A Handful of Sediment Fallacies that Impede Ecological Restoration

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Ecological Restoration of Streams, Floodplains, and Wet Meadows

Bio vs. Geo view on sediment

- A biologist looks at the bed of an incised channel in the summer and sees there is fine sediment, and the bank is eroding.
- That's a problem, and there is the cause.

The horns of a dilemma:

- The geomorphologist knows that the narrow line of trees and the bank they are growing in will eventually erode as the channel evolves to a richer state. This inevitability gives the geomorphologist hope that the stream will improve.
- The biologist wants the already thin and minimal riparian belt conserved. And add some turbulence structures to make the bed coarser. CWA supports this perspective.

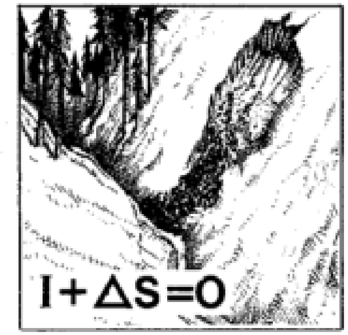
Threading the horns:

- The engineer is asked to stabilize the bank and improve habitat, do it with bioengineering methods. This gets approved and supported with a grant.
- The incised stream looks better, but is now fossilized in its ecologically poor state, at high cost.
- The geomorphologist pulls hair out. Ecosystem recovery is retarded.

Topics to critique

- Erosion vs deposition
- Pool processes and observation bias
- Equilibrium, sediment balance, channel design vs. restoration of processes
- Lack of sediment transport data, poor understanding of rates, faulty assumptions
- Process domains and restoration
- Terminology

Papers



Construction of Sediment Budgets for Drainage Basins

William E. Dietrich, Thomas Dunne, Neil F. Humphrey, and
Leslie M. Reid

$I + \Delta S = O$

I, input or erosion

O, output or net result at any point of interest

ΔS, change in storage, or deposition and erosion

Example: I + ΔS = O
Russian River near Guerneville; mean annual load is 4.5 million yd^3 (USGS 1974)

Load

- 4,500,000* yd^3/yr, or 12,330 yd^3/day

equivalent to

- 150,000 yd^3/day for 1 month
- Customary accuracy is ±10% for flow, ±20+% for suspended sediment

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Bank Erosion: 100 yd x 10 yd x 2 yd, 2000 yd^3

- 0.04% mean annual load
- 450 banks erode in one year to be theoretically detectable, well within variation
- 16 banks in one day to be theoretically detectable, on that day

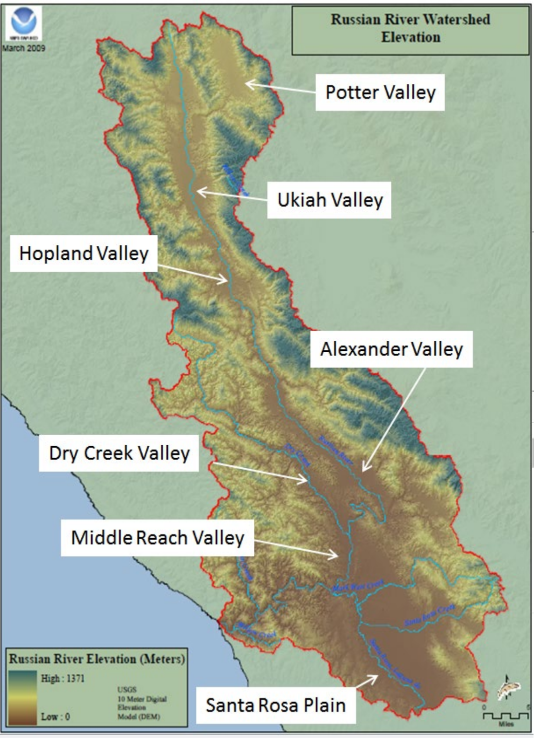
$I + \Delta S = O$

- We regulate and restore for erosion as "the problem".
- It is a symptom of land use, primarily drainage and incision, secondarily upland erosion.
- No natural deposition is the problem.

Example: for the same 2000 yd^3 bank collapse

- 120 acres of floodplain, receive and store 2000 yd^3
- accrete 1/100 ft of sediment in 1 year

Prior to the 1960's the RR Middle Valley alone had 3600 acres of connected floodplain.



Pools and observation bias

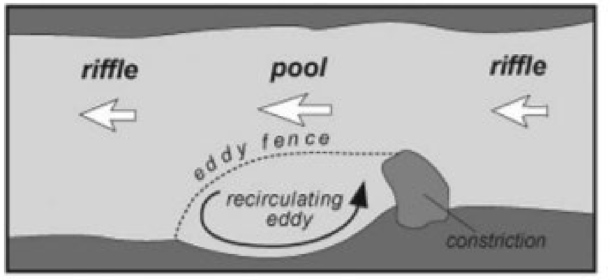


Figure 2. Schematic view of recirculating eddy-enhanced velocity reversal

- What do we examine in terms of habitat?
  - Sediment on the bed, sediment in pools.
- When do we examine channels and habitat?
  - In summer
  - Is that relevant to winter spawning, spring rearing?
  - Especially in incised channels?

Pools are deposition zones for flows less than the 'reversal' velocity (e.g. Keller 1971, Lisle 1979, Carling 1991, Thompson 2011)

- Deposition in pools during moderate to low flows is unavoidable – clearing of pools is automatic during moderately high flows [unless there is a significant sediment supply event (landslide, dam removal)]

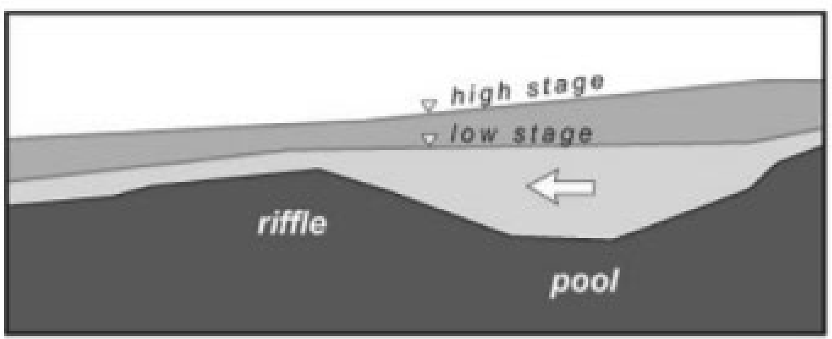
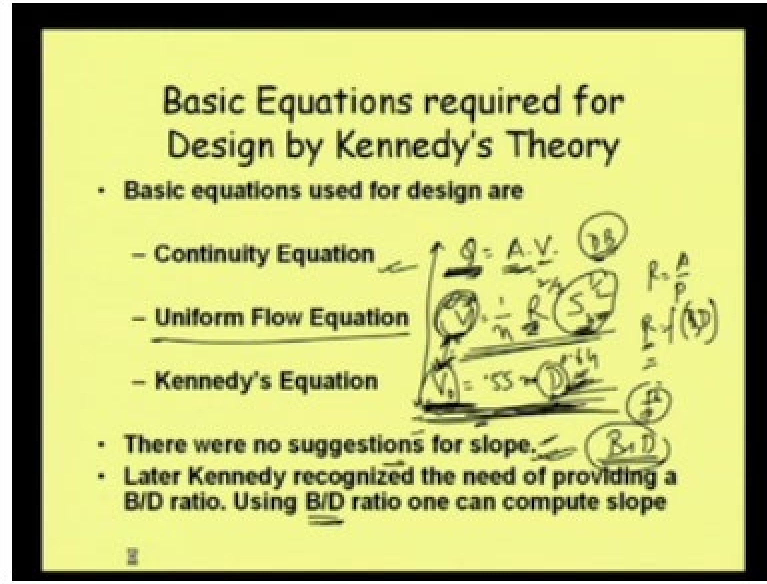


Figure 1. Hypothesized slope reversal over a pool-riffle sequence

Channel design–

Our channel design approach is founded in <u>stable irrigation canal</u> engineering devised in India by colonial British engineers in the early 1900's, "regime equations".



Advanced in the western US in 1950's by USBOR engineers for irrigation canals .

Lane and Borland balance

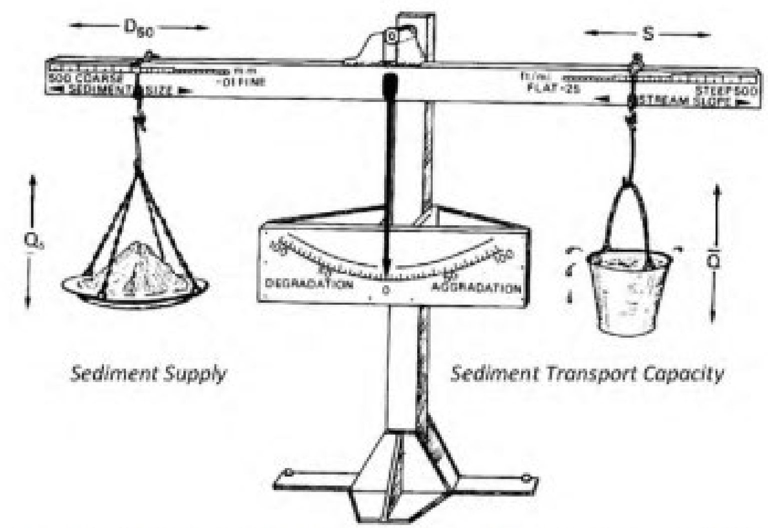


Figure 5. Lane's Balance (after E.W. Lane, from W. Borland) from *Demonstration Erosion Control Design Manual* (Watson et al., 1999) with adaptations.

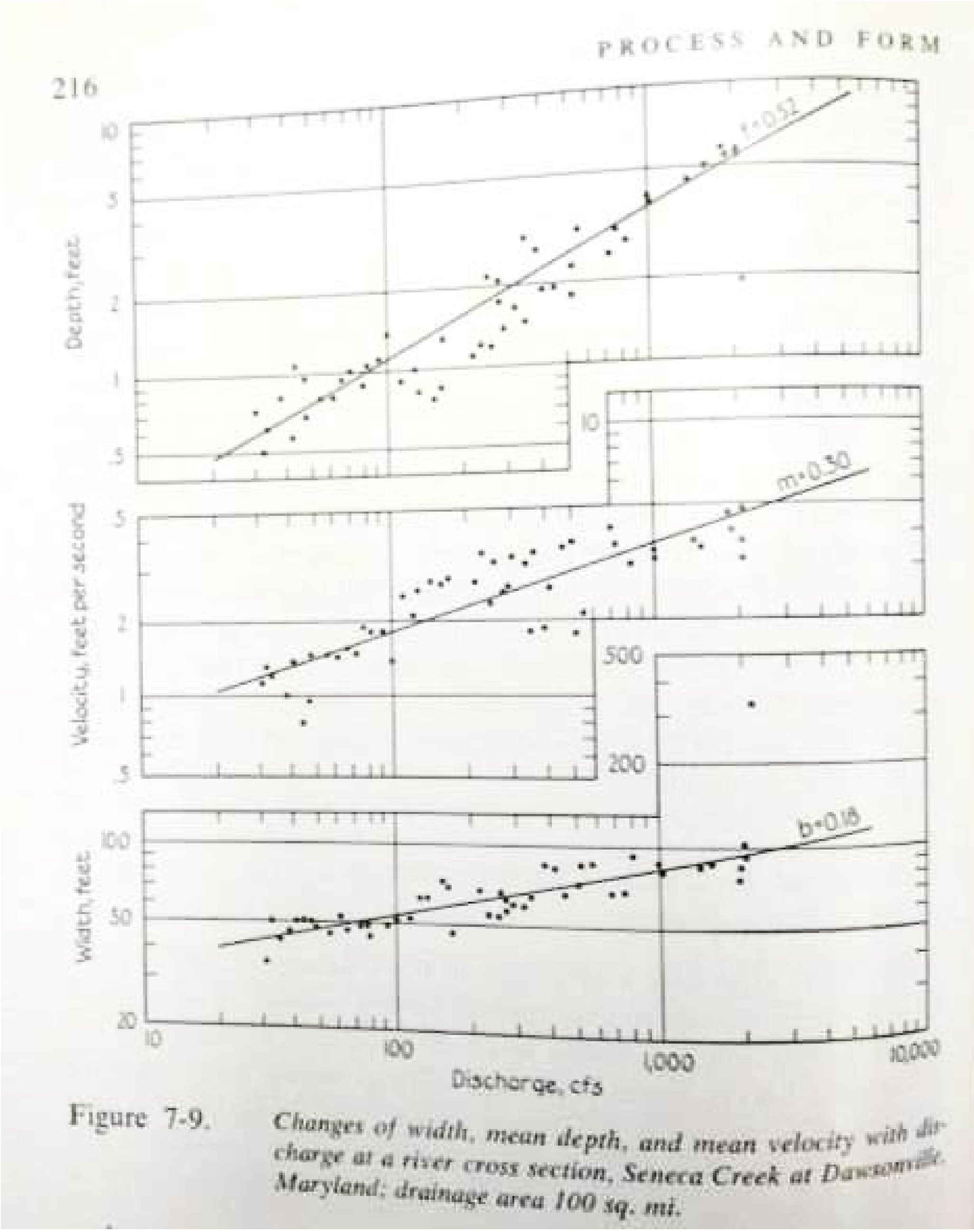
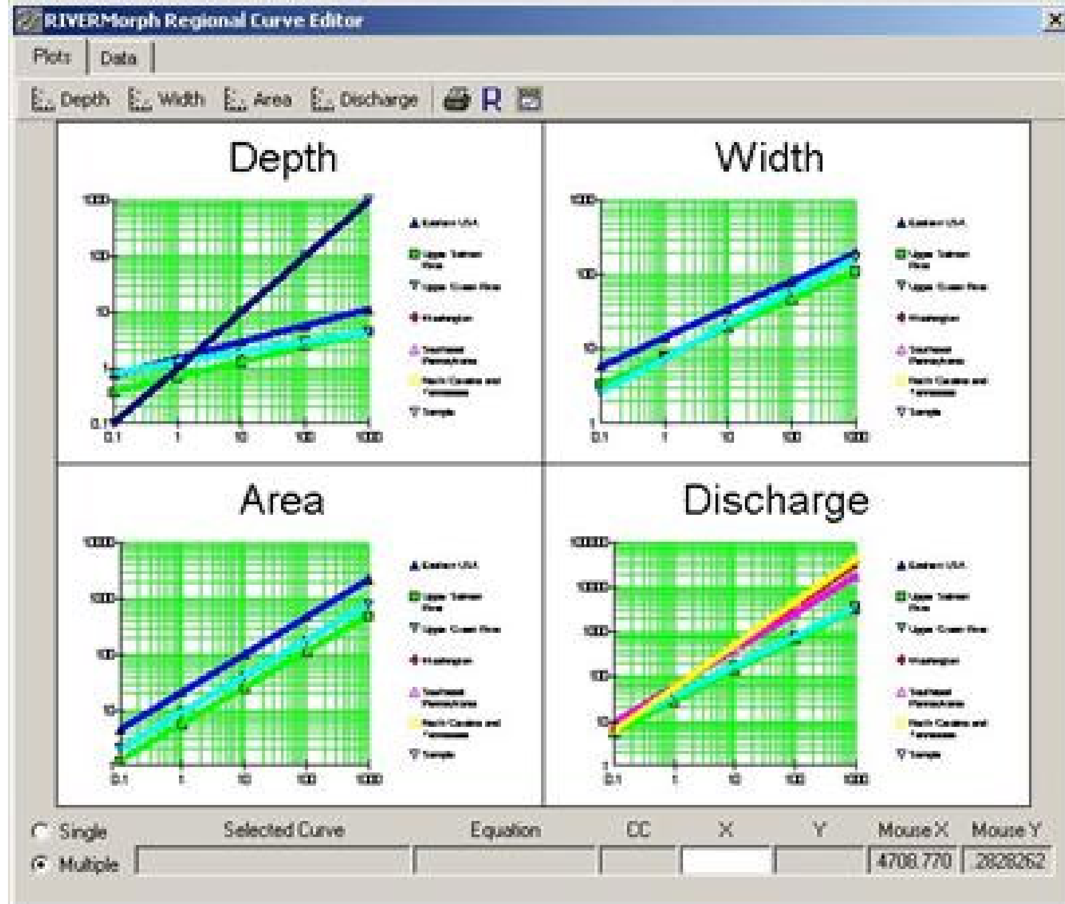


Figure 7-9. *Changes of width, mean depth, and mean velocity with discharge at a river cross section, Seneca Creek at Dawsonville, Maryland; drainage area 100 sq. mi.*

Leopold, Wolman, and Miller; 1964

- The empirical canal design relationships (discharge, slope, depth, width, and stable substrate size) found their way into geomorphology in the 1960's.
- Channel *hydraulic geometry, for "natural channels".*
- Era of *quantitative geomorphology* began.
- People developed these plots for most US regions.
- Data bias concerns:
  - from gaging stations
  - Log/log plots
- To many people, hydraulic geometry is geomorphology.
- Implicit assumption that a 'bankfull' channel is an ecosystem target.
- "Just get the channel dimensions right".

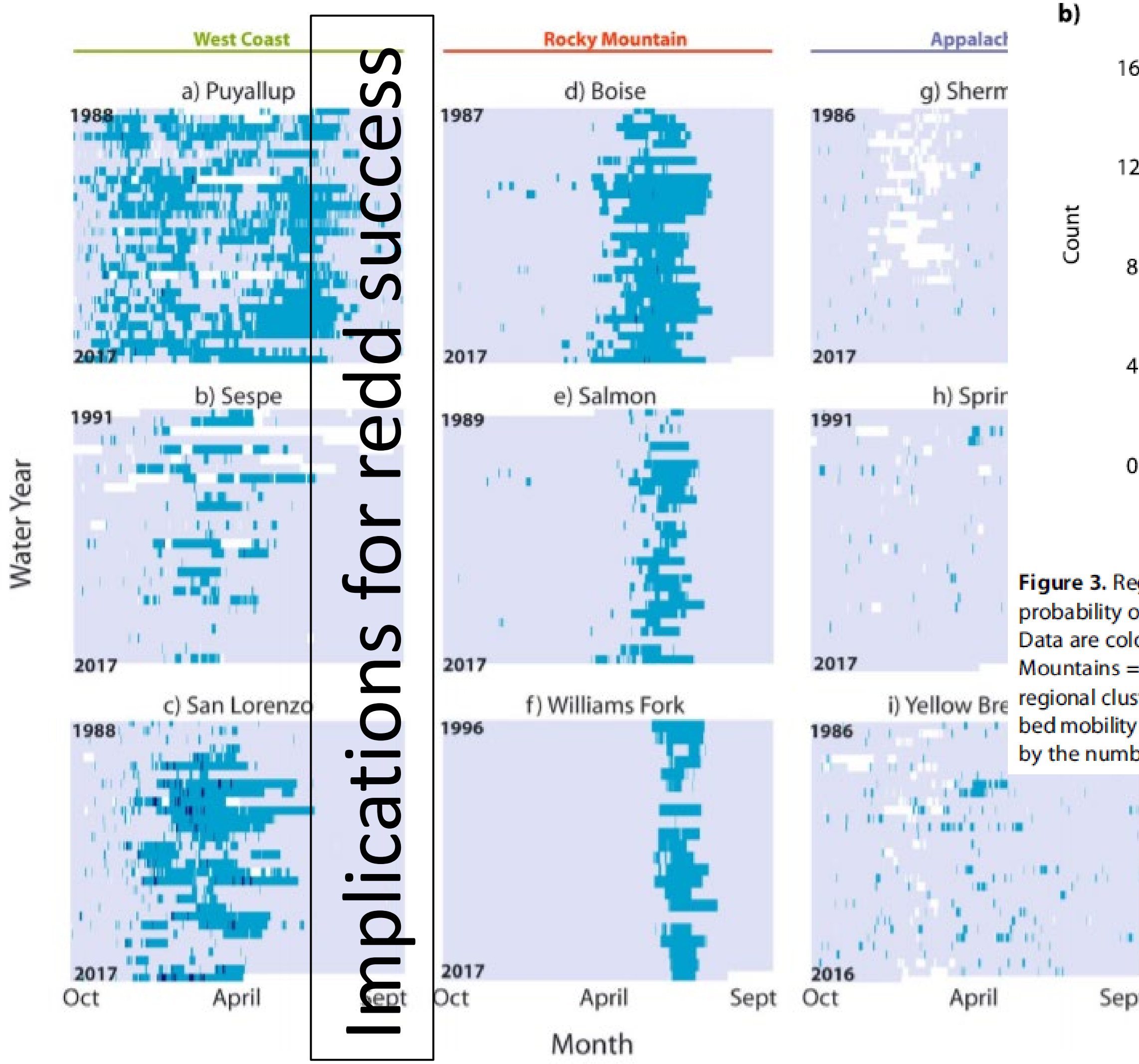
“natural channel design” and “Rosgen approach”



Problem:

- Typical 1.5-2 yr “BF” channel design flow is incised (SEM Stage 3, habitat-poor; Cluer and Thorne)
- Bed mobilized multiple times per year (Phieffer and Finnegan 2018)

Bed mobilization, channel forming flow



Implications for redd success

Figure 2. (a–i) Bed mobility intensity through time for nine example sites, three from each geographic region. Data are separated by water year. Water year is on the vertical axis, month within the water year is on the horizontal axis. Immobile bed is shown in gray, partial mobility in light blue, and full mobility in dark blue. Data gaps are shown in white.

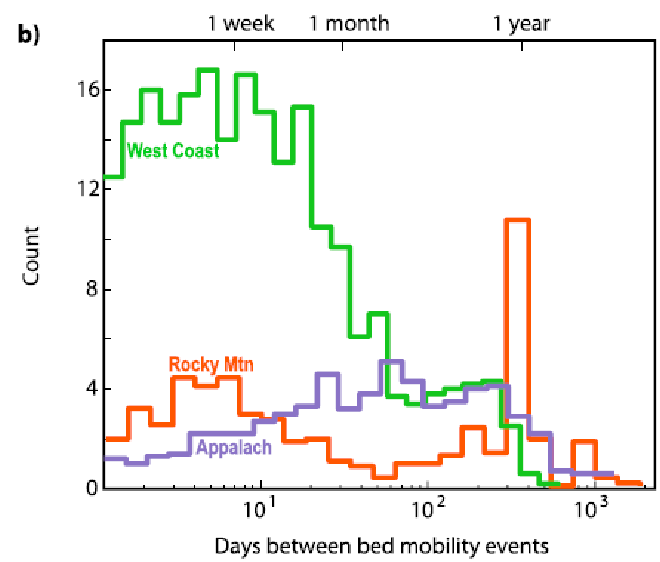


Figure 3. Regional trends in bed mobility. (a) Comparison of the exceedance probability of mobility ($W^* > 0.002$) and the maximum bed mobility. Data are colored by region: West Coast = green diamonds; Rocky Mountains = orange squares; Appalachian = purple circles. Note the strong regional clustering. (b) Histogram showing the number of days in between bed mobility events ($W^* > 0.002$), separated by region. Counts are normalized by the number of sites in that region. Colors match previous figures.

Channel design vs. restoring process

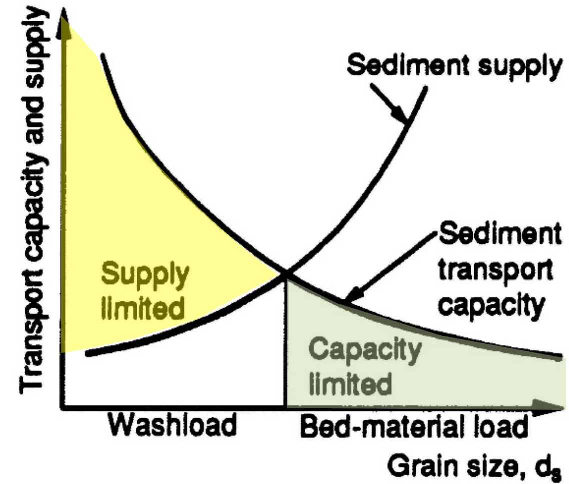
- Stable and incised 1.5-2yr RI capacity.
- Disconnected from floodplain except for a day or a few hours per year.
- Likely a very high risk configuration for juvenile salmon.
- Have you ever seen a channel restoration design, in an alluvial valley, that intended deposition?

Process domain-appropriate restoration

- Alluvial valleys are the result of deposition
- Channel restoration standard practices maintain the drains and incision
  - adds some habitat constructs
  - refrigerator sized habitat can't deliver recovery

- Significant ecosystem uplift occurs from restoring deposition and the ecological processes that follow.

Sediment: little data, less understanding



- Surprises when we create a depositional site.
  - Napa, Dry Creek, others
- Misguided restoration approaches we take when we assume there is little/no sediment.
  - Highly engineered feature elevations
  - Ponds in channels
  - These lead to unanticipated problems and "failures"

Sediment: problem or resource?

- Too much
- Too little
- Wrong size
- Wrong time
- Wrong place
- Don’t want any, can’t stand any
- Don’t think there is any

Summary: Sediment is a Resource!

- The richest habitats and ecosystem hotspots are deposition zones
- Erosion and deposition stimulate dynamics and drive successional processes
- Landscape heterogeneity supports diversity and resilience

Suggested reading:

Pfeiffer, A. M., & Finnegan, N. J. (2018). Regional variation in gravel riverbed mobility, controlled by hydrologic regime and sediment supply. Geophysical Research Letters, 45, 3097–3106. https://doi.org/10.1002/2017GL076747