Draft Functional Assessment Framework Excerpt:

Attributes, Considerations, Criteria

U.S. Environmental Protection Agency, Region 10

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This document is excerpted from the "Draft Functional Assessment Framework", a work-in-progress document reflecting research and exploration of concepts relevant to development of a Stream Mitigation Framework for Oregon, led by the Environmental Protection Agency, Region 10 (EPA) in collaboration with the U.S. Army Corps of Engineers, Portland District (Corps) and the Oregon Department of State Lands (ODSL). EPA initiated the development of the work-in-progress document, based on the Agencies' analysis of limitations which need to be addressed in developing a science-based, consistent, and transparent stream mitigation framework for Oregon (see Appendix A).

An initial "Draft Functional Assessment Framework" was prepared for the EPA by Skidmore Restoration Consulting (Peter Skidmore) and Inter-Fluve (Greg Koonce, Andy Selle); it was wholly funded by the EPA. This evolving document incorporates and reflects on-going discourse and oversight from the Agencies, as well as dialog and input from a series of technical workshops hosted by the Agencies, which included participants from federal, state, tribal and local agencies and organizations.

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STREAM FUNCTION ASSESSMENT

Assessment refers to the process of measuring or predicting outcomes associated with permitted actions and proposed mitigation actions. Assessment may play a role in permit sequencing (e.g. avoidance, minimization, and compensation) by providing a basis for predicting outcomes associated with proposed alternatives. Once permitted, a project assessment predicts impacts associated with permitted actions as the basis for establishing debits, the extent of impact to be mitigated. An assessment can similarly be used to establish outcomes of mitigation restoration. Here, we explore an assessment framework intended to improve environmental outcomes associated with stream mitigation primarily by establishing stream functions as the focus of assessment. The hypothesis inherent in this approach is that applying assessment of stream function as the primary basis of evaluating stream impacts and restoration, rather than stream condition, will improve environmental outcomes where historically condition-based assessment, and restoration, has proven inadequate, or at best uncertain.

For the purposes of this document, we use the following definition specific to a stream mitigation context:

> *stream function*: the processes that create and support a stream ecosystem[1]

In this application, function is differentiated from 'condition', which is commonly applied as the basis for assessment. *Condition* refers to the qualities and structure[2] of a stream ecosystem at a given point in time.

Stream Functions

Stream functions are dynamic and interrelated physical, chemical and biological processes that create and maintain the character of a stream and associated riparian system and determine the flux of energy, materials, and organisms through or within a stream system. A naturally functioning stream ecosystem is inherently stable and resilient to disturbance because the functions at play are generally interrelated, responsive, and unconstrained. Stream functions are dependent upon their landscape context, where landscape context includes the spatial variables surrounding the location of interest (patch, reach, segment) as well as influencing functions at that location, and which are also influenced by functions outside that location. Landscape context refers to any physical, chemical, or biological variables within the surrounding landscape, or watershed for streams, that influence or are influenced by the location or entity under consideration.

The description and categorization of stream functions is an evolving body of science and has not been adequately developed in a mitigation context. Functions are variously and ambiguously defined in the literature (NRC 2002, Sheldon et al. 2005, Fischenich 2006, Sandin and Solimini 2009). "Function" is often characterized as providing ecosystem services. However, such characterizations are inherently subjective and value-based, as 'service' implies a beneficiary (e.g. humans or preferred fish species). The definition applied in this document avoids subjective or value-derived interpretation (Sandin and Solimini 2009).

Fischenich (2006) synthesized input from a collection of international scientists to establish a list and categorization of stream functions. This effort serves as a starting point for refinement of proposed

[1] This definition is consistent with the Clean Water Act where functions are defined as physical, chemical, and biological processes that occur in ecosystems.

[2] The term 'structure' is a component of condition and encompasses "the physical and chemical settings and the biological structure of ecosystems" (Sandin and Solimini 2009).

functions for assessment in this document. Functions described by Fischenich have been re-categorized to compensate for ambiguity in specific function definition, and for overlap among functions. Our process suggested re-characterization of function categories as well. Re-characterization was developed in consultation with colleagues from academic, consulting, and regulatory arenas, and as such represents best professional judgment regarding appropriate categorization of functions for a stream mitigation context.

Functions proposed for assessment in this mitigation context are categorized as:

1. **Hydrologic functions**: includes the variable transfer and storage of water among the stream channel, its floodplain, and associated alluvial aquifer.
2. **Geomorphic functions**: encompasses hydraulic and sediment transport processes that generate variable forces within the channel and the variable input, transfer and storage of sediment within the channel and adjacent environs that are generally responsible for channel form.
3. **Biological functions**: includes processes that result in maintenance and change in biodiversity, trophic structure, habitat, and in some instances, variability in channel form.
4. **Chemical and nutrient functions**: encompasses processes that govern the cycling, transfer, and regulation of nutrients and chemicals in surface and groundwater, and between the stream channel and associated riparian system.

Selection of functions for assessment

To ensure that functions are categorized and described sufficiently for application to mitigation, criteria were developed to guide the selection and definition of functions for our purposes. Criteria serve to clarify the intent and boundaries for development of the subsequent assessment framework. Assessment of stream functions in a mitigation context were evaluated against the following criteria:

1. **Relevance.** Function assessed is relevant to impacts resulting from proposed actions and to diversity of native species among varying stream types and spatial scales. Functions used to evaluate both proposed actions and mitigation outcomes:
   (a) are relevant to the impacts resulting from the permitted actions for which mitigation is required,
   (b) relevant to a broad spectrum of native species,
   (c) can be correlated to regional differences in stream character (stream type).
2. **Utility.** Function assessed is practical for mitigation accounting (debit/credit) because it is measurable, responsive to actions, and predictable. Because the mitigation process is effectively an accounting system that attempts to balance permitted impact (-) with functional lift from mitigation (+), functions serving as the basis for a mitigation accounting framework must be:
   (a) responsive to actions (both impact and mitigation) within practical timescales (1-5 years),
   (b) practically measurable and quantifiable, ideally through existing assessment protocols,
   (d) definable as a potential (reference or improved) condition, even where prior data are unavailable, and
   (e) measurable at a reach scale.
3. **Multi-functionality.** Function assessed has potential to provide cumulative beneficial change ("lift") among interrelated functions. Stream functions are interrelated. It is likely not possible to identify functions that are sufficiently independent that permitted or mitigation actions will influence only a single function. Further, certain functions often play a disproportionate role in influencing other functions (Fischenich 2006). An optimal mitigation project would provide beneficial change across several or all functions. Selection of functions should:
   (a) represent the interrelated character of stream functions as well as the full spectrum of stream functions, and
   (b) strive to select those that are most likely to contribute to positive change in other functions and influence overall stream system health.

A suite of ten stream functions (see Table 1 – Functions Defined) was selected to enable the comprehensive assessment of streams in a mitigation context, and which meet the selection criteria (Table 2 – Function attributes). The intent is to provide a suite of functions that can be applied to any scale of impact and any scale of restoration, but with the understanding that not all functions can be effectively assessed at the scale of impact or restoration when projects are conducted at a site-scale. As such, assessment of functions at a scale where change (impact or mitigation) can be detected will provide the opportunity to assess impact or benefit associated with permitted actions and mitigation restoration.

The ten functions proposed were selected and defined by first reviewing and refining a list of functions developed through an expert workshop focus group (Fischenich 2006), and testing each individual function as well as the collective group of functions against the established criteria for selection of functions. Available listings of functions in the literature were generally limited in application due to ambiguous definitions of "function", or listings of functions that were not consistent with the definition provided. The suite developed and proposed herein reflects the current best-informed perspective.

Assessment of Stream Function

Mitigation assessment frameworks to date have relied primarily on assessment of condition-based metrics, assuming that these metrics are adequate indicators for function (Sandin and Solimini, 2009). Because a healthy and functioning stream ecosystem is a dynamic system, it may be only partially represented by static or point-in-time conditions. An inherent challenge in applying 'function' as opposed to 'condition' as the basis for assessment of impacts and benefits in a mitigation context is that assessment of function by definition requires assessing rates of change in condition. Both 'condition' and 'function' are interrelated, and neither alone may adequately assess change due to impacts. A healthy and functioning stream is not something in a static condition, and so 'condition' assessment quite often provides a limited approach to assessing function, as it focuses on static conditions rather than dynamic functions. Assessment of stream function may best be implemented by selecting both structural indicators of function and measurable functional metrics. Furthermore, the suite of potential structural responses to impacts and to changes in function is varied and context specific (stream type and hydrologic history are among the many variables that influence response). For these reasons, it seems logical to apply a suite of metrics that represents both condition and function, and that allows each stream type and context to be assessed as a unique system.

Function Attributes

Quantification of functions facilitates the assessment of impacts associated with permitted actions as well as mitigation outcomes, and allows us to test hypotheses regarding mitigation outcomes. Function *attributes* are proposed as a mechanism for measuring stream function (Table 2 - Function Attributes). Attributes in this context are specific, measurable features that are a characteristic or inherent part of the function that may indicate the extent to which a particular function is active. Individually they may not necessarily characterize the entirety of the function, but are selected to be representative of the function in conjunction with other attributes. Furthermore, some attributes may serve to represent multiple functions.

Attributes were selected to provide a direct measurement of the function to the extent possible. Where direct measures were impractical, attributes may include *indicators* for the function. Indices of biotic integrity, IBIs, are measures of condition, and are commonly applied as indicators or surrogates for function in rapid assessments and applied in a regulatory context. However, indicators may have uncertain or site-specific correlation with the function (Sandin and Solimini 2009), and are therefore suggested only where direct measures of function may be impractical.

The following criteria were used to evaluate the potential application of the suggested attributes to broad scale mitigation assessment (criteria listed are adapted from Sommerville 2010). Those attributes that are associated with numerous functions may provide greater utility to mitigation assessment, as fewer assessment components may be necessary to evaluate the suite of functions (See Table 2).

- D – Direct measure – attribute assessed is relevant to anticipated impacts and to proposed restoration objectives for mitigation
- Q – Quantifiable – attribute is measurable, can be repeated consistently by different people with same results, and with minimal observer bias and sampling error
- S – Sensitive – attribute is responsive to both impacts and mitigation/restoration actions; response can be correlated to actions, and can indicate a defensible trend within a practical timeframe (5-10 years) using available technology and tools
- P – Practicable – attribute can be measured within a regulatory context given budget, effort, and time considerations.

Attribute Definitions and Intent

Table 3 provides practical definitions for each attribute as well as a short explanation of the reasoning behind inclusion of the attribute.

Assessment Protocols for function attributes

A tremendous number of protocols and methods exist for the assessment and investigation of stream channel and riparian parameters. Two main sources of published protocols exist; many in the first group were developed to aid response to the Federal Clean Water Act reporting requirements and have been generated by state and federal agencies to assess the level of impairment of their streams (See compendium by Somerville, 2010, on-line: http://water.epa.gov/lawsregs/guidance/wetlands/upload/Stream-Protocols_2010.pdf). The second group of methods was derived from peer reviewed academic investigations. Both sources have strengths and were used in the development of Table 4 – Attribute assessment methods and GAP identification. Both rely on a premise that if function cannot easily be measured directly, structural indicators of that function can be used to assess its vigor. Most frameworks to date have operated under this premise; some have documented the connection between condition and function, while others have assumed such a connection without validation.

Three scales are considered for scale of impact/benefit:

1. **Patch[3]:** A patch, or site, is a segment of stream with consistent character; on the order of 1-5 channel widths.
2. **Reach**: A reach is a segment of stream over which geomorphic character is relatively consistent, but with variable patch or site characteristics; on the order of 5-20 channel widths.
3. **Stream Segment**: a segment consists of multiple reaches; > 20 channel widths.

Table 4 is a work in progress. Where appropriate, references are documented that provide useful information on a method or a portion of a method available to define a particular attribute. The table will

[3] Patch is a term borrowed from, and fundamental to, landscape ecology, indicating a relatively homogenous and discrete area within a landscape that changes and fluctuates over time (Forman 1995).

benefit from additional expert review to determine that both the attributes and the methods meet, or can be refined to meet, the needs of a functional approach.

A data need for this effort is the development of numerical values for assessment categories. Assessment protocols will describe how numerical values are derived for each function attribute – which is necessary to quantify each attribute such that it can be used in a mitigation 'accounting' system that measures impact (permitted action) and benefit (mitigation actions). Many existing protocols have established such values either through comparison with reference sites or through a more qualitative – good, better, best- approach.

Performance Standards

The CWA (404) and Oregon Removal-Fill rules stipulate that every mitigation plan include performance standards to assess whether the compensatory mitigation project is achieving its objectives. Performance standards are frequently called "success criteria" but may also be known by other names, such as "success standards," "performance measures," or "release criteria" (NRC 2001). The Final Compensatory Mitigation Rule (EPA/USACE 2008; Final Rule) defines *performance standards* as:

> *Observable or measurable physical (including hydrological), chemical and/or biological attributes that are used to determine if a compensatory mitigation project meets its objectives.*

Performance standards are not prescriptive - they do not mandate how a project will be accomplished, but rather, specify how a project should perform over time.

The Final Rule (EPA/USACE 2008) and Oregon Administrative Rules also stipulate a monitoring requirement to verify performance and a 5-year minimum monitoring period, with allowances for longer monitoring timeframes as needed to verify performance where ecological outcomes may require longer periods to be attained, or where anticipated ecological outcomes are not achieved within the 5-year timeframe.

There are three general types of performance standards as they relate to compensatory stream mitigation:

- *Action completion standards* establish expectations for what actions are performed. They can be used to measure the completion of proposed mitigation actions and may be assessed through monitoring of actions performed and as-built conditions.
- *Ecological performance standards* establish expectations for ecological outcomes. They can be used to measure whether a mitigation project achieves intended goals and objectives in specified timeframes.
- *Ecological trend standards* establish expectations for ecological trends toward an anticipated outcome. They can be used to measure progress toward an intended outcome, where the anticipated timeframe for that outcome may be so far in the future as to be impractical to apply to performance expectations, or where the timeframe to achieve is uncertain.

Criteria for establishing Ecological Performance Standards

While the Final Compensatory Mitigation Rule (EPA/USACE 2008) and Oregon Administrative Rules on compensatory mitigation stipulate *ecological performance standards* as the basis for establishing whether mitigation is accomplished, all three types of performance standards outlined above may be appropriate in application to compensatory stream mitigation and the release of credits to mitigation banks. Ecological performance standards are the primary emphasis of the following discussion on criteria for establishing performance standards, though many of the proposed criteria can be reasonably applied to other types of standards.

Performance standards for stream mitigation projects are necessarily project specific (EPA/USACE 2008). As such, in developing performance standards that can be applied consistently as well as those that are appropriate given project-specific considerations, criteria can be used to guide establishment of performance standards. Following are suggested criteria for establishing performance standards for stream mitigation projects in Oregon.

1. Performance standards should be framed as hypotheses to be tested about intended project outcomes.

Restoration is a common type of compensatory mitigation, yet the ecological benefits of stream restoration are largely unknown and undocumented (Bernhardt et al. 2005, Rumps et al. 2007, Stewart et al. 2009, Whiteway et al. 2010) and an analysis of mitigation outcomes to date (NRC 2001) indicate that anticipated outcomes are often not realized, in part due to the uncertainty of restoration technologies applied. Consequently, outcomes associated with any given compensatory mitigation restoration action are uncertain. Performance standards, other than "action completed" standards, are therefore hypotheses of how the site will perform. A mitigation project proposal should include not only project goals and objectives, but also hypotheses articulating anticipated project outcomes, and specific performance measures for each stream function attribute that will be used to test those hypotheses and establish degree of success in meeting objectives.

Following are specific criteria suggested to support a hypothesis framework for establishment of performance standards:

- Performance standards will relate directly to defined mitigation objectives. For each measurable objective defined in mitigation project proposal, a minimum of one performance standard will be established to directly measure the outcome associated with that objective.
- Performance standards should be sufficiently specific to be unambiguous and enforceable.
- Baseline assessment performed prior to restoration actions and using the same metrics and standards as those proposed for measuring outcomes will serve as a point of comparison for testing hypotheses and measuring outcomes.
- Where a reference stream serves as the basis for establishing hypotheses about projected mitigation outcomes, the reference stream should be of the same type (see stream type discussion), equivalent size, and within the same watershed as the mitigation stream.
- Hypotheses about mitigation outcomes should be defined as falling within a range of acceptable values *and* exhibiting a range of acceptable variation for each function attribute included.

A hypothesis framework for establishing performance standards is supported by the following considerations:

- There is not currently a sufficient body of empirical knowledge to support assumptions regarding outcomes of restoration actions. Consequently, any prediction of outcomes is necessarily a hypothesis, requiring verification.
- Standards expressed as hypotheses are readily adapted to scientific method and monitoring protocols.

2. Performance standards should be developed to verify project outcomes as they relate to project-specific objectives for stream functions.

Project objectives, articulated as a fundamental component of a proposed mitigation project, serve to define desired project outcomes. Objectives should be defined in terms of the proposed changes in stream functions. Performance standards are developed to verify whether a project performs as expected and predicted, specifically with respect to changes in stream function.

Following are criteria suggested to support the development of performance standards that relate specifically to *objectives defining change in stream function*:

- Performance standards should be articulated to define specific projected change in stream function attributes, representing actual change in function. Function attributes serve as the metrics for measuring change in function; performance standards should be articulated using the same attribute metrics.
- Performance standards should be independent of project type. The same type of project in different settings may result in different outcomes for each stream function. Likewise, similar outcomes may result from different actions in different settings. Consequently there is no ecological basis for linking performance standards to project type. There is risk in establishing performance standards in relation to project type, because this could establish unrealistic expectations or promote inappropriate efforts to achieve standards that are inappropriate in a given setting.

3. Performance standards should be context specific, where context refers to stream type, geographic location, existing function status, reference function, and proposed restoration outcomes.

Every compensatory mitigation project is unique. The Final Rule (EPA/USACE 2008) states "Performance standards must be developed on a project-by-project basis, to address the objectives of a compensatory mitigation project." It represents a unique combination of inherent site-specific characteristics (e.g. stream type, size, watershed, geographic location, native species), condition-specific characteristics (existing function conditions and range of potential function end condition), restoration project objectives, and project constraints (Ossinger 1998).

Following are specific criteria suggested to support a context-specific establishment of performance standards:

- Mitigation goals, objectives, and associated performance standards should be set in a watershed context, using a watershed approach (Faber et al 2008; EPA/USACE 2008).
- Performance standards should reflect the specific limits, constraints, and opportunities presented by the specific stream type, size and location. Specific stream types represent a potential range for each function attribute, and within that range, a narrower range that represents full function potential. Performance standards should reflect the specific range of full function potential for each attribute assessed at the restoration site.
- Performance standards should reflect the relative degree of opportunity to restore each function by considering the local and watershed constraints that may limit performance in short- or long-term.

Additional Considerations for Performance Standards

Additional considerations for development of function-based performance standards:

- Encompass the full range of function attributes that may be relevant for hypothesized outcomes. Those functions that are not anticipated to exhibit change resulting from mitigation should be explicitly listed as such.

- Standards should be expressed as a range of values for each function attribute in order to accommodate natural year-to-year variation in function as well as the natural average range of variation for each function attribute, rather than providing a specific target value.
- Where possible, standards should be expressed as metrics that measure actual function attributes, rather than indicator or surrogate metrics for those attributes.
- Clearly articulate the timeframe for measurement for anticipated outcomes, including both the timeframe for achieving outcomes and for how long such outcomes should persist.
- Where possible, measure outcomes as opposed to measuring trajectories toward an outcome. Research indicates that performance trajectories are generally a poor indicator of outcomes (ELI 2004).
- Reflect vetted federal and state guidelines and protocols or peer-reviewed protocols wherever possible.

SITE SELECTION

Mitigation may occur on-site or off-site. On-site permitted actions may preclude practicable mitigation, in which case, off-site mitigation may be required. Additionally, other considerations may lead to environmentally preferable mitigation alternatives at off-site locations. The following criteria are considered for guiding site selection for compensatory mitigation in Oregon.

Watershed Approach

EPA and USACE have endorsed a 'watershed approach' as the basis for planning and site selection for compensatory mitigation, including stream mitigation (EPA/USACE 2008). The 'watershed approach' is a coordinating framework for management that focuses mitigation and restoration efforts to address the highest priority problems within a watershed, and promotes consideration of landscape contexts within the relevant watershed: (http://www.epa.gov/owow/watershed/framework/ch2.html).

The watershed approach "means an analytical process for making compensatory mitigation decisions that support the sustainability or improvement of aquatic resources in a watershed. It involves consideration of watershed needs, and how locations and types of compensatory mitigation projects address those needs. A landscape perspective is used to identify the types and locations of compensatory mitigation projects that will benefit the watershed and offset losses of aquatic resource functions and services caused by activities authorized by (USACE) permits. The watershed approach may involve consideration of landscape scale, historic and potential aquatic resource conditions, past and projected aquatic resource impacts in the watershed, and terrestrial connections between aquatic resources when determining compensatory mitigation requirements for (USACE) permits" (EPA/USACE 2008).

The Final Compensatory Mitigation Rule (EPA/USACE 2008) encourages mitigation planning in the context of available watershed plans, where those plans are appropriate. The ultimate goal of the watershed approach, as applied to compensatory mitigation, is to maintain and improve quality and quantity of aquatic resources within watersheds through strategic selection of compensatory mitigation sites. In the absence of a watershed plan that identifies conservation and restoration priorities consistent with mitigation objectives, the watershed approach for site-selection would typically include consideration of:

- Hydrologic conditions throughout the watershed that influence and are influenced by the site;
- Watershed scale features such as aquatic habitat connectivity and diversity;
- Size and location of mitigation relative to other ecological features in the watershed;
- Compatibility of proposed mitigation with adjacent land use and watershed management plans and associated environmental restoration or protection goals;
- Potential effects of mitigation on ecologically important aquatic or terrestrial resources, including threatened or endangered species; and
- Land use trends within the watershed that will affect or be affected by proposed compensatory mitigation.

Watersheds

Site selection within a watershed context requires spatial definition of watersheds. It is often appropriate and necessary to consider varying scales of watersheds. The watershed approach can be applied at multiple scales in mitigation planning; basins (6-digt HUC) and sub-basins (8-digit HUC) are often used to delineate watershed plans.

Existing watershed plans can facilitate site selection for stream mitigation. Watershed plans often are based on a comprehensive assessment and establish priorities for conservation and restoration that may be consistent with mitigation objectives. A number of resource planning frameworks exist in Oregon. Relevance and appropriateness for mitigation site selection planning will vary by watershed and by mitigation objectives. Existing frameworks that exist and may be considered include:

- *OWEB watershed plans*: The Oregon Watershed Enhancement Board (OWEB) has facilitated the development of watershed plans that often include restoration priorities: http://www.oregon.gov/OWEB/restoration_priorities.shtml
- *OWEB watershed assessments*: OWEB also facilitates watershed assessments, which may provide valuable watershed and landscape context to apply a watershed approach. http://www.oregon.gov/OWEB/MONITOR/watershedassessments_linked.shtml
- *Oregon Conservation Strategy*: In Oregon, 'conservation opportunity areas' have been delineated to meet national directive to states to establish fish and wildlife conservation plans. Based on similar philosophy and approach to the Nature Conservancy's ecoregional planning. This planning framework considers broader objectives than freshwater and streams, and so may have varied or limited relevance.
- *DEQ TMDL documents and watershed assessment reports*: The Department of Environmental quality has developed total maximum daily load documents for many water quality limited streams in Oregon. Watershed assessment technical reports are also available that presents information from their water quality monitoring program. One such document is the Willamette Basin Rivers and Streams Assessment.
- *Conservation and Recovery Plans for ESA species*: Various agencies coordinate completion of conservation and recovery plans for fish populations listed under the federal Endangered Species Act. These plans are generally available from the Oregon Department of Fish and Wildlife.

Universal site-selection criteria

We term as 'universal' those site-selection criteria that apply to site selection for all mitigation projects, including on-site and off-site, in-kind and out-of-kind. The following universal criteria are categorized as those relating to watershed position, connectivity of aquatic resources, function to be mitigated, and the durability or sustainability of mitigation actions at a site. These suggested criteria would optimize "environmentally preferable" mitigation project outcomes, as described in the Final Compensatory Mitigation Rule (EPA/USACE 2008) and Oregon Administrative Rules.

Watershed position criteria

- Site is identified in a watershed or other landscape scale plan as important or critical to aquatic ecosystem functions or other environmental priorities, where watershed plans exist, *and* has potential to address established objectives.
- Site is on same stream type as impacts being mitigated.

Connectivity of aquatic resources criteria

- Where primarily in-channel mitigation is proposed, associated floodplain and associated riparian corridor is unconstrained and fully functioning, *or* mitigation includes restoration of floodplain and riparian corridor.
- Access to site by aquatic organisms (not limited to fish) is not limited by downstream man-made passage barriers *or* includes passage remedy, if appropriate to the functions being replaced/restored.

Function specificity criteria

- Site provides opportunity to improve functions identified as priorities for restoration in the sub-basin, or functions that are most likely to influence and enhance other functions, as indicated by their influence rank.
- Site provides opportunity to improve multiple functions identified as limiting or constrained in a watershed context.
- Site provides opportunity to fully mitigate loss of full extent of each specific function at impact site.
- Site provides opportunity to remove environmental constraints (e.g. armored banks, levees, impoundments, diversions, grade control, infrastructure, adjacent deleterious land use practices, etc.) *or* to improve stream functions identified as limited or constrained at the site.

Durability criteria

- Site provides for enduring and sustainable benefits through existing or new protections such as easements or public ownership.
- Site represents a high probability of success in meeting mitigation objectives relative to other site options for same objectives.
- Site lacks conflicting adjacent land uses that would compromise function and is generally self-sustaining.

Table 1: **Functions defined: stream function categorization, definition, and ecosystem services provided (modified from Fischenich 2006).**

FUNCTION CATEGORY	FUNCTION	DEFINITION AND SERVICES PROVIDED
Hydrologic functions	1. Surface water storage	Temporary storage of surface water in relatively static state, generally during high flow, as in floodplain inundation, backwater channels, wetland depressions. Providing regulating discharge, replenishes soil moisture, provides pathways for fish and invertebrate movement, low velocity habitat and refuge, and contact time for biogeochemical processes.
	2. Sub/surface transfer	Transfer of water between surface and subsurface environments, often through hyporheic zone. Provides aquifer recharge, base-flow, exchange of nutrients/chemicals through hyporheic, moderates flow, maintains soil moisture.
	3. Flow variation	Daily, seasonal and inter-annual variation in flow. Provides variability in stream energy driving channel dynamics, provides environmental cues for life history transitions, redistributes sediment, provides habitat variability (temporal), provides sorting of sediment and differential deposition
Geomorphic functions	4. Sediment continuity	The balance between transport and deposition of sediment such that there is no net erosion or deposition (aggradation or degradation) within the channel. Maintains channel character and associated habitat diversity, provides sediment source and storage for riparian and aquatic habitat succession, maintains channel equilibrium.
	5. Substrate mobility	Regular movement of channel bed substrate. Provides sorting of sediments, mobilizes/flushes fine sediment, creates and maintains hydraulic diversity, creates and maintains habitat.
Biological functions	6. Maintain biodiversity	Maintain the variety of species, life forms of a species, community compositions, and genetics. Biodiversity provides species and community resilience in the face of disturbance and disease, full spectrum trophic resources, balance of resource use (through interspecies competition).
	7. Create habitat (aquatic/riparian)	Create and maintain the suite of physical, chemical, thermal and nutritional resources necessary to sustain organisms. Habitat sustains native organisms. Habitat includes in-channel habitat, as defined largely by depth, velocity, and substrate, and riparian habitat, as defined largely by vegetative structure.
	8. Sustain trophic structure	Production of food resources necessary to sustain all trophic levels including primary producers, consumers, prey species and predators. Trophic structure provides basic nutritional resources for aquatic resources, regulates the diversity of species and communities.
Chemical and nutrient functions	9. Nutrient cycling	Transfer and storage of nutrients from environment to organisms and back to environment. Provides basic resources for primary production, regulates excess nutrients, provides sink and source for nutrients.
	10. Chemical regulation	Moderation of chemicals in the water. Limits the concentration of beneficial and detrimental chemicals in the water.

Table 2: **Function Attributes**

		ATTRIBUTE METRIC	Overbank flow duration	Base flow	Hyporheic Flow	Groundwater flux	Temperature (water)	Bankfull flow frequency	Bankfull flow duration	Floodplain deposition	Change in bed elevation	Active channel bars	Active Channel Banks	Sediment character & complexity	Bed mobility frequency	Hydraulic variability	Large wood frequency and recruitment	Channel and Floodplain Habitat complexity	Benthic Invertebrate Community Structure & Function	Fish Community Structure & Composition	Riparian Vegetation Community Structure and Composition	Macrophyte/Periphyton community structure and composition	Connectivity: lateral & longitudinal	Riparian buffer width and composition	Habitat sustainability	Trophic Level Balance and Composition	Leaf litter breakdown	N, P concentration	Dissolved Oxygen
FUNCTION CATEGORY	FUNCTION	Criteria*	DQSp	DQSP	dQsP	DqsP	DQsP	DQSp	dQSp	DQSP	DQSP	DqsP	dQSP	dQSP	DQSP	dQSP	dQSP	DQSP	DQsP	DQsP	DQsP	DQsP	dQSP	dQSP	dQSP	dQsP	DQsP	DQsP	DQSP
Hydrologic functions	1. Surface water storage		X	X																									
	2. Sub/surface transfer		X	X	X	X	X																						
	3. Flow variation		X	X	X			X		X																			
Geomorphic functions	4. Sediment continuity							X	X		X	X		X		X													
	5. Substrate mobility							X	X	X	X	X		X	X	X		X											
Biological functions	6. Maintain biodiversity																	X	X	X	X	X							
	7. Create habitat (aq/rip)				X												X	X			X		X	X	X				
	8. Sustain trophic structure																		X	X	X	X				X			
Chemical and nutrient functions	9. Nutrient cycling		X														X						X	X			X	X	
	10. Chemical regulation																							X					X

* Criteria: Capital letters indicate that attribute meets criterion. Small letters indicate that attribute may only meet criterion in special circumstances or within limited context.

- D – Direct measure – attribute assessed is relevant to anticipated impacts and to proposed restoration objectives for mitigation
- Q – Quantifiable – attribute is measurable, can be repeated consistently by different people with same results, and with minimal observer bias and sampling error
- S – Sensitive – attribute is responsive to both impacts and mitigation/restoration actions; response can be correlated to actions, and can indicate a defensible trend within a practical timeframe (5-10 years) using available technology and tools

- P – Practicable – attribute can be measured within a regulatory context given budget, effort, and time considerations.

Table 3: **Attribute definitions and intent**

ATTRIBUTE	DEFINITION and INTENT
Overbank Flow Duration	*Definition:* Flow elevation in excess of bankfull in a stream channel. Duration may be defined by a specific event (e.g. days of inundation at a 10 yr event) or defined by a time period (days of inundation per water year) (Poff et al. 1997) *Intent:* At a patch scale evidence of overbank flow may be all that is necessary, however duration estimates at the reach and valley scale indicate the degree of interaction between the floodplain and the channel, providing evidence to the level of function.
Base Flow	*Definition:* The volume of flow in a stream channel derived solely from groundwater. At a basic level determines whether a stream is Perennial, Intermittent, or Ephemeral *Intent:* The base flow of a stream is an important measure of the role the stream plays in the watershed. Ephemeral streams affect a different suite of functions within the fluvial network than Perennial streams. Without this understanding, permitted impacts cannot be fully understood or mitigated. At a patch scale, evaluation may focus simply on the label of Perennial, Intermittent, or Ephemeral. As the spatial scale is increased, quantification of the proportion of base flow to runoff with seasonal variations should be accounted for.
Hyporheic Flow	*Definition:* Flow occurring below the bed elevation of the stream, derived from water present upstream in the channel *Intent:* The hyporheic zone is a critical area within the channel for numerous functions including the regulation of water quality (Fernald et al 2006) , refuge and habitat for benthic species, and water temperature regulation (Burkholder et al 2008).
Groundwater Flux	*Definition:* The elevation of the piezometric surface in relation to the elevation of the surface water. By comparing the two, areas of groundwater discharge and recharge can be identified along a stream length. *Intent:* Groundwater exchange is an important regulating feature in the fluvial system and highly susceptible to anthropogenic impacts (Hancock, 2002) Studies also suggest that benthic productivity can be significantly influenced by the presence of groundwater recharge and discharge areas in a stream (Hunt et al 2006).
Water Temperature	*Definition:* The *average and range* in temperature of active flow in a stream channel, accounting for horizontal, vertical, diel and seasonal differences within the channel *Intent:* Water temperature is a simple indicator in the stream system (Poole and Berman, 2001) of groundwater inputs, riparian shading, dissolved oxygen potential, and upstream manipulations (dams). Streams with extreme temperature ranges behave differently than those with well regulated thermal regimes. Specific thermal thresholds for salmonids (Richter and Kolmes, 2005) do exist.
Bankfull Flow Frequency	*Definition:* The frequency during a time period of interest, maximum discharge in response to a runoff event meets but *does not* exceed the top of bank of the channel. *Intent:* Bankfull flow frequency is an indicator of stability in the channel system. Too frequent occurrences of bankfull flow indicate the potential for channel area to increase. Too few indicate the channel may be in an aggradational phase. Caution must be exercised in choosing an approach to calculating bankfull flow, as indicated in Navratil et al., 2006.
Bankfull Flow Duration	*Definition:* The time period bankfull discharge is maintained but *not* exceeded. Bankfull discharge values are often bracketed within a tight range to account for minor variations in bankfull flow estimates. *Intent:* Along with frequency, duration of bankfull flow plays a role in the level of disturbance visited upon physical and biotic components of the bankfull channel. The disturbance regime of a flashy stream at bankfull Q vs. one with a more classic hydrograph under less disturbed conditions is considerably different.
Floodplain Deposition	*Definition:* The accumulation on the floodplain of material from overbank flow, sediment and organic material *Intent:* Floodplain deposition is a valid indicator of natural channel maintenance processes and an important feedback mechanism for nutrient transfer.
Changes in Bed Elevation	*Definition:* Heterogeneity in elevation along both the channel cross section and the longitudinal axis. Also the overall bed slope of a reach. *Intent:* Elevation changes are indicative of channel bed forms and induce hydraulic variability that maintains the dynamic nature of the channel. Overall bed elevation change dictates stream power and is informative of flow and sediment transport.
Active Channel Bars	*Definition:* Bar types include point bars, alternate bars, channel junction bars, transverse bars (riffles), and mid channel bars. (Knighton 1998). Bar formation may be event based and it is not uncommon to find evidence of bars that shift annually along side those that shift on decadal cycles. *Intent:* Bars are indicative of active sediment transport, and provide necessary media for early successional plant growth. Their presence or absence is indicative of level of channel function.

ATTRIBUTE	DEFINITION and INTENT
Active Channel Banks	*Definition:* Stream banks exhibit evidence of eroding, advancing, or stable conditions at rates consistent with natural channel process and in the absence of anthropogenic controls on this process. *Intent:* Stream banks provide sediment supply and allow natural rates of meander migration to occur within the channel through a process of bank retreat and advancement over time. In some systems this process is accelerated in response to changing watershed conditions or the natural process has been retarded by anthropogenic controls (rip rap or concrete) applied at the channel – bank interface
Sediment Character and Complexity	*Definition:* The type (e.g. silt, clay, sand, gravel, cobble, and boulder) and relative abundance of each grain size included in a representative sample of the bed material. *Intent:* Sediment heterogeneity provides numerous microhabitat opportunities. Differential sorting of sediments by the channel provide near bed roughness that influences boundary layer hydraulics.
Bed Mobility Frequency	*Definition:* Number of times the median grain size of the bed material is mobilized in a time period of interest. *Intent:* Bed mobility is a key disturbance mechanism in the fluvial system. The frequency of bed mobilization provides information on the level of disturbance and sediment transport within the channel. If bed mobility is too frequent or too infrequent the dynamics of both the physical and biological system are affected.
Hydraulic Variability	*Definition:* Relative abundance of laminar and turbulent flow, sub critical and supercritical flow, and the range of bed roughness elements along a channel length *Intent:* Hydraulic variability is evidenced by differential erosion and deposition in the channel and is largely responsible for the maintenance and formation of habitat features. Impacted systems tend to exhibit very low variability, often in response to channelization measures or the removal of LWD.
Large Wood Frequency	*Definition:* Number of pieces of large wood within a given length of channel. Large wood is generally characterized as >10 cm diameter and >100 cm length *Intent:* LW induces hydraulic variability, provides flow refuge, CPOM, and has been a well documented feature of healthy streams with wooded riparian areas.
Channel and Floodplain Habitat Complexity	*Definition:* Development of unique structural characteristics within the channel and floodplain in both the vertical and horizontal planes typically occupied by species specifically adapted to utilize their individual features. *Intent:* In a healthy system, the number of species is directly related to the number of different types of habitat that the channel and floodplain sustain. In documenting this complexity, the function of the channel and associated floodplain can be determined.
Benthic Invertebrate Community Structure and Composition	*Definition:* Structure: The organization of feeding guilds (i.e. shredders, grazers, predators, filterers etc.) Composition: The relative abundance of species or families in each feeding guild *Intent:* Benthic invertebrates are a well documented component in determining stream function at a variety of scales. A number of B-IBIs have been developed and tested, and though shortcomings in this approach persist, the diversity of the community coupled with their specific requirements for feeding and habitat continues to provide a sound understanding of stream health.
Fish Population Structure and Composition	*Definition:* Structure: The organization of feeding guilds (i.e. piscivores, planktivores, insectivores, herbivores, etc.) Composition: The relative abundance of species in each guild *Intent:* The Fish-IBI has been an overused, though essential component in evaluating stream function. The fish community provides information on tolerance to disturbance, clues as to the complexity of habitat, and given theory mobility they can show preference for reaches of higher function along a disturbance scale.
Riparian Vegetation Community Structure and Composition	*Definition:* Structure: The vertical and horizontal organization of vegetation communities (i.e. scrub-shrub wetland, forested floodplain, emergent wetland, submerged wetland etc.) Composition: The presence and relative abundance of plant species that define the community *Intent:* The biotic community is the most visible testament to the overall health of the river system. The vegetation community provides a spatially persistent and somewhat long lived metric to evaluate the conditions of a specific location on the floodplain or at the stream margin.
Connectivity – Lateral and Longitudinal	*Definition:* The ability of organisms and material (water, sediment, organic matter) to move unhindered by anthropogenic structures parallel and perpendicular to the axis of the stream corridor with a frequency consistent with natural flood regimes. *Intent:* Stream connectivity is essential to a number of theories of energy transfer in the river system. Today's highly modified streams with levees, dams, diversions, and road crossings have been likened to a "death of 1000 cuts" for river health. Channel evolution, particularly incision, has made many channels disconnected from their floodplains.

ATTRIBUTE	DEFINITION and INTENT
Riparian Buffer Width and Composition	*Definition:* Length measured perpendicular to flow, between the wetted edge of the channel and the point at which natural vegetation ceases. In the case of unnatural riparian conditions, descriptions of the landuse within a predetermined distance (30m, 100m etc) is essential. *Intent:* In addition to providing habitat for riparian fauna, an intact buffer acts as a filter for water and other material entering the stream from the adjacent watershed. A study on the proper lateral and longitudinal area for buffer evaluation indicated that 30m laterally and 300m longitudinally (assumed upstream) from a point of study were spatially relevant to predicting changes in biotic structure at that location (Frimpong et al 2005).
Habitat Sustainability	*Definition:* The probability of persistence through time of the habitat that maintains a native stream community *Intent:* the dynamic nature of stream systems maintains a consistent regime of disturbance, fostering and maintaining varied habitats. If these processes of disturbance are altered, the resulting driver sustaining various habitats is also altered. A number of stressors act upon lotic communities causing complex reactions. Evaluating such stressors and their potential to impact long term viability of the community is difficult.
Macrophyte/Periphyton Structure and Composition	*Definition:* <u>Structure</u>: The spatial organization of macrophytes and periphyton within the stream environ <u>Composition</u>: The presence and relative abundance of species that define the community *Intent:* Macrophytes and periphyton are showing the most promise in current research associated with determining river health (Finlay et al 2002). The community is sensitive to nutrient changes, as well as physical disturbance from floods. A number of indices have been developed relating disturbance to macrophyte and periphyton community characteristics.
Trophic Level Balance and Composition	*Definition:* The structure of organisms within various trophic levels of the lotic community. This structure should maintain balanced relationships between predator and prey and other trophic levels, as an indicator of the function of energy cycling in the system. *Intent:* The trophic assemblage provides an indicator of the energy flow function through the system. Recent studies have indicated that nutrient enrichment can have an impact on trophic relationships (Davis et al 2010).
Leaf Litter Decomposition Rate	*Definition*: The time required in the stream environ to effectively break down leaf litter mass by both microbes and macroinvertebrates. *Intent:* The speed with which organic matter is broken down is a direct measure of the rate of energy transfer in the stream. Much of the primary productivity in the stream is fostered by allocthanous inputs from riparian vegetation.
N, P Concentration	*Definition:* The concentration of Total Dissolved Nitrogen and Total Dissolved Phosphorous in the flow. These values are extremely dependant on seasonal and flow variations as well as sorption to fine sediment. Results are typically expressed in mass / volume. *Intent:* Nutrient cycling in the river system controls much of the primary productivity and thus has major implications for food webs. Levels of N or P inputs beyond natural levels or seasonal fluctuations have profound impacts on energy consumption and transfer. In most waters, phosphorous acts as the more limiting nutrient.
Dissolved Oxygen	*Definition:* Average (accounting for diel changes) concentration of oxygen in water expressed in units of mass/volume or as percent of saturation. DO can vary with water temperature and pressure between streams. *Intent:* Essential to all aerobic life in the stream system, the maintenance of an appropriate range of DO both daily and seasonally is a sound indicator of the chemical regulation function.

Table 4: **Attribute assessment methods and GAP identification**

Attribute	Spatial Scale	Assessment Level	Assessment Method	Notes
Overbank flow duration	Patch	Qualitative	BPJ	Experienced observers can use debris lines, water inundation marks, presence of algal mats, vegetation patterns of stand age and composition, floodplain scour or deposition patterns to infer at a basic level whether overbank inundation is PRESENT or ABSENT at a site.
	Reach	Categorical	1,2,3	Building upon qualitative observations, an analysis of floodplain soils for redoximorphic features provide useful information into the relative duration of overbank flows in a Reach. An estimate of bankfull flow using slope-area or critical depth calculations coupled with USGS regression equations can provide statistical evidence for the frequency of inundation. The resulting effort should provide evidence as to whether overbank flow is occurring for HOURS, DAYS, WEEKS or is NON-EXISTENT
	Segment	Quantitative	TBD	Building upon qualitative and categorical methods, a detailed modeling effort should be instituted at the Segment scale to provide accurate information for expected overbank flow duration. Efforts would require the development of rainfall runoff relationships, hydrographs, and flow routing coupled with detailed survey data. Methods for this level of analysis exist and are commonly employed among the professional community.
Base flow	Patch	Qualitative	BPJ, 1	Experienced observers can use local knowledge of the area, published maps and data, as well as field indicators to indicate whether base flow is PERENNIAL, INTERMITTENT, or EPHEMERAL.
	Reach	Categorical	**GAP,** 4	Rapid assessment means must be developed that allow a site not only to be characterized as Perennial, Intermittent, or Ephemeral, but also for the relative magnitude of base flow with respect to overall stream discharge patterns to be assessed. An approach has been undertaken in WA and might be implemented here (reference 4)
	Segment	Quantitative	TBD	Base flow at the Segment scale will likely encompass the deployment of stream gages as well as hydrogeologic models to properly assess the dynamic details of baseflow over a minimum of a single water year. Methods for such a detailed approach exist and are commonly employed.

Attribute	Spatial Scale	Assessment Level	Assessment Method	Notes
Hyporheic Flow	Patch	Qualitative	BPJ	Experienced observers can use field indicators such as below bed water temperature, presence/absence of macroinvertabrates below the bed, or DO readings below the bed to indicate PRESENCE or ABSENCE of hyporheic flow within a Patch.
	Reach	Categorical	5	Hyporheic flow can be documented within a Reach using simple bed temperature probes and conductivity meters, to separate groundwater seepage from hyporheic flow. A GAP exists in quantifying data into a categorical definition of this attribute
	Segment	Quantitative	TBD, 5	A map of hyporheic flow along with groundwater discharge / recharge areas for permitted stream impacts at the Segment scale will be necessary. Piezometers, Aerial thermal imaging, and continuous temperature or conductivity meters can be used to adequately explain and map these features at this spatial scale.
Groundwater Flux	Patch	Qualitative	**GAP**	GAP - Localized hydrogeologic maps will have to be developed to allow quick assessment of groundwater flux in a stream at a qualitative level. Temperature and ecological indicators can be used to document the presence of groundwater *discharge* into a stream, but *recharge* zones cannot be identified easily using these techniques.
	Reach	Categorical	5,6	Mapping bed temperature and conductivity readings in a stream can help discern between hyporheic flow and groundwater seeps. Piezometers are somewhat more labor intensive, but can provide information about water table elevation in relation to surface water elevation. Reaches should be categorized as GAINING, LOSING, or VARIABLE.
	Segment	Quantitative	TBD, 5,6	For detailed mapping at the Segment scale, seepage meters can be employed to measure specific rates of groundwater flux in the stream and when coupled with Reach level techniques can provide a map with quantified volumes of groundwater discharge and recharge.
Temperature (water)	Patch	Qualitative	BPJ	At the Patch level, defining a stream as COLD WATER, COOL WATER, WARM WATER, is likely enough to describe this attribute. Most resource agencies at the state level have existing protocols in place to determine this quickly with limited data collection requirements.

Attribute	Spatial Scale	Assessment Level	Assessment Method	Notes
	Reach	Categorical	TBD, 8,9, 10	The thermal regime at the Reach scale should be investigated more thoroughly, following a qualitative designation of COLD COOL or WARM Water. Inexpensive temperature loggers can be used to document diel variations in average stream temperature. Spatial variation can be documented as well, simply by using a thermometer to construct a map of bed, mid column, and surface water temperatures within the Reach of interest. Including a shade component into the data collection would be useful in describing the impact of riparian cover, particularly in streams with relatively narrow wetted widths.
	Segment	Quantitative	TBD, 7, 8, 10	Thermal Infrared Imagery provides a useful method for quantifying a number of stream variables. Numerous data gathering events may be required for impacts at the Segment scale to document seasonal trends, particularly during periods where species (salmon) are at greatest risk from thermal dynamics.
Bankfull flow frequency	Patch	Qualitative	BPJ, 33	Observations related to vegetation patterns, sediment deposition patterns, and bank erosion should be able to indicate at a qualitative level whether bankfull frequency is BELOW, AT, or ABOVE NORMAL at a Patch level. Defining NORMAL frequency may require some effort as will a quasi-standardized suite of bankfull indicators
	Reach	Categorical	2, 11, 26, 33	Quantifying bankfull discharge can be done in the field using the slope - area method or critical depth method to back calculate discharge. The bankfull elevation can be determined using field indicators and subsequent survey to provide a flow area. Recurrence interval for the calculated discharge can be roughly defined from existing gage data, gage transfer methods, or USGS regression equations.
	Segment	Quantitative	TBD, 2, 11, 26	Quantitative methods for defining specific frequency of bankfull events during a period of interest will likely rely on modeling in the absence of sufficient gage data. Utilizing field data methods to ascertain a bankfull discharge, hydrologic models based on rainfall records can be developed to document the historic frequency of bankfull events at a particular location providing a sound basis for assessment.
Bankfull flow duration	Patch	Qualitative	BPJ	Watershed characteristics based on land use and percent impervious cover may provide a basis for ascribing a value of FLASHY or NON-FLASHY to this attribute.

Attribute	Spatial Scale	Assessment Level	Assessment Method	Notes
	Reach	Categorical	**GAP**	In the absence of site-specific gage data, or existing flow duration curves a method and level of effort consistent with a categorical description appears to be lacking.
	Segment	Quantitative	TBD	Flow duration curves can be developed using field data and modeling techniques. In addition, synthetic hydrographs and flood routing procedures can be used to predict the duration of bankfull flow.
Floodplain deposition	Patch	Qualitative	BPJ	Deposition of fine sediment or organic material is an easily quantified attribute. A PRESENCE / ABSENCE value should be used.
	Reach	Categorical	**GAP**	A categorical approach is not evident here, consistent with a medium level of effort. However, noting deposition types (sediment, organic material) and relative areas seems a reasonable start in documenting floodplain function.
	Segment	Quantitative	TBD	Mapping the deposition and sorting patterns of fines and OM along with depth and approximate frequency of deposition would represent a quantitative approach to defining this attribute. Methods for this approach are standard among the geomorphic community, though a specific suite of methods should be tailored to the unique characteristics of the site.
Change in bed elevation	Patch	Qualitative	BPJ	Bed elevation changes can be easily assessed by flow and depth characteristics in a stream and the counting of pools - riffle sequences at the Patch scale. A LOW, MEDIUM, HIGH value can likely be placed on area with respect to either overall slope or ranges of elevations at the Patch scale.
	Reach	Categorical	27	A categorical determination that documents pools, riffles, and glides and the frequency of each would provide a good surrogate of the level of bed elevation change
	Segment	Quantitative	TBD, 26	A topographic survey of the long profile of the segment, coupled with representative cross sections of the channel and adjacent floodplain provide a quantitative basis for this attribute. Simple surveying techniques can be utilized and profiles can be plotted to indicate elevation ranges, overall slopes, max and min bed slope at the microhabitat scale, numbers of pools, riffles, runs etc.
Active channel bars	Patch	Qualitative	BPJ	Channel bars are well-defined features within the channel. At the Patch scale, simply acknowledging bar development as either PRESENT or ABSENT may be sufficient
	Reach	Categorical	**GAP**	A categorical description of bar types and their relative function in the landscape does not appear to be available

Attribute	Spatial Scale	Assessment Level	Assessment Method	Notes
	Segment	Quantitative	TBD	A detailed accounting of channel bars within the Segment scale should include information about the specific type of bar, flow conditions under which they form, and their role in the channel processes of the Segment. This type of analysis is common geomorphic investigation and may require minor hydrologic modeling to define flood magnitudes responsible for forming and maintaining these features.
Active channel banks	Patch	Qualitative	BPJ	Channel banks can be defined as ACTIVE or INACTIVE at the Patch scale by simply defining the resistance of bank materials. Most natural streambank materials allow deformation of the bank over time. This process can be retarded by the presence of armoring materials (such as rip rap or concrete) along the channel margin.
	Reach	Categorical	13	Active banks are part of a healthy stream system. Most methods of assessing bank stability assume that instability or erosion is negative metric. Reference #13 does a good job of assessing bank stability, but a poor job of placing the level of erosion into categories of BELOW, AT or ABOVE NORMAL.
	Segment	Quantitative	TBD, 12	At the Segment scale, the opportunity for active banks to exist should also be quantified with relative rates of bank migration. Historic aerial photos, tree ring cores, and bank pins can help ascertain rates of erosion. Volume estimates of erosion and deposition can begin to quantify whether this process is in balance or skewed. All of these methods are readily available and will result in the development of rates of bank building or retreat.
Sediment character and complexity	Patch	Qualitative	BPJ	Simple descriptions and estimated percentages of bed material (e.g.. cobble, gravel, sand, silt) are useful here. These must be considered in the context of what unimpacted bed lithology should be in order to qualitatively determine the level of function.
	Reach	Categorical	27	This level of assessment consists of pebble counts for coarse bed streams, measures of embeddedness, sketches of bed sediment patterns in the reach. Most of these methods are available from a variety of state and federal guidelines for stream assessment. A few of the many are referenced here.

Attribute	Spatial Scale	Assessment Level	Assessment Method	Notes
	Segment	Quantitative	TBD, 14,15	Detailed analysis of samples representing various gradations found within the stream reach to quantify gradation, specific weight and porosity will be required. Samples at depth within the bed and adjacent bars may also be sued to consider the extent of hyporheic flow. Mapping of bed sediment, numerous measures of embeddedness, and some investigation into upstream sources would constitute a comprehensive approach to defining this attribute. All of these methods are well defined but in particular embeddedness has numerous methodologies and may require appropriate justification of a choice based upon the site to be evaluated.
Bed mobility frequency	Patch	Qualitative	BPJ	Patch scale bed mobility assessment is aimed at describing channel features that may be negatively impacting bed mobility. Structures such as dams, bridges, weirs, and road crossings can have substantial impacts on sediment continuity. If these structures are present, bed mobility function is likely compromised. Evidence of channel incision can also indicate at a qualitative level that function has been compromised. Together these two observations, and likely others not listed here, can provide a qualitative summary of bed mobility that results in a BELOW, AT, or ABOVE NORMAL determination.
	Reach	Categorical	26, 27, 28, 34	A pebble count coupled with a cross section and simple at-a-station hydraulic analysis can provide information into reach scale frequency of bed mobility.
	Segment	Quantitative	TBD	Sediment transport is beset by nuance. Yet threshold methods based upon a hypothesis of equal mobility (once the d50 is mobile the entire bed is mobile) should present a reasonable pathway to evaluate through simple models the frequency of bed mobility. This effort would have to be coupled with other hydrologic investigations, as mentioned in previous attributes. 1-D modeling can provide estimates at a cross section of shear stress and sediment transport functions can be chosen to describe a critical shear the exceedence of which induces bed mobility.
Hydraulic variability	Patch	Qualitative	BPJ	Hydraulic variability can be qualitatively noted by the presence of varying depths and velocities of flow and various roughness elements in the channel at the patch level. This determination is somewhat flow dependant, but even at base flow, bed structure should be identifiable that will provide different hydraulic features in the channel at higher flows.

Attribute	Spatial Scale	Assessment Level	Assessment Method	Notes
	Reach	Categorical	27	Documenting pools, riffles, and surveying a long profile of a stream coupled with simple observations of flow and roughness characteristics can provide a more comprehensive assessment of hydraulic variability at the Reach scale.
	Segment	Quantitative	TBD	A 1-D (HEC-RAS) or 2-D hydraulic model coupled with observations at various flow events will be able to quantify specific areas where flow becomes super critical or subcritical, where velocities increase at a local scale to scour the bed, and where bed forms and roughness provide evidence of near bed turbulence and boundary layer refugia. Data inputs for such an effort would require cross section or perhaps topographic survey data and flood magnitude.
Large wood frequency and recruitment	Patch	Qualitative	BPJ	The presence of large wood as defined is easily observable at the patch scale and should result in either a PRESENCE / ABSENCE determination or a qualitative estimate of density of in-stream and standing stock wood.
	Reach	Categorical	28	Counting individual pieces and jams can provide a semi-quantifiable estimate of density at a reach scale. Providing estimates of stand age or proximity of mature trees to the channel margin can provide an estimate of potential recruitment. Stand age is lacking from the referenced method (ref 28)
	Segment	Quantitative	**GAP**	In addition to quantifying not only the number of jams or pieces of wood in a reach, estimates of the rate of historic input as well as extrapolations into whether future inputs will be sustainable. Quantifying the function of logs in the channel with respect to the impact they have on the bed or banks would be useful from a habitat perspective. Maximum depth of local scour, position in the stream column (submerged, partially exposed, fully exposed). Methods are not readily available for this approach, but components do exist in a few methods.
Channel and Floodplain Habitat Complexity	Patch	Qualitative	22	A number of categorical protocols exist at this level of effort and scale. The QHEI and variations thereof have been able to qualitatively explain levels of complexity at a reach scale. A sampling of Federal and OR specific protocols have been referenced here, but many more exist in the review by Somerville 2010.
	Reach	Categorical	22,28,30	EMAP and ODFW protocols provide a more quantified approach to detailing habitat complexity. Habitat units are delineated in a stream and surveyed.

Attribute	Spatial Scale	Assessment Level	Assessment Method	Notes
	Segment	Quantitative	TBD	Instream flow and habitat models must be used at the segment scale to properly quantify habitat. These models allow dynamic interpretation at various flood magnitudes and allow an extrapolation of field data, note however, these observations are typically collected at less than flood flows. PHABSIM is a commonly referenced model, though species-specific approaches have been developed using 2D hydraulic models which provide high resolution data as well.
Benthic Invertebrate community Structure and Composition	Patch	Qualitative	BPJ, 23	A patch level assessment will have to rely on simple presence / absence and perhaps feeding guild or order level identification and relative abundance from a kick sample or based on a timed site investigation. A GOOD, FAIR, POOR rating should be appropriate
	Reach	Categorical	23,24,31	Macroinvertebrate-IBI fits into this category and regional approaches are well established to draw upon. Metrics should be structured to inform function to the extent possible, though structural characteristics are often good indicators of function with this particular approach.
	Segment	Quantitative	**GAP**	IBI sampling methods can be useful at this level of assessment as well, however, a more detailed picture of the specific components of the benthic community and their specific habitat requirements should be assembled as well as information about trends to the extent possible as impacts at this scale have a high probability of impacting functional rates at a large scale.
Fish Community Structure and Composition	Patch	Qualitative	BPJ, 23	Sampling at this scale will be confined to a presence / absence assessment in the field and a search for known T&E species that might occupy the small area. A GOOD, FAIR, POOR rating can be expected here.
	Reach	Categorical	23,31, 32	Fish-IBI is appropriate here and well documented for use in a number of regions

Attribute	Spatial Scale	Assessment Level	Assessment Method	Notes
	Segment	Quantitative	**GAP**	IBI methods are appropriate at this level, but specific study at the species level should be included. Defining various habitat needs based upon life stages of species present, as well as gaining an understanding of the locale of necessary seasonal habitat (spawning, overwintering, rearing etc) that may exist beyond the Segment scale should be done. An age structure of the community should be done to document reproductive rates, and some understanding of food consumption and availability will ensure the link between trophic levels is understood. Specific approaches to this assessment will be highly variable based on regional stream differences and will require some forethought to substantiate an approach.
Riparian Vegetation Community structure and Composition	Patch	Qualitative	BPJ	Trained observers can make sound observations on the community relevant at the patch scale. Observations should be geared toward a qualitative description of the community, successional characteristics, presence of native and non-native species and species composition of both the woody and herbaceous community. The resulting output should be a GOOD, FAIR, POOR rating
	Reach	Categorical	28,31, 35	By definition a floodplain is a seasonally inundated area, thereby classifying it as a wetland. Wetland indices tend to center around the Hydrogeomorphic Method (HGM) developed specifically for wetland types (riverine wetlands are commonly included). The methods are developed for specific regions and specific wetlands types. An assessment has been developed for Oregon. An HGM application has also been developed for West Virginia headwaters streams
	Segment	Quantitative	**GAP**	Quantifying function at the Segment scale involves the use of metrics similar to the Reach scale assessment but with a greater emphasis on describing the entire community and the links to physical habitat or nutrients. Taking each woody species and constructing an age structure of the community, defining species density according appropriate habitat area, and documenting the process of succession would be just a few of the aspects beyond the IBI approach that get more at riparian function and thus rate, and should be investigated at the Segment scale. Specific guidance and metrics for this level of assessment are beyond the scale of existing methods, but likely exist within the research community and would require some effort to develop, likely on a case-by-case basis

Attribute	Spatial Scale	Assessment Level	Assessment Method	Notes
Macrophyte/Periphyton community structure and composition	Patch	Qualitative	BPJ, 25	Given relatively clear water conditions in a stream, macrophytes and periphyton can be easily observed. Much like patch level assessments for vegetation and macroinvertabrates, this approach will focus on the presence / absence of easily identified species and the relative abundance of those species. In addition to overall abundance of periphyton and macrophytes can provide clues as to the
	Reach	Categorical	16, 23, 25	Periphyton IBIs have been developed and would apply here for characterizing the community at the reach scale
	Segment	Quantitative	16, 25 **GAP**	IBI methods are appropriate but additional assessment should be done to delineate limiting factors for periphyton (DO, nutrients, substrate availability etc) and maps of periphyton distribution should be constructed to understand additional relationships that might exist with areas of groundwater recharge or discharge or hyporheic flow outlets. These methods are not readily available, but likely can be constructed from ongoing academic research in this arena.
Connectivity – lateral and longitudinal	Patch	Qualitative	**GAP**	Longitudinal connectivity transcends scale. The distance upstream and downstream to major barriers to both sediment and organisms should be delineated. This metric must be scaled at some spatial scale to identify streams that are well connected or bisected by numerous barriers, which would therein provide a metric for longitudinal connectivity. Horizontal connectivity should be discerned in the field, likely at the Reach scale, although with Patch scale techniques. The presence or absence of levees on either side, floodplain debris or water lines etc can provide clues as to the whether the channel is occupying its floodplain and whether water on the floodplain can spread out without lateral constraints. Suggested designations made *separately* for lateral and longitudinal connectivity are HIGHLY, SLIGHTLY, or UN - MODIFIED.
	Reach	Categorical	TBD	Reach scale efforts should mimic those at the Patch scale but with a more in depth analysis for lateral connection. Surveyed cross sections should be obtained to evaluate rough elevations and boundaries of flooding at a series of index floods. These sections should be taken at numerous points through the Reach to assess whether connectivity is consistent or if there appear to be natural or unnatural constrictions in place. This effort uses similar methods as Bankfull Frequency and Overbank Flow Duration.

Attribute	Spatial Scale	Assessment Level	Assessment Method	Notes
	Segment	Quantitative	TBD	Modeling at the Segment scale is the best approach to define both lateral and longitudinal connections. 1-D hydraulic models such as HEC-RAS can provide information on the extent of lateral inundation and the extent of backwater longitudinal from road crossings or dams. These methods are commonly employed in floodplain mapping efforts by FEMA.
Riparian buffer width and composition	Patch	Qualitative	BPJ, 28	Buffer width is easily discernable in the field though it transcends the scales of observation listed here. A standard width should be delineated for observation and the distance of natural vegetation within that width, measured. The balance of the area of observation should be characterized by the landuse type, i.e. roads, agriculture, residential; providing a clear picture of landscape scale composition. Riparian buffers have an impact well upstream of a particular area of interest on a stream, be it a Patch, Reach, or Segment. A distance beyond the upstream end of channel study should be delineated to observe riparian buffer characteristics and width. This method should be applied equally at all 3 scales of observation. With the preponderance of GIS The effort required to obtain meaningful results is minimal.
	Reach	Categorical		
	Segment	Quantitative		
Habitat sustainability	Patch	Qualitative	17	This attribute transcends the Patch, Reach, and Segment scale. Sustainability is threatened by changes in processes that govern the healthy lotic environ. Given a suite of potential impacts (as documented in reference 17) what is the probability that these will in fact be manifested and have an impact within an area of study. For example, hydrologic alteration is one of the main threats to lotic habitats. Hydrologic alteration is closely tied to development, either urban, suburban, or agricultural. If an objective assessment of this risk can be made at a site, then the potential for sustainability can be qualitatively estimated. If additional parameters are assessed (siltation, riparian alteration) the net sum is a metric that defines the probability that habitat may remain relatively intact through time.
	Reach	Categorical		
	Segment	Quantitative		
Trophic Level Balance and Composition	Patch	Qualitative	**GAP**	Methods for this assessment at the Patch scale are unknown. Consider however that Patch scale impacts may not influence performance of this function, unless significant inputs to the stream (such as a point discharge) are expected.

Attribute	Spatial Scale	Assessment Level	Assessment Method	Notes
	Reach	Categorical	TBD	Analysis at the Reach and Segment scale can likely follow similar sampling methods for macrophytes, fish, and macroinvertabrates assemblages detailed within those attributes. The analysis of that data however presents a challenge in defining what is "natural' in terms of the trophic structure of the stream and will likely rely on the development of some reference condition. The data for this exercise should be available, as most regions have IBI type sampling programs in place, it will simply require a different analysis of this information.
	Segment	Quantitative		
Leaf Litter breakdown Rate	Patch	Qualitative	18,19	Methods to measure leaf-litter breakdown are the same across spatial scales. The only change is that the number of observations should be equal to the spatial scale of the proposed action (Patch<Reach<Segment). A simple approach is detailed in the reference. As with other assessments, efforts will have to focus on a reference or average condition with which to compare results.
	Reach	Categorical		
	Segment	Quantitative		
N, P concentration	Patch	Qualitative	TBD, 20, 21	Nitrogen and phosphorous are taken in the field and typically analyzed in a laboratory setting. Concentrations of both vary seasonally and with flow events. For assessment at the Patch, Reach and Segment scales, two approaches are valid, though the number and frequency of samples should be scaled accordingly. First, grab samples can be taken and compared to reference conditions in similar watersheds to define nutrient loading. Modeling of N and P concentrations based on watershed conditions has been performed and may represent a means to define reference conditions for a wide range of areas (ref 21). A second approach is to artificially load the stream to attempt to reveal nutrient uptake lengths (ref 20). The latter gets more at the rate of nutrient process and thus is a more direct measure of function. Approaches for the first method are well documented, a reference is provided from a study that used method
	Reach	Categorical		
	Segment	Quantitative		

Attribute	Spatial Scale	Assessment Level	Assessment Method	Notes
Dissolved Oxygen	Patch	Qualitative	BPJ	Dissolved oxygen is easily measured with modern meters. Measurements should focus on DO at the bed, mid column, and surface across the channel cross section. For Reach and Segment scale studies, oxygen profile density should be increased to properly delineate Patch scale trends, particularly with regard to groundwater influx of oxygen poor water. All measurements should be made at two times during the day if not continuously, to account for diurnal fluctuations.
	Reach	Categorical		
	Segment	Quantitative		

REFERENCED METHODS

BPJ — Best Professional Judgment - indicated methods or approaches are well known and applied frequently by practitioners. The need for formal documentation here is not justified

GAP — Indicates methods do not appear to exist that readily assess the attribute at the level of effort required

TBD — To Be Determined - Indicates methods readily exist to quantify the attribute but a FORMAL PROTOCOL does not appear to exist.

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Attribute	Spatial Scale	Assessment Level	Assessment Method	Notes
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Attribute	Spatial Scale	Assessment Level	Assessment Method	Notes
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Attribute	Spatial Scale	Assessment Level	Assessment Method	Notes
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