“It is hard to imagine that a transport estimate made in the absence of a sound understanding of watershed history and dynamics would be of much use at all.”
Great diversity in channels and watersheds...

G. Parker. Fly River, Papua New Guinea.

J. Imran. Brahmaputra River, Bangladesh.

A. Alabyan and A. Sidorchuk. Siberia
...emerging from complex interactions

Wheaton et al., 2011
Is your river ‘messed up’? How and why?
Have hydrology and/or sediment supply ‘changed’ substantially over time?

- 1915: Irrigation releases from Strawberry Tunnel begin
- 1952: Flood of record – 1510 cfs
- 1983-1984: Large magnitude floods, rivaling 1952
- 1997: Irrigation releases delivered from Syar Tunnel Outlet
- 2004: Mandated minimum flows implemented
- 2011: Largest flood since 2004

Graph A: Average daily discharge (cfs)
- 1908-1915
- 1915-2003
- 2004-2017

Graph B: Percent time exceeded
- 1908-1915
- 1915-2003
- 2004-2017

Map: Upper Diamond Fork and Sixth Water Creek, Upper Diamond Fork, Lower Diamond Fork, Sixth Water Creek, active landslide, inactive landslide, alluvium, conglomerate, dacite, glacial drift, limestone, mixed clastic, mudstone, sandstone, shale, siltstone.
How *much* and what *type* of sediment is being delivered to this channel?

What information do you need to answer those questions?

Is sediment supply a BIG number or SMALL number?
Interception Storage
Surface Storage
Unsaturated Zone Storage
Saturated Zone Groundwater Storage
Channel Storage

Atmospheric Moisture

transpiration
evaporation
stemflow, canopy drip
infiltration
percolation
plant uptake
rain, snow, condensation
sub-surface runoff
surface runoff
seepage
outlet

Hydrology matters...
Land use matters...
Soils, surficial and bedrock geology matter...
Storage matters...

Natural and human-caused ‘legacy effects’

Sediment transport through watersheds is complicated
Grain size matters

Figure 7.1. Categories of transported materials in a stream
Sediment type and grain size fractionation matter...
Coarse and fine load often have different sources/transport paths

Floodplains preserve old channel deposits + overbank

Banks and levees made of suspended load

Bed and lower point bars made of bed material load
Sediment type and grain size fractionation matter...

Coarse and fine load often have different sources/transport paths

All else held constant, aggradation on the bed causes...
Sediment type and grain size fractionation matter...
Coarse and fine load often have different sources/transport paths.

All else held constant, aggradation on the floodplain...

So while the sources may be independent, effects on channel morphology and hydraulics are linked.
A few key messages up front…

In many cases, all that is needed/feasible is to know if supply is a big # or small #

Lots of useful info can be gleaned from channel behavior, morphology and bed characteristics

Sometimes you need numbers, but good numbers don’t come easy
   Spatial and temporal variability over wide range of scales, Interactions of many non-linear processes

   Develop conceptual model of sources, sinks, connectivity…

   …then measure/model key rates

Multiple independent and semi-redundant estimates often needed

May need to know locations, mechanisms, and rates of erosion and deposition
   Size matters…boulders, cobbles, gravel, sand, mud play distinct roles
   Models can be useful and/or misleading
   Examine and consider implications of hydrologic non-stationarity
   Many new tools available, none are comprehensive or bullet-proof
Roadmap

**TODAY’S TOPICS**

- Forget rates. What can we learn from basic form-process relationships?

- Basic Reconnaissance
  - With a tight budget, what do you really need to know?

- A bit of hydrology
  - Targeted modeling and metrics. Stationarity Assumption?

- Push-button Geomorphology
  - The geek approach. What computer models can and can’t tell you.

**TOMORROW**

- Basin-average erosion rates: The cosmo method
  - Millennial-scale landscape rates of erosion.

- Reservoir and pond sedimentation rates
  - Time- and space-integrated measurements that may be useful.

- Watershed Sediment Budget
  - Tools and techniques for robust constraints on sources and sinks.
How would you describe these channels?
Insightful books for watershed analysis and stream restoration

Methods in Stream Ecology

Valley Segments, Reaches, and Channel Units

Peter A. Bisson*, John M. Buffington†, and

River Management
Applications of the River Styles Framework

Sediment Budgets as an Organizing Framework in Fluvial Geomorphology

LESLIE M. REID¹ AND THOMAS DUNNE²
¹USDA Forest Service Pacific Southwest Research Station, Arcata, CA, USA
²Donald Bren School of Environmental Science and Management and Department of Geological Sciences, University of California, CA, USA
Stages of a River Styles Assessment

Stage 1  Data Compilation (description and mapping)
  • Derive watershed boundary conditions
  • Determine landscape units
  • Assess river character

Stage 2  Data Analysis
  • Define and interpret River Styles
  • Explain contemporary character/behavior
  • Assess river history

Stage 3  Predict future river structure

Stage 4  Prioritize watershed management issues

Stage 5  Identify target conditions for river
River Styles Hierarchy

- **Watershed**
  - Watershed area determined by drainage divide. Determines the boundary conditions within which rivers operate.

- **Landscape Unit**
  - Topographic unit determined on the basis of local relief, valley slope and morphology. Defines the valley-setting.

- **River Style**
  - Length of channel with a characteristic assemblage of geomorphic units.

- **Geomorphologic Unit**
  - Instream and floodplain landforms (pools, bars, levees, backwaters, etc.) that reflect distinct form-process associations.

- **Hydraulic Unit**
  - Uniform patches of flow and substrate material within a geomorphic unit.

- **Microhabitat**
  - Individual elements (e.g., logs, rocks, gravel patches) within a stream.
Time & Space scales of change are linked

Modified from Montgomery, 2004
Many other classification schemes out there

**TABLE 1 | Temporal Change Is Investigated at Different Spatial Scales**

<table>
<thead>
<tr>
<th>Spatial Scale</th>
<th>Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Catchment</td>
<td>Land cover/land use (LCLU)</td>
</tr>
<tr>
<td></td>
<td>Land topography</td>
</tr>
<tr>
<td>Landscape unit</td>
<td>LCLU and sediment production</td>
</tr>
<tr>
<td></td>
<td>Land topography and sediment production</td>
</tr>
<tr>
<td></td>
<td>Rainfall and groundwater</td>
</tr>
<tr>
<td>Segment</td>
<td>Valley setting</td>
</tr>
<tr>
<td></td>
<td>Channel gradient</td>
</tr>
<tr>
<td></td>
<td>River flows and levels</td>
</tr>
<tr>
<td></td>
<td>Sediment delivery</td>
</tr>
<tr>
<td>Reach</td>
<td>Riparian corridor and wood production</td>
</tr>
<tr>
<td></td>
<td>Channel planform, migration, and features</td>
</tr>
<tr>
<td></td>
<td>Channel geometry</td>
</tr>
<tr>
<td></td>
<td>Sediment transport</td>
</tr>
<tr>
<td></td>
<td>Riparian vegetation, aquatic vegetation, wood</td>
</tr>
</tbody>
</table>

Grabowski et al. 2014
Many other classification schemes out there

Montgomery and Buffington, 1997

Channel-reach morphology in mountain drainage basins

<table>
<thead>
<tr>
<th>Table 1. Diagnostic Features of Each Channel Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dune ripple</td>
</tr>
<tr>
<td>---</td>
</tr>
<tr>
<td>Typical bed material</td>
</tr>
<tr>
<td>Bedform pattern</td>
</tr>
<tr>
<td>Dominant roughness elements</td>
</tr>
<tr>
<td>Dominant sediment sources</td>
</tr>
<tr>
<td>Sediment storage elements</td>
</tr>
<tr>
<td>Typical confinement</td>
</tr>
<tr>
<td>Typical pool spacing (channel widths)</td>
</tr>
</tbody>
</table>
What are the different parts of the watershed? Which detachment, transport, deposition processes are occurring where?
How well connected is the system?
Where are complete or partial barriers?
How has/might connectivity change?

see Fryirs et al., 2007
What are the different parts of the river network?

River Styles™ tree developed for NSW, Australia

You decide how to divide up the river network!

Brierley et al., 2002
Visual representation of NSW River Styles

These are each different ‘process domains’

Different ecological functions hydro-geomorphic processes sensitivities to change potential for recovery
Begin to classify channel network with these primary gradients...

Valley confinement

River longitudinal profile

Flow accumulation
Valley confinement

Confined

Partially Confined

Unconfined
Downstream gradients in a textbook river

Imposed boundary conditions
- Landscape unit: mountains, foothills, alluvial plain
- Valley confinement
- Valley setting: confined, partly-confined, laterally-unconfined

Flux boundary conditions
- Process zone: source, transfer, accumulation
- Sediment transport regime: bedload, mixed load, suspended load
- River type: steep headwater, partly-confined valley with planform-controlled discontinuous floodplain, braided, anastamosing
Downstream gradients in an escarpment river
Second tier characteristics for classification
Indicators of channel behavior

- Assemblage of geomorphic units that make up a reach
- Channel planform
- Bed material texture
<table>
<thead>
<tr>
<th>Unit</th>
<th>Form</th>
<th>Process Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bedrock step (waterfall)</td>
<td>Locally resistant bedrock that forms channel-wide drops. Transverse waterfalls &gt; 1 m high separate a backwater pool from a plunge pool downstream.</td>
<td>Erosional features formed and maintained as turbulent flow falls nearly vertically over the lip of the step. Steps are major elements of energy dissipation. These locally resistant areas may represent headward-migrating knickpoints. Equivalent features may be forced by woody debris.</td>
</tr>
<tr>
<td>Rapid</td>
<td>Very stable, steep, stair-like sequences formed by arrangements of boulders in irregular transverse ribs that partially or fully span the channel in bedrock-confined settings. Rapids in bedrock channels may be analogous with riffles in alluvial systems. Individual particles break the water surface at low flow stage.</td>
<td>Boulders are structurally realigned during high energy events to form stable transverse ribs that are associated with neither divergent nor convergent flow. Typically, 35–50% of the stream demonstrates supercritical flow.</td>
</tr>
<tr>
<td>Cascade</td>
<td>Very stable, coarse-grained or bedrock features observed in steep, bedrock-confined settings. Comprise longitudinally and laterally disorganized bed material, typically cobbles and boulders. Flow cascades over large boulders in a series of short steps about one clast diameter high, separated by areas of more tranquil flow of less than one channel width in extent.</td>
<td>More than 50% of the stream area is characterized by supercritical flow. Typically associated with some downstream convergence of flow. Near-continuous tumbling/turbulent and jet-and-wake flow over and around large clasts contributes to energy dissipation. Finer gravels can be stored behind larger materials or woody debris. During moderate flow events, finer bedload materials are transported over the more stable clasts that remain immobile. Local reworking may occur in high magnitude, low frequency events.</td>
</tr>
<tr>
<td>Run (glide, plane-bed)</td>
<td>Stretches of uniform and relatively featureless bed, comprising bedrock or coarse clasts (cobble or gravel). These smooth flow zones are either free-flowing or imposed shallow channel-like features that connect pools. They may occur in either alluvial or bedrock-imposed situations. Individual boulders may protrude through otherwise uniform flow.</td>
<td>Plane-bed conditions promote relatively smooth conveyance of water and sediment in these linking features. Slopes are intermediate between pools and riffles.</td>
</tr>
</tbody>
</table>
Metrics of channel planform

(a) Number of channels
- Single
- Up to 3 (wandering)
- > 3 (braided)
- > 3 (anastomosing / anabranching)
- Discontinuous or absent

(b) Sinuosity
- Degrees of sinuosity
  - 1 - 1.05 (straight)
  - 1.06 - 1.30 (low sinuosity)
  - 1.31 - 3.0 (sinuous / meandering)
- Types of sinuosity
  - Sinuous
  - Irregular meanders (passive)
  - Regular meanders
  - Tortuous meanders
  - Confined pattern

(c) Lateral stability
- Meander growth and shift
  - Extension / increasing amplitude
  - Translation / downstream progression
  - Rotation
  - Neck cutoffs
- Degree of braiding
  - < 5%
  - 5 - 34%
  - 35 - 65%
  - > 65%
- Character of braiding
  - Mostly bars
  - Bars and islands
  - Mostly islands
  - Diverse shape
  - Mostly islands
  - Long and narrow

Avulsive behavior
- 1st order avulsion
- Wholesale shift
- Regular meanders
- 2nd order avulsion
- Reoccupation
- Tortuous meanders
- 3rd order avulsion
- Thalweg shift
Interpretations from channel planform

Kleinhans, 2010
Channel adjustment in different valley settings

<table>
<thead>
<tr>
<th>Valley setting</th>
<th>Bed character</th>
<th>Channel morphology</th>
<th>Channel planform</th>
<th>Natural capacity for adjustment (band width) and river sensitivity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Confined</td>
<td>Grain size, sorting, and hydraulic diversity are constrained by bedrock, restricting adjustments to local reworking of transient bedload fluxes.</td>
<td>Channel size, shape, and bank morphology are imposed by bedrock or ancient materials. Bank erosion is negligible. Local slope and forcing elements such as woody debris induce the pattern of geomorphic units, such as the spacing of step-pool sequences.</td>
<td>No potential to adjust the number of channels, sinuosity, or lateral stability. Geomorphic units are largely imposed forms. Riparian vegetation is not a significant control on geomorphic structure.</td>
<td>Limited (narrow band) Resilient</td>
</tr>
<tr>
<td>Partly-confined</td>
<td>Bed often constrained by bedrock. Gravel-bed rivers have well-segregated point bars, riffles, etc. that induce significant hydraulic diversity. Surface–subsurface textural variability may be significant. Bed adjustments are dependent on material availability and the history of bedload transporting events.</td>
<td>Channel width and shape are adjustable where floodplain pockets occur; otherwise they are constrained by bedrock or ancient materials along the valley margins. Bank erosion is restricted to areas where floodplain pockets occur. Instream geomorphic units adjust locally where space permits.</td>
<td>Local potential for lateral or downstream translation of bends, but largely constrained by bedrock. Floodplain pockets may be prone to scour, stripping, and reformation. Adjustments are restricted to areas where floodplain pockets occur.</td>
<td>Localized (relatively narrow band) Moderately resilient</td>
</tr>
<tr>
<td>Laterally-unconfined, high-energy with continuous channel(s)</td>
<td>Grain size, sorting, and hydraulic diversity may be constrained by coarse sediments that arm of the bed. Transient bedload fluxes induce significant local adjustments. When adjustment occurs, it tends to be dramatic, as it is driven by infrequent, high magnitude events.</td>
<td>Channel size and shape can adjust laterally and vertically over the valley floor. Moderate potential for bank erosion. Largely bedload dominated geomorphic units.</td>
<td>Significant potential for adjustment to the number, sinuosity, and lateral stability of channels. May be considerable variability in floodplain geomorphic units, with significant potential for floodplain reworking.</td>
<td>Moderately significant (moderately wide band) Moderately sensitive</td>
</tr>
<tr>
<td>Channel setting</td>
<td>Channel size and shape</td>
<td>Channel size and shape</td>
<td>Channel size and shape</td>
<td>Channel size and shape</td>
</tr>
<tr>
<td>---------------------------------------</td>
<td>------------------------</td>
<td>------------------------</td>
<td>------------------------</td>
<td>------------------------</td>
</tr>
<tr>
<td>Laterally-unconstrained, medium-energy with continuous channel(s)</td>
<td>Mobile bed is subject to recurrent shifts in character, composition, and hydraulic diversity as channel geometry and planform adjust. Surface subsurface variability may be significant.</td>
<td>Channel size and shape can adjust laterally and vertically over the valley floor in these mixed load systems. Significance potential for bank erosion. Riparian vegetation and woody debris may be significant controls on channel shape and geomorphic units. High potential for reworking of erosional and depositional geomorphic units.</td>
<td>Significant potential for adjustment to the number, sinuosity, and lateral stability of channels. Floodplains are formed by vertical or lateral accretion, and reworked by various processes, resulting in a wide range of floodplain geomorphic units.</td>
<td>Very sensitive</td>
</tr>
<tr>
<td>Laterally-unconstrained, low-energy with continuous channel(s)</td>
<td>Limited hydraulic diversity with little potential to adjust, given the cohesive sediments.</td>
<td>The capacity for channel size and shape to adjust laterally and vertically is constrained by cohesive banks along these suspended load systems. Little variability in geomorphic unit assemblage given the lack of bedload material.</td>
<td>Moderate potential for adjustment to the number, sinuosity, and lateral stability of channels. Floodplains are dominated by fine-grained vertical accretion deposits. Localized reworking occurs, largely by avulsion. Little variability in floodplain geomorphic units.</td>
<td>Localized (relatively narrow band) Moderately resilient</td>
</tr>
<tr>
<td>Laterally-unconstrained, low-energy with bedrock-based continuous channel(s)</td>
<td>Limited variability as a thin veneer of bedload material adjusts over the bedrock channel bed.</td>
<td>Imposed bed condition. Potential for bank erosion and adjustments to channel geometry are dependent upon floodplain composition and channel alignment. Suspended load systems have limited capacity to adjust their form.</td>
<td>Highly variable, dependent upon planform type. Suspended load systems are prone to avulsion, but have limited capacity to modify the array of geomorphic units given their limited bedload.</td>
<td>Localized (relatively narrow band) Moderately resilient.</td>
</tr>
<tr>
<td>Laterally-unconstrained, low-energy with discontinuous channels</td>
<td>Valley floor texture dependent on sediment supply. Hydraulic diversity is low. Potential for sediment lobe deposition in swamps and floodouts.</td>
<td>Channels absent or discontinuous. Vegetation can induce significant resistance.</td>
<td>Relatively simple geomorphic structure with little potential for adjustment. However, headcuts may impose dramatic adjustments to river morphology.</td>
<td>Limited (relatively narrow band) Moderately resilient (in this state), but very sensitive if subjected to incision.</td>
</tr>
</tbody>
</table>

Limited adjustment potential (resilient)

Localized adjustment potential (moderately resilient)

Significant adjustment potential (sensitive)
Modes of adjustment vary considerably for different river types

<table>
<thead>
<tr>
<th>Channel type</th>
<th>Grain size</th>
<th>Width &amp; depth</th>
<th>Bedforms</th>
<th>Stream gradient (sinuosity/elevation)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Colluvial</td>
<td>p</td>
<td>p</td>
<td>–</td>
<td>–/p&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>Bedrock</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–/–</td>
</tr>
<tr>
<td>Cascade</td>
<td>p</td>
<td>–</td>
<td>–</td>
<td>–/–</td>
</tr>
<tr>
<td>Step-pool</td>
<td>p</td>
<td>–/p&lt;sup&gt;d&lt;/sup&gt;</td>
<td>p</td>
<td>–/p</td>
</tr>
<tr>
<td>Plane-bed</td>
<td>+</td>
<td>p/+</td>
<td>–</td>
<td>–/p</td>
</tr>
<tr>
<td>Braided</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+/+</td>
</tr>
<tr>
<td>Pool-riffle</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+/+</td>
</tr>
<tr>
<td>Dune-ripple</td>
<td>p</td>
<td>+</td>
<td>+</td>
<td>+/+</td>
</tr>
</tbody>
</table>

<sup>a</sup> Modified from Montgomery and Buffington (1997). Response potential for each channel type is discussed elsewhere (Montgomery and Buffington, 1997; 1998; Buffington et al., 2003).

<sup>b</sup> Changes in stream gradient may occur via altered sinuosity or incision/aggradation that alter the absolute elevation change across a reach. Slashes in the table distinguish these two responses.

<sup>c</sup> Fluvial incision/deposition is possible, depending on the degree of colluvial fill.

<sup>d</sup> Changes in channel depth can occur via pool fill/scour.
Armoring allows gravel bed rivers to adjust transport rates to changes in sediment supply. Trends converge (armoring is eliminated) at high sediment concentrations.
Tools for geomorphic assessments

GIS4Geomorphology
http://gis4geomorphology.com/

Topotoolbox (requires Matlab)
https://topotoolbox.wordpress.com/

UMass-Amherst: Collection of Frameworks and Protocols
http://extension.umass.edu/riversmart/fluvial-geomorphology/

USU Fluvial Habitats Center
CHaMP Protocol: Joe Wheaton, Nick Bouwes, Wally MacFarlane, Gary O’Brien etc.
http://etal.joewheaton.org/
Rapid Assessment vs Contextual Analysis

Rapid Assessments:
- Aim to be repeatable, quantitative, and representative
- Limited ability to discern cause of problems in complex systems
- Often require frequent sampling, large number of sites

Contextual Analysis:
- Aim to attain comprehensive, holistic understanding of the system
- Often difficult to quantify components
- Can guide assessments, monitoring, measurements for sed budget
Post-wildfire debris flows influence, and are influenced by, connectivity.

Twitchell Canyon Fire
September 20th, 2010
NASA Picture of the day
started by lightning strike

burned 45,000 acres

1/3 burned at high severity
~ 2 m deposition!
Predicting debris flow susceptibility

D. Bone and K. Schaffrath applied model of Cannon et al. 2010
Predicted debris flow impacts align with observations of channel change
Normalized steepness throughout the channel network.
Normalized steepness throughout the channel network
Where are the sediment transport ‘bottlenecks’?

Murphy et al., 2017, in prep
Watershed scale experiment in channel response to extreme changes in flow and sediment supply
Repeat disturbances in flow and sediment

- 1915
- 1952 flood
- 1983-1984
- 1997
- 2004
- 2011
- 2018

1952

1980s floods

Syar Tunnel

Mandated flows

2011 flood

Q

Qs
Watershed scale experiment in channel response to extreme changes in flow and sediment supply.

### Process domain, Percent confinement, Confining material, Slope (%), Substrate, Geomorphic units, Percent pool, Length (km)

- **Upper Sixth Water Canyon**
  - Percent confinement: 73
  - Confining material: Shale mudstone
  - Slope (%): 5.3
  - Substrate: Bedrock scour pools
  - Geomorphic units: Cascades
  - Percent pool: 21
  - Length (km): 2.1

- **Sixth Water Meadows**
  - Percent confinement: 30
  - Confining material: Shale mudstone, active landslide
  - Slope (%): 4.8
  - Substrate: Cobble gravel
  - Geomorphic units: Long runs broken up by beaver dams
  - Percent pool: 19
  - Length (km): 3.4

- **Lower 6th Water**
  - Percent confinement: 87%
  - Confining material: Cobble gravel
  - Slope (%): 3.1
  - Substrate: Runs, few pools and riffles
  - Geomorphic units: Cascades
  - Percent pool: 14
  - Length (km): 6.0

- **Boulder bedrock cobble gravel**
  - Percent confinement: 87%
  - Confining material: Bedrock scour pools
  - Slope (%): 4.0
  - Substrate: Cascades
  - Geomorphic units: Cascades
  - Percent pool: 35
  - Length (km): 3.0

---

**Upper 6th Water Canyon**

**6th Water Meadows: 30% confined**

**Lower 6th Water: 87% confined**
## Watershed scale experiment in channel response to changes in flow and sediment supply

### Upper 6th Water Canyon

<table>
<thead>
<tr>
<th>Process domain</th>
<th>Percent confinement</th>
<th>Confining material</th>
<th>Slope (%)</th>
<th>Substrate</th>
<th>Geomorphic units</th>
<th>Percent pool</th>
<th>Length (km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Below Confluence</td>
<td>26</td>
<td>Alluvial fans, sandstone roads</td>
<td>1.5</td>
<td>Cobble boulder, gravel, bedrock</td>
<td>Long runs pool/riffle sequences woody debris</td>
<td>N/A</td>
<td>2.9</td>
</tr>
<tr>
<td>Monks Hollow</td>
<td>33</td>
<td>Sandstone alluvial fans, roads</td>
<td>1.1</td>
<td>Cobble gravel boulder</td>
<td>Point bars pool/riffle/run sequences woody debris</td>
<td>N/A</td>
<td>3.5</td>
</tr>
</tbody>
</table>

teraces 0.92 Gravel cobble sand 14 3.4

eraces 0.69 Gravel cobble sand 15 8.1

[Box plots showing active channel width over time for different years.]

**B**

**D**
Comparison of active channel width for laterally unconfined reach in A) 1993, 2004, and 2016 and B) all years.

Comparison of active channel width for mostly confined reach for all years of record.
Reach 1

Steep hillslopes deliver sediment to low gradient valley floor.

Weak tuff and rhyolite bedrock, recent severe burn.

Example: North Fork Cable Creek, Oregon
Reach 2
Channel incised into a narrow, high-gradient valley
Channel gradient steeper, bed material coarser, less heterogeneity
Reach 3

Valley widens, well developed (and connected) floodplain

Much gravel deposition and heterogeneity in bedforms
Reach 4
Channel crosses fault and enters onto hard Columbia River Basalt
Step-pool to pool-riffle morphology
Some history on the landscape we’ll be examining this afternoon
Long profiles of EF, SF Little Bear and other drainages of the Bear River Range

Longitudinal profiles extracted with Stream Profiler Tool: geomorphtools.org
Figure from Gary O'Brien
Your assignment for this afternoon:

Work in groups of 3-4

The Logan River Watershed is being targeted for a major watershed restoration project with the goal of restoring cutthroat and brown trout habitat.

Utah DNR has requested a map illustrating the different reach types that occur along the river. This info will be used to determine which sites to prioritize for further monitoring and restoration.
Your assignment for this afternoon:

1. Obtain GIS and/or Google Earth data

2. Peruse GIS data for 30 min. Identify points/areas of interest along the channel and throughout the watershed.

3. Spend ~30 min delineating distinct reaches of the mainstem Logan River along our tour route. Split logan_mainstem_project at reach breaks and describe each reach wrt:
   1. valley confinement
   2. number of channels, sinuosity and lateral stability
   3. slope and/or discontinuities in the long profile
   4. notable sediment sources and sinks
   5. other relevant attributes

Turn in by tonight:

Shapefile or screen-shot illustrating reach breaks

<1 page document describing each reach, other key points/areas of interest, and any other observations made in the field
Reach 1 – Partly Confined Valley. Most of the channel is along the valley margin, with occasional discontinuous flood plain. The reach is transporting its supplied sediment load to maintain a stable channel; bank-full height ~ 50 cm; slope ~ 3%; bed material mixed sand/gravel/cobble with occasional boulders, D50 ~ 75 cm.

Reach 2 – Confined valley. The river traverses a narrow gorge with steep hills on both channel edges. The reach is transporting its supplied sediment load; bank-full height ~ 80-100 cm; slope ~3%; bed material mixed gravel/cobble/boulder, D50 ~ 100 cm.

Reach 3 – Partly Confined Valley. The river valley widens, and the channel meanders somewhat with a more developed floodplain; the meander and floodplain would likely be more defined if not for agricultural activity surrounding the channel. The reach is transporting its supplied sediment load; bank-full height ~ 50 cm; slope ~2%; bed material mixed sand/gravel/cobble with occasional boulders, D50 ~ 75 cm.

Reach 4 – Partly Confined Valley above Hyrum Reservoir. A steep hillside south of the channel tapers away, creating a broader valley with increased meander, extensive formation of sand/gravel bars, and some multiple channels. The reach appears to be aggrading coarse/medium gravel; bank-full height ~ 30-50 cm; slope ~ 1.5%; bed material mixed sand/gravel/cobble with occasional boulders, D50 ~ 50 cm.

Reach 5 – Unconfined Alluvial Valley below Hyrum Reservoir. The channel moves into a very broad valley with very small slope. Channel appears similar to Reach 4, with sand/gravel bars less well defined and fewer areas with multiple channels; both reductions appear somewhat related to adjacent agricultural land use. The reach appears to be aggrading medium/fine gravel; bank-full height ~ 30-50 cm; slope ~ 1%; bed material mixed sand/gravel with occasional cobble, D50 ~ 25 cm.

Reach 6 – Unconfined Alluvial Valley. It is difficult to pinpoint a single point of transition between Reach 5 and Reach 6, but as the channel moves further downstream there is a noticeable shift. Reduced