Community Structure refers to either the vegetative community or the submerged benthic community, depending on the type of aquatic resource being assessed.

Each of the above referenced functions is scored 0 (function not present) to 10 (function is optimal) based on the level of function and benefit to fish and wildlife. Criteria are provided to aid in the selection of appropriate scores for each function. However, these criteria are largely descriptive, there is no explicit requirement or recommendations for actual sampling of any physical habitat attributes, and there are no technical methods referenced.

FUMAM incorporates both temporal lag and risk to the proposed mitigation site when evaluating proposed gains in ecological function. Temporal lag is based on tabulated adjustment factors (t-factors) associated with the expected time needed for the mitigation site to fully offset the proposed impacts and range from 1 to 3.91. Risk is represented on a scale of 1 to 3, scored in 0.25 increments with higher values representative of increased perceived risk to the mitigation area. The change (delta) in the quantitative assessment score of the proposed mitigation site “with project” vs. “without project” is then divided by the product of the temporal lag and risk factors to obtain Relative Functional Gain (RFG).

The Functional Loss (FL) at the impact site is represented by the change (delta) in the “with project” vs. “without project” quantitative assessments at the impact site, multiplied by the proposed acres of impact. The amount of mitigation required to compensate for the proposed impacts is then determined by the quotient, FL/RFG.

REFERENCE CONDITIONS, PERFORMANCE STANDARDS, & MONITORING:

Neither reference conditions, performance standards, nor monitoring is addressed by FUMAM (F.A.C. 62-345). However, some of the scoring criteria provided for the ecological functions suggest that reference conditions are assumed to be known by the party executing the assessment (e.g. “Water depth, wave energy, currents, and light penetration are optimal for the type of community being assessed.”).

OTHER:

The description of FUMAM in F.A.C. 62-345 leaves application of the protocol difficult to discern. It seems intuitive that a single protocol intended to provide for functional assessment and evaluation of mitigation proposals for all aquatic resources must be characteristically vague, with details to be worked out and modified as the procedure is implemented. Based on the lack of specific guidance provided in F.A.C. 62-345, there exists a widely diverse range of interpretations regarding execution of the assessment protocol.

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Uniform Mitigation Assessment Method
http://www.dep.state.fl.us/water/wetlands/mitigate/uwmam.htm

No. 11 - Guidelines for Assessing Development Project Impacts on Wildlife Habitats and Planning Mitigation Measures for Wildlife Habitat Losses

Kansas Department of Wildlife and Parks (January 1996)

Stream Habitat Evaluation

Kansas Department of Wildlife and Parks (rev. September 2000)

PRIMARY PURPOSE:

The *Guidelines for Assessing Development Project Impacts on Wildlife Habitats and Planning Mitigation Measures for Wildlife Habitat Losses* provide general guidelines to assist in developing mitigation recommendations and also provide consistency for the administration of Kansas Department of Wildlife and Parks (KDWP) environmental services.

PROCEDURE SUMMARY:

All proposed impact areas will be assessed via quantitative and qualitative evaluations of each aquatic and terrestrial habitat type. Mitigation recommendations will be based on the results of standard KDWP habitat evaluation procedures, unless otherwise directed.

While the KDWP *Guidelines* are intended to be applicable to any type of wildlife habitat, aquatic habitat is addressed separately therein. The KDWP *Stream Habitat Evaluation* is a worksheet that is used to score various attributes of the stream being assessed. Variables are arranged under four general subheadings: 1) Physical Habitat, 2) Riparian/Floodplain, 3) Biological Components, and 4) Pollution Components. Each variable has from 3 to 8 attributes that can be used to score the stream being assessed (Table 1). The score for each variable is summed to obtain a total and then divided by 10 to obtain and "R" factor, which is used in mitigation computation equations.

(1) R_x x acres x life of project = Habitat Unit Value of Impacted Habitat

where R_x = Stream Habitat Evaluation of impacted stream

(2) (10-R_y) x acres x life of project = Habitat Units Gained

where R_y = Stream Habitat Evaluation of stream proposed as mitigation

Equation (2) must equal or exceed Equation (1) in order for the proposed mitigation to adequately compensate for the wildlife habitat losses.

Table 1. Variables and attributes used by the Kansas Department of Wildlife and Parks Stream Habitat Evaluation.

Subheading	Variable	Attributes / Definition
Physical Habitat	Flow	Permanence: perennial, intermittent, etc.
	Substrate	e.g., Boulder/cobble, gravel, sand, etc.
	Number of Substrate Types	≥ 4, 3, or ≤ 2
	Silt Cover	Percent of dominant substrate surrounded or covered by fine sediment
	In-stream Cover Types	e.g., Deep pools, coarse woody debris, undercut banks, vegetated shallows, etc.
	Amount of In-stream Cover	Percent of total stream area
	Macrohabitat Types	Number present: pools, riffles, or runs
	Bank Erosion	Little to none, moderate, or severe
	Channel Modifications	e.g., Concrete lining, channelization, riparian clearing, dredging, or riprap/gabion baskets
Riparian / Floodplain	Riparian Vegetation Width	e.g., > 50m, 10-50m, 5-10m, 1-5m, or none
	Canopy Cover [over stream channel]	e.g., (50-75%), (25-50% or 75-90%), or (< 25% or > 90%)
	Adjacent Land Uses	Listed land uses
Biological Components	Fishery Characteristics	Types of fish present (e.g., high quality sportfish, panfish and predaceous fish, etc.)
	Aquatic Insects	Number of Orders present (e.g., >3, 1-3, or 0)
	Molluscs/Crayfish	e.g., Common/Abundant, Sparse, or None
	Amphibians	e.g., Common/Abundant, Sparse, or None
Pollution Components	Silt Turbidity (Secchi)	e.g., >18", 12-18", or <12"
	Pollution	Evidence of pollution other than silt (e.g., None, Moderate, or Severe)
	Chemical Variables	e.g., Not Limiting or Limiting

When reestablishment of woody perennial vegetation is a required component of mitigation, the USDA SCS *Guide for Evaluating the Impact of Water and Related Land Resource Development Projects on Fish and Wildlife Habitat* is used to account for temporal losses (i.e, the credit allocation is discounted based on the time for plantings to reach maturity).

The KDWP Guidelines note that intermittent and perennial streams are the most common aquatic habitats impacted by development activities in Kansas, and mitigation of these impacts is handled on a case by case basis. The Guidelines provide a list of examples of stream mitigation activities, but do not otherwise specify any technical or programmatic guidance to assist with compilation of stream mitigation plans.

REFERENCE CONDITIONS, PERFORMANCE STANDARDS, & MONITORING:

Neither reference conditions, performance standards, nor monitoring criteria are addressed by the KDWP Guidelines. The Stream Habitat Evaluation is a subjective inventory and assessment method, and it's utility as a monitoring protocol is uncertain.

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1) Guidelines for Assessing Development Project Impacts on Wildlife Habitats and Planning Mitigation Measures for Wildlife Habitat
2) Stream Habitat Evaluation
http://www.kdwp.state.ks.us/envsrvs/envsrvsdocs.html

No. 12 - Guidelines for Natural Stream Channel Design for Pennsylvania Waterways

Keystone Stream Team, (rev. March 2003)

PRIMARY PURPOSE:

The *Guidelines for Natural Stream Channel Design for Pennsylvania Waterways* (Guidelines) were developed by a consortium including government and environmental resource agencies, university researchers, sportsmen, citizen-based watershed groups, and private companies to provide a common process for planning, designing, and evaluating natural stream channel restoration projects. The Guidelines are aimed at professionals involved in stream restoration design, construction, and permitting. However, they are not intended to provide a cookbook approach to natural stream channel design, nor serve as a how-to manual (Keystone Stream Team, 2003).

PROCEDURE SUMMARY:

The Guidelines are fundamentally based on evaluation of a stream's fluvial geomorphology and the departure of a stream's geomorphological characteristics from that of stable reference streams. Assessment of general watershed conditions is stressed as a necessary first step to any stream restoration project. Historical and current records documenting stream flow, water quality, watershed geology, and land use are suggested and potential sources of information are identified. Stream classification (Rosgen, 1994; 1996) and channel evolution models (Simon, 1989; Rosgen, 2001) are recommended as a means to help prioritize potential restoration projects and to gain insight into appropriate geomorphological characteristics of streams and their floodplains. Although the Guidelines repeatedly endorse classification and stream channel design methodologies by Rosgen (1994; 1996), they also acknowledge the utility of other stream classifications (e.g., Schumm, 1963; Montgomery and Buffington, 1997).

The Guidelines recommend interdisciplinary teams conduct preliminary site assessments for specific stream reaches using commonly accepted methodologies such as the Stream Visual Assessment Protocol (NRCS, 1998), the Stream Classification Worksheet based on Rosgen (1996), or any of the methods summarized in NRCS (2001). The Guidelines also encourage practitioners to meet with the local watershed community to help evaluate options, garner support, and learn about long-term watershed development plans. Ecological and economic benefits and risks of a proposed project must be used to develop cost-benefit analyses, and these too must be shared with the community.

Rosgen (1996) methods of fluvial geomorphic stream assessment and natural channel design are recommended by the Keystone Stream Team (2003), and Rosgen's field data sheets (Rosgen, 1996; 1998) are included in the appendices.

REFERENCE CONDITIONS, PERFORMANCE STANDARDS, & MONITORING:

The Guidelines require that reference reaches be used during design of a stream restoration project. Reference reaches should be located within the project's watershed or in a neighboring watershed that is within the same hydro-physiographic region, has the same general land use, and has the same stream type and valley form as the project stream. The Guidelines reference Harrelson *et al.* (1994) for identification and documentation of reference reach characteristics.

The Guidelines include a chapter devoted to pre- and post-construction monitoring and also stresses that as-built surveys should be undertaken. Elements of monitoring plans are recommended, including monumented cross-sections, longitudinal profiles, substrate analysis (pebble counts), pattern (sinuosity, meander lengths and radii of curvature), measures of bank stability (e.g., BEHI, erosion pins, Pfankuch (1975), etc.), and the USEPA RBP physical stream habitat assessment (Barbour *et al.*, 1999).

OTHER:

The Guidelines include sections devoted to regulatory permitting, compilation of construction drawings and bid documents, selection of consultants, and recommended construction sequences. The Guidelines are rich with references to established protocols and methods, but also stress the importance of appropriately trained personnel to undertake stream assessment and restoration design.

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http://www.canaanvi.org/nscdguidelines/

No. 13 - Integrated Streambank Protection Guidelines

Washington State Aquatic Habitat Guidelines Program (2003)

PRIMARY PURPOSE:

The Integrated Streambank Protection Guidelines (ISPG) is a component of the Aquatic Habitat Guidelines collection created by a consortium of public agencies with the aim of assisting property owners, planners, designers, and regulators to protect and restore marine, freshwater, and riparian fish and wildlife habitat in Washington State. The ISPG focuses on understanding the mechanisms of streambank erosion and how to best evaluate options for its mitigation.

PROCEDURE SUMMARY:

The ISPG stresses evaluating streambank erosion in context with the fish and wildlife habitat characteristics, needs, and potential of the affected stream, downstream receiving waters, and associated floodplains. Issues of scale (e.g., specific site disturbances that cause erosion vs. larger stream reach or sub-watershed activities that lead to erosion) are repeated throughout. The ISPG points out the need to assess risk, both as it relates to implementation of streambank erosion control measures, as well as evaluation of "no action" alternatives.

The ISPG is rich with conceptual and technical background information pertaining to streambank erosion. There are detailed sections describing specific mechanisms of local streambank failure (e.g., toe erosion, mass wasting, etc.) and watershed or stream reach scale fluvial process that may contribute to erosion (e.g., channel migration, meander cut-offs and knickpoint migration, effects of floodplain constrictions, etc.). The ISPG includes appendices covering open channel hydraulics, hydrologic analysis, sheer stress and scour, fluvial geomorphology and sediment transport, and habitat needs of Pacific Northwest salmonids. There is also an entire chapter devoted to specific streambank protection techniques (Chapter 6), including structural, biotechnical (bioengineering), and flow re-direction techniques.

The ISPG presents three screening matrices to help select streambank protection treatments or methods. Matrix 1 is used to resolve site-specific mechanisms of streambank failure; Matrix 2 addresses reach-scale conditions that lead to streambank failure; and Matrix 3 is used to assess the potential impacts that streambank erosion abatement or streambank protection measures may have on aquatic habitat and identifies how best to mitigate for these impacts. The matrices are consulted in sequential order, with the results of Matrix 1 transferred to the beginning of Matrix 2, etc. In this manner, the matrices act to progressively screen out inapplicable streambank protection methods or conversely, identify the subset of methods that are potentially most applicable for the project site. After utilizing Matrix 2, the user should have a list of alternative streambank protection measures that best address both site specific and reach-scale conditions that are causing or exacerbating streambank erosion on his/her project site. Matrix 3 then allows the user to compare and contrast all applicable methods identified from Matrices 1 and 2 on the basis of their potential impacts to habitat and means to mitigate for those impacts. The ultimate objective is to select one or more streambank protection measures that minimize associated adverse impacts to habitat.

REFERENCE CONDITIONS, PERFORMANCE STANDARDS, & MONITORING:

The ISPG includes an appendix devoted to monitoring streambank protection and habitat improvement projects. Also, each specific technique described in Chapter 6 of the ISPG includes a discussion on monitoring considerations. Monitoring must include documentation of baseline (pre-project) conditions, which must utilize the same measures and methods as proposed for post-project monitoring.

The ISPG defines success criteria as predetermined thresholds of performance for the measurable attributes of a project, and further stresses that success criteria are not the same as monitoring objectives. Success criteria are recommended for streambank protection measures and any associated compensatory mitigation.

OTHER:

The focus of the ISPG is on streambank erosion and not necessarily "whole stream" assessment. Background information on hydrology, sediment transport, geomorphology, etc., is excellent. However, there is little in the ISPG that specifically requires assessment of total stream habitat quality or geomorphology, nor is there a coherent protocol outlined for executing such assessments.

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Integrated Streambank Protection Guidelines
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No. 14 - Standard Operating Procedure Compensatory Mitigation

U.S. Army Corps of Engineers, Charleston District - September 19, 2002

PRIMARY PURPOSE:

The Charleston District SOP is applicable to regulatory actions requiring compensatory mitigation pursuant to Section 404 of the CWA in the USACE Charleston District, State of South Carolina. It's intent is to provide a basic written framework that will result in predictable and consistent development, review, and approval or compensatory mitigation plans. However, it is not intended for use as project design criteria.

The SOP addresses impact and mitigation assessment for various types of jurisdictional waters, including wetlands, streams, seeps, etc. However, the following discussion will focus solely on aspects of the SOP that are applicable to single-channel fluvial resources. Streams with braided channels are evaluated using the wetlands portion of the SOP according to Charleston District protocol.

PROCEDURE SUMMARY:

Worksheets are provided to document various aspects of a project proposing to impact and mitigate stream resources. These include: a) Adverse Impact Factors, b) Riparian Buffer Enhancement Mitigation Factors, and c) Restoration Mitigation Factors. Each worksheet includes a number of metrics that are scored, summed, and then multiplied by the linear feet of stream affected to obtain a total of number of mitigation credits either needed to offset the impacts or that result from the mitigation efforts, respectively.

The Charleston SOP uses six metrics in the Adverse Impact Factors worksheet to determine the number of mitigation credits necessary to satisfactorily compensate for the authorized losses: 1) Lost [Stream] Type, 2) Priority Category, 3) Existing Condition, 4) Duration [of Impact], 5) Dominant [Type of] Impact, and 6) Cumulative Impact.

Riparian buffer enhancement may be utilized to generate up to 75% of the required compensatory mitigation credits for authorized impacts to streams in the USACE Charleston District. The Riparian Buffer Enhancement Mitigation Factors worksheet delineates minimum buffer widths necessary to receive mitigation credit for buffer enhancement (based on adjacent land use and valley slope perpendicular to the stream channel) and stipulates the conditions under which buffer enhancement will be considered as mitigation by the USACE. The worksheet then utilizes five metrics to determine the total number of mitigation credits to be generated by a proposed buffer enhancement plan.

The Restoration Mitigation Factors worksheet uses six metrics to evaluate proposed mitigation plans: 1) Net Improvement, 2) Priority Category, 3) Control, 4) Credit Schedule, 5) Kind, and 6) Location. Stream restoration or relocation provides the greatest Net Benefit, and concomitant number of mitigation credits generated, and is based on level of effort (Priorities 1 through 4) as defined by Rosgen (1997). Table 1 summarizes the metrics and the scoring classes for each metric in the Restoration Mitigation Factors Worksheet.

Table 1. Metrics and classes in the Restoration Mitigation Factors worksheet in the USACE Charleston District SOP to assess proposed stream restoration plans.

Metric	Classes	Description / Example
Net Improvement	Moderate [a]	Priority 4 restoration; livestock exclusion; etc.
	Good [a]	Certain Priority 2 and 3 restorations; etc
	Excellent [a]	Priority 1 (2) restoration; daylighting
Priority Category	Tertiary [a]	Streams not considered Secondary or Primary
	Secondary [a]	Scenic river corridors; species of concern, etc.
	Primary [a]	SCDNR ref streams; T&E species; 303(d); etc.
Control	Covenant Private	Deed restrictions filed by a private party
	Covenant POA	Deed restrictions with oversight by NGO
	Easement	Conservation easement granted to NGO or govt
	Conservancy	Transfer of fee title ownership to NGO or govt
Credit Schedule	Schedule 5	Mitigation undertaken after impacts
	Schedule 4	Majority of mitigation undertaken concurrent with impacts, remainder done afterwards
	Schedule 3	Mitigation is undertaken concurrent with impacts
	Schedule 2	Majority of mitigation completed prior to impacts
	Schedule 1	Mitigation completed prior to adverse impacts
Kind	Category 5	<< only applicable to mitigation banks >>
	Category 4	Out-of-kind
	Category 3	<< only applicable to mitigation banks >>
	Category 2	<< only applicable to mitigation banks >>
	Category 1	In-kind
Location	Zone 5	<< only applicable to mitigation banks >>
	Zone 4	Mitigation site lies in same ecoregion as impacted site, but outside of 8-digit HUC watershed
	Zone 3	<< only applicable to mitigation banks >>
	Zone 2	Mitigation site lies >½ mile from impact site, but within 8-digit HUC watershed
	Zone 1	Mitigation site lies within ½ mile upstream or downstream of impact site

[a] SOP provides much greater definition, detail, and specific criteria by which to assign classes.

REFERENCE CONDITIONS, PERFORMANCE STANDARDS, & MONITORING:

Reference reach data from the same stream type and ecoregion must be collected for restoration design and may also be used to formulate the requisite monitoring plan and success criteria. The SOP includes pages from "*The Reference Reach Field Book*," (Rosgen, 1998) to illustrate applicable geomorphic characteristics to be determined from reference streams in the field.

Monitoring plans must be submitted with mitigation plans. Major restoration projects require both physical and biological monitoring, while monitoring components of smaller projects are determined on a case by case basis. Physical monitoring of stream systems will typically include channel cross-sections, longitudinal profiles, substrate characteristics, and other fluvial geomorphologic characteristics as described by Rosgen (1996). Biological monitoring of stream fauna should be undertaken for projects that target in-stream habitat restoration. For most restoration projects, both pre-construction (baseline) and post-construction surveys should be also be conducted.

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Standard Operating Procedure Compensatory Mitigation
USACE Charleston District
http://www.sac.usace.army.mil/permits/mitigate.html

No. 15 - Stream Attributes Analysis: Impact and Mitigation Assessment

U.S. Army Corps of Engineers, Norfolk District

PRIMARY PURPOSE:

The Stream Attributes Analysis (SAA) is intended to facilitate the rapid and replicable review for projects seeking authorization from the USACE Norfolk District pursuant to Section 404 of the CWA to impact perennial or intermittent stream resources in the Piedmont physiographic region of Virginia.

PROCEDURE SUMMARY:

Six variables are scored a Condition Index (CI) ranging from 0 (poor) to 1.0 (excellent), based on condition classes provided for each variable in the SAA description. These six variables include:

- Width of forested riparian zone (including logged areas)
- Amount of watershed development (Note: Any stream on Virginia's 303(d) List is automatically given the lowest possible CI for this metric regardless of watershed development).
- Degree of channel incision (based on bank height ratio)
- Percent of stream reach with eroding banks
- Percent of stream reach that has been channelized
- Percent of stream reach having in-stream habitat

The proportional length of the Stream Assessment Reach (SAR) that is characterized by the descriptive attributes of the variables is a factor in determining three of the six CI's. Then, the total SAR length is multiplied by each CI to obtain a Stream Condition Unit (SCU) for each variable. Each of the six SCU scores are then summed to obtain a Total Stream Condition Unit (TSCU).

SCU scores are determined for both pre-impact and post-impact conditions, based on the anticipated effects of the project on the six individual CI's. Requirements for compensatory mitigation are based on Impact-SCU's, which are determined by subtracting the post-impact SCU's from each respective pre-impact SCU. The goal of mitigation is to replace an equal number of SCU's for each of the six variables impacted. A defensible rationale must be provided by the permit applicant if he/she either proposes to emphasize one or more variables over other variables, or if full compensation (i.e., "lift" to 1.0 for all CI's) is considered impracticable by the applicant.

The SAA description also points out that watershed condition, as indexed by the Amount of Watershed Development, is often a limiting factor for compensatory mitigation efforts and should therefore be considered during the mitigation site selection process.

Finally, the SAA notes that mitigation for stream impacts should take place on streams of the same size and slope as the impacted resource. The SAA includes a correction equation to discourage mitigating higher stream order impacts on lower order streams (i.e., 3^{rd} order stream impacts mitigated on a 1^{st} or 2^{nd} order stream) by increasing the number of SCU's required. However, no such correction is needed if one proposes to mitigate lower order stream impacts on a higher order stream. Variance in stream gradient is addressed on a case-by-case basis.

REFERENCE CONDITIONS:

There is no direct requirement to include reference reach data in SAA assessments, as these are incorporated by default into the condition class scoring of the six variables. The SAA documentation does not specifically address performance standards or monitoring requirements for in-stream or near-stream mitigation efforts.

OTHER:

The description of the SAA states that the six variables themselves, as well as the condition classes used for scoring for CI's, are based on data collected from reference stream reaches that capture the range of variation for each variable from least disturbed stream conditions to most disturbed stream conditions throughout the Virginia Piedmont. However, there is no information given in the SAA that indicates who collected or analyzed this data, specifically what data was collected, or who to contact for additional information about the data.

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No. 16 - Stream Mitigation Guidelines [for North Carolina]

U.S. Army Corps of Engineers, Wilmington District - April 2003

PRIMARY PURPOSE:

The Stream Mitigation Guidelines were compiled by a workgroup consisting of representatives from USACE Wilmington District, North Carolina Department of Environment and Natural Resources (NCDENR) Division of Water Quality (DWQ), USEPA Region 4, NRCS, and the North Carolina Wildlife Resources Commission (WRC) in an effort to have consistent stream mitigation guidance for the regulated community of North Carolina. The Guidelines include requirements for stream mitigation, definitions of stream mitigation terms and activities, information on crediting for mitigation activities, and monitoring requirements. Additional technical documents are incorporated by reference, as described further below.

PROCEDURE SUMMARY:

The Guidelines stipulate general mitigation ratios on a linear basis for impacts to intermittent and perennial, non-tidal streams in North Carolina. The amount of compensatory mitigation required is based on the existing condition (quality) of the impacted stream and the type of mitigation activities proposed as mitigation. Base mitigation ratios based solely on stream quality range from 1:1 for poor or fair condition streams, 2:1 for good quality streams, and 3:1 for excellent quality streams. A “mitigation activity multiplier” is then determined based on the specific mitigation activities proposed. Due to the wide range of potential enhancement and preservation opportunities that may be available on any given mitigation site, the mitigation activity multiplier ranges from 1.0 to 5.0. Thus, the final mitigation ratio may range from 1:1 for a low quality impacted stream where a high quality restoration plan is proposed, or it may be as high as 15:1 if impacts to an excellent quality stream are proposed to be mitigated via preservation. Note that the Guidelines provide specific criteria that must be met in order for preservation to be an acceptable mitigation option.

The Guidelines reference a number of methods and/or tools that can be used to assess stream quality. For example, the NC Biological Assessment Unit has developed bioclassification and rating protocols in three of the major North Carolina ecoregion types for streams with a wetted width ≥4m (NCDENR, 2003). However, the Guidelines also note that these protocols may require a prohibitive amount of time due to their sampling intensity, and USACE and DWQ are “committed to developing a simpler yet still accurate rapid stream assessment methodology.”

USACE and DWQ have developed a Stream Quality Assessment Worksheet for small perennial streams (<3m wetted width), which had not been field tested as of April 2003. The Worksheet provides a qualitative to semi-quantitative means of assessing or ranking streams with other streams by asking a series of 23 questions concerning the physical conditions of the stream being assessed, channel stability, habitat, and biological conditions. Each question is scored between 0 and 2 to 6, depending on the question and the physiographic region where the stream being assessed is located.

Definitions and/or brief explanations are provided for each question, but there are no specific data values or ranges associated with each potential score. The points for all 23 questions are summed for a total score with a maximum of 100. The Guidelines indicate that "until an acceptable methodology is available, DWQ and USACE will evaluate and determine stream quality on a case-by-case basis with applicants based on the best information that is available at the time of the evaluation."

The Guidelines delimit four types of mitigation: 1) Restoration; 2) Enhancement I; 3) Enhancement II; and 4) Preservation. Only brief descriptions of each type are provided. However, a greater degree of technical guidance and reference is provided in the *Internal Technical Guide for Stream Work in North Carolina* (NCDENR, 2001). Generally, it is recommended that all in-stream restoration, relocation, or enhancement activities utilize Rosgen stream classification and restoration methods (Rosgen, 1994; 1996).

Mitigation site selection criteria is outlined in the Guidance. Mitigation should be accomplished within one stream order of the impacted stream(s) and within the same 8-digit USGS HUC watershed. Mitigation should be provided on the same stream habitat designation(s) as the impacted stream(s), based on WRC habitat guidance (cold, cool, and warmwater designations). Finally, mitigation should be undertaken in the same physiographic region. Any deviation from these criteria may result in higher mitigation ratios.

REFERENCE CONDITIONS, PERFORMANCE STANDARDS, & MONITORING:

Reference conditions are required for all stream restoration, relocation, and in-stream enhancement activities. Success criteria are also required, and the Guidelines provide examples of criteria that should be considered.

The Guidelines require three forms of post-construction monitoring: photo documentation, ecological function, and channel stability measurements. Each of these components is described for each of three levels of rigor for monitoring, based on the magnitude of the specific mitigation activities. An as-built channel survey is required, and the Guidelines recommend that both this survey and the long-term monitoring follow methods outlined by Harrelson *et al.* (1994). Monumented channel cross-sections are required, and more complex stream restoration and enhancement activities may require biological monitoring consistent with NCDENR protocols (NCDENR, 2002).

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Stream Mitigation Guidelines
USACE Wilmington District
http://www.saw.usace.army.mil/wetlands/Mitigation/stream_mitigation.html

APPENDIX C

Non-Regulatory Protocol Reviews

No. 17 - Applied River Morphology

Rosgen (1996)

PRIMARY PURPOSE:

Applied River Morphology (Rosgen, 1996) provides a detailed explanation of the Rosgen stream classification system (Rosgen, 1994) and "how it might be used to incorporate the observed processes of river mechanics into restoration designs...." (Rosgen, 1996). Collectively, the classification, methods, and principles of natural channel design popularized by Dave Rosgen (Wildland Hydrology, Fort Collins, Colorado) are often simply referred to as "the Rosgen method" or even simply "Rosgen."

PROCEDURE SUMMARY:

The Rosgen stream classification (Rosgen 1994, 1996) uses a hierarchical key to demarcate 94 stream types based on specified ranges of quantitative variables (Table 1). *Applied River Morphology* describes specific methods to measure various physical stream, floodplain, and valley features and discusses the significance of these features in the assessment of channel stability. Rosgen (1996) also presents a number of probable channel evolution scenarios illustrating the adjustment of channels from one stream type to another during periods of instability caused by perturbations in stream discharge, sediment load, or bank stability. Rosgen (1996) modified a channel stability evaluation proposed by Pfankuch (1975) to account for inherent differences in channel stability among stream types, and later presented a comprehensive step-wise methodology to assess stream channel stability (Table 2) (Rosgen, 2001a).

Table 1. Stream type delineation criteria used in the Rosgen stream classification (Rosgen, 1996),

Attribute Class	Attribute	Definition or Example
Plan-View Morphology	Sinuosity	Stream length divided by valley length
	Meander Width Ratio	Meander belt width divided by bankfull channel width
Longitudinal Features	Channel Slope	
	Bed Features	Examples: pools, riffles, rapids, cascades, and steps
Cross-Sectional Geometry	Entrenchment ratio	Width of the floodprone area at an elevation of 2x the maximum bankfull depth divided by bankfull width
	Width/Depth ratio	Bankfull width divided by bankfull depth
	Dominant Channel Materials	Representative particle size (D50) of most prevalent channel material type/size

Table 2. Step-wise channel stability methodology proposed by Rosgen (2001a).

Steps	Attributes	Definition / Examples
1) Condition Categories	Riparian Vegetation	Composition, density, & potential climax communities
	Sediment Deposition Patterns	Eight potential patterns: e.g. Point bars, few mid-channel bars, many mid-channel bars, side bars, diagonal bars, etc. (Rosgen, 1996)
	Debris Occurrence	Type and frequency of debris and/or other channel blockages
	Meander Patterns	Eight potential patterns: e.g. Regular, tortuous, irregular, truncated, etc.
	Stream Size / Order	Based on bankfull width and stream order
	Flow Regime	e.g. Perennial, intermittent, ephemeral, subterranean
	Altered States	Unnatural conditions due to direct disturbance
2) Vertical Stability	Bank Height Ratio (BHR)	Lowest cross-sectional bank height divided by the maximum bankfull depth: 1.0>BHR>1.05 = stable channel; BHR>1.5 = highly unstable channel
	Entrenchment Ratio (ER)	ER < 1.4 ± 0.2 = entrenched (incised) channel
3) Lateral Stability	Meander Width Ratio	See definition in Table 1.
	Streambank Erosion Hazard Index (BEHI)	Index based on bank height/bankfull height; rooting depth/bank height; bank angle; and bank surface protection (Rosgen 1996; 2001a)
	Near-Bank Stress	
4) Channel Pattern	Dimensionless ratios of 1) meander width ratio; 2) radius of curvature/bankfull width; 3) sinuosity; 4) meander length/bankfull width; 5) arc length and arc angle.	
5) River Profile and Bed Features	1) Pool to pool spacing; 2) max pool depth/channel depth; 3) max riffle depth/mean bankfull depth; 4) longitudinal thalweg profile also identifies changes in bed gradient	
6) Channel Dimension Relations	Changes in width/depth ratio measured as departure from reference conditions in a stable stream.	
7) Sediment Competence	Critical Dimensionless Sheer Stress: Used to determine the size of sediment particle that can be moved in the channel	
8) Stream Channel Stability	Modified from Pfankuch (1975)	
9) Dimensionless Ratio Sediment Rating Curves		
10) Stream Type Evolutionary Scenarios		

REFERENCE CONDITIONS, PERFORMANCE STANDARDS, & MONITORING:

The Rosgen stream classification is itself internally calibrated to reference conditions observed and measured by the author. All efforts to assess channel stability or otherwise evaluate, design, and construct stream enhancement or restoration projects using Rosgen methods must be firmly rooted in establishing reference conditions from stable streams of the target stream type. Rosgen (1998) outlines the role of reference conditions used to develop natural channel design.

OTHER:

The Rosgen stream classification and Rosgen methods of natural stream channel design have become de facto standards in many parts of the United States. The National Research Council recommended a stream restoration planning process and systematic guidelines to minimize the use of inappropriate in-stream structures proposed by Rosgen and Fittante (1986), which was based in part on an early version of Rosgen's stream classification.

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No. 18 - Basinwide Estimation of Habitat and Fish Populations in Streams

USFS Southeastern Forest Experiment Station (Dolloff *et al.,* 1993)

PRIMARY PURPOSE:

The *Basinwide Visual Estimation Technique* (BVET) (Hankin and Reeves, 1988) was developed to provide a statistically valid, accurate, and cost-effective alternative for developing habitat and fish population inventories (Dolloff *et al.*, 1993). BVET was conceptualized as an alternative to extrapolating habitat and fish population estimates from representative reaches of a stream to an entire watershed.

PROCEDURE SUMMARY:

BVET is a two-step inventory during which the survey team first classifies the habitat units by type and visually records observations such as surface area and substrate type. Then, these visual observations are paired with actual measurements at a predetermined number of individual habitat units (at least 10 for each habitat type) to develop ratios. Dolloff *et al.* (1993) recommend that teams unfamiliar with BVET collect actual measurements on one out of every five habitat units, for a sampling fraction of 20%.

Dolloff *et al.* (1993) provide specific methods to describe habitat units, including measurement interval, necessary equipment, and recommended means of recording data. Essentially, an entire stream system within a given watershed is surveyed in the field. Hip chains or other measuring devices are used to estimate spacing and longitudinal dimensions of habitat types. Then cross-sections with more detailed measurements are used at predetermined intervals to more accurately characterize horizontal dimensions, slope, etc. Methods for conducting fish surveys are also described using the same premise as BVET habitat surveys.

REFERENCE CONDITIONS, PERFORMANCE STANDARDS, & MONITORING:

Neither reference conditions, nor performance standards are addressed by Dolloff *et al.* (1993). BVET can be used to monitor applicable physical stream features, as well as changes in those features as a result of stream enhancement or restoration practices. They may also be useful for identifying applicable reference conditions and/or performance standards for stream enhancement or restoration projects.

OTHER:

Dolloff *et al.* (1993) also discuss data entry and analysis techniques to estimate habitat area and fish populations with associated variances and confidence intervals for each habitat type and stream segment.

Dolloff *et al.* (1997) compared estimates of stream habitats in three Southern Appalachian watersheds using BVET and the representative reach extrapolation technique (RRET), whereby habitat inventories are conducted only in representative reaches of a stream and extrapolated to an entire stream system. They found that eight out of nine estimates of total habitat area by habitat type (e.g. pools, riffles, and cascades) on a watershed scale using RRET were outside of the 95% confidence intervals of estimates derived from using BVET. The authors concluded that it was unrealistic to expect to a single stream reach to reflect the characteristics of an entire stream, unless that reach approached the total length of the stream.

Dolloff *et al.* (1993) indicate that an experienced BVET team of surveyors (2 persons) can assess 1-1.5km (<1 mi) of stream per day. The strength of BVET is its characterization of stream habitat throughout a watershed. However, stream impacts most often proposed for CWA Section 404 permits are typically localized to only a specific stream reach. The whole-basin inventory approach of BVET may prove useful in determining more accurate reference conditions that could be included into a restoration design.

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Basinwide Estimation of Habitat and Fish Populations in Streams
http://www.srs.fs.usda.gov/pubs/viewpub.jsp?index=1764

No. 19 - Beneficial Use Reconnaissance Project: 1999 Workplan for Wadeable Streams

Idaho Division of Environmental Quality (BURP TAC, 1999)

PRIMARY PURPOSE:

The Idaho Division of Environmental Quality (IDEQ) *Beneficial Use Reconnaissance Project* (BURP) was developed in part to meet CWA requirements for ambient monitoring and development of biological criteria for water quality standards. BURP aims to integrate biological and chemical monitoring with physical stream habitat characterizing stream integrity and water quality. The original pilot project begun in 1993 was based on protocol that closely followed the USEPA RBP (Plafkin *et al.*, 1989).

BURP includes methods to characterize stream habitat, macroinvertebrates, fish, bacteria, and periphyton. This summary will focus solely on the stream habitat portion of the BURP Workplan.

PROCEDURE SUMMARY:

The BURP Workplan outlines a method for selecting monitoring sites and also discusses requirements for properly documenting each site. Ecoregional setting, stream order, Rosgen stream type (Rosgen, 1996), and land use are all factors considered for selection of BURP monitoring sites. Sample stream reaches should be a minimum of 40 times the wetted width or 200m, whichever is larger.

The Workplan then lists core BURP variables for wadeable streams (Table 1) and provides rationale for the selection of each variable. Specific methods for measuring or estimating each core variable are provided and briefly described.

A number of field data sheets are provided and include all site location information, potential riparian land use categories, and diagrammatic representations of various valley types and categorical stream channel sinuosities. Additional data sheets are used to record pebble counts, large woody debris inventories, canopy closure (shading), bankfull and wetted width dimensions, streambank conditions, longitudinal habitat descriptions, and pool quality.

REFERENCE CONDITIONS, PERFORMANCE STANDARDS, & MONITORING:

IDEQ stratifies reference conditions based on Rosgen stream classification (Rosgen, 1996) and ecoregions in Idaho and also considers land use and ownership. IDEQ has compiled specific guidance used to select reference reaches and identify the range of reference conditions (IDEQ, Draft 1999).

The BURP Workplan outlines what is essentially a monitoring plan that may have utility to assess post-construction stream enhancement or restoration projects. It does not address performance standards, but may be useful for identifying such standards.

Table 1. 1999 BURP core variables for assessing physical stream habitat in wadeable streams.

Variable	Description	Quantitative or Subjective
Stream Name	Standard name	Q
Flow (Discharge)	One measurement per site	Q
Width/Depth	Measure wetted and bankfull dimensions at 3 locations	Q
Shade	Measure with densiometer from three channel locations (left bank, center, and right bank) at 3 riffles	Q
Bank Cover and Stability	Based on percent coverage of perennial vegetation or roots, rocks of cobble size or larger, or large woody debris; also consider fracture lines, slumping ,etc.	S
Substrate	Modified Wolman pebble counts at 3 riffles (minimum 50 counts per riffle)	Q
Habitat Types	Determine habitat types present along longitudinal axis (wetted portions of channel are assigned to 1 of 4 types: pool, glide, riffle, or run)	S
Pool Complexity	Length, maximum width, maximum depth, and depth at pool tailout measured from a minimum of 4 pools	Q, S
Large Woody Debris	LWD > 10cm diameter and > 1m length; Measured within bankfull zone of influence	Q
Stream Channel Classification	Rosgen Level I letter-classification, including stream order, descriptive valley type, aspect, and lithology	Q
Habitat Assessment	Follow Hayslip (1993) protocol	Q, S
Temperature	Measure instantaneous measurements	Q
Photopoints	Photograph upstream and downstream at lower end of reach	Q
Conductivity	Measure at transect 1 of sample reach	Q
Latitude/Longitude	Differentially corrected GPS	Q

OTHER:

Fore and Bollman (2002) evaluated the BURP protocol stream habitat assessment and proposed a revision to the original Habitat Index (HI), which was modeled after Hayslip (1993) and included 15 habitat variables. The authors reviewed existing BURP data from each of the three main ecoregions in Idaho and evaluated each HI variable and 26 additional habitat variables collected during BURP assessments after 1995, for measurement error, discriminatory power to identify disturbance or impact, and correlation with biological stream conditions.

The SHI is comprised of the 10 variables that minimize measurement error (bias), while also exhibiting the greatest discriminatory power and strong correlations with stream biota: 1) in-stream cover, 2) large organic debris, 3) percent fines <2mm diameter, 4) embeddedness, 5) number of Wolman particle size classes, 6) channel shape, 7) percent bank vegetative cover, 8) percent canopy cover, 9) disruptive pressures, and 10) zone of influence. Some of these variables were included in the original HI, and others were not. Each variable is scored 1-10 for a maximum possible score of 100. Specific values or narrowly defined ranges of data representing each variable are used to allocate point scores, and these values or ranges are themselves adjusted based on ecoregion.

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Beneficial Use Reconnaissance Project: 1999 Workplan for Wadeable Streams
http://www.deq.state.id.us/water/water1.htm#burp

No. 20 - Physical Habitat Characterization (EMAP)
USEPA (Kaufmann and Robison, 1998)

PRIMARY PURPOSE:

The USEPA Environmental Monitoring and Assessment Program (EMAP) is a research program aimed at developing the tools necessary to monitor and assess the status and trends of national ecological resources. Physical Habitat Characterization (PHC) is Section 7 in the *EMAP Surface Waters: Field Operations and Methods for Measuring the Ecological Condition of Wadeable Streams* (Lazorchak *et al.*, 1998). PHC is a collection of procedures recommended where quantitative descriptions of stream reach-scale habitat are desired using easily learned, objective, and repeatable measures of physical habitat in lieu of estimation wherever possible (Kaufmann and Robison, 1998).

PROCEDURE SUMMARY:

There are four components of PHC: 1) stream discharge; 2) thalweg profile; 3) large woody debris tally; and 4) channel and riparian characterization. All data is collected from a stream reach 40 times as long as the stream's low flow wetted width, but not less than 150m. The reach is divided into 10 equally spaced segments with cross-sections established at each union for a total of 11 cross-sections; the first being established at the downstream end of the reach. Stream discharge is measured at a single carefully selected cross-section following methods in Kaufmann (1998). The thalweg profile is a longitudinal survey of depth, habitat class, and presence of soft/small sediment at predetermined intervals based on channel width. The woody debris tally is recorded in each of the 10 reach segments between the cross-sections. Channel and riparian characterization includes measures and/or visual estimation of channel dimensions, substrate, fish cover, bank characteristics, riparian vegetation structure, and evidence of human disturbance. These measures are obtained at each of the 11 cross-sections.

The PHC provides very detailed step-by-step instructions for laying out the sample reach and describes what to measure, how to measure, and in what sequence to measure all of the PHC components. Channel habitat unit classes are defined for the thalweg profile, large woody debris is defined and various "influence zones" are illustrated for the debris tally, and precise descriptions are provided for the whole suite of channel and riparian characterization variables. Comprehensive data forms are provided, and the PHC provides a list of equipment and supplies necessary to execute the characterization.

Finally, the PHC recommends notation and data entry features and styles to facilitate quantitative statistical assessment and series analysis of the data following methods in Kaufmann *et al.* (1999).

REFERENCE CONDITIONS, PERFORMANCE STANDARDS, & MONITORING:

The EMAP protocols in general, and the PHC methods in particular, are intended to be used as part of monitoring programs carried out to assess biological criteria for the recognized beneficial uses of water, to monitor surface water quality, and to evaluate the health of the aquatic environment. Thus, the EMAP protocols can be used to monitor applicable physical stream features, as well as changes in those features as a result of stream enhancement or restoration practices.

Neither reference conditions, nor performance standards are addressed by EMAP protocols. However, they may be useful for identifying applicable reference conditions and/or performance standards for stream enhancement or restoration projects.

OTHER:

Kaufmann and Robison (1998) indicate that field trials of the PHC show that a two-person team can typically complete the channel, riparian, and discharge measurements in approximately 3 hours. However, field work may take less than 2 hours for streams less than 4m wide and upwards of 5 hours for large (>10m), complex channels.

The PHC has been revised as part of a *Western Pilot Study Field Operations Manual for Wadeable Streams* (Peck *et al.*, Draft 2001). The Western Pilot includes a number of procedural modifications for collecting data on substrate particle size, in-stream fish cover, human influence, and thalweg habitat classification (Kaufmann and Robison, Draft 2001). There are also three new PHC metrics in the Western Pilot: 1) size and proximity of large, old riparian trees and occurrence of invasive plant species in the riparian area; 2) degree of geomorphic channel constraint; and 3) evidence of major floods or debris torrents.

The primary strength of the PHC is its reliance upon quantitative means of data collection, which strengthens the accuracy and precision (repeatability) of the assessments.

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Physical Habitat Characterization (EMAP)
USEPA
http://www.epa.gov/emap/html/pubs/docs/groupdocs/surfwatr/field/ws_abs.html

No. 21 - Rapid Habitat and Visual Stream Assessments (EMAP)

USEPA (Lazorchak *et al.*, 1998a)

PRIMARY PURPOSE:

The USEPA Environmental Monitoring and Assessment Program (EMAP) is a research program to develop the tools necessary to monitor and assess the status and trends of national ecological resources. Rapid Habitat and Visual Stream Assessments (RHVSA) is Section 14 in the *EMAP Surface Waters: Field Operations and Methods for Measuring the Ecological Condition of Wadeable Streams* (Lazorchak *et al.*, 1998b). The rapid habitat component of the RHVSA focuses on integrating information from specific parameters characterizing the structure of physical stream habitat (Lazorchak *et al.*, 1998a). In contrast, the objective of the visual stream assessment component is to record field observations useful for data validation, future data interpretation, ecological value assessment, development of associations, and verification of stressor data (Lazorchak *et al.*, 1998a).

PROCEDURE SUMMARY:

The rapid habitat assessment is an adaptation of the USEPA RBP protocols (Plafkin *et al.*, 1998), and is intended to be undertaken after all other samples and field data have been collected from a sample reach. As with all EMAP protocols, the length of the sample reach is 40 times the stream's low flow wetted width, but not less than 150m. Different field data sheets are used depending on whether the stream is dominated by "riffle/run" habitat types or "pool/glide" habitat types. For each type, 12 parameters are considered as part of the rapid assessment, and each parameter is scored 0 to 20 based on the overall quality of the sample reach. The sum of all parameters is the total rapid habitat assessment score, which has a maximum possible of 240.

The visual stream assessment component of the RHVSA includes notes and observations pertinent to watershed activities and observed disturbances, general stream reach characteristics, waterbody character, general assessment, and anecdotal information. Watershed activities or disturbances are rated as one of four classes: not observed, low, medium, or high. These are subjective assessments of abundance or influence of such activities as residential development, recreational facilities, agriculture, industry (including logging), and management activities (e.g., water treatment, dredging or channelization, etc.) in the watershed. The proportion of stream reach that is characterized by each riparian cover type and land use on the data form is similarly rated as either rare (<5%), sparse (5-25%), moderate (25-75%), or extensive (>75%). Waterbody character is based on degree of human development and aesthetics, and is subjectively ranked on a scale of 1 to 5 from highly disturbed to pristine and from unappealing to appealing, respectively. General assessment observations should include such information as riparian stand age, wildlife observed during the assessment, diversity of the riparian vegetation, etc. Any comments or information provided to the assessment team by local citizens or residents should be noted in the anecdotal information section of the data form.

REFERENCE CONDITIONS, PERFORMANCE STANDARDS, & MONITORING:

The EMAP protocols in general, and the RHVSA methods in particular, are intended to be used as part of monitoring programs carried out to assess biological criteria for the recognized beneficial uses of water, to monitor surface water quality, and to evaluate the health of the aquatic environment. Thus, RHVSA may be an applicable component of methods to monitor applicable physical stream features, as well as changes in those features as a result of stream enhancement or restoration practices.

OTHER:

The RHVSA has been revised as part of a *Western Pilot Study Field Operations Manual for Wadeable Streams* (Peck *et al.*, Draft 2001). The Western Pilot made the rapid habitat assessment component of the RHVSA optional, and included evidence of fire as a disturbance in the visual stream assessment (Herlihy and Lazorchak, Draft 2001).

A stream assessment program using RHVSA would require an initial effort to calibrate the data to local conditions in order to allow a given stream to be placed into context of local stream conditions. The RHVSA is largely a subjective and qualitative (to semi-quantitative) assessment of stream conditions. As stated previously in this review, the RHVSA was not developed with the intent of being a sole assessment protocol. Rather, it is intended to augment interpretation and verification of data collected using other EMAP protocols.

LITERATURE CITED:

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Lazorchak, J.M., A.T. Herlihy, and J. Green. 1998a. Rapid Habitat and Visual Stream Assessments, Section 14 in J.M. Lazorchak *et al.* (eds). *EMAP- Surface Waters: Field Operations and Methods for Measuring the Ecological Condition of Wadeable Streams*. EPA/620/R-94/004F, US EPA, Washington, D.C.

Lazorchak, J.M., D.J. Klemm, and D.V Peck (eds). 1998b. *Environmental Monitoring and Assessment Program-Surface Waters: Field Operations and Methods for Measuring the Ecological Condition of Wadeable Streams*. EPA/620/R-94/004F, USEPA, Washington, D.C.

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Plafkin, J.L., M.T. Barbour, K.D. Porter, S.K. Gross, and R.M. Hughes. 1989. *Rapid Bioassessment Protocols for Use in Streams and Rivers: Benthic Macroinvertebrates and Fish*. EPA/440/4-89/001. USEPA, Washington, D.C.

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Rapid Habitat and Visual Stream Assessments (EMAP)
USEPA
http://www.epa.gov/emap/html/pubs/docs/groupdocs/surfwatr/field/ws_abs.html

No. 22 - Fairfax County Stream Physical Assessment Protocols

Stormwater Management Branch, Fairfax County, VA (Draft, August 2002)

PRIMARY PURPOSE:

Fairfax County, Virginia has developed a Stream Protection Strategy as part of on-going progress towards a watershed management program. The *Stream Physical Assessment Protocols* build upon the bioassessment program already underway in Fairfax County and will allow the Stormwater Management Branch to better anticipate, prevent, mitigate, and correct stormwater impacts. According to the authors, the Protocols provide a practical, technical reference and establish procedures for maintaining uniform operational and quality control guidance (CH2M Hill, 2002).

PROCEDURE SUMMARY:

The Protocols outline three main types of data to be collected as part of physical stream assessment: 1) habitat assessment, 2) geomorphic assessment, and 3) infrastructure inventory. The habitat assessment component of the Protocols is modeled after the USEPA RBP (Barbour *et al.*, 1999) and includes 10 stream attributes scored on a scale of 0 to 20. There are different variables and different scoring criteria for streams dominated by riffle/run habitats versus glide/pool habitats. Table 1 describes the variables and scoring criteria for habitat assessment of riffle/run prevalent stream types.

A Rosgen Level 1 geomorphic characterization (Rosgen, 1996) comprises the geomorphic component of the Protocols. Channel cross-sections at bankfull stage form the basis for Level 1 evaluation, and streams can then be classified into one of 9 broad stream types according to the Rosgen classification (Rosgen, 1994; 1996).

The third main component of the Protocols is a survey that identifies and characterizes infrastructure elements in or near the stream corridor. These include such things as pipes, ditches, dump sites, head cuts, utility lines, obstructions, deficient buffer vegetation, erosional areas, and road and other stream crossings. Field forms for the infrastructure inventory include impact scores ranging from 0 to 10, which are used to characterize the magnitude of stream character disturbance.

The Protocols also include a Stream Characteristics form that summarizes qualitative stream channel and riparian traits that may not be captured on field forms covering the three assessment and inventory procedures noted above. Descriptive characteristics on the form include, water appearance (e.g., milky, cloudy, turbid, etc.), water odor (e.g., sewage, fishy, chlorine, etc.), sediment odor, presence/absence of fish, presence/absence of aquatic plants, and algae characteristics (e.g., color, growth form, etc.).

Table 1. Variables included in the habitat assessment component for riffle/run prevalent streams in the *Fairfax County Stream Physical Assessment Protocols*.

Variable	Definition	Scoring Criteria
In-stream Cover	Availability of substrates as refuge for aquatic organisms (e.g., large woody debris, deep pools, overhanging vegetation, etc.)	Percent coverage of habitat(s) expected for stream type and number of habitat types present (common to rare).
Epifaunal Substrate	Availability of benthic habitat for macroinvertebrates.	Dimensions (preponderence) of riffles and substrate particle size.
Embeddedness in Run Areas	Degree to which cobble, boulders, or other rock substrate in run habitats is surrounded by fine sediment	Percentage of embeddedness and particle size of fine sediment.
Channel / Bank Alteration	Degree of large-scale alteration of in-stream habitat (e.g., embankments, rip-rap, dredging, dams or bridges, etc.)	Presence/absence and gravity of man-made perturbation; Percent of assessment reach affected.
Sediment Deposition	Amount of sediment accumulated on channel bottom with commensurate changes in stream morphology	Percent of channel bottom affected by sand or silt accumulation.
Frequency of Riffles	Frequency of occurrence of riffles (used as a measure of sinuosity)	Based on run-to-riffle ratio (average distance between riffles / average width of stream)
Channel Flow Status	Degree to which stream flow coves the channel bottom during normal flow conditions	Percentage of channel bed substrate exposed.
Bank Vegetative Protection	Amount of stream bank covered by vegetation	Percent coverage of native/natural vegetation, number of structural strata represented, and affects of vegetation management.
Bank Stability	Existence or potential for detachment of soil from upper and lower stream banks	Bank angle and percent of “raw” or slumping stream banks in assessment reach
Vegetation Buffer Zone Width	Width and condition of buffer zone vegetation or land use in riparian zone	Width and community structure of vegetated buffer zone and percent impervious surfaces in riparian zone

REFERENCE CONDITIONS, PERFORMANCE STANDARDS, & MONITORING:

Neither reference conditions, performance standards, nor monitoring is addressed by the *Fairfax County Stream Physical Assessment Protocols*. However, the habitat assessment component of the Protocols implies that the reviewer is familiar enough with similar stream types in the region to know the types of habitats characteristics of various Rosgen (1994, 1996) stream classes. The procedures outlined are essentially an inventory tool used to help document baseline conditions for impact assessment due to stormwater management activities. The data generated from these procedures may also be useful for prioritizing stream restoration efforts.

LITERATURE CITED:

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Rosgen, D.L. 1994. A classification of natural rivers. *Catena* 22:169-199.

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Fairfax County Stream Physical Assessment Protocols
http://www.fairfaxcounty.gov/gov/DPWES/Watersheds/psa.htm

No. 23 - Field Evaluation Manual for Ohio's Primary Headwater Habitat Streams

Ohio EPA, Division of Surface Water - September 2002

PRIMARY PURPOSE:

The *Field Evaluation Manual for Ohio's Primary Headwater Habitat Streams* is intended to promote standardized assessment of actual and expected biological conditions in primary headwater habitat (PHWH) streams in Ohio. The principal regulatory and/or administrative impetus for development of the protocols was pursuant to water quality standards (designated uses, water quality criteria, antidegradation) for the NPDES program.

"Primary headwater habitat streams" are defined as "surface waters of the State, as defined in Ohio Administrative Code, having a defined bed and bank, with either continuous or periodical flowing water, with watershed area less than or equal to 1.0 mi^2 (259 ha), and maximum depth of water pools equal to or less than 40 cm." The methods outlined in the Manual are designed to statistically differentiate among three quality classes (designated uses) of PHWH streams in Ohio:

Class III PHWH Stream (cool-cold water adapted native fauna);
Class II PHWH Stream (warm water adapted native fauna);
Class I PHWH Stream (ephemeral stream, normally dry channel).

PROCEDURE SUMMARY:

The Manual presents a three-tiered protocol for assessing PHWH streams in Ohio: 1) Rapid habitat evaluation referred to as the Headwater Habitat Evaluation Index (HHEI); and two levels of biological assessment, 2) Family-level taxonomic identification; and 3) Genus-species level taxonomic identification. Methods in the Manual should only be undertaken after a determination has been made that the stream has no possibility of supporting a well balanced fish community as measured by the fish-IBI, and that other State of Ohio aquatic life designations (OAC Chapter 3745-1) are not appropriate.

The Headwater Habitat Evaluation Index (HHEI) is a rapid habitat evaluation tool based on three physical measurements found to be highly correlated with biological measures of PHWH stream quality in Ohio: 1) channel substrate composition; 2) maximum pool depth; and 3) average bankfull width. The HHEI rapid assessment tool is most predictive when "modified" channels are separated from natural channels having little or no evidence of channel modification. Specific methods are presented for each of the above referenced metrics, and the data is entered on a PHWH Evaluation Form. Scores for each of the three metrics are summed and compared to categories defining each of the three stream designated use categories.

Channel substrate composition is visually assessed in a 200' PHWH stream assessment reach to determine dominant substrate type (among 9 types possible) and total number of substrate types. A pebble count is not required, but "can be used to quantify percentages of the most common substrate types." Maximum pool depth is simply the single deepest pool located in the assessment reach, recorded to the nearest centimeter. Average bankfull width is recorded as the average of 3-4 bankfull width measurements in the assessment reach, each of which is identified using indicators from Rosgen (1996) or other such suitable indicators, such as the boundary line where terrestrial vegetation begins.

All PHWH evaluations also include assessment of riparian zone and floodplain quality, flow regime, sinuosity, and gradient, although none of these factors are included in the calculation of the HHEI score. Riparian zone and floodplain quality includes observations of riparian zone width and floodplain land use. Flow regime is categorized as simply whether surface water is flowing or if flow is interstitial, intermittent, or ephemeral. Sinuosity is estimated based on the number of stream bends per 200' channel length, and stream gradient is estimated on a scale of 1 to 5, from "flat (0.5'/100')" to "severe (10'/100')".

If the HHEI assessment is questionable, or additional support for the designated use category determined using the HHEI is desired, one can conduct a Headwater Macroinvertebrate Field Evaluation Index and a rapid bioassessment of vertebrates (salamanders) using one of two tiers of effort presented in the Manual. Specific sampling protocols for each are dutifully referenced. Biological or HHEI assessments can be undertaken at any time of the year, but from June to September is optimal.

REFERENCE CONDITIONS, PERFORMANCE STANDARDS, & MONITORING:

Reference conditions for the evaluation of PHWH streams in Ohio are, in essence, internal to the protocol itself. Fifty-nine PHWH streams were surveyed from four of the major ecoregions in Ohio in 1999, during which chemical, biological, and physical habitat evaluations were conducted. This evaluation was a continuation of a PHWH stream assessment initiative that OEPA has been conducting over the last decade. An additional 215 randomly selected PHWH streams were sampled from 5 rapidly developing areas in 10 Ohio counties, and 18 streams were sampled to assess seasonal trends in the benthic macroinvertebrate assemblage in 2001.

Performance standards and monitoring are not applicable to the Field Evaluation Manual for Ohio's Primary Headwater Habitat Streams.

OTHER:

If the watershed size is greater than 1 mi^2 or if there are natural pools deeper than 40 cm, regardless of watershed size, then a Qualitative Habitat Evaluation Index (QHEI) should be undertaken following procedures in Rankin (1989) (see review this volume). It may also be relevant to note that neither HHEI nor QHEI are calibrated to well balanced benthic macroinvertebrate assemblages. Instead, HHEI is primarily calibrated to the presence-absence of salamander species with multi-year larval periods, and the QHEI is calibrated to the presence of well balanced fish assemblages.

The Field Evaluation Manual for Ohio's Primary Headwater Habitat Streams is intended and calibrated solely to classify PHWH streams into one of the three stream designated uses defined in Ohio Administrative Code. Thus, the resolution provided by the data may not be detailed enough to thoroughly evaluate stream conditions for enhancement or restoration projects.

LITERATURE CITED:

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Field Evaluation Manual for Ohio's Primary Headwater Habitat Streams
http://www.epa.state.oh.us/dsw/wqs/headwaters/index.html

No. 24 - Guidelines for Evaluating Fish Habitat in Wisconsin Streams

USFS North Central Forest Experiment Station (Simonson *et al.*, 1993)

PRIMARY PURPOSE:

The *Guidelines for Evaluating Fish Habitat in Wisconsin Streams* (Guidelines) establishes a standardized general protocol "that can be used when conducting any stream habitat survey, evaluation, monitoring program, appraisal, or special project...when precise, defensible methods are needed to substantiate management objectives. priorities, or effectiveness [of management treatments]," (Simonson *et al.*, 1994). The authors state that the Guidelines are intended primarily for use in permanent (perennial), wadeable streams that are large enough to support well-developed fish communities (>1.5m wide, mostly <1.2m deep, with a watershed of >13km^2). They may be used on smaller streams, but the authors did not test the Guidelines in such streams.

PROCEDURE SUMMARY:

Simonson *et al.* (1994) recommend that habitat data be collected using the basic framework of the transect method suggested by Platts *et al.* (1983) (see review this volume). Sample stream reaches should be approximately 35 times the mean wetted width, with a minimum reach length of 100m, and should not include any permanent tributaries or hydraulic controls (e.g., bridges, dams, waterfalls, etc.). Transects are spaced two times the mean wetted stream width apart throughout the sample reach, for a total of at least 18 sample transects per reach. Accuracy of sampling small streams (<10m wide) is not compromised by sampling transects spaced every three times the mean wetted width, but the authors recommend no fewer than 18 transects on larger channels (Simonson *et al.*, 1994).

Stream habitat characteristics are measured or estimated from one or more locations relative to each transect: 1) within a specified distance above and below the transect, 2) along the transect (e.g., 5m total belt width), or 3) at positions along the transect line, typically four equally spaced positions across the channel, plus the thalweg (Simonson *et al.*, 1994). Methods to measure or estimate each habitat characteristic are suggested (Table 1), and the authors also report the accuracy and precision of each method based on their own analysis of survey results.

Simonson *et al.* (1994) provide field data sheets and also discuss data management and analysis. The authors also present the Fish Habitat Rating (FHR) index as a means to compare habitat surveys of streams by rating the physical habitat of streams to support diverse, healthy fish communities. Seven selected variables or ratios are rated as poor, fair, good, or excellent based on reference conditions provided in the Guidelines for Wisconsin streams (Simonson *et al.*, 1994): 1) riparian buffer width, 2) bank erosion, 3) pool area, 4) width/depth ratio, 5) riffle-to-riffle ratio or bend-to-bend ratio, 6) percent fine sediment, and 7) cover for fish. Points are allocated to each quality category and then summed to obtain a total FHR index.

Table 1. Habitat features and variables recommended by Simonson *et al.* (1994) in *Guidelines for Evaluating Fish Habitat in Wisconsin Streams*.

Habitat Feature	Variable	Method
Riparian Conditions	Riparian Land Use	Visual estimate of defined land use categories to nearest 10% along a transect line extended 10m from stream edge.
	Riparian Buffer Width	Length of contiguous undisturbed land use along a transect line extended 10m from stream edge.
	Bank Erosion	Length of bare soil along a transect line extended 1m from stream edge.
	Shading	Measure of overhead canopy at each point (5) along the transect; (a) visual estimate and (b) densiometer .
Channel Morphology	Habitat Units	Map/inventory the length of major habitat types and their distance from the downstream end of the sample reach: bends, riffles, runs, pools, islands, dams, and log jams. Used to determine bend-to-bend ratio, riffle-to-riffle ratio, and sinuosity.
Stream Bed Features	Substrate	Visually estimate percentage of each substrate category present in 0.3m x 0.3m quadrats placed at each point (5) along the transect.
	Embeddedness	Visually estimate embeddedness of gravel or cobble substrates from 0.3m x 0.3m quadrats placed at each point (5) along the transect.
	Sediment Depth	Measure depth of sediment to nearest 1cm at each point (5) along the transect.
Cover	Cover	Reported as percentage of transect line with cover ~ measure the length of cover intersecting the transect line (within 0.3m); specific definitions and examples of cover are provided.
Stream Features	Width	Mean wetted width.
	Depth	Measure water depth to nearest 1cm at each point (5) along the transect.
	Velocity	Time of passage of a neutrally buoyant object.
	Discharge	Measured at one cross-section.
	Stage	Elevation of water surface above a datum.
	Water Level	Stage relative to “normal” water level.
	Physicochemical Parameters	DO, water temperature, conductivity, and turbidity.

REFERENCE CONDITIONS, PERFORMANCE STANDARDS, & MONITORING:

Neither reference conditions, nor performance standards are addressed by Simonson *et al.* (1994). However, the Guidelines can be used to monitor the physical features of streams and the changes in those features as a result of stream enhancement or restoration practices. They may also be useful for identifying applicable reference conditions and/or performance standards for stream enhancement or restoration projects.

OTHER:

Simonson *et al.* (1994) indicate that a trained crew can typically complete a habitat survey in 2-4 hours using the methods outlined in the Guidelines, depending on the size of the stream.

The State of Wisconsin, Department of Natural Resources has issued "Guidelines for Evaluating Habitat of Wadeable Streams," (revised June 2002), which very closely mirrors Simonson *et al.*, (1994).

LITERATURE CITED:

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Guidelines for Evaluating Fish Habitat in Wisconsin Streams
http://www.ncrs.fs.fed.us/pubs/gtr/gtr_nc164.pdf

No. 25 - Hawaii Stream Visual Assessment Protocol

USDA NRCS Hawaii, January 31, 2001

PRIMARY PURPOSE:

The *Hawaii Stream Visual Assessment Protocol* (HSVAP) is a basic quality evaluation for streams in Hawaii, based on the national version of the NRCS Stream Visual Assessment Protocol (NWCC, 1998) (see review this volume).

PROCEDURE SUMMARY:

HSVAP recommends that streams be classified using the Montgomery/Buffington classification (Montgomery and Buffington, 1993; 1997) prior to assessment. An assessment is performed on one or more reaches of stream channel that are 20 times as long as the active channel width, or a minimum of 100m, but a maximum of 300m.

The assessment is completed by scoring up to 10 stream and riparian zone variables on a scale of 0 to 2.0 (Table 1). Scoring is based on stream and riparian zone observations relative to the descriptions of conditions in the protocol. The sum of the variables scored divided by the number of variables utilized in the assessment provides an overall score that is then compared to a four level quality condition index. Overall scores equal to or less than 1.0 are considered "poor" quality streams; scores from 1.1 to 1.4 are "fair;" 1.5 to 1.7 are "good;" and overall scores equal to or greater than 1.8 are considered excellent quality streams. HSVAP stresses analysis of the individual scores of the 10 variables to discern causes of impairment rather than the overall score, unless the assessment objective is overall trend analysis.

Additional stream corridor characteristics and observations are noted on a separate Stream Characterization data sheet. These include Montgomery-Buffington stream class, water temperature, dominant substrate composition, average active channel width, flow velocity and average water depth, flow status (high, normal, or low relative to mean high water line), and a sketch of a typical channel cross-section.

REFERENCE CONDITIONS, PERFORMANCE STANDARDS, & MONITORING:

In contrast to the national SVAP, HSVAP places no emphasis on reference sites and in fact fails to even mention them. The HSVAP documentation notes that persons with only limited knowledge of biology or hydrology can perform the assessments after minimal training.

Table 1. Assessment variables and descriptions used in the Hawaii Stream Visual Assessment Protocol.

Assessment Variable	Description	Notes
Turbidity	Water clarity ~ depth to which objects can be seen	Do not assess turbidity if water depth is too shallow.
Plant Growth	Amount of algae and aquatic macrophyte growth	Used to assess nutrient enrichment
Channel Condition	Channel stability ~ degree to which the channel has been altered	Channel stability may be affected by direct channel perturbation (e.g., channelization, riprap, etc.) or changes to water or sediment budgets that cause the channel to aggrade or degrade.
Channel Flow Alteration	Water withdrawals / diversions	Score presence/absence of channel flow alteration solely in the assessment reach and note whether it is permanent or temporary
Percent Embeddedness	Degree to which cobble substrate is surrounded by fine sediment	Assess only from riffles or runs
Bank Stability	Potential for soil erosion from upper and lower streambanks ~ eroded or disturbed/total area	Consider bank height, bank angle, bank composition, root depth, root density, & surface protection
Canopy/Shade	Canopy shading over the active channel	Average percent-canopy using densiometer or visual estimates
Riparian Width / Condition	Width of natural vegetation in riparian zone	Consider vegetative composition (coverage and strata), land use in the riparian zone, and concentrated overland flows through the riparian zone
Habitat Available for Native Species	Variety and abundance of suitable in-stream habitat and flow	Based on number of habitat types (e.g., seeps and springs, pools, runs, etc)
Litter / Trash	Presence of litter, trash, or animal carcasses in stream and riparian zone	

LITERATURE CITED:

Montgomery, D.R., and J.M. Buffington. 1993. *Channel classification, prediction of channel response, and assessment of channel condition*. TFW-SH10-93-002, Washington Department of Natural Resources, Olympia, WA. 84 pp.

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http://www.hi.nrcs.usda.gov/technical/bioindex.html

No. 26 - Methods for Evaluating Stream, Riparian, and Biotic Conditions

USFS Gen. Tech. Rpt. INT-138 (Platts *et al.*, 1983)

PRIMARY PURPOSE:

Platts *et al.* (1983) set out to propose a "valid, objective, quantitative, repeatable procedure that will provide accurate evaluation of the stream and its biotic communities under any set of conditions." *Methods for Evaluating Stream, Riparian, and Biotic Conditions* presents standard techniques for measuring aquatic, riparian, and biotic attributes of stream systems and also presents an analysis of the accuracy and precision of most of the assessment variables recommended.

Platts *et al.* (1983) present methods for measuring a litany of physical stream variables to characterize stream habitat and riparian zone conditions, as well as methods to evaluate fish populations and macroinvertebrate assemblages. Only those portions of Platts *et al.*, (1983) that address stream habitat and riparian zone conditions will be summarized here.

PROCEDURE SUMMARY:

Platts *et al.* (1983) is a collection of technical methods to measure various physical stream assessment variables. The authors stress transect-based methods for physical stream characterization, whereby channel and riparian zone cross-sections (transects) are established from which one or more physical stream and riparian zone attributes are inventoried as they intersect each transect.

Table 1 lists the stream assessment variables recommended by Platts *et al.* (1983), as well as the relative accuracy and precision of each method cited by the authors. Accuracy was rated poor, fair, good, or excellent based on time series graphical interpretation of habitat estimates over a 2 to 15 year period in Idaho, Utah, and Nevada relative to the true value of the respective variable. Precision was similarly rated based on confidence intervals obtained for each habitat measurement.

REFERENCE CONDITIONS, PERFORMANCE STANDARDS, & MONITORING:

Neither reference conditions, nor performance standards are addressed by Platts *et al.* (1983). The Methods outlined by the authors can be used to monitor the physical features of streams and the changes in those features as a result of stream enhancement or restoration practices. They may also be useful for identifying applicable reference conditions and/or performance standards for stream enhancement or restoration projects.

Table 1. Components and variables recommended by Platts *et al.* (1983) in *Methods for Evaluating Stream, Riparian, and Biotic Conditions*.

Assessment Component	Variable	Accuracy / Precision [1]
Stream Habitat	Stream width and depth	Good to Excellent
	Shore water depth	Good to Excellent
	Percent pool	Fair to Poor
	Percent riffle	Fair to Poor
	Pool quality (Platts, 1974)	Fair to Poor
	Formative pool feature	Not Rated
	Stream discharge	Not Rated
	Solar radiation reaching the channel surface	Not Rated
Streambank	Streambank soil alteration - physical bank stability	Fair to Poor
	Streambank vegetative stability	Fair to Poor
	Undercut	Good to Excellent
	Channel-bank angle	Good to Excellent
Stream Bottom	Channel gradient	Not Rated
	Channel elevation	Not Rated
	Sinuosity	Not Rated
	Substrate embeddedness	Fair to Poor
	Subsurface particle size	Not Rated
	Channel cross-sectional surveys	Not Rated
	Coarse woody debris	Not Rated
Riparian Zone	Streamside cover rating	Fair to Poor
	Vegetation use by animals	Good to Excellent
	Herbage production and utilization	Not Rated
	Habitat type	Fair to Poor

[1] Accuracy and/or precision of the assessment method as rated poor, fair, good, or excellent.

OTHER:

The *Methods* manual by Platt *et al.* (1983) is presented in such a manner that emphasizes the authors' assessment of the efficacy of the suggested methods rather than as a coherent collection of methods (a protocol) compiled for a specific purpose. Many of the recommended methods have been modified and/or incorporated for use in other protocols in the two decades since the *Methods* manual was published [e.g. Simonson *et al.* (1994); see review this volume].

LITERATURE CITED:

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Simonson, T.D., J. Lyons, and P.D. Kanehl. 1993. *Guidelines for Evaluating Fish Habitat in Wisconsin Streams*. Gen. Tech. Rpt NC-164, USFS North Central Experiment Station, St. Paul, MN. 36 pp.

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No. 27 - Physical Habitat and Water Chemistry Assessment Protocol for Wadeable Stream Monitoring Sites

Minnesota Pollution Control Agency (rev. December 2002)

PRIMARY PURPOSE:

The Minnesota Pollution Control Agency (MPCA), Biological Monitoring Program developed the *Physical Habitat and Water Chemistry Assessment Protocol for Wadeable Stream Monitoring Sites* to support assessment of water quality and development of biological criteria for Minnesota streams. These procedures are also applicable for EMAP stations and sites suspected of being impacted by a source of pollution.

PROCEDURE SUMMARY:

Criteria for siting sample stream reaches are outlined in MPCA's *Reconnaissance Procedures for Initial Visit to Stream Monitoring Sites*. A sample stream reach is 35 times the mean stream width, which is based on the distance necessary to capture a representative and repeatable sample of the fish community (Lyons, 1992). The minimum sample reach is 150m, and the maximum is 500m.

Quantitative stream habitat data is collected using a transect-point method modified from Simonson *et al.* (1993) (see review this volume). Thirteen equally spaced transects are established perpendicular to stream flow in the sample reach, and measurements or observations of habitat features are recorded from 0.3m x 0.3 m quadrats set at four equally spaced points (1/5, 2/5, 3/5, and 4/5 of wetted stream width) and the channel thalweg along each transect. Key habitat features describe channel morphology, substrate, cover, and riparian condition (Table 1).

Data forms are provided and must be filled out individually for each transect. A single Station Features data sheet records the length and location (spacing) of major morphological and habitat features within the sample reach, including riffles, runs, pools, meander bends, islands, log jams, beaver dams, and other such features that may affect channel morphology, such as bridges, culverts, dams, and tributaries.

REFERENCE CONDITIONS, PERFORMANCE STANDARDS, & MONITORING:

Neither reference conditions nor performance standards are addressed by the MPCA Protocol. The Protocol itself is a monitoring program and could be used to monitor applicable physical stream features, as well as changes in those features as a result of stream enhancement or restoration practices. The MPCA Protocol may also be useful to aid in the identification of reference conditions and performance standards for stream enhancement or restoration projects.

Table 1. Variables measured or observed at stream sample transects for the MPCA *Physical Habitat and Water Chemistry Assessment Protocol for Wadeable Stream Monitoring Sites*.

Type of Measurement	Variable	Description
Transect Point Measurements	Water Depth	Water depth to nearest 1cm
	Depth of Fines + Water Depth	Water depth plus the depth of fine sediment (<2.0mm); later converted to only depth of fines
	Embeddedness of Coarse Substrate	Extent to which coarse stream substrate (e.g., gravel or larger) is covered or surrounded by fines ~ visually estimated to nearest 25%
	Dominant Substrate	Visual estimate of dominant substrate type (size)
	Percent Algae	Visual estimate of percent coverage of algae to nearest 5%
	Percent Aquatic Macrophytes	Visual estimate of percent coverage of aquatic macrophytes to nearest 5%
Cover and Land Use Characteristics	Percent Cover for Fish	Amount of cover or shelter available for fish (e.g., undercut banks, overhanging vegetation, woody debris, etc.) estimated to nearest 5% from a 0.3m belt across the channel centered on the transect line
	Bank Erosion	Vertical measurement of bare soil susceptible to erosion at each end of the transect from edge of water to top of bank (maximum 5m)
	Riparian Land Use	Visual estimate of predominant land use (a) within 30m of waters edge, and (b) from 30m to 100m of waters edge
	Riparian Buffer Width	Amount of contiguous undisturbed land within a 10m buffer from waters edge
	Canopy/Shading	Densiometer measurement of overhead canopy cover measured in four cardinal directions at center of channel
Field Water Chemistry	Air temperature, water temperature, conductivity, DO, turbidity, pH, stream discharge, transparency, & water level	

LITERATURE CITED:

Lyons, J. 1992. The length of stream to sample with a towed electrofishing unit when fish species richness is estimated. *North American Journal of Fisheries Management* 16:241-256.

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Physical Habitat and Water Chemistry Assessment Protocol for Wadeable Stream Monitoring Sites
http://www.pca.state.mn.us/water/biomonitoring/bio-streams-fish.html

No. 28 - A Physical Habitat Index for Freshwater Wadeable Streams in Maryland

Maryland Department of Natural Resources (Paul *et al.*, 2002)

PRIMARY PURPOSE:

The Maryland Department of Natural Resources (MDNR) developed the Physical Habitat Index (PHI) as a multi-metric physical habitat index capable of discriminating reference stream conditions from degraded stream conditions in Maryland. This work updates and revises a provisional PHI developed by MDNR in 1999 (Hall *et al.*, 1999).

Paul *et al.* (2002) used biological, chemical, land use, and physical stream habitat data that had been collected throughout the State of Maryland from 1994-2000 as the basis for development of the PHI. The authors describe their methods and analyses used to develop the PHI, but they do not provide a standard method or protocol describing how the data used to develop the PHI was collected. In this respect, the PHI summary is an anomaly in this review. The PHI is included in this review primarily to illustrate an example of calibrating a physical stream assessment protocol with regional biological stream conditions, thereby strengthening the utility of the assessment protocol itself.

PROCEDURE SUMMARY:

Based on a review of data collected from 1994-2000, the authors classified Maryland streams based on physiographic setting and selected criteria to represent reference and degraded stream conditions (principally land use). Stream habitat metrics were identified and tested to discriminate between reference and degraded conditions, and these metrics were then assembled into a final revised PHI (Paul *et al.*, 2002).

Different PHI metrics are used for each of three stream classes based on physiography. The metrics used for Coastal Plain streams include bank stability, in-stream wood, in-stream habitat quality, epibenthic substrate, shading, and remoteness (distance to a road). The PHI for Piedmont streams is based on riffle quality, bank stability, in-stream wood, in-stream habitat quality, epibenthic substrate, shading, remoteness, and embeddedness. Finally, stream metrics used to generate the Highlands PHI, which includes the Blue Ridge, Ridge and Valley, and Appalachian Plateau physiographic regions, include bank stability, epibenthic substrate, shading, riparian width, and remoteness.

Paul *et al.* (2002) report that the final PHIs were unrelated to watershed area and had an overall discrimination efficiency of 80%. The PHIs were also significantly correlated with indices of biotic integrity for both benthic macroinvertrbates (B-IBI) and fish (F-IBI). However, the strength of these correlations varied across physiographic regions and even river basins within physiographic regions.

REFERENCE CONDITIONS, PERFORMANCE STANDARDS, & MONITORING:

As a result of basing the PHI on data collected from over 1400 Maryland streams, reference conditions for the index are essentially built into the PHI itself. However, as noted above, the specific methods for collecting the data utilized by the authors to generate the PHI is not described herein. Paul *et al.* (2002) point out that while the PHI may be used to assess physical habitat in Maryland streams and may also be useful for identifying the number of habitat impaired streams statewide, the stream metrics used to generate the PHI are not the only such metrics that are important for stream assessment. Furthermore, additional variables not incorporated into the PHI itself will likely prove important when diagnosing specific causes of habitat impairment at sites identified by the PHI (Paul *et al.*, 2002).

OTHER:

The reader is referred to the summary of the *Eastern Kentucky Stream Assessment Protocol* (No. 9 in this volume) for an example of a similarly calibrated physical stream assessment protocol representative of regional biological stream conditions. In contrast to the PHI, the Eastern Kentucky Stream Assessment Protocol was developed specifically for use in the CWA 404 regulatory program.

LITERATURE CITED:

Hall, L.W., Jr., R.P. Morgan, E.S. Perry, and A. Waltz. 1999. *Development of a Provisional Physical Habitat Index for Maryland Freshwater Streams*. Maryland Department of Natural Resources, Monitoring and Non-Tidal Assessment Division, Annapolis, MD. 141 pp.

Paul, M.J, J.B. Stribling, R.J. Klauda, P.F. Kazyak, M.T. Southerland, and N.E. Roth. 2002. *A Physical Habitat Index for Freshwater Wadeable Streams in Maryland*. CBWP-MANTA-EA-03-4, Maryland Department of Natural Resources, Monitoring and Non-Tidal Assessment Division, Annapolis, MD. 150 pp.

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A Physical Habitat Index for Freshwater Wadeable Streams in Maryland
http://www.dnr.state.md.us/streams/index.html

No. 29 - The Qualitative Habitat Evaluation Index (QHEI): Rationale, Methods, and Application

State of Ohio, Environmental Protection Agency (Rankin, 1989)

PRIMARY PURPOSE:

The Qualitative Habitat Evaluation Index (QHEI) is an index of macro-habitat quality designed to assess stream habitat that is generally accepted to influence fish communities and which are also important to other aquatic life (Rankin, 1989). QHEI was designed as a measure that would require a minimal amount of time and with a minimum of field measurements, but also relies upon experienced field biologists to execute the evaluation within acceptable ranges of accuracy and precision. In fact, Rankin (1989) stresses that regular training is a necessity to minimize bias and ensure comparability of assessments among field biologists.

PROCEDURE SUMMARY:

The QHEI is based on six metrics: 1) substrate, 2) in-stream cover, 3) channel morphology, 4) riparian and bank condition, 5) pool and riffle quality, and 6) gradient. A field data sheet provides qualitative condition descriptors for 1 to 7 variables under each stream metric heading. The surveyor matches the condition description for each variable with observed conditions in the field and checks the appropriate box. Each box includes an affiliated point score. These are totaled for each metric to provide subtotals related to the above six metrics. The sum of all metric subtotals provides the total QHEI score, which has a maximum of 100. More detailed definitions of terms used on the field data sheet, including broader descriptions of each variable are provided by OEPA (1989).

The QHEI was found to be significantly different among Ohio ecoregions and significantly correlated with fish IBI (Rankin, 1989). However, the correlation was weaker in wadeable and headwater streams relative to larger channels requiring boat access. Rankin (1989) suggests that due to the inherent interconnectedness of smaller channels with their watersheds and riparian zones, disturbances outside of the stream channel itself may exert a more prominent impact on the biological community, thus affecting IBI more than QHEI and thereby adversely affecting the correlation of the two. Rankin (1989) also notes that general basin characteristics and overall habitat quality exert a greater influence on fish communities than does site specific habitat, such as that assessed using the QHEI. Thus, he concludes, the QHEI (or any other site specific habitat measure) is not inclusive enough to be an absolute site specific predictor of fish communities without further consideration of basin-wide or reach-wide influences on stream biota (Rankin, 1989).

REFERENCE CONDITIONS, PERFORMANCE STANDARDS, & MONITORING:

Neither reference conditions nor performance standards are addressed by QHEI. The index itself is a monitoring tool intended to “fill the gap” between completely subjective habitat description and more labor intensive assessment protocols, such as Habitat

Suitability Indices developed for each species of a fish community assemblage. QHEI is perhaps best used as a screening method to rapidly collect baseline habitat data on stream conditions in entire watersheds or ecoregions.

LITERATURE CITED:

Ohio EPA. 1989. *Biological criteria for the protection of aquatic life: Volume III. Standardized biological field sampling and laboratory methods for assessing fish and macroinvertebrate communities*. Ohio Environmental Protection Agency, Columbus, OH.

Rankin, E.T. 1989. *The Qualitative Habitat Evaluation Index (QHEI): Rationale, Methods, and Application*. Ohio Environmental Protection Agency, Division of Water Quality Planning & Assessment, Ecological Assessment Section. Columbus, OH. 73 pp.

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The Qualitative Habitat Evaluation Index (QHEI): Rationale, Methods, and Application
http://www.epa.state.oh.us/dsw/bioassess/BioCriteriaProtAqLife.html

No. 30 - Rapid Bioassessment Protocols for Use in Wadeable Streams and Rivers, 2nd Edition

USEPA Office of Water (Barbour *et al.*, 1999)

PRIMARY PURPOSE:

The stated primary purpose of the Rapid Bioassessment Protocols for Use in Wadeable Streams and Rivers (RBP) is "to describe a practical technical reference for conducting cost-effective biological assessments of lotic ecosystems," (Barbour *et al.*, 1999). While the RBP includes methods to sample periphyton, benthic macroinvertebrates, fish, and physical habitat, this summary will focus solely on habitat.

While the RBP Stream Habitat Assessment method was developed for use in biological assessment programs and has become one of the most common and/or emulated such procedures, its use and utility has expanded well beyond bioassessment and includes stream inventory, assessment, monitoring, and management.

PROCEDURE SUMMARY:

The RBP stream habitat assessment is a visual-based rapid assessment that relies upon visual characterizations of ten stream features in a 100m sample stream reach in order to categorize the quality of those features as either poor, marginal, suboptimal, or optimal. The range of quality from poor to optimal is further defined on a point scale from 0 to 20 for each stream habitat parameter assessed. Thus, the maximum point score for the RBP habitat assessment is 200. Quality descriptions are provided on the field data sheets and elaborated upon in the text of the RBP manual itself.

The stream habitat parameters cover various aspects of the stream and riparian environment including in-stream habitat, channel morphology, bank structural features, and riparian vegetation. There are a few different or modified stream habitat parameters used in the assessment based on whether the stream has a high gradient and is therefore dominated by riffle/run habitat types and coarse substrate, or a low gradient dominated by glide/pool habitats and typically finer substrates (Table 1).

REFERENCE CONDITIONS, PERFORMANCE STANDARDS, & MONITORING:

Barbour *et al.* (1999) stress that reference conditions should be used "to scale the assessment to the 'best attainable conditions.'" Further, practitioners should be trained in the assessment procedure and work in teams in order to minimize observer bias (See Section 2.3.1 in the body of this report for a discussion of accuracy and variability of the RBP). The authors also state that the RBP is not intended to be a static document, but rather one that can and should be adapted to best fit regional conditions.

Table 1. Habitat parameters assessed in the USEPA RBP stream habitat assessment method.

Habitat Parameter		Definition	Applicability (High or Low gradient streams)
1	Epifaunal Substrate / Available Cover	Relative quantity and variety of natural structures in the stream available as refugia, feeding, or spawning and nursery sites for fish.	H, L
0	Embeddedness	Extent to which rocks (gravel, cobble, & boulders) and snags are covered or sunken into silt, sand, or mud on the stream bottom	H
2b	Pool Substrate Characterization	Type and condition of bottom substrates found in pools	L
0	Velocity / Depth Combinations	Variable combinations of water depth and flow velocity (i.e., slow-deep, slow-shallow, fast-deep, & fast-shallow)	H
3b	Pool Variability	Overall mixture of pool types based on size and depth (i.e., large-shallow, large-deep, small-shallow, & small-deep)	L
4	Sediment Deposition	Amount of sediment that accumulated in pools and the changes that have occurred to the stream bottom as a result of deposition.	H, L
5	Channel Flow Status	Degree to which the channel is filled with water ~ affected by channel widening, water diversion, etc.	H, L
6	Channel Alteration	Measure of large-scale changes in the shape of the channel (e.g., channelization, embankments, riprap, dams and bridges, etc.)	H, L
0	Frequency of Riffles (or Bends)	Frequency and variety of riffles or bends ~ based in part on ratio of distance between riffles/stream width or run/bend	H
7b	Channel Sinuosity	Degree of meandering or sinuosity of stream channel ~ thalweg length/valley length	L
8	Bank Stability (Condition of Banks)	Magnitude of streambank erosion or potential for erosion ~ bank stability based in part on bank slope	H, L
9	Bank Vegetative Protection	Amount of vegetative protection afforded to streambank and near-stream riparian zone ~ based on total coverage and number of vegetative strata	H, L
10	Riparian Zone Vegetation Width	Width of natural vegetation in riparian zone measured from top of bank	H, L

OTHER:

The RBP habitat assessment is a common component of stream assessment protocols. Seven protocols in this review include RBP habitat assessments or adaptations thereof. These visual-based rapid habitat assessments can be useful tools to define performance standards or monitoring provisions, but in most cases should be augmented with additional geomorphic variables to capture changes in stream channel hydraulic geometry and/or planform.

Barbour *et al.* (1999) describe the general RBP habitat assessment, as illustrated, as a Level I approach that takes approximately 15-20 minutes in the field. However, the authors also suggest that more quantitative and less ambiguous measures of stream habitat parameters, such as USEPA EMAP methods (Kaufmann and Robison, 1997), result in considerably greater precision. The range of point scores within each quality category could be easily scaled to actual parameter measurements to further minimize the potential for observer bias to which visual estimates are prone.

LITERATURE CITED:

Barbour, M.T., J. Gerritsen, B.D. Snyder, and J.B. Stribling. 1999. *Rapid Bioassessment Protocols for Use inStreams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates, and Fish*, Second Edition. EPA 841-B-99–002. USEPA Office of Water, Washington, D.C.

Kaufmann, P.R., and E.G. Robison. 1998. Physical Habitat Characterization, Section 7 in J.M. Lazorchak *et al.* (eds). *EMAP- Surface Waters: Field Operations and Methods for Measuring the Ecological Condition of Wadeable Streams*. EPA/620/R-94/004F, US EPA, Washington, D.C.

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Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates, and Fish (2nd Edition)
http://www.epa.gov/owow/monitoring/rbp/

No. 31 - Rapid Stream Assessment Technique (RSAT) Field Methods

Metropolitan Washington Council of Governments (Galli, 1996)

PRIMARY PURPOSE:

The Rapid Stream Assessment Technique (RSAT) was developed for Montgomery County, Maryland to provide a simple, rapid reconnaissance-level assessment of stream quality conditions on a watershed scale. RSAT was originally intended for use in non-limestone Piedmont streams with a watershed of approximately 10-15 square miles (Galli, 1996).

PROCEDURE SUMMARY:

According to Galli (1996), RSAT is a synthesis of USEPA RBP (Plafkin *et al.*, 1989), the Izaak Walton League and Save Our Streams survey techniques, and the USDA Water Quality Indicators Guide: Surface Waters (Terrell and Perfetti, 1992). Six evaluation categories are used to assess and score an index representative of overall stream quality. Each category includes a number of individual stream variables that are measured or estimated in the field in order to assign a point score based on descriptions in RSAT (Table 1). Measurements or observations are collected from riffle transects (typically 12-13 per stream mile) spaced approximately 400 feet apart along a sample stream reach. The six evaluation categories are weighted to place more emphasis on channel stability and less on riparian habitat conditions. The maximum possible RSAT score is 50.

REFERENCE CONDITIONS, PERFORMANCE STANDARDS, & MONITORING:

Galli (1996) states that RSAT utilizes a reference stream. However, it is not clear how a reference stream is incorporated into the assessment. One may infer that reference streams are assessed in order to place the project streams into context with other streams in the region, but there is no discussion to verify this. Galli (1996) provides a footnote indicating that reference streams for drainage areas of various sizes were utilized for a stream assessment survey in Montgomery County, Maryland, but again, there is no detail illustrating how reference was incorporated.

Performance standards are not applicable to RSAT, considering that it is not necessarily intended as a restoration or mitigation tool.

OTHER:

Galli (1996) states that RSAT provides a quantitative measurement of the six evaluation categories by employing a” rigorous field evaluation protocol.” However, Galli (1996) fails to provide any recommendations for specific methods to measure stream variables in each category, and in fact utilizes mostly subjective estimates of channel features in

Table 1. Evaluation categories and variables used RSAT.

Evaluation Category	Variables	Subjective or Quantitative
Channel Stability	Streambank stability (percent sloughing, slumping, or failure)	S
	Stream bend stability	S, Q
	Root exposure on banks; number of tree falls per river-mile	S
	Erodibility of bottom 1/3 of streambank material	S
	Shape of channel cross-section (e.g., V, U, or trapezoidal)	S
Channel Scouring / Sediment Deposition	Percent embeddedness in riffles	S, Q
	Number of deep pools and pool substrate composition	S
	Presence or preponderance of "streambed streak marks and/or banana-shaped sediment deposits"	S
	Presence or preponderance of recent, large sand deposits	S
	Presence and stability of point bars	S
Physical In-stream Habitat	Percent of bottom channel width covered with water	Q
	Variety of habitat types and flow conditions present	S
	Composition (particle size) of riffle substrate	Q
	Riffle depth	Q
	Depth of large pools and proportion of overhead cover	S
	Degree of channel alteration or growth of point bars	S
	Riffle:pool ratio (specific ranges provided)	Q
	Summer afternoon water temperature (ranges provided)	Q
Water Quality	Substrate fouling ~ percentage of cobble-sized or larger stone coated with a biological film or growth on underside	S
	Total Dissolved Solids (specific ranges provided)	Q
	Water clarity / visibility	S, Q
	Odor	S
Riparian Habitat Conditions	Width and continuity of forested buffer	S, Q
	Canopy coverage over the channel	S
Biological Indicators	Diversity of benthic macroinvertebrates present	S
	Number of individual benthic macroinvertebrates	S

order to assign point scores for each evaluation category. Galli (1996) indicates that a two-person team can assess approximately 1.0-1.25 stream miles (roughly equivalent to 12-15 transects) per day.

LITERATURE CITED:

Galli, J. 1996. *Rapid Stream Assessment Technique (RSAT) Field Methods*. Metropolitan Washington Council of Governments, Washington, D.C.

Plafkin, J.L., M.T. Barbour, K.D. Porter, S.K. Gross, and R.M. Hughes. 1989. *Rapid bioassessment protocols for use in streams and rivers: Benthic macroinvertebrates and fish*. EPA 440-4-89-001, USEPA Office of Water Regulations and Standards, Washington, D.C.

Terrell, C.R. and P.B. Perfetti. 1989. Water Quality Indicators Guide: Surface Waters. USDA Soil Conservation Service, Washington, D.C. 129 pp.

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Rapid Stream Assessment Technique (RSAT) Field Methods
http://www.cwp.org/tools_assessment.htm

No. 32 - The RCE: A Riparian, Channel, and Environmental Inventory for small streams in the agricultural landscape

Petersen (1992)

PRIMARY PURPOSE:

The RCE attempts to provide a rapid assessment of the physical and biological condition of streams and emphasizes the physical structure of the riparian zone and land uses in the watershed, as well as channel morphology and simple biological observations (Petersen, 1992). The RCE was designed to assess small (<3m wide), low gradient streams in agricultural landscapes in the temperate region and is based primarily on observations in Europe and North America.

PROCEDURE SUMMARY:

The RCE was modeled after Pfankuch (1975) and borrows heavily from that procedure, which the USFS has used to assess channel stability in the western United States. RCE assessment takes place on a 100m stream reach, and most variables can be determined (scored) by direct observation (Petersen, 1992).

Sixteen stream and riparian zone variables are assigned to one of four defined conditions and scored with a maximum score per variable ranging from 15 to 30 (Table 1). Scoring is weighted to place greater emphasis on those variables that the author deemed most important to the overall condition of small lowland streams in agricultural settings. Weighting is also commensurate with the ability of the practitioner to accurately measure or estimate the variable in the field (Petersen, 1992).

REFERENCE CONDITIONS, PERFORMANCE STANDARDS, & MONITORING:

Neither reference conditions, nor performance standards are addressed by Petersen (1992).

OTHER:

The author tested the RCE procedure in southern Sweden, and colleagues also used it to assess 483 streams in the northern Italian province of Trento, 15 streams in the western Italian province of Livorno, and three locations on Mink Creek in Idaho (Petersen, 1992). All of these investigations reported that the RCE worked well, despite that the streams in Trento and Idaho were alpine streams or in catchments described as cold Rocky Mountain interbasin desert, respectively. The investigation in Livorno was undertaken concurrent with collection of benthic macroinvertebrates, and there was a significant positive correlation between biological indices and the RCE (Petersen, 1992). Thus, Petersen(1992) concludes that because emphasis of the RCE is on the presence and condition of the riparian zone, it may have wider application beyond the lowland, agricultural, temperate streams for which it was intended.

Table 1. Stream and riparian variables used to assess RCE (Petersen, 1992).

Variable	Description	Maximum Score
Land use pattern beyond the immediate riparian zone;	Ranging from undisturbed to mainly row crops	30
Width of riparian zone from stream edge to field;	Ranging from >30m wide to entirely absent	30
Completeness of riparian zone	Percent-continuous vegetative cover	30
Vegetation of riparian zone within 10m of channel	Relative proportion of native, non-pioneer species	25
Retention devices	Presence and stability of rocks, logs, etc. capable of retaining organic matter	15
Channel structure	Based on ranges of width/depth ratio	15
Channel sediments	Influence of sand and fine sediment on channel structure (e.g., bar formation)	15
Streambank structure	Bank stability ~ vegetative cover and soil properties	25
Bank undercutting	Presence and distribution of bank undercutting	20
Stony substrate feel and appearance	Stones rounded or sharp, blackened color or bright	25
Stream bottom	Substrate stability, PSD, and embeddedness	25
Riffles and pools, or meanders	Occurrence and spacing (5-7 channel widths)	25
Aquatic vegetation	Presence and percent coverage of moss, algae, and vascular aquatic plants	15
Fish	Presence/abundance of rheophilous fish	20
Detritus	Composition of organic matter (leaves, wood, fine flocculant, etc.)	25
Macrobenthos	Subjective species richness	20

LITERATURE CITED:

Petersen, Jr., R.C. 1992. The RCE: A Riparian, Channel, and Environmental Inventory for small streams in the agricultural landscape, *Freshwater Biology* 27:295-306.

Pfankuch, D.J. 1975. Stream Reach Inventory and Channel Stability Evaluation. USDA Forest Service, Northern Region, Intermountain Forest and Range Experiment Station, Ogden, UT. 26 pp.

FOR ADDITIONAL INFORMATION:

No. 33 - Revised Methods for Characterizing Stream Habitat in the National Water Quality Assessment Program

U.S. Geologic Survey, WRI Report 98-4052 (Fitzpatrick *et al.*, 1998)

PRIMARY PURPOSE:

The goal of the National Water Quality Assessment (NAWQA) Program is to assess status and trends in water quality nationwide and to develop an understanding of the major factors influencing observed conditions and trends. Stream habitat assessments are conducted as part of NAWQA water quality investigations in order measure habitat characteristics essential in describing and interpreting water chemistry and biological conditions (Fitzpatrick *et al.*, 1998).

The Revised Methods for NAWQA stream habitat characterizations integrate data at four spatial scales: 1) basin (watershed); 2) segment; 3) reach; and 4) microhabitat. Basin and segment-scale assessments are undertaken using GIS, topographic maps, aerial photographs, etc. A stream segment is defined in the NAWQA program as "a length of stream that is relatively homogeneous with respect to physical, chemical, and biological properties," and may be over several kilometers long (Fitzpatrick *et al.*, 1998). Watershed size, climate and potential runoff characteristics, and land use are determined at the basin-scale, while stream gradient, sinuosity, and water management features are measured at the segment-scale. The stream reach-scale is most commonly at issue in the CWA Section 404 Program, and the remainder of this summary will focus primarily on stream reach-scale aspects of the Revised Methods.

PROCEDURE SUMMARY:

The stream reach is the principal scale at which physical, chemical, and biological data is collected to represent conditions in the larger river or stream segment for the NAWQA program. Generally, the reach-scale assessment is conducted in a length of stream equivalent to 20 times the mean wetted channel width (minimum 150m, maximum 300m) in order to capture at least one complete meander wavelength (Leopold *et al.*, 1964). Reach-scale data is collected in the field from 11 systematically placed, equally-spaced transects (channel cross-sections); the spacing of which is based on stream width. The Revised Methods includes quantitative, semi-quantitative, and qualitative metrics (Table 1). Specific methods for measuring or estimating reach-scale data for wadeable streams are provided.

Data forms are also provided for recording basin, segment, and reach-scale data, although it is acknowledged that some may need revision to meet local needs. The Revised Methods manual also includes a suggested data management hierarchy that is available on the internet, which can be imported into a variety of commercial spreadsheet and database software applications. Data analysis is described, and specific statistical procedures that can be utilized to identify relationships among habitat variables and/or relationships among habitat variables and biological components of the stream system are recommended.

Table 1. Reach-scale data recommended for wadeable streams in the Revised Methods for Characterizing Stream Habitat in the NAWQA Program.

	Item	Description / Example
General Reach Data		
	General condition of stream reach	Evidence of recent floods
		Manmade alterations
		Point sources of sediment or other pollutants
		Beaver activity
		Other
	Stream discharge	Measured in the field; Note staff gauge if near gauging station
	Water surface gradient	Slope of the water surface
	Bankfull stage	Several examples of bankfull indicators are described (i.e., Williams, 1978; Dunne and Leopold, 1978; Knox, 1985)
Transect Data (data collected per transect)		
	Item	**Description / Example**
	Channel width	Wetted channel width; bankfull channel width
	Riparian vegetation traits	Open canopy angle from center of channel; canopy closure
	Riparian land use	Dominant land use in 30m riparian zone on each of channel
	Bank stability index (mod. Simon and Hupp, 1992)	Presence/absence of bank erosion; angle; height; dominant substrate; vegetative cover
	Water depth and velocity	
	Dominant bed substrate	Estimates based on modified Wentworth scale
	Embeddedness	
	Presence of in-stream habitat cover	e.g. debris piles, undercut banks, large boulders, aquatic macrophytes, etc.
Optional Data		
	Item	**Description / Example**
	Cross-sectional surveys	Provides quantitative means of monitoring changes in channel pattern and hydraulic geometry
	Riparian Vegetation Characterization	Density, dominance, and species distribution
	Substrate characterization	Wolman pebble counts (Wolman, 1954)

REFERENCE CONDITIONS, PERFORMANCE STANDARDS, & MONITORING:

Reference conditions and performance standards, as these terms are typically understood in context of the CWA Section 404 Program, are not applicable to the Revised Methods for Characterizing Stream Habitat in the NAWQA Program. The Revised Methods can be used to monitor physical stream variables, as well as changes in those features as a result of stream enhancement or restoration practices. They may also be useful for identifying applicable reference conditions and/or performance standards for stream enhancement or restoration projects.

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Revised Methods for Characterizing Stream Habitat in the National Water Quality Assessment Program
http://water.usgs.gov/nawqa/protocols/WRI98-4052/wri98-4052.pdf

No. 34 - Riparian Area Management: Process for Assessing Proper Functioning Condition

USDOI Bureau of Land Management
Prichard *et al.* (1993; rev. 1995 & 1998); Prichard *et al.* (1998)

In conjunction with other agencies, the USDOI Bureau of Land Management (BLM) has developed several methods to assess and manage riparian areas. Some 19 technical documents have been developed since 1987, that provide guidance relative to various aspects of riparian area management, including inventory and monitoring, classification, grazing management, ecological inventory, vegetation resources, assessing proper functioning condition of lentic and lotic systems, and managing, restoring, and conserving springs. This review is limited to the riparian area management documents applicable to riverine systems: *Process for Assessing Proper Functioning Condition* (TR 1737-9, Prichard *et al.*, 1993) and *A User Guide to Assessing Proper Functioning Condition and the Supporting Science for Lotic Areas* (TR 1737-15, Prichard *et al.*, 1998).

PRIMARY PURPOSE:

The 1991 *Riparian-Wetland Initiative for the 1990's* established national goals and objectives for BLM management of riparian-wetland resources on public lands. One of the primary goals of this initiative was to restore and maintain riparian-wetland areas so that 75 percent or more are in PFC by 1997. PFC assessment is a qualitative procedure based on quantitative science that can be used to assess the condition of riparian-wetland areas (Prichard *et al.*, 1998), including streams.

PROCEDURE SUMMARY:

Process for Assessing Proper Functioning Condition (TR 1737-9, Prichard et al., 1993)

The procedure recommends that the user review *Riparian and Wetland Classification Review* (TR 1737-5, Gebhardt *et al.*, 1990), *The Use of Aerial Photography to Inventory and Monitor Riparian Areas* (TR 1737-2, Batson *et al.*, 1987), *Inventory and Monitoring of Riparian Areas* (TR 1737-3, Myers, 1989), and *Procedures for Ecological Site Inventory-With Special Reference to Riparian-Wetland Sites* (TR 1737-7, Leonard *et al.*, 1992).

The functional status of riparian-wetland areas is characterized as one of four different categories: 1) Proper functioning condition; 2) Functional-at risk; 3) Nonfunctional; and 4) Unknown. PFC for riparian wetland areas is defined as follows (Prichard *et al.*, 1993):

> *"Riparian-wetland areas are functioning properly when adequate vegetation, landform, or large woody debris is present to dissipate stream energy associated with high waterflows, thereby reducing erosion and improving water quality; filter sediment, capture bedload, and aid floodplain development; improve flood-water retention and ground-water recharge; develop root masses that stabilize streambanks against cutting action;*

develop diverse ponding and channel characteristics to provide the habitat and water depth, duration, and temperature necessary for fish production, waterfowl breeding, and other uses; and support greater biodiversity."

The procedure describes three steps in assessing PFC: 1) Review existing documents; 2) Analyze the definition of PFC for riparian-wetlands; and 3) Assess functionality. Analysis must be based on the riparian-wetland's "capability" and "potential." Capability refers to the highest ecological status capable of being attained given political, social, or economic constraints. In contrast, potential refers to the highest ecological status capable of being attained absent the above referenced constraints- often referred to as "potential natural community (PNC)."

Management plans are developed using an eight-step assessment process: 1) Determine existing conditions; 2) Determine potential conditions (PNC); 3) Determine the minimum conditions necessary for PFC; 4) Determine existing and potential resource values; 5) Negotiate specific objectives to reach management goals; 6) Design management actions; 7) Design appropriate monitoring strategies; and 8) Maintain management flexibility. Appendices include reporting tables (data sheets), examples of channel evolution patterns, riparian-wetland functional checklist, and photographs and descriptions of riparian-wetlands in various conditions.

A User Guide to Assessing Proper Functioning Condition and the Supporting Science for Lotic Areas (TR 1737-15, Prichard *et al.*, 1998)

Although Prichard *et al.* (1998) acknowledge the qualitative nature of PFC, the authors recommend using quantitative sampling techniques in conjunction with the PFC checklist when individual calibration is needed, answers are uncertain, or if the experience of the field survey team is limited. The checklist itself consists of a series of Yes/No (or N/A) questions for 17 variables that address hydrology, vegetation, and erosion/deposition in riparian-wetland areas (Table 1). Prichard *et al.* (1998) provide background and rationale for each variable in the PFC checklist, provide examples of various characterizations for many of these variables (e.g., PFC, functional at-risk, or nonfunctional), and also suggest specific methods to quantitatively assess each variable. These quantitative methods are further described in Leonard *et al.* (1992).

PFC is intended to be a rapid assessment and, according to Prichard *et al.* (1998), the qualitative PFC checklist should work for most sites if the procedure is followed and the definitions are understood. The first step in assessing functionality in PFC is to stratify sample units based on terrestrial (USFS, 1994) or aquatic (Maxwell *et al.*, 1995) ecological units in order to minimize natural variability among sample sites. It is implicit in the checklist that practitioners are familiar with normal (natural) variation among stream and riparian wetland features in a given region. Indeed, Prichard *et al.* (1998) also stress that different riparian-wetland areas (i.e. different stream types, different watershed settings, etc.) "can and do function quite differently," and as a result need to be assessed "against their own capability and potential." Understanding channel

Table 1. Riparian-wetland variables assessed using the PFC checklist (Prichard *et al.*, 1998).

PFC Checklist Variables for Riparian-Wetland Areas	
Hydrology	1) Floodplain above bankfull is inundated in “relatively frequent” events.
	2) Where beaver dams are present they are active and stable.
	3) Sinuosity, width/depth ratio, and gradient are in balance with the landscape setting (e.g., landform, geology, and bioclimatic region).
	4) Riparian-wetland area is widening or has achieved potential extent.
	5) Upland watershed is not contributing to riparian-wetland degradation.
Vegetation	6) There is a diverse age-class distribution of riparian-wetland vegetation (recruitment for maintenance/recovery).
	7) There is diverse composition of riparian-wetland vegetation (for maintenance/recovery)
	8) Species present indicate maintenance of riparian-wetland soil moisture characteristics.
	9) Streambank vegetation is comprised of those plants or plant communities that have root masses capable of withstanding high-stream flow events.
	10) Riparian-wetland plants exhibit high vigor.
	11) Adequate riparian-wetland vegetative cover is present to protect banks and dissipate energy during high flows.
	12) Plant communities are an adequate source of coarse and/or large woody material (for maintenance/recovery)
Erosion / Deposition	13) Floodplain and channel characteristics (i.e., rocks, overflow channels, coarse and/or large woody debris are adequate to dissipate energy.
	14) Point bars are revegetating with riparian-wetland vegetation.
	15) Lateral stream movement is associated with natural sinuosity.
	16) System is vertically stable.
	17) Stream is in balance with the water and sediment being supplied by the watershed (i.e., no excessive erosion or deposition).

evolution and riparian vegetation successional sequences is also important when assessing PFC in riparian-wetland areas.

A final determination of the functional rating of a riparian-wetland is a subjective exercise based on a review of the Yes/No answers from the checklist. There is not point score associated with these answers, and PFC, functional at risk, or nonfunctional is determined based on the collective opinion of the field survey team.

REFERENCE CONDITIONS, PERFORMANCE STANDARDS, & MONITORING:

Familiarity with reference conditions is required in order to be able to assess an area's "potential," as defined in Prichard *et al.* (1993). However, the explicit requirement for reference conditions or a reference stream reach is never stated. In addition, although performance standards are not specifically referenced, the quantitative methods described in Leonard *et al.* (1992) and summarized in Prichard *et al.* (1998) may conceivably be used to identify them.

Prichard *et al.* (1993) stress establishment of a long-term monitoring program to evaluate the effectiveness of management actions towards achieving PFC. TR 1737-3 (Myers, 1989) is referenced as a tool to help develop monitoring criteria.

OTHER:

The procedure is applicable to the Federal Land Policy and Management Act (FLPMA) of 1976, which directs BLM to manage public lands in a manner that will provide for multiple use and at the same time protect natural resources for generations to come. In addition, to FLPMA, numerous laws, regulations, policies, Executive Orders, and Memoranda of Understanding direct BLM to manage its riparian-wetland areas for the benefit of the nation and its economy.

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Batson, F.T., P.E. Culpin, and W.S. Crisco. 1987. *Riparian Area Management: The Use of Aerial Photography to Inventory and Monitor Riparian Areas*, Technical Reference 1737-2, BLM/YA/PT-87/021+1737, Bureau of Land Management, Denver, CO. 16 pp.

Gebhardt, K., S. Leonard, G. Staidl, and D. Prichard. 1990. *Riparian Area Management: Riparian and Wetland Classification Review*, Technical Reference 1737-5, BLM/YA/PT-91//002+1737, Bureau of Land Management, Denver, CO. 56 pp.

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Prichard, D., J. Anderson, C. Correll, J. Fogg, K. Gebhardt, R. Krapf, S. Leonard, B. Mitchell, and J. Staats. 1998. *Riparian Area Management: A User Guide to Assessing Proper Functioning Condition and the Supporting Science for Lotic Areas,* Technical Reference 1737-15, BLM/RS/ST-98/001+1737, Bureau of Land Management, Denver, CO. 136 pp.

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BLM Technical References:
http://www.blm.gov/nstc/library/techref.htm

Order form:
http://www.or.blm.gov/nrst/Tech_References/tech_references.htm

PFC critique:
http://www.mtnvisions.com/Aurora/pfc.html

No. 35 - Physical Habitat Monitoring, Section 10.0 in Standard Operating Procedures for Sample Collection and Handling

New Mexico Environment Department, Surface Water Quality Bureau (2004)

PRIMARY PURPOSE:

The *Standard Operating Procedures for Sample Collection and Handling* (SOP) are a comprehensive set of protocols addressing preparation, execution, and analysis of sampling efforts to characterize the chemical, physical, and biological attributes of surface waters in the State of New Mexico. The Monitoring and Assessment Section of the New Mexico Environment Department, Surface Water Quality Bureau conducts surface water quality monitoring in support of various provisions of the Clean Water Act (CWA) and the New Mexico Water Qaulity Act, including water quality standards, waste load allocations, TMDL's, effectiveness of nonpoint source water pollution controls, and compilation of CWA Section 305(b) reports. This summary will address solely Section 10.0 of the SOP, which addresses Physical Habitat Monitoring.

PROCEDURE SUMMARY:

Physical Habitat Monitoring includes geomorphological measurements, a survey of topographical features, and completion of the USEPA RBP habitat assessment forms (Barbour *et al.*, 1999). Standardized methods for collection, recording, and processing of river morphology data are required, and the reader is referred to Harrelson *et al.* (1994) and Rosgen (1996) for such methods. The SOP indicates that river morphology measurements and associated data are appropriate and should be collected on any perennial or intermittent stream when the any of the following conditions apply:

1. A stream is evaluated for violations of the general permit for stream bottom sediments;
2. A stream is evaluated for instability;
3. A stream is evaluated for biological habitat;
4. Baseline stream data are required for monitoring temporal changes in the assessment reach;
5. Monitoring differences above and below a perturbation or best management practice designed to influence sediment transport; or
6. Reviewing plans or proposals for in-stream construction activities (e.g., CWA 401/404 activities).

River morphology measurements must be conducted in a reach equal in length to 20-30 bankfull stream widths or two meander wavelengths. The reach should include recognizable bankfull indicators, which should be verified through a regional curve or calibrated at a nearby USGS gauge for a return interval of 1 to 2 years. A single channel cross-section should be surveyed that incorporates bankfull features, terraces, the active floodplain, water's edge, thalweg, and all significant breaks in slope along the channel bed and banks. While this cross-section should be conducted in a riffle, the SOP notes that a pool cross-section may be helpful in characterizing the reach as well.

A longitudinal profile should also be surveyed that incorporates the location of the cross-section. The profile should include elevations of the thalweg, water's edge, and bankfull features at the top, middle, and bottom of all habitat units encountered along the length of the profile (pools, riffles, runs, and glides). Stream discharge should be measured, and a pebble count should be conducted. Embeddedness and BEHI are additional parameters that should be evaluated "depending on the nature of the survey," (NMED SWQB, 2004). The stream should also be classified according to Rosgen (1994; 1996). All data should be recorded in a bound, hardcover data field book, such as The Reference Reach Fieldbook (Rosgen, 1998).

REFERENCE CONDITIONS, PERFORMANCE STANDARDS, & MONITORING:

Neither reference conditions, nor performance standards are addressed in the Physical Habitat Monitoring section of the SOP. However, the procedures outlined therein may be useful to help identify reference conditions and performance standards for stream enhancement or restoration projects. In fact, reviewing plans or proposals for in-stream work, such as that which may be included as part of CWA Section 401/404 authorizations, are noted in the document as reason to consult the SOP.

LITERATURE CITED:

Barbour, M.T., J. Gerritsen, B.D. Snyder, and J.B. Stribling. 1999. *Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates, and Fish*, Second Edition. EPA 841-B-99–002. US EPA Office of Water, Washington, D.C.

Harrelson, C.C., C.L. Rawlins, and J.P. Potyondy. 1994. *Stream Channel Reference Sites: An Illustrated Guide to Field Technique*. USFS Rocky Mountain Forest and Range Experiment Station, General Tech Report RM-245, Fort Collins, CO. 61 pp.

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Physical Habitat Monitoring, Section 10.0 in Standard Operating Procedures for Sample Collection and Handling. New Mexico Environment Department, Surface Water Quality Bureau, June 22, 2004

http://www.nmenv.state.nm.us/swqb/Monitoring+Assessment/index.html

No. 36 - Stream*A*Syst: A Tool to Help You Examine Stream Conditions on Your Property

Oregon State University Extension Service (Andrews and Johnson, 2000)

PRIMARY PURPOSE:

The Stream*A*Syst handbook is targeted to landowners who wish to learn more about stream and riparian conditions on their property. It is not intended to be all inclusive, nor does it require any technical expertise to utilize.

PROCEDURE SUMMARY:

The Stream*A*Syst handbook includes a worksheet with 15 questions directing the observer to notice various stream attributes, including visual signs of water pollution, barriers to fish passage, floodplain obstructions, and riparian vegetation. These questions are answered simply yes or no. "Yes" answers then lead to a brief set of recommendations and contact persons/agencies where the land owner can receive assistance or additional information. All applicable State and Federal contact information is included.

REFERENCE CONDITIONS, PERFORMANCE STANDARDS, & MONITORING:

Not applicable.

OTHER:

This is a very basic observational procedure intended to be used by persons with no technical or educational background in stream assessment or any other related field.

LITERATURE CITED:

Andrews, G., and L. Townsend. 2000. *Stream*A*Syst: A Tool to Help You Examine Stream Conditions on Your Property*. Oregon State University Extension, Corvallis, OR.

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No. 37 - Stream and Riparian Habitats Rapid Assessment Protocol

USFWS Cheaspeake Bay Field Office (Starr and McCandless, March 2001)

PRIMARY PURPOSE:

Starr and McCandless (2001) describe the *Stream and Riparian Habitats Rapid Assessment Protocol* from the Chesapeake Bay Field Office of the USFWS as a comprehensive stream and riparian corridor assessment and inventory protocol for use by trained practitioners to rapidly identify, assess, and prioritize stream corridor conditions. The authors go on to state that the Protocol provides only a relative ranking of streams rather than a quantitative evaluation and may neither identify the extent of stream degradation, nor the cause and effect relationships influenced by conditions outside of the assessment area (Starr and McCandless, 2001).

The authors acknowledge that as of the date of publication, March 2001, the Protocol had not been field tested or peer reviewed. To this end, they also suggest potential limitations of the Protocol that may be revealed during field testing (e.g., inability to discern different stream conditions due to lack of resolution in the scoring of the assessment parameters).

PROCEDURE SUMMARY:

The Protocol is comprised of two main sections: 1) stream stability, which is itself divided into two sub-sections to assess vertical (bed) stability and horizontal (bank) stability, and 2) riparian and in-stream habitat assessment. Vertical (bed) stability is measured via 3 physical stream parameters, horizontal (bank) stability is assessed via 5 parameters, and riparian and in-stream habitat assessment is comprised of 9 parameters (Table 1).

Each assessment parameter receives an individual rating of 1 to 12, where every 3 points comprises a new condition class: poor, marginal, suboptimal, or optimal. Parameters comprising each assessment component are then summed to obtain a subtotal index reflecting the two main assessment sections (stream stability and riparian and in-stream habitat assessment). The sum of these two subtotals provides an overall stream corridor assessment score with a maximum of 204. As with the individual parameter ratings, the total score is divided into four stream condition classes, where 34 to 76 points represents a stream corridor in poor condition, 77 to 119 points is marginal, 120 to 162 points is suboptimal, and 163 to 204 points represents a stream corridor in optimal condition. Any component of this scoring, from the total score to the individual parameter ratings, may be analyzed to reveal potential problem areas or to assist in prioritizing restoration efforts.

The assessment reach is delineated according to Rosgen Level I stream classification protocols (Rosgen, 1996) and should not exceed 2000'. Bank stability is determined following Rosgen (1996) with adjustments for bank materials and bank material stratification as outlined in Starr and McCandless (2001). Bed stability is based in part on USEPA RBP (Barbour *et al.*, 1999) and a channel evolution model presented by Rosgen

Table 1. Components and parameters in the USFWS Chesapeake Bay Field Office, Stream and Riparian Habitats Rapid Assessment Protocol.

Assessment Component	Parameters	Description / Indicators
Stream Stability		
Vertical (bed) stability	Aggrading bed stability	Deposition of new bed material (bars, islands, etc.), excessive floodplain deposition, high W/D ratio, etc.
	Degrading bed stability	Localized down-cutting, scour, headcuts, high incision, low entrenchment, etc.
	Stream stability evolutionary trend	Rosgen (1996)
Horizontal (bank) stability	Bank Height Ratio	Bank height / max bankfull depth
	Rooting depth	Depth of root penetration visible in stream banks
	Root density (%)	Root density in rooting depth x (root depth/bank height) x 100%
	Bank angle (degrees)	
	Surface protection (%)	Percentage of bank protected ~ 100% - (percent of bank with exposed bare soil)
Riparian and In-Stream Habitat Assessment		
	In-stream cover	Amount and availability of physical habitat for fish
	Epifaunal cover	Amount and availability of physical habitat for aquatic insects and invertebrates
	Velocity/depth regimes	Variability of stream flow velocity and depth
	Shading	Degree of shading due to overhanging vegetation
	Water appearance	Turbidity, color, sheens, etc.
	Nutrient Enrichment	Amount of algae and aquatic macrophytes; color
	Riparian vegetation zone	Width and structure (strata) of natural vegetation in riparian zone
	Riparian zone nutrient uptake potential	Structure (strata) of riparian vegetation; slope of adjacent valley walls; prevalence of sheet flow; etc.
	Bank vegetation	Vegetative cover and stability of stream banks

(1996). Seven of the 9 riparian and in-stream habitat assessment parameters are from either the USEPA RBP or the NRCS SVAP (NRCS, 1998).

REFERENCE CONDITIONS, PERFORMANCE STANDARDS, & MONITORING:

Neither reference conditions, nor performance standards are addressed in the Protocol. However, the Protocol may be useful to help identify reference conditions and performance standards for stream enhancement or restoration projects. They may also be useful to monitor changes in the physical stream environment as a result of those activities.

OTHER:

Starr and McCandless (2001) indicate that a trained field team of two persons should be able to complete 2 to 3 miles of stream assessment per day. The authors also note that optimal conditions for stream assessment are during the warmer months and leaf-out.

LITERATURE CITED:

Barbour, M.T., J. Gerritsen, B.D. Snyder, and J.B. Stribling. 1999. *Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates, and Fish*, Second Edition. EPA 841-B-99–002. US EPA Office of Water, Washington, D.C.

NRCS, 1998. *Stream Visual Assessment Protocol*. NWCC Technical Note 99-1, National Water and Climate Center, USDA Natural Resources Conservation Service, Washington, DC. 36 pp.

Rosgen, D.L. 1996. Applied River Morphology. Wildland Hydrology, Pagosa Springs, CO.

Starr, R.R. and T. McCandless. 2001. *Stream and Riparian Habitats Rapid Assessment Protocol*. U.S. Fish and Wildlife Service, Chesapeake Bay Field Office, Annapolis, MD. 28 pp.

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No. 38 - Stream Channel Reference Sites: An Illustrated Guide to Field Technique

USFS Gen. Tech. Report RM-245 (Harrelson *et al.*, 1994)

PRIMARY PURPOSE:

Stream Channel Reference Sites: An Illustrated Guide to Field Technique (Harrelson *et al.*, 1994) presents techniques from numerous published sources addressing the establishment and monitoring of permanent reference sites for collecting data about streams and rivers. The authors aimed to identify relatively inexpensive procedures capable of providing high quality data needed to quantify the physical character of stream channels without a great deal of practitioner or equipment specialization (Harrelson *et al.*, 1994).

PROCEDURE SUMMARY:

The Guide is essentially a collection of technical methods to assess the geomorphological conditions of wadeable streams. The authors stress that methods in the Guide need to be expanded upon and/or combined with other methods to suit particular project objectives. They further point out that the Guide covers only the minimum procedure necessary to accurately characterize stream channels and illustrates the technically correct way to undertake those measurements (Harrelson *et al.*, 1994).

The minimum procedure includes the following:

1. Select a site;
2. Map the site and the location;
3. Measure the channel cross section;
4. Survey a longitudinal profile;
5. Measure stream discharge;
6. Measure stream bed (substrate) material;
7. Permanently file the information.

The Guide describes the Rosgen stream classification (Rosgen, 1994) as a means to stratify stream assessment and facilitate meaningful comparisons of streams. Each component of the above listed 7-step procedure is discussed in great detail, including site documentation (suggested mapping protocols), supplies, logistical considerations, use and care of equipment, and of course, the technical procedures themselves.

REFERENCE CONDITIONS, PERFORMANCE STANDARDS, & MONITORING:

Reference conditions are not specifically addressed in the Guide. Rather, the technical methods presented could be utilized to document reference conditions at appropriately selected sites. Likewise, performance standards and monitoring *per se* are inapplicable to the Guide. However, the methods enumerated therein could be used to identify and document performance standards, and these methods could form the basis of a quantitative stream morphological monitoring plan.

LITERATURE CITED:

Harrelson, C.C., C.L. Rawlins, and J.P. Potyondy. 1994. *Stream Channel Reference Sites: An Illustrated Guide to Field Technique*. General Tech Report RM-245, USFS Rocky Mountain Forest and Range Experiment Station, Fort Collins, CO. 61 pp.

Rosgen, D.L. 1994. A classification of natural rivers. *Catena* 22:169-199.

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USFS Stream Channel Reference Sites: An Illustrated Guide to Field Technique
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No. 39 - Stream Corridor Assessment Survey Protocols
Maryland Department of Natural Resources (Yetman, 2001)

PRIMARY PURPOSE:

The Maryland Department of Natural Resources, Watershed Restoration Division designed the *Stream Corridor Assessment (SCA) Survey Protocols* to "rapidly assess the general physical condition of a stream system and identify the location of a variety of common environmental problems within the stream's corridor," (Yetman, 2001). It is not intended to be a detailed scientific survey. Rather, it provides a rapid method of examining an entire drainage network in order to target future monitoring, management and/or conservation efforts.

PROCEDURE SUMMARY:

Assessment areas are rated on a scale of 1 to 5 for three separate site characteristics: 1) Problem Severity, 2) Correctability, and 3) Accessibility. These scores are subjective, and require no detailed collection of site specific data. Severity refers to the degree or magnitude of the specific type of problem (e.g., channel alteration, pipe outfall, inadequate buffer, etc.) relative to problem areas on other streams or stream reaches in the same problem category. Correctability is an assessment of the relative ease with which the assessment team believes a problem could be corrected. Accessibility represents a measure of how difficult the problem area is to gain access to in order to correct the problem.

Assessments are documented on 10 field data sheets (Table 1), which include 9 problem category sheets and a Representative Site data sheet that is completed by the assessment team during its survey of both in-stream habitat and adjacent stream corridor conditions in 0.25-0.5 mile intervals. The Representative Site data sheet is modeled after the USEPA RBP physical habitat assessment data sheet (Barbour *et al.*, 1999), and includes 10 in-stream and riparian zone attributes that are rated as poor, marginal, sub-optimal, or optimal based on surveyor observations.

The *SCA Protocols* include detailed discussions concerning selection of watersheds to assess, establishing partnerships with watershed stakeholders, logistics of stream/watershed assessment, and necessary equipment. Respect for the desires and interests of private property owners is stressed, and the safety of assessment participants is considered paramount. The *SCA Protocols* also include detailed instructions on documenting the results of stream/watershed assessments, including assigning unique site identification numbers, recording observations on maps and data forms, and constructing photographic records. A chapter devoted to data management discusses data entry and verification, cataloguing, GIS data entry and verification, and procedures to review and modify data.

Table 1. Field data sheets used in the MDNR Watershed Restoration Division, *Stream Corridor Assessment Survey Protocols*.

Data Sheet	Description
Channel Alteration	Widening, straightening, dredging, etc.; Lining streams with concrete, gabions, rip-rap, etc. for >50'.
Erosion Site	Unstable stream reaches with significant erosion problems
Exposed Pipes	Pipes in the stream or immediately adjacent to it that may be damaged during high flows, not including outfalls (see below).
Pipe Outfalls	Pipes or small man-made channels designed to discharge directly into a stream.
Fish Barrier	Natural or man-made features that preclude fish movement either due to an excessive elevation change, water that is too shallow, or water that flows too swiftly.
Inadequate Buffer	Lack of forested buffer at least 50' wide on both sides of the stream.
In/Near Stream Construction	Major disturbance (construction activities) in or near the stream.
Trash Dumping	Places where large amounts of trash have been dumped near the stream or where trash tends to accumulate as a result fo flood flows.
Unusual Condition or Comment	Used to document observations or conditions that are not easily accommodated by one of the other field data forms.
Representative Site	Data sheet used to document in-stream habitat and riparian zone conditions; very similar in format to the EPA RBP habitat assessment form.

REFERENCE CONDITIONS, PERFORMANCE STANDARDS, & MONITORING:

Neither reference conditions nor performance standards are addressed in the *SCA Protocols*. The utility and accuracy of information documented on the field data forms is likely dependant on the collective experience of the team performing the assessment. Yetman (2001) recommends a 5-day training course that includes both classroom and field exercises and is designed to expose participants to the potential range of stream conditions they are likely to encounter.

OTHER:

The author reports that the *SCA Protocols* are designed so that teams of two to three individuals who have received training in the use of *SCA Protocols* can survey an average of two to three stream miles per day. While detailed knowledge of stream hydrology or ecology are not required, the 5-day training course introduces the participants to basic premises of stream function and the ramifications of riparian and/or watershed disturbances.

The *SCA Protocols* are intended to quickly identify problem areas and potential restoration opportunities. A more detailed investigation of high priority restoration areas would then be required. This detailed assessment may then start to expose specific stream instability issues that would logically lead to conceptualization of performance standards and monitoring protocols.

LITERATURE CITED:

Barbour, M.T., J. Gerritsen, B.D. Snyder, and J.B. Stribling. 1999. *Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates, and Fish*, Second Edition. EPA 841-B-99–002. US EPA Office of Water, Washington, D.C.

Yetman, K.T. 2001. *Stream Corridor Assessment Survey Protocols*. Maryland Department of Natural Resources, Watershed Restoration Division, Annapolis, MD. 70 pp.

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Stream Corridor Assessment Survey Protocols
http://www.dnr.state.md.us/streams/stream_corridor.html

No. 40 - Stream Corridor Restoration: Principles, Processes, and Practices

Federal Interagency Stream Corridor Restoration Working Group (FISCRWG) (1998)

PRIMARY PURPOSE:

Stream Corridor Restoration: Principles, Processes, and Practices was a result of a consortium of 15 federal agencies including USDA, USEPA, TVA, FEMA, USDC, USDOD, USDHUD, and USDOI. The procedure provides "broadly applicable guidance" to stream restoration that spans across physiographic regions. The primary use of the procedure is for technical and managerial teams responsible for planning, designing, and implementing stream corridor restoration initiatives.

The Interagency manual provides a detailed treatise on physical, chemical, structural, hydrological, geomorphological, ecological, and biological characteristics of streams including processes, functions, and identification of natural and anthropogenic disturbances to streams. It defines stream restoration, provides stepwise guidance in developing a restoration plan, and offers guidelines for implementing stream restoration and monitoring.

PROCEDURE SUMMARY:

Several methods are presented to assess various components of stream corridor condition with references citing the fundamental premise of each, including classification (Strahler, 1957; Montgomery and Buffington, 1993; 1997), channel evolution (Schumm *et al.*, 1984; Simon, 1989; Simon and Downs, 1995), stream bank failure (Hagerty, 1991), riparian zone (Prichard *et al.*, 1993, revised 1995, 1998), and channel geomorphology (Rosgen, 1996). Sediment transport in alluvial channels is also covered (Schumm, 1977). Hydraulic geometry theory is discussed in context with bankfull discharge and channel forming processes. Hydraulic geometry relationships such as velocity, depth, and width are discussed with emphasis on bankfull discharge and dimension. In addition, the utility of developing regional hydraulic curves is emphasized (Dunne and Leopold, 1978).

The Interagency manual covers several components of river restoration including spatial issues, soil and vegetation properties, in-stream, riparian, and terrestrial habitat recovery, stream channel and streambank restoration, and land use scenarios. It presents a hierarchy of five spatial scales from the broad regional scale to the stream-reach scale, and stresses the importance of integrating the stream channel, active floodplain, and the transitional upland fringe into a complete stream corridor restoration and management plan. Two general methods of stream corridor restoration are recognized: the cognitive approach (reference reach) and the analytical approach (functional requirements of a target species). One highlight of the Interagency manual is a restoration checklist that includes planning, implementation and management, and post-restoration components.

A stepwise procedure for channel reconstruction is presented. Design considerations include use of channel dimensions, reference reaches, and meander design (i.e., planform). Stable channel methods using analytical approaches are tabulated and cited. The protocol also describes numerous channel physical and computer models with specific citations provided. Several soil properties related to river restoration are discussed including compaction, soil microfauna, and soil salinity. Restoration of riparian buffer strips is emphasized using vegetation that improves habitat, conduit, filter/barrier, source, and sink functions. The importance of retaining native vegetation is also discussed.

The effectiveness of several techniques of streambank restoration is addressed and illustrated with case studies. Channel stabilization techniques covered in the Interagency manual include anchored cuttings, geotextile fabrics, use of trees and logs, in-stream habitat structures, and integrative systems. The design of aquatic habitat structures is presented in six steps including: 1) plan layout; 2) selection of structural types; 3) size of structures; 4) investigation of hydraulic effects; 5) effects on sediment transport; and 6) selection of material and design structures.

The final chapter in the Interagency manual is devoted to implementation, monitoring, and management. This chapter describes the advantages and disadvantages of passive vs. active restoration methods. An eight-step process for implementation of restoration projects is presented, including: 1) developing a schedule; 2) obtaining necessary permits; 3) conducting pre-implementation meetings; 4) informing and involving property owners; 5) securing site access and easements; 6) securing site access and easements; 7) locating existing utilities; and 8) confirming sources of materials and ensuring standards of materials. Issues related to earthmoving, diversion of water, and installation of plant materials are also discussed. Appendix A of the procedure includes detailed descriptions with illustrations of in-stream techniques and practices.

REFERENCE CONDITIONS, PERFORMANCE STANDARDS, & MONITORING:

Reference conditions are stressed as an essential means of identifying opportunities for stream corridor enhancement or restoration. Restoration goals and objectives are also discussed. The importance of routine and timely inspections, monitoring, and maintenance are emphasized.

OTHER:

In addition to the science and technology applicable to stream corridor restoration, the procedure provides excellent, detailed guidance related to establishing holistic watershed management plans, which includes involvement and coordination with federal, state, and local government agencies, stakeholders, and public outreach (advisory boards). Communication between various technical teams, advisory boards, and the decision makers is emphasized.

LITERATURE CITED:

Dunne, T. and L.B. Leopold. 1987. Water in environmental planning. W.H. Freeman Co., San Franciso.

FISCRWG, 1998. *Stream Corridor Restoration: Principles, Processes, and Practices*. By the Federal Interagency Stream Restoration Working Group (15 Federal agencies of the US gov't). GPO Item No. 0120-A; SuDocs No. A 57.6/2:EN 3/PT.653. ISBN-0-934213-59-3.

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Prichard, D., H. Barrett, J. Cagney, R. Clark, J. Fogg, K. Gebhardt, P.L. Hansen, B. Mitchell, and D. Tippy. 1993. *Riparian Area Management:* Process for Assessing Proper Functioning Condition, Technical Reference 1737-9, BLM/SC/ST-9/003+1737+REV95+REV98, Bureau of Land Management, Denver, CO. 60 pp.

Rosgen, D.L. 1996. Applied River Morphology. Wildland Hydrology, Colorado.

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Simon, A. 1989a. A model of channel response in distributed alluvial channels. *Earth Surface Processes and Landforms* 14(1): 11-26.

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Strahler, A.N. 1957. Quantitative analysis of watershed geomorphology. *American Geophysical Union Transactions* 38: 913-920.

FOR ADDITIONAL INFORMATION:

Stream Corridor Restoration: Principles, Processes, and Practices
http://www.usda.gov/stream_restoration/

No. 41 - Stream Habitat Assessment Procedures, Chapter 8 in Surface Water Quality Monitoring Procedures Manual

Texas Natural Resources Conservation Commission, (1999)

PRIMARY PURPOSE:

The [Texas] Stream Habitat Assessment Procedures is Chapter 8 in the Surface Water Quality Monitoring (SWQM) Procedures Manual (TNRCC, 1999). The SWQM Program is responsible for collecting data statewide to accurately describe the physical, chemical, and biological characteristics of state waters. These data are primarily utilized to define long-term trends, determine water quality standards compliance, assign designated aquatic life uses to streams in Texas, and to compile CWA Section 305(b) reports.

The TNRCC Stream Habitat Assessment Procedure provides a good example of quantitative physical stream assessment data used in place of visual-based habitat assessment to generate a habitat quality index. The form of this index is similar to many other stream assessment habitat indices compiled by federal, state, or local entities that are modeled after the USEPA RBP habitat assessment.

PROCEDURE SUMMARY:

Stream habitat assessments are undertaken on a stream reach that is 40 times the average stream width in wadeable streams (minimum 150m, maximum 500m). Sample reaches in non-wadeable streams must incorporate one full meander of the stream channel, and if possible, include two examples of at least two stream habitat types (e.g., riffle, run, glide, pool) (minimum 500m, maximum 1km). In-stream channel measurements are collected from equally-spaced transects established perpendicular to stream flow throughout the sample reach. The number of transects varies from five (5) transects in a reach 150m-300m, six (6) transects in a reach 301m-500m, and 6-11 transects in non-wadeable streams such that the distance between transects in greater than 100m (TNRCC, 1999).

Stream assessments include in-stream channel measurements, stream morphology measurements, and characteristics of the riparian environment (Table 1). Additional general observations include maximum width and depth of the largest pool (if applicable), stream discharge measured at one location along the assessment reach, and photographs from mid-channel facing upstream and downstream.

Summary forms are provided on which all transect and reach-scale data and observations are then summarized. Most transect data is averaged to obtain single

Table 1. Stream habitat assessment variables in *Stream Habitat Assessment Procedures* (TNRCC, 1999).

Variable		Description
In-stream Channel Measurements	Habitat Type	Habitat type (riffle, run, pool, or glide) along each transect
	Number of Riffles	Number of riffles present throughout the assessment reach
	Dominant Substrate	Dominant particle size estimated visually or via particle size analysis within a 6m belt centered on each transect
	Percent Gravel or Larger	Estimate of the percentage of substrate >6mm in size within a 6m belt centered on each transect
	Algae / Macrophytes	Subjective visual determination of abundance within a 6m belt centered on each transect
	In-stream Cover Types	Cover types present within a 6m belt centered on each transect (e.g., undercut banks, cobble, leaf packs, etc.)
	Percent In-stream Cover	Visual estimate of percentage of in-stream cover present within a 6m belt centered on each transect
Stream Morphology	Stream Bends	Number of stream bends in assessment reach and subjective evaluation of definition (well, moderate, or poor)
	Channel Obstructions or Modifications	Presence of channel obstructions (e.g., fences, log jams, culvert, etc.) or modifications (e.g., channelization, levees, concrete lining, rip-rap, cleared riparian zones, etc.)
	Flow Status	Degree to which water covers available channel substrate
	Stream Width	Wetted channel width
	Stream Depth	Water depth measured at 4 to 10 equally-spaced points, including the thalweg, across each transect
Riparian Environment	Aesthetics	Subjective categorical descriptor of the riparian zone throughout the assessment reach
	Percent Riparian Vegetation	Percentage of riparian vegetation types on each bank: trees, grasses and forbes, cultivated fields, or other
	Bank Slope (Angle)	Bank slope (angle) of each bank at each transect
	Bank Erosion	Area of evident or potential erosion within a 6m belt centered on each transect
	Tree Canopy	Percent cover of channel shading using a densiometer
	Dominant Riparian Vegetation	Types of riparian vegetation within a 6m belt centered on each transect
	Width of Natural Buffer Vegetation	Width in meters of natural or native buffer vegetation perpendicular from each bank at each transect

values for each variable representative of the assessment reach as a whole. The Summary of Physical Characteristics of Water Body form is then used to complete a Habitat Quality Index form that assigns points for each of nine variables based on the actual values measured or estimated at the assessment reach relative to descriptions on the Habitat Quality Index.

These nine variables include: 1) available in-stream cover; 2) bottom substrate stability; 3) number of riffles; 4) dimensions of largest pool; 5) channel flow status; 6) bank stability; 7) channel sinuosity; 8) riparian buffer vegetation; and 9) aesthetics of the reach.

REFERENCE CONDITIONS, PERFORMANCE STANDARDS, & MONITORING:

Neither reference conditions nor performance standards are addressed in the Procedures. However, it is likely that TNRCC can or has identified reference sites based on the statewide SWQM Program data. Performance standards are not applicable to the SWQM Program or the Stream Habitat Assessment Procedures given their intended programmatic use. The SWQM Program is in essence a monitoring program and the Procedures manual itself could be used to identify performance standards and nearby reference conditions fo stream restoration or enhancement projects.

LITERATURE CITED:

TNRCC, 1999. “Stream Habitat Assessment Procedures,” Chapter 8 In *Surface Water Quality Monitoring Procedures Manual*, GI-252, Water Quality Division, Texas Environmental Quality Commission (formerly Texas Natural Resources Conservation Commission), Austin, TX.

FOR ADDITIONAL INFORMATION:

Stream Habitat Assessment Procedures, Chapter 8 In Surface Water Quality Monitoring Procedures Manual
http://www.tnrcc.state.tx.us/admin/topdoc/gi/252.html

No. 42 - Stream Habitat Classification and Inventory Procedures for Northern California

USFS Pacific Southwest Region (McCain *et al.*, 1990)

PRIMARY PURPOSE:

McCain *et al.* (1990) present a stream habitat inventory procedure to classify and quantify fish habitat based on physical channel features. The *Stream Habitat Classification and Inventory Procedures for Northern California* is based on data collected from gravel and boulder bed streams in the western Cascade Mountains of Oregon and Washington and in the Klamath Mountains of California. The Procedures manual is a standardized habitat assessment protocol that accommodates varying budgets and man power (McCain *et al.*, 1990).

PROCEDURE SUMMARY:

The Procedures describe a method for classifying physical stream habitat features at the stream reach or basin scale. Twenty-two pre-defined habitat types comprising various classes of riffles, runs, and pools have been identified and delineated in northern California, and it is under this framework that McCain *et al.* (1990) present the Procedures. Basin level inventories are based on homogenous areas of habitat that are approximately equal to or greater in length than one channel width. In contrast, stream reach scale assessments include habitat features less than one channel width in length, and are used to evaluate and quantify changes in physical stream habitat as result stream enhancement or restoration projects (McCain *et al.*, 1990).

The Procedures basically entail walking the entire length of stream being assessed and measuring each habitat type using any appropriate measuring device (e.g., tape, rod, optical rangefinder, hip chain, etc.). The authors suggest that other variables describing stream substrate, canopy cover, riparian quality, etc., may be measured during the habitat inventory and classification, but they suggest no specific methods for doing so.

REFERENCE CONDITIONS, PERFORMANCE STANDARDS, & MONITORING:

Neither reference conditions, nor performance standards are addressed by McCain *et al.* (1990). The Procedures outlined by the authors can be used to monitor stream habitat types and changes in the number or distribution of those habitat types as a result of stream enhancement or restoration practices.

OTHER:

The authors indicate that description and measurement of 22 habitat types is labor intensive, and a trained crew of 2 to 3 persons can survey approximately 1 mile of stream per day.

LITERATURE CITED:

McCain, M., D. Fuller, L. Decker, and K. Overton. 1990. Stream Habitat Classification and Inventory Procedures for Northern California. *FHR Currents*, Tech. Bulletin No. 1, USFS Pacific Southwest Region, Arcata, CA. 15 pp.

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Stream Habitat Classification and Inventory Procedures for Northern California
http://www.fs.fed.us/biology/fishecology/currents/index.html

No. 43 - Stream Survey Report Criteria

King County, Washington
Department of Development and Environmental Services

PRIMARY PURPOSE:

The *Stream Survey Report Criteria* (Criteria) are intended to improve the validity, consistency, and usefulness of fisheries information in King County, Washington by addressing the appropriate scope and methods of stream and fisheries studies.

PROCEDURE SUMMARY:

The Criteria recommend three progressive levels of detail based on stream system classification (designated uses) and fish utilization. Stream surveys for large scale projects (e.g., master drainage plans and subdivisions) must encompass stream reaches 0.25 miles upstream and downstream of the project, or to the next higher order stream (Strahler, 1957). Surveys for smaller projects (e.g., building permits, short subdivisions, etc.) shall encompass stream reaches 500 feet upstream and downstream of the site. Habitat and stream channel stability surveys are required for all Class 1 and 2 streams traversing the project site, and should include the following general site survey information:

- Natural drainage system configuration and stream classification;
- Riparian zone land uses;
- Riparian vegetation (structure, species composition, and density);
- Description of adjacent wetlands;
- Animal habitat and utilization;
- Riparian soils, channel morphology, and bank stability;
- Substrate composition;
- Large woody debris and pool quality (Platts *et al.*, 1987);
- Benthos (invertebrates);
- Fish habitat and utilization;
- Photographs taken at 25-foot intervals.

The specific Habitat Survey Form, which is required for all surveys, includes 15 variables that are evaluated and scored based on comparison with objective or subjective descriptions associated with each condition class: poor, fair, good, or excellent (Table 1).

Level I - Basic stream survey data must conform to King County Surface Water Management methods, which are derived from McCain *et al.* (1990) (see review this volume). Field data sheets are provided to record habitat types, large woody debris, channel obstructions, dominant substrate, channel dimensions, etc. Level II - Intermediate surveys must include all of Level I information, plus a list of all fish species documented in the stream based on the “two-pass removal electrofishing method.”

Table 1. Variables evaluated on the Habitat Survey Form required as part of Stream Survey Report Criteria in Unincorporated King County, Washington.

Variable		Description
Upper Banks	Landform Slope	Bank slope
	Mass Wasting or Failure (existing or potential)	Evidence of streambank failure or significant erosion
	Debris Jam Potential (floatable objects)	Size and amount of woody debris in channel
	Vegetative Bank Protection	Percent coverage and subjective assessment fo rooting vigor
Lower Banks	Channel Capacity	Based on width/depth ratio
	Bank Rock Content	Percent of bank comprised of rock, plus consideration of rock size
	Obstructions, Flow Deflectors, Sediment Traps	Amount and stability of large rock and logs causing hydraulic roughness in channel
	Cutting	Degree of channel migration ~ bank undercutting leading to unstable banks
	Deposition	Formation, movement, or growth of point bars or longitudinal bars
Channel Bottom	Rock Angularity	Subjective assessment of angularity of substrate
	Brightness	Subjective assessment of staining on substrate
	Consolidation or Particle Packing	Subjective assessment of substrate armoring
	Bottom Size Distribution and Percent-Stable Materials	Subjective assessment of substrate PSD and stability
	Scouring and Deposition	Percent of channel bottom affected by scouring or deposition
	Clinging Aquatic Vegetation (moss and algae)	Subjective assessment of coverage and location of moss and algae

Level III - Detailed stream surveys must include all Level I and Level II information, plus a detailed map drawn to scale to illustrate location and dimensions of habitat types, spawning areas, and large woody debris (≥10 inches diameter and ≥10 feet long) throughout the sample area. Level II surveys also require channel cross-sections every 300 feet (or a minimum of 3 cross-sections) on every Class 1 and 2 stream on the project site and up to 0.25 miles downstream. The following data is required at each cross-section: 1) elevation at 1-foot intervals up to the ordinary high water mark; 2) substrate composition; 3) representative macroinvertebrate species and numbers; 4) stream habitat types within 5 channel widths upstream and downstream; and 5) position, species, and size of all trees at least 10 inches diameter within 20 feet upstream and downstream of the cross-section and within 100 feet laterally from the ordinary high water mark.

REFERENCE CONDITIONS, PERFORMANCE STANDARDS, & MONITORING:

Reference conditions are not addressed in the Criteria, and performance standards and monitoring are not applicable. Procedures outlined in the criteria may be useful for identifying performance standards and monitoring variables for stream enhancement or restoration projects. Collectively, streams surveyed according to these standard protocols may help identify reference conditions in King County.

LITERATURE CITED:

McCain, M., D. Fuller, L. Decker, and K. Overton. 1990. Stream Habitat Classification and Inventory Procedures for Northern California. *FHR Currents*, Tech. Bulletin No. 1, USFS Pacific Southwest Region, Arcata, CA. 15 pp.

Platts, W.S., C. Armour, G.D. Booth, M. Bryant, J.L. Bufford, P. Cuplin, S. Jensen, G.W. Lienkaemper, G.W. Minshall, S.B. Monsen, R.L. Nelson, J.R. Sedell, and J.S. Tuhy. 1987. Methods for Evaluating Riparian Habitats with Applications to Management. Gen. Tech. Rpt. INT-221, USFS Intermountain Research Station.

Strahler, A.N. 1957. Quantitative analysis of watershed geomorphology. *American Geophysical Union Transactions* 38:913-920.

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No. 44 - Stream Visual Assessment Protocol

National Water and Climate Center Technical Note 99-1
USDA NRCS, December 1998

PRIMARY PURPOSE:

The *Stream Visual Assessment Protocol* (SVAP) was designed as a simple, comprehensive assessment method suitable as a first approximation of stream conditions that may also indicate the need for more robust, accurate assessment methods.

PROCEDURE SUMMARY:

SVAP recommends that streams be classified prior to assessment (NWCC, 1998) and suggests a three-tiered classification system based on ecoregion, drainage area, and stream gradient. Alternatively, it recommends utilizing either the Rosgen classification (1994; 1996), the Montgomery/Buffington classification (Montgomery and Buffington, 1993; 1997), or any other classification the practitioner is familiar with (NWCC, 1998).

An assessment is performed on one or more reaches of stream channel that are 12 times as long as the active channel width. “Active channel width” is considered synonymous with bankfull width. The assessment is completed by scoring up to 15 stream and riparian zone variables (Table 1). Only those variables that are applicable to the stream being assessed are utilized (scored), and each is scored from 1 to 10. Scoring is based on stream and riparian zone observations relative to the descriptions of conditions in the protocol and observed conditions from nearby reference streams. The sum of the variables scored divided by the number of variables utilized in the assessment provides an overall score that is then compared to a four level quality condition index. Overall scores less than 6.0 are considered “poor” quality streams; scores between 6.1 and 7.4 are “fair;” 7.5 to 8.9 are “good;” and overall scores greater than 9.0 are considered excellent quality streams.

REFERENCE CONDITIONS, PERFORMANCE STANDARDS, & MONITORING:

SVAP emphasizes the importance of reference sites and encourages practitioners not only to utilize reference sites within appropriate stream classes, but also to check with applicable State agencies to see if they have identified and characterized reference streams in the project area.

Table 1. Assessment variables and descriptions used in SVAP.

Assessment Variable	Description	Indicators
Channel condition	Lateral and vertical channel stability	Evidence of channelization; head cutting, downcutting; diversions; etc.
Hydrologic alteration	"Normal" flood regime; Stream with unimpeded access to its floodplain	No channel incision, dams, or water withdrawals
Riparian zone	Characteristic vegetative zone adjacent to stream channel	Width, structure, and species composition of natural vegetation
Bank stability	Potential for stream bank erosion to contribute to stream sediment load	Actively erooding banks with a lack of vegetative protection
Water appearance	Turbidity, color, and other visual water quality characteristics	Depth of visibility; cloudiness; color, etc.
Nutrient enrichment	High levels of nutrients (esp. nitrogen and phosphorus)	Water color; excess rooted aquatic macrophytes, algae, etc.
Barriers to fish movement	Structures or withdrawals that impede aquatic fauna mobility	Drop structures, culverts, dams, or water diversions
Instream fish cover	Availability of physical habitat cover in the stream channel	Scored by number of cover types: large woody debris, deep pools, overhanging vegetation, riffles, etc.
Pools	Depth and abundance of pools	Mixture of shallow and deep pools (definitions provided)
Invertebrate habitat	Stable benthic macroinvertebrate habitat	Number of habitat types: fine woody debris, leaf packs, undercut banks, coarse substrate, etc.
Canopy cover*	Varied canopy coverage desired based on "coldwater" vs. "warmwater" fishery stream	Amount of canopy coverage overhanging the stream (e.g. shading)
Manure presence*	Livestock operations or straight-pipe sewage discharges	Presence of manure or well worn livestock paths
Salinity*	Especially problematic in arid regions, highly irrigated regions, or oil and gas well operations	Burning or leaching of aquatic vegetation, stunted growth; whitish salt encrustments on stream banks
Riffle embeddedness*	Degree to which gravel or cobble are surrounded by finer sediment	Depth of embeddedness
Macroinverte-brates observed*	Presence of pollution intolerant insect species	Percent dominance of taxa per pollution tolerance group as defined in SVAP

* Optional variable to be used only in applicable circumstances

OTHER:

SVAP is intended to be applicable nationwide. However, the authors stress that the protocol can be enhanced by modifying the assessment variables to account for regional conditions. The SVAP documentation even provides a recommended sequence of steps and considerations important to regionalize the protocol, which reiterates the importance of stream type classification and use of reference reaches.

SVAP does not permit a quantified assessment of the causes or symptoms of channel instability or degradation. The practitioner can review scores of individual assessment variables for insight into such matters, but this is where SVAP recommends use of more rigorous assessment methods and protocols.

The authors also note that SVAP reviews conditions solely within a channel reach and thereby omits broader watershed conditions that could be affecting conditions within the reach. In field trials testing the accuracy, precision, and “usability” of early versions of the protocol, SVAP appropriately scored streams in good to moderate condition, while “over rating” poor quality streams. The final version of SVAP aimed to correct this problem.

LITERATURE CITED:

Montgomery, D.R., and J.M. Buffington. 1993. *Channel classification, prediction of channel response, and assessment of channel condition*. TFW-SH10-93-002, Washington Department of Natural Resources, Olympia, WA. 84 pp.

---------. 1997. Channel reach morphology in mountain drainage basins. *Geological Society of America Bulletin* 109:596-611.

NNWCC, 1998. *Stream Visual Assessment Protocol*. USDA Natural Resources Conservation Service, National Water and Climate Center Technical Note 99-1, Washington, D.C.

Rosgen, D.L. 1994. A classification of natural rivers. *Catena* 22:169-199.

Rosgen, D.L. 1996. Applied River Morphology. Wildland Hydrology, Pagosa Springs, CO.

FOR ADDITIONAL INFORMATION:

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USDA National Water and Climate Center
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USDA NRCS Stream Visual Assessment Protocol
http://www.wcc.nrcs.usda.gov/wqam/wqam-docs.html

No. 45 - [Vermont] Stream Geomorphic Assessment Protocol Handbooks

Vermont Agency of Natural Resources (April 2003)

PRIMARY PURPOSE:

The *Vermont Stream Geomorphic Assessment Protocol Handbooks* (Handbooks) were prepared by the Vermont Agency of Natural Resources (VANR) and are the result of a collaborative effort by the Vermont Department of Environmental Conservation (VDEC), the Vermont Department of Fish and Wildlife, and the Vermont Geological Survey. The Handbooks were developed to help meet VANR's watershed and river conservation and assessment goals and provide a method for gathering scientifically sound information to use in "understanding, evaluating, and, ultimately, resolving or avoiding conflicts between river systems and human interests and values," (VANR, 2003).

The Handbooks are not intended to provide a full compendium of field techniques, nor do they provide a complete methodology for project design. Data generated from methods in the Handbooks will support project design, but should not be used in lieu of hydraulic or hydrologic modeling, or sediment transport analysis in cases where such information is warranted.

PROCEDURE SUMMARY:

The Handbooks include three phases of assessment intended to successively increase the level of detail, accuracy, and precision of data to support stream type classification, channel evolution prediction, and ultimately, restoration efforts. All phases of assessment require technical training. Phase 1 is the remote sensing phase during which information is gathered from maps, aerial photographs, existing studies, and very limited field studies or "windshield surveys." Phase 2 is the rapid field assessment phase, which includes collection of field data from measurements at the stream reach or sub-reach scale. Phase 3 is the survey-level field assessment phase and includes collection of detailed, quantitative measurements of channel dimensions, pattern, profile, and sediment.

VANR has adopted a system of stream classification that combines elements of Schumm (1977), Rosgen (1996), and Montgomery and Buffington (1993; 1997). VANR's stream classification system can be used to generally characterize: 1) the relationship of the stream with its floodplain; 2) the respective roles of bed form, relative channel depth, and stream gradient in sediment transport processes; 3) the size and quantity of sediment in transport; 4) the boundary resistance of the stream bed and banks; and 5) hydrologic runoff characteristics (VANR, 2003).

The Handbooks also include a "sensitivity rating" to communicate a stream's potential rate of change associated with adjustment and channel evolution processes. Parameters used to rate sensitivity include: 1) erodibility of channel boundary materials; 2) sediment and flow regimes (volume and runoff characteristics); 3) confinement and slope of the valley; and 4) degree of departure from reference conditions (VANR, 2003).

During Phase 1 assessments, valley types are identified and geologic conditions investigated to generate provisional stream types. Departure from reference conditions are postulated based on watershed and stream corridor land use and channel or floodplain modifications. Phase 1 assessments are useful to help prioritize stream reaches for potential Phase 2 assessment, and they also serve as cataloguing databases where the results of Phase 2 and 3 assessments can be entered and tracked on a watershed scale over time.

Phase 2 assessments include the USEPA RBP stream habitat assessment (Barbour *et al.*, 1999), a rapid geomorphic assessment index, and a suite of measured or estimated parameters characterizing the broader stream valley, channel morphology, and streambanks and riparian corridors, all of which are used to identify existing stream type and on-going channel adjustment processes. Qualitative field evaluations of erosion and depositional processes, changes in channel and floodplain geometry, and riparian land use/land cover are used to assess stream geomorphic condition, physical habitat, adjustment processes, reach sensitivity, and stage of channel evolution (VANR, 2003). Although Phase 2 assessments are described and labeled as “rapid,” the Handbooks indicate that they may take 1-2 days in the field to describe a 1 mile stream reach.

Like Phase 2 assessments, Phase 3 assessments are also completed on a stream reach or sub-reach scale. Phase 3 assessments include the use of field survey equipment and other accurate measuring devices and are typically undertaken to support requirements for design and implementation of restoration projects. A physical habitat assessment component is currently under development and will be included as part of Phase 3. The Handbooks note that Phase 3 assessments may take 3-4 days to complete on a stream reach that is two meander wavelengths in length.

Appendices in the Handbooks provide field data forms, database recommendations and instructions, technical information, and detailed techniques and methods for various components of stream geomorphic assessment.

REFERENCE CONDITIONS, PERFORMANCE STANDARDS, & MONITORING:

The Handbooks require use of reference sites chosen based on watershed zone, confinement (valley width/channel width), and valley slope in Phase 1, and expanded in Phase 2 to include entrenchment, width/depth ratio, sinuosity, channel slope, substrate, and bed form.

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Vermont Stream Geomorphic Assessment Protocol Handbooks
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APPENDIX D

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