Avoiding Geohazards in the Mid-Atlantic Highlands by Using “Natural Stream” Principles

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North Fork South Branch Potomac River, Hopeville, WV

Photo: W. Gillespie
“Natural Stream” Principles?


Developed from Relatively Unimpaired Streams

“Packaged” by Dave Rosgen.¹

Must Be Fine Tuned to Region’s flood meteorology, topography, geology, ecology, land-use, politics, & culture.

Why Use Natural Stream Principles in Engineering & Construction?

1. Aesthetics
2. Ecosystem Support
3. Long-Term Cost Effectiveness

4. Reduce Flood Hazard
   - In Face of Increasing Flood Severity

Image from Will Harman, Michael Baker Corp.
We should not be surprised when, sooner or later, the River exerts its authority over its whole domain.
What is the “Work” of a Stream?

1. Water Delivery

Little Conemaugh River, Johnstown, PA

Photo: J.S. Kite
“Work” of a Stream?

2. Framework for Ecosystem Structure

Constructed Floodplain
Mitchell River Basin, NC
Michael Baker Corp
“Work” of a Stream?

3. Sediment Transport

Ignore Sediment Transport: Other Systems Do Not Work

Photo: J.S. Kite
Delicate Balance
between sediment supply & system’s ability to transport sediment

"Grade"

J.S. Kite
Wolman-Miller Dominant Flow Hypothesis

Dominant Flow (1-3 Year)

Entrainment Threshold

Frequency
Event Sediment Transport
Cumulative Sediment Transport

Recurrence Interval (Years)

Graphic: S. Kite, WVU
Bank-Full = Dominant Flow Controlling Hydraulic Geometry

- Overbank Silt Loam
- Sand & Gravel Channel Deposits
- Bedrock

Bank-Full Stage

Bedload

Graphics: J.S. Kite, WVU
Road Crossings

Conventional Culverts May Be Migration Barriers & Block Sediment Transport

Photo: J.S. Kite
Culvert Area - **Bankfull** Channel Area Ratio

Addresses Culvert’s Ability to Pass “Floods”

\[
\text{Culvert Area - Bankfull Channel Area Ratio} = \frac{\text{Area}_{\text{Culvert}}}{\text{Area}_{\text{Bankfull Channel}}}
\]

Graphics: J.S. Kite, WVU
Channel Area vs. Culvert Area:

Non-aggrading and **Aggrading** Reaches

Arch Culvert

Photo: J.S. Kite
Lower Culvert Allows Bank-Full Flow, Sediment Transport, Fish Migration

Higher Culverts for Flood Passage

Image from Will Harman, Michael Baker Corp.
Prefab Concrete Box Culverts ≈ Bridge

Image from Will Harman, Michael Baker Corp.
Natural Stream Design May Rely on Structures (e.g. Cross Veins)

Flow Directed to Mid-Channel to Reduce Bank Shear Stress

Constructed Reach
WVU Stream Design Workshop, Mitchell River Basin, NC

Photo: J.S. Kite
Good “Design” Must Address Dominant (1-3 Year) Flow, Not Just Big (10-200 Year) Floods

Bank-Full “Flood” = Dominant Flow

Constructed Channel Reach
WVU Stream Design Workshop,
Mitchell River Basin, North Carolina
J.S. Kite, WVU
Mitchell River at Devotion Road (Rt. 1330), End of Construction

Floodway for Extreme (e.g. 50 year) Floods

Channel for Dominant (e.g. 1-3 year) Floods

Photo by Will Harman
Michael Baker Corp.
Color Overlay: J.S. Kite
Common Flood Mitigation Error – Over-Widening of Channel

Overbank Silt Loam

Bank-Full Stage

Sand & Gravel Channel Deposits

Bedrock

Graphics: J.S. Kite, WVU
Common Flood Mitigation Error – Over-Widening of Channel

Old Bank-Full Stage

Bedrock

Graphics: J.S. Kite, WVU
Common Flood Mitigation Error – Over-Widening of Channel

Old Bank-Full Discharge Becomes a Flood

Old Bank-Full Stage

Bedrock

Graphics: J.S. Kite, WVU
Common Flood Mitigation Error –

Old Flood Becomes a Worse Flood

Old Bank-Full Stage

Bedrock

No Matter What the Mayor Says!
Don’t Over-Widen Channels after a Flood.
Re-Construct Bank-Full Channel Dimensions
for Sediment Transport

J.S. Kite, WVU
Base Level & Profile Equilibrium

**Base Level** = Lowest elevation to which a stream can erode (e.g. Sea Level, Lake, Falls, Downstream Reach, etc.)

Image Source: http://www.rustycans.com/OhioFalls.jpeg
Stream Adjustments to Lower Base Level

• **Equilibrium** - Concave Profile

Graphics: J.S. Kite, WVU
Stream Adjustments to **Lower Base Level**

- **Incision** to Adjust Profile

Graphics: J.S. Kite, WVU
Lewis Run, Rockingham County, VA

Large Gravel Pit Operations Lowered Channel Causing Retreating Knickpoint

Lewis Creek, Rockingham Co., Va., 10 Nov 1985

Photo: J.S. Kite
Key to Reducing Flood Damage: Bank Stability

Anthony Creek, Greenbrier Co., W.Va. Photo: J.S. Kite
W.Va. Rt. 28/55, Near Champe Rocks: Before 1985 Flood

Old Channels

USGS Photo Graphics: J.S. Kite, WVU
Vegetation = Nature’s Bank Protection

Image from Will Harman, Michael Baker Corp.
Photo by Will Harman, Michael Baker Corp.
Dense Root Wads Reduce Bank Shear

Mitchell River Basin

Photo: J.S. Kite
Hydraulic Geometry in Plan View

Sinuosity = \( P = \) 
River Distance Along Thalweg / Straight-Line Distance

<table>
<thead>
<tr>
<th>Sinuosity</th>
<th>Rosgen Class</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0 - 1.2</td>
<td>Low</td>
</tr>
<tr>
<td>1.2 - 1.5</td>
<td>Moderate</td>
</tr>
<tr>
<td>1.5 +</td>
<td>High</td>
</tr>
</tbody>
</table>

Graphics: J.S. Kite, WVU
North Fork South Branch Potomac River, Hopeville: Before

USGS Photo
North Fork South Branch Potomac River, Hopeville Anticline

Photo: J.S. Kite
North Fork South Branch Potomac River, Hopeville: After

WV DOT Photo
North Fork South Branch Potomac River, Hopeville, WV, 1987

$R_c = 250 \text{ m (800 ft)}$

$R_c = 310 \text{ m (1020 ft)}$

$R_c = 330 \text{ m (1080 ft)}$

Graphics: J.S. Kite, WVU
North Fork South Branch
Potomac River,
Hopeville, WV, 1987
After Flood Mitigation

7 Upstream Meanders
Mean $R_c = 302$ m

$R_c = 135$ m
(440 ft)

$R_c = 315$ m
(1030 ft)

Photo: TerraServer-USGS
Graphics: J.S. Kite, WVU
North Fork South Branch
Potomac River, Hopeville, WV, 1987
After Flood Mitigation

7 Upstream Meanders
Mean $R_c = 302$ m

$R_c = 302$ m (990 ft)

$R_c = 315$ m (1030 ft)

Graphics: J.S. Kite, WVU
When ‘Rules of the River’ are not respected, adverse channel adjustments often result.”

(Luna Leopold, 1994)
National Interactive Forum on Geomorphic Reclamation

“Putting a New Face on Mining Reclamation”

September 12-14, 2006
Farmington Civic Center
Farmington, New Mexico

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www.ott.wrcc.osmre.gov/forums/Geomorph%20Reclamation/nifgr.htm