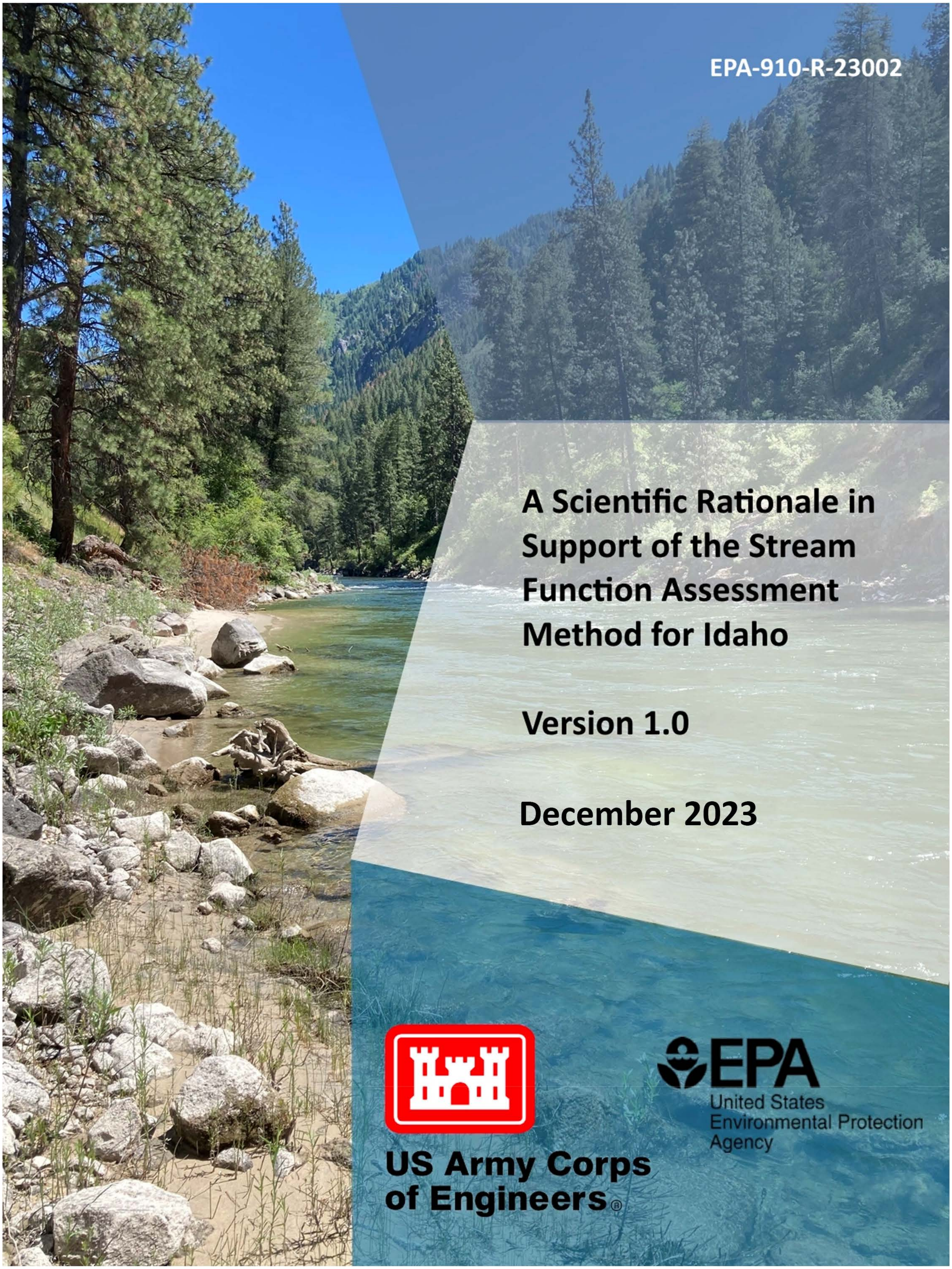

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A Scientific Rationale in Support of the Stream Function Assessment Method for Idaho

Version 1.0

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Acronyms

AEP	annual exceedance probability
BFW	bankfull width
BHR	bank height ratio
B-IBI	benthic-index of biotic integrity
CMH	create and maintain habitat
CR	chemical regulation
CV	coefficient of variation
CWA	Clean Water Act
DBH	diameter at breast height
DD.MM	degrees.minutes (to hundredths of a degree)
DRNAREA	drainage area
EAA	extended assessment area
ESU	evolutionarily significant unit
FEMA	Federal Emergency Management Agency
FV	flow variation
GIS	geographic information system
GPS	global positioning system
HUC	hydrologic unit code
IBI	index of biotic integrity
IDEQ	Idaho Department of Environmental Quality
IDFG	Idaho Department of Fish and Game
IMPNLCD01	percentage of impervious area
MB	maintain biodiversity
NARS	National Aquatic Resource Survey
NC	nutrient cycling
NFHL	National Flood Hazard Layer
NHD	National Hydrography Dataset
NOAA	National Oceanic and Atmospheric Administration
NRSA	National Rivers and Streams Assessment
PAA	proximal assessment area
SC	sediment continuity
SDAM	Streamflow Duration Assessment Method
SFAM	Stream Function Assessment Method
SM	substrate mobility
SST	sub/surface transfer
STS	sustain trophic structure
SWS	surface water storage
TMDL	Total Maximum Daily Load
ToT	time of travel

TR	thermal regulation
USACE	United States Army Corps of Engineers (Corps)
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey

1.0 Introduction

The Stream Function Assessment Method (SFAM) for Idaho has been developed to provide a standardized, rapid, more function-based method for assessing stream function statewide. It is intended to assist federal and state agencies in mitigation planning. The U.S. Army Corps of Engineers (USACE) and U.S. Environmental Protection Agency (USEPA) Final Compensatory Mitigation Rule (2008; Mitigation Rule), under Clean Water Act (CWA) Section 404, promotes the use of function assessment to determine the appropriate amount of compensatory mitigation to replace the loss of functions due to unavoidable impacts to aquatic resources. Federal policies (CWA Section 404)[1] require mitigation for impacts to waters of the U.S. This includes impacts to streams. SFAM provides a predictable, transparent, consistent, and scientifically robust approach to assessing the ecological processes affected by unavoidable impacts to streams in Idaho. While SFAM has been collaboratively developed by the agencies for mitigation application, it has broader application where a rapid function-based stream assessment could inform management, conservation, and restoration decision-making and monitoring efforts.

This Scientific Rationale, a companion to the SFAM User Manual for Idaho (Nadeua *et al*. 2023), closely follows the scientific support document developed for the initial SFAM in Oregon (Nadeau *et al*., 2020a, b). It serves as a sister document describing the modifications made to reflect Idaho-specific data sources and incorporating more recently available data and research. A scientific rationale for individual function and value measures used in Idaho is provided, including a detailed description of the standard performance index for each function measure and establishment of a standard index scale to give ecological meaning to measure scores. Together these documents provide the scientific underpinning of the method, supporting a deeper critical understanding of the method, providing transparency and avoiding "black box" calculations, facilitating the transfer and adaptation of SFAM, and promoting method improvements as new data and information become available.

Idaho's extremely varied climate, hydrology, and geology result in a broad range of streams and rivers. The Bitterroot Mountains, part of the rocky Mountain Range, dominate northern and north-central Idaho, while much of the southern and south-central Idaho belong to the arid Snake River Plain and Basin and Range Province. Elevation ranges from about 722 feet at the confluence of the Clearwater and Snake rivers to 12,660 feet at the highest peak (Jackson and Kimerling, 2003). Winter precipitation maxima and midsummer minima range from annual averages of 40-50 inches at higher elevations to less than 10 inches in the southern plains and valleys. The delivery of precipitation in the Pacific Northwest is generally greatest during the winter months, resulting in fairly distinct wet winter/spring and dry summer seasons. The dominance of seasonal winter precipitation, as rain or snow, overlays a variety of regional climates (Jackson and Kimerling, 2003).

[1] "Compensatory Mitigation for Losses of Aquatic Resources; Final Rule" Department of Defense 33 CFR Parts 325 and 332. Environmental Protection Agency 40 CFR Part 230 73(70) (10 April 2008), pp 19594-19705.

SFAM is primarily applicable to wadeable streams. The agencies are exploring scientifically-supported modifications for non-wadeable streams and large rivers, which may be addressed in future versions of the method.

2.0 Development Process

A summary overview of the ten-year SFAM development process, documenting method conception through measure development, iterative field testing and statistical method (model) analysis, the peer-review process, and measures that were considered but not included in the current method version has been previously described (Nadeau *et al*., 2020b).

In this document, we describe key aspects and basic components of SFAM, the relationship of measures to assessed functions and values, and present specific modifications and updates that were made in adapting SFAM for use in Idaho.

2.1 Components

To achieve our objectives for the federal mitigation program in Idaho in implementing the Mitigation Rule, SFAM aims to provide for a site level assessment, but also considers that site in the context of its larger watershed. To meet regulatory program needs, the method must also be science-based, yield credible results, and be relatively rapid, easy to use, repeatable and applicable across most of Idaho's streams. SFAM was developed to meet these objectives:

- **Science-based**- Integrating the best available science using ecological functions applied in a watershed context;
- **Rapid**- Two trained professional field scientists should be able to complete the field assessment at any time of year for a 1000-foot reach in one day. Total time for completing all work (including all office work, data entry and score calculations) could take two days;
- **Credible**- Sensitive to year-over-year changes within a site and to differences among sites, and repeatable, so that any two assessment teams would arrive at a similar outcome for the same site;
- **Transparent**- Where all measures, calculation formulas, etc., can be easily accessed and understood by a variety of stakeholders, not just the trained professionals applying the assessment methodology; and
- **User-friendly**- Manuals, documentation, and tools are available online and are easy to use.

SFAM is a stand-alone function assessment method, with an associated mitigation accounting protocol that calculates credits and debits using SFAM outputs. This allows SFAM to evolve independently as scientific understanding, data availability, and collection techniques advance, and promotes transparency in clearly explaining program policy decisions and their implementation through the separate mitigation accounting protocol. Furthermore, separate assessment and accounting protocols facilitate the transfer and adaptation of SFAM for use in other programs and where different mitigation policies are in place.

Direct measure of stream function is the optimal approach to evaluating function; however, such measurements present two significant challenges for use in mitigation. Direct measurement of function requires that data be collected and evaluated over longer time frames and larger spatial scales than are within the practical scope of individual permitted actions. While longer-term and intensive monitoring may enable assessment of changes in function associated with many permitted actions or mitigation actions, calculating debits and credits for regulatory purposes requires a narrower timeframe. Additionally, changes in stream function may only be detectable after some lag-time following permitted impacts or mitigation restoration, or when the combined effects of multiple projects are considered (Moreno-Mateos *et al.,* 2012; Santelmann *et al*., 2022, Sudduth *et al.,* 2011). In the current method we identify attributes that indicate function and directly measure those attributes to assess stream function within program constraints. As a result, we describe the method as "functionally based."

Function & Value as Defined in SFAM

Function - the processes that create and support a stream ecosystem

Value - the ecological and societal benefits that riverine systems provide

Recognizing the varied interpretations and contexts for which *function* has been defined (Fischenich, 2006; NRC, 2002; Sandin and Solimini, 2009), we define *function* as the processes that create and support a stream ecosystem. 'Function' is often characterized as providing societal services, such as clean water, food resources, or recreation. However, such characterizations are inherently subjective and value-based, as 'service' implies a beneficiary (e.g., humans or preferred fish species) (Palmer and Filoso, 2009). In the assessment method presented here, *values* (i.e., ecosystem services) are assessed separately from function, and are defined as the ecological and societal benefits that riverine systems provide. The definition of function used for SFAM focuses solely on ecological processes.

SFAM assesses 11 clearly defined stream functions, based in part on foundational documents (Fischenich, 2006; U.S. Environmental Protection Agency, 2012; see **Section 3.2**), and their associated values (see **Table 3.1**). Because direct measurement of stream processes is a challenge, SFAM relies on attributes which create a link to the measurable characteristics that represent a particular function and the extent to which that function is active on a given stream reach. Attributes describe specific components of that function and may connect to multiple functions. For example, overbank flow is an attribute of surface water storage and subsurface transfer. Measures are information or data that is collected to indicate the extent to which an attribute is expressed (**Figure 2.1**). The peer-reviewed and vetted list of functions and attributes provide the foundation for the 17 measures of function used in SFAM (see **Section 4.2, Table 4.1**).

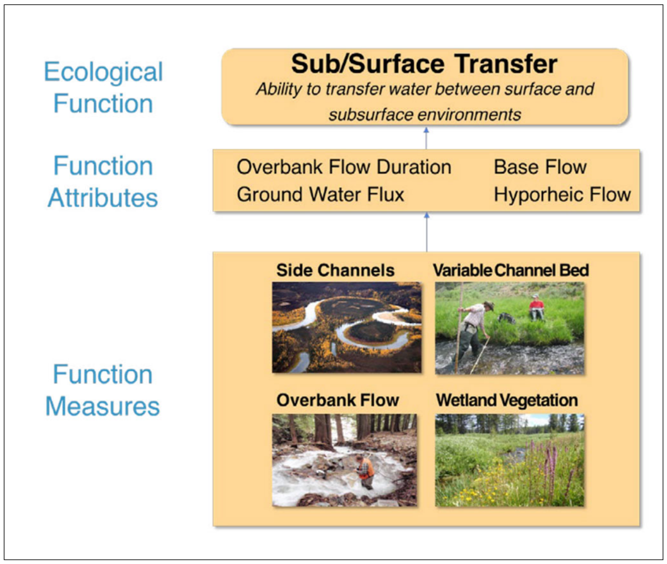


Figure 2.1. Relationship of Function Measures to Attributes of Function, Using the Sub/Surface Transfer Function as an Example

Measures of value for each SFAM function assess the opportunity to provide a particular function and the local significance of that function. The majority of these 16 measures of value are assessed in the office using existing spatial data layers, some administered by federal agencies and some by state agencies. Much of the effort to modify SFAM for use in Idaho focused on identifying appropriate Idaho-specific data layers for assessing measures of value (see **Appendix A**). To inform measures of value, existing data layers were evaluated against the following criteria:

- **Appropriate spatial extent:** The data layer provides information for the entire state.
- **Transparent/verifiable:** The data generation methods are clear and the data is gathered by an objective source using sound (replicable) scientific methods.
- **Relevant:** Data have a clear and direct connection to informing the assessment of functions and values of a stream system.
- **Reliable:** Data were generated by an organization that uses a clear quality assurance and quality control process including periodic updates.

While SFAM assesses both functions and values ('services'), as required by the CWA Section 404, the scoring for stream reach function and value are separate by design. In addition to the function and value measures, several other attributes provide context for scoring. These context factors are used in some instances to adjust subscores (outputs) based on differing functional expectations (e.g., ecoregion) and may rely on data sources specific to Idaho.

Concurrent with method modification we developed a User Manual to facilitate efficient and consistent method application. Thus, SFAM for Idaho has three components including the current document:

1. Excel Workbook
2. User Manual
3. Scientific Rationale

2.2 Standard Performance Indices for Function Measures

To provide ecological meaning to scoring the function measures included in the SFAM model, standard performance indices (range of expected performance) are needed. Such performance indices facilitate standardization of individual measure — and thus function —scores to a common scale, which is important for calculating function subscores, as the measures are used additively in the function formulas (Independent Multidisciplinary Science Team [IMST], 2007, 2009). Measure standardization also allows comparison of SFAM scores.

Because the primary sensitivity of SFAM lies in the thresholds used to score each of the function measures, we extended extensive effort in developing scientifically-based standard performance indices and thresholds (Nadeau *et al*., 2020b). These are the basis of SFAM output interpretation and allow detection of relatively small changes in function.

Context is important to interpreting many of the measures and thresholds. To assure that function measure scores are evaluated against appropriate standard performance indices where factors such as stream size or ecoregion may affect expected performance, standard performance indices of some function measures are stratified on these attributes (David *et al*., 2021; Harman *et al*., 2021), where there is data-driven support to do so. For example, when assessing the frequency of large wood in the bankfull channel, differences would be expected based upon stream width and geographic location (i.e., Western Mountains or Xeric ecoregion). This was supported in the data and literature used to develop the standard performance index for large wood, which is stratified by both stream width and geographic location of the subject stream.

The SFAM was originally developed using data and research from across the Pacific Northwest; however, modifying SFAM for use in Idaho provided an opportunity to update standard performance indices using new data and research, and to assure data-driven stratification and thresholds appropriate for Idaho. For instance, the National Rivers and Stream Assessment program, one of the collaborative National Aquatic Resource Surveys led by USEPA, released 2018 and 2019 survey data which resulted in updates to the standard performance indices for five measures of function (Natural Cover, Wood, Incision, Embeddedness, and Channel Bed Variability). A detailed development description and rationale for each SFAM measure, including standard performance index development, threshold establishment, stratification, and noting updates and revisions, is provided in **Section 4**, and forms the bulk of this document.

3.0 Ecological Functions & Values

Stream functions are the dynamic and interrelated physical, chemical and biological processes that create and maintain the character of a stream and the associated riparian system, and determine the flux of energy, materials and organisms through or within a stream system.

Functions are distinct from conditions, which are the qualities and structure of a stream ecosystem at a given point in time. A naturally functioning stream ecosystem is inherently stable and resilient to disturbance because the functions at play are generally interrelated, responsive, and unconstrained. Stream values are the ecological and societal benefits that the stream functions provide.

3.1 Thematic Groups & Specific Functions

Four functional groups provide the basis for the function-based assessment for streams:

1. Hydrologic functions: Include movement of water through the watershed and the variable transfer and storage of water among the stream channel, its floodplain, and associated alluvial aquifer.
2. Geomorphic functions: Encompass 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 at multiple scales.
3. Biologic functions: Include processes that result in maintenance and change in biodiversity, trophic structure, and habitat within the stream channel.
4. Water quality functions: Encompass processes that govern the cycling, transfer, and regulation of energy, nutrients, chemicals, and temperature in surface and groundwater, and between the stream channel and associated riparian system.

Within these broad groups, a suite of 11 stream functions were identified. The 11 functions were modified from a suite of functions identified through an expert workshop and extensive literature review, using the work of Fischenich (2006) as a foundation. Included functions were selected and defined during the original SFAM development process for Oregon (Nadeau *et al*., 2020b) and, following review, were adopted without change for SFAM for Idaho. To ensure that functions are categorized and described sufficiently for application to compensatory mitigation, criteria were developed to guide the selection and definition of functions. Stream functions were evaluated against the following criteria:

1. Relevance: function assessed is relevant to impacts resulting from proposed actions and is relevant to a broad spectrum of native species across varying stream types and spatial scales.
2. Utility: function assessed is practical for mitigation accounting because it is practically measurable and quantifiable, responsive to actions, and predictable.
3. Multi-functionality: function assessed represents the interrelated character of stream

functions and is likely to contribute to positive change in other functions and influence overall stream system health.

Table 3.1 Eleven Stream Functions

Function Group	Specific Functions/Values
Hydrologic	Surface Water Storage Sub/Surface Transfer Flow Variation
Geomorphic	Sediment Continuity Substrate Mobility
Biologic	Maintain Biodiversity Create and Maintain Habitat Sustain Trophic Structure
Water Quality	Nutrient Cycling Chemical Regulation Thermal Regulation

Although values differ from functions, the values identified through this process correspond to the same 11 categories used for functions. The difference between the functions and values lies in how they are expressed. While a function is a description of process, values are determined by (a) the opportunity to provide a particular function, and (b) the local significance of that function (Adamus, 1983). In a practical manner, a function can either be expressed or not expressed at a given site, while a value is the context of that function in the broader landscape. Assessment of values often differs between physical/chemical functions and biological functions. A higher value is often assigned to hydrologic and water quality functions when natural processes have been altered upstream, such that the given site has greater opportunity to moderate their delivery or expression downstream. In contrast, a higher value is assigned for biological functions when hydrology, geomorphology, and water quality is not impaired since the health of biota is ultimately dependent on these underlying processes.

3.2 Function & Value Definitions

a) Surface Water Storage

The surface water storage (SWS) function reflects the ability of a site to temporarily store surface water in a relatively static state, generally during high flow. This function is important for regulating discharge, replenishing soil moisture, providing pathways for fish and invertebrate movement, creating low velocity habitat and refugia, and extending the hydrologic contact time necessary for certain biogeochemical processes.

Opportunity would be higher if water from the contributing watershed is running off quickly and there are no upstream impoundments. Significance would be higher if there is infrastructure or crops downstream that are or could be damaged by flooding.

b) Sub/Surface Transfer

The sub/surface transfer (SST) function represents the ability of a site to transfer water between surface and subsurface environments, often through the hyporheic zone. This function provides aquifer recharge, maintains base-flow, allows hyporheic exchange of nutrients and chemicals, moderates in-channel flows, and maintains soil moisture.

Opportunity would be higher if the contributing watershed otherwise lacks capacity for water transfer between surface and subsurface environments. Significance would be higher if groundwater recharge is important in or near the project area.

c) Flow Variation

The flow variation (FV) function represents daily, seasonal and/or inter-annual variation in flow, which provides variability in the stream energy driving channel dynamics. Such variability provides environmental cues for life history transitions and provides temporal habitat variability. It also drives redistribution and sorting of sediment and causes differential deposition.

Opportunity would be higher if water comes into the project area during limited time frames, and upstream flow variation is low. Significance would be higher if there are species in the riparian area or downstream that are dependent on the benefits that flow variation provides and there are habitat limitations downstream. Significance would be lower if there are downstream impoundments.

d) Sediment Continuity

The sediment continuity (SC) function represents a balance between transport and deposition of sediment such that there is no net erosion (degradation) or deposition (aggradation) within the channel. Continuity of sediment maintains channel character and the associated habitat diversity, provides sediment source and storage for riparian and aquatic habitat succession, and maintains channel equilibrium.

Opportunity would be higher if sediment is not in balance upstream or upslope. This could mean that the stream reach is receiving too much sediment or not enough sediment. Significance of balanced sediment through the project area would be higher if the downstream floodplain area lacks infrastructure, the reach is not easily erodible, and there are no impoundments downstream.

e) Substrate Mobility

The substrate mobility (SM) function represents regular movement of the channel bed substrate. Movement of substrate provides sorting of sediments, mobilizes/flushes fine sediment, creates and maintains hydraulic diversity, and creates and maintains habitat.

Opportunity would be higher if there is either unsorted or uniform substrate being delivered into the project area. Sorting within the project reach would benefit downstream habitats, increasing significance, if there are habitat designations, rare species, or unique habitat features nearby dependent on certain substrate characteristics.

f) Maintain Biodiversity

The maintain biodiversity (MB) function represents the maintenance of a 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 as well as a full spectrum of trophic resources and balance of resource use (through interspecies competition).

Opportunity would be higher if a diverse array of species can access and utilize the site from surrounding habitats upstream, downstream, and adjacent to the project area. Significance would be higher if the area/surrounding area contains habitat designations, rare species, or unique habitat features.

g) Create and Maintain Habitat

The create and maintain habitat (CMH) function represents the ability of the site to provide the suite of physical, chemical, thermal, and nutritional resources necessary to sustain organisms. Habitat includes both in-channel habitat, defined largely by depth, velocity, and substrates, and riparian habitat, defined largely by vegetative structure.

Opportunity would be higher if the project area receives the suite of physical, chemical, thermal, and nutritional resources needed to sustain organisms. Significance would be higher if processes in the project area are able to reach and benefit downstream and adjacent habitats.

h) Sustain Trophic Structure

The sustain trophic structure (STS) function represents the 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, and promotes growth and reproduction of biotic communities across trophic levels.

Opportunity would be higher if the project area is connected to natural habitats. Significance would be higher if nutritional resources produced or flowing through the project area are able to reach and benefit downstream and adjacent habitats.

i) Nutrient Cycling

The nutrient cycling (NC) function represents the transfer and storage of nutrients from environment to organisms and back to environment. This function provides basic resources for primary production, regulates excess nutrients, and provides sink and source areas for nutrients.

Opportunity would be higher if waters are impaired or if conditions in the contributing basin result in increased transport of nutrients to the project area. Significance is higher if waters flow to areas used as drinking water sources or those that provide important habitat to fish, invertebrate, amphibian, and reptile species.

j) Chemical Regulation

The chemical regulation (CR) function represents the ability to moderate chemicals in the water. Moderation of chemicals limits the concentration of beneficial and detrimental chemicals in the water.

Opportunity would be higher if waters are impaired or if conditions in the contributing basin result in increased transport of chemicals to the project area. Significance is higher if waters flow to areas used as drinking water sources or those that provide important habitat to fish, wildlife, or plant species.

k) Thermal Regulation

The thermal regulation (TR) function represents the ability to moderate water temperature. It limits the transfer and storage of thermal energy to and from streamflow and the hyporheic zone.

Opportunity would be higher if the water temperature coming from upstream can be maintained through the project area. This is more likely to occur when the riparian area upstream is more natural and continuous, and the contributing watershed has less impervious surfaces. Significance is higher if there are species downstream that benefit from cooler water.

3.3 Scales of an SFAM Assessment

Each measure in SFAM is evaluated at a scale or spatial extent applicable or relevant for the particular measure being assessed. To accomplish this, SFAM establishes three assessment area extents: Project Area, Proximal Assessment Area, and Extended Assessment Area (**Figure 3.1**).

The **Project Area (PA)** is the spatial extent of the direct impact (e.g., removal, fill, grading, planting, etc.) that a project (e.g., permitted action, mitigation, restoration) will have on a stream and surrounding area. Some projects may have multiple areas of impact but are part of a singular larger project.

The **Proximal Assessment Area (PAA)** allows for assessment of functions likely to be directly impacted by actions taken in the PA. The PAA includes the entire channel, both streambanks, the riparian area, and upland adjacent to the impacted area on both sides of the stream.

The PAA has two sets of boundaries. The longitudinal boundaries are determined by the upstream and downstream extent of the PA, or 50 feet, whichever is greater. The lateral boundaries extend from the channel edge a distance of two times the bankfull width (2 × BFW) or 50 feet, whichever is greater.

The **Extended Assessment Area (EAA)** allows for assessment of functions that may be expressed at a reach scale that is broader than the footprint of the project. The EAA has the same lateral boundaries as the PAA (2 × BFW, 50 feet minimum), but the longitudinal boundaries extend a distance equal to five times BFW in each direction from the PAA. The EAA includes the entire PAA.

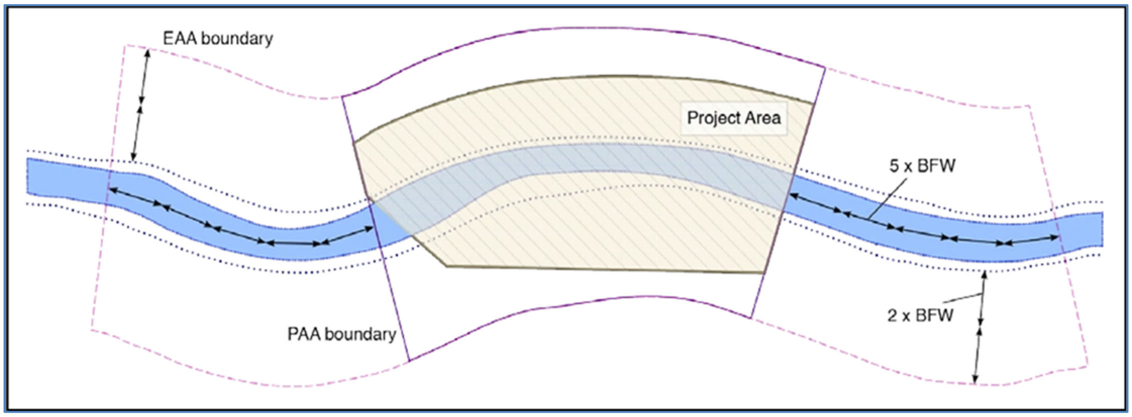


Figure 3.1. Layout of the three assessment areas in SFAM

3.4 Function & Value Scoring Formulas

Idaho and Oregon share, and are fully encompassed by, the aggregated Western Mountains and Xeric Level III Ecoregions, as delineated by the USEPA for the continental U.S. SFAM for Idaho was tested at several sites, and in a range of hydrologic landscapes, across Idaho. SFAM function and value scoring formulas have not been modified from the initial SFAM (Nadeau et al., 2020a, b) for use in Idaho. However, several standard performance indices for measures of function have been updated using recent data and research (**Section 4.2**) and Idaho-specific data are used for measures of value (**Section 4.3**).

Table 3.2 Formulas for Each of the Eleven Functions

The formula narrative provides a very brief description of the various factors that inform the overall function measure.

Function	Function Score Formula[4]	Formula Narrative
SWS	=AVERAGE(SideChan, BedVar, OBFlow, Exclusion)*6 + AVERAGE(Incision, Wood)*4	The score for this function is the weighted sum of (a) the average of the measure scores that represent the proportion of side channels, the variability of the channel bed, the existence of overbank flow, and the degree of floodplain exclusion, and (b) the average of the measure scores that represent the degree of streambank incision and the frequency of wood.
SST	=AVERAGE(BedVar, WetVeg, SideChan, OBFlow)*10	The score for this function is an average of the measure scores that represent the variability of the channel bed, the presence and distribution of wetland vegetation, the proportion of side channels, and the existence of overbank flow.
FV	=AVERAGE(BedVar, Embed, ImpoundUS)*10	The score for this function is an average of the measure scores that represent the variability of the channel bed, the degree of substrate embeddedness, and the absence of upstream impoundments.
SC	=AVERAGE(Incision, Erosion, LatMigr)*10	The score for this function is an average of the measure scores that represent the degree of streambank incision, bank erosion, and the ability of the channel to migrate laterally.

Function	Function Score Formula[4]	Formula Narrative
SM	=Armor*3 + Embed*3 + BedVar*4	The score for this function is the weighted sum of (a) the degree of bank armoring, (b) the degree of substrate embeddedness, and (c) the variability of the channel bed.
MB	=(Barriers * AVERAGE(BedVar, Wood, SideChan))*5 + AVERAGE(InvVeg, WoodyVeg, LgTree, WetVeg)*5	The score for this function is the sum of (a) the average of the measure scores that represent the variability of the channel bed, the frequency of wood, and the proportion of side channels, with the average modified by the presence of any fish passage barriers, and (b) the average of the measure scores that represent the abundance of invasive plants, the abundance of native woody plants, the abundance of large trees, and the presence and distribution of wetland vegetation.
CMH	=AVERAGE(Exclusion, WoodyVeg, LgTree)*5 + (Barriers * AVERAGE(Incision, Wood, Embed, BedVar, SideChan))*5	The score for this function is the sum of (a) the average of the measure scores that represent the variability of the channel bed, the frequency of wood, and the proportion of side channels, with the average modified by the presence of any fish passage barriers, and (b) the average of the measure scores that represent the abundance of invasive plants, the abundance of native woody plants, the abundance of large trees, and the presence and distribution of wetland vegetation.
STS	=AVERAGE(OBFlow, Cover, InvVeg, WoodyVeg)*7 + WetVeg*3	The score for this function is the weighted sum of (a) the average of the measure scores that represent the existence of overbank flow, the degree of natural cover overhanging the stream, the abundance of invasive plants, and the abundance of native woody plants, and (b) the presence and distribution of wetland vegetation.
NC	=AVERAGE(OBFlow, BedVar, RipWidth, Cover, WetVeg)*10	The score for this function is the average of the measure scores that represent the existence of overbank flow, the variability of the channel bed, the width of the riparian corridor, the degree of natural cover overhanging the stream, and the presence and abundance of wetland vegetation.
CR	=AVERAGE(RipWidth, BedVar, WetVeg, OBFlow)*10	The score for this function is the average of the measure scores that represent the width of the riparian corridor, the variability of the channel bed, the presence and abundance of wetland vegetation, and the existence of overbank flows.
TR	=Cover*10	The score for this function is based on the degree of natural cover overhanging the stream.

Key to function measure abbreviations: SideChan = Side Channels; BedVar = Channel Bed Variability; OBFlow = Overbank Flow; Exclusion = Floodplain Exclusion; Incision = Incision; Wood = Wood; WetVeg = Wetland Vegetation; Embed = Embeddedness; ImpoundUS = Impoundments Upstream; Armor = Bank Armoring; Erosion = Bank Erosion; LatMigr = Lateral Migration; Barriers = Fish Passage Barriers; InvVeg = Invasive Vegetation; WoodyVeg = Native Woody Vegetation; LgTree = Large Trees; Cover = Natural Cover; RipWidth = Vegetated Riparian Corridor Width.

Table 3.3 Formulas for Each of the Values Associated with the Eleven Functions

Scores are made up of two components: the opportunity subscore and the significance subscore. The opportunity subscore represents the set of circumstances that makes it favorable for the project area to be able to provide a specific set of functions, predicted in part by what is upslope and upstream of the project area. The significance subscore represents the importance of a specific function (or set of functions) being provided at the particular location of the project area, predicted by what is adjacent to (floodplains) and downstream of the project area (that may be affected by the function being provided in the assessment area), and by how unique or rare the function or the aquatic resource type is in the landscape. The formula narrative provides a very brief description of the various factors that inform the overall value.

Value	Value Score Components			Formula Narrative
	Opportunity Subscore	Significance Subscore	Final Score	
Surface Water Storage (SWS)	=AVERAGE (ImpArea, Runoff, ImpoundUS)*5	=AVERAGE(MAX (DwnFP,Zoning), DwnFld,Fish)*5	Opportunity + significance	The score for this value is the sum of (a) the average of the measure scores that represent the prevalence of impervious area in the contributing basin, the abundance of surface water runoff, and the absence of impoundments upstream, and (b) the average of the measure scores that represent the existing or potential infrastructure in the downstream floodplain, the frequency of downstream flooding, and the presence of rare fish species or a designation Essential Salmonid Habitat.
Sub/Surface Transfer (SST)	=AVERAGE (AqPerm, SoilPerm)	=Source	=IF(Source=1,10, AVERAGE (AqPerm,SoilPerm)*10	This value is assigned the maximum score if the site is within close proximity to a water source or designated groundwater management area. Otherwise, the score for this value is the average of measure scores representing the soil and aquifer permeability of the local area.
Flow Variation (FV)	=AVERAGE (ImpArea, MAX(FlowMod, FlowRest,1-ImpoundUS),AqPerm, SoilPerm)*5	=AVERAGE (ImpoundDS,MAX(RarInvert, RarAmRep,Fish)*5	Opportunity + significance	The score for this value is the sum of (a) the average of the measure scores that represent the prevalence of impervious area in the contributing basin, known streamflow issues, and local soil and aquifer permeability, and (b) the average of the absence of impoundments downstream and the nearby occurrences of rare species

Value	Value Score Components			Formula Narrative
	Opportunity Subscore	Significance Subscore	Final Score	
				that might depend on hydrologic cues.
Sediment Continuity (SC)	= SedList*4 + AVERAGE (ImpArea, ImpoundUS, Position)*5	=AVERAGE(1-DwnFP,Erode, ImpoundDS)*5	Opportunity + significance	The score for this value heavily weights the presence of known sediment impairment and sums it with (a) the average of the measure scores that represent the prevalence of impervious area in the contributing basin, the absence of impoundments upstream, and the site's relative position in the watershed and (b) the average of the measure scores that represent infrastructure in the downstream floodplain, the erodibility rating of the local basin, and the absence of impoundments downstream.
Substrate Mobility (SM)	=AVERAGE(ImpArea,ImpoundUS)*5	=AVERAGE(SubFeat, MAX(Fish, RarPlant, RarAmRep, RarInvert))*5	Opportunity + significance	The score for this value is the sum of (a) the average of the measure scores that represent the prevalence of impervious area in the contributing basin and the absence of impoundments upstream and (b) the average of the measure scores that represent the presence of unique habitat features and nearby occurrences of rare species.

Value	Value Score Components			Formula Narrative
	Opportunity Subscore	Significance Subscore	Final Score	
Maintain Biodiversity (MB)	=AVERAGE (Passage, SurrLand,RipCon)*5	=AVERAGE(HabFeat,Protect, MAX(Fish, RarInvert, RarAmRep, Waterbird, RarBdMm, RarPlant))*5	Opportunity + significance	The score for this value is the sum of (a) the average of the measure scores that represent the presence of fish passage barriers upstream and downstream, the surrounding land cover types, and the extent of the contiguous riparian corridor and (b) the average of the measure scores that represent the presence of unique habitat features, the proximity of protected natural areas, and nearby occurrences of rare species.
Create and Maintain Habitat (CMH)	=AVERAGE(1-ImpArea, ImpoundUS, RipArea, RipCon, MAX(1-NutrImp, 1-FlowMod,1-FlowRest)*5	=AVERAGE(MAX(1-DwnFP,1-Zoning), ImpoundDS,HabFeat)*5	Opportunity + significance	The score for this value is the sum of (a) the average of the measure scores that represent the prevalence of impervious area in the contributing basin, the absence of impoundments upstream, the extent and connectivity of intact riparian area in the contributing basin, and the absence of known flow and nutrient impairments and (b) the average of the measure scores that represent the existing or potential infrastructure in the downstream floodplain, the presence of unique habitat features, and the absence of impoundments downstream.

Value	Value Score Components			Formula Narrative
	Opportunity Subscore	Significance Subscore	Final Score	
Sustain Trophic Structure (STS)	=AVERAGE (SurrLand, 1-ImpArea, Passage, RipArea,RipCon,1-NutrImp,1-TempImp)*5	=AVERAGE(Protect,MAX (1-DwnFP,1-Zoning), MAX(Fish, RarInvert, RarAmRep, Waterbird, RarBdMm, RarPlant),Hab Feat)*5	Opportunity + significance	The score for this value is the sum of (a) the average of the measure scores that represent the surrounding land cover types, the prevalence of impervious area in the contributing basin, the presence of fish passage barriers upstream and downstream, the extent and connectivity of intact riparian area in the contributing basin, and the absence of known flow and nutrient impairments and (b) the average of the measure scores that represent the site's proximity to protected areas, the existing or potential infrastructure in the downstream floodplain, documented rare species occurrences, and presence of unique habitat features.
Nutrient Cycling (NC)	=NutrImp*4+AVERAGE(ImpArea,1-RipArea,1-RipCon, SedList,Position)*1	=AVERAGE (MAX(Fish, RarInvert, RarAmRep), Source)*5	Opportunity + significance	The score for this value heavily weights the presence of known nutrient impairment and sums it with (a) the average of the measure scores that represent the prevalence of impervious area in the contributing basin, the extent and connectivity of intact riparian area, known sediment impairment, and the site's relative position in the watershed, and (b) the average of the measure scores that represent documented rare species occurrences and proximity to important water sources.

Value	Value Score Components			Formula Narrative
	Opportunity Subscore	Significance Subscore	Final Score	
Chemical Regulation (CR)	=ToxImp*4+AVERAGE(ImpArea,1-RipArea,1-RipCon,SedList,Position)*1	=AVERAGE(MAX(Fish, RarInvert, RarAmRep, Waterbird, RarBdMm, RarPlant),Source)*5	Opportunity + significance	The score for this value heavily weights the presence of known toxics impairment and sums it with (a) the average of the measure scores that represent the prevalence of impervious area in the contributing basin, the extent and connectivity of intact riparian area, known sediment impairment, and the site's relative position in the watershed, and (b) the average of the measure scores that represent documented rare species occurrences and proximity to important water sources.
Thermal Regulation (TR)	=(1-TempImp)*4 +AVERAGE (RipArea,RipCon, ImpArea)*1	=AVERAGE (ThermFeat, MAX(Fish, RarInvert, RarAmRep)*5	Opportunity + significance	The score for this value heavily weights the absence of a known temperature impairment and sums it with (a) the average of the measure scores that represent the prevalence of impervious area in the contributing basin, and the extent and connectivity of intact riparian area, and (b) the average of the measure scores that represent unique habitat features and documented rare species occurrences.

Key to Value Measure Abbreviations:

ImpArea = Impervious Area; Runoff = Surface Water Runoff; ImpoundUS = Impoundments Upstream; DwnFP = Extent of Downstream Floodplain Infrastructure; Zoning = Zoning; DwnFld = Frequency of Downstream Flooding; Fish = Essential Salmonid Habitat or Rare Non-anadromous Fish; AqPerm = Aquifer Permeability; SoilPerm = Soil Permeability; Source = Designated Water Source; FlowMod = Flow Modification; FlowRest = Streamflow Restoration Need; SurrLand = Surrounding Land Type; RarInvert = Rare Invertebrates; RarAmRep = Rare Amphibians and Reptiles; SedList = Sediment Impairment; Position = Watershed Position; Erode = Erodibility; ImpoundDS = Impoundments Downstream; HabFeat = Unique Habitat Features; RarPlant = Rare Plants; Passage = Fish Passage Barriers; RipCon = Riparian Continuity; Protect = Protected Areas; Waterbird = Important Bird Areas or Rare Waterbirds; RarBdMm = Rare Songbirds and Mammals; RipArea = Riparian Area; NutrImp = Nutrient Impairment; TempImp = Temperature Impairment; ToxImp = Toxics Impairment

3.5 Assessment Outputs

The formulas for each specific function and value produce a numerical *score* between 0.0 and 10.0. For ecological functions, a score of 0.0 indicates that negligible function is being provided by the stream whereas a score of 10.0 indicates that the stream is providing maximum function (as defined) given certain contextual factors (e.g., ecoregion, size). For values, a score of 0.0 indicates that even if a specific ecological function can be provided within the project area, there is negligible opportunity for the site to provide that function, or even if it does, it is not particularly significant given the context of the site. Conversely, a value score of 10.0 indicates that a site has the opportunity to provide a specific function and that it is highly significant in that particular location. For all function and value formulas, both extents of the scoring range (0.0 and 10.0) are mathematically possible.

To facilitate conceptual understanding and communication of outputs, numerical *scores* are translated into *ratings* of Lower, Moderate, or Higher. The numerical thresholds for each of these rating categories are consistent across all functions and values such that scores of <3.0 are rated "Lower," scores ≥3.0 but ≤7.0 are rated "Moderate," and scores that are >7.0 are rated "Higher." These thresholds are consistent with the standard scoring scheme applied to all individual function measures.

Each specific function, and its associated value, is included in one of the four thematic groups described in **Section 3.1**: hydrologic, geomorphic, biologic, and water quality functions. Function groups provide an indication of the degree to which each group of processes is present at a site. Groups are represented by the highest function with the highest associated value among the two to three functions that comprise each group. This hierarchical selection system ensures that thematic functional groups are represented by the highest performing and highest valued ecological function. If multiple specific functions are equally ranked in the selection hierarchy, the function with the highest numerical function score is selected.

SFAM was designed as a standalone function assessment; it is not, in and of itself, a credit quantification tool. Any associated mitigation policy and accounting protocols are structured around the method, with the understanding that individual scores can be directly compared across sites and across functions and that group scores represent an aggregation of the information from individual scores.

4.0 Measures of Function & Value

Stream functions are expressed in varied and complex ways; therefore, they are difficult, costly, and time-consuming to measure directly. To enable the assessment of functions and values within the constraints of a rapid method, measures were identified for each function.

Measures are metrics that allow a quantitative or qualitative assessment of specific attributes that may indicate the extent to which a particular function is active. Measures can be continuous or discrete variables and may be assessed in the field (e.g., streambank incision, substrate embeddedness, bankfull width), in the office (e.g., GIS analysis of land use or impervious areas), or collected from existing sources (e.g., 303(d) listing, NOAA ESA fish listing). SFAM measures are primarily quantitative; however, where no practical quantitative approach exists to assess an attribute, measures consisting of observations and scores that represent a defined range (rather than a continuous set of measures) are used.

An initial list of measures was compiled for this project from multiple data sources, including the scientific literature, existing stream assessment protocols, spatial data sources, state-wide databases, and office-based analysis techniques. Selection criteria were then applied to assure the scientific validity of each measure and its practicality for use in a rapid assessment tool. SFAM measures (**Table 4.1**) meet the following inclusion criteria:

- **Rapid:** Attribute can be measured within the anticipated timeframe of a rapid assessment method.
- **Repeatable:** Multiple trained assessment teams would likely come up with the same value for this metric for a site at a given point in time.
- **Science-based:** A panel of scientists with relevant expertise would agree that the measure is either a direct measure or highly correlated indicator of a particular stream function attribute; it is likely that the relationship between the measure and the function could be substantiated through peer-reviewed literature or through rigorous scientific evaluation.

Table 4.1 SFAM Function and Value Measures

Function Measures		Value Measures	
F1	Natural Cover	V1	Rare Species Occurrence & Special Habitat Designations
F2	Invasive Vegetation	V2	Water Quality Impairments
F3	Native Woody Vegetation	V3	Protected Areas
F4	Large Trees	V4	Impervious Area
F5	Vegetated Riparian Corridor Width	V5	Riparian Area
F6	Fish Passage Barriers	V6	Extent of Downstream Floodplain Infrastructure
F7	Floodplain Exclusion	V7	Zoning
F8	Bank Armoring	V8	Frequency of Downstream Flooding
F9	Bank Erosion	V9	Impoundments
F10	Overbank Flow	V10	Fish Passage Barriers
F11	Wetland Vegetation	V11	Water Source
F12	Side Channels	V12	Surrounding Land Cover
F13	Lateral Migration	V13	Riparian Continuity
F14	Wood	V14	Watershed Position
F15	Incision	V15	Flow Restoration Needs
F16	Embeddedness	V16	Unique Habitat Features
F17	Channel Bed Variability		

4.1 Measure Development & Scientific Rationales

The following sections provide in-depth descriptions of each function and value measure included in the Stream Function Assessment Method, including the models, scientific rationale, and a brief history of the evolution of each measure. The synopsis of each measure is structured as follows:

- **Measure text**: Provides the exact wording of the question, identical to that found in the SFAM User Manual and the SFAM Workbook.
- **Measure description**: Provides a conceptual overview of what the measure represents and assesses, as well as a quick-reference outline of the functions or values informed by the measure and the model(s) used to quantify the measure. For function measures, this includes tabular and graphical representations of performance indices.

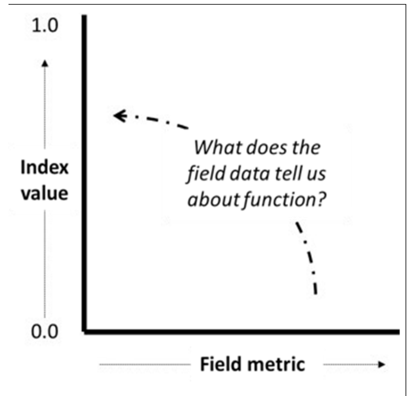
- **Standard performance index** (functions only): Provides a description of how the standard performance index was developed, including the level of information available to develop the index, the method for determining thresholds, and the rationale behind stratification (if applicable). Standard performance indices were developed using different approaches based on the quantity, quality, and type of relevant data and literature available.
- **Scientific support for ecological functions** (functions only): Provides an explanation of the state of scientific understanding relating measures to the performance of functions, highlighting any key studies that were assessed to develop standard performance indices.
- **Measure development** (functions only): Provides a description of how the measure was explored and developed, including alternatives considered and input from technical reviewers.
- **Rationale for inclusion** (values only): Provides an explanation of the scientific support for a value measure to inform both the opportunity for a stream site to provide specific ecological functions and the significance of those functions given the context of the site.

Creating standard performance indices

Standard performance indices (range of expected performance) for each function measure included in the SFAM model provide ecological meaning to scoring the measures. Such performance indices are also needed to facilitate standardization of individual measure – and thus function – scores to a common scale, which is important for calculating and comparing assessment scores. The 17 function measures included in the method result in a variety of field metrics, including percentages, ratios, absolute values, coefficients of variance, and qualitative responses. These metrics must be converted into a common, calibrated unit before they can be incorporated into function formulas. The performance index for each function measure is set to a standardized scale that results in a measure score ranging from 0.0 to 1.0. Standard performance indices were developed using the following steps:

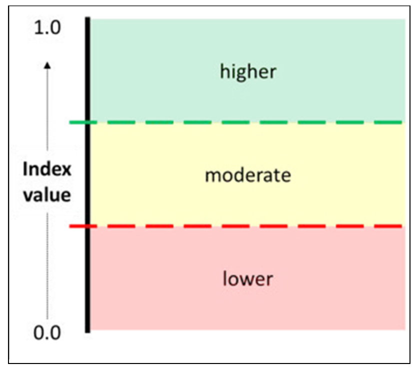
1. Establish index scales (axes).

For each index, the x-axis represents the field metric, and the range varies depending on the metric type (e.g., 0–100 for percentages). The y-axis represents possible index values, ranging from 0.0 to 1.0. Linear models are needed to translate field metrics to numeric index values.



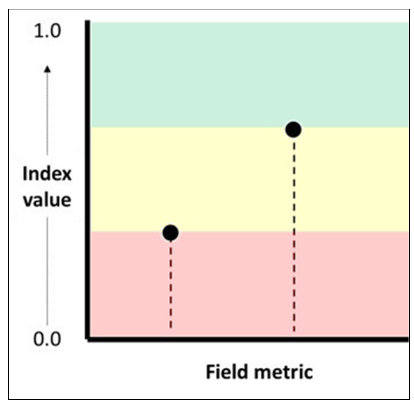
2. Identify index value thresholds (calibrate y-axis).

Standard function thresholds were applied to the index value scale in order to ensure that all measures are assigned scores that have consistent ecological meaning. The threshold indicating a shift from lower to moderate functioning is set at 0.3. The threshold indicating the difference between moderate and higher functioning is set at 0.7.



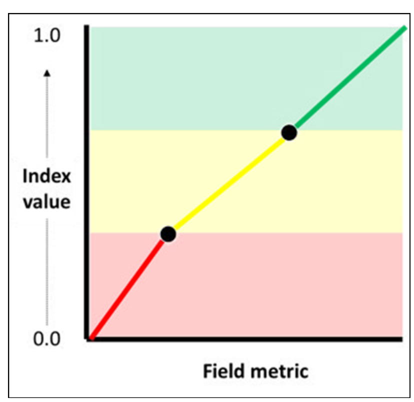
3. Identify field metric thresholds (calibrate x-axis).

Regional ecological literature and data sets were evaluated to identify field metric values that correspond with a change in functioning. These ecological thresholds indicate the point at which the functional rate of return may shift.
See the following section for further description of the methods used to determine field metric thresholds.



4. Create linear models between thresholds.

The models describe the rate of functional return expected for increases (or, for inverse scales, decreases) in the field metric value. The use of linear (continuous) models allows the measure score to reflect incremental changes.



To assure that function measure scores are evaluated against appropriate standard performance indices where factors such as stream size or ecoregion may influence expected performance, standard performance indices of some function measures are stratified on these attributes. For example, when assessing natural cover over a stream, differences would be expected based upon stream width and geographic location and, therefore, cover measurements should be evaluated against appropriate standard performance indices. Stratified standard performance indices were developed when there was sufficient scientific support to do so.

Data availability for generating standard performance indices

Given the diversity of function measures used in SFAM, we took different approaches to developing standard performance indices based on the availability of data. The three categories of data availability are as follows:

1. Substantial literature exists linking measures to ecological functioning. Indices are based on trends and thresholds expressed in research results reported in the literature.
2. In the absence of substantial literature, we relied on an abundance of raw data provided by the USEPA National Aquatic Resource Survey (NARS). Indices are based on data distributions and known reference site data that could be used to set expectations, supported by existing literature linking measures to ecological functioning.
3. In the absence of substantial literature or an abundance of raw data, we relied on the current scientific understanding of how measures relate to functioning.

Regardless of the level of data availability, scientific understanding from the current literature informed performance index thresholds. Thresholds, as illustrated above, are the break points between general levels of functioning (i.e., the point at which a function or value should be considered Moderate rather than Lower or Higher). The approaches used to develop standard performance indices and identify appropriate thresholds are detailed below.

1. Performance indices generated using available literature

For six of the 17 function measures (Invasive Vegetation, Native Woody Vegetation, Large Trees, Vegetated Riparian Corridor Width, Floodplain Exclusion, Side Channels), the standard performance indices and associated thresholds were developed based directly on analysis of research results reported in the scientific literature. The basic process for this was as follows:

a. Queried Pacific Northwest researchers who have conducted relevant studies, and agencies responsible for assessment, management, and monitoring of the stream resource, to assist in identifying existing data relevant to SFAM function and measures of function;
b. Conducted an extensive, systematic search of the scientific literature with a focus on studies conducted in the Pacific Northwest (Idaho, Oregon, Washington, and British Columbia);
c. Selected studies that measured aspects of stream function, and described the degree of function, related to identified SFAM functions and using similar measures of function (i.e., percent cover of invasive vegetation, native woody vegetation, and large trees; width of vegetated riparian corridor; percent of floodplain connectivity; availability of side channels); and
d. Analyzed the data relevant to each measure to produce a standard performance index (0-1

scale) and thresholds of function (Low, Moderate, High).

A discussion of which studies were chosen and why, and how the thresholds were established for each standard performance index developed, is provided in the detailed description of each of these measures (**Section 4.2**).

2. Performance indices generated using USEPA NARS National Rivers and Stream Assessment data

For five of the 17 function measures (Natural Cover, Wood, Incision, Embeddedness, and Channel Bed Variability), the standard performance indices were developed using raw data made available by the NARS, a program of the USEPA in collaboration with states and tribes. NARS is designed to assess the quality of the nation's coastal waters, lakes and reservoirs, rivers and streams, and wetlands using a statistical survey design. From these data, abiotic criteria for the least disturbed condition were developed by the USEPA, based in part on research conducted by Herlihy *et al.* (2008), Whittier *et al.* (2007), and Stoddard *et al.* (2006). The physical habitat metrics developed by the NARS program have been used extensively for analysis and informing natural resource conservation and management by federal and state agencies (Bryce *et al*., 2008, 2010; Faustini *et al*., 2009; Griffith *et al*., 2003; Herlihy *et al*., 2020; Hubler *et al*., 2016; Hughes *et al*., 2010; Jessup *et al*., 2014; Lomnicky *et al*., 2021; Paulsen *et al*., 2008).

As part of the NARS program, physical, chemical and biological data were collected from streams for the 2008-2009, 2013-2014, and 2018-2019 National Rivers and Streams Assessment (NRSA) across the continental U.S. The assessments used a common methodology (USEPA, 2019a, 2019b) across all sites, with some slight deviations for wadeable versus non-wadeable streams. Sites ranged in size from small mountain headwater streams to large rivers, reflecting the variety and types of rivers and streams across the U.S.

In NARS surveys, sampling sites are randomly selected to represent a specific portion of the total resource or population of interest. Because of the statistical nature of site selection, results from the sampled population can be extrapolated to the entire (sampled and unsampled) population. For this reason, probability surveys are well suited for making unbiased assessments of the status of an entire resource across large geographic areas without assessing every water body (USEPA 2019c). Data from the NARS surveys are made publicly available on the USEPA website: https:/www.epa.gov/national-aquatic-resource-surveys.

To develop standard performance indices for SFAM measures, a subset of the NRSA data was used. Specifically, data were taken from three NRSA data files, one from each of the three national stream and river sampling periods to date:

1. NRSA 0809 Physical Habitat Larger Set of Metrics (csv)
2. NRSA 1314 Physical Habitat Larger Set of Metrics (csv)
3. NRSA 1819 Physical Habitat Larger Set of Metrics (csv)

Data from these files were combined and then limited to data collected from assessments conducted in the two ecoregions which occur in the Pacific Northwest: Western Mountains (WMT) and Xeric (XER) (**Figure 4.1**). Ecoregions have been developed and identified through synthesis of data by similar soils, climate, and geography rather than geo-political boundaries.

For this reason, our analysis used all data from these two ecoregions that were applicable to SFAM measures. This large dataset provides increased confidence in the data interpretation through improved statistical power and reduced variance. It also allows the application of these measures and associated indices throughout the WMT and XER ecoregions which includes the entire Pacific Northwest (Oregon, Washington and Idaho).

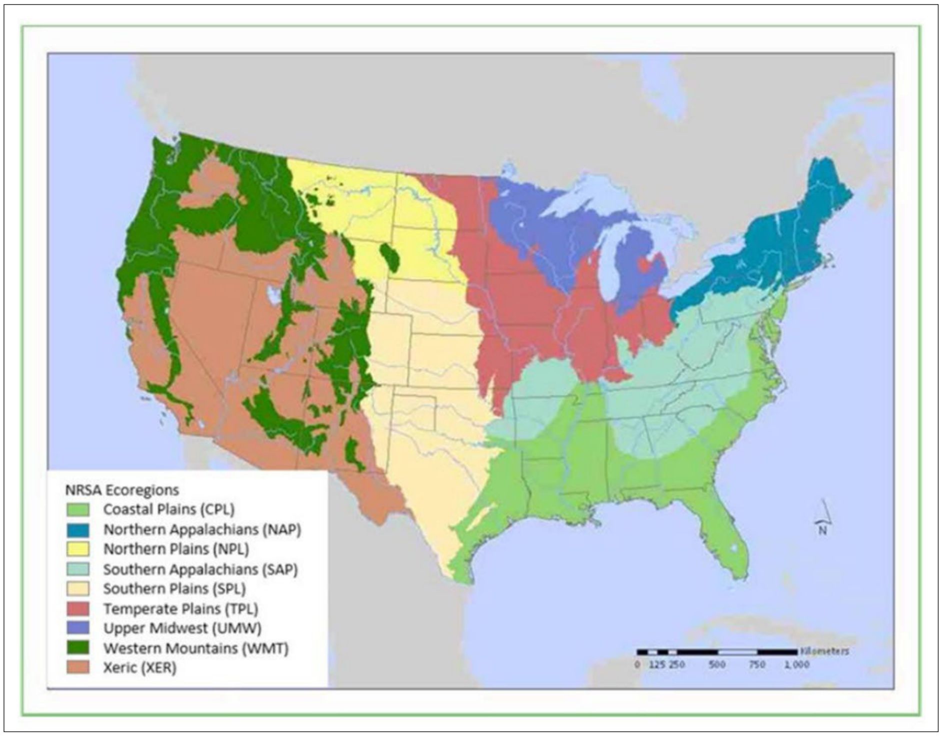


Figure 4.1 The Nine Ecoregions Used in the National Rivers and Streams Assessments (NRSA)
These are aggregations of the Level III ecoregions delineated by USEPA for the continental U.S. (https://www.epa.gov/national-aquatic-resource-surveys/ecoregion-descriptions-national-aquatic-resource-surveys). Survey data from the Western Mountains (green) and the Xeric (orange) ecoregions were used to inform standard performance index development.

The data from the XER and WMT ecoregions were further reduced with the following limitations:

1. Selected only the parameters used for SFAM standard performance index development (**Table 3.2**)
2. Selected records for sites designated as "visit 1" (excluded data from repeat site assessments within a sampling period).
3. Selected only records that indicted the data collection protocol as "Wadeable" or "Boatable". Both of these data collection protocols produced consistent data appropriate for use in the development of SFAM standard performance indices. The small subset of NRSA assessment records that did not indicate collection method were removed.
4. Removed one record that had missing data for all parameters.

The resulting data set includes a total sample size of 1,346 assessment sites. Note that not all assessment site records included data for every parameter of interest. The actual sample size used to develop specific standard performance indices is provided in the detailed descriptions of relevant SFAM measures of function (**Section 4.2**). NRSA metrics used to select relevant site records and develop standard performance indices for SFAM measures of function are summarized in **Table 4.2**.

Table 4.2. USEPA NRSA Data Metrics Used to Develop Standard Performance Indices for SFAM Measures of Function

NRSA data variable	Description
Used for selecting relevant NRSA records	
VISIT_NO	Identifies if data were collected during the first or second site visit. Only first site visit data used.
AG_ECO9	NARS 9-level reporting region, based on aggregated Level III ecoregions. Only XER and WMT ecoregions used.
PROTOCOL	Field sampling type Wadeable or Boatable. Records unassigned for this variable were excluded.
Used for developing standard performance indices (SPI)	
XCDENBK	Canopy density at bank (mean percent). Used to calculate SPI for natural cover.
XBKF_W	Mean bankfull width (m).
XBKF_H	Mean bankfull height above wetted channel (m). Used to calculate BHR and SPI for inclusion.
XINC_H	Terrace height above water level (m). Used to calculate BHR and SPI for inclusion.
XDEPTH_CM	Mean thalweg depth (cm). Used to calculate BHR and SPI for inclusion.
C1WM100	Bankfull channel wood count. Used to calculate SPI for wood.
XEMBED	Mean streambed embeddedness (%). Used to calculate SPI for embeddedness.
CVDTH	Coefficient of variation of thalweg depth (standard deviation of depth/depth). Used to calculate SPI for channel bed variability.
CVWIDTH	Coefficient of variation of wetted width (standard deviation of width/width). Used to calculate SPI for channel bed variability.

Objectives for using the NRSA data to inform the development of the standard performance indices for select measures included (a) identify the range and distribution of data values across a representative population of streams and rivers, (b) explore values across stream attributes to identify potential factors for stratifying expectation of performance, and (c) use probabilistic site data to inform index thresholds (Low, Moderate, High). To address these objectives, frequency distributions of the corresponding data were evaluated for each relevant measure. Analyses of the data are discussed in the *Standard Performance Index* section for each of the five measures (**Section 4.2**).

A standard set of rules was applied to translate percentile values from the NRSA data distributions into index thresholds upon which to base standard performance models (**Figure 4.2**):

- **the threshold for "low"** functioning was determined using the 25th percentile value of the survey site data, thus asserting that sites with a metric value as low as, or lower than, the bottom 25% of all NRSA sites are providing a "low" level of function to the stream;
- **the threshold for "high"** functioning was determined using the 75th percentile value of the survey site data, thus asserting that sites with a metric value as high as, or higher than, the top 75% of all NRSA sites are providing a "high" level of function to the stream;
- **the maximum metric value,** when needed, was determined using the 90th percentile value of the survey site data, thus asserting that a metric value as high, or higher than, the top 10% of all NRSA sites would be assigned the maximum index value (1.0). Maximum metric values were needed for metrics whose scales are not fixed.

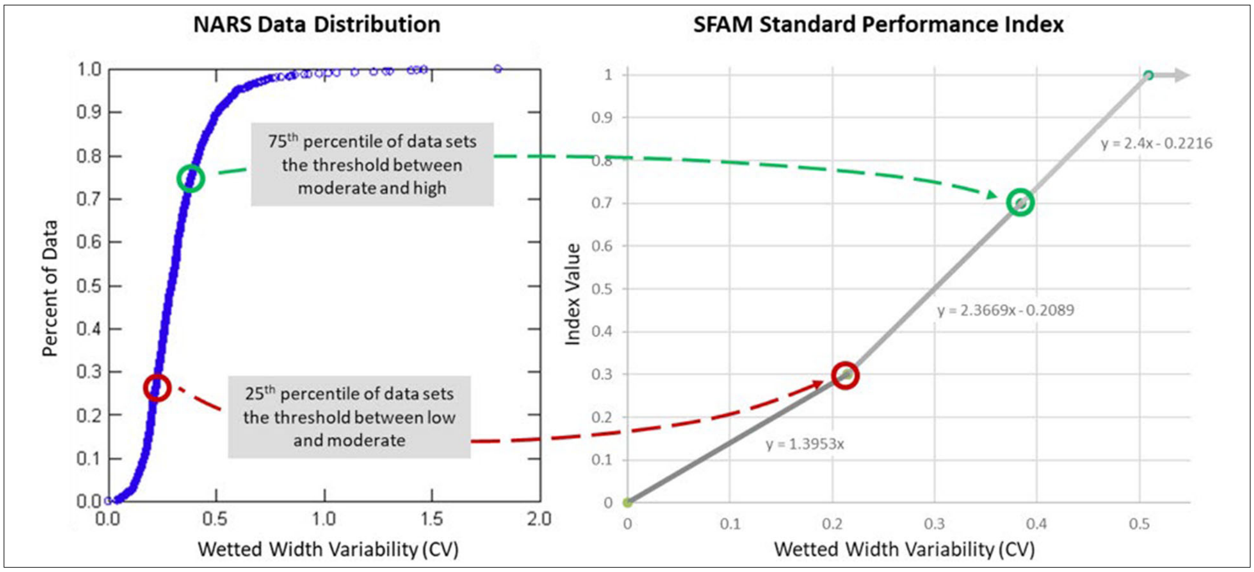


Figure 4.2 Raw Data Distributions from USEPA NARS Surveys are Used to Set Performance Expectations

For metrics that operate on an inverse scale (i.e., lower values correspond with higher functioning), the inverse of this rule set was applied.

3. Performance indices generated based on current scientific understanding

For six of the 17 function measures (Fish Passage Barriers, Bank Armoring, Bank Erosion, Overbank Flow, Wetland Vegetation, Lateral Migration), neither existing studies, NRSA data, nor other sources of data were identified that could inform data driven standard performance indices. Thus, indices for these measures were developed based on current scientific understanding and expert review. The basic process for this was as follows:

a. Queried Pacific Northwest researchers who have conducted relevant studies, and agencies responsible for assessment, management, and monitoring of the stream resource, to assist in identifying existing data relevant to SFAM function and measures of function;

b. Conducted an extensive, systematic search of the scientific literature with a focus on studies conducted in the Pacific Northwest (Idaho, Oregon, Washington, and British Columbia); and

c. Identifying no studies or applicable data sources providing the level of data necessary to support standard performance index development, indices and associated thresholds for these measures are based on current scientific understanding of these processes and their linkages to the stream functions they support.

A discussion of the literature supporting these standard performance indices is provided in the detailed description of these measures (**Section 4.2**).

4.2 Function Measures

Detailed descriptions of the scientific basis for each of the 17 function measures are included in the following section. These measures are primarily field-based and often require collection of quantitative data. There are several measures that can be estimated before conducting field work, but it is expected that any estimated answers be confirmed in the field. Data collection instructions for each measure are included in the SFAM User Manual.

Table 4.3. Measures Informing Each Function Formula

	Function Measures																
Function	Natural Cover	Invasive Vegetation	Native Woody Vegetation	Large Trees	Vegetated Riparian Corridor Width	Fish Passage Barriers	Floodplain Exclusion	Bank Armoring	Bank Erosion	Overbank Flow	Wetland Vegetation	Side Channels	Lateral Migration	Wood	Incision	Embeddedness	Channel Bed Variability
Surface water storage							X			X		X		X	X		X
Sub/surface transfer										X	X	X					X
Flow variation*																X	X
Sediment continuity									X				X		X		
Substrate mobility								X								X	X
Maintain biodiversity		X	X	X		X					X	X		X			X
Create & maintain habitat			X	X		X	X					X		X	X	X	X
Sustain trophic structure	X	X	X							X	X						
Nutrient cycling	X				X					X	X						X
Chemical regulation					X					X	X						X
Thermal regulation	X																

**Flow Variation is also informed by the value measure, Impoundments. See Section 4.3 for information on this measure*

F1. Natural Cover

MEASURE TEXT

What is the percent natural cover above the stream within the Proximal Assessment Area (PAA)?

Measure the percentage of cover above the stream, including overstory and understory vegetation, and overhanging banks, by averaging spherical densiometer measurements taken at each transect within the PAA.

MEASURE DESCRIPTION

The presence of natural cover, including both vegetation and overhanging banks, is a major factor in water temperature maintenance and cooling which, in turn, regulates chemical fluctuations. Vegetative cover (including trees, shrubs, and other plants) that shade streams can provide important food and shelter resources for aquatic-dependent species by contributing leaf litter and wood to the stream habitat.

Function Groups: Biology, Water Quality
Functions Informed: Sustain Trophic Structure (STS), Nutrient Cycling (NC), Thermal Regulation (TR)
Stratification: This measure is stratified by both ecoregion (Western Mountains; Xeric) and stream size (small ≤ 50 ft width; large >50 ft width)
Metric: Percent cover

Model:
Western Mountains ecoregion; ≤ 50 ft wide:

IF Cover < 60, THEN = 0.005*Cover

IF Cover = 60-94, THEN = 0.0118*Cover - 0.4059

IF Cover > 94-98, THEN = 0.075*Cover - 6.35

IF Cover > 98, THEN =1.0

Western Mountains ecoregion; > 50 ft wide:

IF Cover < 15, THEN = 0.02*Cover

IF Cover = 15-60, THEN = 0.0089*Cover + 0.1667

IF Cover > 60-78, THEN = 0.0167*Cover - 0.3

IF Cover > 78, THEN = 1.0

Xeric ecoregion; ≤ 50 ft wide:

IF Cover < 43, THEN = 0.007*Cover

IF Cover = 43-89, THEN = 0.0087*Cover - 0.0739

IF Cover > 89-96, THEN = 0.0429*Cover - 3.1143

IF Cover > 96, THEN = 1.0

Xeric ecoregion; > 50 ft wide:

IF Cover < 13, THEN = 0.0231*Cover

IF Cover = 13-52, THEN = 0.0103*Cover + 0.1667

IF Cover > 52-71, THEN = 0.0158*Cover - 0.1211

IF Cover > 71, THEN = 1.0

The model scoring index is summarized in **Table 4.4** and shown graphically in **Figures 4.3 to 4.6**.

Table 4.4 Natural Cover Scoring Index

Natural Cover as measured by percent of coverage over stream				
Function Value Ranges	Low	Moderate	High	
Western Mountains; ≤ 50 ft width	< 60	60-94	> 94-98	> 98
Western Mountains; > 50 ft width	< 15	15-60	> 60-78	> 78
Xeric; ≤ 50 ft width	< 43	43-89	> 89-96	>96
Xeric; > 50 ft width	< 13	13-52	> 52-71	> 71
Index Value	0.0 - < 0.3	0.3-0.7	> 0.7-1.0	1.0

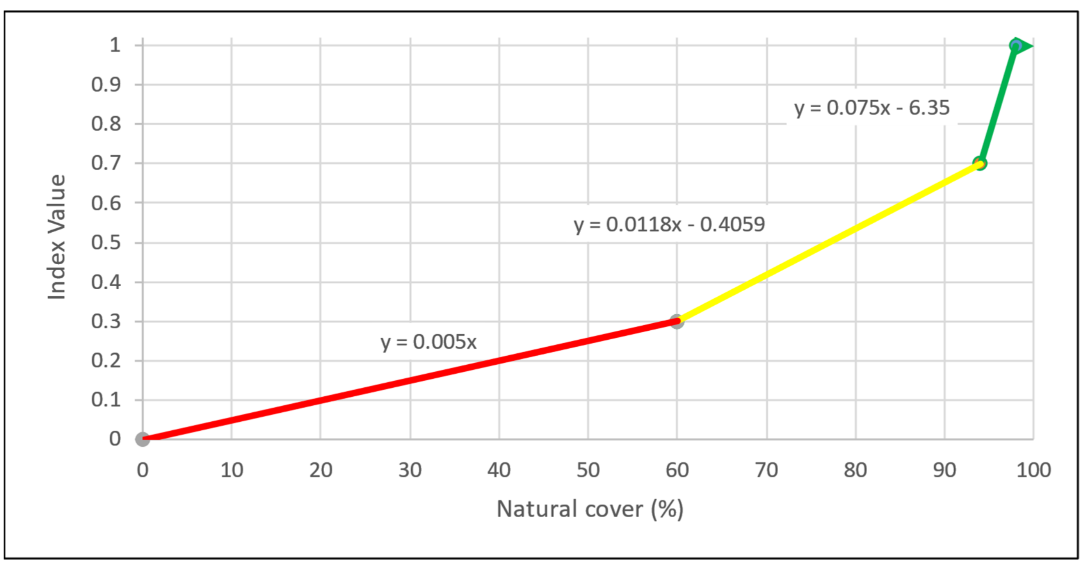


Figure 4.3. Natural Cover Standard Performance Index - Western Mountains Ecoregion; ≤50 ft width

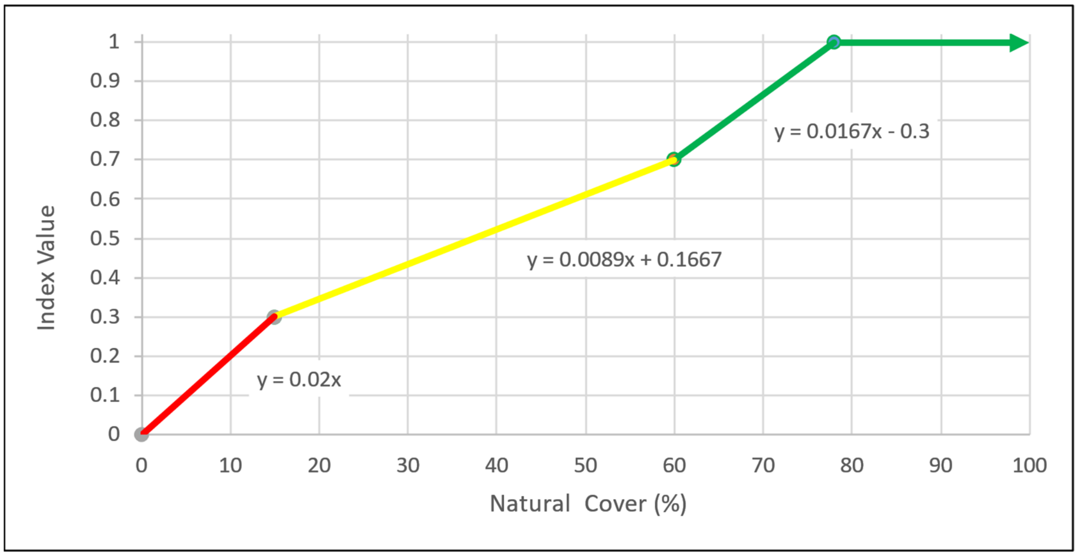


Figure 4.4. Natural Cover Standard Performance Index - Western Mountains Ecoregion; >50 ft width

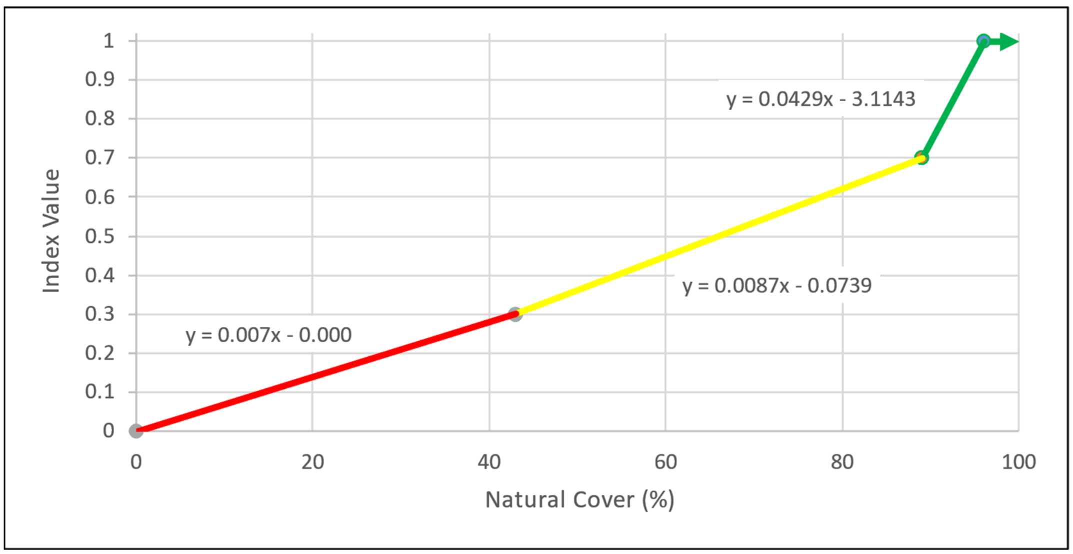


Figure 4.5. Natural Cover Standard Performance Index - Xeric Ecoregion; ≤50 ft width

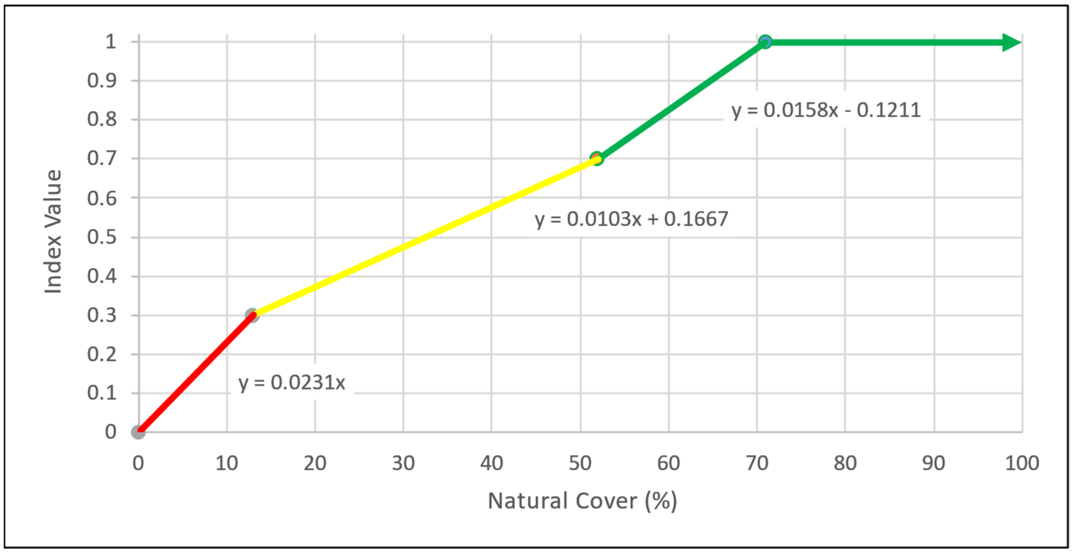


Figure 4.6. Natural Cover Standard Performance Index - Xeric Ecoregion; >50 ft width

STANDARD PERFORMANCE INDEX

Development Method

There is significant information in the literature to support that stream cover provided by riparian vegetation has a positive relationship with thermal and chemical regulation in streams. The range of specific function responses and the variety of methods used to quantify stream cover (percent cover, percent canopy closure, canopy height, shading, buffer width) in the literature make it difficult to quantify the resulting influence of cover on stream function and to develop a performance index based on this information. Therefore, the standard performance indices presented here were developed based on the distribution of field-collected data from the 1419 steam sites in the Western Mountains and Xeric ecoregions as part of the 2008-2009, 2013-2014, and 2018-2019 NRSA stream surveys (USEPA, 2020). The presented standard performance indices were developed using the NRSA metric XCDENBK (mean percent natural overhead cover at the stream bank). The index thresholds were determined using the approach described in **Section 4.1**. The threshold values for this measure are presented in **Table 4.4**.

Stratification

It is expected that streams occurring in dry (xeric) climates, where riparian vegetation is likely to be less dense and shorter, have less canopy cover for stream shading and nutrient inputs compared to streams in wetter climates, even for streams in pristine condition. Additionally, one might expect larger streams to have lower percent stream cover because a larger proportion of the stream is farther away from where the riparian vegetation is rooted. Therefore, we evaluated using ecoregion (Western Mountains and Xeric) and two stream width categories small (width ≤ 50 ft) and large (width > 50 ft) to stratify the NRSA stream cover data (**Figure 4.7**).

The results illustrated that percent of canopy cover tends to be greater for streams in the Western Mountains ecoregion than the Xeric ecoregion, and that small (width ≤ 50 ft) streams have greater percentage cover than larger streams in both ecoregions. Given the differences in percent cover by stream size and ecoregion in the NRSA data, in addition to literature supporting different expectations of natural cover, this measure is stratified on both ecoregion and stream width. A standard performance index was developed for each combination of stratifiers.

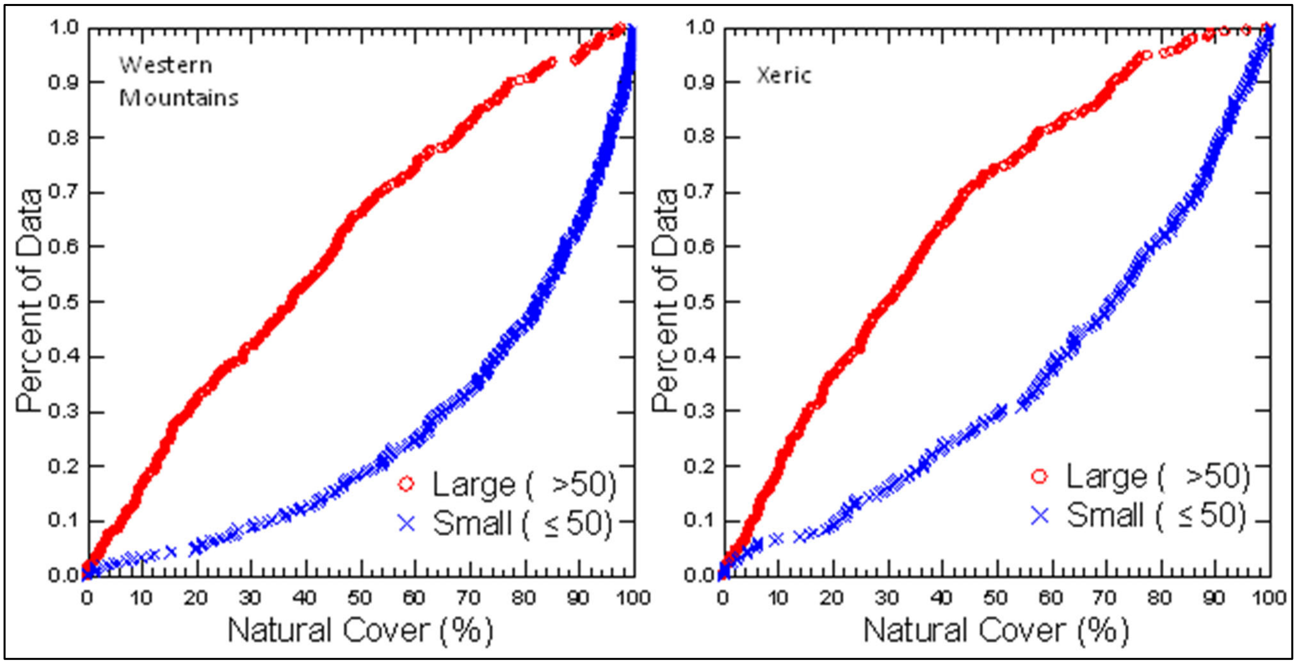


Figure 4.7. Frequency Distribution of Percent Natural Cover Values for 1341 Stream Reaches by Ecoregion and Stream Width category

SCIENTIFIC SUPPORT FOR ECOLOGICAL FUNCTIONS

Biologic Function

There is strong connectivity between terrestrial and aquatic ecosystems (Poff *et al.,* 2012) and riparian vegetation influences stream biota in several ways. Inputs of allochthonous material from riparian plants, including leaves, twigs, seeds, flowers, and terrestrial invertebrates and wood, provides food which helps sustain the productivity and biocomplexity of stream ecosystems (Wipfli *et al.,* 2007). In a synthesis paper describing the ecological linkages between upstream and downstream waters, and the transport of organic materials, Wipfli *et al*. (2007) noted that allochthonous, nutrient rich inputs partially drive the energetics and structure of aquatic food web dynamics and production. Organic matter, once in the stream, can be processed through consumption by various organisms from microbes to invertebrates, and may be repackaged as feces for consumption by other organisms. Wipfli *et al.* (2007) indicated that the conversion, retention, and transport of organic material is an important part of the ecological connectivity between terrestrial and aquatic systems. Terrestrial invertebrates, which are associated with both understory and overstory riparian plants, were found to be over half of the prey mass ingested by salmonids in southeastern Alaska streams (Wipfli, 1997).

The link between riparian and aquatic ecosystems is also evident from the evaluation of stream restoration projects and stream riparian buffer effect studies. In a modeling study of twelve western Washington stream reaches, Whitney *et al*. (2020) concluded that while the outcomes of restoration activities were varied, they can result in large increases in juvenile salmon biomass and that riparian cover and stream temperature were leading factors explaining the spatial variability.

Olson *et al*. (2022) similarly found that buffer effects were evident for several fish and amphibian species in their study of riparian forest buffer management impact in western Oregon headwater streams. Higher densities of coastal giant salamanders, torrent salamanders and sculpin were detected in reaches with wide (~70 m), unmanaged buffer than in streams with more narrow buffers (6 m or 15 m) or with wide (140 m) but managed (thinned) buffers.

Table 4.5. Frequency Distribution of NRSA Stream Cover Data (Percent Shading), Stratified by Ecoregion and Stream Width
The 25th percentile of data, establishing the threshold between "lower" and "moderate" function index values, is highlighted in red. The 75th percentile of data, establishing the threshold between "moderate" and "higher" function index values, is highlighted in green. The 90th percentile of the data, establishing the threshold for the maximum index value (1.0), is highlighted in blue.

Natural Cover (%)				
Summary Statistics	Western Mountains		Xeric	
	Small (≤50')	Large (>50')	Small (≤50')	Large (>50')
Number of Sites	390	356	271	324
Minimum	0	0	0	0
Maximum	100	97.6	100	99.3
Arithmetic Mean	73.5	39.5	64.1	34.1
Standard Deviation	25.7	27.2	28.6	24.6
Distribution of Data				
1.0%	1.4	0	0	0.1
10.0%	33.3	6.3	20.7	5.2
25.0%	60.4	15.1	42.8	12.5
50.0%	82.4	37.4	70.9	30
75.0%	93.9	60.4	88.9	51.9
90.0%	98.4	77.5	95.9	71.3

Water Quality Functions

Individual studies (Sakamaki and Richardson, 2011) and literature reviews (Sweeney and Newbold, 2014) have found that canopy cover is one mechanism by which riparian buffers affect stream water quality measures and nutrient cycling. The effects of the riparian buffers on water quality are geographically specific and related to site and regional variables such as hillslope, upslope land management, evapotranspiration potential, stream gradient, and discharge. While riparian harvest clearly impacts stream ecosystems, in a meta-analysis of studies the direction and magnitude of change in water chemistry, primary production, and organic matter inputs was highly variable (Richardson and Béraud, 2014). Anderson *et al.* (2007) found that effective riparian buffer width can be defined by topographic variation or vegetation community transition as it relates to nutrient cycling and temperature regulation.

Nutrient Cycling

Despite the variable influence of riparian vegetated corridor width, studies in the Pacific Northwest lead to some generalizations. For a summary of the relationship between riparian corridor width and nutrient cycling, which includes functions provided by the canopy such as allochthonous carbon input, see resources cited in the rationale for Vegetated Riparian Corridor Width (**Section 4.2[F5]**).

Thermal Regulation

A review of multiple studies from across the Pacific Northwest finds that the shading and temperature control that a riparian buffer provides depend in part on the width of the buffer since light may pass obliquely to the stream entirely through the understory. Sweeney and Newbold (2014) suggest a minimum buffer width of 20-30 m depending on length of buffer along stream, stream size, orientation, local topography, and the type, height, and density of streamside vegetation. In particular, Sweeney and Newbold (2014) note that streams oriented north-south may require wider buffers to promote thermal regulation function.

A collaborative study between the Bureau of Land Management, U.S. Department of Agriculture, U.S Geological Survey (USGS), and Oregon State University in western Oregon forests found that buffers ≥ 15 m width ensure daily maximum air temperature above stream center increased by ≤ 1°C, and that daily minimum relative humidity was ≤ 5% lower than for reaches with no upslope harvest (Anderson *et al.,* 2007). However, the authors caution that rather than define a constant buffer width, buffers of widths defined by the transition from riparian to upland vegetation or topographic slope breaks appear sufficient to mitigate the impacts of upslope harvest (Anderson *et al.,* 2007).

Other studies have found light, irradiance, temperature, and photosynthetically active radiation (PAR) to be controlling factors in stream primary production, nutrient cycling, and chemical fate (Kiffney *et al*., 2003; Sakamaki and Richardson, 2011). Kiffney *et al.* (2003) found that in small streams periphyton biomass, PAR, and temperature increased as buffer width decreased from 30 m to 10 m to 0 m.

In a review comparing Coast Range forests (western Oregon) and Blue Mountain forests (eastern Oregon), Allen and Dent (2001) showed that total cover was approximately 17% less in unharvested Blue Mountain sites versus Coast Range sites, and 27% less in harvested sites. Unharvested stands had higher function in terms of shade provided to the stream, which is important to temperature regulation. In the Blue Mountains, areas of higher shading had a significant difference in basal area (large tree abundance) compared to areas of lower shading ($p<0.001$). The low and high shade categories began to differ at 40 feet from bankfull ($p=0.076$). No difference between shade categories was observed in Coast Range riparian forest zones demonstrating a difference in relative contribution of large trees to shading. In summary, shade over streams in the Blue Mountains appears to be more sensitive to having additional trees farther away from the stream than the Coast Range. Allen and Dent (2001) developed two separate models to relate forest cover to shade for the two regions, which supports the stratification of SFAM Natural Cover standard performance indices by ecoregion.

In a study of cumulative effects of riparian disturbance of grazing in eastern Oregon (John Day

River Basin), investigators found greater canopy cover was associated with lower daily maximum temperatures and rainbow trout abundance was negatively correlated with solar radiation and maximum temperature, particularly in streams with a north-south aspect that would have longer daily exposure to solar radiation (Li *et al*., 1994). In this study, as in western Oregon streams, solar insolation causes an increase in algal and invertebrate biomass. However unlike in Western Mountains ecoregion streams, increases in invertebrate biomass were not related to trout uses, demonstrating that in xeric regions of eastern Oregon where temperature nears lethal levels for salmon and trout, thermal regulation is a stronger driver of trout abundance than invertebrate abundance.

The effects of climate change on stream temperature and suitable habitat for salmonids are of significant concern. Modeling studies predict stream warming in Pacific Northwest streams over the next 20-40 years will reduce the available habitat for salmonids (Fuller *et al*., 2022; Wondzell et al., 2019). Large-scale restoration of riparian vegetation shade has been shown to offset some or all the expected stream temperature impacts of climate change (Cao *et al*., 2016; Fuller *et al*., 2022; Justice *et al*., 2017; Wondzell *et al*., 2019). Simulations conducted for the John Day Basin in Oregon estimated a '2002 baseline' effective shade of 19% and considered several scenarios of effective shade cover, including a scenario with a mature riparian forest having 50% canopy density providing 70% effective shade (Wondzell *et al.,* 2019). Simulations using this mature forest level of shade resulted in a 5.8-8.9 ºC reduction in seven-day average daily maximum temperature along the 37 km study reach. In a similar study in northeastern Oregon, Justice *et al*. (2017) found that a combination of riparian restoration and channel narrowing predicted an average reduction of 6.5 ºC in peak summer water temperatures in the Upper Grande Ronde River and an average reduction of 3.0 ºC in Catherine Creek in the absence of other perturbations resulting in increases in modeled Chinook salmon (*Oncorhynchus tshawytscha*) parr abundance of 590% and 67% respectively. Justice *et al*. (2017) expect that the climate change impact on water temperature will be substantial (median increase in Grande Ronde 2.7 ºC by 2080) and predict that basin wide restoration of riparian vegetation and channel width could offset expected water temperature increases.

Table 4.6. Summary of Supporting Literature and Data for Natural Cover Standard Performance Indices

Reference	Metric	Function Response Variable	SFAM Functions Informed	Metric Classifications	Informative Conclusions
Data Sources					
USEPA NRSA Rivers and Streams Assessment data (2008-2019)	% canopy cover at stream banks using NRSA metric XDENBNK	Stream condition	None	Many available; evaluated ecoregion and stream width (large vs small)	Evaluation of this large data set (n=965) from stream reaches representative of the Ecoregions which occur in Oregon provide the expected range and distribution of stream cover measures.
Decision Support for Biologic and Water Quality Functions					
Allen and Dent, 2001	Trees per 1,000 feet	Shade	TR	Coastal Range, Blue Mountains, Oregon	Contribution of riparian trees to shade differs between East and West Regions; supports stratification by region
Anderson *et al.*, 2007	Variable buffer width; upslope thinning treatments	Temperature (microclimate) changes	TR	Coastal Range, PNW, western Oregon forests; headwaters	Buffers at least 15 m kept increase in max daily temp ≤1 °C and decrease in humidity ≤5%, regardless of upslope treatment. Buffer widths defined by topographic or vegetation transition are sufficient.
Cao *et al.*, 2016	Modelled stream temperature	Riparian cover shade; projected precipitation, discharge, air temperature and land use changes	TR	Puget Sound Basin, Washington	Restoration of riparian vegetation could mitigate much of the projected stream temperature increases; and at a basin scale, the effect of riparian vegetation cover is much larger than that of land-use change on stream temperatures.
Fuller *et al.*, 2022	Modelled stream temperature	Riparian shade and climate change scenarios	TR	Columbia River Basin	Riparian vegetation shade restoration across large spatial extents could reduce stream temperatures (0.62 °C) from their current state.
Justice *et al.*, 2017	Temperature, salmon abundance	Riparian vegetation shade and channel morphology	TR, STS, MB, CMH	Northeast Oregon, Grande Ronde River Basin	Riparian vegetation shade restoration and channel narrowing was predicted to reduce peak summer water temperatures by 6.5 °C on average in the Upper Grande Ronde 3.0 °C in Catherine Creek resulting into increases in Chinook salmon parr abundance of 590% and 67% respectively.

Reference	Metric	Function Response Variable	SFAM Functions Informed	Metric Classifications	Informative Conclusions
Kiffney *et al.,* 2003	Buffer width	Periphyton growth, Chlorophyll a, dissolved nutrients, temperature, PAR	TR, STS, NC	PNW, managed forest; headwaters	PAR, temperature increased as buffer decreased and this resulted in increased PP (Chlorophyll a and periphyton biomass). The authors note that light penetrates through sides of the buffer.
Li *et al.*, 1994	Insolation	Temperature, algal biomass, invertebrate biomass, rainbow trout biomass, other stream habitat characteristics	TR, STS	John Day River Basin, Oregon	Effect of solar insolation due to lack of canopy cover is to increase temperature to levels that elevate primary and secondary productivity but reduce fish abundance. Response differs in Xeric vs Western Mountains rivers. Supports stratification by ecoregion.
Olson *et al.*, 2022	Fish and amphibian abundance and size metrics	Riparian buffer management (widths)	TR, STS	Western Oregon	There is a positive association of aquatic species density with larger and unmanaged (un-thinned) riparian buffers in western Oregon headwater streams.
Sakamaki and Richardson, 2011	Buffer width; vegetation (conifer or conifer + deciduous mix)	Rock biofilm (stream-origin POM), fine sediment POM, and fine POM suspended in water, and benthic macro-invertebrates	TR, STS	PNW, managed forest; headwaters	A six-variable model explained 72.6% of total variance in biogeochemical properties of fine POM, but riparian buffer was not significant alone. Fine POM of sediment is a good indicator of local environment, while fine POM of water is not. Fine sediment POM was significantly related to irradiance and coarse POM.
Sweeney and Newbold, 2014	Review paper-buffer width to maintain stream health	Temperature	TR	Various	Buffers ≥ 30 m wide are needed to protect the physical, chemical, and biological integrity of small streams with watersheds 100 km^2, or about fifth order or smaller in size.
Whitney *et al.*, 2020	Modelled juvenile salmon biomass	Multiple physical and biogeochemical condition scenarios including canopy cover	TR, STS	Northern Washington State, Methow River Basin	Restoration outcomes were variable across twelve stream reaches but can result in large increases in juvenile salmon biomass; riparian cover and stream temperature were leading factors explaining the spatial variability in outcomes

Reference	Metric	Function Response Variable	SFAM Functions Informed	Metric Classifications	Informative Conclusions
Wondzell *et al.*, 2019	Modelled stream temperature	Air temperature, discharge and riparian vegetation	TR	Northeast Oregon, John Day River Basin	Simulations of stream temperature showed a wide range of future thermal regimes ranging from 2.9 °C warmer to 7.6 °C cooler depending primarily on shade from riparian vegetation.

Notes:
CPOM: Coarse particulate organic matter
NC: Nutrient Cycling
PAR: Photosynthetically active radiation
PNW: Pacific Northwest
POM: Particulate organic matter
PP: Primary production
STS: Sustain Trophic Structure
TR: Thermal Regulation

MEASURE DEVELOPMENT

Except for revised standard performance indices and thresholds reflecting an updated analysis including additional data from the 2018-2019 NARS surveys, and inclusion of more recent scientific support literature, this measure remains unchanged from the previous version of SFAM (Nadeau *et al*., 2020a). The data collection protocol for this measure is consistent with the protocol used in the NARS surveys. For more information on the development history and inclusion of this measure of function in SFAM, please see Nadeau *et al*. (2020b; Section 4.2(a)).

F2. Invasive Vegetation

MEASURE TEXT

What is the percent cover of invasive plants within the PAA?

Conduct a line-intercept survey along three transects in the PAA to evaluate riparian vegetation composition. This method is used to collect data for three functional groups of vegetation, including invasive vegetation. Consult the SFAM User Manual (Appendix 4) for a list of plant species considered invasive in Idaho. Additional information on invasive vegetation is available on the iNaturalist web site (https://www.inaturalist.org/observations?place_id=22&project_id=imapinvasives-usa-and-canada-invasive-species&verifiable=any&iconic_taxa=Plantae).

MEASURE DESCRIPTION

This measure indicates the presence and relative abundance of non-native, invasive plant species. 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 habitat availability, diversity, and food resource availability on the floodplain or at the stream margin. The presence of invasive plants can create increased competition for native species and can alter habitat and food resources available for wildlife.

Function Group: Biology
Functions Informed: Maintain Biodiversity (MB), Sustain Trophic Structure (STS)
Stratification: This measure is not stratified
Metric: Percent cover

Model:

IF InvVeg ≥ 50, THEN = 0.0

IF InvVeg > 15 - < 50, THEN=-0.0086*InvVeg+0.4286

IF InvVeg = 1-15, THEN= -0.0286*InvVeg + 0.7286

IF InvVeg < 1, THEN= -0.3*InvVeg + 1

Table 4.7. Invasive Vegetation Scoring Index

Invasive Vegetation as measured by percent cover				
Function Value Ranges	Low		Moderate	High
Field Value	≥ 50	> 15 - < 50	1-15	< 1
Index Value	0.0	> 0.0 - < 0.3	0.3-0.7	> 0.7-1.0

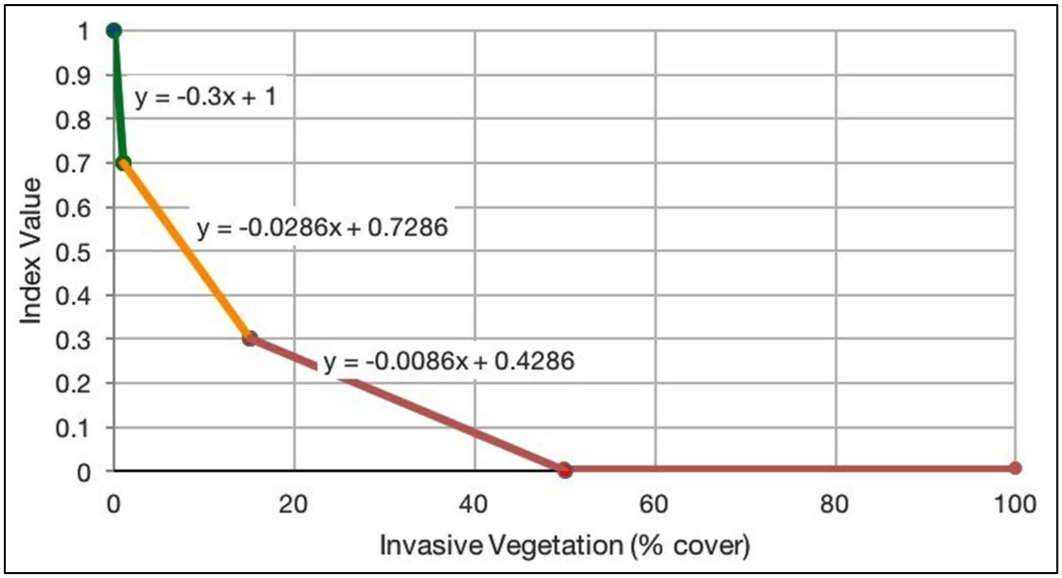


Figure 4.8. Invasive Vegetation Standard Performance Index

STANDARD PERFORMANCE INDEX

Development Method

Extensive information in the scientific literature indicates that when invasive plant species establish in place of native species, the altered successional trajectories can change the biological environment leading to changes in local and watershed scale riparian ecology (see papers cited in Schmitz and Jacobs, 2007). The development of the standard performance index for this measure was informed by data from studies conducted in the western U.S., and index thresholds are based on an assessment of these studies and current scientific understanding of the effects of invasive vegetation. The model for this measure uses continuous data to make the best use of the data collection method.

SCIENTIFIC SUPPORT FOR ECOLOGICAL FUNCTIONS

Biologic Function

Studies of invasive vegetation suggest that relatively low levels of invasion may lead to monocultures of plant cover relatively rapidly in areas of the Pacific Northwest (e.g., within a decade). It is hypothesized that monocultures of riparian vegetation would alter ecosystems by altering trophic structure and biodiversity compared to native and more diverse vegetation communities. Some authors have studied the effect of changes in allochthonous inputs, nutrients and decay rates by plant species in the Pacific Northwest, however it is challenging to relate the change in plant composition to change in biological function, and the effect of invasive vegetation differs depending on the invasive species (e.g., Braatne *et al*., 2007; Mineau *et al*., 2012). Using an approach to relate the most common invasive weeds in the western U.S. to biological function, Ringold *et al*. (2008) observed that instream biotic integrity was lower when even a single invasive plant target taxon was present than when invasive plant species were absent. Taken together, these findings support best professional judgment that suggests that relatively low levels of cover by invasive vegetation (e.g., invasive vegetation < 1%) can reduce stream function to moderate levels.

Table 4.8. Summary of Supporting Literature for Invasive Vegetation Standard Performance Index

Reference	Metric	Function Response Variable	SFAM Functions Informed	Informative Conclusion
Braatne *et al.*, 2007	Allochthonous leaf litter organic matter input	Macroinvertebrate colonization	MB, STS	Allochthonous inputs from Japanese knotweed had no effect on leaf decomposition or macroinvertebrate dynamics
Mineau *et al.*, 2012	Organic matter processing	Primary production, Ecosystem respiration	STS	Russian olive altered allochthonous inputs but not autochthonous organic material processing
Ringold *et al.*, 2008	Invasive weed presence	Instream Biotic Integrity indices	MB, STS	Lower IBI with presence of common invasive weeds

Notes:
CMH: Create and Maintain Habitat
IBI: Index of Biological Integrity
MB: Maintain Biodiversity
STS: Sustain Trophic Structure

MEASURE DEVELOPMENT

This measure remains unchanged from the previous version of SFAM (Nadeau *et al*., 2020a). For more information on the development history and inclusion of this measure of function in SFAM, please see Nadeau *et al*. (2020b; Section 4.2(b)).

F3. Native Woody Vegetation

MEASURE TEXT

What is the percent cover of native woody vegetation within the PAA?

Conduct a line-intercept survey along three transects in the PAA to evaluate riparian vegetation composition for three functional groups of vegetation, including native woody vegetation.

MEASURE DESCRIPTION

This measure indicates the presence and relative abundance of native woody vegetation. 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 habitat availability, diversity, and food resource availability on the floodplain or at the stream margin. Increased cover of woody vegetation often indicates higher quality riparian areas as the vegetation can create microclimates, increase habitat complexity, facilitate terrestrial/aquatic interactions, and provide organic material to the stream system.

Function Group: Biology
Functions Informed: Maintain Biodiversity (MB), Create and Maintain Habitat (CMH)
Stratification: This measure is not stratified
Metric: Percent cover

Model:

IF WoodyVeg < 20, THEN=0.015*WoodyVeg;

IF WoodyVeg = 20-60, THEN= 0.01*WoodyVeg + 0.1;

IF WoodyVeg > 60, THEN=0.0075*WoodyVeg + 0.25

Table 4.9. Native Woody Vegetation Scoring Index

Native Woody Vegetation as measured by percent cover			
Function Value Ranges	Low	Moderate	High
Field Value	< 2 0	20-60	> 60
Index Value	0.0 - < 0.3	0.3-0.7	> 0.7-1.0

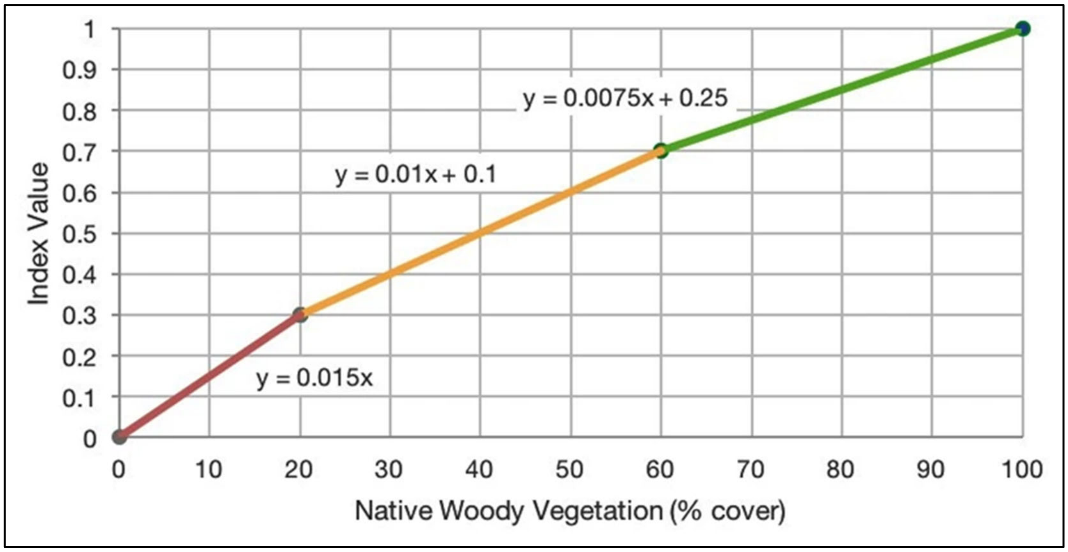


Figure 4.9. Native Woody Vegetation Standard Performance Index

STANDARD PERFORMANCE INDEX

Development Method

Riparian ecosystems provide essential ecological functions and are the focus of extensive research which indicates that while plant species may vary, native vegetation, including woody species, supports high functioning aquatic systems (see papers cited in Poff *et al.,* 2012). The development of the standard performance index for this measure was informed by data from studies conducted in the western U.S., and index thresholds are based on an assessment of these studies and current scientific understanding. The model for this measure uses continuous data to make the best use of the data collection method.

SCIENTIFIC SUPPORT FOR ECOLOGICAL FUNCTIONS

Biologic Function

In the John Day River Basin of eastern Oregon, cover by shrubs ranged from 0-65% in reaches where grazing was prevented and with better riparian area function (e.g., association with higher mesic and wetland plant diversity) (Kauffman *et al.,* 2002). In a high mountain meadow (Stanley Basin, Idaho), light or medium grazing reduced willow cover 19% and 27% respectively, compared to no grazing over 10 years; however, all three treatments showed increases in willow cover suggesting sites represented some recovery of condition and are within the range of moderate to good function (Clary, 1999). In western Oregon, riparian areas with shrub cover of approximately 60-85% occur naturally in mature forests (Hibbs and Bower, 2001; Pabst and Spies, 1998). Taken together, studies suggest that in more arid regions, shrub cover (like tree cover) can range considerably in streams considered to be in relatively good condition, however the addition of shrubs and trees can improve function for species that depend on wetland-type environments and shade. High stream function is likely to occur where woody vegetation is greater than 60%, whereas reductions of approximately 20-40% of woody vegetation cover can still provide moderate stream function.

Table 4.10. Summary of Supporting Literature for Native Woody Vegetation Standard Performance Index

Reference	Metric	Function Response Variable	SFAM Functions Informed	Informative Conclusion
Clary, 1999	% willow cover	Vegetation community	CMH	Light or medium grazing reduced woody vegetation recovery 19% and 27% respectively
Hibbs and Bower, 2001	% cover by overstory canopy (conifer or hardwood), shrubs, herbs; seedlings per hectare	Managed riparian area or unlogged	MB, CMH	High function streams may have large tree cover ≥50% and woody vegetation cover ≥85%
Kauffman *et al.*, 2002	% cover for shrubs, trees	Indices of plant biodiversity, wetland indicator score	CMH	Woody vegetation cover above 65% indicates good condition with elevated function
Pabst and Spies, 1998	% cover by species	Vegetation community	MB, CMH	High function streams may have mean woody vegetation cover of 63%

Notes:
CMH: Create and Maintain Habitat MB:
Maintain Biodiversity

MEASURE DEVELOPMENT

This measure remains unchanged from the previous version of SFAM (Nadeau *et al*., 2020a). For more information on the development history and inclusion of this measure of function in SFAM, please see Nadeau *et al*. (2020b; Section 4.2(c)).

F4. Large Trees

MEASURE TEXT

What is the percent cover of large trees (DBH>20 in) within the PAA?

Conduct a line-intercept survey along three transects in the PAA to evaluate riparian vegetation composition for three functional groups of vegetation, including large trees. Large trees are those trees with a diameter at breast height (DBH) greater than 20 inches. Note that cover from large, native trees will be counted twice; once as native woody vegetation and once as large trees.

MEASURE DESCRIPTION

This measure indicates the presence and relative abundance of large trees. The biotic community is the most visible testament to the overall health of the river system. The vegetation community, and particularly large trees, provide a spatially persistent and long-lived metric to evaluate habitat availability, diversity, and food resource availability on the floodplain or at the stream margin. The presence of large trees is assessed independently from other types of woody vegetation as it indicates longevity of the riparian habitat and a persistent source of in-stream wood.

Function Group: Biology
Functions Informed: Maintain Biodiversity (MB), Create and Maintain Habitat (CMH)
Stratification: This measure is stratified by ecoregion
Metric: Percent cover

Model:

Northern Rockies Ecoregion:

IF LgTree < 10, THEN = 0.03*LgTree

IF LgTree = 10-40, THEN = 0.0133*LgTree + 0.1667;

IF LgTree > 40, THEN = 0.005*LgTree + 0.5

Central, Southern, and Eastern Idaho Ecoregions:

IF LgTree < 10, THEN = 0.03*LgTree

IF LgTree = 10-20, THEN = 0.04*LgTree - 0.1;

IF LgTree > 20, THEN = 0.0038*LgTree + 0.625

Table 4.11. Large Trees Scoring Index

Large Trees as measured by percent cover			
Function Value Ranges	Low	Moderate	High
Field Value - Northern Rockies ecoregion	< 10	10-40	> 40
Field Value - Central and Eastern Idaho ecoregions	< 10	10-20	> 20
Index Value	0.0 - < 0.3	0.3-0.7	> 0.7-1.0

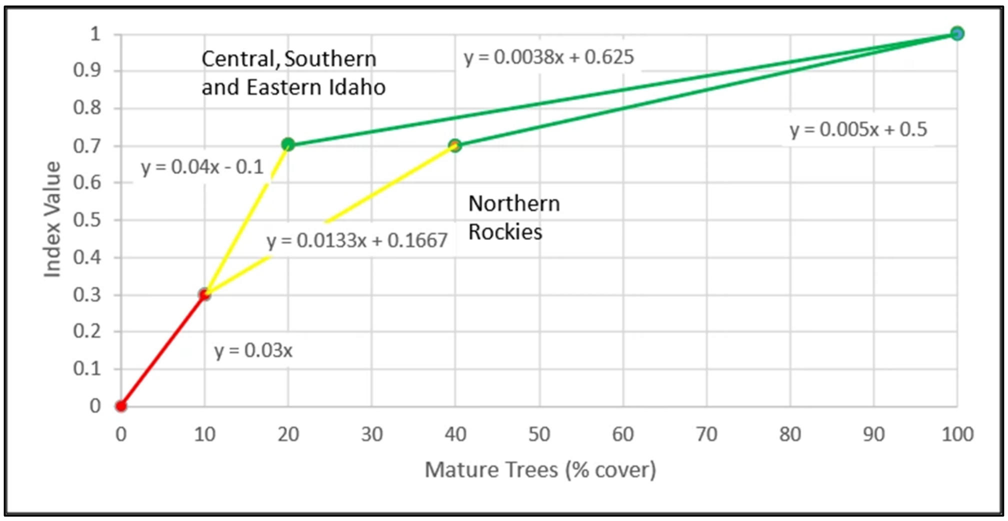


Figure 4.10. Large Trees Standard Performance Index

STANDARD PERFORMANCE INDEX

Development Method

The development of the standard performance index for this measure was informed by data from studies conducted in the Pacific Northwest and literature describing forest composition in Idaho.

Stratification

Trends presented in the literature supported stratifying expectations of large tree cover based on ecoregion. While Idaho-specific data on large tree cover and comparisons across riparian areas of Idaho are limited, in Oregon, Allen and Dent (2001) and Dent (2001) compared conditions at sites statewide and their data indicated that the cover of large trees around streams differs noticeably between the wetter west and dryer east sides of the state.

Idaho, like Oregon, has an extremely varied climate and diversity of ecosystems (Jackson and Kimerling, 2003). The Idaho Panhandle is comprised largely of the Northern Rockies Level III ecoregion (Figure 4.11), which has a wet and cool maritime-influenced climate producing denser forests of large coniferous trees relative to the other ecoregions of Idaho (McGrath *et al.*, 2002;

Witt *et al.*, 2012). The mixed conifer forests of the Northern Rockies ecoregion share some similarities to the forests of western Oregon, but do not provide for the same productivity and resulting tree size and density as those in western Oregon (Jackson and Kimerling, 2003). The central, southern, and eastern parts of Idaho include the Blue Mountains, Columbia Plateau, Idaho Batholith, Northern Basin and Range, Snake River Plain and Middle Rockies ecoregions (Figure 4.11). The forests of the Idaho Batholith and Central Rockies tend to be relatively dry, with low density pine forests similar to those found in the Blue Mountains of eastern Oregon (McGrath *et al.*, 2002). Therefore, the standard performance curve for large trees in Idaho is stratified between the Northern Rockies and the rest of the state, with the expectation of greater large tree cover in riparian areas of the Northern Rockies ecoregion.

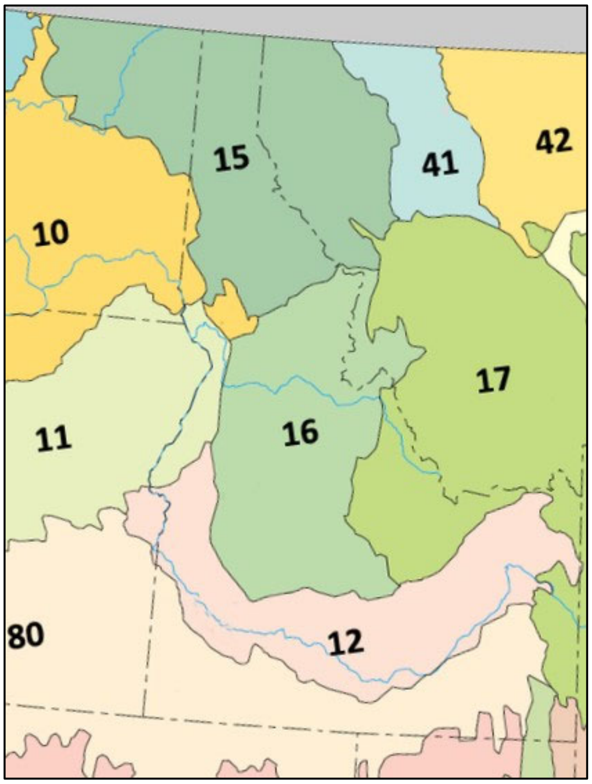


Figure 4.11. Level III Ecoregions of Idaho

Columbia Plateau (10), Blue Mountains (11), Snake River Plain (12), Northern Rockies (15), Idaho Batholith (16), Middle Rockies (17) and Northern Basin and Range (80). All ecoregions except the Northern Rockies are included in central, southern, and eastern Idaho for purposes of this measure. Image excerpted from USEPA Level III Ecoregions of the Continental United States map available at https://www.epa.gov/eco-research/level-iii-and-iv-ecoregions-continental-united-states.

SCIENTIFIC SUPPORT FOR ECOLOGICAL FUNCTION

Biologic Function

Large riparian trees contribute to stream function by providing a source of large wood to the stream channel, significant stream shade, and allochthonous inputs to the aquatic food web. The functional importance of shade and inputs to the aquatic food web are discussed with the Cover measure in **Section 4.2(F1)** above. The in-stream wood provided by large trees is functionally significant because it can be long-lived and greatly influence sediment dynamics in streams.

Large-diameter wood is particularly important in retaining sediment and forming jams (Abbe and Montgomery, 2003). Wood provided by large trees also experiences longer residence times in streams (Wohl and Goode, 2008). Additional discussion of the functional importance of large wood in streams can be found in the Wood measure **Section 4.2(F14)** below.

Woody vegetation cover may vary considerably across streams considered to be in good condition. Kauffman et al. (2002) found that total cover of woody vegetation (trees + shrubs) ranged from 1 to 129% across stream reaches in various conditions, with cover by trees ranging from 0 to 9%. Dent (2001) showed that on eastern Oregon streams, the number of large trees (basal area of hardwoods + conifer) and the maximum canopy cover provided (which creates shading that contributes to habitat structure) are on average about half that seen on western Oregon streams. Review of literature on mature forests (Dent, 2001) shows the basal area of mature trees in managed forest in eastern Oregon may be, on average, three quarters of that in western Oregon. Mature trees may not be present even in stream sections considered to be in good condition. However, where mature trees are present, shading improves function by lowering temperatures, and the presence of large trees is associated with more salmonids and sculpins and higher macroinvertebrate biomass (Tait et al., 1994). These studies provide evidence that in the dryer ecoregions, expectations for high stream function are associated with less large tree cover (≥ 20%) than in the wetter ecoregions.

Generally, canopy cover provided by large trees has been found to be similar between unlogged forests and managed riparian buffers adjacent to logged areas, which supports the use of managed riparian buffers for maintaining stream function (Allen and Dent, 2001; Dent, 2001; Hibbs and Bower, 2001). A literature review showed cover values (as it relates to shade) ranged up to 75 to 82% in old growth stands, 89% in stands with no recent harvest, and 71-90% in harvested areas with 30 to 50-foot buffers (Allen and Dent, 2001). However, the probability of trees becoming large wood is reduced in managed riparian stands compared to unlogged stands by as much as 60% (Dent, 2001), and unharvested stands tended to have greater average shade, live crown ratios, tree heights, basal area, and trees per acre in both the wetter and dryer areas of Oregon, but especially in the dryer eastern side (Allen and Dent, 2001). Total shade-producing cover was approximately 17% less in unharvested Blue Mountain sites compared to Oregon Coast Range sites, but approximately 27% less in harvested sites (Allen and Dent, 2001). For SFAM purposes, the assumption was made that managed riparian buffers, while affected by human disturbance, still contribute to a moderate to high stream function.

Table 4.12. Summary of Supporting Literature for Large Tree Standard Performance Indices

Reference	Metric	Function Response Variable	SFAM Functions Informed	Informative Conclusion
Allen and Dent, 2001	Trees per 1,000 feet	Shade	CMH	Contribution of riparian trees to shade differs between east and west regions of Oregon; supports stratification by region

Reference	Metric	Function Response Variable	SFAM Functions Informed	Informative Conclusion
Dent, 2001	Trees per 1,000 feet	Large wood recruitment potential, shade	CMH	In western region of Oregon, high function streams may have large tree cover ≥50%. In eastern region, high function streams may have large tree cover 25-40%; supports stratification by region
Hibbs and Bower, 2001	Percent cover by overstory canopy (conifer or hardwood), shrubs, herbs; seedlings per hectare	Managed riparian area or unlogged	MB, CMH	High function streams may have large tree cover ≥50%
Kauffman *et al.*, 2002	% cover for shrubs, trees	Indices of plant biodiversity, wetland indicator score	CMH	Woody vegetation cover above 65% indicates good condition with elevated function
Nierenberg and Hibbs, 2000	Species, DBH, age, dominant overstory type, tree regeneration	Frequency of dominant cover type	MB, CMH	High function streams may have large tree cover ≥50%

Notes:
CMH: Create and Maintain Habitat
DBH: Diameter at Breast Height
MB: Maintain Biodiversity

MEASURE DEVELOPMENT

Stratification of the standard performance indices of this measure of function are based on the ecoregions of Idaho, and informed by additional references, but otherwise this measure of function remains unchanged from the previous version of SFAM. For more information on the development history and inclusion of this measure of function in SFAM, please see Nadeau *et al*. (2020b; Section 4.2(d)).

F5. Vegetated Riparian Corridor Width

MEASURE TEXT

What is the average width of the vegetated riparian corridor within the PAA?

An intact vegetated riparian corridor is defined as one typified by largely undisturbed ground cover and dominated by "natural" species. Natural does not necessarily mean pristine and can include both upland plants and species with wetland indicator status, and native and non-native species. Natural does not include pasture or cropland, recreational fields, recently harvested forest, pavement, bare soil, gravel pits, or dirt roads. Note that relatively small features, such as a narrow walking trail, that likely have negligible effects on water quality can be included within the vegetated riparian corridor width.

MEASURE DESCRIPTION

This measure quantifies the length between the wetted edge of the channel and the point at which natural vegetation ceases, averaged across transects within the PAA. An intact vegetated riparian corridor acts as a filter for water and other material entering the stream from the adjacent watershed. Riparian vegetation provides a buffer from the potential negative impacts of adjacent land uses and reduces the amount of nonpoint source pollutants (sediment, nutrients) that reach the stream.

Function Group: Water Quality
Functions Informed: Nutrient Cycling (NC), Chemical Regulation (CR)
Stratification: This measure is not stratified
Metric: Absolute value (feet)

Model:

IF RipWidth < 33, THEN = 0.0091*RipWidth;

IF RipWidth = 33-99, THEN = 0.0061*RipWidth + 0.1;

IF RipWidth > 99, THEN = 0.0013*RipWidth + 0.5703;

IF RipWidth > 328, THEN = 1.0

Table 4.13. Vegetated Riparian Corridor Width Scoring Index

Vegetated Riparian Corridor Width (feet)				
Function Value Ranges	Low	Moderate	High	
Field Value	< 33	33-99	> 99-328	> 328
Index Value	0.0 - < 0.3	0.3-0.7	> 0.7-1.0	1.0

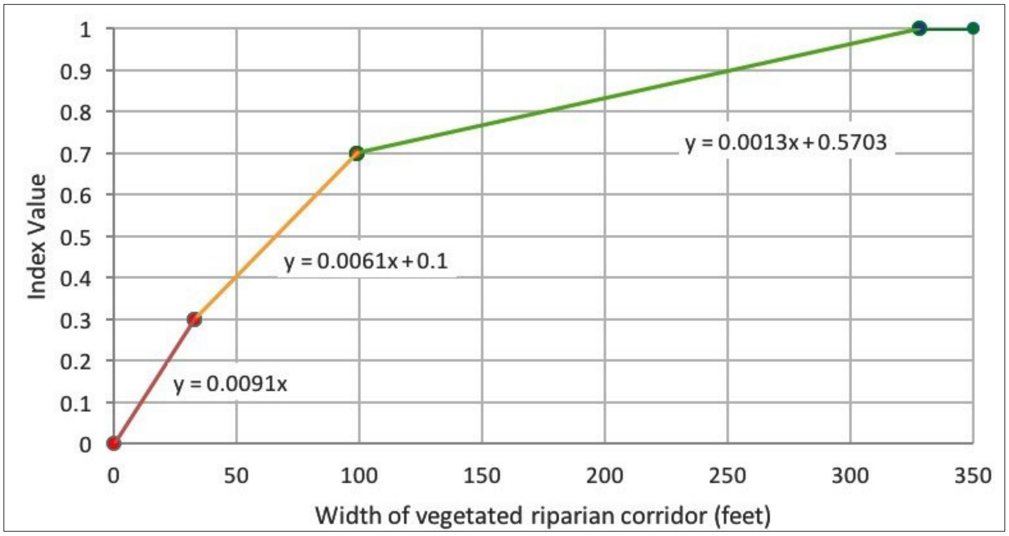


Figure 4.12. Vegetated Riparian Corridor Width Standard Performance Index

STANDARD PERFORMANCE INDEX

Development Method

Extensive work has been done evaluating the effectiveness of vegetated riparian corridors, and the width of such corridors, in attenuating excess nutrients and other pollutants and improving stream water quality (e.g., Mayer *et al*., 2005) and it remains an active area of research. The development of the standard performance index for this measure was informed by data from studies conducted primarily in the western U.S. and index thresholds are based on these studies.

SCIENTIFIC SUPPORT FOR ECOLOGICAL FUNCTIONS

Water Quality Functions

Individual studies (Sakamaki and Richardson, 2011; Wigington *et al*., 2003) and literature reviews (Gomi *et al*., 2005; Sweeney and Newbold, 2014) have found the effect of riparian buffer width on stream water quality measures and nutrient inputs, cycling, and removal to be geographically specific and related to site and regional variables such as hillslope, upslope land management, evapotranspiration potential, stream gradient, and discharge. While riparian harvest clearly impacts stream ecosystems, in a meta-analysis of studies the direction and magnitude of change in water chemistry, primary production, and organic matter inputs was highly variable (Richardson and Béraud, 2014). Anderson *et al.* (2007) find that effective riparian buffer width can be defined by topographic variation or vegetation community transition, while Gomi *et al.* (2005) suggest that riparian substrate composition be considered. Despite the variable influence of riparian buffer width, studies in the Pacific Northwest lead to some generalizations, discussed below.

In the literature reviewed here, stream discharge data is not always provided. Streams were typically identified as "headwaters," "tributaries," or by stream order. Based on the description of the streams available in the text and photographs, almost all streams studied would be considered small to medium in size (< 70 feet wide). The review by Sweeney and Newbold (2014) considers results from studies of 1st-5th order streams; however, results are not given by stream size. It is possible that larger streams are less studied because of challenges with manipulating the riparian buffer and detecting changes in function on a large scale.

Nutrient Cycling

In the Willamette Valley, Oregon, Sobota *et al.* (2012) used an ^{15}N tracer to look at the fate of nitrate in forested streams compared to urban and agricultural streams with and without a riparian buffer. Urban and agricultural streams with a buffer displayed export and uptake storage components more similar to forested streams than did those without a buffer. Nitrogen was more likely to be taken up by filamentous algae in streams without a riparian buffer (Sobota *et al.,* 2012). Uptake by autotrophic organisms may help explain why some studies have found no difference in dissolved nutrients when comparing post-harvest treatments in small streams (0 m, 10 m [33 ft], 20 m [66 ft] buffer) (Kiffney *et al*., 2003).

Studies done on small streams in an experimental forest in southwestern British Columbia found that the chemical signature of fine stream sediment POM varied with reach-scale conditions, including inputs of coarse POM (Sakamaki and Richardson, 2011), but that clear-cut reaches contributed significantly less litter than reaches with either a 10 m (33 ft) or 30 m (99 ft) riparian buffer (Kiffney and Richardson, 2010). However, decomposition rate of alder litter was significantly slower in clear-cut, 10 m (33 ft) buffer, and 30 m (99 ft) buffer reaches compared to reference reaches (Lecerf and Richardson, 2010). Therefore, we conclude that any buffer as narrow as 10 m (33 ft) for forested, agricultural, or urban streams may indicate a nutrient cycling function of moderate, but that buffers equal to or greater than 30 m (99 ft) are required, even in small streams, to ensure high functioning nutrient cycling similar to function prior to harvest or land use changes (Lecerf and Richardson, 2010; Sweeney and Newbold, 2014).

Chemical Regulation

Though many pollutants can impact stream health, the most commonly studied in the literature are excess nitrate (Sweeney and Newbold, 2014; Wigington *et al*., 2003) and excess or contaminated sediment input (Gomi *et al.,* 2005; Sweeney and Newbold, 2014). In understanding how buffer width relates to nitrate and sediment removal, we point to the review by Sweeney and Newbold (2014) where the authors considered 30 studies on nitrate removal by riparian corridors ranging from 5-220 m (16-722 ft), and 22 studies on sediment removal by riparian corridors ranging from 3-65 m (10-213 ft) in width. Plant compositions ranged from grass, sedge, herb, and shrub mix to forest. By combining data from these studies, Sweeney and Newbold (2014) developed an exponential relationship between buffer width and nitrate removal efficiency and a hyperbolic relationship between buffer width and sediment removal which are shown in graphical form below (**Figure 4.13**). Since Sweeney and Newbold (2014) included studies with riparian corridor plant composition dominated by a range of vegetation types (grass and sedge, shrub, herb, or forest), the results are applicable to both the Western Mountains and Xeric ecoregions in the Pacific

Northwest.

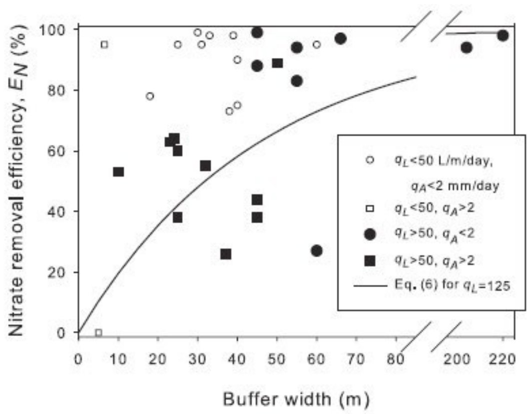


FIGURE 1. Nitrate Removal Efficiency *vs.* Buffer Width. Solid fill designates buffers receiving water flux $q_L \geq 50$ l/m/day. Square symbols designate areal loadings $q_A > 2$ mm/day. The curve is Equation (6) for $\alpha = 2.72$ l/m^2/day and $q_L = 125$ l/m/day.

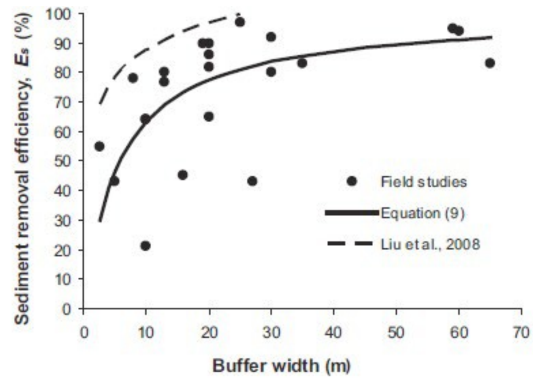


FIGURE 3. Sediment Removal Efficiency *vs.* Buffer Width. Studies were conducted in unconfined field settings or in plots where hydraulic loading was >1.0 l/m/s. Also shown are the least-squares fit of Equation (8) and the equation obtained by Liu *et al.* (2008), as fitted to 79 studies conducted under a broad range of conditions.

Figure 4.13. Relationship between Riparian Buffer Width and Nitrate or Sediment Removal Efficiency
Note: data from (Sweeney and Newbold, 2014)

Critical to = using the nitrate removal equation for buffer width is knowing the amount of subsurface flow (q) through the buffer at medium depth since that will affect removal efficiency (1.5-2.1 m [5-7 ft] depth) (Sweeney and Newbold, 2014; Wigington *et al.,* 2003). In addition, it is important to know the contribution of subsurface flow to total streamflow. For instance, a study of grassy agricultural 30-48 m (99-158 ft) buffers in Oregon's Willamette Valley found that buffers removed significantly more nitrate than the non-buffered treatment, but that in this case, poorly draining soils reduced subsurface flow and subsurface flow was such a small component of streamflow it did not have a measurable effect on stream nitrogen (Wigington *et al.,* 2003). Higher subsurface flow may enhance nitrate removal in waters passing through the biologically active root zone of the riparian area. To meet the objective that SFAM be a relatively rapid assessment of stream function, it is understood that subsurface flow may not be quantitatively characterized for most study sites. However, substrate conductivity may be roughly estimated based on known local geology. For sites where subsurface flow is sufficient to contribute substantially to streamflow, Sweeney and Newbold (2014) suggest a simplified model for nitrate removal efficiency where a 30 m (99 ft) buffer will have 48% nitrate removal efficiency, increasing to 90% removal efficiency for a 100 m (328 ft) buffer.

For sediment removal, the relationship is more straightforward, yet knowledge of K_{50}, the 50% efficiency buffer width, is still required and may not be readily available. Sweeney and Newbold (2014) suggest a simplified model for sediment removal efficiency where a 10 m (33 ft) buffer would remove approximately 65% of sediments and a 30 m (99 ft) buffer will trap about 85%. Sediment removal (and therefore chemical regulation for other pollutants) occurs at the surface and depends less on subsurface connectivity than nitrate removal.

We have plotted these relationships below, with nitrate removal in blue and sediment removal in black (**Figure 4.14**). An important observation is that for all stream sizes, riparian buffers show more efficient removal of sediment than nitrates for a given buffer width, as shown by the difference between the blue and black lines in **Figure 4.14**. It should also be noted that for streams with poor subsurface flow conductivity, the curves for nitrate removal efficiency would be shifted farther toward the left in this plot.

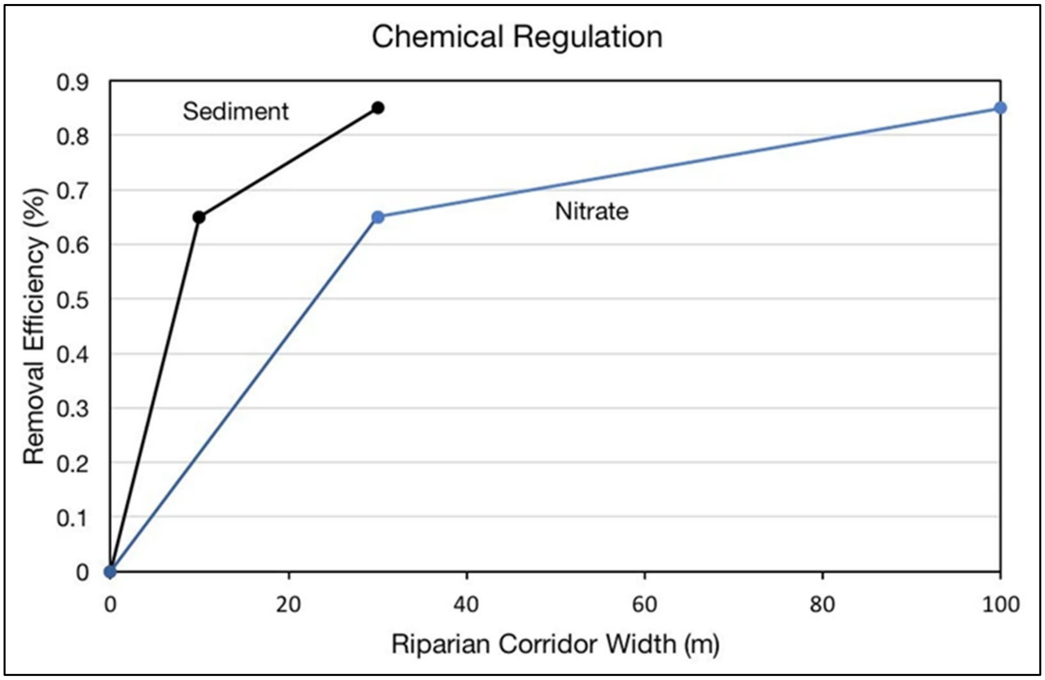


Figure 4.14. Relationships between Vegetated Riparian Corridor Width and Chemical Removal for Small to Medium Streams (Watersheds from 5-10,000 ha or 1st-5th Order Streams)

Nutrient cycling is largely driven by nitrogen cycles. Nitrate removal shows a similar response to riparian buffer width as nutrient cycling. **Table 4.14** shows a comparison of the magnitude of the response of each type of chemical response summarized by the literature presented here.

Table 4.14. Summary of Magnitude of Change in Stream Function with Increase in Riparian Width

	Functional Response		
Riparian Buffer Width	**Nutrient Cycling**	**Nitrate Removal**	**Sediment Removal**
< 10 m (< 33 ft)	Low	--	--
10 m (33 ft)	Moderate	--	65%
30 m (99 ft)	High	48%	85%
100 m (328 ft)	--	90%	--

To support SFAM use, a relatively conservative standard performance index was developed based on the magnitude in change of nitrate removal and nutrient processing in areas of good subsurface flow, thus encompassing a more general relationship between riparian buffer width and chemical and nutrient function.

Table 4.15. Summary of Supporting Literature for Vegetated Riparian Corridor Width Standard Performance Index

Reference	Metric	Function Response Variable	SFAM Functions Informed	Informative Conclusion
Gomi *et al.*, 2005	Regional review of forest management practices, buffer widths ranged from 0-30 m	Sediment inputs to stream and turbidity	CR	Local hillslope, length of buffer zone along stream, and roads are important to suspended sediment input. Wider buffer should be used in areas with deep unconsolidated sediment.
Kiffney and Richardson, 2010	Buffer width treatments: 0 m, 10 m, 30 m, control	Litter (CPOM)	NC	Input of CPOM was lower at clearcut sites; "A model with both linear and quadratic terms suggests a positive slope between litter inputs and buffer width, with a unit increase in reserve width from clear-cut sites up to about 10 m to 30 m treatments, with no further increase past this point."
Kiffney *et al.*,2003	Buffer width treatments: 0 m, 10 m, 30 m, control	Dissolved nutrients	NC	Dissolved N increased as buffer width decreased, but not significantly.
Lecerf and Richardson, 2010	Buffer width treatments: 0 m, 10 m, 30 m, control, 50% thinning	Decomposition rate by 1) stream shredder macro-invertebrates, 2) fungal	NC	Significantly slower shredder decomposition in clearcut reach regardless of buffer. No difference in fungal decomposition.

Reference	Metric	Function Response Variable	SFAM Functions Informed	Informative Conclusion
Richardson and Béraud, 2014	Meta-Analysis: effect size of riparian harvest treatments	Water chemistry, primary production, fine and coarse organic matter	NC, CR	Absolute value effect size in multiple measures was statistically significant. A publication bias for changes in conductivity, pH, phosphorus concentration results was found.
Sakamaki and Richardson, 2011	Buffer width treatments: 0 m, 10 m, 30 m, control; vegetation (conifer or conifer + deciduous mix)	Rock biofilm (stream-origin POM), fine sediment POM, and fine POM suspended in water, and benthic macroinvertebrates	NC	A six-variable model explained 72.6% of total variance in biogeochemical properties of fine POM, but riparian buffer was not significant alone. Fine POM of sediment is a good indicator of local environment, while fine POM of water is not. Sediment fine POM was significantly related to irradiance and coarse POM.
Sobota *et al.,* 2012	Land use; buffer vs. no buffer, width not given	Nitrogen tracer processing, storage, and fate	NC, CR	Urban and agricultural streams with riparian buffer had detectable denitrification and were more similar to forested streams in N cycle; non-buffered stream showed greater uptake by filamentous algae.
Sweeney and Newbold, 2014	Review Paper- buffer width to maintain stream health	Relevant functions: 1) Subsurface nitrate removal, 2) Sediment trapping	CR	Buffers ≥ 30 m wide are needed to protect the physical, chemical, and biological integrity of streams with watersheds 0.05-100 km^2 (5-10,000 ha), or about fifth order or smaller in size.
Wilkerson *et al.,* 2010	Buffer width treatments: 0 m, 11 m, 23 m, partial harvest with no buffer, control		NC	Unbuffered streams had significantly elevated concentrations of chlorophyll *a* as well as increased abundance of algae eaters 3 years after timber harvest. Streams with 11 m buffers had substantial (10-fold) but nonsignificant increases in chlorophyll *a* three years after harvest.
Wigington *et al.*, 2003	Buffer widths: 0 m and varying 30-48 m	Nitrate removal	CR	Riparian buffers of variable width related to significantly lower nitrate in shallow groundwater, but groundwater was a negligible input to total streamflow.

Notes:
Metric to standard conversions: 10m ≈ 33ft, 15m ≈ 50ft, 20m ≈ 66ft, 30m ≈ 99ft
CR: Chemical Regulation
CPOM: Coarse Particulate Organic Matter
DOC: Dissolved Organic Carbon
LWD: Large Woody Debris

NC: Nutrient Cycling
POM: Particulate Organic Matter PP: Primary Production
WQ: Water Quality

MEASURE DEVELOPMENT

This measure remains unchanged from the previous version of SFAM (Nadeau *et al*., 2020a). For more information on the development history and inclusion of this measure of function in SFAM, please see Nadeau *et al*. (2020b; Section 4.2(e)).

F6. Fish Passage Barriers

MEASURE TEXT

Is there a man-made fish passage barrier in the PAA?

Select an answer from the drop-down menu. Man-made barriers to fish passage can include structures such as dams, culverts, weirs/sills, tide gates, bridges and fords that can block physical passage or can create unsuitable conditions for passage (e.g., high velocity). The level of passage provided can first be researched in the office using Idaho Department of Fish and Game's (IDFG's) fish passage barrier GIS database (https://data-idfggis.opendata.arcgis.com/datasets/fish-barriers/explore), then confirmed in the field. Do not include natural barriers. If more than one barrier is present, answer for the one with the most restricted level of passage (e.g., blocked).

Not all fish passage barriers are documented, and recent actions to improve fish passage at a barrier may not be reflected in the fish passage barrier data layer. Idaho's design criteria for culverts and bridges are found in Idaho Administrative Code 37.03.07.059, which can be found at https://casetext.com/regulation/idaho-administrative-code/title-idapa-37-water-resources-department-of/rule-370307-stream-channel-alteration-rules/section-370307059-culverts-and-bridges. Contact your local IDFG office with questions.

MEASURE DESCRIPTION

This measure asks about the level of fish passage provided at man-made obstructions within the PAA. Connectivity allows fish to move, unhindered by man-made structures, between habitats. This affects not only the variety and life cycle forms of fish species, but the broader biological community composition, genetics, and resources necessary to sustain a variety of aquatic species.

Function Group: Biology
Functions Informed: Maintain Biodiversity (MB), Create and Maintain Habitat (CMH)
Stratification: This measure is not stratified
Metric: Degree of access

Model:

IF Passage = blocked, THEN = 0.0;

IF Passage = partial, THEN = 0.5;

IF Passage = none or unknown, THEN = 1.0

Table 4.16. Fish Passage Barriers Scoring Index

Passage measured as degree of access			
Function Value Ranges	**Low**	**Moderate**	**High**
Field Value	Blocked	Partial	No Barrier/Unknown
Index Value	0.0	0.5	1.0

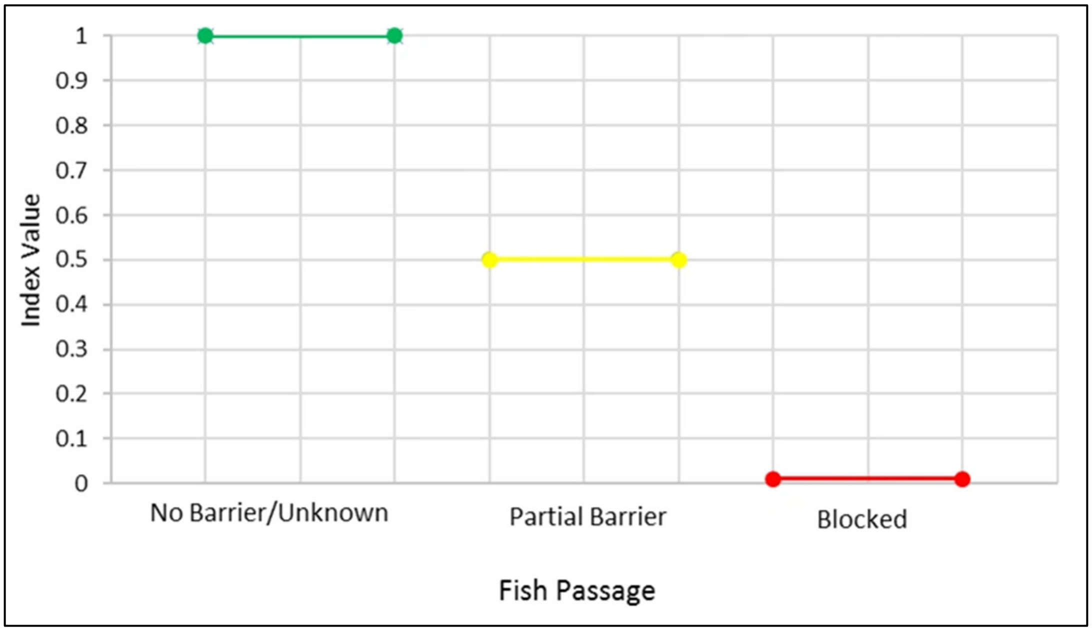


Figure 4.15. Fish Passage Barrier Standard Performance Index

STANDARD PERFORMANCE INDEX

Development Method

There are extensive data related to fish passage barriers, as well as scientific literature linking fish passage connectivity to biologic functions. The model for this measure uses categorical data (as opposed to continuous) given the relative difficulty in objectively assessing the degree of passage at different flow conditions, for different fish species, and for different life stages. Categorical breaks were informed by the relevant literature.

SCIENTIFIC SUPPORT FOR ECOLOGICAL FUNCTIONS

Biologic Functions

Barriers to fish passage can negatively impact a stream's functional ability to Create and Maintain Habitat (CMH) and Maintain Biodiversity (MB) by limiting fish access to needed habitats and resources including spawning grounds, juvenile rearing habitats, food resources, cold-water refugia and protection from high velocities during storm events.

Barriers to fish migration and the resulting fragmentation of stream networks has been recognized as a serious threat to the population diversity, abundance and persistence of many aquatic species world-wide (e.g., Dunham *et al*., 1997; Sheldon, 1988). The construction of infrastructure such as dams, culverts, and other water diversion structures are largely to blame for these connectivity losses (Doehring *et al*., 2011; Park *et al*., 2008). There are over two million dams and other structures across the United States that block fish from migrating to habitats used to complete their lifecycles (NOAA, 2017).

In the Pacific Northwest, barriers to native diadromous fish (salmon and steelhead) to access their spawning grounds has caused significant decreases in fish abundance and contributed to the listing of several Evolutionarily Significant Units (ESUs) on the endangered species list. In an evaluation of the impact of passage barriers to salmon in the Lower Columbia and Willamette River basins, Sheer and Steele (2006) identified 1,491 anthropogenic barriers to fish passage blocking 14,931 km (9278 mi) of streams; an estimated loss of 40% of fish habitat. Fish passage barriers not only limit access to spawning grounds but can exclude fish from important rearing habitat. In a case study on Washington's Skagit River, Beechie *et al*. (1994) estimated that the summer rearing habitat for coho salmon (*Oncorhynchus kisutch*) has been reduced by 24% and linked 10% of that reduction directly to culvert barriers.

Barrier removal can result in significant and rapid improvement to habitat availability for salmon and improve overall stream function. Idaho's Pahsimeroi River Chinook salmon population was previously restricted to the lower portion of the river by multiple irrigation structures. The largest barrier was removed in 2009, more than doubling the amount of accessible linear habitat. Copeland *et al.* (2020) documented redds in newly accessible habitat immediately following barrier removal and accounted for a median of 42% of all redds in the Pahsimeroi River watershed during 2009-2015. Snorkel surveys also documented juvenile rearing in newly accessible habitat.

Salmon are not the only species impacted by fish passage barriers. Lampreys, another important native species, also migrate up many Pacific Northwest streams and are unable to transverse many artificial barriers. Lacking paired fins, lampreys are weak swimmers and have no jumping ability. To climb, they must find rough surfaces that they can cling to in areas with low or moderate currents (Kostow, 2002).

Native non-migratory fish can also be impacted by fish passage barriers. Results from a genetic study of coastal cutthroat trout in southwest Oregon concluded that fish separated by passage barriers can persist as partially independent populations, and that fish passage barriers can dramatically and rapidly influence coastal cutthroat trout genetic variation (Wofford *et al*., 2005).

Some barriers allow for partial fish passage (dependent on season and fish size), meaning that the habitat can be accessed during certain parts of the year. SFAM acknowledges that some function may be provided when passage is only partially blocked.

Table 4.17. Summary of Supporting Literature for Fish Passage Standard Performance Index

Reference	Metric	Function Response Variable	SFAM Functions Informed	Informative Conclusions
Beechie *et al*., 1994	Habitat loss	Smolt production	MB	Human impacts, including fish passage barriers (culverts) reduce the rearing capacity of the Skagit river in Washington State.
Copeland *et al*., 2020	Fish passage barrier removal	Salmon reproduction	CMH, MB	Removal of barriers resulted in increased salmon reproduction and smolt rearing
Sheer and Steele, 2006	Fish passage barriers	Fish habitat	CMH, MB	Lower Columbia and Willamette Basin fish passage barriers result in an estimated loss of 40% of fish habitat.
Wofford *et al*., 2005	Fish passage barriers	Genetic variation	MB	Fish-passage barriers can dramatically and rapidly influence coastal cutthroat trout genetic variation.

Notes:
CMH: Create and Maintain Habitat
MB: Maintain Biodiversity

MEASURE DEVELOPMENT

When present, this measure is used as a modifier (by multiplication) to the instream aspects of the functions it informs (MB, CMH), rather than as a contributing factor to be averaged with other measures informing those functions (Section 3.3, Table 3.2). This is the only measure in SFAM used in this way.

Apart from the elimination of the 'passable' variable in the model for this measure, which does not exist in the Idaho data source, and the inclusion of more recent scientific support literature, this measure remains unchanged from the previous version of SFAM (Nadeau *et al*., 2020a). For more information on the development history and inclusion of this measure of function in SFAM, please see Nadeau *et al*. (2020b; Section 4.2(f)).

F7. Floodplain Exclusion

MEASURE TEXT

What percent of the floodplain area has been disconnected within the PAA?

For alluvial rivers, the floodplain is defined by a distinct break in slope at valley margins, a change in geologic character from alluvium to other, indications of historical channel alignments within a valley, or as the 100-year flood limit.

Disconnection refers to any portion of the floodplain area no longer inundated due to levees, channel entrenchment, roads or railroad grades, or other structures (including buildings and any associated fill) within the proximal assessment area. All barriers should be included when estimating disconnection, even if the barrier is not present during all flood stages (e.g., a barrier up to the 25-year flood, but not during the 100-year flood); except where the structure is expressly managed for floodplain function and inundation.

MEASURE DESCRIPTION

This measure represents a stream's ability to access its floodplain. Floodplain connectivity results in areas that are capable of storing water and providing floodplain habitat. Connectivity to the floodplain allows organisms and material (water, sediment, organic matter) to move, unhindered by anthropogenic structures, perpendicular to the axis of the stream corridor with a frequency consistent with natural flood regimes.

Function Groups: Hydrology, Biology
Functions Informed: Surface Water Storage (SWS) and Create and Maintain Habitat (CMH)
Stratification: This measure is not stratified
Metric: Percent exclusion

Model:

IF Exclusion > 80%, THEN=0.0;

IF Exclusion > 40-80%, THEN=0.2;

IF Exclusion > 20-40%, THEN=0.5;

IF Exclusion ≤ 20%, THEN=1.0

Table 4.18. Floodplain Exclusion Scoring Index

Exclusion measured as percent disconnection				
Function Value Ranges	Low		Moderate	High
Field Value	> 80%	> 40-80%	> 20-40%	≤ 20%
Index Value	0.0	0.2	0.5	1.0

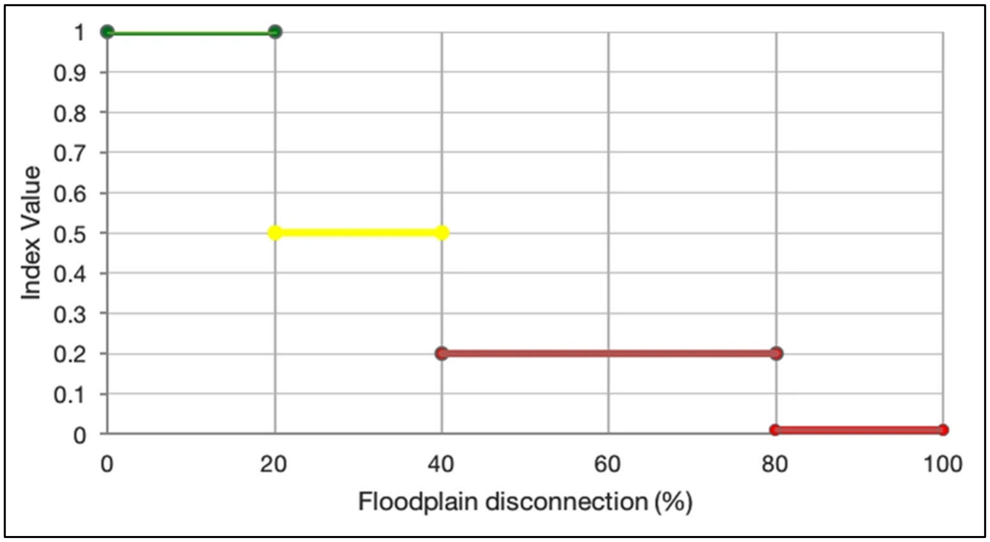


Figure 4.16. Floodplain Exclusion Standard Performance Index

STANDARD PERFORMANCE INDEX

Development Method

There is extensive data related to floodplain exclusion, as well as literature that links floodplain connectivity to hydrologic and biologic functions. The development of the standard performance index for this measure was supported by data from numerous studies throughout the Pacific Northwest.

The model for this measure uses categorical data (as opposed to continuous) given the relative difficulty in rapidly and objectively assessing a precise degree of disconnection. Categorical breaks were informed by the relevant literature.

SCIENTIFIC SUPPORT FOR ECOLOGICAL FUNCTIONS

Hydrologic Function

Exclusion, as defined in the SFAM model, has been reported in the literature in terms of floodplain connection or disconnection. Where streams can access their floodplains, floodplains can provide surface water storage in intermittent or ephemeral meanders or wetlands. Most floodplains and floodplain wetlands are highly disconnected from streams in the Pacific Northwest, and it is widely recognized that during high flows, surface water storage can be reduced and flow velocities can increase in the main channel, conveying larger-magnitude flood peaks to downstream areas than under historic conditions. However, little work has been done to directly measure the effect of floodplain disconnection in the Pacific Northwest on surface water storage as a function provided by floodplains. The loss of surface water storage is a growing area of research in the Pacific Northwest given the desire to better mitigate for large floods that cause damage to developed areas and infrastructure downstream.

As a part of a proposal to restore floodplain surface water storage to the Chehalis River Basin in Washington, Abbe *et al.* (2016) reviewed case studies from around the world that could be applicable to floodplain conditions in the Pacific Northwest. Abbe *et al*. (2016) found that maintenance or restoration of connected floodplain, off-channel meanders, and wetland complexes reduced the magnitude of large peak flood events by measurable amounts. For example, in Otter Creek, Vermont, stream flow during Tropical Storm Irene was reduced by more than 50% after flowing through 30 miles of connected floodplain and wetlands in the 9,000-acre Otter Creek swamp complex, which includes conservation and agricultural land (Watson *et al.,* 2016). In western Alberta, Canada, flood volume from a beaver dam failure was reduced to 7% of the upstream event volume after overbank flow passed through a 90-hectare (222 acre) connected wetland complex (Hillman, 1998). In the Pacific Northwest, the role of the floodplain in the attenuation of flows can be observed in the Skagit River of western Washington, where during some large precipitation events, peak flow has been observed to decrease across an area of 38 miles of river that is connected to its floodplain between two stream gauges (Abbe *et al.,* 2016).

Several recent examples exist from the state of Washington where levee setbacks and active floodplain reconnection are the focus of river restoration projects that have successfully increased surface water storage by allowing inundation of floodplain areas or by restoring perennial flow to abandoned side-channels (Floodplains by Design, 2017a). For instance, in the Skagit River tidal floodplain, an increase in connected freshwater marsh area from 10 acres to 56 acres resulted in an increase in flood storage capacity from 64 acre-feet to 309 acre-feet (Salish Sea Wiki, 2021). In the City of Portland, Oregon, access to 63 acres of floodplain was restored in the Johnson Creek drainage, allowing for 140 acre-feet of flood storage and reducing downstream flooding and impacts to transportation infrastructure (City of Portland, 2017). Many more small-scale floodplain reconnection projects are in development, and post-project monitoring will provide additional data on the magnitude of functional change.

In summary, evidence from the literature suggests that naturally connected floodplains can provide surface water storage for a large proportion of the volume of large flood events. Relatively smaller-scale, ongoing floodplain reconnection projects have successfully reduced risk of damage by large floods to communities downstream, as well as increased floodplain area available for shaping by geomorphic processes and use as aquatic habitat. Initial monitoring of floodplain reconnection projects suggests that surface water storage function can increase in a roughly linear manner in relation to the area of reconnected floodplain (**Table 4.19**).

Biologic Function

In western coastal regions, emergent floodplain wetlands that are connected to mainstem rivers create ephemeral habitat for non-salmonid fish species (Henning *et al.,* 2006), amphibians, and other aquatic species. For instance, extensive surface area of shallow, flooded riverine wetlands with slow-moving water provides habitat for foraging and resting water birds. Riverine wetlands have been reduced by approximately 52% in Oregon's Willamette Valley, with associated shifts in water bird numbers; species that were previously common but are now rare or of unknown abundance include trumpeter swans, snow goose, long-billed curlew, and red-necked phalarope (Taft and Haig, 2003).

Coho salmon appear to thrive and grow in ephemerally connected floodplain wetlands; these habitats are a component of the diverse life histories of the species that allow for resilience to variable river and ocean conditions (Henning *et al.,* 2006). Overall fish abundance appears to be driven by emigration which occurs in summer with an increase in temperature and decline in dissolved oxygen (DO) that occurs with contraction of habitat and disconnection from mainstem flow due to desiccation in summer (Henning *et al.,* 2007). In the floodplain wetland habitats of the Chehalis River Basin in Washington, connections to the mainstem flow occur over variable durations (e.g., 3-275 days), however duration of connection was not related to fish abundance, suggesting even short duration connections are enough to allow fish to use good quality habitat (Henning *et al.,* 2007).

For species that use floodplain habitat for portions of their life cycle, such as rearing juvenile coho salmon, floodplain habitat can be more productive than mainstem stream habitat, therefore loss of floodplain connections has an inordinately large effect on the total creation and maintenance of habitat. In a small stream with a relatively narrow floodplain (Carnation Creek, British Columbia) floodplain habitat made up 13.5% of winter habitat for coho salmon, but contributed 15.3% and 23.1% of the coho salmon smolts for 1983 and 1984, respectively (Brown and Hartman, 1988). High flows in the main channel reduced contribution of fish rearing in the main channel to total productivity of the population, evidence of the dependence of coho salmon on slow-water habitat in winter. Annual productivity of floodplain habitat was related to degree of connection created by magnitude of fall flood events, and water levels in ephemeral habitat in spring related positively to coho production.

In the Skagit and Stillaguamish Rivers of Washington, 52% and 68% of historic floodplain habitat in sloughs and beaver ponds have been lost due to disconnection from the river (Beechie *et al.,* 1994; Pollock *et al.,* 2004). Coho salmon smolt production was estimated to decrease by a constant factor in relation to floodplain habitat disconnection. In the Skagit River, floodplain disconnection accounted for 73% and 91% of the total reduction in coho smolt production losses compared to historical condition for summer and winter rearing areas, respectively. In the Stillaguamish River, losses due to floodplain disconnection only were not estimated, but the loss of slough habitat combined with loss of beaver pond habitat in floodplains was extensive, accounting for 28% and 96% of the reduction in coho smolt production in summer and winter, respectively. These studies suggest that in large rivers with broad floodplains, moderate levels of floodplain disconnection can have a disproportionately large impact on total habitat area for species like coho salmon that use the floodplain extensively for rearing.

Installation of dams on Oregon's McKenzie River has reduced peak flows to bankfull discharge or less, disconnecting the river from its floodplain and causing channel simplification and reduced habitat complexity for native salmonids (Ligon *et al.,* 1995). Since the installation of dams, there has been a reduction in availability and transport of island-building material (cobble and wood), reduced erosion and transport of spawning gravel from floodplain areas, and reduced area available for spawning, leading to redd superimposition. From 1930 to 1990, wetted area (m^2) was reduced by 27% mainly due to channel simplification and loss of braided reaches. Additionally, the number of islands was reduced by 53%, island area was reduced by 51%, and island perimeter was reduced by 59%. In this case, a moderate reduction in active floodplain area (represented by wetted area) has resulted in a loss of 50-60% of habitat features created by islands.

In Oregon's Willamette River floodplain, lower mean maximum flows have been reduced compared to historical conditions due to flood storage in reservoirs and riprapped banks impairing habitat-shaping geomorphic processes (Dykaar and Wigington, 2000). Mean annual maximum flow has been reduced to 64% historic flows at Albany (from 3,128 to 1,996 m^3/sec, pre-dam versus post-dam), a city located along the Willamette River. Island area was reduced by 80%

between 1910 and 1988. Islands are an important physical substrate to support riparian cottonwood forest development, which create and maintain habitat by adding large woody debris, cause deposition of fine sediment, make fluvial landforms resistant to erosion, and add organic matter to substrate and water. This study (Dykaar and Wigington, 2000) demonstrates that a moderate reduction in flood flows caused a disproportionately large reduction in instream habitat.

The geomorphic response to floods at a 30-year and 7-year recurrence interval was found to be a function of the degree of confinement and distance downstream of a diversion dam in Washington's Cedar River (Gendaszek *et al.,* 2012). After damming, higher flood stages have been associated with revetments and channel simplification. Redistribution of sediment, localized channel widening, limited avulsions, and recruitment of large wood occurred mainly in relatively unconfined reaches. In confined reaches, gravel was eroded and redeposited on topographically higher bars where gravel cannot be used by spawning salmon. Pools (used by fish as habitat) were least frequent within an engineered channel at the mouth of the river (river mile 0-3.1) and most frequent in a relatively unconfined section between river mile 9.3 and 12.4. A roughly linear, negative relationship exists between the inverse of the percent of the riverbank artificially confined (representing floodplain disconnection) and pool number across sections of river that range from an average of 20-80% artificially confined.

Few studies were found that address the effect of floodplain disconnection on surface water storage or creating and maintaining habitat in xeric areas of the Pacific Northwest. However, it is clear that prior to the era of dams and diversion of surface water for irrigation, connected floodplains and off-channel habitats were an important habitat and source of temperature refuge in rivers east of the Cascades (Stanford *et al.,* 2002). Blanton and Marcus (2013) observed that in floodplains on both the west and east sides of the Cascades in Washington (Chehalis River Basin and Yakima River Basin, respectively), roads and railroads in valley bottoms are associated with truncated meanders, lower sinuosity, reduced channel complexity, fewer bars and islands, less large wood, reduced side-channel habitat, and less riparian forest cover. Responses to confinement were similar for west- and east-side streams, and across different channel sizes and valley settings.

To summarize, a review of the literature revealed several case studies that demonstrate magnitudes of floodplain connection, disconnection, or channel confinement in association with metrics related to creating and maintaining habitat. Based on the data reviewed, low to moderate levels of floodplain disconnection are associated with disproportionately large losses in stream function, especially creating and maintaining habitat (**Table 4.20**). It is notable that in cases of relatively high floodplain disconnection (e.g., Gendaszek *et al.,* 2012; Pollock *et al.,* 2004), some geomorphic function and habitat use persists, supporting a standard performance index that allows for small increases in stream function indexing up to approximately 80% floodplain disconnection. These data come from disparate sources and represent different methods; however, they provide a general sense of the magnitude of the stream function response to floodplain disconnection.

Table 4.19. Summary of Magnitude of Change in Stream Function with Floodplain Disconnection

Reference	Floodplain Connection Metric	Functional Response Metric
Beechie *et al.,* 1994	52% loss of floodplain slough area	Floodplain smolt productivity 38% (summer) and 47% (winter) of historic levels
Dykaar and Wigington, 2000	36% loss of mean annual maximum flow	Island area 20% of pre-dam era
Gendaszek *et al.,* 2012	51%-79% average river bank confinement	0.7-2.8 pools per km; roughly linear correlation with river bank confinement
Ligon *et al.,* 1995	27% loss of wetted area	Island habitat 41- 49% of historic levels
Pollock *et al.,* 2004	68% loss of floodplain slough and beaver pond area	Floodplain smolt productivity 14% (summer) and 9% (winter) of historic levels
The Nature Conservancy, 2017	5.6-fold area reconnected	4.8-fold increase in flood storage capacity

Table 4.20. Summary of Supporting Literature for Floodplain Exclusion Standard Performance Index

Reference	Metric	Function Response Variable	SFAM Functions Informed	Informative Conclusions
Decision Support for Hydrologic Function				
Beechie *et al.,* 1994; Pollock *et al.,* 2004	Loss of coho salmon floodplain rearing habitat	Coho salmon smolt production capacity	CMH	Loss of large areas of floodplain slough and beaver pond habitat can account for the majority of total coho smolt production losses in large rivers.
Blanton and Marcus, 2013	Presence or absence of transportation infrastructure	Difference in wetted channel area, large wood, off-channel habitat, riparian forest	CMH	Presence of channel- confining infrastructure is associated with impaired geomorphic and riparian processes that shape habitat. Similar responses seen in a coastal River and interior river, suggesting response to exclusion is similar across ecoregions.

Reference	Metric	Function Response Variable	SFAM Functions Informed	Informative Conclusions
Brown and Hartman, 1988	First fall storm maximum discharge, off-channel water level, mainstem flow, accessibility	Contribution by floodplain winter habitat to total population productivity	CMH	Seasonally inundated floodplain habitat contributed relatively more Coho salmon smolts than main channel habitat. Productivity was related to connectivity.
Dykaar and Wigington Jr., 2000	Reduction in peak flows due to water storage behind dams	Reduced island area for cottonwood development	CMH	Reduced floodplain inundation impairs geomorphic processes and riparian cottonwood forest development that shape habitat for fish.
Gendaszek *et al.,* 2012	Proportion of river banks artificially confined per river mile	Mean pool frequency per every 5 river miles	CMH	Artificial channel confinement ranging from 20% to 80% was related to pool number and reduced geomorphic response to large floods.
Henning *et al.,* 2006, 2007	Duration of ephemeral floodplain wetland connectivity, flow, water quality	Fish abundance, Coho salmon growth and survival	CMH	Multiple fish species use floodplain wetland habitat. Short duration connections can allow large numbers of fish to use habitat. Fish emigration is related to water quality changes that result from seasonal disconnection.
Ligon *et al.,* 1995	Reduction in peak flows due to water storage behind dams	Wetted area of river below dams, island number, island area, island perimeter, redd superimposition, salmon declines	CMH	Reduced peak flows have led to decreases in wetted area, channel complexity, and substrate available for habitat.
Taft and Haig, 2003	Loss of riverine wetlands	Change in bird species status from common to uncommon or rare	CMH	Loss of riverine wetlands due to floodplain disconnection contributes to rarity of water birds.
Decision Support for Biologic Function				
Abbe *et al.,* 2016	Floodplain, off-channel meander, and wetland disconnection	Annual peak flow magnitude and timing	SWS	Review of literature identifies examples of flood water storage by connected floodplain systems in North America.

Notes:
CMH: Create and Maintain Habitat
SWS: Surface Water Storage

MEASURE DEVELOPMENT

Note that while this measure describes the spatial extent of floodplain connectivity, the Overbank

Flow measure (Section 4.2(F10) assesses whether flooding or overbank flow occurs; each measure captures a different process. This measure remains unchanged from the previous version of SFAM (Nadeau *et al*., 2020a). For more information on the development history and inclusion of this measure of function in SFAM, please see Nadeau *et al*. (2020b; Section 4.2(g)).

F8. Bank Armoring

MEASURE TEXT

What percentage of the banks are armored?

What percentage of the streambank has been stabilized using rigid methods to permanently prevent meandering processes? Examples of armoring include gabion baskets, sheet piles, rip rap, large woody debris that covers the entire bank height, and concrete. Bank stabilization methods that return bank erosion to natural rates and support meandering processes are not counted as armoring. Examples include many bioengineering practices, large woody debris placed along the bank toe, and in-stream structures that still use native vegetation cover on the streambanks. Percent armoring is calculated as the sum of the armored lengths of the left and right banks, divided by the sum total of both banks within the PAA (i.e., twice the total PAA length).

MEASURE DESCRIPTION

This measure is an indicator of whether a stream has access to sediment on its banks. Armoring of stream banks prevents natural erosion of channel banks and bottoms during runoff events.

Stream banks can be major contributors of sediment to hydrologic systems. Stream bank armoring can occur naturally due to aggregations of substrate (pebbles, rocks, etc.), but this measure is an indicator of the degree to which manmade armoring (that does not use low-impact bio-engineering techniques) is present.

Function Group: Geomorphology
Function Informed: Substrate Mobility (SM)
Stratification: This measure is not stratified
Metric: Percent of banks stabilized

Model:

IF Armor > 40%, THEN=0.0;

IF Armor > 20-40%, THEN = -0.015*Armor + 0.6;

IF Armor = 10-20%, THEN = -0.04*Armor + 1.1;

IF Armor < 10%, THEN = -0.03*Armor + 1.0

Table 4.21. Bank Armoring Scoring Index

Bank Armoring measured as percent stabilized				
Function Value Ranges	Low		Moderate	High
Field Value	> 40%	> 20-40%	10-20%	< 10%
Index Value	0.0	0.0 - < 0.3	0.3-0.7	> 0.7-1.0

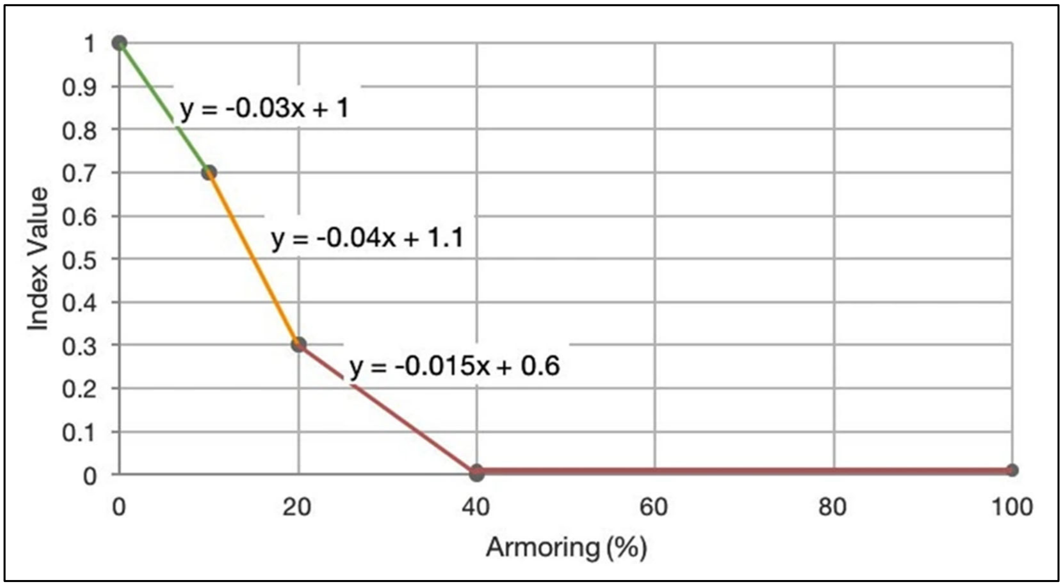


Figure 4.17. Bank Armoring Standard Performance Index

STANDARD PERFORMANCE INDEX

Development Method

Data and literature related to this metric is extremely limited. While scientific studies could not be used to directly inform the development of this standard performance curve, the curve is supported by current scientific understanding of how stream channel armoring relates to geomorphologic function.

This measure uses continuous data. Calculating the index score using a continuous scale allows for better detection of any change that results from impacts or mitigation activities.

SCIENTIFIC SUPPORT FOR ECOLOGICAL FUNCTIONS

Geomorphic Function

Generally, it is recognized that assessing the change in stream function associated with modifications to geomorphic condition is challenging to do in a rapid assessment or at project-level scales. Geomorphic processes are affected by surrounding landscapes and occur across long distances longitudinally in a stream so that processes that occur many miles upstream are linked to conditions downstream. In streams with high function, sediment transport and sorting occur over such large areas that evaluation on the scale of the PAA represents a snapshot of the overall balance in aggradation and erosion or channel migration. Therefore, it is acknowledged that evaluating geomorphic conditions in one PAA does not fully define the overall geomorphic function of that PAA since it is also affected by processes occurring upstream and downstream.

Anthropogenic bank armoring is assessed in SFAM as an impairment to geomorphic processes and thus an adverse effect on stream function, specifically sediment mobility (SM) (regular movement of the channel bed substrate that provides sorting and flushing). Bioengineered armoring can effectively increase resistance to erosion occurring at an accelerated rate due to anthropogenic disturbance and counteract the adverse effect of unbalanced rates of erosion on stream function.

The relative change in stream function associated with a given geomorphic condition is context-dependent. Generally, controls on the suite of geomorphic processes include climate, geology, vegetation, and topography, in addition to past natural or anthropogenic disturbances (Montgomery and MacDonald, 2002). While these controls contribute to the variability in sensitivity of the response of a certain measure of stream function over time and space, we did not find sufficient information to meaningfully stratify the standard performance index at this time.

MEASURE DEVELOPMENT

This measure remains unchanged from the previous version of SFAM (Nadeau *et al*., 2020a). For more information on the development history and inclusion of this measure of function in SFAM, please see Nadeau *et al*. (2020b; Section 4.2(h)).

F9. Bank Erosion

MEASURE TEXT

What percentage of the bank is actively eroding or recently (within previous year or high flow) eroded?

Bank erosion is indicated by vertical or near vertical streambanks that show exposed soil and rock, evidence of tension cracks, active sloughing, or are largely void of vegetation or roots capable of holding soil together. Percent eroding is calculated as the sum of the eroded lengths of the left and right banks, divided by the total length of both banks within the PAA (i.e., twice the total PAA length).

MEASURE DESCRIPTION

This measure is an indicator of how active the channel banks are. Channel bank stability is influenced by the cohesiveness and character of bank materials (soil composition, subsoil composition), bank vegetation (rooting characteristics), and the hydraulic forces acting on the bank, particularly at the toe of the bank slope. 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. Stream banks provide sediment supply and allow natural rates of meander to occur within the channel through a process of bank retreat and advancement over time. However, bank erosion and instability can be exacerbated by impacts to channel banks, especially vegetation removal, and by changes in channel hydraulics due to changes in hydrology or channel form. Excessive bank erosion can lead to sedimentation. In some systems, this process is accelerated in response to changing watershed conditions or when the natural process has been retarded by anthropogenic controls (e.g., riprap, concrete) applied at the channel-bank interface.

Function Group: Geomorphology
Function Informed: Sediment Continuity (SC)
Stratification: This measure is not stratified
Metric: Percent of bank eroding

Model:

IF Erosion ≥ 60%, THEN = 0.0;

IF Erosion ≥ 40 - <60%, THEN = -0.015*Erosion + 0.9;

IF Erosion ≥ 20 - <40%, THEN = -0.02*Erosion + 1.1;

IF Erosion ≥ 10 - <20%, THEN = -0.03*Erosion + 1.3;

IF Erosion < 10%, THEN = 1.0

Table 4.22. Bank Erosion Scoring Index

Stream Function Measure: *Bank Erosion measured as percent eroding*					
Function Value Ranges	**Low**		**Moderate**	**High**	
Field Value	≥ 60%	≥ 40 - < 60%	≥ 20 - < 40%	10 - < 20%	< 10%
Index Value	0.0	0.0 - < 0.3	0.3-0.7	> 0.7-1.0	1.0

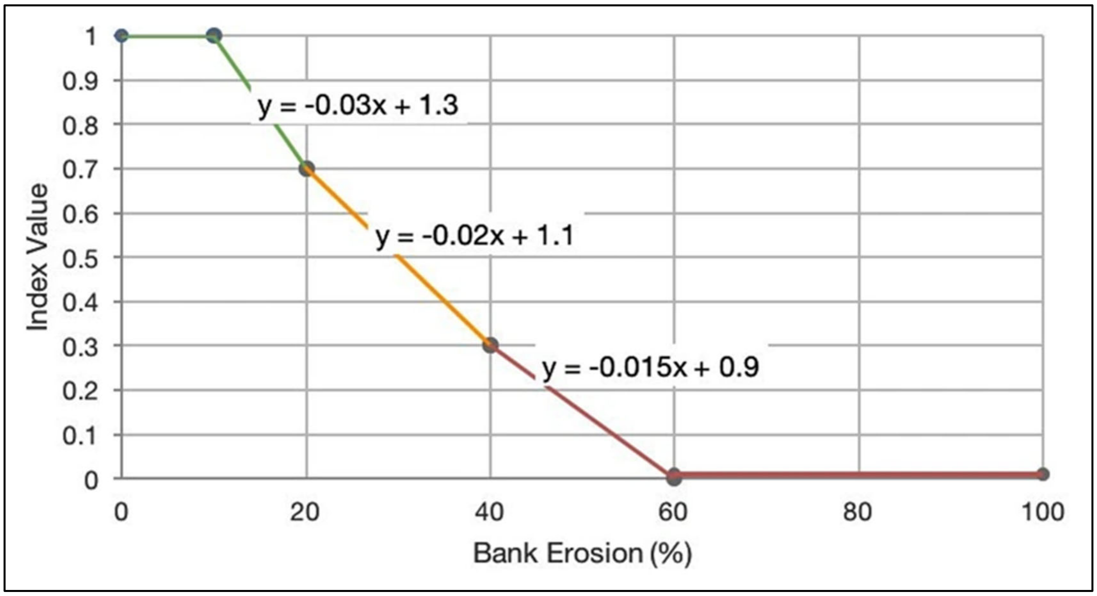


Figure 4.18. Bank Erosion Standard Performance Index

STANDARD PERFORMANCE INDEX

Development Method

Data and literature related to this metric is extremely limited. While existing data could not be used to directly inform the development of this standard performance index, the index is supported by current scientific understanding of how stream bank erosion relates to geomorphologic function.

This measure uses continuous data. Calculating the index score using a continuous scale allows for better detection of any change that results from impacts or mitigation activities.

SCIENTIFIC SUPPORT FOR ECOLOGICAL FUNCTIONS

Geomorphic Function

Generally, it is recognized that assessing the change in stream function associated with modifications to geomorphic condition is challenging to do in a rapid assessment or at project-level scales. Geomorphic processes are affected by surrounding landscapes and occur across long distances longitudinally in a stream so that processes that occur many miles upstream are linked to conditions downstream. In streams with high function, sediment transport and sorting occur over such large areas that evaluation on the scale of the PAA represents a snapshot of the overall balance in aggradation and erosion or channel migration. Therefore, it is acknowledged that evaluating geomorphic conditions in one PAA does not fully define the overall geomorphic function of that PAA since it is also affected by processes occurring upstream and downstream.

SFAM evaluates the relative area of impairments to geomorphic processes (e.g., barriers to lateral migration) and the area actively undergoing changes in geomorphology (e.g., bank erosion). The relative equilibrium of geomorphic processes is estimated by using measures of function that counterbalance each other (i.e., low scores given for high bank erosion would be counterbalanced by high scores for high opportunity for lateral migration).

The relative change in stream function associated with a given geomorphic condition is context dependent. Generally, controls on the suite of geomorphic processes include climate, geology, vegetation, and topography, in addition to past natural or anthropogenic disturbances (Montgomery and MacDonald, 2002). Montgomery and MacDonald (2002) state that, "The site-specific interactions between channel type, forcing mechanism, and channel response must be understood to select the variables for monitoring and design effective monitoring projects…. When designing a monitoring project, one must consider the relative sensitivity of each channel characteristic by channel type, forcing mechanism and biogeomorphic context." Channel type, forcing mechanisms, and channel responses for bank stability are described below.

Channel Type

Channel types proposed by Montgomery and Buffington (1997) integrate seven stream characteristics that could each individually be considered controlling factors of geomorphic function (**Table 4.23**).

Table 4.23. Diagnostic Features of Each Channel Type
(Adapted from Montgomery and Buffington, 1997)

Feature	Dune ripple	Pool riffle	Plane bed	Step pool	Cascade	Bedrock	Colluvial
Typical bed material	Sand	Gravel	Gravel-cobble	Cobble-boulder	Boulder	Rock	Variable
Bedform pattern	Multilayered	Laterally oscillatory	Featureless	Vertically oscillatory	Random	Irregular	Variable
Dominant roughness elements	Sinuosity, bedforms (dunes, ripples, bars) grains, banks	Bedforms (bars, pools), grains, sinuosity, banks	Grains, banks	Bedforms (steps, pools), grains, banks	Grains, banks	Boundaries (bed and banks)	Grains
Dominant sediment sources	Fluvial, bank failure	Fluvial, bank failure	Fluvial, bank failure,	Fluvial, hillslope, debris flows	Fluvial, hillslope, debris flows	Fluvial, hillslope, debris flows	Hillslope, debris flows
Sediment storage elements	Overbank, Bedforms	Overbank, bedforms	Debris flows	Bedforms	Lee (steep) and stoss (gentle) sides of flow obstructions	Pockets	Bed
Typical confinement	Unconfined	Unconfined	Overbank	Confined	Confined	Confined	Confined
Typical pool spacing (channel widths)	5-7	5-7	Variable	1-4	< 1	Variable	Unknown

Forcing Mechanisms

Interacting forcing mechanisms of bank erosion are summarized in **Table 4.24**.

Table 4.24. Interacting Factors that Influence Erosion
(Adapted and modified from Fischenich, 2001; Montgomery and MacDonald, 2002)

Factor	Relevant Characteristics
Spatial location within the channel network	Sediment production zone, sediment transfer zone, or sediment deposition zone
Substrate size	Boulder to silt
Soil cohesion	Cohesive soils are more resistant to erosion
Flow properties	Frequency, variability, velocity, sheer stress and turbulence
Climate	Rainfall, freezing
Subsurface conditions	Seepage forces, piping, soil moisture levels
Channel geometry	Width, depth, height and angle of bank, bend curvature
Vegetation	Roughness displaces velocity upwards away from soil; roots add cohesion, elevates critical velocity/ sheer stress
Sediment load	High suspended sediment load dampens turbulence; elevates critical thresholds 1.5 to 3x
Anthropogenic factors	Urbanization, flood control, boating, irrigation

Channel Response

In the SFAM model, bank stability, measured as amount of bank erosion, affects sediment continuity (SC) (the balance between transport and deposition). Fischenich (2001) states that, "The stability of a stream refers to how it accommodates itself to the inflowing water and sediment load," and that, "When the ability of the stream to transport sediment exceeds the availability of sediments within the incoming flow, and stability thresholds for the material forming the boundary of the channel are exceeded [due to hydraulic forces], erosion occurs."

The extent to which minor erosion should be considered an adverse effect on stream function depends largely on duration of high flow and deviation from sediment transport processes that are considered "normal" for a given climate and position in the watershed (Fischenich, 2001). Evaluation of erosion within a single PAA may not be adequate to understand the magnitude of deviation from normal sediment transport processes that occur over larger areas and periods of time. A PAA with large areas of eroding banks would receive a reduced SFAM score for Bank Erosion, even if sediment transport and deposition are relatively well balanced over a larger geographic area. Nonetheless, the score of a PAA with actively eroding banks would be counterbalanced with higher scores if lateral migration is not confined.

MEASURE DEVELOPMENT

This measure remains unchanged from the previous version of SFAM (Nadeau *et al*., 2020a). For more information on the development history and inclusion of this measure of function in SFAM, please see Nadeau *et al*. (2020b; Section 4.2(i)).

F10. Overbank Flow

MEASURE TEXT

Does the stream interact with its floodplain?

Is there evidence of fine sediment deposition (sand or silt) on the floodplain, organic litter wrack on the floodplain or in floodplain vegetation, or scour of floodplain surfaces, extending more than 0.5 × BFW onto either the right or left bank floodplain within the PAA? Do not include evidence from inset floodplains developing within entrenched channel systems.

If the abutting land use limits the opportunity to observe evidence of overbank flow, is there other credible information that would indicate regular (at least every two years) overbank flow in the PAA? Examples of "other credible information" include first-hand knowledge, discharge/ stream gauge measures, etc. Note the evidence on the Cover Page.

MEASURE DESCRIPTION

This measure represents a stream's interaction with its floodplain. Floodplain deposition, the accumulation on the floodplain of material from overbank flow, is a valid indicator of natural channel maintenance processes and is an important feedback mechanism for nutrient transfer. The connection between a stream channel and its floodplain (for alluvial rivers) is maintained primarily via periodic flood inundation. Connectivity to the floodplain allows organisms and material (water, sediment, organic matter) to move, unhindered by anthropogenic structures, perpendicular to the axis of the stream banks with a frequency consistent with natural flood regimes. Flood inundation supports detention and moderation of flood flows, groundwater and baseflow recharge, filtration to maintain water quality, access to side-channel and off-channel refuge and feeding habitats, and sedimentation and seed distribution to maintain riparian vegetation succession. Stream connectivity is essential to a number of theories of energy and material transfer in the river system and the process of overbank flow provides food resources to the stream's surrounding habitat.

Function Groups: Hydrology, Biology, Water Quality

Functions Informed: Surface Water Storage (SWS), Sub-surface transfer (SST), Sustain Trophic Structure (STS), Nutrient Cycling (NC), Chemical Regulation (CR)

Stratification: This measure is not stratified

Metric: Presence/absence

Model:

Cannot be answered if no floodplain

IF OBFlow = no, THEN=0.0;

IF OBFlow = yes, THEN=1.0

Table 4.25. Overbank Flow Scoring Index

Overbank flow measured as presence or absence		
Function Value Ranges	**Low**	**High**
Field Value	No	Yes
Index Value	0.0	1.0

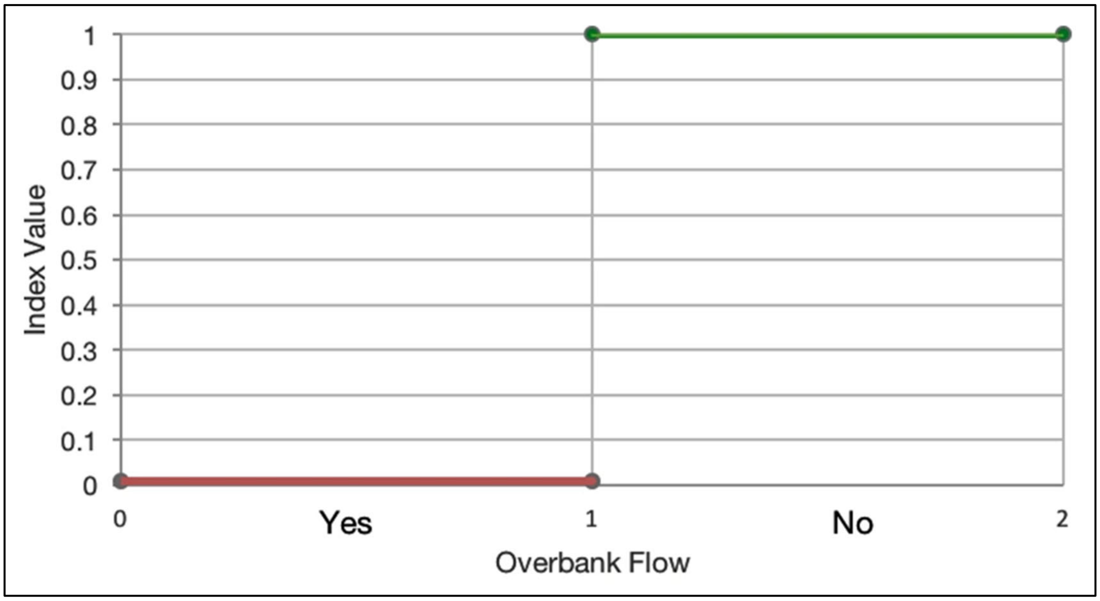


Figure 4.19. Overbank Flow Standard Performance Index

STANDARD PERFORMANCE INDEX

Development Method

There is extensive information in the literature linking overbank flow to hydrologic, biologic, and water quality functions. The development of the standard performance index for this measure was supported by numerous studies throughout the Pacific Northwest.

The model for this measure is binary, simply absence or presence, given the relative difficulty in rapidly and objectively assessing the degree of overbank flow.

SCIENTIFIC SUPPORT FOR ECOLOGICAL FUNCTIONS

Overbank flows shape alluvial floodplains in two ways, 1) by controlling hydrology and nutrient cycles that support distinct vegetative patterns, and 2) through recurrent destruction and reformation of soils and vegetation as rivers move laterally within valley bottoms (Naiman *et al.,* 2010).

In temperate areas that experience powerful fall and winter storms, such as the Pacific Coast Range ecoregion, overbank flows may occur on a seasonal basis, resulting in more frequent and regular priming of the floodplain processes (Naiman *et al*., 2010; Sutfin *et al*., 2010). In the Xeric ecoregion of eastern Oregon, Washington, and Idaho, flooding may occur as flash floods that are infrequent, and re-initiation of floodplain processes may occur more randomly (Sutfin *et al*., 2010). Nevertheless, the basic premise that overbank flow supports processes such as surface water storage, recharge of subsurface flows, and nutrient storage in deposited sediments are similar in xeric regions compared to temperate regions (Elmore and Bechsta, 1987).

Hydrologic Function

Overbank flow supports the Surface Water Storage (SWS) function of streams by allowing the stream to expand across large areas of floodplain, redistributing water and slowing velocity of the flow. Where streams can access their floodplains, floodplains can provide SWS in intermittent or ephemeral meanders or wetlands. Most floodplains and floodplain wetlands are highly disconnected from streams in the Pacific Northwest, and it is recognized that during high flows larger-magnitude flood peaks can be conveyed to downstream areas than under historic conditions. Evidence from the literature around the world suggests that naturally connected floodplains can provide SWS of a large proportion of the volume of large flood events. For a review of case studies on floodplain storage see the rationale for Floodplain Exclusion (**Section 4.2[F7]**).

The loss of SWS provided by overbank flow is a growing area of research in the Pacific Northwest due to the desire to better mitigate for large floods that cause damage to developed areas and infrastructure downstream. A few relatively smaller-scale, ongoing floodplain reconnection projects in the Pacific Northwest have successfully reduced the risk of damage by large floods to communities downstream, as well as increased floodplain area available to be shaped by geomorphic processes and to be used as aquatic habitat (e.g., City of Portland, 2017; Floodplains by Design, 2017b). Many more projects are in the early stages of development and data on the magnitude of surface water storage provided has yet to be collected. Initial monitoring of floodplain reconnection projects suggests that SWS function can increase in a roughly linear manner in relation to the area of reconnected floodplain (City of Portland, 2017). In unconfined, alluvial floodplains, overbank flow can recharge areas of sub-surface flow, also described as areas of hyporheic flow connected to the main channel.

Biologic Function

Overbank flow supports biologic function by sustaining trophic structure in floodplain areas and adjacent stream reaches in primarily two ways, 1) by providing nutrient subsidies in temporarily flooded floodplain areas (Tockner and Stanford, 2002) and 2) by connecting stream reaches with a shifting mosaic of floodplain habitats (i.e., surface riparian zones and subsurface hyporheic zones) that provide thermal and structural heterogeneity and as a result, supports a broader range of species than in streams that do not undergo overbank flooding (Ward and Stanford, 1995).

Transport of nutrient rich-sediment and other organic material (such as wood and salmon carcasses) from the river to the floodplain are why floodplains are among the most productive landscapes on earth. Depositional floodplains enhance primary productivity not only in riparian vegetation, but also phytoplankton in temporarily flooded areas that provides a boost to aquatic invertebrate production (Schemel *et al*., 2004; Tockner and Stanford, 2002). Areas of high productivity in ephemerally-flooded areas can support diverse assemblages of vertebrate species (Henning *et al.*, 2007 [fish]) or can provide concentrated resources for fast growth of discrete life stages of certain key species such as coho salmon (Henning *et al.*, 2006; Sommer *et al*., 2001 [terrestrial and aquatic wildlife]; Taft and Haig, 2003 [waterbirds]).

In many streams in the Pacific Northwest, flood control has reduced channel complexity and connection to thermally heterogeneous areas of gravel islands and off-channel habitats or spring-brook areas fed by groundwater (e.g., the McKenzie River, OR [Ligon *et al.*,1995]; the Yakima River, WA [Stanford *et al.*, 2002]). Overbank flows historically maintained these connections on a seasonal basis and large floods caused major rerouting of sediments and river avulsions that contributed to channel complexity. It is estimated that the loss of overbank flows has contributed to the decline of salmon species in these rivers, in part due to lack of overbank flows that previously connected salmon with trophic resources in off-channel habitats (Stanford *et al*., 2002).

Water Quality Functions

Surface nutrient processes

Globally, flooding controls nutrient cycles by increasing contact time between water and soil and by controlling the mode of nutrient delivery to the ecosystem (Pinay *et al*., 2002). Nutrient cycles are driven by processes that occur at the interface between particulate material and water, both at the surface and subsurface. Lateral expansion of wetted areas during overbank flows increases the interface area between soil and water. Floods affect nutrient cycling directly by controlling the duration of oxic and anoxic phases, as well as indirectly by influencing soil structure.

Floodplains are recognized as important storage areas for nutrients that retain higher amounts of organic matter compared to stream reaches in confined valley segments (Bellmore and Baxter, 2014). In the Pacific Coast Range ecoregion, nutrients are exported to the floodplain from the main channel during overbank flows via the deposition of organic matter attached to fine sediment that has been eroded and transported from upstream areas (Naiman *et al*., 2010). Carbon is stored in the floodplain in several organic forms, such as in plants and animals, but dissolved organic carbon attached to floodplain sediments is the major component of floodplain carbon storage (Sutfin *et al.*, 2016). Soil type influences nutrient (dissolved organic carbon) storage; fine grained sediments serve as organic carbon sinks whereas sandy soils release available carbon during high flows (Sutfin *et al*., 2016). Overbank flow not only mobilizes nutrients by deposition of sediment or plant material, but in the Pacific Northwest where salmon runs are still sustained at historic levels, the deposition of salmon carcasses in the floodplain during seasonal floods is a measurable nitrogen subsidy that becomes incorporated in riparian vegetation and higher trophic levels that feed upon that vegetation, such as small rodents (BenDavid *et al*., 1998).

Distribution of floodplain sediment depends on hydrologic cycles. In temperate areas, seasonal redistribution of sediment and resetting of nutrient cycles may occur, whereas sediment and nutrient redistribution is more random in xeric areas that experience flash flooding. Following an overbank flow event, fresh depositional surfaces are quickly exposed to chemical weathering that releases nutrients in usable forms for plants, particularly nutrients that are often limiting such as phosphorous and base cations (Naiman *et al*., 2010). Young floodplain soils can be considered open systems because coarse soils allow leaching and a high level of export of nutrients to the main channel. As floodplain vegetation and fine soils mature, floodplains transition to closed systems with more efficient nutrient retention (Naiman *et al*., 2010). Overbank flows may reset the floodplain soil development cycle, reinitiating the process of high nutrient delivery to the main channel. In a plan to restore environmental flows to Oregon's Willamette River basin below high head dams, Gregory *et al*. (2008) suggested that releases that create small floods (of a magnitude observed on a 2-10 year interval) may increase nutrient transport from the floodplain with mobilization of sediment, but that nutrient concentrations imported from the floodplain may decrease with large floods that maintain floodplain processes (of a magnitude greater than a 10 year interval) due to dilution.

Subsurface nutrient processes

Subsurface flow, often affected by overbank flows, enhances nutrient cycling between the floodplain and channel. High flows rearrange hyporheic zone sediments, increasing hydraulic conductivity and surface area for nutrient exchange (Pinay *et al*., 2002). Large floods in coastal Oregon in 1996 caused major changes in stream morphology and subsurface flow paths in alluvial areas, but less change was observed in bed-rock controlled reaches (Wondzell and Swanson, 1999). When the water table was high and connected to hyporheic flow paths, nitrate was leached from rooting zone of streamside alders, a nitrogen-fixing plant (Wondzell and Swanson, 1996, 1999). In the Willamette River basin, Laenen and Bencala (2001) found solute storage in the hyporheic zone occurred for longer periods during high stream discharge. These cases demonstrate ways in which overbank flow can affect nutrient storage and delivery to a stream via rearranging or forcing the direction of flow paths below the surface during high flow events. For further discussion on the effect of subsurface flow through the riparian zone on nutrient cycling, refer to the rationale for Vegetated Riparian Corridor Width (**Section 4.2[F5]**).

Chemical (pollutant) regulation

Overbank flow can regulate distribution and storage of contaminants in the floodplain. Extensive and persistent contamination from a single point source can result when contaminated sediment from upstream sources is redistributed to floodplain areas and stored until subsequent overbank flows occur. Contaminants then become reintroduced from the floodplain to the main channel via erosion and mass wasting (bank slumping and cutting) (Axtmann and Luoma, 1991). In this way, the floodplain that is at first a sink, may later become a source of contaminants. This dynamic is important to consider when assessing overall contaminant budgets of a watershed; declining contaminant levels in stream water may not reflect an overall reduction in contaminants at the watershed level, but rather a temporary redistribution and storage in the floodplain (Walling and Owens, 2003). For more detail on contaminant mobilization, see the rationale for Vegetated Riparian Corridor Width (**Section 4.2[F5]**).

Table 4.26. Summary of Supporting Literature for Overbank Flow Standard Performance Index

Reference	Metric	Function Response Variable	SFAM Function Informed	Informative Conclusions
Decision Support for Hydrologic Function				
Elmore and Beschta, 1987	Floodplain processes	Functions provided by floodplain riparian vegetation	SWS, SST	Authors review knowledge on contribution of riparian vegetation in xeric areas with linkages to overbank flow. Similar dynamics of surface water storage, subsurface recharge, and sediment trapping occur in xeric areas of eastern Oregon compared to temperate areas.
Decision Support for Biologic Function				
Ligon *et al*., 1995	Reduction in peak flows due to water storage behind dams	Wetted area of river below dams, island number, island area, island perimeter, redd superimposition, salmon declines	STS	Reduced peak flows have led to decreases in wetted area, channel complexity, and substrate available for habitat.
Schemel *et al.,* 2004	Flood cycle	Water chemistry, phytoplankton biomass	STS	Yolo bypass on the Sacramento River, CA, is a managed seasonally flooded floodplain. Phytoplankton biomass increased with length of time flooded and discharge from floodplain to river was enriched in Chlorphyll *a* (phytoplankton).
Sommer *et al*. 2001; Taft and Haig, 2003; Henning *et al*., 2006, 2007	Ephemerally flooded habitat in the floodplain	Vertebrate use of floodplain habitat resources	STS	Each of these studies documents the use of floodplain areas by vertebrate species and demonstrates the uniquely role that productive ephemeral floodplain environments can play in sustaining aquatic species.
Stanford *et al*., 2002	Water storage and diversion	Disconnection from alluvial floodplain	STS	In the Yakima River Basin, WA, the Yakima River no longer floods and reconnects with floodplain features that create habitat complexity and thermal heterogeneity like spring brooks. Fish observed using spring brook habitat in the Yakima Basin likely benefited from unique trophic structure away from the main channel.
Tockner and Stanford, 2002	Review of global floodplain status	Productivity	STS	Describes global and historic trends in floodplain productivity resulting from flood pulses.

Reference	Metric	Function Response Variable	SFAM Function Informed	Informative Conclusions
Ward and Stanford, 1995	Flow regulation	Disconnection from floodplain processes	STS	Spatio-temporal heterogeneity of physical attributes floodplains creates a diversity of habitats and successional stages of riparian vegetation.
Decision Support for Water Quality Function				
Axtmann and Luoma, 1991; Walling and Owens, 2003	Floodplain deposition of contaminated sediment	Contaminant retention and transport	CR	Floodplains alternately become sinks and sources for contaminants as sediment becomes deposited and then remobilized
Bellmore and Baxter, 2014	Confined vs unconfined river segments	Dissolved nutrients, allochthonous inputs, aquatic primary producers, organic matter retention, aquatic macroinvertebrates	NC	In the Salmon River, ID, confined river segments had more leaf litter than unconfined segments, but unconfined floodplain areas had higher vegetation biomass and organic matter retention. Benthic macroinvertebrate diversity was higher in segments with floodplains.
BenDavid *et al.*, 1998	Flooding; Distance from channel bank	Marine-derived nitrogen	NC, STS	In southeast Alaska stream, regular seasonal overbank flow was identified as a mechanism for delivery of marine- derived (MD) nutrients from salmon carcasses to the floodplain. MD-nitrogen levels in vegetation declined with distance from streams and areas of salmon carcass deposition.
Laenen and Bencala 2001	Subsurface flow paths	Solute transport	NC	Dye tracer experiments demonstrate transport rates of solutes in the hyporheic zone
Naiman *et al.*, 2010	Floodplain processes	Nutrient dynamics, soil deposition, riparian vegetation successional processes	NC	In the Pacific Coast Range ecoregion where flooding occurs seasonally, nutrients are exported to the floodplain with soil deposition and nutrients are imported back to the river during early phases of riparian soil development.
Pinay *et al.*, 2002	Floodplain processes	Nitrogen cycling	NC	Review article on mechanisms by which flooding affects nutrient cycling. Two main themes are the way floods increase contact time between soil and water, and how floods resort soils and increase contact area between substrate and water. Applies to both surface and subsurface flow.

Reference	Metric	Function Response Variable	SFAM Function Informed	Informative Conclusions
Sutfin *et al*., 2010	Floodplain dissolved organic carbon	Dynamics of retention, accumulation, and storage	NC	A global review of carbon cycling in floodplains. Distribution of sediment- associated DOC depends on hydrologic cycles and sediment type.
Wondzell and Swanson 1996, 1999	Large floods of 1996	Subsurface flow paths, subsurface nutrient transport	NC	Large floods of 1996 represented an opportunity to study before and after changes in hyporheic flow paths. High flow also allowed for nitrogen transport from alder root zones.

Notes:
CR: ChemicalRegulation
NC: Nutrient Cycling
SST: Sub/Surface Transfer
STS: Sustain Trophic Structure
SWS: Surface Water Storage

MEASURE DEVELOPMENT

This measure remains unchanged from the previous version of SFAM (Nadeau *et al*., 2020a). For more information on the development history and inclusion of this measure of function in SFAM, please see Nadeau *et al*. (2020b; Section 4.2(j)).

F11. Wetland Vegetation

MEASURE TEXT

Are there wetland indicator plants adjacent to the channel and/or in the floodplain?

Determine if vegetation in the riparian area of the PAA has a wetland indicator status of obligate or facultative wet.

MEASURE DESCRIPTION

This measure is an indicator of water availability in the floodplain, as well as an indicator of diversity of habitat and food resources. Wetland vegetation provides food and critical habitat for organisms that live in or near water resources, such as algae, macroinvertebrates, amphibians, fish and birds. Wetland vegetation can also provide water quality benefits, through the uptake of nutrients, metals, and other contaminants. 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.

Function Groups: Hydrology, Biology, Water Quality

Functions Informed: Sub/Surface Transfer (SST), Maintain Biodiversity (MB), Sustain Trophic Structure (STS), Nutrient Cycling (NC), Chemical Regulation (CR)

Stratification: This measure is not stratified

Metric: Presence/absence and distribution

Model:

IF plants with wetland indicator status are absent from the stream banks and floodplain throughout the PAA; THEN = 0.0;

IF plants with wetland indicator status are present within the PAA but are located less than 0.5 × bankfull width (BFW) away from the bankfull edge; THEN = 0.25;

IF plants with wetland indicator status are present within the PAA and are located more than 0.5 × BFW from the bankfull edge, but are present along less than 70% of the reach length on at least one side of the stream; THEN = 0.5;

IF plants with wetland indicator status are present within the PAA and are located more than 0.5 × BFW from the bankfull edge, and are present along 70% of the assessment reach; THEN = 1.0

Table 4.27. Wetland Vegetation Scoring Index

Wetland Vegetation as measured by presence and proximity/distribution				
Function Value Ranges	**Low**		**Moderate**	**High**
Field Value	Wetland plants absent	Wetland plants present, but are located < 0.5 × BFW from stream	Wetland plants present; located more than 0.5 × BFW from stream, but distributed along < 70% of assessment reach	Wetland plants present; located more than 0.5 × BFW from stream for ≥ 70% of assessment reach
Index Value	0.0	0.25	0.5	1.0

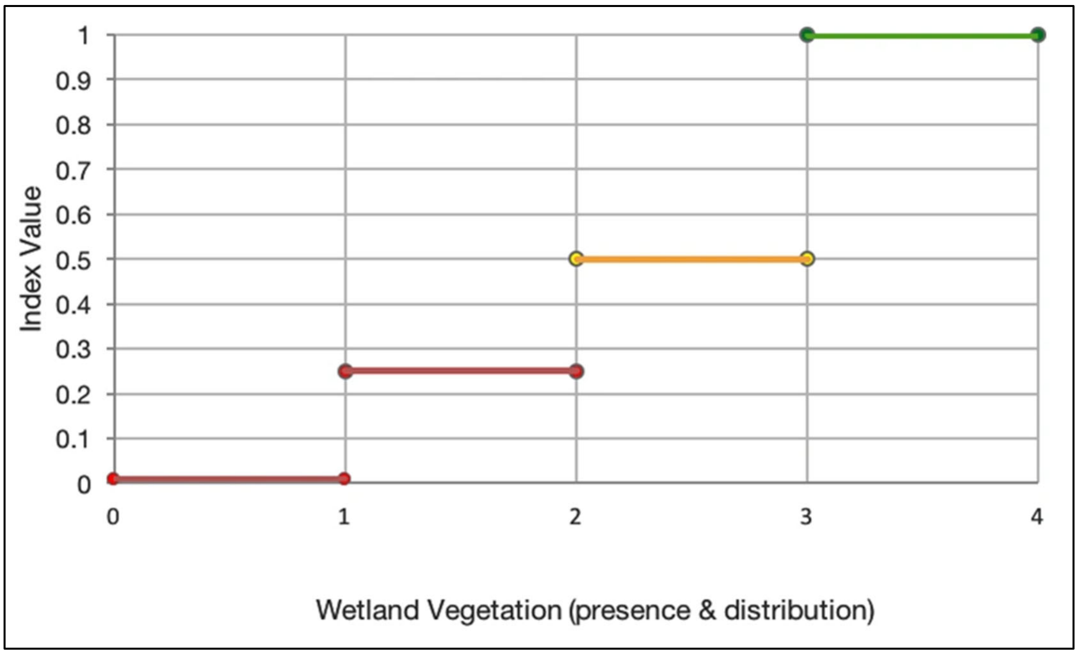


Figure 4.20. Wetland Vegetation Standard Performance Index

STANDARD PERFORMANCE INDEX

Development Method

While there are many studies that discuss how wetlands (and therefore wetland vegetation) are related to hydrologic, biologic, and water quality functions, there is limited information indicating critical abundance and/or proximity measurements of wetland vegetation that can be linked to stream functioning. Therefore, the categories and the associated index values for this measure were informed by current scientific understanding of how hydrophytic vegetation is linked to ecological functioning. The four categories resulted from consultation with technical experts and the scoring thresholds are designed to align with the indexing scale established for SFAM.

SCIENTIFIC SUPPORT FOR ECOLOGICAL FUNCTIONS

Hydrologic Function

The presence and distribution of wetland plants can be used as an indicator of the duration of soil saturation in or near stream channels. Hydrophytic plants have long been used as one of the three defining features of wetted areas (e.g., U.S. Army Corps of Engineers, 1987), and it is well-established that flooding and soil saturation foster conditions that a majority of plants cannot tolerate (Cronk and Fennessy, 2001). Streams interact with ground water in all types of landscapes—they may gain water from the inflow of ground water, lose water to ground water by outflow, or gain in some reaches and lose in others (Winter *et al*., 1998). Most wetlands are ground water discharge sites, and floodplain wetlands also recharge ground water (Tiner, 1999). In the bed and banks of streams, water and solutes can exchange in both directions across the streambed and into riparian areas and alluvial deposits (Winter *et al*., 1998); this subsurface zone of exchange is the hyporheic zone. This exchange can occur in both flooded and non-flooded conditions (Bencala, 2011). Given that they are subject to periodic changes in water-level, riverine wetlands have especially complex hydrological interactions (Winter *et al.*, 1998).

Biologic Function

Riparian areas and floodplains are dynamic areas of periodic or episodic inundation, resulting in a shifting landscape mosaic that supports plant and animal species adapted to such environmental gradients and stochasticity, including wetland plants. Riparian systems are generally an ecotone between aquatic and upland ecosystems, with continuous interactions between these ecosystems through exchanges of energy, nutrients, and species (Mitsch and Gosselink, 1993). They are functionally connected to upstream and downstream ecosystems, and are laterally connected to upslope (upland) and downslope (aquatic) ecosystems (Mitsch and Gosselink, 1993). Thus, there is often high primary productivity of plants and algae in riparian areas which provides abundant food resources for foraging, hunting, and breeding for fish, amphibians, and aquatic invertebrates, and draws in terrestrial species such as birds and mammals (see papers cited in USEPA, 2015). While the seeds and other parts of riparian wetland plants provide food for many animals, a major aspect of riparian plant primary productivity is that the biomass is broken down into fine particulate organic matter, both physically and through the action of microbes and invertebrates - the foundation of the aquatic food web (Allan, 1995; Tiner, 1999). The combination of diverse habitat structure and abundant food resources in riparian systems results in high species diversity and high species densities (see papers cited in USEPA, 2015).

Water Quality Function

Wetland plants as components of riparian areas both within and outside of floodplains affect the biogeochemistry of riverine systems through overbank flooding, internal biogeochemical processes, and hyporheic exchange (see papers cited in USEPA, 2015). These processes influence nitrogen, carbon, phosphorous, and pollutant cycling in the riverine environment. Transport from upstream reaches, surface flow, or through the hyporheic zone is an important source of these substances. Wetland plants remove nutrients from flooding and other waters, through absorption and assimilation, for biomass production; this can result in long term storage and/or subsequent burial in sediments (Cronk and Fennessy, 2001; Tiner, 1999). Additionally, adsorption, sedimentation, or other transformational processes exert major influences on the availability of these substances (Mitsch and Gosselink, 1993). Many streams in Idaho have been impacted by historic mining and thus have significant toxic metal contamination in associated riparian sediments (Idaho Conservation League, 2023). Riparian wetlands and their associated plants, soils and microbiomes are effective filters and mitigators of the mobile toxic metals (Balistrieri *et al*., 2007; Schumann *et al*., 2017) Wetland and riparian areas reduce water velocity, trapping sediments which often transport adsorbed nutrients, pesticides, heavy metals and other polluting toxins, lowering turbidity, and reducing siltation (Cronk and Fennessy, 2001; Mitsch and Gosselink, 1993; Tiner, 1999). The presence of both anaerobic and aerobic sediments also promotes denitrification, chemical precipitation, and other chemical reactions, mostly mediated by microbial populations, that remove certain chemicals from the water (Mitsch and Gosselink, 1993). Plant uptake and plant tissue accumulation can also be reversed when plants die back after the growing season, which can break down and serve as a source of nutrients and minerals (Cronk and Fennessy, 2001; Mitsch and Gosselink, 1993).

MEASURE DEVELOPMENT

Except for the inclusion of additional scientific support literature, this measure remains unchanged from the previous version of SFAM (Nadeau *et al*., 2020a). For more information on the development history and inclusion of this measure of function in SFAM, please see Nadeau *et al*. (2020b; Section 4.2(k)).

F12. Side Channels

MEASURE TEXT

What proportion of the Extended Assessment Area (EAA) length has side channels? Side channels include all open conveyances of water, even if the channel is plugged (i.e., there is no above-ground flow to/from the main channel) on one end. If both ends are plugged, do not count as a side channel. A side channel that exists due to an instream island has less flow by volume relative to the main channel.

MEASURE DESCRIPTION

This measure is an indicator of the extent of seasonally inundated areas that have surface water connections to the main channel. Side channels are flowing water bodies having identifiable upstream and downstream connections to the main channel. Side channels support hydrologic functions by slowing stream flow and creating more opportunity for groundwater replenishment, support nutrient cycling and water quality functions, and create specialized habitat for fish and wildlife by providing refuge from high velocity flows, thermal refugia during summer low flows, and access to food sources.

Function Groups: Hydrology, Biology

Functions Informed: Surface Water Storage (SWS), Sub-Surface Transfer (SST), Maintain Biodiversity (MB), Create and Maintain Habitat (CMH)

Stratification: This measure is not stratified

Metric: Percent of channel with adjacent side channels

Model:

IF SideChan < 10%, THEN=0.03*SideChan;

IF SideChan = 10-50%, THEN=0.01*SideChan + 0.2;

IF SideChan > 50%, THEN=0.006*SideChan + 0.4

Table 4.28. Side Channels Scoring Index

Side channels measured as proportion of EAA length			
Function Value Ranges	Low	Moderate	High
Field Value	< 10%	10-50%	> 50%
Index Value	0.0 - < 0.3	0.3-0.7	> 0.7-1.0

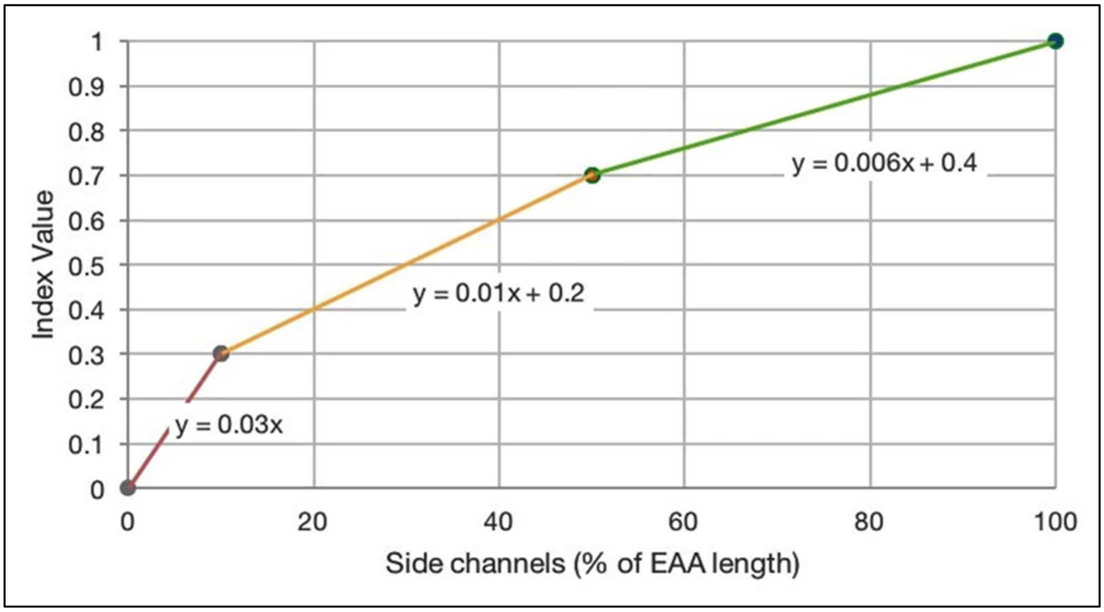


Figure 4.21. Side Channels Standard Performance Index

STANDARD PERFORMANCE INDEX

Development Method

As an active area of research in the fisheries and restoration arena, there is a solid body of information in the literature linking the presence of side channels to hydrologic and biologic functions. Studies throughout the Pacific Northwest supported development of the standard performance index for this measure.

This measure uses continuous data. Calculating the index score using a continuous scale is supported by the literature and enables better detection of any change that results from impacts or mitigation activities.

SCIENTIFIC SUPPORT FOR ECOLOGICAL FUNCTIONS

Hydrologic Function

Side channels are features of alluvial river systems created through fluvial processes, that are adjacent to the main channel at some flows (Landers *et al.,* 2002). They are off-channel flowing water bodies having identifiable upstream and downstream connections to the main channel (Landers *et al.,* 2002). Over time, side channels generally evolve into back water sloughs or alcoves.

In the Umatilla River, a high desert gravel and cobble bedded river in a well-developed floodplain in northeastern Oregon, baseflow water temperatures of hyporheic discharge to side channels were monitored using potentiometric surface maps, piezometers, and temperature loggers (Arrigoni *et al.,* 2008). Data were collected on the scale of channel units (e.g., a single gravel bar created side channel). These researchers found that hyporheic exchange enhances temperature diversity in surface and subsurface habitats, moderates both diel and annual temperature cycles, and creates dynamic reach-scale mosaics of channel water temperatures observable across channel habitats.

Data in the supporting literature cited in **Table 4.29** indicate that water exchange with the stream subsurface creates spatial and temporal thermal variation across geomorphic features or channel unit types (i.e., side channel, spring channel, and main channel) (e.g., Ock *et al.,* 2015). Fernald *et al.* (2006) found that cooling patches were associated with longer flow paths and higher flow rate. Higher flow was associated with younger bar features (Fernald *et al.,* 2006). Cooler patches can provide thermal refugia for species stressed by peak mainstem temperatures (Fernald *et al.,* 2006).

Raw data—local time-varying temperature and lag—while not converted to the metric used in SFAM, provide support for the standard performance index based on percent length of side channels in the EAA because increasing length would imply an increasing contribution to the SWS and STS functions, as well as increasing thermal refugia. The index supporting the SFAM model was plotted with two assumptions: 1) that "per channel unit" data provided in the available literature are scalable to an EAA with multiple units; and 2) that percent total length is a reasonable measure of the units.

Biologic Function

Stream forming processes may occur within side channels, and pool-riffle sequences may also develop (Landers *et al.,* 2002). Many species rely on off-channel habitats for some, or all of their life history. For thermally sensitive aquatic species, these habitats provide cold water refugia during summer low flow periods. Juvenile salmonids use these habitats for their abundant resources and to escape high velocity flows. For example, the Oregon Conservation Strategy (2016) notes that seasonal floodplain habitats in the lower Willamette River are occupied by subyearling Chinook salmon from lower Columbia River and upper Columbia River summer-fall evolutionarily significant units (ESU), in addition to those from the upper Willamette ESU. Many native nongame fish species develop in these habitats before moving into the main river channel, while fish like the Oregon chub require these habitats year-round. Native plant communities, amphibians, turtles, and freshwater mussels also depend on these habitats.

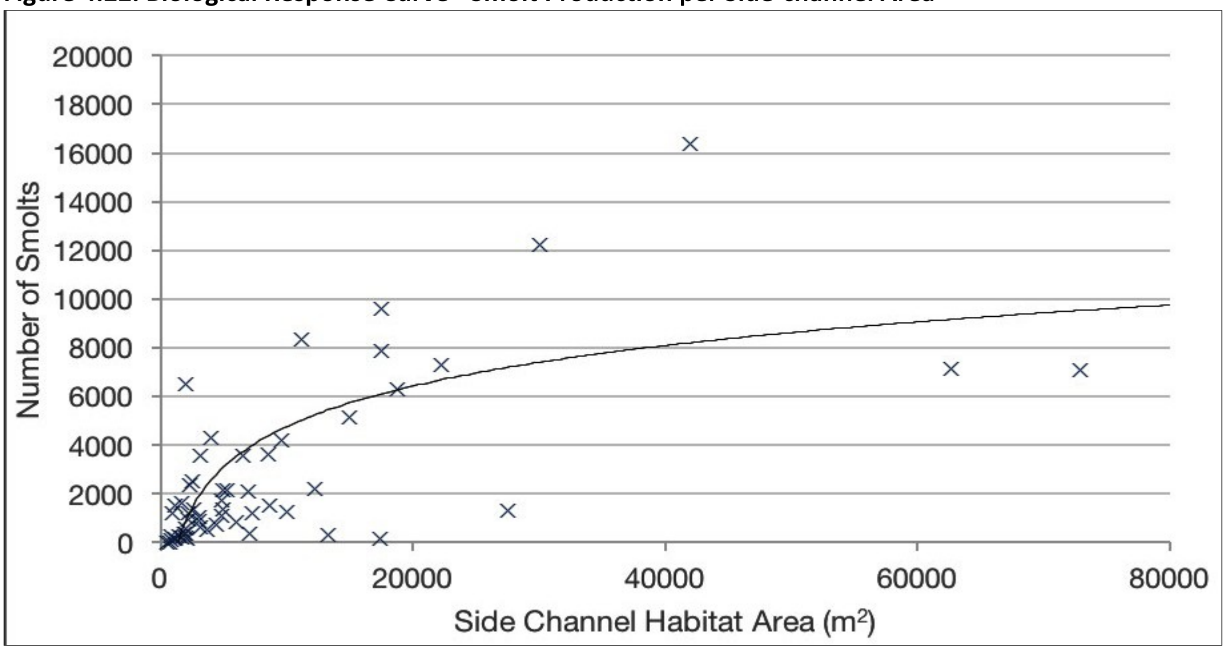
Several studies in the Pacific Northwest have evaluated the contribution of stream side channels to fish habitat. Researchers (Ogston *et al.*, 2015; Roni *et al.,* 2006; Rosenfeld *et al.,* 2008) measured coho smolt production in response to side-channel habitat area at restored sites. The side channels studied span three orders of magnitude in size. Raw data from these studies were plotted and a line fitted to the natural changes in slope to understand how data might inform score ranges (i.e., Low, Moderate, High) for this measure of function. For the relationship between side-channel habitat area and smolt productivity, smolt numbers may increase with relatively small increases in habitat area, as suggested by the data plotted in **Figure 4.22.**

Data in these papers provide a physical measure of side-channel habitat and quantify the ability to create habitat in terms of coho smolt production. Although these data give a measure of side-channel habitat specifically for coho salmon, coho salmon are considered an umbrella species for side-channel habitat. Benefits of side-channel habitat conferred to coho salmon are related to biodiversity and population responses of other fishes; therefore, data can be used to quantify the ability to Maintain Biodiversity (MB) for fish (Branton and Richardson, 2014). The relationships to habitat for other species (e.g., amphibians and benthic invertebrates), however, is less clear (Branton and Richardson, 2014). Restored side-channel habitat area can be used as a surrogate for natural side-channel habitat area; no difference in the amount of smolt production was observed between natural and constructed side-channel habitat (Morley *et al.,* 2005). Carmichael et al. (2020), using high resolution LiDAR data coupled with hydrodynamic and bioengineering modelling, highlight the importance of restoration activities that construct and reconnect lateral habitat to the main channel, develop slow water areas, and increase the overall channel length to increase the total suitable area for juvenile Chinook salmon along the Lemhi River in eastern Idaho.

Data from the literature are not an exact fit for the Side Channel measure because they are absolute area of side-channel habitat rather than percent length of an EAA as used in SFAM; however, length proportion scales to stream size better than area does and one can infer that greater side-channel length and area are correlated.

There is a linear relationship between log (area) and smolt production, with raw data showing an asymptotic effect at approximately 20,000-30,000 m^2 (2-3 ha) (**Figure 4.22**). The biological response (number of smolts produced) increases rapidly relative to the difference in area of the sampled side channels, supporting the SFAM model scoring index for side channels (**Table 4.29**).

Figure 4.22. Biological Response Curve - Smolt Production per Side-channel Area



Note: Data from Roni et al., 2006, Rosenfeld et al., 2008, and Ogston et al., 2015. Graphic is focused on an area that emphasizes the shape of the curve but excludes the highest data points.

Table 4.29. Biological Response Scale - Smolt Production per Side-channel Area

Function Value Ranges	Low	Moderate	High
Relative Difference in Area of Sampled Side Channels	0-10%	11-50%	> 50%
Side-channel Area *(m^2)*	565-6,000	6,500-27,492	30,100-140,000
Number of Smolts Produced	11-6,500	156-9,590	3,916-32,050

Note:
Data from Ogston *et al.,* 2015; Roni *et al.,* 2006; and Rosenfeld *et al.,* 2008

Smolt production in the data presented in **Figure 4.22** is similar to the mean smolt production reported by Rosenfeld *et al.* (2008) (0.476 smolts/m^2) and was also consistent with the Beechie *et al.* (1994) estimate of 0.319-0.775 smolts/m^2 for slough habitat in the Skagit watershed in Washington. Beechie *et al.* (1994) suggest that summer slough potential smolt production should be 0.319/m^2, while winter smolt production would be higher. Data from Ogsten *et al.* (2015) show similar trends between side-channel area and smolt production.

Table 4.30. Summary of Supporting Literature for Side Channels Standard Performance Index

Reference	Metric	Function Response Variable	SFAM Functions Informed	Informative Conclusions
Decision Support for Hydrologic Function				
Arrigoni *et al.,* 2008	Location, time	Channel water temperature, hyporheic discharge temperature, phase, and variation	SST, CMH	Hyporheic discharge had little effect on overall stream water temperature but created patches of cooler and warmer water.
Burkholder *et al.,* 2008	Channel temperature, time	Hyporheic discharge temperature, mainstem temperature	SST, CMH	Hyporheic discharge had little effect on overall stream water temperature but created patches of cooler and warmer water.
Fernald *et al.,* 2006	Location	Hyporheic, main stem, and side-channel/ alcove water temperature	SST, CMH	Hyporheic discharge had a cooling effect in side-channel alcoves, depending gravel age and flow rate.
Ock *et al.,* 2015	Time, location, by construction type	Water temperature, phase	SST, CMH	Constructed off- channel habitat created cooled patches but depended on construction method.

Reference	Metric	Function Response Variable	SFAM Functions Informed	Informative Conclusions
Decision Support for Biologic Function				
Beechie *et al.,* 1994	% of historic side-channel habitat remaining	% of historic Coho smolt production	CMH, MB	The decline in smolt production is strongly associated with the loss of side-channel habitat from the historic condition.
Branton and Richardson, 2014	Coho abundance, coho biomass, environmental variables	Fish and listed fish species richness, abundance, and biomass	CMH, MB	Coho are an umbrella species; a benefit to coho confers benefit to populations of co-occurring species with similar habitat requirements.
Morley *et al.,* 2005	Constructed vs. natural side-channel habitat	Coho smolt production	CMH, MB	No difference in the amount of smolt production observed between constructed and natural side- channel habitat and supports rationale for using restored side-channel area as a metric.
Ogston *et al.,* 2015; Roni *et al.,* 2006; Rosenfeld *et al.,* 2008;	Area of side channel habitat	Coho smolt production	CMH, MB	The area of restored side channels is related to coho smolt production. Coho smolt production shows a logarithmic response to increase in restored side-channel area.

Notes:
CMH: Create and Maintain Habitat
MB: Maintain Biodiversity
SST: Sub/Surface Transfer
SWS: Surface Water Storage

MEASURE DEVELOPMENT

Except for the inclusion of more recent scientific support literature, this measure remains unchanged from the previous version of SFAM (Nadeau *et al*., 2020a). For more information on the development history and inclusion of this measure of function in SFAM, please see Nadeau *et al*. (2020b; Section 4.2(l)).

F13. Lateral Migration

MEASURE TEXT

What percent of both sides of the channel is constrained from lateral migration? Constraints on lateral migration of the channel within 2 × BFW or 50 feet (whichever is greater) includes bank stabilization and armoring, bridges and culverts, diversions, roads paralleling the stream and any other intentional structures or features that limit lateral channel movement whether intentionally or not. For cross-channel structures (diversions, bridges, culverts, etc.), record 4x the bankfull width (BFW) as the length constrained on both sides of the channel. For linear features, record the length on each side of the channel. For segmented bank features, such as bendway weirs or log jams acting in concert, record the effective length of stabilization on each side of the channel affected. It is appropriate to include relevant armoring that is recorded in the Bank Armoring question; these measures are not double-counted in SFAM.

In the office, use aerial imagery to identify and map all constraints to lateral migration as defined above on both sides of the channel within the EAA, up to a maximum distance of 330 feet from the bankfull edge.

MEASURE DESCRIPTION

This measure is an indicator of whether important geomorphological processes, such as erosion and deposition, are occurring or are being unnaturally constrained. Lateral migration of a stream channel is expected when sediment movement is in balance. Unconstrained banks of a channel are exposed to natural erosion processes, which can lead to a widened channel, natural meandering, and creation of diversity in stream energy and sediment deposition rates.

Function Group: Geomorphology
Function Informed: Sediment Continuity (SC)
Stratification: This measure is not stratified
Metric: Percent constrained

Model:

IF LatMigr > 40, THEN=0.0;

IF LatMigr > 20-40; THEN= -0.015*LatMigr + 0.6;

IF LatMigr = 10-20, THEN= -0.04*LatMigr + 1.1;

IF LatMigr < 10, THEN= -0.03*LatMigr + 1.0

Table 4.31. Lateral Migration Scoring Index

Lateral Migration measured as percent constrained				
Function Value Ranges	**Low**		**Moderate**	**High**
Field Value	> 40	> 20-40	10-20	< 10
Index Value	0.0	0.0 - < 0.3	0.3-0.7	> 0.7-1.0

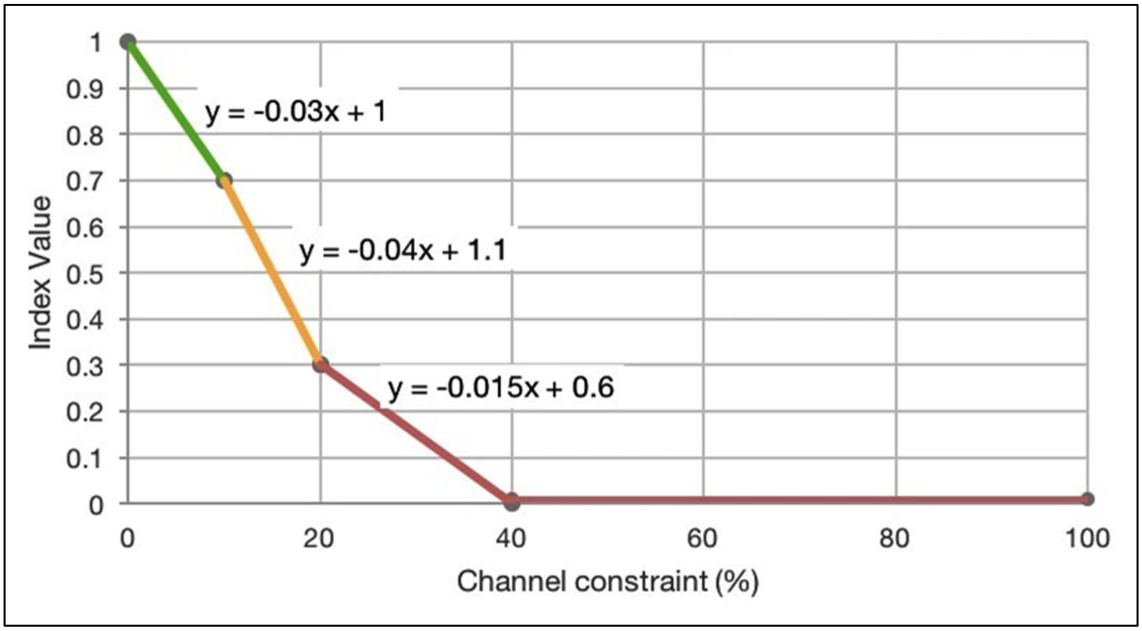


Figure 4.23. Lateral Migration Standard Performance Index

STANDARD PERFORMANCE INDEX

Development Method

Data and literature related to this measure is extremely limited. While scientific studies could not be used to directly inform the development of this standard performance curve, the curve is supported by current scientific understanding of how stream channel constraint relates to geomorphologic function.

This measure uses continuous data. Calculating the index score using a continuous scale allows for better detection of any change that results from impacts or mitigation activities.

SCIENTIFIC SUPPORT FOR ECOLOGICAL FUNCTIONS

Geomorphic Function

Generally, it is recognized that assessing the change in stream function associated with modifications to geomorphic condition is challenging to do in a rapid assessment or at project-level scales. Geomorphic processes are affected by surrounding landscapes and occur across long distances longitudinally in a stream so that processes that occur many miles upstream are linked to conditions downstream. In streams with high function, sediment transport and sorting occur over such large areas that evaluation on the scale of the EAA represents a snapshot of the overall balance in aggradation and erosion or channel migration. Therefore, it is acknowledged that evaluating geomorphic conditions in one EAA would not be adequate to define the overall geomorphic function of that EAA since it is also affected by processes occurring upstream and downstream.

SFAM evaluates the relative area of impairments to geomorphic processes (i.e., barriers to lateral migration) and the area actively undergoing changes in geomorphology (i.e., bank erosion). Geomorphic stream function is represented in SFAM by measuring condition, but the relative equilibrium of geomorphic processes is estimated by using measures of function that counterbalance each other (i.e., low scores given for high bank erosion would be counterbalanced by high scores for high opportunity for lateral migration).

The relative change in stream function associated with a given geomorphic condition is context dependent. Generally, controls on the suite of geomorphic processes include climate, geology, vegetation, and topography, in addition to past natural or anthropogenic disturbances (Montgomery and MacDonald, 2002). Montgomery and MacDonald (2002) state that, "The site-specific interactions between channel type, forcing mechanism, and channel response must be understood to select the variables for monitoring and design effective monitoring projects…. When designing a monitoring project, one must consider the relative sensitivity of each channel characteristic by channel type, forcing mechanism and biogeomorphic context." Channel type, forcing mechanisms, and channel responses for lateral migration are described below.

Channel Type

Channel types proposed by Montgomery and Buffington (1997) integrate seven stream characteristics that could each individually be considered controlling factors of geomorphic function (**Table 4.32**).

Table 4.32. Diagnostic Features of Each Channel Type
(Adapted from Montgomery and Buffington, 1997)

Feature	Dune ripple	Pool riffle	Plane bed	Step pool	Cascade	Bedrock	Colluvial
Typical bed material	Sand	Gravel	Gravel-cobble	Cobble-boulder	Boulder	Rock	Variable
Bedform pattern	Multilayered	Laterally oscillatory	Featureless	Vertically oscillatory	Random	Irregular	Variable
Dominant roughness elements	Sinuosity, bedforms (dunes, ripples, bars) grains, banks	Bedforms (bars, pools), grains, sinuosity, banks	Grains, banks	Bedforms (steps, pools), grains, banks	Grains, banks	Boundaries (bed and banks)	Grains
Dominant sediment sources	Fluvial, bank failure	Fluvial, bank failure	Fluvial, bank failure	Fluvial, hillslope, debris flows	Fluvial, hillslope, debris flows	Fluvial, hillslope, debris flows	Hillslope, debris flows

Feature	Dune ripple	Pool riffle	Plane bed	Step pool	Cascade	Bedrock	Colluvial
Sediment storage elements	Overbank, bedforms	Overbank, bedforms	Debris flows	Bedforms	Lee (steep) and stoss (gentle) sides of flow obstructions	Pockets	Bed
Typical confinement	Unconfined	Unconfined	Overbank	Confined	Confined	Confined	Confined
Typical pool spacing (channel widths)	5-7	5-7	Variable	1-4	< 1	Variable	Unknown

Forcing Mechanisms

Other interacting forcing mechanisms of Lateral Migration include:

- Spatial location within the channel network in a sediment production zone, sediment transfer zone, or sediment deposition zone
- Temporal variability in inputs (peak flows or mass wasting events versus monthly or annual averages)
- Valley slope
- Proximity to sources or sinks of sediment, water, or wood
- Vegetation
- Disturbance history

While these controls contribute to the variability in sensitivity of the response of a certain measure of stream function over time and space, there was not sufficient information to meaningfully stratify the standard performance index at this time.

Channel Response

In the SFAM model, anthropogenic constraints to lateral migration affect sediment continuity (SC) (the balance between transport and deposition). The rationale for this relationship is rooted in a statement from Montgomery and MacDonald (2002) that "lateral confinement provides an initial guide to the potential range of channel response," since channel confinement in wide floodplains may limit a stream's ability to change course, sinuosity, or planform in response to disturbance. Channels confined by anthropogenic infrastructure such as roads are narrower, simpler in planform, and are devoid of depositional surfaces such as bars and islands and the associated floodplains lack the channel complexity that supports other functions like water quality and habitat (Blanton and Marcus, 2013). Broadly speaking, anthropogenic constraints to lateral migration alter sediment transport processes resulting in diminished stream function.

MEASURE DEVELOPMENT

This measure remains unchanged from the previous version of SFAM (Nadeau *et al*., 2020a). For more information on the development history and inclusion of this measure of function in SFAM, please see Nadeau *et al*. (2020b; Section 4.2(m)).

As SFAM continues to develop and as relevant information becomes available, stratification of this standard performance index based on channel type could be considered. While anthropogenic constraint to lateral migration can be considered broadly to diminish stream function, the magnitude of change in stream function may depend on channel type and other forcing mechanisms.

F14. Wood

MEASURE TEXT

What is the frequency of large wood in the bankfull channel?

What is the frequency (pieces per 328 feet (100 m) of channel) of independent pieces of wood, defined here as woody material with a diameter of at least 4 inches (10 cm) for a length of 5 feet (1.5 m) within the EAA? This means that at least 5 feet of the piece of wood must be larger than 4 inches in diameter (i.e., a circumference > 12.5 inches). Independent pieces include all those individual pieces that meet size criteria either separate from or within log jams. To be counted, wood must have some part of its length within the bankfull channel. Exclude any wood that has been intentionally anchored to or within channel banks (using spikes, cables, ballast, etc.) for the purpose of permanently preventing bank erosion or meandering processes (armoring). Wood that is incorporated into an armored streambank for the purpose of providing habitat (e.g., as may be required by the agencies as a best management practice), or that is anchored in-stream to support meandering processes, may be counted. Live trees (i.e., trees that are standing, rooted, having or producing foliage) are not considered "wood" for this measure. Trees that are fully or partially fallen, have an exposed root wad, show evidence of being removed from the soil, or show other signs of dying (e.g., bare branches) are counted as "wood."

MEASURE DESCRIPTION

This measure quantifies the amount of wood that is in the stream channel and available to contribute to several stream ecosystem components, including: habitat diversity for fish and macro-invertebrates; substrate for primary producers; sediment storage; transient hydraulic storage and water velocity variability.

Function Groups: Hydrology, Biology

Functions Informed: Surface Water Storage (SWS), Maintain Biodiversity (MB), Create and Maintain Habitat (CMH)

Stratification: This measure is stratified by both ecoregion (Western Mountains; Xeric) and stream size (small ≤ 50 feet (~15 m) width; large > 50 feet width)

Metric: Pieces of wood per 328 feet (100 meters)

Model:

Western Mountains ecoregion; ≤ 50 feet wide:

IF Wood < 1.9, THEN = 0.1579*Wood;

IF Wood ≥ 1.9-24.8, THEN = 0.0175*Wood + 0.2668;

IF Wood > 24.8-37, THEN = 0.0153*Wood + 0.3204;

IF Wood > 37, THEN = 1.0

Western Mountains ecoregion; > 50 feet wide:

IF Wood ≤ 4.1, THEN = 0.0976*Wood + 0.3;

IF Wood > 4.1-8.7, THEN = 0.0652*Wood + 0.4326;

IF Wood > 8.7, THEN = 1.0

Xeric ecoregion; ≤ 50 feet wide:

IF Wood ≤ 8.2, THEN = 0.0488*Wood + 0.3;

IF Wood > 8.2-22.8, THEN = 0.0205*Wood + 0.5315;

IF Wood > 22.8, THEN = 1.0

Xeric ecoregion; > 50 feet wide:

IF Wood ≤ 1.4, THEN = 0.2857*Wood + 0.3;

IF Wood > 1.4-4.4, THEN = 0.1*Wood + 0.56;

IF Wood > 4.4, THEN = 1.0

Table 4.33. Wood Scoring Index

Pieces of wood (per 328 feet)				
Function Value Ranges	Low	Moderate	High	
Western Mountains; ≤ 50 ft width	< 1.9 pcs	1.9-24.8	> 24.8-44.4	> 44.4
Western Mountains; > 50 ft width	N/A	≤ 4.1	> 4.1-8.7	> 8.7
Xeric; ≤ 50 ft width	N/A	≤ 8.2	> 8.2-22.8	> 22.8
Xeric > 50 ft width	N/A	≤ 1.4	> 1.4-4.4	> 4.4
Index Value	0.0 - < 0.3	0.3-0.7	> 0.7 - < 1.0	1.0

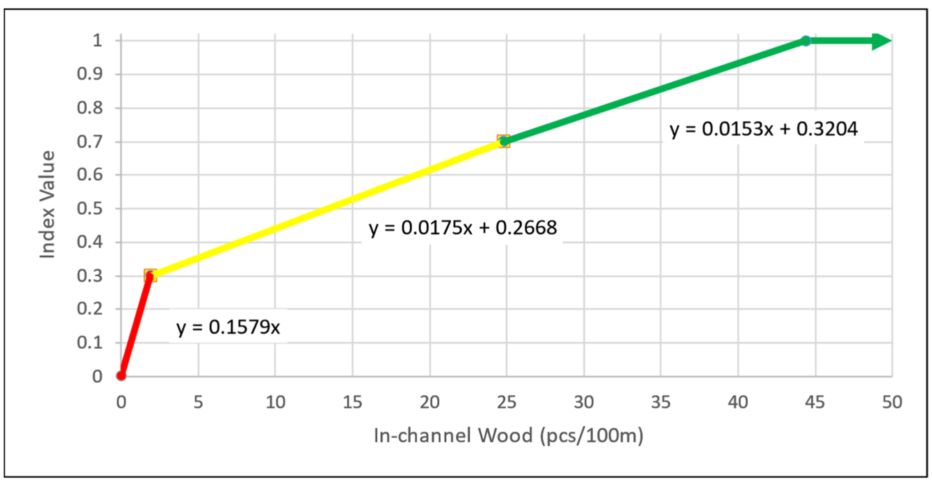


Figure 4.24. Wood Standard Performance Index – Western Mountains Ecoregion; ≤ 50 ft width

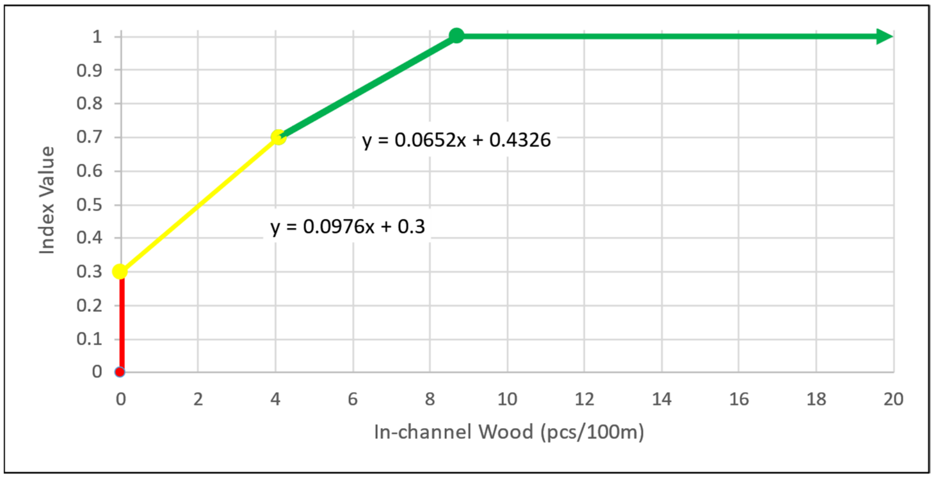


Figure 4.25. Wood Standard Performance Index – Western Mountains Ecoregion; > 50 ft width

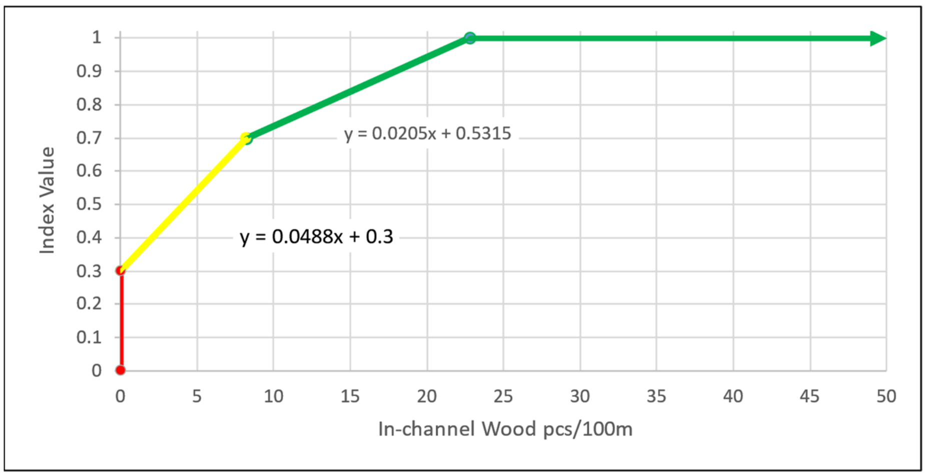


Figure 4.26. Wood Standard Performance Index - Xeric Ecoregion; ≤ 50 ft width

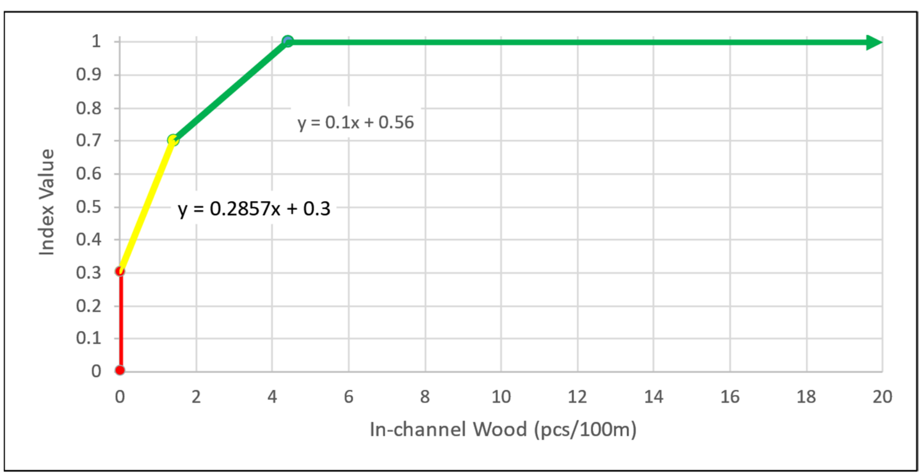


Figure 4.27. Wood Standard Performance Index - Xeric Ecoregion; > 50 ft width

STANDARD PERFORMANCE INDEX

Development Method

While there are many studies that relate the presence of wood, or a specific treatment of added wood to stream function (typically channel complexity and/or salmonid habitat/abundance) there is limited literature indicating critical loadings of wood for function response or regressions of wood-loading to response functions. Therefore, the standard performance indices presented here were developed based on the distribution of field-collected data from the USEPA NRSA surveys conducted in 2008-2009, 2013-2014, and 2018-2019 (USEPA, 2020). The index thresholds were determined using the approach described in **Section 4.1**. Threshold values are presented in **Table 4.34**, below.

This measure uses continuous data. Calculating the index score using a continuous scale allows for better detection of any change that results from impacts or mitigation activities.

Stratification

Streams occurring in dry (xeric) climates, where riparian vegetation is less dense and streams have lower wood recruitment rates than streams in wetter climates, are generally expected to have lower amounts of in-stream wood (Berg *et al.,* 1998; Dunkerley, 2014; Hering *et al.,* 2000; Lester *et al.,* 2006). Additionally, one would expect larger streams to have a smaller quantity of wood because wood is less stable and more easily transported downstream than in smaller streams (Curran, 2010; Hyatt and Naiman, 2001). Therefore, we evaluated using ecoregion (Western Mountains and Xeric) and two stream width categories, small (width ≤ 50 feet [15 m]) and large (width > 50 feet), to stratify the NRSA in-stream wood data.

The frequency distribution plots of the NRSA data (**Figure 4.28**) show that wood amounts tend to be greater in streams in the Western Mountains ecoregion than in the Xeric ecoregion and greater in smaller (width ≤ 50 feet) streams versus larger streams, especially in the Western Mountains ecoregion. Given the differences in wood frequency by stream size and ecoregion in the NRSA data, in addition to support of these expectations in the scientific literature, this measure is stratified on both ecoregion and stream width. A standard performance index was developed for each combination of stratifiers.

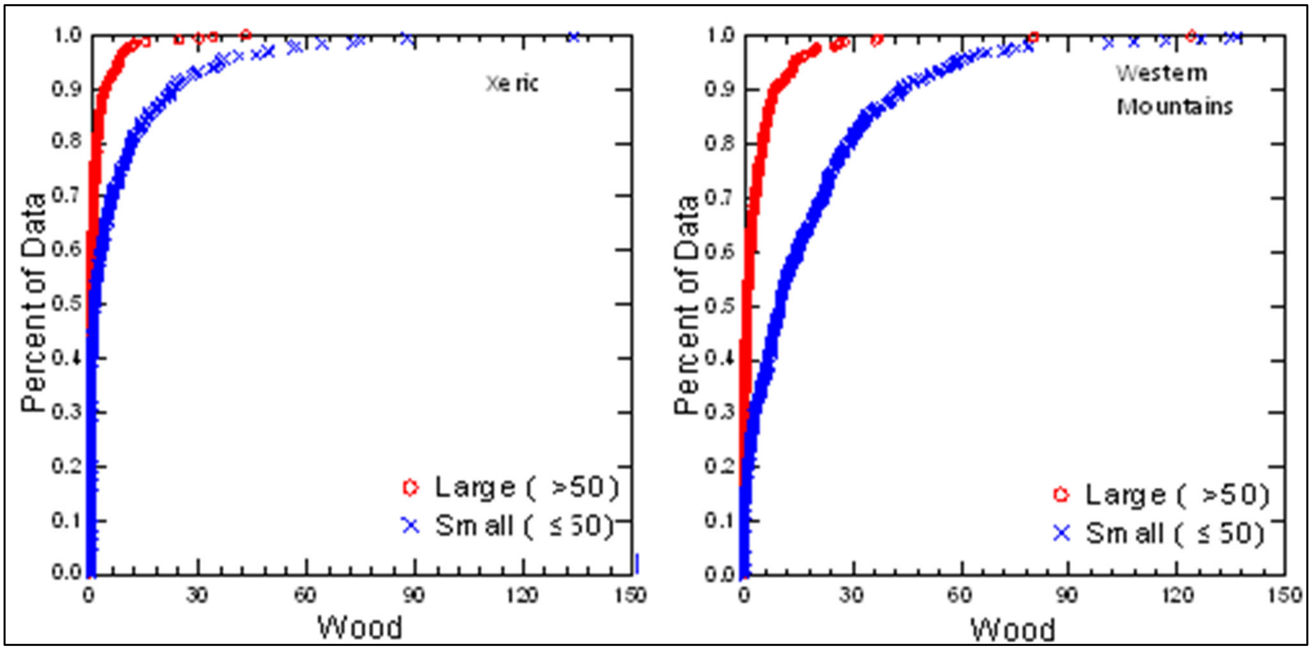


Figure 4.28. Frequency Distribution of Large Woody Debris Counts (per 328 feet) for 1314 Stream Reaches by Ecoregion and Stream Size

Table 4.34. Frequency Distribution of NRSA Large Wood Counts (per 328 feet [100 m]), Stratified by Ecoregion and Stream Size

The 25th percentile of data, establishing the threshold between "low" and "moderate" function index values, is highlighted in red. The 75th percentile of data, establishing the threshold between "moderate" and "high" function index values, is highlighted in green. The 90th percentile of the data, establishing the threshold for the maximum index value (1.0), is highlighted in blue.

Wood				
Summary Statistics	Western Mountains		Xeric	
	Small (≤ 50′)	Large (> 50′)	Small (≤ 50′)	Large (> 50′)
Number of Sites	381	352	263	318
Minimum	0	0	0	0
Maximum	202	124.2	133.8	42.9
Arithmetic Mean	18.2	3.7	7.7	1.6
Standard Deviation	24.9	9.3	15.6	4.3
Distribution of Data				
1.0%	0	0	0	0
10.0%	0	0	0	0
25.0%	1.9	0	0	0
50.0%	10	0.91	0.91	0.1
75.0%	24.8	4.1	8.2	1.4
90.0%	44.4	8.6	22.8	4.4

SCIENTIFIC SUPPORT FOR ECOLOGICAL FUNCTIONS

Hydrologic & Biologic Functions

There is extensive literature on the topic of wood function in streams in the western U.S. A review article by Roni *et al.* (2015) focuses on studies regarding wood placement used in river restoration and concludes, among other things, that "the vast majority of studies on wood placement have reported improvements in physical habitats (e.g., increased pool frequency, cover, habitat diversity) and most evaluations of fish response to wood placement have shown positive responses for salmonids."

As noted in the Roni *et al.* (2015) review, many studies show that large woody debris (LWD) contributes to stream complexity including studies conducted in Oregon and Washington (Johnson *et al.,* 2005; Kaufmann *et al.,* 2012; Martens and Devine, 2023). Work by Kaufmann *et al.* (2012) indicates a positive linear correlation between LWD and transient hydraulic storage in Western Oregon streams with LWD loads ranging from 6-97 pcs/100 m. Studies conducted in Rocky Mountain streams found LWD contributing to channel complexity and pool formation (Wohl and Goode, 2008; Little *et al*., 2012). Little *et al*. (2012) concluded that the pools formed by in-stream wood structures captured fine sediments resulting from wildfire disturbance.

Studies have shown positive responses of stream biota to LWD. Johnson *et al*. (2005) found juvenile steelhead and coho salmon survival increased in a stream where the volume of wood was increased from ~20 m^3 per 100 m to 60 m^3 per 100 m. In a study in the Upper Midwest (Johnson *et al.,* 2003), 85% and 95% of the total macroinvertebrate taxa encountered were found in wood habitats in Michigan and Minnesota streams, respectively. In the Michigan streams, 17% of the taxa were unique to the wood habitats.

Table 4.35. Summary of Supporting Literature or Data for Wood Standard Performance Indices

Reference	Metric	Function Response Variable	SFAM Functions Informed	Metric Classifications	Informative Conclusions
Data source					
USEPA NRSA Rivers and Streams Assessment data (2008-2019)	LWD counts (pieces per 100 m)	None	None	Many available; evaluated ecoregion and stream width (large (> 50 ft) vs. small (< 50 ft)	Evaluation of this large data set (n=1368) from stream reaches representative of the ecoregions which occur in Oregon provide the expected range and distribution of stream wood counts.
Decision Support for Hydrologic and Biologic Functions					
Johnson *et al.*, 2003	Wood volume and "length density"	Macroinvertebrate taxa richness and abundance	MB, CMH, SWS	Low gradient streams in the Upper Midwest	Wood represents an important habitat for macroinvertebrates in this region. A significant portion of local macroinvertebrate diversity can be attributed to the presence of large wood.
Johnson *et al.*, 2005	LWD counts by size class; estimated volume	Abundance and survival of juvenile salmonids	CMH, MB	Coastal Oregon	An increase in LWD increased fish habitat (summer pool habitat and side-channel habitat) as well as measured freshwater survival of steelhead and coho.

Reference	Metric	Function Response Variable	SFAM Functions Informed	Metric Classifications	Informative Conclusions
Kaufmann *et al.*, 2012	LWD counts (pcs per 100 m) by size class; estimated volume	Transient hydraulic storage	MB, CMH, SWS,	Western Oregon wadeable streams	LWD as well as variability in stream depth and width contribute to transient hydraulic storage, a channel process important for biotic habitat as well as nutrient retention and cycling.
Little et al., 2012	In-stream wood structures	Pool spacing, pool type and sediment storage burned vs unburned drainage	CMH, SWS	Headwater streams in Canadian Rockies	The number of in-stream wood structures were similar in the burned and unburned basins 1.5 and 1.48/100m respectively. The volume of fine sediments in pools was greater in the burned catchment stream.
Martens and Devine, 2023	LWD count and size class	Pool formation	CMH, MB, SWS	Western Washington second growth forests	Pool formation is highly correlated with instream wood. Larger wood had a much higher likelihood of forming pools.
Roni *et al.*, 2015	Review of wood placement literature	Effectiveness of placed wood	CMH, MB, SWS	Considered literature from around the world	The majority of studies report improvements in physical habitat in response to wood placement, and most evaluations of fish response to wood placement were positive for salmonids.

Notes:
CMH: Create and Maintain Habitat
MB: Maintain Biodiversity
SWS: Surface Storage

MEASURE DEVELOPMENT

Except for revised standard performance indices and thresholds reflecting an updated analysis including additional data from the 2018-2019 NARS surveys, and inclusion of more recent scientific support literature, this measure remains unchanged from the previous version of SFAM (Nadeau *et al*., 2020a). The data collection protocol for this measure is consistent with the protocol used in the NARS surveys. For more information on the development history and inclusion of this measure of function in SFAM, please see Nadeau *et al*. (2020b; Section 4.2(n)).

F15. Incision

MEASURE TEXT

What is the degree of channel incision within the EAA?

At each of the 11 transects within the EAA, measure the bank height ratio (BHR). The BHR is the height from the stream thalweg to the level of the first terrace of the valley floodplain divided by the bankfull height. Do not consider inset floodplains. Note that in a very connected/non-incised stream, the first terrace height and bankfull height are equal.

MEASURE DESCRIPTION

This measure provides information about hydrologic connectivity and channel stability. Stream bank incision ratios are a measure of the vertical containment of a stream and indicate the potential for a stream to interact with its floodplain. A lower bank height ratio corresponds with more frequent access to the floodplain by the stream's waters.

Function Groups: Hydrology, Geomorphology, Biology

Functions Informed: Surface Water Storage (SWS), Sediment Continuity (SC), Create and Maintain Habitat (CMH)

Stratification: This measure is not stratified

Metric: Bank height ratio

Model:

IF Incision > 2.72, THEN = 0.0;

IF Incision > 1.95-2.72, THEN = -0.3896*Incision + 1.0597;

IF Incision = 1.26-1.95, THEN = -0.5797*Incision + 1.4304;

IF Incision < 1.26, THEN = -1.1538 *Incision + 2.1538

Table 4.36. Incision Scoring Index

Incision measured as bank height ratio				
Function Value Ranges	**Low**		**Moderate**	**High**
Field Value	> 2.72	> 1.95-2.72	1.26-1.95	< 1.26
Index Value	0.0	> 0.0 - < 0.3	0.3-0.7	> 0.7-1.0

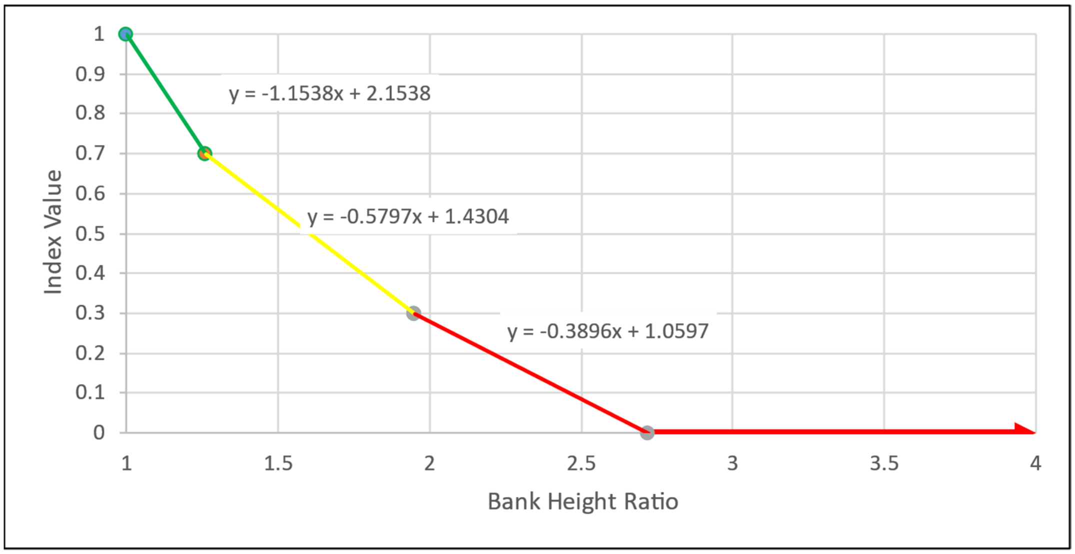


Figure 4.29. Incision Standard Performance Index

STANDARD PERFORMANCE INDEX

Development Method

While there is significant information in the literature to support that the degree of incision influences floodplain interaction and streambank erosion processes, there is limited indication of critical bank height ratios for function response. Therefore, the standard performance index presented here was developed based on the distribution of field-collected data from the USEPA NRSA surveys (USEPA, 2020). The NRSA data parameters XDEPTH (mean thalweg depth [cm], XBKF_H (mean bank full height), and XINC_H (mean incision height) were used to calculate BHR. The index thresholds were determined using the approach described in **Section 4.1**. Threshold values are presented in **Table 4.36**, above.

Stratification

The Incision measure is not stratified as the bank height ratio is normalized by the bankfull depth. Therefore, a BHR of 1.0 means that water will flow out of the banks at a stage above bankfull. Evaluation of the NRSA BHR data by ecoregion and stream size show that while there is some difference in BHR between large and small streams in the Western Mountains ecoregion sites, it only occurs at BHR values that would likely be considered “low” and is not significant enough to warrant stratification for BHR (**Figure 4.30**). There is no indication of significant differences in BHR between the Western Mountain and Xeric ecoregions.

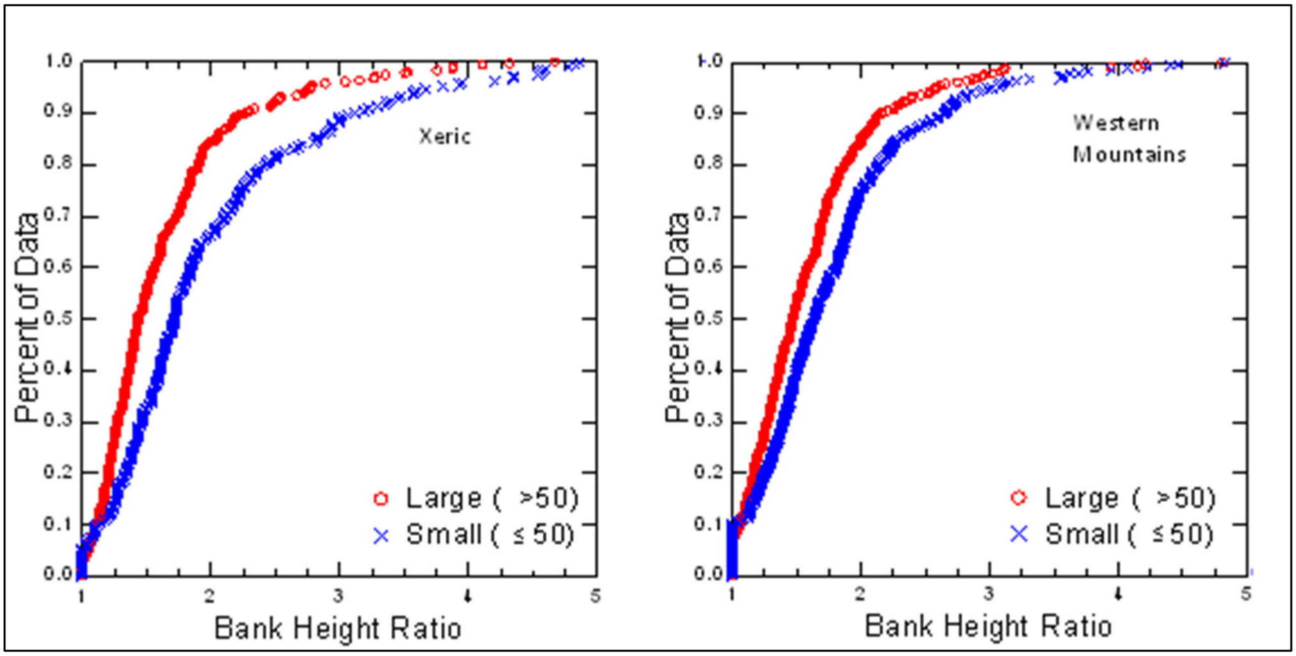


Figure 4.30. Frequency Distribution of Bank Height Ratio Values for 1339 Stream Reaches by Ecoregion and Stream Width

Table 4.37. Frequency Distribution of NRSA Incision Data (Bank Height Ratio)

This measure has an inverse scale; higher ratios indicate lower functioning. The 25th percentile of data, establishing the threshold between "moderate' and "high" function index values, is highlighted in green. The 75th percentile of data, establishing the threshold between "low" and "moderate" function index values, is highlighted in red. The 90th percentile of data, establishing the threshold for an index value of 0.0 is highlighted in blue.

Incision (bank height ratio)	
Summary Statistics	
Number of Sites	1339
Minimum	0.04
Maximum	78.6
Arithmetic Mean	1.9
Standard Deviation	9.9
Distribution of Data	
1.0%	0.49
10.0%	1.0
25.0%	1.3
50.0%	1.6
75.0%	1.9
90.0%	2.7

SCIENTIFIC SUPPORT FOR ECOLOGICAL FUNCTIONS

Stream and river channel incision is recognized as a widespread environmental problem that has caused extensive ecosystem degradation, affecting instream and riparian habitat (Montgomery, 2007; Pollock *et al*., 2007; Wang *et al*., 1997). Incision is the process of downcutting into a stream channel leading to a decrease in the channel bed elevation and therefore higher stream banks (Darby and Simon, 1999), reducing the frequency and duration of flooding onto the adjacent floodplain (Pollock *et al*., 2007). While natural processes can cause channel incision, many instances of channel incision have been shown to be caused by or to be correlated with changes in land use (Cooke and Reeves, 1976; Montgomery, 2007). Incision is a common response of streams to land use changes throughout much of the semi-arid regions of the American West (Pollock *et al*., 2007).

Hydrologic Functions

One significant result of channel incision is the disconnection of a stream from its floodplain. Floodplain disconnection has significant impact on hydrologic functions, especially the storage of surface water (SWS). When a stream is unable to access its floodplain, water cannot be transferred away from the main channel during high flow events and instead the full volume must instead by transferred by the channel resulting in increased velocity of flow and an increase in downstream flood severity.

While the literature contains few studies directly linking stream incision (and magnitude thereof) to functional loss, there are several case studies citing a significant reduction in downstream flooding following the re-connection of stream floodplain. A number of these case studies are discussed in a review paper by Abbe *et al*. (2016). In a modelling study of river wetland corridors, Powers et al. (2022) isolated legacy anthropogenic incision versus evolutionary natural incision of central Washington's Entiat River and correlated this to "likely profound salmonid habitat loss" that helps explain historical and ongoing declines in Chinook salmon and steelhead trout (*Oncorhynchus mykiss*). The loss of hydrologic functions resulting from floodplain disconnection is further discussed in the rationale for the SFAM Floodplain Exclusion measure (**Section 4.2[F7]**).

In addition to reducing water storage during high-water periods, an incised stream can effectively lower the local water table thereby reducing stored water available for discharge during dry periods and for riparian vegetation (Chaney *et al*., 1990; Green, 2016; Rosgen, 1997; Solins and Cadenasso, 2020). In a Northern California urban setting where stormwater runoff was causing channel incision, Solins and Cadenasso (2020) found increased stress in riparian trees during seasonal dry periods due to the lowered water table.

In summary, the evidence in the scientific literature clearly demonstrates that stream incision can have significant negative impacts on the surface water storage function, which in turn can increase downstream flooding and reduce water availability during low-flow periods.

Geomorphic Functions

It is generally recognized that assessing the change in stream function associated with modifications to geomorphic condition is challenging to do using a rapid assessment or at project-level scales. Geomorphic processes are affected by surrounding landscapes and land uses and occur across long distances longitudinally in a stream, such that processes that occur many miles upstream are linked to conditions downstream. In high functioning streams, sediment transport and sorting occur over large areas, and evaluation on the scale of the EAA (in the case of incision) represents a snapshot of the overall stream geomorphology.

In SFAM, the average BHR as measured in the EAA helps describe the overall balance (or imbalance) of sediment transport processes (i.e., Sediment Continuity (SC)). When sediment transport increases or erosion resistance decreases such that the excavation rate of streambed sediment is faster than its replacement rate, channel incision will occur (Beechie *et al*., 2008; Cluer and Thorne, 2014). While BHR does not indicate timing or direction (aggradation or degradation), an incised stream is less likely to have sediment processes that are in balance.

As the BHR increases over 1.0 (floodplain height is greater than the bankfull height), indicating some degree of incision, the streambank heights increase, become less stable and are prone to erosion adding sediment to the downstream bedload (Rosgen, 1997). As discussed above, an incised stream is less connected to its floodplain and therefore has less opportunity to deposit fine material outside the channel. This increased bedload affects instream structure, including substrate embeddedness and the filling of pools (Greene, 2016). Stream incision is widely recognized by stream geomorphologists as both a consequence and cause of stream sediment process instability.

Biologic Functions

Stream incision can affect both riparian and instream habitat. The floodplain disconnection which results from incision reduces surface water storage and can lower the local water table, which in turn reduces the available water for wetland and riparian plants dependent on connection to the stream water. The reduction in stored water and lowered water table also limits source water in the dry season, which can result in the drying of streams or the warming of water due to a lower volume of cool water inputs (Chaney *et al*., 1990; Green, 2016; Rosgen, 1997).

During high flow periods, incised channels must transfer the full volume of water downstream, reducing access to the floodplain, low-velocity refugia and other resources used by fish (Beechie *et al*., 1994; Henning *et al*., 2006, 2007). The increased water velocity in incised channels also results in reduced channel complexity. Channels that have been disconnected from their floodplains through incision will tend to have fewer side-channels, islands and pools reducing the available area for species who depend on those habitats (Gendaszek *et al*., 2012). Native riparian wet meadow drained by incision resulted in succession to sagebrush and dryland grasses (Loheide and Gorelick 2007). **Section 4.2 (F7)**, Exclusion, discusses several studies detailing the impacts of floodplain disconnection on riparian and aquatic habitat and associated biota.

MEASURE DEVELOPMENT

Except for revised standard performance indices and thresholds reflecting an updated analysis including additional data from the 2018-2019 NARS surveys, and inclusion of more recent scientific support literature, this measure remains unchanged from the previous version of SFAM (Nadeau *et al*., 2020a). The data collection protocol for this measure is consistent with the protocol used in the NARS surveys. For more information on the development history and inclusion of this measure of function in SFAM, please see Nadeau *et al*. (2020b; Section 4.2(o)).

F16. Embeddedness

MEASURE TEXT

What is the degree of substrate embeddedness in the stream channel?

To what extent are larger stream substrate particles surrounded by finer sediments (i.e., silt and/or sand) on the surface of the streambed? Measurements are taken at 11 transects within the EAA.

MEASURE DESCRIPTION

This measure represents the degree to which rocks, gravel, and cobble are surrounded by (embedded in) fine substrates, such as sand, silt, and mud. Measuring stream bed embeddedness provides information about the stream's sediment regime (influenced by substrate type and flow regime), and quantifies the availability of interstitial spaces that can provide shelter and spawning habitat for fish and macroinvertebrate species. Increases in fine sediment deposition within a stream reach can indicate decreases in stability and habitat quality.

Function Groups: Hydrologic, Geomorphology, Biology
Functions Informed: Flow Variation (FV), Substrate Mobility (SM), Create and Maintain Habitat (CMH)
Stratification: This measure is not stratified
Metric: Percent embeddedness

Model:

IF Embed > 78, THEN = -0.0136*Embed + 1.3636;

IF Embed = 37-78, THEN = -0.0098*Embed + 1.061;

IF Embed = 24-37, THEN = -0.0231*Embed + 1.5538;

IF Embed < 24, THEN = 1.0

Table 4.38. Embeddedness Scoring Index

Embeddedness as measured by percent				
Function Value Ranges	**Low**	**Moderate**	**High**	
Field Value	> 78%	> 37-78%	24-37%	< 24%
Index Value	0.0 - < 0.3	0.3-0.7	> 0.7-1.0	1.0

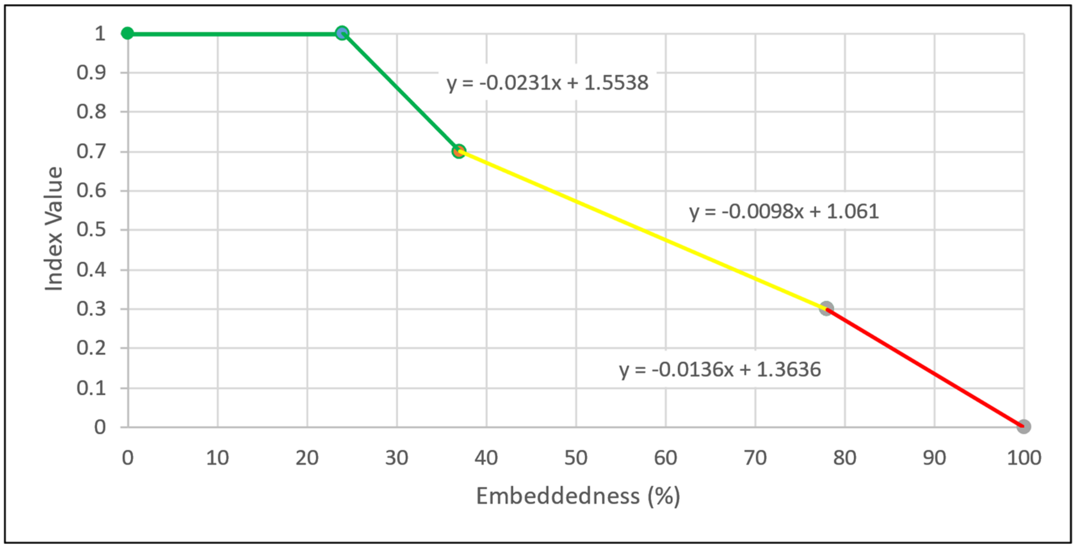


Figure 4.31. Embeddedness Standard Performance Index

STANDARD PERFORMANCE INDEX

Development Method

While there are many studies that relate the degree of embeddedness to various biological and physical stream functions, there is limited literature indicating critical values for function response. Therefore, the standard performance index presented here was developed based on the distribution of field-collected data from the USEPA NARS surveys (USEPA, 2020). The index thresholds were determined using the approach described in **Section 4.1**. Threshold values are presented in **Table 4.38.**

Table 4.39. Frequency Distribution of NRSA Embeddedness Data (Percent Embedded)

This measure has an inverse scale; higher ratios indicate lower functioning. The 25th percentile of data, establishing the threshold between "moderate' and "high" function index values, is highlighted in green. The 75th percentile of data, establishing the threshold between "low" and "moderate" function index values, is highlighted in red. The 10th percentile of data, establishing the threshold for the maximum index value (1.0) is highlighted in blue.

Embeddedness (%)	
Summary Statistics	
Number of Sites	853
Minimum	0
Maximum	100
Arithmetic Mean	56.7
Standard Deviation	25.2
Distribution of Data	
1.0%	6.5
10.0%	**24.3**
25.0%	**37.3**
50.0%	53.9
75.0%	**77.4**
90.0%	94.6

SCIENTIFIC SUPPORT FOR ECOLOGICAL FUNCTIONS

Hydrologic & Geomorphic Function

Embeddedness is a measure of the degree to which fine particles surround coarse substrate (gravel and cobble) on the surface of the streambed and is a common measure used to indicate excessive stream sedimentation (Sennatt *et al.,* 2006; Sutherland *et al.,* 2010). Excessive sediment inputs from land disturbance have significant impacts on streams and rivers in North America and elsewhere (Canadian Council of Ministers of the Environment [CCME], 1995; USEPA, 2002).

There are many causes of excessive sedimentation in streams, including the flushing of fine material from roadways, excessive bank erosion caused by streamside disturbances (e.g., grazing, roads, vegetation removal, etc.), and impoundments that cause changes in the magnitude or timing of stream flows. Multiple studies show a positive relationship between increases in stream sedimentation and watershed land use disturbance (Price and Leigh, 2006; Sutherland *et al.,* 2010; Walser and Bart, 1999; Waters, 1995).

As stream substrates become more embedded, the interstitial space between particles is reduced, effectively reducing streambed roughness and altering channel bedform and hydraulics, limiting the opportunity for hyporheic flow. Substrate mobility can also be substantially affected by the quantity and characteristics of deposited fine material (Wilcock, 1998). It is also well documented that changes to stream flow regime (i.e., changes in flow variation) often result in altered stream sediment characteristics (Elliot and Parker, 1997; Sylte and Fischenich, 2002; Williams and

Wolman, 1984).

To inform the Flow Variation and Substrate Mobility functions, SFAM uses substrate embeddedness as a measure of change in the hydrologic flow regime and to indicate impairment to the mobility of stream substrate.

Biologic Function

Substrate embeddedness resulting from excessive fine sediment deposition reduces the interstitial spaces and substrate surface area relied on by macroinvertebrates, amphibians and fish for shelter and food resources. It reduces streambed roughness that creates habitat and provides respite from stream flow and excessive currents. Embeddedness has been correlated with degraded benthic habitat and a decline in stream macroinvertebrate diversity and abundance (Angradi, 1999; Larson *et al*., 2019; Waters, 1995). In a state-wide assessment of stream biological health in Washington State, Larson *et al* estimated that 60% of stream kilometers rated as poor could be improved by reducing percent fines and sand in the substrate. Additionally, high embeddedness has been shown to reduce amphibian abundance (Lowe and Bolger, 2000).

As part of a fish assemblage and stream physical habitat survey across streams in the Willamette River Basin, Oregon, Waite and Carpenter (2000) found substrate embeddedness to be correlated with low abundance of salmonids and higher abundances of non-native fish species at "heavily impacted" sites within the basin. Further, controlled experiments (Suttle *et al.,* 2004) evaluating varying degrees of embeddedness concluded that embeddedness results in significant decreases in juvenile salmon growth and survival, as well as a decrease in the macroinvertebrate community used by the juvenile salmon as food. As part of a causal assessment of regional reference sites, non-impacted sites and impaired sites in western Washington using the USEPA CADDIS (Causal Analysis/Decision Information System) approach, Marshalonis and Larson (2018) found that mean B-IBI were negatively correlated with B-IBI scores of 39.5, 32.9 and 26.7 and mean % fines of 13%, 23% and 47% for reference, non-impacted and impaired sites respectively. They concluded that fine sediments, flashy flow, and altered habitat were the primary stressors causing the reduced macroinvertebrate B-IBI scores in the Soos Creek watershed.

In an analysis of data from 557 mountain streams across 12 western states as part of the USEPA Environmental Monitoring and Assessment Program (EMAP, precursor to NRSA), quantile regression analysis determined maximum aquatic vertebrate (fish and amphibian) index of biotic integrity (IBI) scores decreased by 4.4 points (0-100 scale) for every 10% increase in sand and fines above a minimal effect threshold of 13% (Bryce et al., 2010). For macroinvertebrates, IBI scores decreased by 3.7 points for every 10% increase above 10% sand and fines.

MEASURE DEVELOPMENT

Except for revised standard performance indices and thresholds reflecting an updated analysis including additional data from the 2018-2019 NARS surveys, and inclusion of more recent scientific support literature, this measure remains unchanged from the previous version of SFAM (Nadeau *et al*., 2020a). The data collection protocol for this measure is consistent with the protocol used in the NARS surveys. For more information on the development history and inclusion of this measure of function in SFAM, please see Nadeau *et al*. (2020b; Section 4.2(p)).

F17. Channel Bed Variability

MEASURE TEXT

Is the channel bed variable?

Channel bed variability submeasures include variation in wetted channel width and stream thalweg depth as measured along the length of the EAA.

MEASURE DESCRIPTION

Channel bed variability is a summary measure of two geomorphic characteristics of the stream: wetted width variability and thalweg depth variability. This measure informs several functions and is a surrogate for assessing the effects of sediment transport and aquatic habitat. Heterogeneity in the elevation along the cross section and the longitudinal axis is indicative of hydraulic variability that maintains the dynamic nature of the channel. Overall bed elevation changes dictate stream power and are reflective of flow and sediment transport. Impacted systems tend to exhibit low variability.

Function Groups: Hydrology, Geomorphology, Biology, Water Quality

Functions Informed: Surface Water Storage (SWS), Sub/Surface Transfer (SST), Flow Variation (FV), Substrate Mobility (SM), Maintain Biodiversity (MB), Create and Maintain Habitat (CMH), Nutrient Cycling (NC), Chemical Regulation (CR)

Metric: Coefficient of variation

Model:

Overall measure = AVERAGE (WidVar, DepthVar)

Wetted Width Variability (WidVar) submeasure:

IF WidVar < 0.217, THEN = 1.3953*WidVar;

IF WidVar = 0.217-0.391, THEN = 2.2989*WidVar - 0.1989;

IF WidVar > 0.391-0.516, THEN = 2.4*WidVar - 0.2384;

IF WidVar > 0.516, THEN = 1.0

Thalweg Depth Variability (DepthVar) submeasure:

IF DepthVar < 0.315, THEN = 0.9524*DepthVar;

IF DepthVar = 0.315-0.567, THEN = 1.5873*DepthVar - 0.2;

IF DepthVar > 0.57-0.741, THEN = 1.7241*DepthVar - 0.2776;

IF DepthVar > 0.741, THEN =1.0

Table 4.40. Channel Bed Variability Scoring Index

Wetted Width and Thalweg Depth as a coefficient of variation				
Function Value Ranges	**Low**	**Moderate**	**High**	
Wetted Width Variability	< 0.217	0.217-0.391	> 0.391-0.516	> 0.516
Thalweg Depth Variability	< 0.315	0.315-0.567	> 0.567-0.741	> 0.741
Index Value	0.0 - < 0.3	0.3-0.7	> 0.7-1.0	1.0

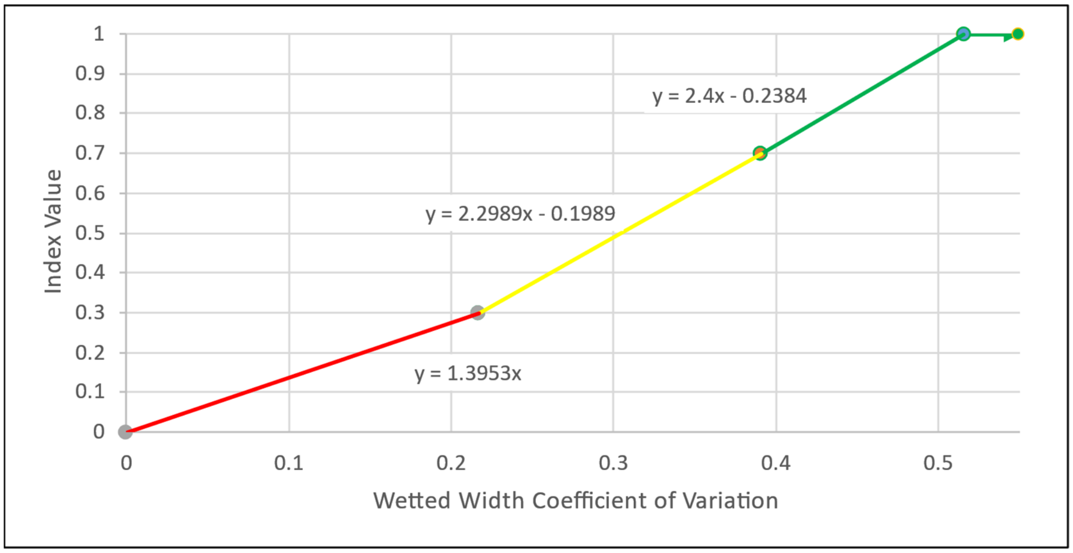


Figure 4.32. Wetted Width Standard Performance Index

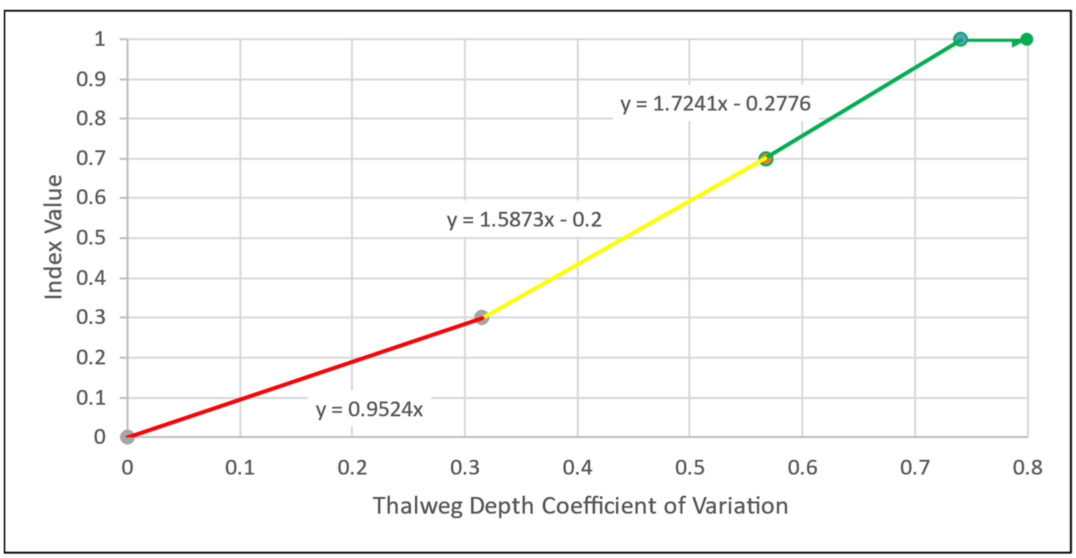


Figure 4.33. Thalweg Depth Standard Performance Index

STANDARD PERFORMANCE INDICES

Development Method

There is significant information in the literature to support that channel bed variability factors have positive relationships with numerous hydrologic, geomorphic, biologic, and water quality functions. The range of specific function responses and the variety of methods used to quantify channel bed variability made it difficult to use the literature to establish standard expectations from the resulting influence of channel bed variability on stream function. Therefore, development of standard performance indices for included submeasures was based on the distribution of field-collected data from the USEPA NRSA surveys (USEPA, 2020). The wetted width submeasure identifies the degree of variability in the wetted stream width of the sample site measured at 11 transects throughout the EAA. Higher variability is considered an indicator of better habitat quality. The thalweg depth submeasure represents the degree of thalweg depth variability in the stream bed with higher variability considered an indicator of better habitat quality. The index thresholds for these submeasures were determined using the approach described in **Section 4.1**. Threshold values are presented in **Tables 4.41** and **4.42** below.

Stratification

Stratification by stream size is unnecessary, given that the coefficient of variation is a scaled metric. Initially, channel slope was considered as a potential factor for stratification of the wetted width and thalweg depth variability measures, but analysis of the NRSA data provided no evidence to support stratification (i.e., the differences in variation between streams with low [<2%], moderate [2-6%], and high [>6%] slopes were small and not significant).

Table 4.41. Frequency Distribution of NRSA Wetted Width Data (Coefficient of Variation)
The 25th percentile of data, establishing the threshold between "low" and "moderate" function index values, is highlighted in red. The 75th percentile of data, establishing the threshold between "moderate" and "high" function index values, is highlighted in green. The 90th percentile of the data, establishing the threshold for the maximum index value (1.0), is highlighted in blue.

Wetted Width (coefficient of variation)	
Summary Statistics	
Number of Sites	1343
Minimum	0
Maximum	1.8
Arithmetic Mean	0.33
Standard Deviation	0.18
Distribution of Data	
1.0%	0.062
10.0%	0.16
25.0%	0.22
50.0%	0.30
75.0%	0.39
90.0%	0.52

Table 4.42. Frequency Distribution of NRSA Thalweg Depth Data (Coefficient of Variation)
The 25th percentile of data, establishing the threshold between "low" and "moderate" function index values, is highlighted in red. The 75th percentile of data, establishing the threshold between "moderate" and "high" function index values, is highlighted in green. The 90th percentile of the data, establishing the threshold for the maximum index value (1.0), is highlighted in blue.

Thalweg Depth (coefficient of variation)	
Summary Statistics	
Number of Sites	1346
Minimum	0.003
Maximum	3.2
Arithmetic Mean	0.47
Standard Deviation	0.24
Distribution of Data	
1.0%	0.078
10.0%	0.24
25.0%	0.31
50.0%	0.42
75.0%	0.57
90.0%	0.74

SCIENTIFIC SUPPORT FOR ECOLOGICAL FUNCTIONS

In SFAM, Channel Bed Variability is measured by the average of two dimensionless metrics: 1) the coefficient of variation (CV) of thalweg depth and 2) the CV of stream wetted width. These metrics capture structural components of what is often referred to as channel habitat complexity.

It is challenging to quantify channel habitat complexity in a meaningful way as part of a rapid stream function assessment intended to be applied across a broad range of stream types and sizes. The submeasures used here are common components of many protocols used to quantify channel complexity, are relatively easily applied to most stream reaches, and are applicable to a wide variety of stream sizes. Because of their operational simplicity, measures of stream width and depth variance have been used to characterize channel complexity (e.g., Gooseff *et al*., 2007; Kaufmann and Faustini, 2012; Laub *et al.*, 2012; Moore and Gregory, 1988).

The literature demonstrates that channel bed variability contributes to a wide range of stream ecological functions. SFAM uses this measure to inform functions of all four functional groups: hydrology, geomorphology, biology and water quality.

Hydrologic Function

Streams that have variable widths and depths create the opportunity for hydrological complexity within that stream. Such complexity results in increases in residual time of water, residual pool volumes, and hydraulic roughness providing Surface Water Storage (SWS) and Flow Variation

(FV) (Gooseff *et al*., 2007; Kaufmann and Faustini, 2012). In a study of small upland cobble/ gravel bottom streams, Kaufmann and Faustini (2012) predicted with significant precision the transient hydraulic storage fraction using the thalweg depth variance ($R^2 = 0.64$-0.91). Transient hydraulic storage is a process by which water is temporarily stored in flow 'dead zones' in the surface waters (pools, eddies) or below the streambed in the hyporheic zone. These areas of stored water provide opportunity for a variety of other ecological functions to occur.

Variation in the geomorphic structure of streams has been found to significantly influence hyporheic exchange (SST) patterns and fluxes (Cardenas *et al*., 2004; Gooseff *et al*., 2006). Gooseff *et al*. (2006) used a modelling approach to identify that slope breaks in the longitudinal profile of streams can be used to predict the spacing between zones of upwelling (flux of hyporheic water into the stream) and downwelling (flux of stream water into the hyporheic zone) in the beds of mountain streams. Harvey and Bencala (1993) found exchange between stream channels and adjacent subsurface waters to be enhanced by convexities and concavities in stream bed topography.

Increases in transient hydraulic storage and retention (dead zones), residual pools, flow velocity variation, and hyporheic flow are properties of streams resulting from multiple attributes of channel structure and can have significant impact on stream hydrology, biology and chemistry.

Geomorphic Function

Variation of channel bed structure and related hydrologic variation provide the opportunity for a more complex and dynamic channel substrate. Variation in flow velocities caused by morphological heterogeneity promotes particle sorting during sedimentation and greater substrate diversity (Kaufmann and Faustini, 2012; Pearsons *et al*., 1992). Areas of low velocities created behind in-channel structure (wood, large cobble), at pool edges, and the inside of meanders will support the deposition of small gravel or fine material, while areas with higher velocities will have larger substrate. Channel bed variability also promotes the dynamic nature of the substrate as the variations in velocity will change depending on the stream stage. Thus, channel bed variability contributes to the dynamic nature of the stream substrate, which in turn supports the maintenance of the varied habitat needed for biologic and water quality functions.

Biologic Function

Biologic function of streams, including the Creation and Maintenance of Habitats (CMH) and Maintaining Biodiversity (MB), requires heterogeneity in the physical environment. Channel bed variation, as discussed above, promotes variation in critical components of the aquatic environment of streams including water depths, velocities, and substrate composition.

There is significant evidence in the literature describing the positive correlation between habitat complexity and biological diversity and abundance (e.g., Carmichael *et al*., 2020; Chisholm *et al*., 1976; Downes *et al*., 2005; Gorman and Karr, 1978). Habitat diversity positively influences species diversity by providing increased physical space, refuge, resources and increases niche availability.

In a study of 41 stream reaches in the Snake River basin, Walrath *et al*. (2016) found that fish species diversity was positively associated with all four components of habitat diversity (substrate, cover, water depth, and water velocity) ($P < 0.09$, Adjusted $R^2 = 0.642$). This study, conducted on reaches with a range of impacts, also concluded that habitat diversity was negatively related to each of five stream condition factors: livestock trails on streambanks, streambank stability, channel width-to-depth ratio, percent fine substrates, and woody riparian vegetation, illustrating the link between land use, stream condition, habitat complexity and fish assemblage.

Many studies have shown the relationship between macroinvertebrate community richness, stream substrate diversity, and variety of stream velocities (Erman and Erman, 1984; Larson *et al*., 2019; Principe *et al*., 2007). In a detailed study of macroinvertebrate communities and channel meso-habitat characteristics Beisel *et al*. (1998) conclude that the relationship between community organization and environmental variables indicate that substrate may be a primary determinant of community structure. Current velocity and water depth emerged as secondary factors.

Water Quality Function

As previously discussed, channel bed variability is an indicator of hydrologic and geomorphic heterogeneity providing transient storage, increased hyporheic connection, channel roughness and varied habitat within the stream substrate. These attributes provide the time, space and surface area for the chemical processes for Nutrient Cycling (NC) and Chemical Regulation (CR) to take place.

Numerous studies discuss the importance of channel complexity and related hydrologic properties to in-stream chemical and nutrient processes (Ensign and Doyle, 2005; Gucker and Boechat, 2004; Lamberti *et al*., 1988). Kaufmann and Faustini (2012) cited the importance of transient hydraulic (''dead zone'') storage as important for retention and ''spiraling'' of dissolved and particulate nutrients. The capacity of the hyporheic zone for transient solute storage was found to correlate with channel morphology, bed roughness, and permeability (Triska, 1989).

Biofilms (bacterial and algal communities) on stream substrates provide active locations for chemical processes contributing to the mechanisms of nutrient uptake (inorganic and organic) and retention of potentially harmful chemicals (e.g., heavy metals and herbicides) (Sabater *et al*., 2007). A complex, variable channel bed provides more surface area and varied environments for biofilms to form.

In summary, channel bed variability contributes to the physical and biotic heterogeneity that provide the opportunity for nutrient cycling and chemical regulation.

MEASURE DEVELOPMENT

Except for revised standard performance indices and thresholds reflecting an updated analysis including additional data from the 2018-2019 NARS surveys, and inclusion of more recent scientific support literature, this measure remains unchanged from the previous version of SFAM (Nadeau *et al*., 2020a). The data collection protocol for this measure is consistent with the protocol used in the NARS surveys. For more information on the development history and inclusion of this measure of function in SFAM, please see Nadeau *et al*. (2020b; Section 4.2(q)).

4.3 Value Measures

Descriptions of each of the 16 value measures are included in the following section. These measures are primarily office-based and generally require evaluation of spatial data sets from a variety of online sources, which are described in more detail in **Appendix A**.

Data collection instructions for each of the following value measures are included in the SFAM User Manual.

Table 4.42 Measures Informing Each Value Formula

Value	Value Measures																Context Measures			
	Rare Species & Habitat Designations[1]	Water Quality Impairments[2]	Protected Areas	Impervious Areas	Riparian Area	Extent of Downstream Floodplain Infrastructure	Zoning	Frequency of Downstream Flooding	Impoundments[3]	Fish Passage Barriers	Water Source	Surrounding Land Cover	Riparian Continuity	Watershed Position	Flow Restoration Needs	Unique Habitat Features	Surface Water Runoff	Aquifer Permeability	Soil Permeability	Erodibility
Surface water storage	X			X		X	X	X	X								X			
Sub/surface transfer											X							X	X	
Flow variation	X	X		X					X						X			X	X	
Sediment continuity		X		X		X			X					X						X
Substrate mobility	X			X					X							X				
Maintain biodiversity	X		X							X		X	X			X				
Create & maintain habitat		X		X	X	X	X		X				X		X	X				
Sustain trophic structure	X	X	X	X	X	X	X			X		X	X			X				
Nutrient cycling	X	X		X	X						X		X	X						

Chemical regulation	X	X		X	X						X		X	X						
Thermal regulation	X	X		X	X								X			X				

[1] This measure includes six independently-scored submeasures: (1) Essential Salmonid Habitat or Rare Non-Anadromous Fish Species, (2) Rare Amphibian and Reptile Species, (3) Important Bird Areas or Rare Waterbirds, (4) Rare Songbirds, Raptors, and Mammals, (5) Rare Invertebrate Species, and (6) Rare Plant Species. A value formula that uses information from this measure does not necessarily use all six subscores.

[2] This measure includes five independently-scored submeasures: (1) Sediment Impairment, (2) Nutrient Impairment, (3) Metals or Other Toxics Impairment, (4) Temperature Impairment, (5) Flow Modification. A value formula that uses information from this measure does not necessarily use all five subscores.

[3] This measure includes two independently-scored submeasures: (1) Upstream Impoundments, (2) Downstream Impoundments. A value formula that uses information from this measure does not necessarily use both subscores.

V1. Rare Species & Habitat Designations

MEASURE TEXT

Are there rare species or special habitat designations in the vicinity of the PA? Answer each submeasure using rare species and habitat information from the online sources described in the User Manual, as well as any available survey data for the PA and its vicinity or personal knowledge about the site.

Note: The SFAM Workbook includes rankings of High, Intermediate, Low, or None for each category of rare species associated with aquatic and riparian habitat. Upgrade a ranking to High if there is a recent (within 5 years) onsite observation of any of these species by a qualified observer under conditions similar to what now occur. Provide references in the notes section of the cover page.

DESCRIPTION

This measure uses information from multiple databases to assess the likelihood that various rare species will access and use a particular site as habitat. Rare species are those likely to be found in wetland and aquatic habitats that have been identified as Species of Greatest Conservation Need in the 2023 *Idaho State Wildlife Action Plan*. Rare species ratings are determined for six categories of species (fish, amphibians and reptiles, waterbirds, other birds and mammals, invertebrates, and plants) using the following definitions for the likelihood that species of conservation concern are observed or known to access particular areas:

High = within the PAA = 1.0

Intermediate = streams within 1 mile of the PAA, but not within the PAA = 0.5

Low = streams within the same HUC6 watershed, but not within 1 mile of the PAA = 0.25

None or not known = 0

Two special designations (PA within a HUC12 that supports anadromous species and Important Bird Area within a 2-mile radius of the PA) are also considered in SFAM when determining the likelihood of rare salmonid and waterbird species benefitting from the stream site. See **Appendix A** for a detailed explanation of these datasets.

Function Groups: Hydrology, Geomorphology, Biology, Water Quality

Values Informed: Surface Water Storage (SWS), Flow Variation (FV), Substrate Mobility (SM), Maintain Biodiversity (MB), Sustain Trophic Structure (STS), Nutrient Cycling (NC), Chemical Regulation (CR), Thermal Regulation (TR)

Model:

IF Fish = PA supports anadromous species OR high rare species score, THEN = 1.0;

IF Fish = intermediate rare species score, THEN = 0.5;

IF Fish = low rare species score, THEN = 0.25;

IF Fish = none/not known, THEN = 0.0

IF RarAmRep/RarBdMm/RarInvert/RarPlant = high rare species scores, THEN = 1.0;

IF RarAmRep/RarBdMm/RarInvert/RarPlant = intermediate rare species scores, THEN = 0.5;

IF RarAmRep/RarBdMm/RarInvert/RarPlant = low rare species scores, THEN = 0.25;

IF RarAmRep/RarBdMm/RarInvert/RarPlant = none/not known, THEN = 0.0

IF Waterbird = Important Bird Area OR high rare species score, THEN = 1.0;

IF Waterbird = intermediate rare species scores, THEN = 0.5;

IF Waterbird = low rare species score, THEN = 0.25;

IF Waterbird = none/not known, THEN = 0.0

RATIONALE FOR INCLUSION

Rare species scores and habitat type occurrences indicate the possibility that species that are locally uncommon may be accessing and utilizing the stream site for food and shelter, reproduction, or migration. These types of species contribute disproportionately to regional biodiversity given their relative rarity. Generally speaking, a site has greater value on the landscape if the various hydrologic, geomorphic, and chemical processes are highly functioning, given that the site will be better able to support the populations of rare species with quality habitat. Each of these processes has different impacts on habitat quality and may affect some types of species more than others.

Hydrologic processes, such as water storage and flow variability, are of high value in areas where rare invertebrates, amphibians, reptiles, and fish may be present because they can create a diversity of habitats. Stream features that create low-velocity refugia and provide pathways for fish movement are important in areas used by rare species as they help individuals shelter from predators and access areas with important resources. Additionally, species of invertebrates, amphibians, reptiles, and fish may rely on environmental cues, such as variability in water flow, to trigger life stage transitions. Therefore, there is high value in maintaining natural, variable flow regimes when there are rare species in the area that may be reliant on temporal variation in hydrologic patterns. The geomorphic process of substrate movement is highly valued in areas with rare species as it can regulate the type of sediment transported to, and through, habitats. For example, some fish, reptile, and plant species may be sensitive to high levels of fine sediment. A stream system that is maintaining a balance of substrate materials would likely provide a more suitable and stable habitat for these types of organisms. Similarly, many species of fish, invertebrates, amphibians, reptiles, birds, mammals, and plants will be sensitive to imbalances in chemical and nutrient content or thermal regime. A site that can regulate these potential water quality issues will provide more suitable habitat to a variety of species, therefore providing a great value in areas that are known to support rare species. Finally, the biological processes of a stream are highly valued when there are rare species present given that they are indicators of the type of habitat that is being provided. A site with increased biodiversity and trophic complexity will be more suitable to support additional species, given that it likely has a diversity of resources.

V2. Water Quality Impairments

MEASURE TEXT

Is this reach on the 303(d) list or other Total Maximum Daily Load (TMDL; Categories 3B-5) for the following: sediment impairment, nutrient impairment, metals or other toxics impairment, temperature impairment, or flow modification?

DESCRIPTION

This measure is used to assess known water quality issues within the project reach. Water quality issues can adversely affect aquatic plant and animal species and often indicate an increased need for regulating functions. There are five categories of impairments assessed in this measure: sediment (sedimentation, total suspended solids, turbidity), nutrient (phosphorus, nitrate, dissolved oxygen, aquatic weeds or algae, chlorophyll a), chemical (toxics, dioxin, heavy metals), temperature, and flow modification. This measure can be answered by accessing the Idaho Department of Environmental Quality's (IDEQ) water quality data, which are used by the state to determine whether water bodies meet water quality standards and support beneficial uses. See **Appendix A** for a detailed explanation of this dataset.

Function Groups: Hydrology, Geomorphology, Biology, Water Quality

Values Informed: Flow Variation (FV), Sediment Continuity (SC), Create and Maintain Habitat (CMH), Sustain Trophic Structure (STS), Nutrient Cycling (NC), Chemical Regulation (CR), Thermal Regulation (TR)

Model:

IF SedList/NutrImp/ToxImp/TempImp/FlowMod = yes; THEN = 1.0;

IF SedList/NutrImp/ToxImp/TempImp/FlowMod = no; THEN = 0.0

The inverse model is used for CMH, STS and TR.

RATIONALE FOR INCLUSION

In stream reaches that have known water quality impairments, the ability of the stream to perform regulating functions is highly valuable. Streams receiving waters that have sediment, nutrient, chemical, temperature, or flow impairments have greater opportunity to alleviate (or at the very least, not contribute to) water quality problems. The value of such regulating functions includes benefits to aquatic life that might be adversely affected by the impairments, as well as benefits to public health, recreation, and industry. For the hydrologic, geomorphic, and water quality processes whose value is informed by impairments, a known impairment indicates that the site has the *opportunity* to provide a valuable ecological function if it has the capacity to address the impairment.

While documented impairments cause the regulating functions of the reach to be of higher value, they decrease the value of biological and thermal regulation functions. The opportunity to provide the suitable habitat and resources necessary for the biological community is likely to be negatively affected by the impairments. The presence of water quality impairments has wide-reaching impacts on biological communities. For example, the vigor and survival of aquatic species can be affected by high levels of dissolved oxygen, and increased levels of nitrates and phosphorus can have profound effects on energy consumption and transfer. While algae and macrophytes (which can increase when nutrient levels are high) provide food and habitat to aquatic species, an overabundance of these can decrease dissolved oxygen availability, leading to decreased food sources and poor habitat conditions. The significance of the thermal regulation function is less when the stream reach has a known temperature impairment. While natural cover above the stream can help prevent additional solar warming, it is not likely to cool the water within the length of the project area.

V3. Protected Areas

MEASURE TEXT

Is the Project Area (PA) boundary within 300 feet of a protected natural area? Answer using information from IDFG's map viewer, as well as other available data for the PA and its vicinity.

DESCRIPTION

Areas with protection designations likely provide high quality habitat or resources and, due to their protected status, may experience decreased levels of disturbance. IDFG's map viewer indicates whether the project site is within 300 feet of various types of conservation sites, as described in greater detail in Appendix A.

Function Group: Biology
Values Informed: Maintain Biodiversity (MB), Sustain Trophic Structure (STS)

Model:

IF Protect = Yes, THEN = 1.0;

IF Protect = No, THEN = 0.0

RATIONALE FOR INCLUSION

A stream reach located in close proximity to a protected area has the potential to expand the spatial scope of habitat and resources for a variety of plant and animal species. Natural areas that have special protection designations often support species and resources that can benefit from increased habitat availability and connectivity, and they provide natural areas where human disturbance is limited. It is a well-accepted ecological theory that larger areas often contain a greater number of species, so a stream resource that exhibits the ability to support a diversity of species and the resources to sustain a trophic structure can provide significant value to biodiversity on a landscape scale when expanding on other established natural areas. A network of natural areas in close proximity allows for species movement between habitats and encourages immigration as the total amount of available resources increases.

V4. Impervious Area

MEASURE TEXT

What is the percent impervious area in the drainage basin?

Answer using information (IMPNLCD01) from the site's StreamStats Report.

DESCRIPTION

This measure assesses the prevalence of impervious surfaces in the site's contributing area. Impervious surfaces are those that do not allow infiltration of surface water into the soil, such as pavements (asphalt, concrete, brick) and rooftops. Increased amounts of impervious surfaces are known to cause increased water runoff, which adversely affects water quality and alters hydrologic timing. The size of a site's drainage basin, and the total percent of impervious area within that basin, can be calculated using the USGS's StreamStats tool.

Function Groups: Hydrology, Geomorphology, Biology, Water Quality

Values Informed: Surface Water Storage (SWS), Flow Variation (FV), Sediment Continuity (SC), Substrate Mobility (SM), Create and Maintain Habitat (CMH), Sustain Trophic Structure (STS), Nutrient Cycling (NC), Chemical Regulation (CR), Thermal Regulation (TR)

Model:
IF ImpArea < 10%, THEN = 0.0;
IF ImpArea = 10-25%, THEN = 0.3;
IF ImpArea > 25-60%, THEN = 0.7;
IF ImpArea > 60%, THEN =1.0

The inverse model (1-ImpArea) is used for CMH and STS.

RATIONALE FOR INCLUSION

A higher percentage of impervious surfaces in the drainage areas of a stream results in increased surface runoff and quicker delivery to streams. Surface runoff is much more common in developed watersheds (Booth and Jackson, 1997). Drainage areas with extensive impervious surfaces can have as much as five times the proportion of stream flow coming from surface runoff than for forested drainage areas (Arnold and Gibbons, 1996). Impervious surfaces retain less sediment, nutrients, and chemicals than natural surfaces, and are also a direct source of heated water, nutrients, and chemicals. Therefore, the value of stream reaches with capacity to delay surface water, vary flows, process sediment and nutrients, and moderate chemicals and nutrients is higher because of the opportunity to intercept surface water and benefit waters further downstream.

A lower percentage of impervious surfaces implies that land in the drainage area is more natural and that the stream reach has more opportunity to support biological functions. Macroinvertebrates that are sensitive to impervious cover are generally lost when impervious cover is in the range of 3% to 23%, depending on the taxa (Utz *et al.,* 2009). Macroinvertebrate and fish community composition begins to be impacted at about 5% impervious surface, depending on the proportion of agricultural land in the drainage area (Waite *et al.,* 2006).

V5. Riparian Area

MEASURE TEXT

What is the percentage of intact riparian area within 2 miles upstream of the PA? Intact refers to a riparian area with forest or otherwise unmanaged (i.e., natural) perennial cover appropriate for the basin that is at least 15 ft wide on both sides of the channel. Unmanaged perennial cover is vegetation that includes wooded areas, native prairies, sagebrush, vegetated wetlands, as well as relatively unmanaged commercial lands in which the ground and vegetation is disturbed less than annually, such as lightly grazed pastures, timber harvest areas, and rangeland. It does not include water, pasture, row crops (e.g., vegetable, orchards, tree farms), lawns, residential areas, golf courses, recreational fields, pavement, bare soil, rock, bare sand, or gravel or dirt roads.

DESCRIPTION

This measure provides an indication of the percentage of intact riparian area that can buffer the stream from other land use types and provide habitat support and water quality benefits. Riparian areas meeting the criteria can be evaluated by locating stream and river flowlines within 2 miles upstream of the stream reach on the National Hydrography Dataset and evaluating the cover and width of adjacent riparian areas using aerial imagery. While the percentage of intact riparian area of the entire drainage basin may be an important extent to consider, this data is not readily available for users and 2 miles was chosen as a reasonable distance and level of effort to evaluate.

Function Groups: Biology, Water Quality

Values Informed: Create and Maintain Habitat (CMH), Sustain Trophic Structure (STS), Nutrient Cycling (NC), Chemical Regulation (CR), Thermal Regulation (TR)

Model:

IF RipArea > 50%, THEN = 1.0;

IF RipArea > 35-50%, THEN = 0.7;

IF RipArea = 15-35%, THEN = 0.3;

IF RipArea < 15%, THEN = 0.0

The inverse model (1-RipArea) is used for NC and CR.

RATIONALE FOR INCLUSION

Riparian areas can intercept surface flows and subsurface inputs and provide for biological and physical processing of nutrients and chemicals. Vegetation in riparian areas promotes these processes by:

- increasing roughness to slow water and filter out sediments and the nutrients and chemicals adsorbed to sediment particles;
- increasing biological activity in the soil to process nutrients and chemicals; and
- taking up nutrients through their roots and storing them.

A stream reach that lacks intact riparian areas in upstream waters is more likely to receive nutrient and chemical-rich water and sediment. The ability of the stream reach to process and moderate those sediments and nutrients provides benefits (value) to waters further downstream.

Riparian vegetation also provides shade to prevent water from heating, and provides food, cover, and habitat structure for aquatic species. Corridors of perennial vegetation connect various habitats and help protect species as they move between them. Therefore, largely intact riparian areas upstream provide greater opportunity for the health of the aquatic system to be sustained through the project area.

V6. Extent of Downstream Floodplain Infrastructure

MEASURE TEXT

What is the extent of infrastructure (buildings, bridges, utilities, row crops) in the floodplain?

Consider the floodplain area between the PA and either the next largest water body (large tributary, mainstem junction, lake, etc.) or 2 miles downstream, whichever is less.

DESCRIPTION

This measure provides an indication of how developed the downstream floodplain is. An estimate of development in the floodplain can be obtained by viewing the mapped floodplain (Federal Emergency Management Agency [FEMA]) overlaid on aerial imagery to identify structures and agricultural lands.

Function Groups: Hydrology, Geomorphology, Biology

Values Informed: Surface Water Storage (SWS), Sediment Continuity (SC), Create and Maintain Habitat (CMH), Sustain Trophic Structure (STS)

Model:

IF DwnFP > 50%, THEN=1.0;

IF DwnFP = 1-50%, THEN=0.5;

IF DwnFP = none or the downstream floodplain is not mapped, THEN=0.0

The inverse model (1-DwnFP) is used for SC, CMH and STS.

RATIONALE FOR INCLUSION

In areas with more infrastructure located within the downstream floodplain, the economic and social value of water storage in upstream locations is greater as it can provide protection against flood damages. A stream that can store and delay water by diverting it into side channels or onto floodplains, or retain it within the channel due to geomorphic variability within the channel, is highly valued in areas where downstream infrastructure or agricultural lands are at-risk from floodwater inundation (Adamus *et al.,* 2016).

Conversely, increased development often causes degradation to water quality and biological functions. Development of areas surrounding the stream reach would limit accessibility and introduce stressors to the stream habitat, limiting the value of the site's habitat and trophic resources. While there is benefit in providing habitat refugia within a highly developed area, the negative effects of nearby land-uses likely restrict the site's ability to support diverse biological communities.

This measure is also used inversely to inform one of the geomorphic indicators, sediment continuity. Floodplains provide an area for streams to deposit sediment, but if the floodplain is highly developed, it is likely disconnected and therefore leads to a lower significance of the stream having the ability to moderate sediment processes.

V7. Zoning

MEASURE TEXT

What is the dominant zoned land use designation downstream of the PA? Consider the floodplain area between the PA and either the next largest water body (large tributary, mainstem junction, lake, etc.) or 2 miles downstream, whichever is less.

DESCRIPTION

This measure provides an indication of the type of development that is expected to occur in the downstream floodplain. An estimate of the dominant land use can be obtained by viewing the mapped floodplain (FEMA). In areas that may experience significant development, the zoning may be quite different than the current land use. For projects located in such areas, the parcel viewer for the county in which the project is located should be consulted to determine the zoning.

Function Groups: Hydrology, Biology

Values Informed: Surface Water Storage (SWS), Create and Maintain Habitat (CMH), Sustain Trophic Structure (STS)

Model:

IF Zoning = developed, THEN = 1.0;

IF Zoning = agriculture/rural residential, THEN =0.5

IF Zoning = forest, open space, or public lands, THEN = 0.0

IF Zoning = none/no information, THEN = 0.0

The inverse model (1-Zoning) is used for CMH and STS.

RATIONALE FOR INCLUSION

This measure is used only in conjunction with the previous measure, Extent of Downstream Floodplain Infrastructure (DwnFP), such that the maximum score from only one of the two measures is used in scoring. While DwnFP is used to capture current development in the floodplain, Zoning captures the likely future use of the land. The future need for surface water storage may increase the most where zoning allows for higher-intensity development that may alter the amount, rate, and/or timing of water delivered further downstream (Adamus *et al.,* 2016). Conversely, future development is expected to cause degradation to biological functions (Adamus *et al.,* 2016).

V8. Frequency of Downstream Flooding (DwnFld)

MEASURE TEXT

What is the frequency of downstream flooding?

Consider the floodplain area between the PA and either the next largest water body or 2 miles downstream, whichever is less. Determine the frequency of flooding downstream of the PA that affects infrastructure (i.e., affects use of the site, causes economic losses, etc.).

DESCRIPTION

This measure indicates whether downstream flooding is a known problem and, if so, the frequency at which it is occurring. This measure can be answered based on local knowledge and best professional judgment. Flooding history may also be documented in a city or county floodplain management plan or at FEMA's Flood Map Service Center, which contains flood maps and other flood risk information for communities across the country.

Function Group: Hydrology
Value Informed: Surface Water Storage (SWS)

Model:

IF DwnFld = frequent, THEN=1.0;

IF DwnFld = moderate, THEN=0.7;

IF DwnFld = infrequent, THEN=0.3;

IF DwnFld = never or not known, THEN=0.0

RATIONALE FOR INCLUSION

This measure is a direct indicator of the significance of a stream's capacity to store and delay surface water, as this function can provide protection to infrastructure and specific land uses. Stream characteristics that result in reduced flood speeds and reduced flood stage downstream are highly valuable when flooding is a known and frequent problem. Natural water storage function allows reduced investment and dependence on costly flood-control infrastructure.

V9. Impoundments (Impound)

MEASURE TEXT

What is the prevalence of impoundments (within 2 miles upstream and downstream of the PA) that are likely to cause shifts in timing or volume of water inputs?

The shift may be by hours, days, or weeks, becoming either more muted (smaller or less frequent peaks spread over longer times, more temporal homogeneity of flow or water levels) or more flashy (larger or more frequent spikes but over shorter times).

DESCRIPTION

This measure indicates whether there are artificial structures in proximity to the site that may be altering the natural hydrologic and/or geomorphic processes by interrupting free-flowing water systems, trapping sediment, and creating access issues for aquatic species. This measure can be answered by using local knowledge and observation and by evaluating the National Hydrography Dataset, which includes dam locations as point features. The fish passage barrier dataset discussed in V10 below may also contain data on impoundments. See **Appendix A** for a detailed explanation of this dataset. An impoundment should be counted even if it is only in place for part of the year.

Function Groups: Hydrology, Geomorphology, Biology

Values Informed: Surface Water Storage (SWS), Flow Variation (FV), Sediment Continuity (SC), Substrate Mobility (SM), Create and Maintain Habitat (CMH)

Model:

Scored separately for upstream and downstream:

IF Impound = 1 or more large dams or other impoundments, THEN=0.0;

IF Impound = 1-2 small dams or other impoundments, but 1 or more large dams or other impoundments are not present THEN=0.5;

IF Impound = none, THEN = 1.0

The inverse model (1-Impound) is used for FV (ImpoundUS only).

RATIONALE FOR INCLUSION

Impoundments impede landscape connectivity in the river corridor by changing the natural amount, rate, and/or timing of the movement of water, sediment, substrate, and wood. Impoundments may also restrict the movement of aquatic organisms and limit access to the suite of conditions and resources they need.

The opportunity for a stream reach to provide surface water storage, sediment continuity and substrate mobility is lower when there are impoundments upstream. The need for surface water storage is less because water is already being stored to some extent upstream. The opportunity to provide sediment continuity and substrate mobility functions is less because delivery of these materials to the reach is impeded. Conversely, the opportunity of a stream reach to moderate variations in flow is higher when impoundments upstream are altering natural hydrologic patterns.

Restricted movement of aquatic organisms traveling upstream or downstream reduces the value of the habitat provided in a reach. In addition, changes in habitat from free flowing to slack water behind an impoundment can cause changes in the physical, chemical, and thermal properties of the water.

V10. Fish Passage Barriers (Passage)

MEASURE TEXT

Are there man-made fish passage barriers within 2 miles upstream and/or downstream of the PA?

DESCRIPTION

This measure indicates whether fish species can access a stream reach. Man-made barriers to fish passage include structures such as dams, culverts, weirs, and tide gates that can block physical passage or create unsuitable conditions for passage (e.g., high velocity). This measure can be answered by using a fish passage barrier layer maintained by IDFG. See **Appendix A** for a detailed explanation of this dataset. Impoundments noted in the previous measure (Impound) should *also* be counted here if they are barriers to fish passage. The two measures inform different functions and are not double-counted in SFAM.

Function Group: Biology
Values Informed: Maintain Biodiversity (MB), Sustain Trophic Structure (STS)

Model:

(Upstream score + Downstream score)/2

Upstream and Downstream scores are calculated as follows:

IF Passage Upstream/Downstream = blocked, THEN = 0.0;

IF Passage Upstream/Downstream = partial, THEN = 0.5;

IF Passage Upstream/Downstream = passable, THEN = 1.0;

IF Passage Upstream/Downstream = none or unknown, THEN = 1.0

RATIONALE FOR INCLUSION

A stream reach that is accessible by fish has greater opportunity to support diverse biological communities and the local food web than one that is made inaccessible by barriers. Some barriers allow for partial fish passage (dependent on season and fish size), meaning that the habitat can be accessed during certain parts of the year; this is considered more valuable than an inaccessible reach, but could still be improved upon.

V11. Water Source (Source)

MEASURE TEXT

Is there an area that is of special concern for drinking water sources or groundwater recharge within 2 miles downstream of the PA?

This includes any of the following: the source area for a surface-water drinking water source; the source area for a groundwater drinking water source; a designated Groundwater Management Area; or a designated Sole Source Aquifer area.

DESCRIPTION

This measure indicates whether the site being assessed is located in an area whose waters contribute to important drinking water sources (both surface and groundwater) or groundwater areas. This measure can be answered by evaluating data layers from both state and federal agencies that monitor water quality and water use. IDEQ maintains the Source Water Assessment and Protection data layer, which describes drinking water sources and groundwater and surface water areas that potentially contribute to those drinking water sources. The USEPA maintains the Sole Source Aquifer data layer, which designates drinking water supplies in areas that have few or no alternative sources to the groundwater resource. See **Appendix A** for detailed descriptions of each of these data layers.

Function Groups: Hydrology, Water Quality

Values Informed: Sub/Surface Transfer (SST), Nutrient Cycling (NR), Chemical Regulation (CR)

Model:

IF WaterSource = yes, THEN = 1.0;

IF WaterSource = no, THEN = 0.0

RATIONALE FOR INCLUSION

A stream reach that is located within a source area for drinking water is particularly valuable when its water transfer processes are functioning effectively. The ability to maintain transfer of water between surface and sub-surface sources replenishes groundwater sources and supports balance and predictability in streamflow through inflow of groundwater through the streambed and outflow to groundwater. Communities across the state are dependent on the replenishment of the surface and groundwater sources for consumptive uses.

Additionally, it is also highly valuable for a stream resource to have effective nutrient and chemical regulation processes when the water from that resource is contributing to drinking water sources and groundwater supplies. Nutrients and chemicals are introduced from a variety of point and non-point sources. Major sources of nutrient and chemical inputs include fertilizer runoff from crop fields and lawns, livestock and pet waste, effluent from manufacturing and sewage-treatment facilities, and stormwater runoff. In excess amounts, these nutrients and chemicals can have deleterious effects on water resources and, in turn, human health. Nutrient pollution can lead to increased levels of nitrate in drinking water, which can be particularly harmful to infants (Adamus *et al.,* 2016), as well as in algal blooms, which can produce toxins and bacterial growth. A stream that can transfer excess nutrients and chemicals to its riparian areas, floodplains, and nearby wetlands for storage and filtering is valuable for keeping the nutrients from reaching drinking water sources and reducing human exposure to harmful chemicals.

V12. Surrounding Land Cover (SurrLand)

MEASURE TEXT

What are the land cover types surrounding the PA?

Draw a 2-mile radius circle around the PA. Provide an estimate of the area within the resulting polygon that matches each land cover description. Enter 0% if none. Enter 1% if barely present. Must sum to 100%.

DESCRIPTION

This measure is an indicator of the relative distribution of natural, managed, and developed land cover types near the site. Land cover and land use is an important factor for understanding trends of habitat fragmentation and modification, habitat loss, and stressors introduced from urban and rural land use practices. These trends are known to influence habitat suitability and terrestrial and aquatic biodiversity. This measure can be answered by a visual examination of aerial imagery for the project area.

Function Group: Biology

Values Informed: Maintain Biodiversity (MB), Sustain Trophic Structure (STS)

Model:

Sum of all the below:

IF unmanaged vegetation (wetland, native grassland, forest) or water; THEN = percent of area * 1.0;

IF managed vegetation (pasture, regularly watered lawn, row crops, orchards); THEN = percent of area * 0.5;

IF none of the above (bare areas [dirt, rock], roads, energy facilities, residential, commercial, industrial); THEN = percent of area * 0.0

RATIONALE FOR INCLUSION

This measure evaluates connectivity between the stream and the surrounding landscape based on the land cover. Habitat fragmentation is the division of large, continuous habitats into a greater number of smaller and more isolated habitat patches. The impacts of patch area, edge effects, isolation and landscape matrix contrasts are well-known to impact community structure and ecosystem functioning. Dominant effects include declines in population density and species richness, alterations to community composition, and reductions in the ability of populations to recover after disturbance.

V13. Riparian Continuity (RipCon)

MEASURE TEXT

What is the longitudinal extent of intact riparian area that is contiguous to the PA?

Select the longest length of contiguous riparian corridor in either the upstream or downstream direction, but do not include the project area length itself.

Intact refers to a riparian area with forest or otherwise unmanaged (i.e., natural) perennial cover appropriate for the basin that is at least 15 feet wide on both sides of the channel. Contiguous means there are no gaps > 100 feet in forested cover or unmanaged perennial cover. Select the longest length of contiguous riparian corridor in either the upstream or downstream direction, but do not include the PA length itself. Unmanaged perennial cover is vegetation that includes wooded areas, native prairies, sagebrush, vegetated wetlands, as well as relatively unmanaged commercial lands in which the ground and vegetation is disturbed less than annually, such as lightly grazed pastures, timber harvest areas, and rangeland. It does not include water, pasture, row crops (e.g., vegetable, orchards, tree farms), lawns, residential areas, golf courses, recreational fields, pavement, bare soil, rock, bare sand, or gravel or dirt roads.

DESCRIPTION

This measure is an indicator of the extent of natural area buffering the stream from other land use types, providing stream shade and water quality benefits, and providing habitat connectivity for wildlife and aquatic species. Measures of buffering and connectivity can provide understanding of both the stressors that the stream resource will be exposed to (e.g., nutrient and chemical inputs, thermal loading), as well as the potential spatial influence of stream function and habitat benefits (e.g., expanded habitat corridors, refugia from stressors). This measure can be answered by evaluating aerial imagery to determine (a) if an intact riparian buffer exists at the site, and (b) the distance beyond the site that the buffer remains intact.

Function Groups: Biology, Water Quality

Values Informed: Maintain Biodiversity (MB), Create and Maintain Habitat (CMH), Sustain Trophic Structure (STS), Nutrient Cycling (NC), Chemical Regulation (CR), Thermal Regulation (TR)

Model:

IF RipCon < 100 ft, THEN=0.0;

IF RipCon = 100-500 ft, THEN=0.5;

IF RipCon > 500 ft, THEN=1.0

The inverse model (1-RipCon) is used for NC and CR.

RATIONALE FOR INCLUSION

Riparian corridors are important for improved water quality and as habitat for wildlife and aquatic habitat. Continuity along the river corridor limits solar exposure of the stream and provides increased opportunity to maintain cool water in the stream. Continuity also facilitates the movement of animals upstream and downstream, increasing species resilience, and providing access to different habitats and food resources. Conversely, gaps in the corridor, either natural or man-made, may receive more inputs of nutrients and chemicals from surrounding land uses if they cannot be filtered before reaching the stream. Stream reaches that can cycle these nutrients and regulate these chemicals have higher value to downstream areas.

V14. Watershed Position (Position)

MEASURE TEXT

What is the relative position of the PA in its HUC8 watershed?

DESCRIPTION

This measure describes the landscape position of the site, which can provide a general indication of the characteristics and processes that can be supported by the stream reach. This measure can be answered by evaluating both the National Hydrography Dataset and the Watershed Boundary Dataset to determine the relative positioning of a stream reach compared to the watershed's origin, outlet, and watershed divides.

Function Groups: Geomorphology, Water Quality

Values Informed: Sediment Continuity (SC), Nutrient Cycling (NC), Chemical Regulation (CR)

Model:

IF Position = lower 1/3, THEN = 1.0;

IF Position = middle 1/3, THEN = 0.5;

IF Position = upper 1/3, THEN = 0.0

RATIONALE FOR INCLUSION

A stream's position within its watershed informs the opportunity that it has to provide important regulating functions, based on the expected characteristics, processes, and stressors associated with each position category. Streams in the upper portion of the watershed tend to be headwaters and source channels, while streams in the lower portion of the watershed likely have higher stream order and are likely to receive proportionately more sediment, nutrients, and chemicals. Streams in the lower portion of the watershed also transport water and material from greater contributing areas and may be subject to more erosive floods. All these factors increase the value of the stream's capacity to intercept and stabilize suspended sediment, filter nutrients, and process chemicals when it is lower in the watershed. A stream that can effectively transfer, filter, and store excess sediment and nutrients is highly valued in areas that may be receiving nutrient-rich, turbid, and/or chemical-laden waters (Adamus *et al.,* 2016).

V15. Flow Restoration Needs (FlowRest)

MEASURE TEXT

Is the PA on a stream reach listed as a Protected Water or Minimum Flow water by the Idaho Department of Water Resources?

DESCRIPTION

This measure indicates whether the stream reach has been identified as a critical area for protection and restoration due to a combination of instream water deficits and a biological ranking. This measure can be answered by evaluating datasets for Minimum Stream Flow, National Wild and Scenic Rivers System, and Aquifer Recharge Districts. Prioritization models considered (a) the number of months during which instream water rights are not met at least 50% of the time and (b) biological factors including the presence of fish resources, habitat integrity, risks to fish survival, and restoration potential. See **Appendix A** for a detailed explanation of these datasets.

Function Groups: Hydrology, Biology
Values Informed: Flow Variation (FV), Create and Maintain Habitat (CMH)

Model:

IF FlowRest = Not ranked/Low, THEN = 0.0

IF FlowRest = Moderate, THEN = 0.5

IF FlowRest = High/Highest, THEN = 1.0

The inverse model (1-RipCon) is used for CMH.

RATIONALE FOR INCLUSION

The datasets described above identify areas where streamflow restoration would be valuable due to the instream benefits that wildlife, specifically fish, would likely realize. A stream reach that provides for additional flow in a reach where streamflow restoration is prioritized is therefore more valuable. Conversely, restricted availability of water limits the opportunity of the stream reach to support the habitat needs of species.

V16. Unique Habitat Features (HabFeat, SubFeat, ThermFeat)

MEASURE TEXT

Are there rare aquatic habitat features within the EAA that are not common to the rest of the contributing basin?

DESCRIPTION

This measure indicates whether there are any rare features within close proximity of the project area that provide disproportionate value to the resource. Rare features include large log jams (spanning 25% or more of the active channel width), braided channels (or otherwise multiple channels that result in islands), large spatial extent (> 30%) of wetlands in the floodplain, or seeps, springs, or tributaries that contribute colder water to the project area. While some of these features can be identified using aerial imagery or, in the case of seeps/springs, identified on the National Hydrography Dataset, this measure must be evaluated and verified in the field. All the listed feature types are considered in the overall measure score, which factors into the value scores for two biological functions. There are two sub-models, specific to the value scores for Substrate Mobility and Thermal Regulation, that consider only those features that are relevant to the respective functions.

Function Groups: Geomorphology, Biology

Values Informed: Substrate Mobility (SM), Maintain Biodiversity (MB), Create and Maintain Habitat (CMH), Sustain Trophic Structure (STS), Thermal Regulation (TR)

Model:

IF HabFeat= none, THEN=0.0;

IF HabFeat= any one of the options, THEN=0.5;

IF HabFeat= any two or more of the options, THEN=1.0

Substrate submeasure model (looking ONLY to braided channels and multiple channels):

IF HabFeat = no, THEN = 0.0;

IF HabFeat = yes, THEN = 1.0

Thermal submeasure model (looking ONLY to wetland and cool water input features):

IF HabFeat= none, THEN=0.0;

IF HabFeat= any one of the options, THEN=0.5;

IF HabFeat= any two or more of the options, THEN=1.0

RATIONALE FOR INCLUSION

Stream reaches where rare features occur are more significant because scarcity typically increases value. Larger log jams are rare in many streams because large woody debris is often removed due to potential damages to bridges and other crossings, dangers for boaters, and drainage issues. Natural sources of large wood have decreased due to logging and reduced connectivity to source areas (e.g., reduced delivery to the stream through landslides), although man-made log structures may have been added for stream restoration. Braided or multiple channels, and a large spatial extent of wetlands in the floodplain are often rare because many lowland streams have been straightened and confined into a single, deeper channel to facilitate other land uses. Many of Idaho's streams are too warm for some beneficial uses so seeps, springs, and tributaries that can provide cooler water into a stream reach are valuable for moderating water temperatures.

4.4 Context Measures

This section describes measures which provide landscape or physical context about the subject stream site and how they are used in SFAM.

a) Hydrologic Landscape Classification

MEASURE DESCRIPTION

The Hydrologic Landscape Classification (Leibowitz *et al*. 2016) describes the hydrologic and physical characteristics of streams using local parameters (i.e., climate, terrain, hydrologic seasonality, groundwater permeability, soil permeability) and characteristics of the upstream drainage basin. Accounting for local water availability and upstream water sources is important for identifying both water availability and opportunity for storage.

The Hydrologic Landscape Classification and Gradient are the two components of the 'runoff' parameter used in the 'opportunity' portion of the Surface Water Storage (SWS) Value calculation. The Cover Page of the SFAM Workbook asks whether the project site (Climate_l_wet) or the contributing basin (Climate_w_wet) are classified as moist, wet, or very wet. The response to these questions, along with the estimates of Gradient, are used to calculate the 'runoff' parameter according to **Table 4.43**.

Function Group: Hydrology
Value Informed: Surface Water Storage (SWS)

Table 4.43. Model For Calculating Runoff Parameter

Hydrological Landscape Classification				Gradient		
				>6%	2-6%	<2%
Project Site is Moist, Wet, or Very Wet	Yes	Contributing Basin is Moist, Wet, or Very Wet	Yes	1.0	0.75	0.75
	Yes		No	1.0	0.75	0.75
	No		Yes	0.5	0.25	0.25
	No		No	0	0	0

Aquifer Permeability (local)

Data on aquifer permeability, determined by assessing the percent of permeable bedrock based on literature values of estimated hydraulic conductivity, can be obtained from the Hydrologic Landscape Classification tool described above. A rating of "Low" was assigned to areas where estimated hydraulic conductivity is < 0.0085 meters per day and a rating of "High" was assigned to areas where estimated hydraulic conductivity is ≥ 0.0085 meters per day. The entire local-scale unit was then assigned the permeability class (Low, High) with the highest percent within that unit area.

Function Group: Hydrology
Values Informed: Sub/Surface Transfer (SST), Flow Variation (FV)

Model:

IF AqPerm = High; THEN = 0.0;

IF AqPerm = Low; THEN = 1.0

Soil Permeability (local)

The soil permeability data from the Hydrologic Landscape Classification tool represents the potential for infiltration and shallow water movement. Permeability of the soil was determined using soil textural classes and related saturated hydraulic conductivity values from the Natural Resources Conservation Service (https://www.nrcs.usda.gov/conservation-basics/natural-resource-concerns/soil/gis-and-digital-mapping-for-soil-survey) to define thresholds for two soil permeability classes: low (≤1.52 cm/h) and high (>1.52 cm/h). This 1.52 cm/h threshold represents the cutoff between silt (low) and clay loam (high) soil textures (Leibowitz *et al*., 2016). The entire local-scale unit was then assigned the permeability class (Low, High) with the highest percent coverage.

Function Group: Hydrology
Values Informed: Sub/Surface Transfer (SST), Flow Variation (FV)

Model:

IF SoilPerm = High; THEN = 0.0;

IF SoilPerm = Low; THEN = 1.0

Erodibility (local)

Erodibility information is based on the Geological Map of Idaho, which is maintained by the Idaho Geological Survey. Map units on the Geological Map are assigned by the user to one of three erodibility classes (Easily Erodible, Moderately Erodible, Difficult to Erode) based on the described geological characteristics of that map unit. Examples of the geological characteristics associated with each erodibility class are provided in **Table 4.44**.

Table 4.44. Erodibility Classification

Rating Class	Geological Characteristics
Easily Erodible	Quaternary sediments, including alluvial and glacial deposits (gravel, sand, silt, colluvium)
Moderately Erodible	Sedimentary, including dissolvable (e.g., limestone, dolomites), fine-grained (e.g., shales, mudstones, clays), medium-grained, and coarse-grained (e.g., conglomerates, pyroclastics)
Difficult to Erode	Consolidated volcanics (e.g., basalt, granite, rhyolite), metamorphics (e.g., marble)

Function Group: Geomorphology
Value Informed: Sediment Continuity (SC)

Model:

IF Erode = Moderately Erodible; THEN = 0.0

IF Erode = Difficult to Erode; THEN = 0.75

IF Erode = Easily Erodible; THEN = 1.0

Gradient

Gradient for the PA can be estimated using the digital tools described in the User Manual. The percent slope (rise/run*100) can be calculated between the minimum and maximum elevation (rise) over the length of the stream segments (run) in the local-scale unit. The user then selects one of three gradient categories: percent slope < 2%, percent slope ≥ 2% and ≤ 6%, or percent slope > 6%.

Function Group: Hydrology
Value Informed: Surface Water Storage (SWS)

Model: See the model described above for calculating the 'runoff' parameter. This is the only parameter that uses Gradient.

b) Flow Duration or Permanence Class

MEASURE DESCRIPTION

The flow permanence class of a channel—whether it is perennial, intermittent, or ephemeral—may be provided by the Flowline layer within the NHD (USGS). If there is no NHD information available about the subject stream reach, or there is disagreement with the NHD designation, and other information is available it can be used to support a flow permanence class designation. If there is no information available, the Streamflow Duration Assessment Method for the Pacific Northwest (Nadeau, 2015; Nadeau *et al.,* 2015) can be applied in the field to determine whether the subject stream reach is perennial, intermittent, or ephemeral. While flow permanence class does not directly inform assessment of SFAM function or value measures, it does provide site-specific context and may be used by the agencies in determining whether a proposed mitigation site would be eligible to offset the proposed impacts at the subject stream site. For these reasons, this information is made available as part of an SFAM assessment.

c) Level III Ecoregion

MEASURE DESCRIPTION

Ecoregions denote areas of similarity in the mosaic of biotic, abiotic, terrestrial, and aquatic ecosystem components with humans being considered as part of the biota. Ecoregions are identified by analyzing the patterns and composition of biotic and abiotic phenomena that affect or reflect differences in ecosystem quality and integrity (Omernik, 1987, 1995). These phenomena include geology, landforms, soils, vegetation, climate, land use, wildlife, and hydrology. The USEPA ecoregion framework is derived from Omernik (1987) and from mapping done in collaboration with USEPA regional offices, other federal agencies, state resource management agencies, and neighboring North American countries. Level III Ecoregion information ("Western Mountains" versus "Xeric") is used to set performance expectations for several function measures.

d) Average Stream Width

Whether the average stream width is greater than or less than 50 feet is input provided directly by the SFAM user. This information is used to set performance expectations for several function measures.

e) 2-Year Peak Flow

MEASURE DESCRIPTION

The 2-Year Peak Flow is provided by the StreamStats Report (USGS) that is generated as part of completing the Office Component of SFAM. It is an estimate of the magnitude of peak streamflow at or near bankfull discharge or effective discharge for the 2-year recurrence interval. While the 2-Year Peak Flow does not directly inform SFAM function or value measures, it does provide site-specific context to SFAM users and reviewers of SFAM assessments.

f) Drainage Area

MEASURE DESCRIPTION

Drainage area (the total basin areas flowing into the project area) is provided by the StreamStats Report (USGS) that is generated as part of completing the Office Component of SFAM. Note that the StreamStats method for calculating drainage area is based upon a natural landscape, and if the stream is primarily fed by piped streams and waterways, modeled data will not necessarily be accurate. While drainage area does not directly inform SFAM function or value measures, it does provide site-specific context to SFAM users and reviewers of SFAM assessments.

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Appendix A. SFAM Relevant Map Layers[2]

StreamStats

Data source: U.S. Geological Survey (USGS)
Description excerpted from: https://streamstats.usgs.gov/ss/

StreamStats is a Web application that provides access to an assortment of GIS analytical tools that are useful for water-resources planning and management, and for engineering and design purposes. The map-based user interface can be used to delineate drainage areas for user-selected sites on streams, and provide basin characteristics and estimates of flow statistics for the selected sites anywhere this functionality is available.

National Map Viewer

Data source: USGS
Description excerpted from: https://www.usgs.gov/tools/national-map-viewer

The National Map Viewer is a collection of free, nationally-consistent geographic datasets that describe the landscape of the United States and its territories. Included in the National Map Viewer are the latest elevation data from the 3D Elevation Program (3DEP), surface water data from the National Hydrography Dataset (NHD), and place name data from the Geographic Names Information System (GNIS). In addition, the National Map Viewer provides continuously-updated, seamless datasets for recreational trails, roads, boundaries, structures, land cover, and imagery.

Pacific Northwest Hydrologic Landscapes

Data source: U.S. Environmental Protection Agency (USEPA)
Description excerpted from: Leibowitz *et al*. 2016
https://cfpub.epa.gov/si/si_public_record_report.cfm?Lab=NHEERL&dirEntryId=311666

The hydrologic landscapes (HLs) concept was developed to address streamflow vulnerability from climate change. Originally developed for Oregon, the HL approach was expanded in 2016 to the Pacific Northwest (including Washington and Idaho)(Leibowitz *et al*. 2016). Assessment units are based on National Hydrography Dataset catchments, overlaid with estimates of aquifer and soil permeability.

Geologic Map of Idaho

Data source: Idaho Geological Survey
Description excerpted from:
https://www.idahogeology.org/pub/Maps/Geologic_Map_of_ID_booklet_3.pdf

The Geologic Map of Idaho is compiled from more than ninety map sources. Mapping from the 1980s includes work from the USGS Conterminous U.S. Mineral Appraisal Program (Worl *et al*., 1991; Fisher *et al*., 1992). Mapping from the 1990s includes work by the USGS during mineral assessments of the Payette and Salmon National forests (Evans and Green, 2003; Lund, 2004). In the late 1990s,

[2] Note that only layers used to complete an SFAM assessment are described in Appendix A. The data sources are listed in the order that they appear in this document.

the Idaho Geological Survey began completing the mapping within 30’ × 60’ quadrangles (e.g., Lewis *et al*. 2001, 2002, 2005, 2008; Kauffman *et al*., 2005, 2009). Map units from the various sources were condensed to 74 units statewide, and major faults were identified.

National Hydrography Dataset

Data source: USGS
Description excerpted from: https://nhd.usgs.gov/NHD_High_Resolution.html

The National Hydrography Dataset (NHD) represents the nation’s drainage networks and related features, including rivers, streams, canals, lakes, ponds, glaciers, coastlines, dams, and stream gages. The NHD High Resolution, at 1:24,000 scale or better, is the most up-to-date and detailed hydrography dataset for the nation.

Level III Ecoregions

Data source: USEPA
Description excerpted from: https://www.epa.gov/eco-research/ecoregions

Ecoregions are areas where ecosystems (and the type, quality, and quantity of environmental resources) are generally similar. The Level III Ecoregions framework is derived from Omernik (1987) and from mapping done in collaboration with USEPA regional offices, other federal agencies, state resource management agencies, and neighboring North American countries. Designed to serve as a spatial framework for the research, assessment, and monitoring of ecosystems and ecosystem components, ecoregions denote areas of similarity in the mosaic of biotic, abiotic, terrestrial, and aquatic ecosystem components with humans being considered as part of the biota. These regions are critical for structuring and implementing ecosystem management strategies across federal agencies, state agencies, and nongovernmental organizations that are responsible for different types of resources within the same geographic areas (McMahon *et al.,* 2001; Omernik and Griffith, 2014).

Ecoregions are identified by analyzing the patterns and composition of biotic and abiotic phenomena that affect or reflect differences in ecosystem quality and integrity (Omernik, 1987; 1995). These phenomena include geology, landforms, soils, vegetation, climate, land use, wildlife, and hydrology. The relative importance of each characteristic varies from one ecological region to another regardless of the hierarchical level.

Generalized Fish Distribution

Data source: Idaho Department of Fish and Game (IDFG)

Description excerpted from: https://data-idfggis.opendata.arcgis.com/datasets/IDFGgis::generalized-fish-distribution/about

This GIS data source is a compilation of data on the current presence and use type by fish species, run, subrun, and stream section. It includes presence and suspected presence data showing where fish have been found given a certain time, place, and method, and where they are likely to be found given the above and adjacent, accessible, and suitable habitat. The data are derived from range-wide assessments and survey data for the following species: Snake River spring, summer, fall Chinook salmon, Snake River sockeye salmon, coho salmon, Snake River summer steelhead trout, Pacific lamprey, white sturgeon, bull trout, westslope cutthroat trout, Bonneville cutthroat trout, redband trout, and yellowstone cutthroat trout.

Idaho Crucial Habitat Layer

Data source: IDFG
Description excerpted from: https://data-idfggis.opendata.arcgis.com/datasets/IDFGgis::idaho-crucial-habitat/explore

This dataset represents Idaho's contribution to the Western Governors' Association Crucial Habitat Assessment Tool launched in December 2013. It is an aggregated measure of crucial habitat for species of interest to the western state's fish and wildlife management agencies. Crucial habitat describes places that are expected to contain the resources necessary for continued health of fish and wildlife populations or important ecological systems expected to provide high value for a diversity of fish and wildlife.

Protected Resources App

Data source: National Oceanic and Atmospheric Administration (NOAA) Fisheries
Description excerpted from:
https://www.webapps.nwfsc.noaa.gov/portal/apps/webappviewer/index.html?id=7514c715b8594944a6e468dd25aaacc9

The Protected Resources App displays spatial data for marine and anadromous species listed under the federal Endangered Species Act (ESA). The core datasets, managed by the Protected Resources Division of NOAA Fisheries' West Coast Region, are ESA-listed species' ranges and critical habitat.

Not all ESA-listed species and critical habitat under the jurisdiction of NOAA Fisheries are displayed in this app. Only those within the West Coast Region (Idaho, Oregon, Washington, California, and U.S. marine waters adjacent to those states) that have available data are displayed. Under the ESA, the term "species" can refer to a taxonomic species, subspecies, Distinct Population Segment (DPS), or an Evolutionarily Significant Unit (ESU) for a DPS of Pacific salmon.

Salmon ESUs and steelhead DPSs are depicted as ranges using watershed polygons that circumscribe important spawning, rearing, and migration habitats. ESA critical habitat is depicted as lines to represent protected rivers and streams and as polygons to represent protected water bodies, marine areas, estuaries, marshes, etc.

Idaho Species Diversity Database

Data source: IDFG
Description excerpted from: https://idfg.idaho.gov/species/

The Idaho Species Diversity Database is a comprehensive repository for site-specific data on Idaho's fish, wildlife, and plant diversity. The database is maintained by the Idaho Fish and Wildlife Information System as the Idaho Natural Heritage Program and includes the Wildlife Diversity Program at IDFG. Observations are contributed by federal, state, tribal, non-governmental organizations, private consultants, and the public.

iNaturalist

Data source: iNaturalist

Description excerpted from: https://www.inaturalist.org/pages/what+is+it

iNaturalist is a crowdsourced species identification system and an organism occurrence recording tool. It can be used to record your own observations, get help with identifications, collaborate with others to collect this kind of information for a common purpose, or access the observational data collected by other iNaturalist users.

Important Bird Areas

Data source: Audubon Society
Description excerpted from: https://gis.audubon.org/portal/apps/sites/?_gl=1*v33xif*_ga*MTY1ODY5NDcyMS4xNjc4OTE4NTY5*_ga_X2XNL2MWTT*MTY4MDA0NDM3My4zLjEuMTY4MDA0NDQ4MS4yMS4wLjA.#/nas-hub-site/pages/data-review

Idaho's Important Bird Areas (IBA) Program was launched in 1996 as a partnership between Idaho Partners in Flight and the Idaho Audubon Council. Since 1997, the IBA Technical Committee has encouraged and reviewed nominations for potential IBAs. To date, 55 sites have been officially recognized as Important Bird Areas in Idaho, representing 3.8 million acres of public and private wetland and upland habitat throughout the state. The monitoring phase of the Idaho IBA program is underway, with monitoring at several IBAs being conducted either by biologists responsible for the management of the area, or by volunteers. These monitoring efforts, which are intended to collect basic information about the IBAs, will create an inventory of bird species present at each site, at a minimum, and will likely lead to further investigations.

An IBA is a site that has been selected for its outstanding habitat value and imperative role it plays in hosting birds, whether for breeding, migrating, or over-wintering. The IBA designation is internationally-recognized. State-level IBAs are nominated through a public process and reviewed by a Technical Advisory Committee.

IBAs are identified for their value to species that are:

- Threatened or endangered
- Restricted to a particular biome or region
- Restricted to one habitat type
- Occurring at high densities during some portion of the year.

IBA boundaries are not absolute and definitive. Instead, they should be considered approximations of critical habitat areas.

Water Quality (Lakes & Streams)

Data source: Idaho Department of Environmental Quality (IDEQ)
Description excerpted from: https://www.deq.idaho.gov/water-quality/surface-water/monitoring-and-assessment/

Every two years, IDEQ is required by the federal Clean Water Act (CWA) to conduct a comprehensive analysis of Idaho's water bodies to determine whether they meet state water quality standards and support beneficial uses, or if additional pollution controls are needed. This analysis is summarized in an "Integrated Water Quality Monitoring and Assessment Report" (Integrated Report). The Integrated Report Interactive Mapper displays the results of the Integrated Report, 305(b)- and 303(d)- listed streams, with links to IDEQ's monitoring data and USEPA-approved TMDLs.

Conservation Sites

Data source: IDFG
Description excerpted from:
https://www.arcgis.com/home/item.html?id=b1314f8e41c5483283637e1a7e37ae91

This data source contains spatial and other information for over 750 sites of conservation, scientific, and ecological interest distributed across all of Idaho's landscapes. Sites represent a variety of ecosystems and typically have intact ecological processes, exemplary native plant communities, unique geologic processes, or important habitat for species. Conservation site boundaries often include most of the land area necessary to maintain the ecological processes of interest. For most areas, site boundaries also include a variable width buffer, but do not necessarily include an entire watershed. Descriptions for each site include its location, size, design considerations, biological or other natural significance, ecological processes and functions, ecological condition and integrity, conservation or protection status, stewardship concerns, and known occurrences of communities and rare species.

Approximately 475 of the sites contain significant wetland or riparian habitat. Wetland sites were typically classified according to habitat diversity, biodiversity significance, condition, and landscape context or viability into these conservation priority categories:

Class I—highest priority; relatively undisturbed; often support unique or rare wetland types that are very sensitive to disturbance; often supports high concentrations of globally and state rare plant or animal species, and high diversity of common plant associations in excellent ecological condition; provide a high level of diverse wetland functions (i.e., hydrologic processes, water quality, etc. are intact); impacts should be avoided as these sites may be impossible to replace within a human lifetime; alteration may result in significant degradation that is not easily mitigated or restored; conservation efforts should focus on full protection including maintenance of hydrologic regimes.

Class II—second highest priority; differentiated from Class I sites based on condition or biological significance; often support globally or state rare plant or animal species and/or contains rare or unique wetland types; human influences are apparent (i.e., portions of wetland are in excellent condition, however drier, accessible sites are impacted); moderate to high diversity of common plant associations in good to excellent ecological condition; wetland functions are intact; impacts and hydrologic modification should be avoided; mitigation and restoration may be possible, but may involve significant investments to be successful; improved stewardship may be necessary to alleviate low level impacts (e.g., improper livestock grazing).

Reference—support common plant associations in good ecological condition, contain rare or unique wetland types in fair condition, and/or support state rare plant or animal species; human impacts are present, but functions are mostly intact; these wetlands may be the best remaining examples in areas of relatively high human influence and are therefore sometimes useful for monitoring the progress of restoration or enhancement of similar wetland types; they may also serve as donor sites for plant material used in restoration or enhancement; improved stewardship is often needed to maintain or improve function and condition.

Habitat—provide moderate to outstanding wetland functions, such as food chain support, maintenance of important (and scarce) plant and wildlife habitat, or water quality support; provide numerous ecological services, although ecological condition is often impaired due to human activities; restoration, enhancement, and/or management may be necessary to improve or maintain wetland functions and condition; may have high potential for designation as, or expansion of, existing wildlife refuges or publicly managed areas.

Restoration Opportunity—currently supports, or has the high likelihood of supporting, at least several important or rare (at local watershed scale) wetland functions and values, such as habitat for common and/or rare species, unique wetland types, or other locally important functions (e.g., water quality), but where human disturbance has notably decreased all functions and ecological condition; however, functions and condition are restorable with moderate levels of investment and coordination and a mix of public and private ownership (with willing landowners); often in areas with completed watershed or water quality management or improvement plans.

100-Year Floodplain

Data source: Federal Emergency Management Administration (FEMA)
Description excerpted from: https://www.fema.gov/flood-maps/national-flood-hazard-layer

The 100-year floodplain data can be obtained from the National Flood Hazard Layer (NFHL) maintained by FEMA. The NFHL is a geospatial database that contains current effective flood hazard data. FEMA provides the flood hazard data to support the National Flood Insurance Program. The NFHL is made from effective flood maps and Letters of Map Change delivered to communities. NFHL digital data covers over 90 percent of the U.S. population. New and revised data are added continuously.

Fish Passage Barriers

Data source: IDFG
Description excerpted from: https://data-idfggis.opendata.arcgis.com/datasets/IDFGgis::fish-barriers/about

IDFG's fish passage barrier layer was created from several different sources. The initial set of anadromous barriers came from the presence/absence data obtained during the Smolt Density and Carrying Capacity studies circa 1989-90, as reported in "Idaho Habitat/Natural Production Monitoring. Part 1. General Monitoring Subproject. Annual Report." The first set of diversion data came from the ongoing program to screen, consolidate, and replace diversions in the upper Salmon River Drainage. The IDFG screen shop maintains that data and reports it to Bonneville Power Administration (BPA), in reports like "Operation, Repair, and Maintenance of Fish Screens in the Salmon River Drainage. Annual Project Closing Report." The other sources of barrier data came from a process headed up by the U.S. Forest Service for distribution updates for westslope cutthroat trout and Yellowstone cutthroat trout. The methods and data were reported in "Status of Westslope Cutthroat Trout (*Oncorhynchus* *clarki lewisi*) in the United States: 2002" and a similar report for Yellowstone cutthroat trout. Data on culverts are from the national forest inventories, such as those described in "Fish Passage at Road Crossings Assessment Boise National Forest FY 2003."

Source Water Assessment and Protection

Data source: IDEQ
Description excerpted from: https://www2.deq.idaho.gov/water/swaOnline/About

IDEQ assesses every public water system in Idaho for its relative susceptibility to contaminants that are regulated by the federal Safe Drinking Water Act. IDEQ conducts source water assessments based on a land use inventory of the delineated source water assessment area, sensitivity factors associated with the drinking water source, and local aquifer characteristics. The ultimate goal of each source water assessment is to provide data that communities can use to develop protection strategies for their drinking water sources.

The online mapping tool summarizes information about public water systems in Idaho. However, the results of source water assessments should not be used as an absolute measure of risk, nor should they be used to undermine public confidence in the public water system. A particular susceptibility score does not imply that any regulatory or legal actions will occur. IDEQ strongly encourages each public water system and community to use its source water assessment, combined with local knowledge and concerns, to develop strategies to protect drinking water sources.

Sole Source Aquifers

Data source: USEPA
Description excerpted from: https://www.epa.gov/dwssa

This coverage displays sole source aquifers in Idaho, as designated under the National Environmental Policy Act. The Sole Source Aquifer protection program is authorized by section 1424(e) of the Safe Drinking Water Act of 1974 (Public Law 93-523, 42 U.S.C. 300 et seq.). This program is designed to protect drinking water supplies in areas with few or no alternative sources to the ground water resource, and where, if contamination occurred, using an alternative source would be extremely expensive. USEPA defines a sole or principal source aquifer as an aquifer that supplies at least 50 percent of the drinking water consumed in the area overlying the aquifer. These areas may have no alternative drinking water source(s) that could physically, legally and economically supply all those who depend on the aquifer for drinking water. For convenience, all designated sole or principal source aquifers are referred to as “sole source aquifers.” The designation protects an area’s ground water resource by requiring USEPA to review certain proposed projects within the designated area.

Minimum Stream Flow

Data source: Idaho Department of Water Resources (IDWR)
Description excerpted from:
https://gis.idwr.idaho.gov/portal/home/item.html?id=28d7ff1b24744ea79630a70a017b4aaa

This GIS representation of state-protected waters includes three datasets: Minimum Lake Level, Minimum Stream Flow (Lines) & Minimum Stream Flow Points. Idaho's Minimum Stream Flow Program was approved by the Legislature in 1978 to preserve stream flows and lake elevations for public health, safety, and welfare. The minimum stream flow is the amount of flow necessary to preserve desired stream values, including fish and wildlife habitat, aquatic life, navigation and transportation, recreation, water quality, and aesthetic beauty. Minimum stream flow water rights are held by the Idaho Water Resource Board in trust for Idaho citizens (Idaho Code, Title 42, Chapter 15). Any person or entity can make a request to the Idaho Water Resource Board to file an application for stream flow on any water body within the state. To be approved, a minimum stream flow water right must be in the public interest, must not adversely affect senior water rights, must represent the minimum flow and not the desirable flow, and must show the flow is capable of being maintained.

National Wild and Scenic Rivers

Data source: National Wild and Scenic Rivers System
Description excerpted from: https://www.rivers.gov/wsr-act.php

The National Wild and Scenic Rivers System was created by Congress in 1968 (Public Law 90-542; 16 U.S.C. 1271 et seq.) to preserve certain rivers with outstanding natural, cultural, and recreational values in a free-flowing condition for the enjoyment of present and future generations. Rivers may be designated by Congress or, if certain requirements are met, the Secretary of the Interior. Each river is administered by either a federal or state agency. Designated segments need not include the entire river and may include tributaries. For federally administered rivers, the designated boundaries generally average one-quarter mile on either bank in the lower 48 states in order to protect river-related values.

Rivers are classified as wild, scenic, or recreational.

Wild River Areas – Those rivers or sections of rivers that are free of impoundments and generally inaccessible except by trail, with watersheds or shorelines essentially primitive and waters unpolluted. These represent vestiges of primitive America.

Scenic River Areas – Those rivers or sections of rivers that are free of impoundments, with shorelines or watersheds still largely primitive and shorelines largely undeveloped, but accessible in places by roads.

Recreational River Areas – Those rivers or sections of rivers that are readily accessible by road or railroad, that may have some development along their shorelines, and that may have undergone some impoundment or diversion in the past.

Idaho has approximately 107,651 miles of river, of which 891 miles are designated as wild & scenic—less than 1% of the state's river miles.

Aquifer Recharge Districts

Data source: IDWR
Description excerpted from: https://idwr.idaho.gov/water-rights/aquifer-recharge-districts/

Aquifer Recharge Districts are created by order of the IDWR Director, per Idaho Code Title 42, Chapter 4201 et seq., upon petition by water right holders within a proposed area for the purpose of raising assessments to manage recharge facilities and conduct recharge projects. These districts are similar to Irrigation Districts in method of creation and organization.

National Wetlands Inventory

Data source: U.S. Fish and Wildlife Service (USFWS)
Description excerpted from: https://www.fws.gov/wetlands/Documents/Frequently-Asked-Questions-Wetlands-Mapper.pdf

The National Wetlands Inventory (NWI) was established by the USFWS to conduct a nationwide inventory of U.S. wetlands to provide biologists and others with information on the distribution and type of wetlands to aid in conservation efforts. The type and location of each wetland were identified through aerial imagery. The scale, type and date of imagery used in a project is provided in a pop-up window when a wetland polygon is selected on the Wetlands Mapper. Additional metadata that are available include inventory method, data limitations, geographic features, landforms, and wetland types. The Wetlands Mapper also includes historic map information for some areas, such as wetland types, vegetation, regional and temporal conditions, and other geographic features.