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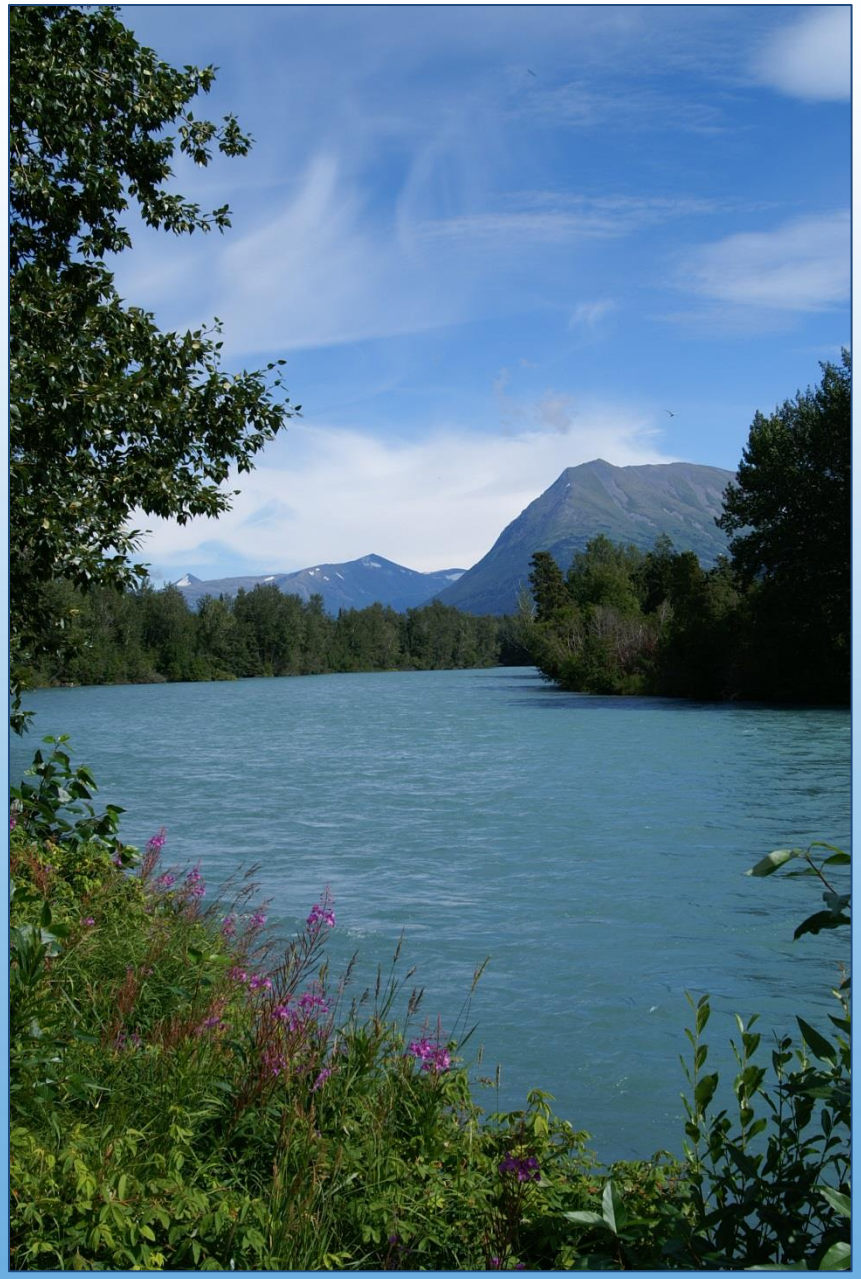
Function-Based Framework for Stream Assessment and Restoration Projects



Will Harman, PG
Stream Mechanics

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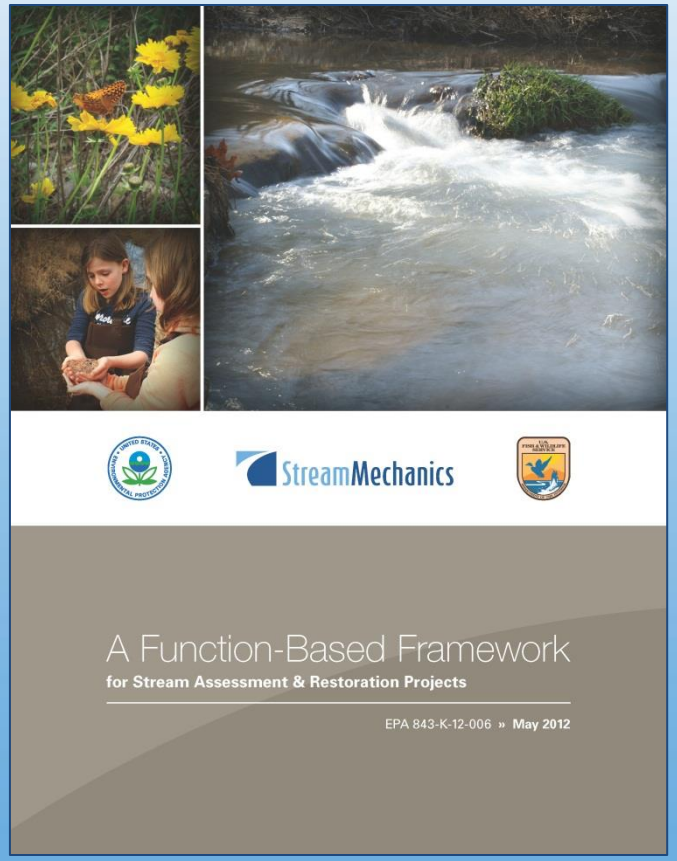
A Brief History

- Idea for a Stream Functions Pyramid
- Working with EPA and FWS
  - Pilot Workshop
  - Revisions and Further Review
- Final Document
  - "Living Document"
  - Your Role



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What is restoration?

"Stream restoration is a catchall term used to describe a wide range of management actions and as such is difficult to define. The definition of stream restoration can vary with the perspective or discipline of the practitioner or with the temporal and spatial scale under consideration."

Simon et al,. 2011. *Stream Restoration in Dynamic Fluvial Systems: Scientific Approaches, Analyses, and Tools*. American Geophysical Union, Washington, DC.

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Stream Function Perspectives

Engineers

Geologists

Ecologists

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Regulatory Definition

"Restoration means the manipulation of the physical, chemical, or biological characteristics of a site with the goal of returning **natural/historic functions** to a former or degraded aquatic resource."

- Re-establishment
- Rehabilitation

2008 Federal Mitigation Rule: 33 C.F.R. § 332/40 C.F.R. § 230

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What is restoration?

- Restoring lost functions

OR

- Restoring to a pre-disturbed condition

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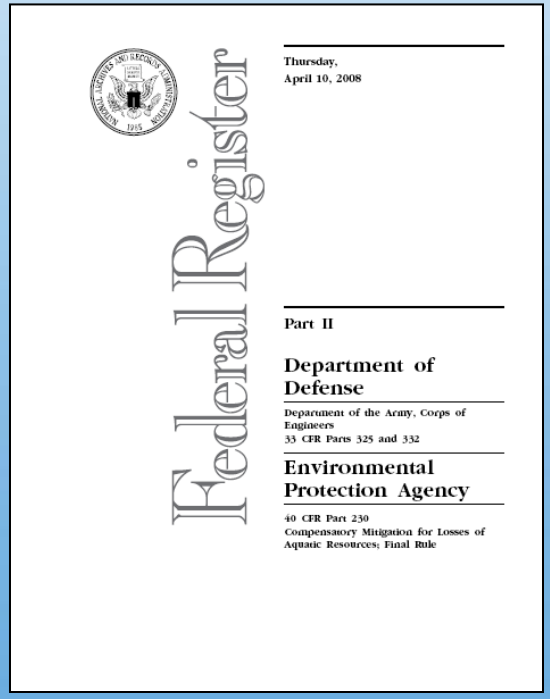
Idea Guided By Mitigation Rule

- Quantify lost functions at proposed impact site and “functional lift” at proposed mitigation site
  - Based on a functional/conditional assessment
- “Credit” reflects difference between restored condition and baseline condition
- Performance standards



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- *Functional capacity* - the degree to which an aquatic resource performs a specific function.
- *Functions* - the physical, chemical, and biological processes that occur in ecosystems.

Source: Michael Baker Corp

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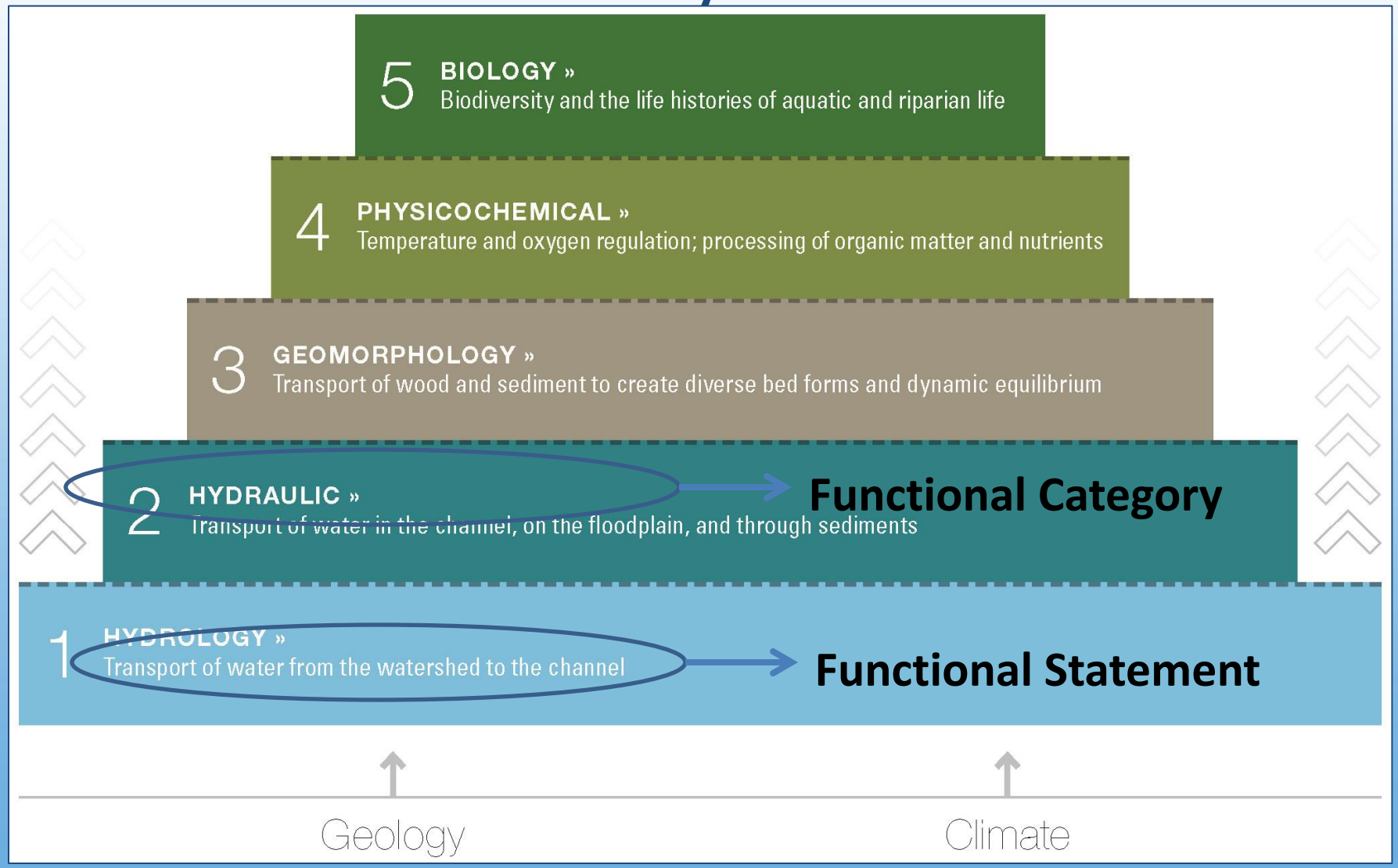
Stream Functions Pyramid: Broad Level



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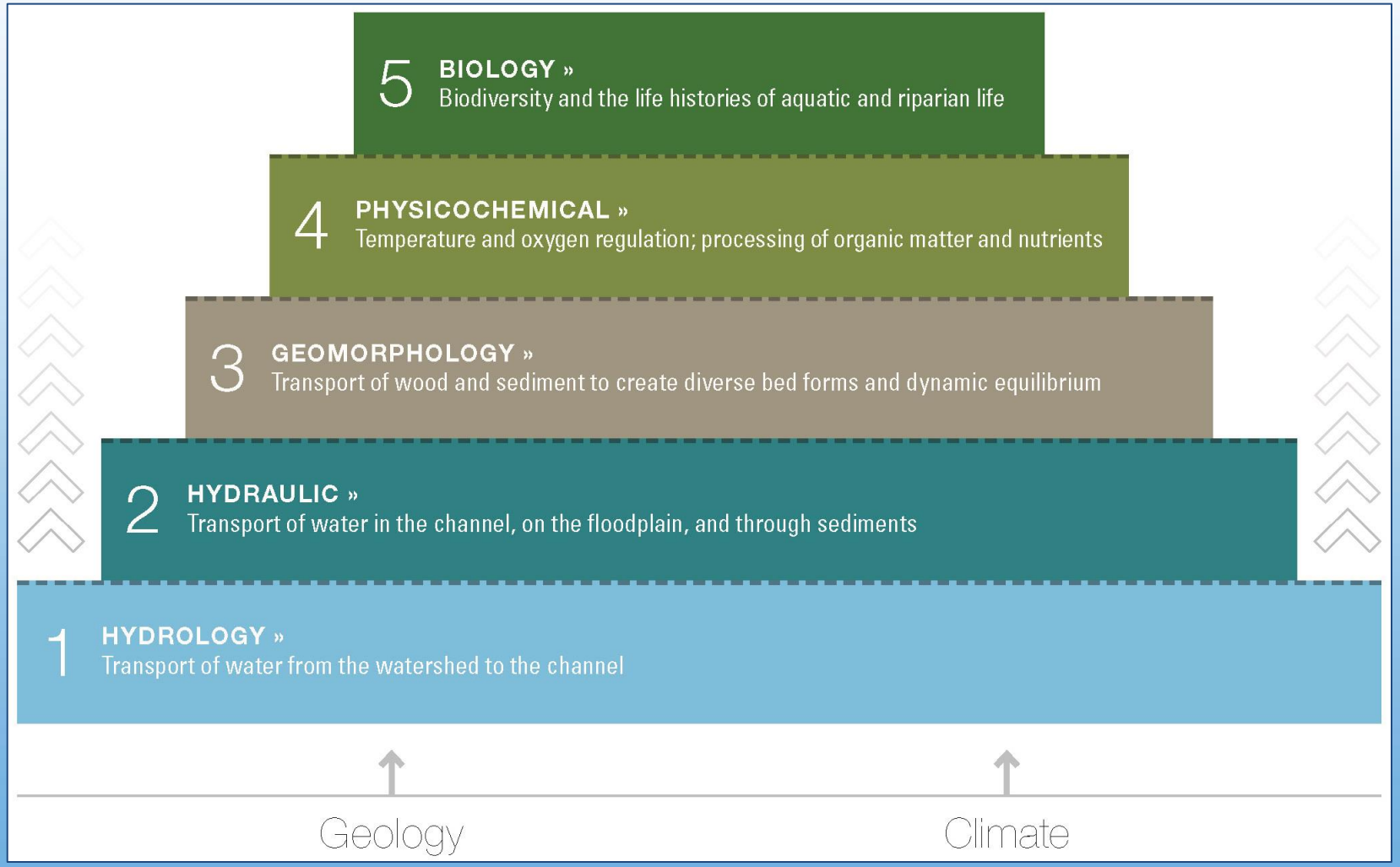
Effect

Cause



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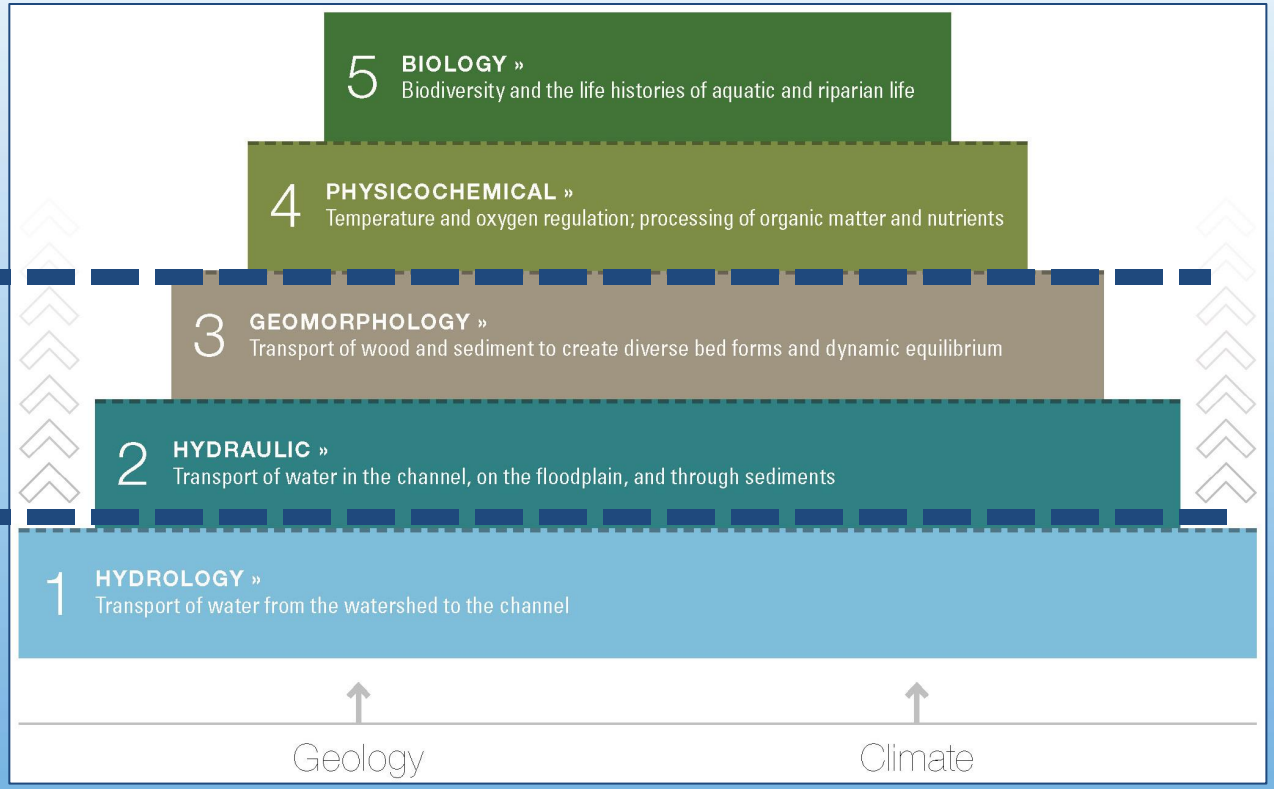
Site Selection

Reach Scale Improvements



Generally independent variables in larger streams; can be altered in headwater streams.

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Primary Thought Process

- If you want to restore a certain function, what supporting functions must be addressed?

Level 5

Increase brook trout biomass

Level 4

Temperature regulation

Level 2 & 3

Sediment continuity (3)
Substrate & structural processes (3)
Riparian processes (3)
General hydrodynamic balance (2)

Level 1

Water delivered to stream via overland and subsurface flow

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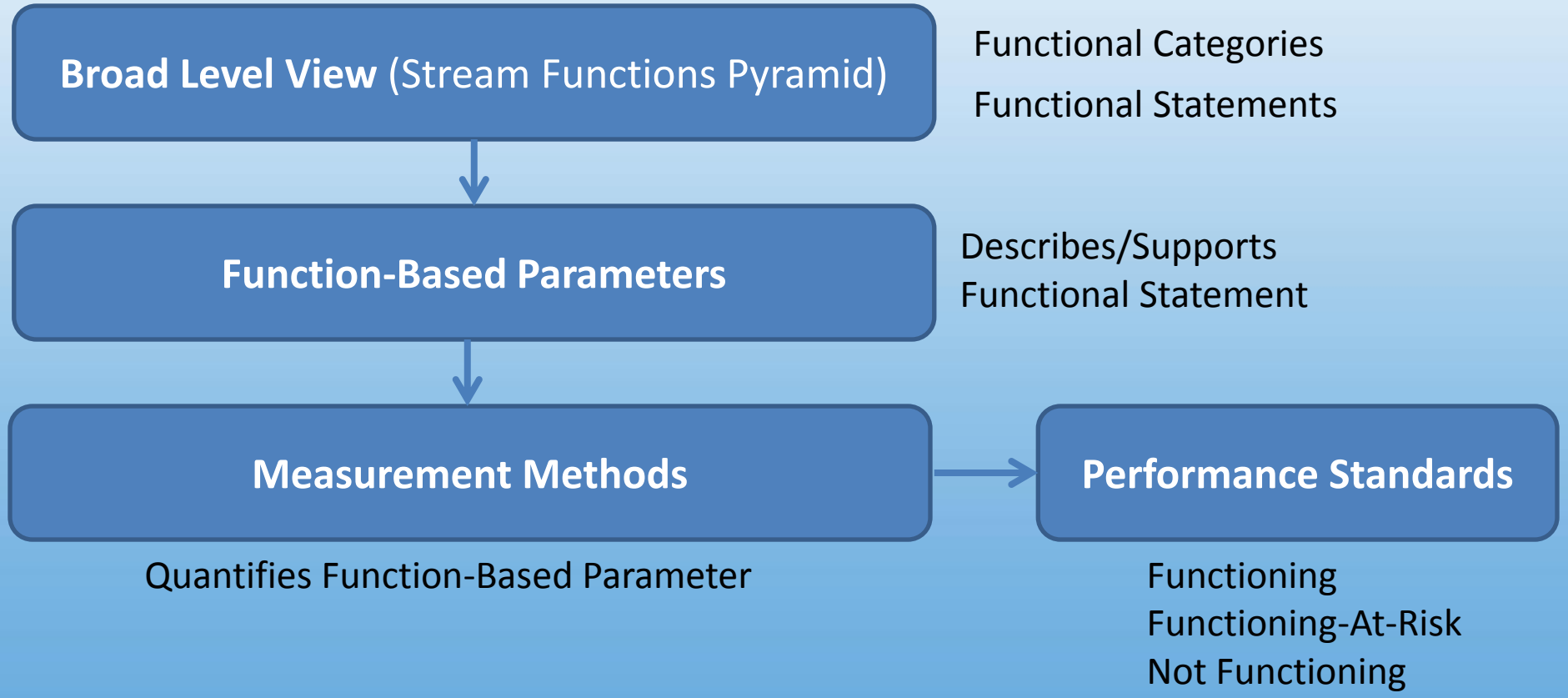
Stream Functions Pyramid Framework (SFPF)



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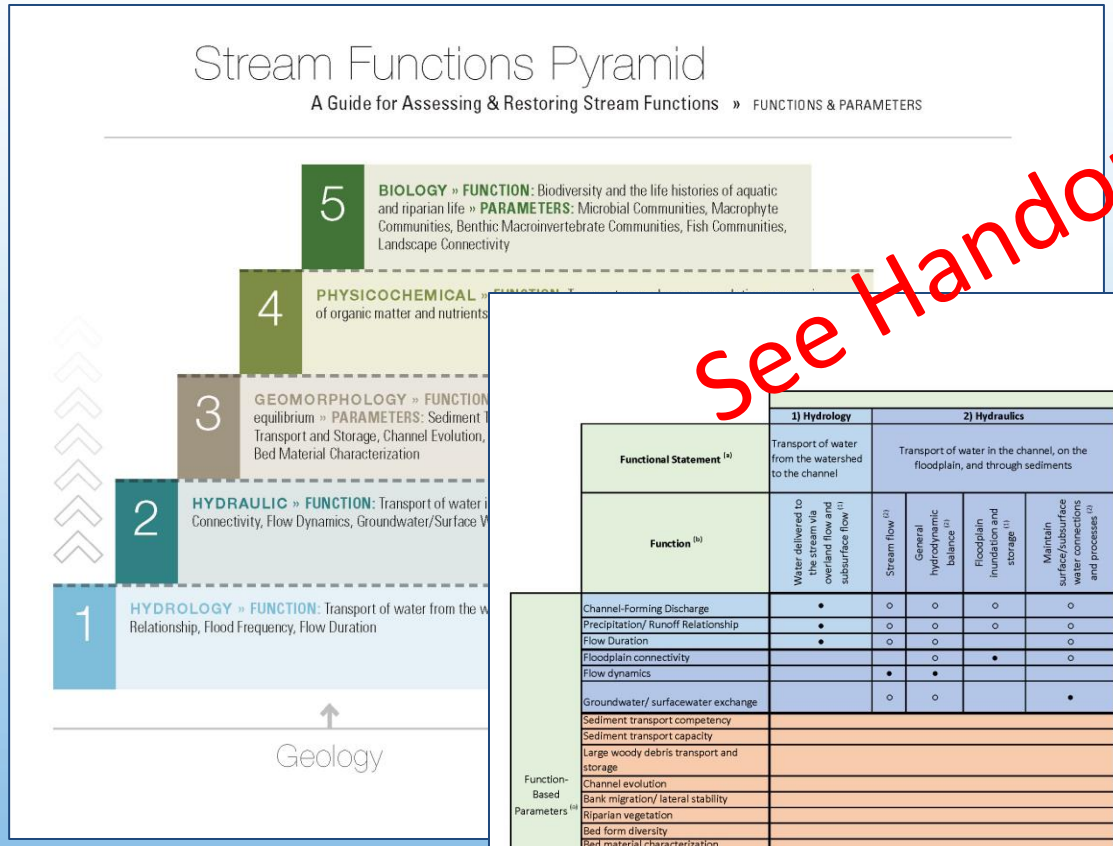
Function-Based Parameters

- Included within each **Functional Category**
- Parameters that are used to quantify or describe the **Functional Statement** provided in the broad-level view of the Stream Functions Pyramid.
  - They can be a structural type of parameter that describes a stream condition at a point in time, or they can be an actual function expressed as a rate that directly relates to a stream process

Function-Based Parameters



See Handouts

Stream Functions Pyramid Framework
Draft Functional Uplift Table

		Functional Category [a]																		
		1) Hydrology	2) Hydraulics				3) Geomorphology						4) Physicochemical				5) Biology		
	Functional Statement [a]	Transport of water from the watershed to the channel	Transport of water in the channel, on the floodplain, and through sediments				Transport of wood and sediment to create diverse bed forms and dynamic equilibrium						Temperature and oxygen regulation; processing of organic matter and nutrients				Biodiversity and the life histories of aquatic and riparian life		
	Function [b]	Water delivered to the stream via overland flow and subsurface flow [1]	Stream flow [2]	General hydrodynamic balance [2]	Floodplain inundation and storage [1]	Maintain surface/subsurface water connections and processes [2]	Sediment continuity [2]	Maintain substrate and structural processes [2]	Sediment and wood transport and storage [2]	Riparian processes and succession [1&2]	Stream Evolution Processes [1]	Erosion and sediment supply [1]	Maintain chemical processes and nutrient cycles [2]	Maintain water and soil quality [1]	Organic matter transport and storage [2]	Temperture and oxygen regulation	Maintain trophic structures and processes [1]	Support biological communities and processes [2]	Maintain landscape pathways [2]
Function-Based Parameters [a]	Channel-Forming Discharge	●	○	○	○	○	○	○	○		○	○							
	Precipitation/ Runoff Relationship	●	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
	Flow Duration	●	○	○		○		○					○	○	○	○	○	○	○
	Floodplain connectivity			○	●	○	○	○	○	○	○	○	○	○	○	○	○	○	○
	Flow dynamics		●	●			○	○	○	○	○	○	○	○	○	○	○	○	○
	Groundwater/ surfacewater exchange		○	○		●		○		○			○	○	○	○	○	○	
	Sediment transport competency						●	○	●		○	○			○		○	○	
	Sediment transport capacity						●	○	●		○	○			○		○	○	
	Large woody debris transport and storage						○	○	●		○	○	○		○	○	○	○	
	Channel evolution						○	○	○	○	●	○	○				○	○	○
	Bank migration/ lateral stability						○	○		○	○	●	○	○	○	○	○	○	
	Riparian vegetation									●	○	○	○	○	○	○	○	○	○
	Bed form diversity						●	●	●		○			○	○	○	○	○	○
	Bed material characterization							●	○			○					○	○	
	Water quality												○	●		●	○	○	
	Nutrients												●	○			○	○	
	Organic carbon												○	○	●		○	○	
	Microbial communities																●	○	
	Macrophyte communities																○	●	
	Benthic macroinvertebrate communities																○	●	
	Fish communities																○	●	
	Landscape connectivity																		●

Legend

● Function-based parameter that directly represents the corresponding function.

○ Denotes functions that are supported by the function-based parameter with the ● symbol.

Practitioner Note: Manipulation of function-based parameters in Levels 1 - 3 denoted with a ● may lead to functional uplift of other functions denoted by ○ for that same parameter.

a Terminology from *A Function-Based Framework for Stream Assessment and Restoration Projects* by Harman et al.

b Functions from *Functional Objectives for Stream Restoration* by Craig Fischenich and *Stream and Watershed Restoration*, edited by Philip Roni and Tim Beechle

1 Functions from *Functional Objectives for Stream Restoration*

2 Functions from *Stream and Watershed Restoration*

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Measurement Methods

APPENDIX A.c. Parameters and Measurement Methods

HYDROLOGY	
Parameter	**Measurement Method**
Channel-Forming Discharge	1. Regional Curves
Precipitation/Runoff Relationship	1. Rational Method 2. HEC-HMS 3. USGS Regional Regression Equations
Flood Frequency	1. Bulletin 17b
Flow Duration	1. Flow Duration C 2. Crest Gage 3. Monitoring Devi 4. Rapid Indicators

HYDRAULICS	
Parameter	**Measurement Metho**
Floodplain Connectivity	1. Bank ht Rati 2. ent R 3. Stag versus Dis
Flow Dynamics	1. Stream Velocity 2. Shear Stress 3. Stream Power
Groundwater/Surface Water Exchange	1. Piezometers 2. Tracers 3. Seepage Meters

Parameter	Measurement Method
Floodplain Connectivity	1. Bank Height Ratio 2. Entrenchment Ratio 3. Stage/Q Relationships

BIOLOGY	
Parameter	**Measurement Method**
Microbial Communities	1. Taxonomic Methods 2. Non-Taxonomic Methods 3. Biological Indices
Macrophyte Communities	1. Taxonomic Methods 2. Non-Taxonomic Methods 3. Biological Indices
Benthic Macroinvertebrate Communities	1. Taxonomic Methods 2. Non-Taxonomic Methods 3. Biological Indices
Fish Communities	1. Taxonomic Methods 2. Non-Taxonomic Methods 3. Biological Indices
Landscape Connectivity	1. Spatial Analysis 2. Species Tracking 3. Habitat Models

GEOMORPHOLOGY	
Parameter	**Measurement Method**
Sediment Transport Competency	1. Shear Stress Curve 2. Required Depth and Slope 3. Spreadsheets and Computer Models
Sediment Transport Capacity	1. Computer Models 2. FLOWSED and POWERSED
	2. Buffer Density 3. Buffer Composition 4. Buffer Growth 5. Canopy Density 6. Proper Functioning Condition (PFC)
Bed Form Diversity	1. Percent Riffle and Pool 2. Facet Slope 3. Pool-to-Pool Spacing 4. Depth Variability
Bed Material Characterization	1. Bevenger and King (1995) 2. Riffle Stability Index (RSI)

PHYSIOCHEMICAL	
Parameter	**Measurement Method**
Basic Water Chemistry	1. Temperature 2. Dissolved Oxygen 3. Conductivity 4. pH 5. Turbidity
Nutrients	1. Field test kits using reagents reactions 2. Laboratory analysis
Organic Carbon	1. Laboratory analysis

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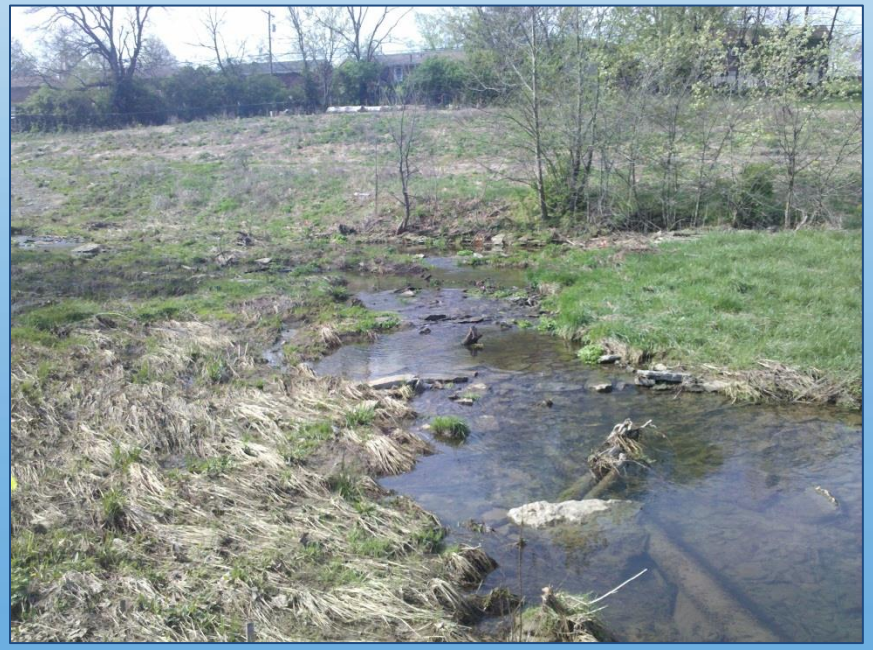
- Channel is smaller than “bankfull” channel by design.
- Floodplain connectivity is definitely achieved.
- Use another measurement method.



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Measurement Methods

- **Quantify / Describe** the Function-Based Parameter
- The methods provided are **examples.**
- **More specific** than Function-Based Parameters.
  - Specific calculations
  - Simple spreadsheet tools
  - Complex computer models
  - Assessment method

Function-Based Parameter	Measurement Method
Flow Dynamics	Velocity (specific calculation)
Riparian Vegetation	US FWS Method (Assessment method)

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Measurement Methods

- More Detail in Chapter 4 and Appendix A
  - **Type**
    - Tool, Technique, Metric, Assessment Approach
  - **Level of Effort**
    - Rapid, Moderate, Intensive
  - **Level of Complexity**
    - Simple, Moderate, Complex
  - **Direct versus Indirect** Measure of Parameter

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Performance Standards

- Based on Functional Capacity
- Divided into three categories:
  - Functioning
  - Functioning-At-Risk
  - Not Functioning

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Functioning

Means that the measurement method is quantifying or describing one aspect of a function-based parameter in a way that **does support** a healthy aquatic ecosystem. A single functioning measurement method may not mean that the function-based parameter is functioning.

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Functioning-At-Risk

Means that the measurement method is quantifying or describing one or more aspects of a function-based parameter in a way that **can support** a healthy aquatic ecosystem. In many cases, this indicates the function-based parameter is adjusting in response to changes in the reach or the watershed. The trend may be towards lower or higher function. A Functioning-at-Risk score implies that the aspect of the function-based parameter, described by the measurement method, is between Functioning and Not Functioning.

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Not Functioning

Means that the measurement method is quantifying or describing one aspect of a function-based parameter in a way that **does not support** a healthy aquatic ecosystem. A single not functioning measurement method may not mean that the function-based parameter overall is not functioning.

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Criteria Used to Select Performance Standards

- Provided in peer-reviewed journals;
- Provided in government documents;
- Provided in books or proceeding papers; and
- Professional judgment of the authors.

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Performance Standards
Floodplain Connectivity Example

- Performance standards are examples and can be modified based on local reference conditions / design goals

Measurement Method	Functioning	Functioning-At-Risk	Not Functioning
Bank Height Ratio (BHR)	1.0 to 1.2	1.3 to 1.5	> 1.5
Entrenchment Ratio (ER) for C and E Stream Types	> 2.2	2.0 to 2.2	< 2.0
Entrenchment Ratio (ER) for B and Bc Stream Types	> 1.4	1.2 to 1.4	< 1.2

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This is a Framework

- Users can add Function-Based Parameters, Measurement Methods, and Performance Standards to fit their region and project goals.
- Function-Based Parameter
  - Helps to describe/understand the functional statement
- Measurement Method
  - A measure of the Function-Based Parameter
- Performance Standards
  - Functional Capacity
  - Tied to Measurement Method

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Frequently Asked Questions

- Was the SFPF created for Natural Channel Design Projects?
  - No. The SFPF can be used for any type of restoration approach; however, the Measurement Methods and Performance Standards may change from one approach to another.

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Frequently Asked Questions

- How many Rosgen-based Parameters, Measurement Methods, and Performance Standards are there?
  - There are no parameters that are unique to Rosgen.
  - There are approximately 42 total Measurement Methods. 10 (24%) are from Rosgen. All are in the Hydraulic and Geomorphology Categories

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Frequently Asked Questions

- What if a Parameter or Measurement Method that I like is not included in the SFPF? Does that mean the SFPF doesn't apply to my project?
  - Simply add the Parameter, Measurement Method, and Performance Standard to the correct Functional Category. You may also need to add supporting Parameters, Measurement Methods, and Performance Standards.
  - The SFPF still applies.

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Frequently Asked Questions

- What if the Performance Standard doesn't fit my region or project site condition?
  - Modify the Performance Standard based on local information, e.g. from a local reference reach.
  - This must be done during the design process and before the project is constructed.

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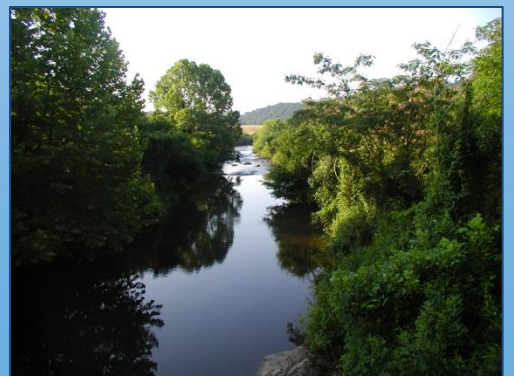
Frequently Asked Questions

- What about Performance Standards that would change over time, like buffer growth?
  - Change can be shown with multiple years of monitoring data. For buffers, a restoration project will be Functioning-At-Risk or even Not Functioning during the first year after construction, but will evolve towards Functioning over time.



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Frequently Asked Questions

- How does the SFPF deal with the issue of measuring structure versus function?
  - It uses a combination and the user can pick based on the project purpose and budget.
  - Structural measures cannot be used to describe functions outside of its Functional Category. For example, Bed Form Diversity (Level 3) cannot be used to predict Macroinvertebrate health (Level 5)

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Applications

Goals and Objectives

Function-Based Assessments

Debit and Credit Determination

And Beyond

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Developing Function-Based Goals and Objectives & Restoration Potential

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Function-based Goals and Objectives

- Goals
  - Should answer the question, “What is the purpose of this project?” **Why** is it being proposed?
  - Should address a problem.
  - Relate to a function
- Objectives
  - More specific and possibly more quantitative
  - Relate to parameters, measurement methods, and performance standards
  - **The what and how**

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Programmatic Versus Design Goals

- Programmatic
  - Broad, program and/or regulatory goals
  - Funding driver
- Design Goals and Objectives
  - Comes after a Function-Based Assessment
  - Tied to Restoration Potential

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Example Programmatic Goals

- Provide mitigation credit
- Develop TMDL's
- Can be tied to watershed need, e.g., nutrient reduction
- Can be tied to a species of interest, e.g., native brook trout

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Examples of Design Goals

- Restore native “pick your favorite fish.”
- Reduce sediment supply from streambank erosion.
- Protect adjacent infrastructure from lateral migration.
- Reduce nitrogen and phosphorus loading.

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Habitat Goals

The goal of this project is to improve native brook trout habitat (Levels 1-3).

The goal of this project is to increase the biomass of native brook trout populations (Levels 1-5).

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Design Goals and Objectives

- **Common Goal**
  - Create a stable dimension, pattern and profile so that the channel doesn't aggrade or degrade
- **Better Goal (Example)**
  - Reduce sediment supply from bank erosion to improve smallmouth bass habitat:
    - Restore floodplain connectivity,
    - Reduce streambank erosion,
    - Improve bedform diversity, and
    - Establish a riparian buffer.

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Quantitative Objectives

- Floodplain Connectivity
  - Reduce bank height ratios from 2.0 to 1.0.
  - Increase entrenchment ratio from 1.2 to 3.0.
- Bedform Diversity
  - Decrease p-p spacing ratio from >10 to 4 to 6.
  - Increase pool depth ratio from < 1.5 to 2 to 3.
- Streambank erosion
  - Reduce erosion rates by 95%.
  - Reduce erosion rates to reference reach condition.
- Riparian Buffer
  - Increase buffer width from 0 feet to 50 feet.

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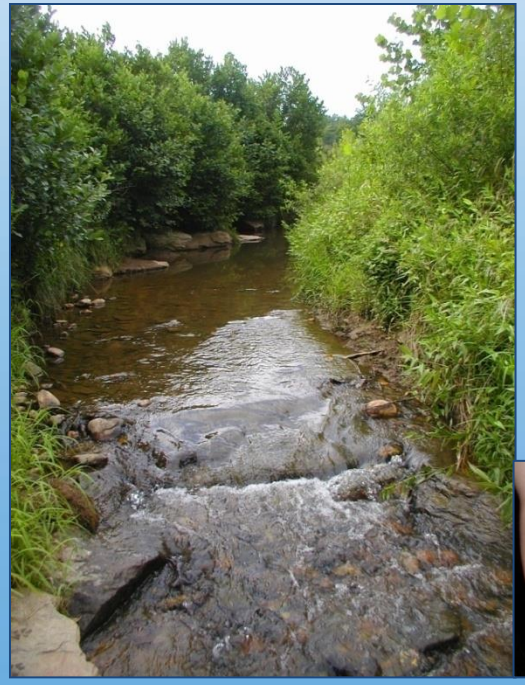
Restoration Potential

Highest level of restoration that can be achieved based on watershed conditions, results of the function-based assessment and project constraints.

Restoration Potential =Level 5



- Catchment supports functioning biology
- Minimal or no project constraints

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Restoration Potential

Restoration Potential = Level 4

- Catchment health may not support “functioning” biology
- Headwater stream or very long project reach
- Existing nutrient inputs
- Restoration approach can increase retention time, ground water surface water interaction, plant uptake, etc.

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Restoration Potential

Restoration Potential =Level 3

- Catchment health may not support “functioning” biology.
- Minimal to high constraints.
- Project approach is stability based: floodplain connectivity, bed form diversity, lateral stability, and establishment of riparian buffer.

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Matching Restoration Potential with Design Goals

Restoration Potential	Example Design Goal
Level 5 (Biology)	Restore native "pick your favorite fish" biomass. Level 5
Level 4 (Physicochemical)	Reduce nutrient loadings to meet TMDL requirements. Level 4
Level 3 (Geomorphology)	Reduce sediment supply from eroding streambanks. Increase "pick your favorite fish" habitat. Level 3

Notes:

- The design goal cannot exceed the restoration potential.
  - Cannot have a Restoration Potential of Level 3 and a biology design goal (Level 5).
- The design goal can be less than the restoration potential.
  - Stability goal (Level 3) with a Level 5 restoration potential.

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Functional Category	Level 5: Biology	Level 4: Physicochemical	Level 3: Geomorphology	Level 2: Hydraulics	Level 1: Hydrology
Design Goal (Why)	Restore a species of interest or to reference condition	Reduce nutrient loadings (N, P, or N&P)	Reduce sediment supply	Increase floodplain inundation, attenuation	Increase base flow duration
Restoration Potential	Level 5	Level 4	Level 3	Level 2	Level 1
Design Objectives and Function-Based Parameters	Develop objectives by selecting function-based parameters that must be "Functioning" in order to meet the goal. Use the Functional Uplift Table as a guide for selecting parameters. Select parameters within and lower than the goal's Functional Category.				
Select/Develop Measurement Methods	Select or Develop Measurement Method(s) for each parameter.				
Select/Develop Performance Standards	Select or Develop Performance Standards for each measurement method based on stream type, catchment size, and landscape setting.				

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Developing Function-Based Stream Assessments

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Reach-Scale Existing Condition Assessment

- Rapid
  - As part of a site selection process. Go/No go
  - Mostly Qualitative Measurement Methods
- Detailed
  - After site selection
  - More Quantitative Measurement Methods

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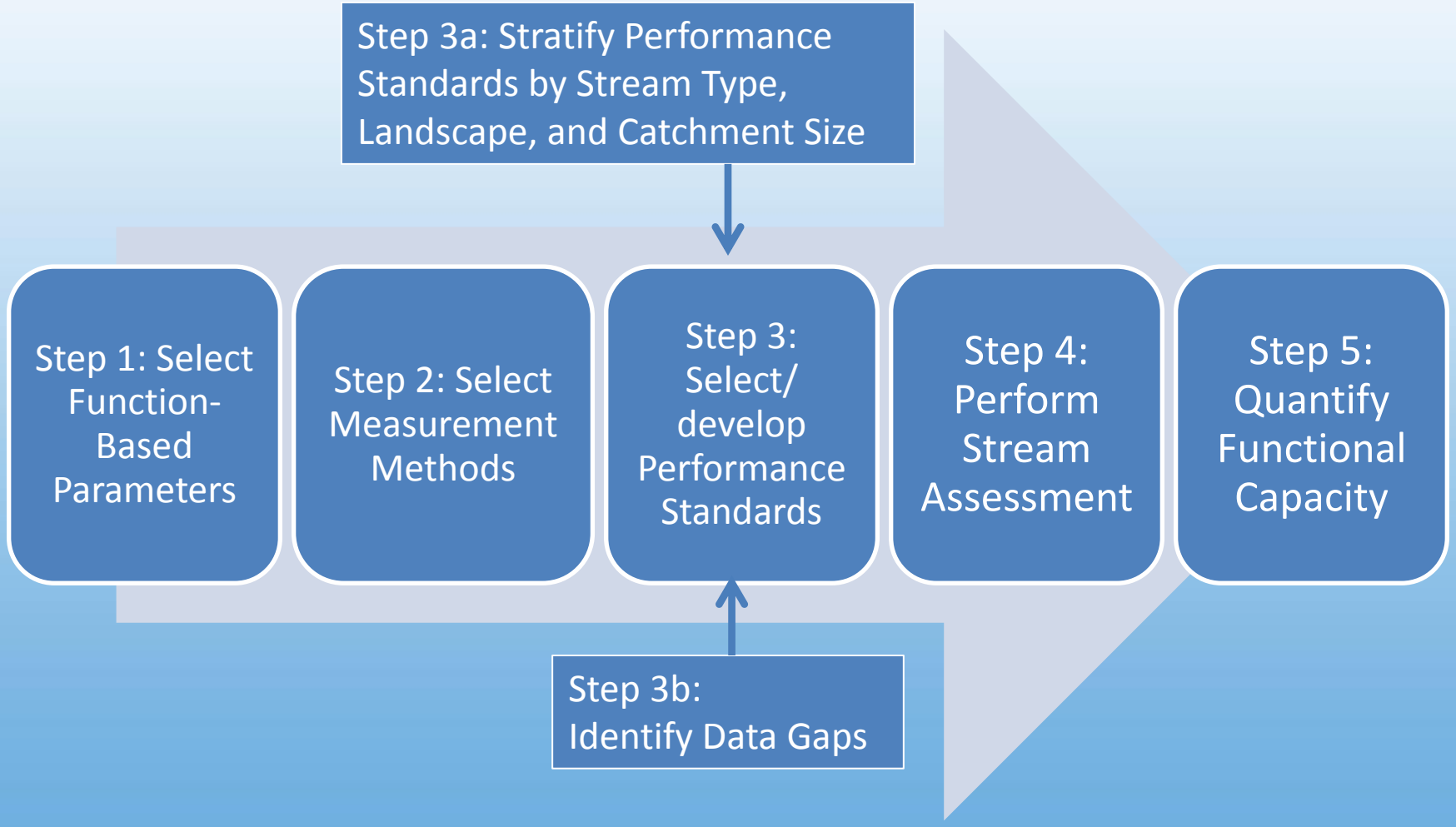
Steps for Developing Reach-Scale Assessment Methodology



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Step 1:Select Parameters

Included with all Assessments:
Minimum Requirements

- Floodplain Connectivity
- Bedform Diversity
- Streambank Erosion (Lateral Stability)
- Riparian Buffer

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Step 2: Select/Develop Measurement Methods

- Rapid Examples
  - Bank height ratio using regional curve (Floodplain Connectivity)
  - Visual indicators of high temperature (Water quality)
  - Buffer width (Riparian Vegetation)
  - Presence of headcuts (Channel Evolution)
- Detailed Examples
  - Stage/Q measurements (Floodplain Connectivity).
  - Upstream/downstream temperature measurements (Water quality)
  - Riparian buffer composition and density (Riparian Vegetation)

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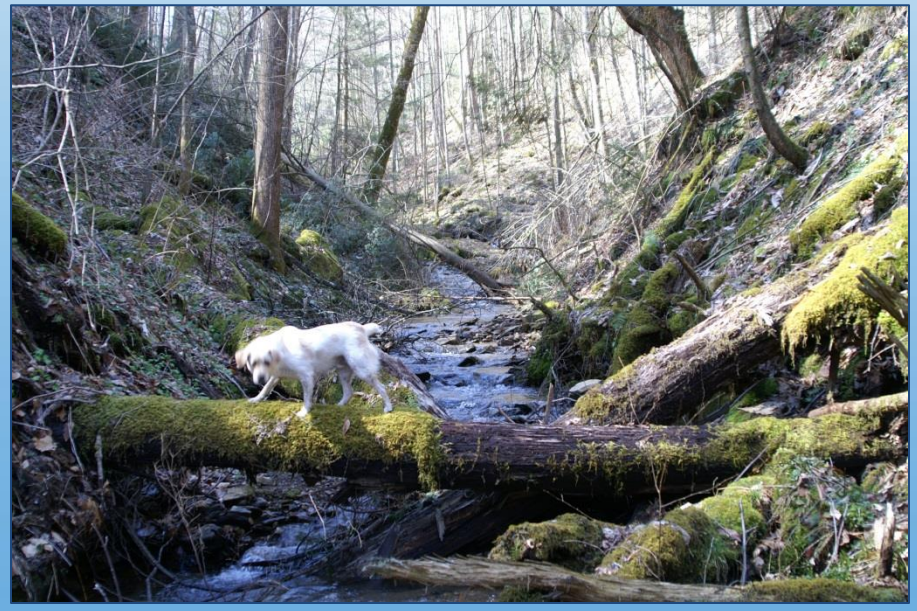
Step 3: Select/Develop Performance Standards

- Stratify by Stream Type, Landscape Setting, and Catchment Size



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Perennial, Intermittent, Ephemeral

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Landscape Setting

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Catchment Size

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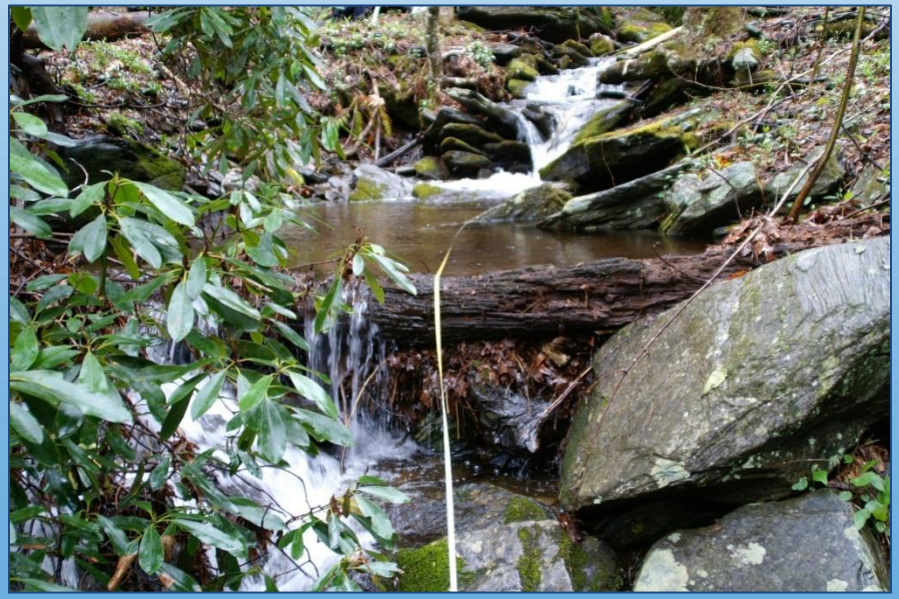
Step 3b: Data Gaps

- Measurement Methods that do not have Performance Standards
  - Large Woody Debris



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Step 5: "Quantify" Functional Capacity

- Without Index Scoring
  - Professional Judgment

VII. Quantify Proposed Functional Lift

Functional Lift Score (FLS) = PCS – ECS, where:

PCS = Proposed Condition Score and ECS = Existing Condition Score

$FF_{Existing}$ = ECS X ESL

$FF_{Proposed}$ = (FLS X ESL) + (PCS X NSL)

Proposed Functional Lift (PFL_{feet}) = $FF_{Proposed}$ - $FF_{Existing}$

Where: ESL = Existing Stream Length, NSL = New Stream Length

- With Index Scoring
  - Under development

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Communicating Functional Lift

Functional Category	Function-Based Parameter	Pre-Restoration Condition	Post- Restoration Condition
Hydrology	Runoff		
Hydraulics	Floodplain Connectivity		
Geomorphology	Bed Form Diversity		
Geomorphology	Lateral Stability		
Geomorphology	Riparian Vegetation		
Geomorphology	Large Woody Debris		
Physicochemical	Temperature / DO		
Physicochemical	Nutrients		

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Communicating Functional Lift

Functional Category	Function-Based Parameter	Pre-Restoration Condition	Post- Restoration Condition
Biology	Aquatic Insects		
Biology	Fish Communities		

Existing Condition

As-Built Condition

Reference Condition