Today's E-mail

11:19 a.m. - KCI is looking for scientists and engineers to help us grow our offices in Maryland, Virginia, and North Carolina. Opportunities are available from entry level to senior positions. Desirable experience includes watershed planning, stormwater modeling, wetland delineation and permitting, stream assessment and mitigation design. Specific experience in fish passage, sediment transport, and natural channel design is highly desirable.

9:08 a.m. - Acer Environmental, Inc. is seeking a full-time hydrologist/water resource engineer/stream restoration designer to join our team of natural resource professionals. Acer Environmental, Inc. is a small but rapidly growing environmental consulting firm specializing in mitigation banking, wetland and stream restoration, natural resource management, permitting and land development for both private and public sectors across the southeast.

“Modern” Stream Classification

• One System Drawing Most Attention:
Stream Classification Hierarchy

- Valley Segments (may be many miles)
- Stream Reaches (~30 channel widths)
- Channel Units (~1 channel width)

After Montgomery & Buffington (1998)

Rosgen Stream Classification Criteria

- Single Channel vs. Multiple Channels
- Entrenchment Ratio
- Width/Depth Ratio
- Sinuosity
- Slope
- Bedload Texture

Rosgen Level II Classification: Cross-Sectional Delineating Criteria

Entrenchment Ratio
(Flood-prone Width / Bank-full Width)
Floodplain Width = Width @ 2 Times
Maximum Bankfull Depth

Width/Depth Ratio
(Bank-full Width/Bank-full Depth)
If You Don’t Know Bank-Full, ...
“Entrenchment” Ratio = \[ \frac{\text{Flow Width @ 2X Bank-Full Stage}}{\text{Bank-Full Width}} \]

Width-Depth Ratio

- \(~12:1~\)
- \(~20:1~\)
- \(~40:1~\)

Rosgen Level II Classification:

**Plan-Form Pattern Delineating Criteria**

**Sinuosity** (P) = 

\[(\text{Stream Length} / \text{Valley Length})\]

**Meander-Width Ratio** = 

\[(\text{Meander Belt Width} / \text{Bank-Full Channel Width})\]
**Sinuosity** = \( P = \frac{\text{River Distance Along Thalweg}}{\text{Straight-Line Distance}} \)

<table>
<thead>
<tr>
<th>Sinuosity ( P )</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>

**Radius of Curvature**

**Meander Belt Width**

**Rosgen Stream Classification, Fig 5-3**

http://www.r6.fws.gov/pfw/images/Class2.gif

Review: Concept of Graded Stream

Unpaired Stream Terraces:

Paired Stream Terraces:
Strath =
Erosional (Unpaired) Terraces

Depositional (Paired) Terraces

Slip-Off Terrace
Erosion with Slight Downward Component
Deposition = Accretion
Maximum Turbulence
Valley Type Classification
Thornbury, 1969

- Antecedent (Predates Structures)
- Superposed (Super-imposed)
- Consequent (Flows Down Bedding Dip)
  vs. Obsequent (Flows Opposite Dip)
- Subsequent (Eroded into Weak Rocks)

THEORIES OF LANDSCAPE DEVELOPMENT
(after Higgins, 1975)

3 Theories

W.M. Davis: Geomorphic Cycle
W. Penck: Parallel Slope Retreat
J.T. Hack: Dynamic Equilibrium
Davis: First Systematic, Genetic Landscape Classification on a Descriptive Basis

Normal Cycle (≈ Fluvial Cycle)
Rapid Uplift of Landscape, Followed by Prolonged Tectonic Stillstand
Landscapes Reflect Process & Time Stages:
  Youth - Maturity - Old Age

YOUTH: Dominated by Vertical Erosion and Ungraded Streams

1. Numerous Short, Straight Tributaries and Gullies Extending Headward.
2. V-Shaped Cross Profile
3. Poorly Developed Floodplain
4. Broad, Poorly Drained Interfluves
5. Falls and Rapids at Crossing of Resistant Rocks
6. Few Meanders

Black Canyon of the Gunnison, Colorado
MATURITY:

1. Well-Integrated Drainage
2. Some Structural Control of Tributaries
3. Sharp, Well-Drained Interfluves
4. Waterfalls & Lakes Obliterated
5. Floodplains Considerable, with Shifting Meanders
6. Valley Floor Width = Meander Belt Width
7. Most of Landscape in Slope

OLD AGE:

Lateral Erosion Dominant, Stream Graded near Base Level, Little Erosion
1. Valleys Broader than Meander Belt
2. Large Floodplains with Broadly Meandering Streams, Flood Basin, Swamps, etc.
3. Low Hills, Low Valley Slopes
4. Effect of Lithology Obscure
5. Extensive Areas at, or Near, Base Level: Peneplain (Truncates Structure) - Monadnock (Resistant Bedrock Knob)
Old Age

REJUVENATION

Large Meanders Juxtaposed with Deep V-Shaped Valleys

*Interpretation:*
Development of Peneplain
Subsequent Uplift
Do Davis’s Concepts Make Sense?

• Sure!
Geology: Epeirogeny

- Continental-Wide Erosion Episodes in Geological Record.
- North American Craton 6 Major Unconformities in Last 600 My.
- Base of Sauk - Tippecanoe - Kaskasia - Absaroka - Zuni - Tejas Sequences
- Continent "Highstands"- Correlate with Low Sea-Floor Spread Rates & Deep Ocean-Basin Geometry

Peneplain Tracing Worldwide: 1899-1950

Dr. Harry M. Fridley, arrived WVU 1931
Projected Profiles (1;62,500)
Accordant Surfaces
Fridley’s 2 Peneplains in This Area
Kittatinny (Schooley)
Allegheny
Problems: Better Topo Maps Show Surfaces are Not Accordant?

Blackwater Canyon - Youth
Why Were Davis's Ideas Successful?

• Simple and Filled a Void.

Davis's Lasting Contributions

• Landforms Change in an Orderly Manner as Fluvial Processes Operate Through Time.

• Under Uniform Conditions, Orderly Sequences of Landforms Develop.

Walther PENCK

"Die Morphologiche Analyse"

1924

- Translated by L.C. King.
PENCK

- Long Continued Crustal Movement
- Parallel Slope Retreat
  - Retreating Fluvial Knickpoints
  - Graded Slopes.

Canyonlands National Park

Arches National Park, Utah

Walther PENCK

Long Lasting Tectonics
Parallel Slope Retreat
Retreating Knickpoints
Graded Slopes.
John T. HACK
(1965)

Dynamic Equilibrium Concept:
Much Inherited from Gilbert (1880s) &
Strahler (Columbia School of 1950s).
Hack: Landforms Part of an Open
System Tending to Steady-State
Equilibrium.

Hack’s Assumptions:
Balance Between Erosion & Rock
Resistance
All Landscape Elements Down-
waste at the Same Rate
Form Is Explainable in Terms of
Bedrock Geology:
“Accordant Summits” Have
Similar Structure and Lithology.

MacDonald
Range, Australia
Hack’s “Sequence”

- Short Early Ungraded Episode
- Long Period of Uniform Downwasting of Steady-State Landforms…

Where Does Each Landscape Evolution Model Fit Best?

**Davis:**
Cratons & Tectonic Landscapes

*Not* Rivers & Valleys of Appalachians
Where He Came Up with Concepts.

Black Sea Coast near Varna, Bulgaria
Where Does Each Model Fit Best?

Penck:

Arid & Semiarid Landscapes.
Where Does Each Model Fit Best?

Hack:

Erosional Landscapes with Varied Rock Types
Rivers and Valleys of Appalachians.
Armoring of Hollows

Topographic Inversion
W-Shaped Hollows

Gully Gravure (Bryan, 1940)
Paleohydrology & Paleoflood Hydrology

*See 2001 Lecture for more slides*
Prediction from Geomorphology & Holocene Stratigraphy

Deposits
- Slackwater: Stage
- Bedload: Tractive Force, Stream Power

Paleosols
- Interruption of Stability

Landforms
- Slackwater Terraces

Tool Kits for the Paleohydrologist

- Vegetation Along Stream
- Proxy Records, e.g. Tree Rings
- Bedload Competence
- Channel Geometry: Plan and Cross-Section
- Slackwater Deposits: Bath-Tub Rings

Tractive Load Size

- How to determine what moved.
- Flake scars bruises on sheltered surfaces, multiple impact marks, Fe staining (Cheat), imbricated w/tires, plastics, lumber, etc., aerial photography (BFR)

\[ \tau = \gamma D S \]
\[ \gamma = \text{gamma} = \text{specific weight of water} \]
\[ D = \text{depth} \]
\[ S = \text{gradient (slope)} \]

**Critical Tractive Force =**

\[ \tau_c = \gamma D S \]

\[ d = \text{grain diameter (mm)} \]

**Critical Tractive Force: Force Required to Move Particle of diameter = d**

\[
\begin{align*}
D &= 0.0001 A^{1.21} S^{-0.57} \quad \text{(Knox, 1987)} \\
V &= 0.065 d^{0.5} \quad \text{(Williams, 1983)} \\
V_c &= 0.18 d^{0.44} \quad \text{(Koster, 1978)} \\
V_c &= 0.18 d^{0.49} \quad \text{(Costa, 1983)} \\
Q_{1.5} &= 0.011 L_m^{1.54} \quad \text{(Williams, 1983)} \\
\lambda_m &= 166 Q_m^{0.46} \quad \text{(Carlston, 1965)} \\
\tau &= 0.030 d^{1.49} \quad \text{(Williams, 1983)} \\
\tau &= 0.17 d \quad \text{(Williams, 1983)} \\
(\omega) &= 0.079 d^{1.29} \quad \text{(Williams, 1983)}
\end{align*}
\]
A  = intermediate axis of largest clasts, mm
\(d\)  = particle diameter, mm
\(D\)  = competent flow depth, m
\(\lambda_m\)  = meander wavelength, m
\(Q_{1.5}\)  = discharge of 1.5 yr flood, m\(^3\)/s
\(Q_m\)  = mean annual discharge, m\(^3\)/s
\(S\)  = energy slope (approx. = topo. gradient), m/m
\(V\)  = mean flow velocity, m/s
\(V_c\)  = threshold (critical) flow velocity, m/s
\(\tau_c\)  = threshold (critical) tractive force, N/m
\(\tau\)  = bed shear stress, N/m
\(\omega\)  = stream power/m of width, watts/m\(^2\)

Floods & Quaternary Stratigraphy
Arid Streams (Most Sensitive: Most Studied)
"Pluvials" Wet Episodes (≈ "Glacials")
Vegetation Cover Critical
Holocene Arroyo-Cutting and Filling
Under Drought:
Hyper-Arid: Loss of Channel Vegetation
Promotes Erosion of Channel
Semi-Arid: Loss of Slope Vegetation
Promotes Erosion of Slopes + Filling of Channels

Dendrohydrology
Datable Flood Scar

Symbols (Williams, 1984)
The Arroyo Problem in the Southwestern United States

Brandon J. Vogt
U.S. Geological Survey

http://geochange.er.usgs.gov/sw/impacts/geology/arroyos/

Tucson 1940

Tucson 1982
Precipitation Style & Floods

Convectional Thunderstorms: Favored by Hot Air Masses (Drought?)

Hurricanes: Favored by Warm SST & ITC North of Equator. Requirements Not Met in No. Hemisphere During "Glacials"

Frontal Precip: Driven By Energy of System (Increases w/ Warmer Oceans), But Circulation Pattern Is Locally More Important

Snow-Melt: Favored by Longer Winters, but Not If It Gets Too Cold (= Too Dry)

Floods & Quaternary Stratigraphy in Eastern US

Convectional Thunderstorms: Favor Debris Flows, Erosion of Gullies & Small Channels; Inefficient Middle to Large Streams

Hurricanes: Favor Debris Flows, Efficient Sed Transport on Small to Middle Streams

Frontal Precip: Efficient Sed Transport in Middle to Large Streams. Low Rainfall Intensity Limits Sediment Delivery by Small Streams

Snow-Melt: Freeze-Thaw Produces Lots of Sediment on Slopes, Inefficient Transport by Small Streams, Erosion by Large Rivers
Quaternary Fluvial Stratigraphy in Eastern US
Complicated by Base-Level Fluctuations

Sea-Level Changes (Drop w/ Glaciation)
e.g. Unglaciated Potomac, James basins

Local Basel Level (Rise w/ Outwash Aggradation) e.g. Glaciated Ohio, Allegheny River & Tribs

Quaternary Fluvial Stratigraphy in Eastern US

Where & When Are Base-Level Fluctuations More Important Than Climate-Driven Sediment Supply?

Unglaciated Rivers in Ohio River Basin (Kanawha, Mon, etc.):
Ohio River Outwash Aggradation vs. Upland Sediment Flux (Local Slopes + Tribs)