Stream Functions Pyramid

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We are at a 2nd Crossroad

Crossroad # 1

Traditional Channel Design
Transport water quickly; Bed and banks don’t move

Natural Channel Design
Create a dimension, pattern, and profile that transports water and sediment.
Crossroad # 2

Restoration of Dimension, Pattern, and Profile

Restoration of Functions
What is a Stream Function?

“The physical, chemical, and biological processes that occur in ecosystems,” Clean Water Act (33 CFR 332.2; 40 CFR 230.92)

“The processes that create and support a stream system.“ EPA Region 10
Stream Function and Structure

- **Structural measures** evaluate stream condition at a point in time
  - Channel Form, Habitat Features, Number of Species
  - Describes “How the System Is.”

- **Functional Attributes** describe processes and rates (per unit time)
  - Describes how the system is performing

Source: Palmer and Bernhardt, 2009
Stream Functions Pyramid

1. HYDROLOGY » Transport of water from the watershed to the channel
2. HYDRAULIC » Transport of water in the channel, on the floodplain, and through sediments
3. GEOMORPHOLOGY » Transport of wood and sediment to create diverse bed forms and dynamic equilibrium
4. PHYSIOCHEMICAL » Temperature and oxygen regulation; processing of organic matter and nutrients
5. BIOLOGY » Biodiversity and the life histories of aquatic and riparian life
Stream Functions Pyramid

1. **HYDROLOGY**
   - **FUNCTION:** Transport of water from the watershed to the channel
   - **PARAMETERS:** Precipitation/Runoff relationship, Channel Forming Discharge, Flood Frequency, Flow Duration

2. **HYDRAULIC**
   - **FUNCTION:** Transport of water in the channel, on the floodplain, and through sediments
   - **PARAMETERS:** Velocity, Shear Stress, Stream Power, Bank Height Ratio, Entrainment Ratio, Rating Curves (discharge vs. stage), Groundwater/Surface Water Exchange

3. **GEOMORPHOLOGY**
   - **FUNCTION:** Transport of wood and sediment to create diverse bed forms and dynamic equilibrium
   - **PARAMETERS:** Sediment Transport Capacity and Competency, Channel Evolution, Streambank Erosion Rates, Percent Riffle and Pool, Depth Variability, Substrate Distributions, Large Woody Debris Transport and Storage, Riparian Vegetation density and composition

4. **PHYSIOCHEMICAL**
   - **FUNCTION:** Temperature and oxygen regulation; processing of organic matter and nutrients
   - **PARAMETERS:** Dissolved Oxygen, Temperature Regulation, pH, Conductivity, Nutrient Processing, Organic Processing, Turbidity

5. **BIOLOGY**
   - **FUNCTION:** Biodiversity, the life histories of aquatic and riparian life
   - **PARAMETERS:** Primary and Secondary Production, Macri/invertebrate Communities, Fish Communities, Riparian Communities, Landscape Pathways

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A Guide for Assessing & Restoring Stream Functions

FUNCTIONS & PARAMETERS
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**PHYSIOCHEMICAL**

**FUNCTION:** Temperature and oxygen regulation; processing of organic matter and nutrients

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*Parameters in bold are also functions*
Why do we need the Pyramid?

- So we don’t incentivize this result and we think about what we’re trying to achieve.
• So we don’t miss key functions and processes during the design process.
• So we don’t do this!
Why are we struggling with success?

• We don’t ask *why*.
  – We don’t link functional lift to functional loss.

• Because we don’t focus on *what* functions can be improved and *how* to restore those functions.

• We don’t align the site selection with the functional goals.
  – We’re not going to fully restore biological functions with severely degraded watersheds and patchwork restoration.
So, what do we do?
How can we use the Pyramid to help?

To Create Better:

- Goals and Objectives
- Function-Based Assessment Protocols
- SOP’s
  - Debit and Credit Determination Methods
  - Success Criteria
  - Performance Standards
To Create Better Goals and Objectives

• **Common Goal**
  - Create a stable dimension, pattern and profile so that the channel doesn’t aggrade or degrade

• **Better Goal**
  - Reduce sediment supply to improve native fish populations:
    • Restore floodplain connectivity,
    • Reduce streambank erosion,
    • Improve bedform diversity, and
    • Establish a riparian buffer.

Objectives
Functional Drivers for C and E Stream Types

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

**Requires**

- Appropriate Watershed Condition.
- Adequate hydrology functions.
- Reach scale versus watershed scale understanding.
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
  – Convert riffle dominated bedform (95% riffle) to riffle-pool sequence (70/30).
• 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.
Framework for Function-Based Assessments

- Functional Assessments
  - Focus on parameters listed in pyramid
  - Acknowledge the hierarchy
  - Tailor to different regions
Assessments for Different Reasons

• Mitigation Related
• Departure from Stability and Restoration Potential
• Watershed Management and Planning
Assessments for Different Reasons

- Mitigation Related
  - Assess lost functions at permitted impact site
  - Assess functional lift at mitigation site
  - Basis for credit determination and performance
Assessments for Different Reasons

- Departure from Stability and Restoration Potential
  - Hydrologic Changes
  - Geomorphic Assessments
  - Physiochemical and Biological Health
  - Restoration Potential

- Watershed Management and Planning
Assessments for Different Reasons

• Watershed Management and Planning
  – Watershed scale
  – ID healthy sub-watersheds
  – ID unhealthy sub-watersheds / reaches and the stressor
  – Develop management plan to restore functions
    • Use all appropriate tools, like restoration, BMPs, preservation, etc.
Framework for Mitigation SOPs

• SOPs
  – Move from restoration of dimension, pattern, and profile to functions.
  – Better link between impact site and mitigation site.
  – Applies to:
    • Debit and Credit Determination Methods
    • Functional Assessment
    • Performance Standards
Rural Piedmont: South Fork Mitchell River
Darnell / Harman Reach

- Not a mitigation project
- Funded by the NC Clean Water Management Trust Fund
- Mitchell River Watershed Coalition and Surry Soil and Water Conservation District
- Watershed scale effort
- Design by Michael Baker Corporation
Pre-Restoration Condition

Widespread bank erosion
Channel is re-adjusting pattern
### Pre-Restoration Condition

<table>
<thead>
<tr>
<th>Feature</th>
<th>Stream Type</th>
<th>BKF Area</th>
<th>BKF Width</th>
<th>BKF Depth</th>
<th>Max BKF Depth</th>
<th>W/D</th>
<th>BH Ratio</th>
<th>ER</th>
<th>BKF Elev</th>
<th>TOB Elev</th>
</tr>
</thead>
<tbody>
<tr>
<td>Riffle</td>
<td></td>
<td>76</td>
<td>27.77</td>
<td>2.74</td>
<td>4.16</td>
<td>10.15</td>
<td>1.5</td>
<td>&gt;357.20</td>
<td>87.84</td>
<td>89.95</td>
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</tbody>
</table>

**Cross-section 7+50**

- **Elevation (ft)**: 80 to 110
- **Station (ft)**: 600 to 850

- **Bankfull**
- **Floodprone**

**Moderately Incised. BHR = 1.5**
Pre-Restoration Profile

South Fork Mitchell River - Longitudinal Profile

Elevation

Station
Functional Lift

- Hydrology
- Hydraulic
- Geomorphic
- Physiochemical
- Biological
Hydrology

• No lift
  – No change in rainfall / runoff relationship
  – No change in design discharge (bankfull)
  – No change in flow duration
Hydraulics

- Floodplain Connectivity
  - Bank Height Ratio reduced from 1.5 to 1.0
  - Entrenchment ratio did not change

- Flow Dynamics
  - Reduced average channel velocities
  - Reduced shear stress from 0.85 to 0.67 lbs/sqft
  - Reduced stream power
Floodplain Connectivity

Before

After
Floodplain Connectivity

Cross-section 9+45 -- Riffle

Elevation (ft)

Distance (ft)

Bankfull
Geomorphic

- Sediment Transport Competency
  - Reduced average depth from 3.4 to 2.5
  - As-built depth matches required depth

- Sediment Transport Capacity
  - Not quantitatively assessed
Geomorphic

• Channel Evolution
  – Pre-restoration condition
    • E moving towards a Gc – F – C – E
  – Restored to a C/E
Geomorphologic

- Lateral Stability
  - Did not do before and after BEHI assessments, which could be used for functional lift
  - Used cross section surveys to show lateral stability after restoration construction.
Lateral Stability

Darnell Reach Post Construction
Cross-section 3+90 -- Pool

- 1/27/2003
- 3/26/2004
- 3/22/2005
- Bankfull
Bed Form Diversity

- Percent Riffle and Pool
- Pool Depth Variability
- Substrate Distributions
Rosgen Priority 1
Profile After Restoration
# Percent Riffle and Pool

<table>
<thead>
<tr>
<th>Bed Form</th>
<th>Before Restoration Percentage</th>
<th>Year 5 Restoration Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Riffle</td>
<td>51</td>
<td>46</td>
</tr>
<tr>
<td>Pool</td>
<td>49</td>
<td>54</td>
</tr>
</tbody>
</table>
Cross Vane Too High

Downstream Cross Vane

Upstream Riffle
Substrate Variability
Pre and Post Beaver Dam

Summer 2008

Winter 2008
Physiochemical Functional Lift

• Not measured
  – DO
  – Temperature
  – pH
  – Conductivity
  – Nutrients

• Discussion
Biological Functional Lift

• Primary Production – not measured
• Macroinvertebrate Communities
  – Ken Bridle, Ecologic
• Fish Communities
  – Stamper Aquatics
• Riparian Communities
# Macroinvertebrate Communities

## Total Number of Taxa

<table>
<thead>
<tr>
<th>Station</th>
<th>2003</th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project</td>
<td>35</td>
<td>54</td>
<td>46</td>
<td>31</td>
<td>51</td>
</tr>
<tr>
<td>Downstream</td>
<td>39</td>
<td></td>
<td>48</td>
<td></td>
<td>35</td>
</tr>
</tbody>
</table>

## Total Number of Organisms

<table>
<thead>
<tr>
<th>Station</th>
<th>2003</th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project</td>
<td>135</td>
<td>294</td>
<td>278</td>
<td>149</td>
<td>286</td>
</tr>
<tr>
<td>Downstream</td>
<td>186</td>
<td></td>
<td>362</td>
<td></td>
<td>184</td>
</tr>
</tbody>
</table>
Fish Communities

Darnell Species Percent Composition (2003-2007)

Golden Species Percent Composition (2003-2007)

Darnell Site 2003-2007
Volunteer Monitoring 2007-8
Riparian Communities
# Riparian Communities

<table>
<thead>
<tr>
<th>Tree Species</th>
<th>2004 Stem Count</th>
<th>2005 Stem Count</th>
<th>2006 Stem Count</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Prunus serotina,</em> Black cherry</td>
<td>0</td>
<td>6</td>
<td>8</td>
</tr>
<tr>
<td><em>Diospyros virginiana,</em> Persimmon</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td><em>Platanus occidentalis,</em> Sycamore</td>
<td>9</td>
<td>11</td>
<td>10</td>
</tr>
<tr>
<td><em>Acer rubrum,</em> Red maple</td>
<td>2</td>
<td>10</td>
<td>3</td>
</tr>
<tr>
<td><em>Liriodendron tulipifera,</em> Tulip poplar</td>
<td>3</td>
<td>8</td>
<td>7</td>
</tr>
<tr>
<td><em>Juglans nigra,</em> Black walnut</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td><em>Fraxinus pennsylvanica,</em> Green ash</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td><em>Nyssa sylvatica,</em> Black gum</td>
<td>3</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>Total Stems</strong></td>
<td><strong>21</strong></td>
<td><strong>40</strong></td>
<td><strong>32</strong></td>
</tr>
<tr>
<td><strong>Stems/Acre</strong></td>
<td><strong>378</strong></td>
<td><strong>720</strong></td>
<td><strong>576</strong></td>
</tr>
</tbody>
</table>
Volunteer Wetland Monitoring
Fun for the whole family ...
Mountain Stream Example
Mitchell River, Mickey Reach

- Drainage Area = 0.45 square miles
- Channel Slope = 3.5%
- Bankfull Discharge = 55 cfs
- Bankfull Cross Sectional Area = 14 ft²
- D50 = 31 mm (Coarse gravel)
- Rosgen Stream Type = B4
- Design by Michael Baker Corporation
Existing Condition
Before Restoration Profile

Mickey Reach Profile Chart

7 pools out of 3,300 feet of channel
## Pool to Pool Spacing / Bankfull Width and Total Number of Pools

<table>
<thead>
<tr>
<th>Year</th>
<th>Min</th>
<th>Max</th>
<th>Total #</th>
<th>Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>2002</td>
<td>1</td>
<td>&gt;100</td>
<td>7</td>
<td>Existing</td>
</tr>
<tr>
<td>2003</td>
<td>2</td>
<td>16</td>
<td>29</td>
<td>As-built</td>
</tr>
<tr>
<td>2005</td>
<td>0.5</td>
<td>9</td>
<td>53</td>
<td></td>
</tr>
<tr>
<td>2006</td>
<td>0.5</td>
<td>9</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>2007</td>
<td>0.6</td>
<td>8</td>
<td>48</td>
<td></td>
</tr>
</tbody>
</table>
Lower end of project
Riparian Buffer
Functional Summary

• Improved floodprone area connection in lower reach.
  – Converted G to B

• Improved bed form diversity
  – 7 pools to ~50 pools
  – Maintained pool to pool spacing

• Improved wetland / bog

• Created riparian buffer
Thank You