International Conference on Engineering and Ecohydrology for Fish Passage

International Conference on Engineering and Ecohydrology for Fish Passage 2016

Jun 21st, 1:45 PM - 2:00 PM

Modeling: Stream Power Applications

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Milone & MacBroom

MacBroom, James; Schiff, Roy; and Pica, Jessica, "Modeling: Stream Power Applications" (2016). *International Conference on Engineering and Ecohydrology for Fish Passage*. 42.
https://scholarworks.umass.edu/fishpassage_conference/2016/June21/42

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$$\omega = \frac{\gamma . Q . S}{w}$$

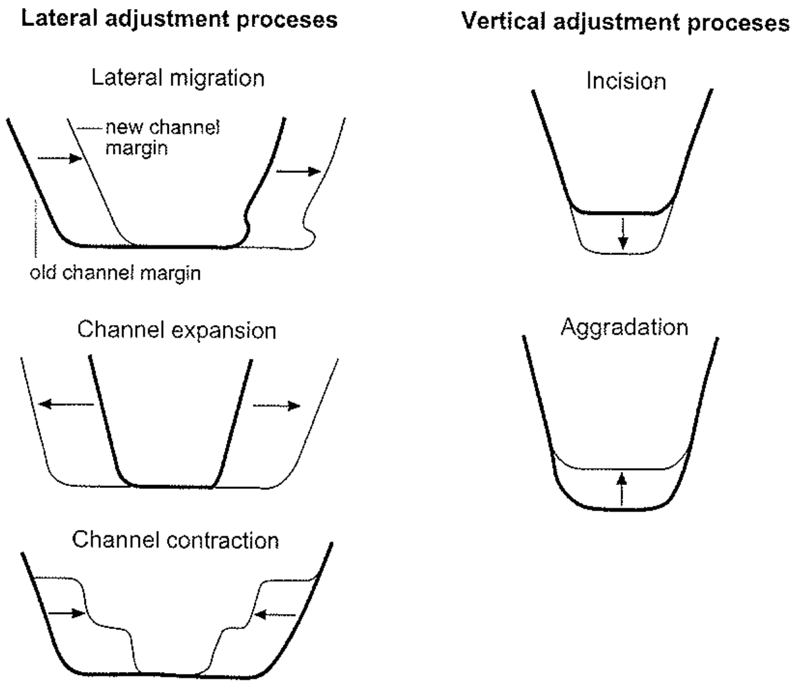
Stream Power Applications

Presented by James MacBroom, P.E.
with assistance from Roy Schiff, PhD, P.E.,
and Jessica Pica, P.E.

June 21, 2016

Agenda

- Potential Stream Power Applications
- What is Stream Power?
- Literature Review
- Local Stream Power Data
- Application Examples



Recent Stream Power Technical Applications

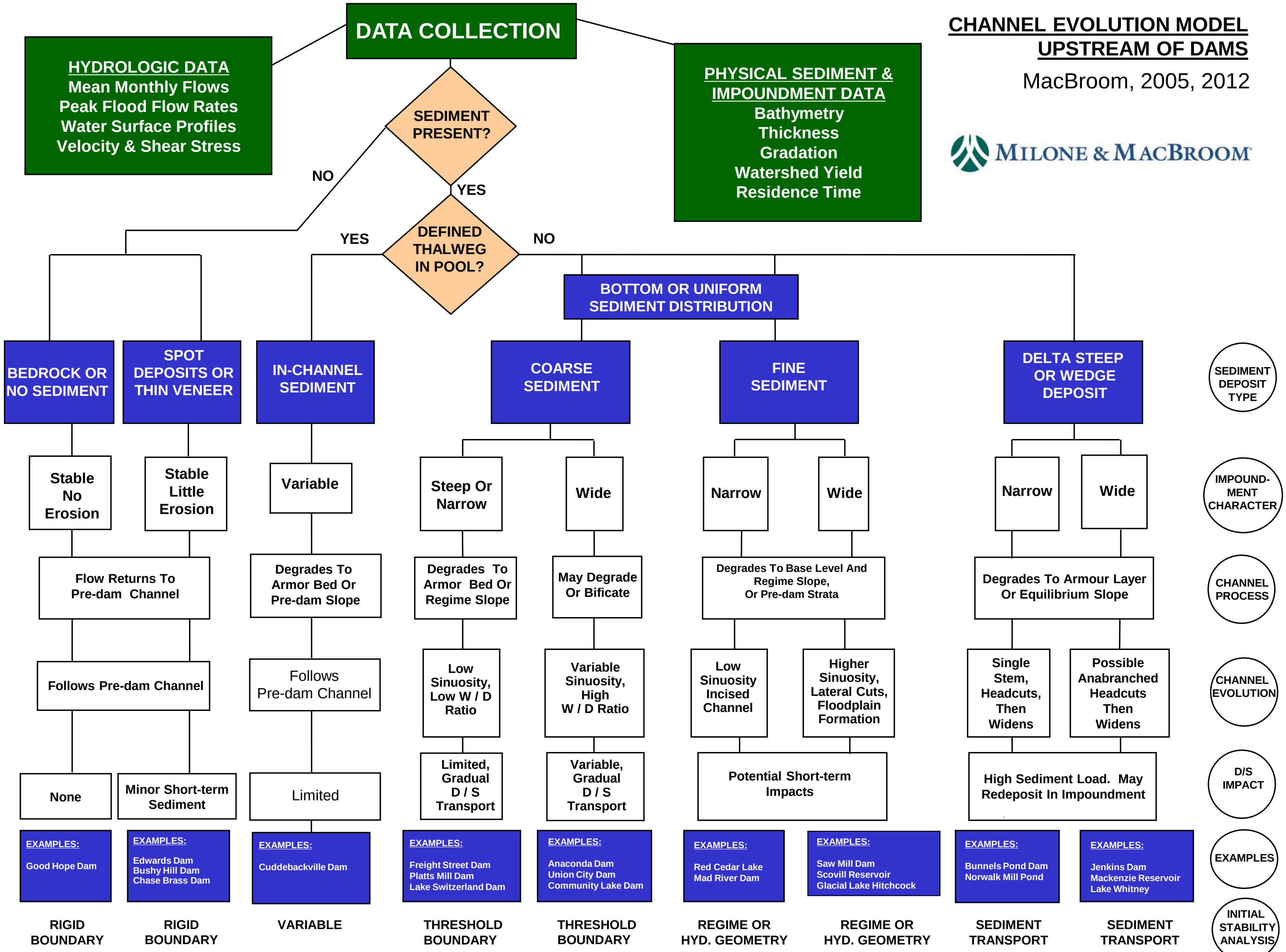
- **NRCS 1997 – Emergency Earth Dam Spillways**
- **Annandale 1995, 2005 – Dams, Bridge Scour**
- **USACOE 2008 – Bedrock Spillway Scour**
- **Kleinhans 2010 – Channel Patterns**
- **FHWA 2012 – Bridge Pier Scour**
- **EU 2014 – Channel Processes and Classification**

- **MMI 2008-16: Channel Stream Continuity & Fish Passage**
  Culvert Vulnerability Screening
  Geomorphic Evolution & Channel Classification
  Bridge and Culvert Scour
  Dam Removal

CHANNEL EVOLUTION MODEL UPSTREAM OF DAMS

MacBroom, 2005, 2012

Milone & MacBroom



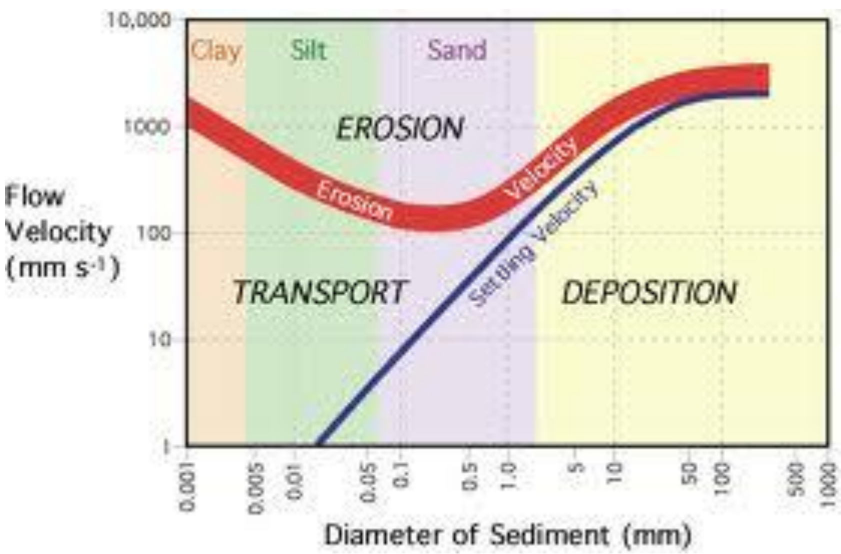
* RESERVOIR WIDTH GREATER THAN THREE TIMES THE CHANNEL'S TOP WIDTH

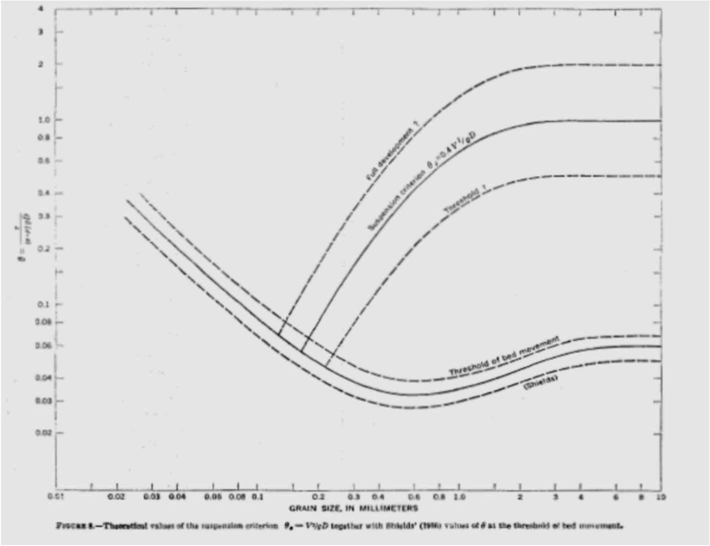
Stability Metrics

Flow Velocity (Q/A)

Shear Stress ($\tau = \Upsilon RS$)

Stream Power ($\Omega = \Upsilon QS$)





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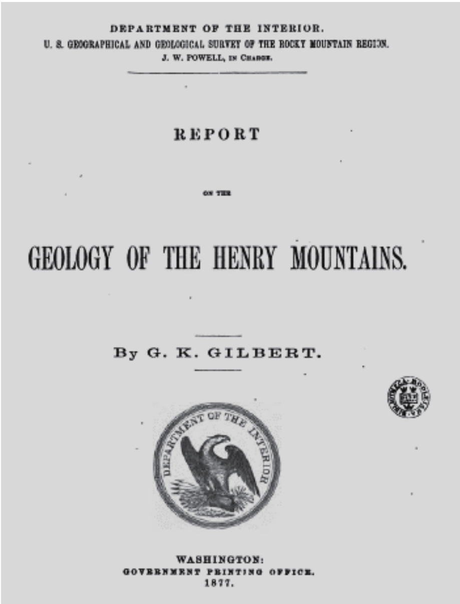
G.K. Gilbert



DEPARTMENT OF THE INTERIOR.
U. S. GEOGRAPHICAL AND GEOLOGICAL SURVEY OF THE ROCKY MOUNTAIN REGION.
J. W. POWELL, IN CHARGE.

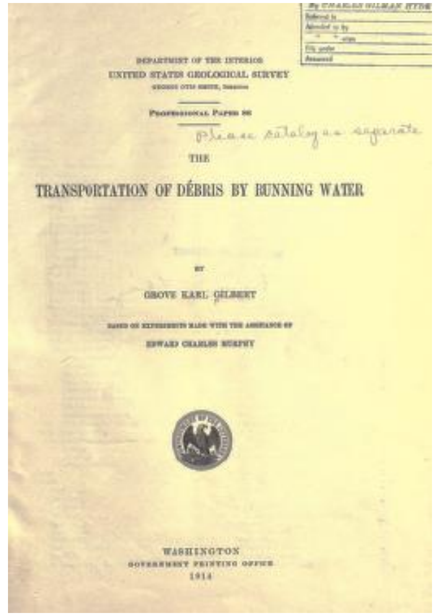
REPORT

ON THE

GEOLOGY OF THE HENRY MOUNTAINS.

By G. K. GILBERT.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1877.



DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

THE

TRANSPORTATION OF DÉBRIS BY RUNNING WATER

BY

GROVE KARL GILBERT

EDWARD CHARLES MURPHY

WASHINGTON
GOVERNMENT PRINTING OFFICE
1914

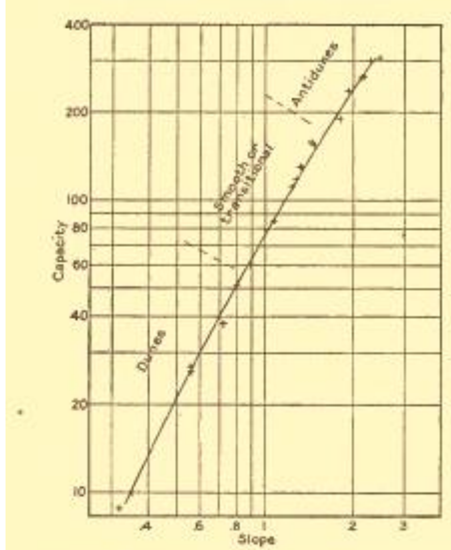


FIGURE 14.—Logarithmic plot of a series of observations on capacity and slope. Compare figure 13.

Thus rate of transportation, as well as capacity for transportation, is favored by fineness of *débris*, by declivity, and by quantity of water.

1877

Load versus energy.—The energy of a stream is measured by the product of its discharge (mass per unit time), its slope, and the acceleration of gravity. In a stream without load the energy is expended in flow resistances,

1914

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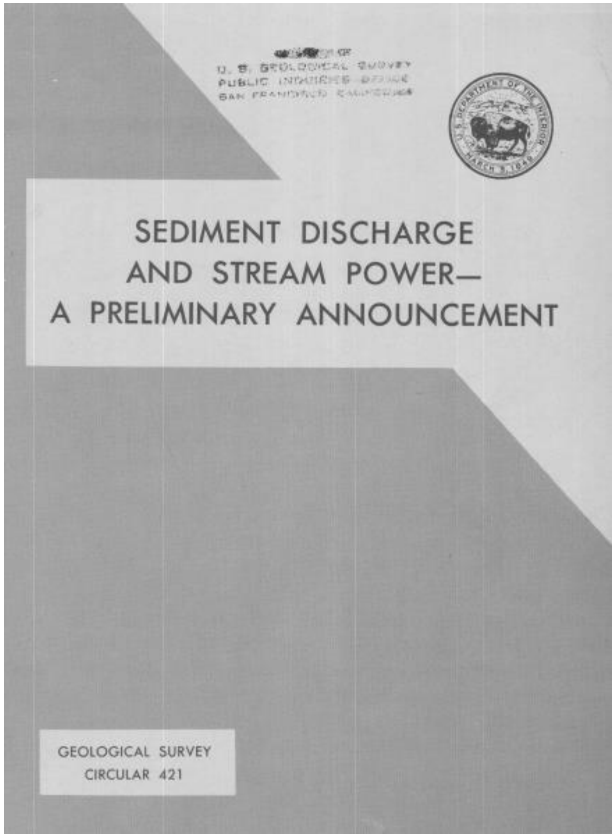
Bagnold Papers on Stream Power

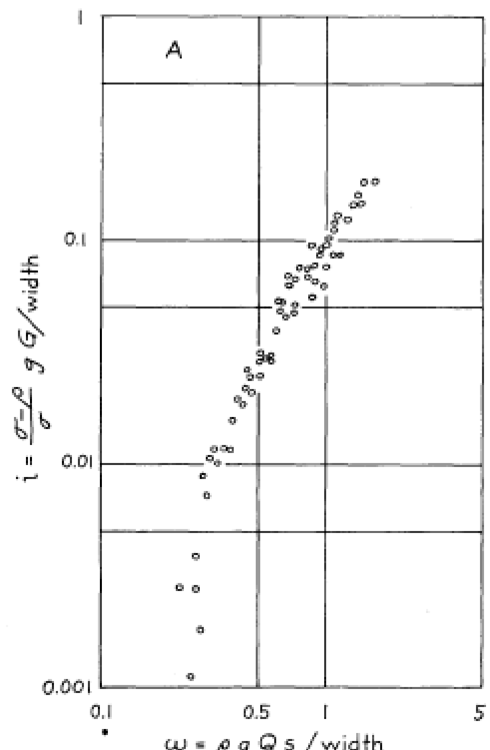

SEDIMENT DISCHARGE
AND STREAM POWER—
A PRELIMINARY ANNOUNCEMENT

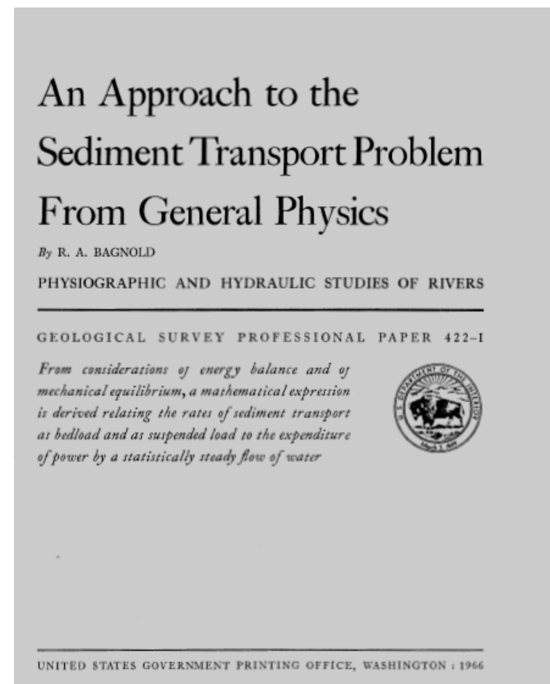
GEOLOGICAL SURVEY
CIRCULAR 421

1960

When any real substance (water) impels any other real substance (sediment) to move, all experience shows that energy must be expended by the first substance in maintaining the motion of the second against some kind of dynamic opposition. And power--that is, a time rate of energy expenditure--is necessary to maintain the motion at a given time rate. Thus a stream can be regarded as a transporting machine; and we have the dynamic relation

rate of work done = efficiency x available power (1)




An Approach to the Sediment Transport Problem From General Physics

By R. A. BAGNOLD

PHYSIOGRAPHIC AND HYDRAULIC STUDIES OF RIVERS

GEOLOGICAL SURVEY PROFESSIONAL PAPER 422-I

From considerations of energy balance and of mechanical equilibrium, a mathematical expression is derived relating the rates of sediment transport as bedload and as suspended load to the expenditure of power by a statistically steady flow of water

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1966

1966

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Stream Power Particle Thresholds

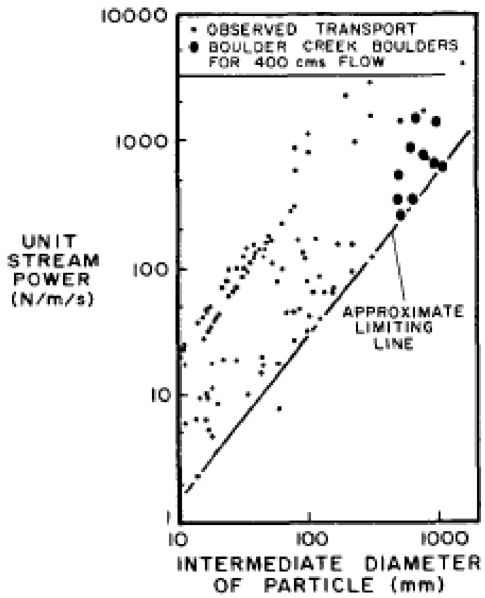
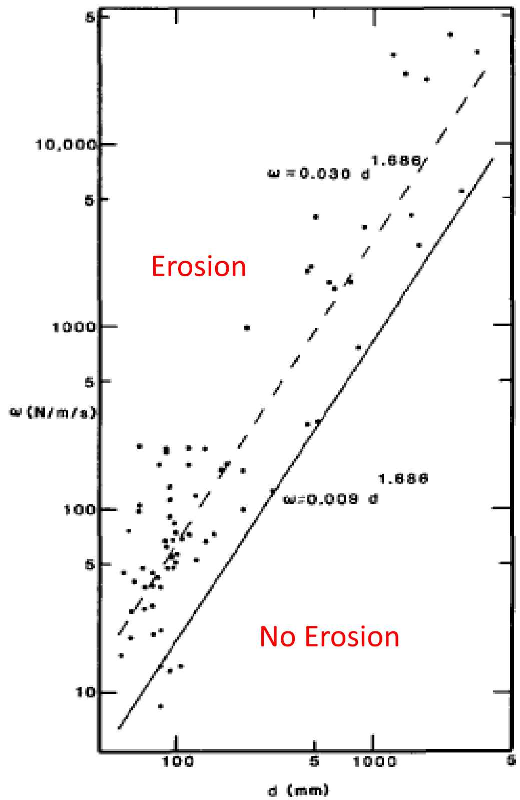


Figure 9. Modified version of Williams' (1983) compilation of field-measured stream power as a function of transported boulder size. Williams (1983, p. 230) fitted, by eye, an approximate limiting line to represent "the lowest unit stream power, which, according

O'Conner, 1986, GSA



Costa,1983, GSA

empirical and semi-empirical bedload transport relationships (Bagnold, 1980; Costa, 1983; Williams, 1983) have been fairly successful in using stream power as a transport criterion. Bagnold (1966) defined unit stream power as:

$$\omega = \frac{\gamma Q S_f}{\text{flow width}} = \tau v \qquad (2)$$

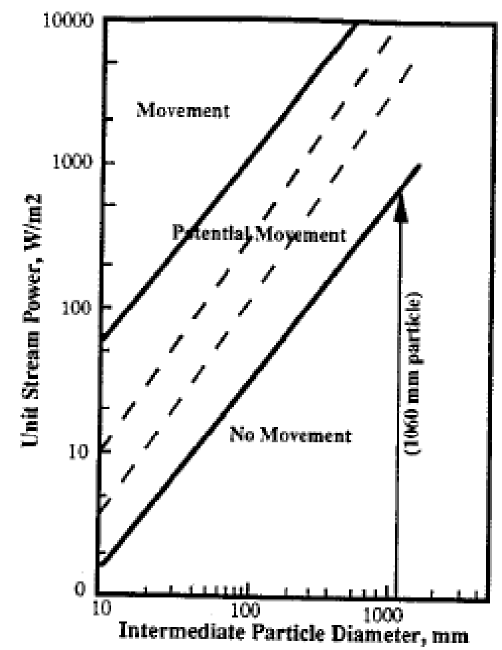
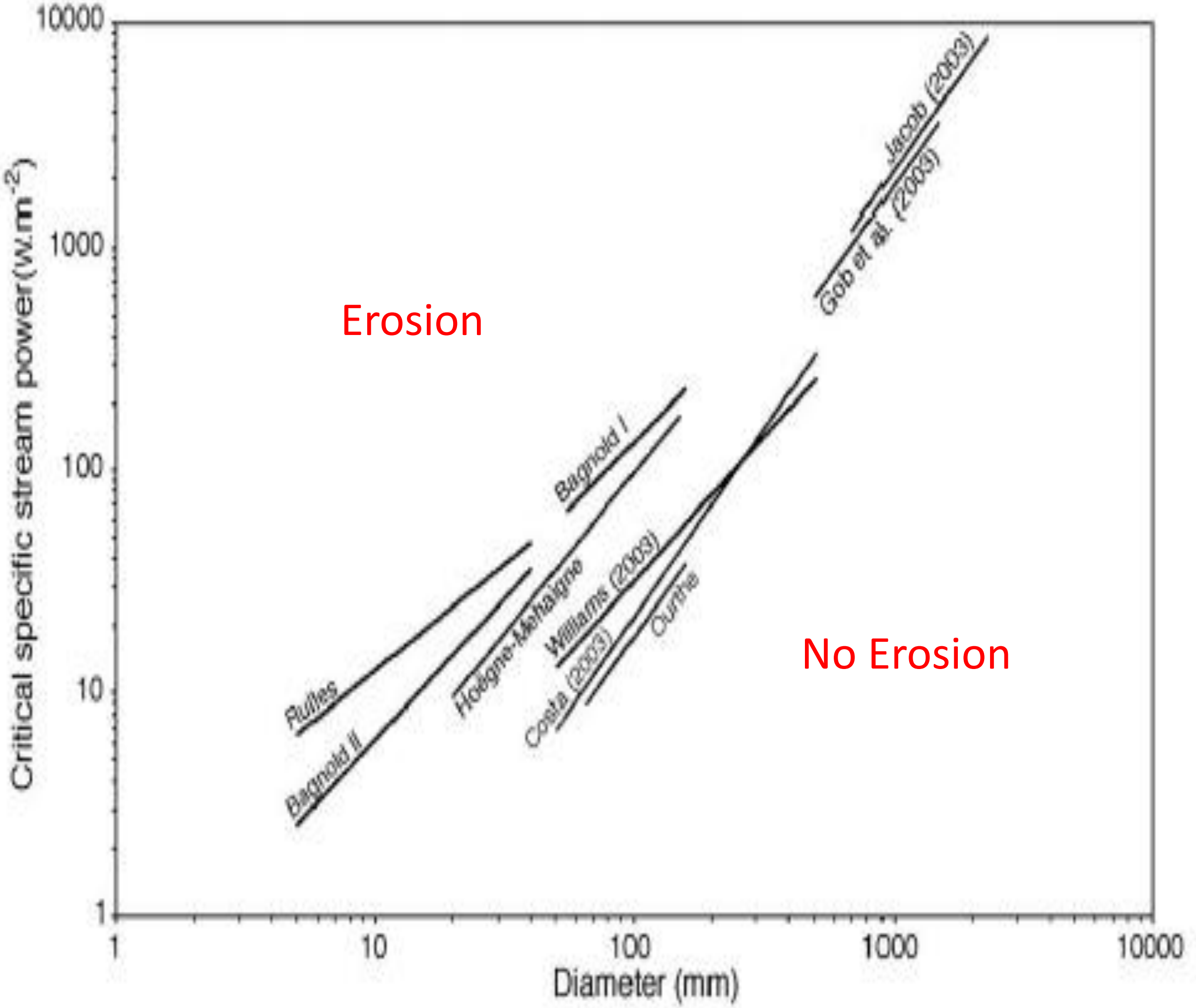


Figure 3: Approximation of the likelihood of particle movement for a given particle diameter and unit stream power. (Source: Williams 1983).

Williams, 1983

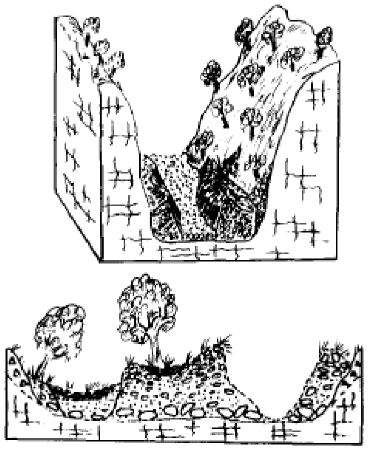
Critical Specific Stream Power



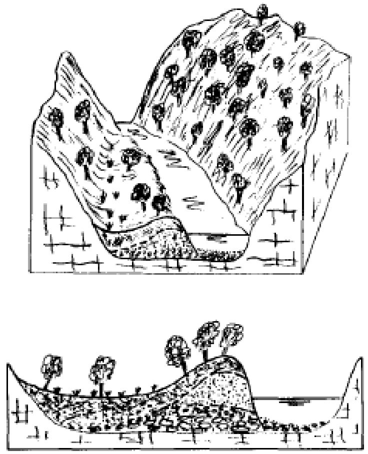
Petit et al, 2005

High-Energy Floodplains

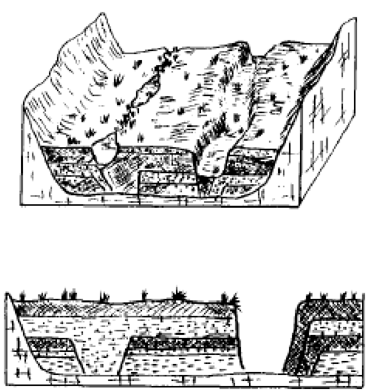
i) **Confined Coarse-Textured Floodplain**
$\omega = >1000 Wm^{-2}$



ii) **Confined Vertical-Accretion Sandy Floodplain**
$\omega = 300\text{-}1000 Wm^{-2}$

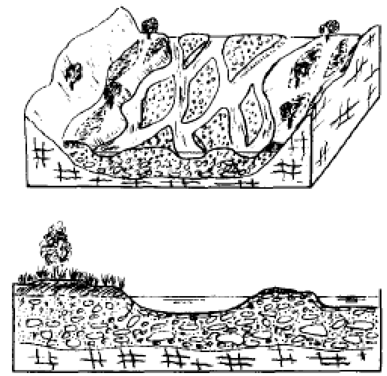


iii) **Cut and Fill Floodplain**
$\omega = \sim 300 Wm^{-2}$

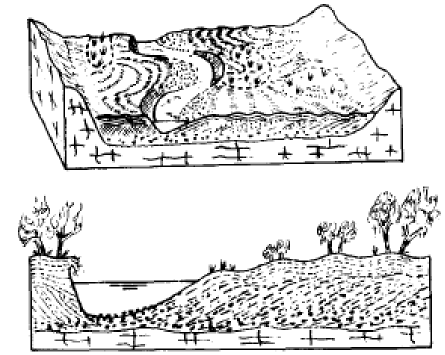


Medium-Energy Floodplains

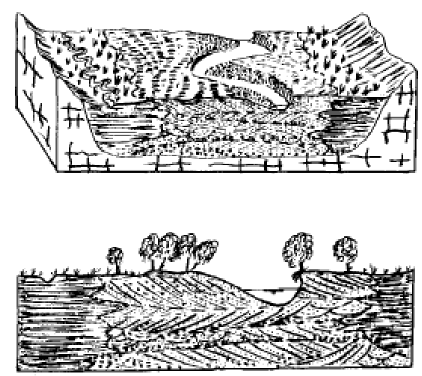
i) **Braided River Floodplain**
$\omega = 50\text{-}300 Wm^{-2}$



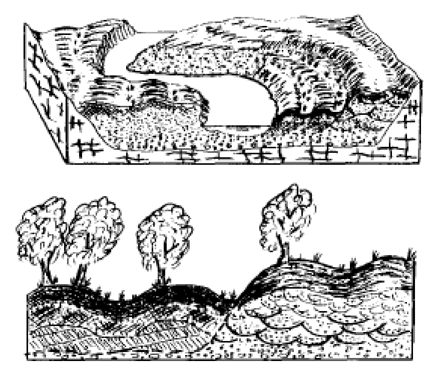
ii) **Lateral Migration, Scrolled Floodplain**
$\omega = 10\text{-}60 Wm^{-2}$



iii) **Lateral Migration / Backswamp Floodplain**
$\omega = 10\text{-}\ll 60 Wm^{-2}$

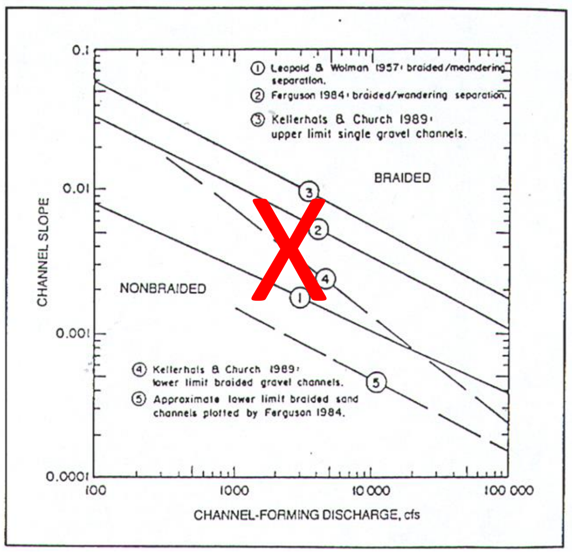


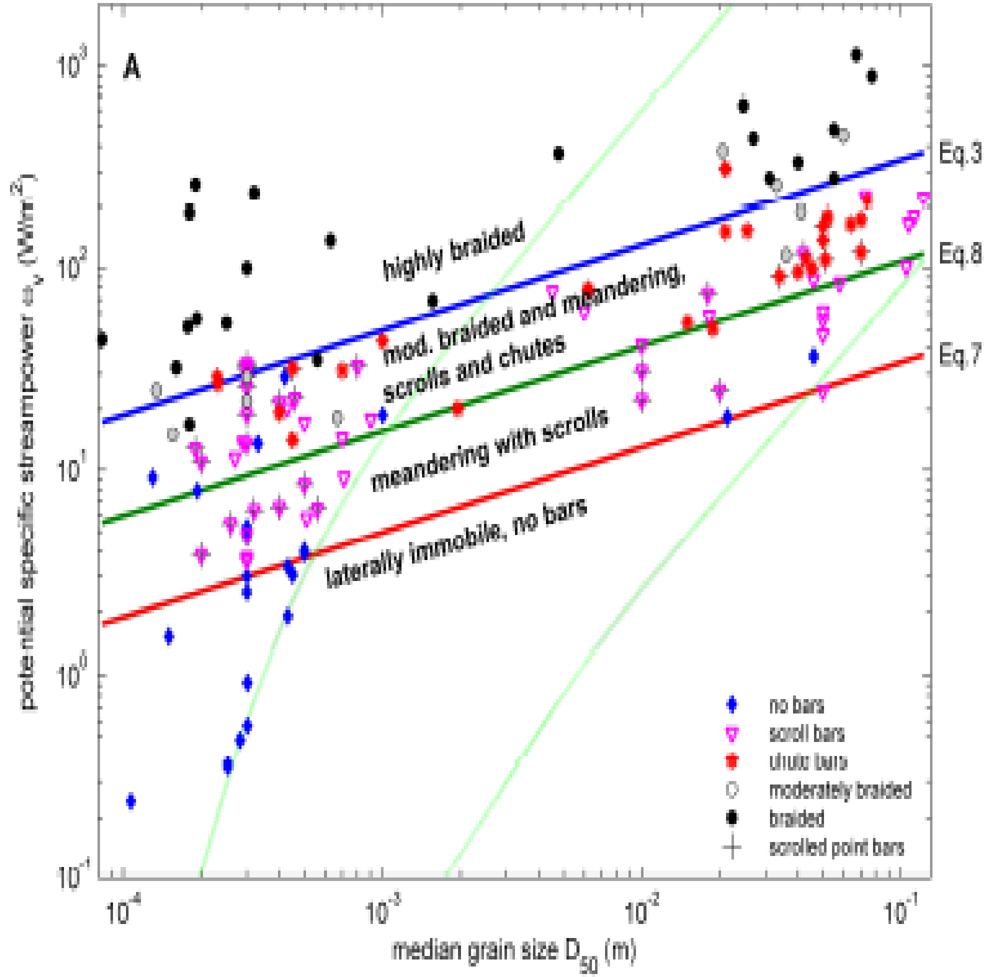
iv) **Lateral Migration, Counterpoint Floodplain**
$\omega = 10\text{-}\ll 60 Wm^{-2}$



Source: Nanson and Croke, 1992

Channel Patterns Based Upon Stream Power





Kleinhans , 2010

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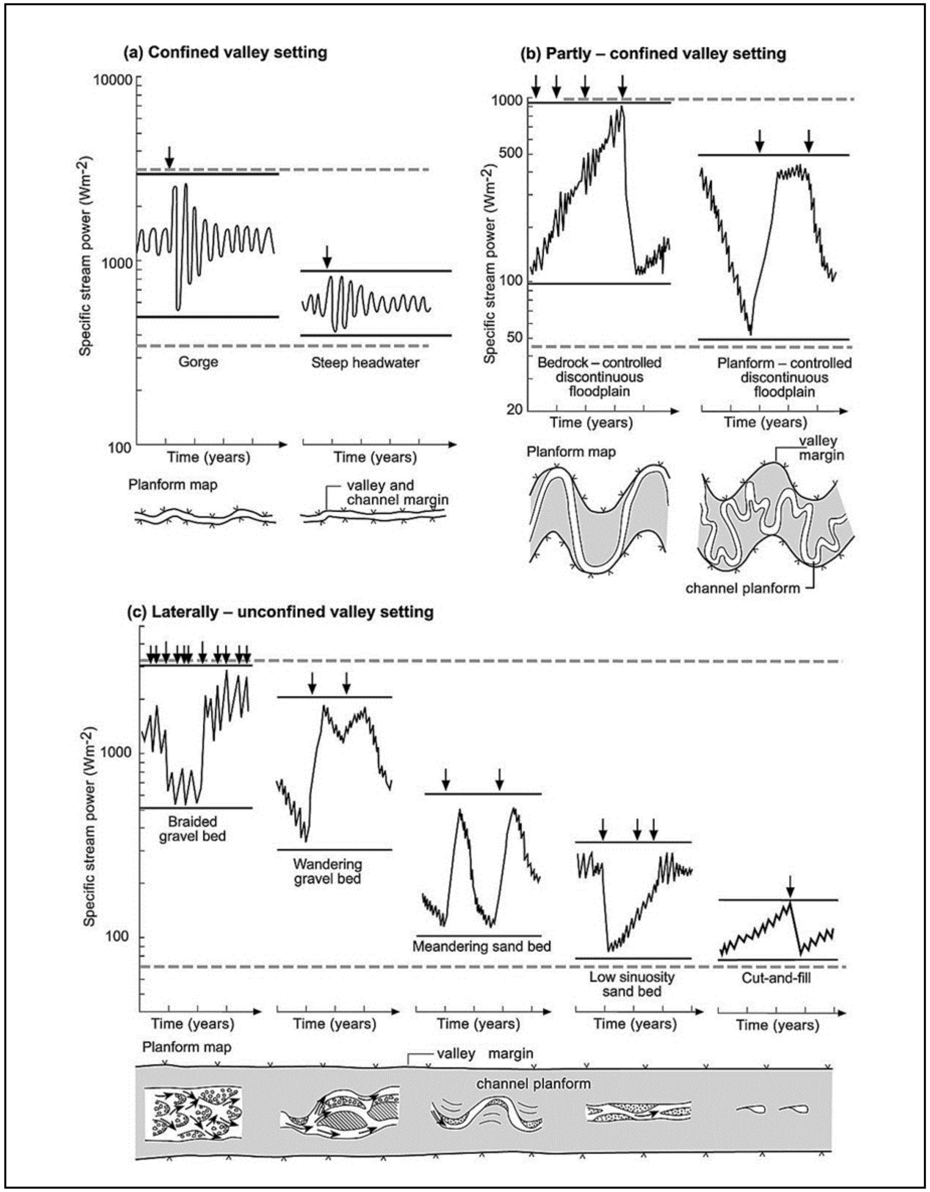
River Styles By Specific Stream Power



Brierley & Fryirs, 2005, 2013

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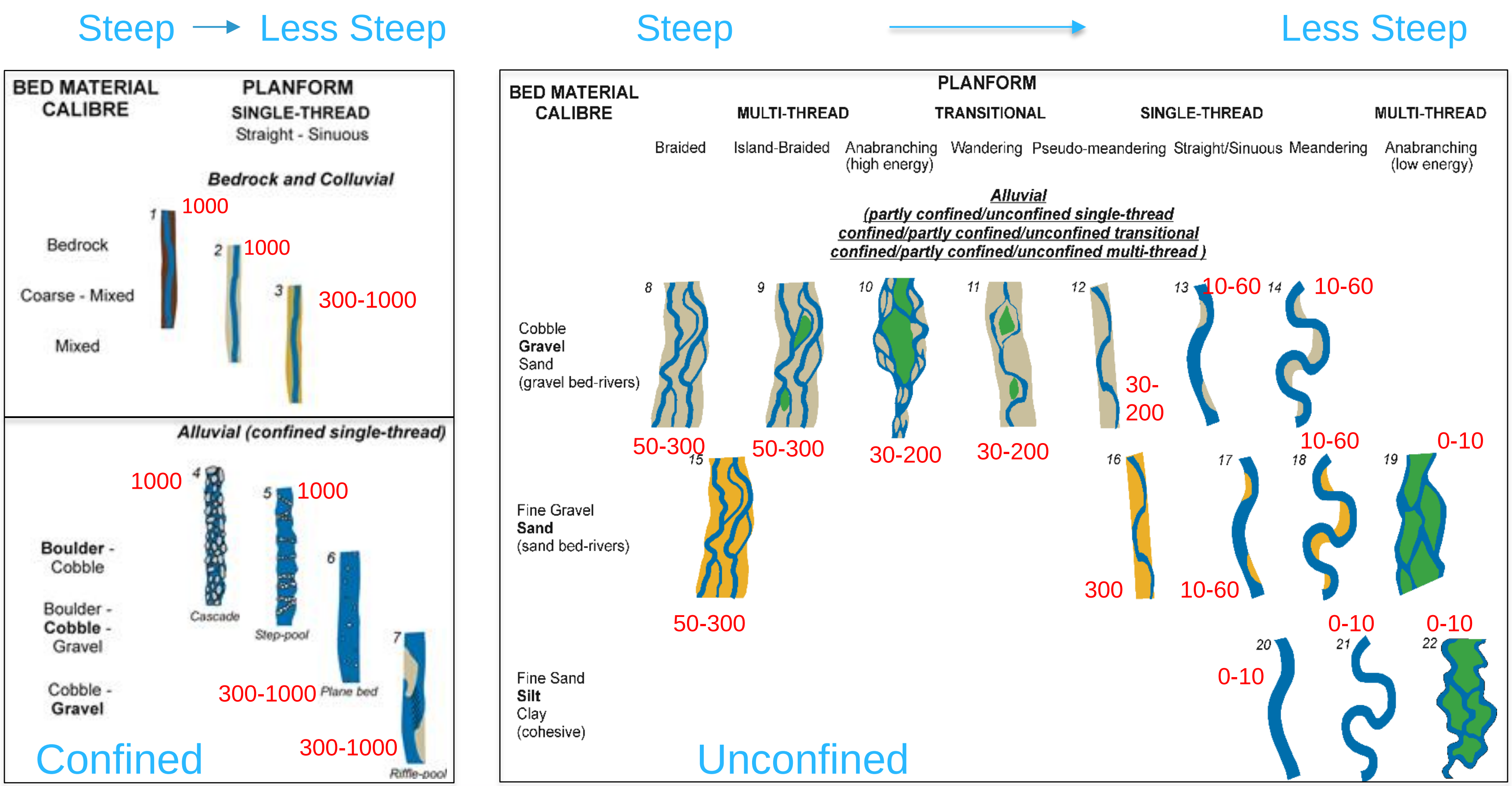
REFORM
REstoring rivers FOR effective catchment Management

THE REFORM FRAMEWORK: 3. ASSESSMENT, I RIVER TYPE

Modified from EU REFORM, 2014



Channel Degradation

New Incision

Armored Bed

SSP = 3504

Westkill Widening & Landslide

SSP 2206

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Channel Degradation

Pre Flood, Cobble Bed

6-8 Feet Incision

Westkill Creek, NY, SSP = 1752

NY Road Embankment Scour

SSP = 1247

Floodplain Scour

Prattsville, SSP = 332

Floodplain Deposition

Frost Valley, SSP = 246

Pomperaug River
SSP = 78

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Rondout Creek Van Aken Property

Wandering Channel

SSP = 132

West River, Low Energy Flood

SSP = 74

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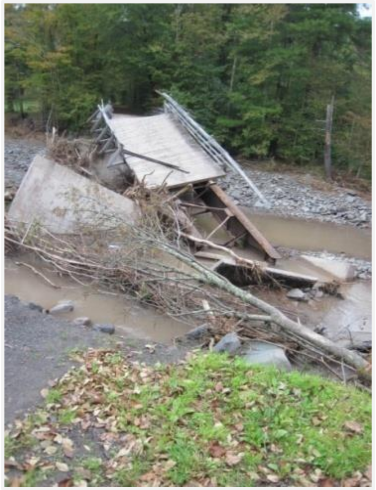
Bridge & Culvert Scour



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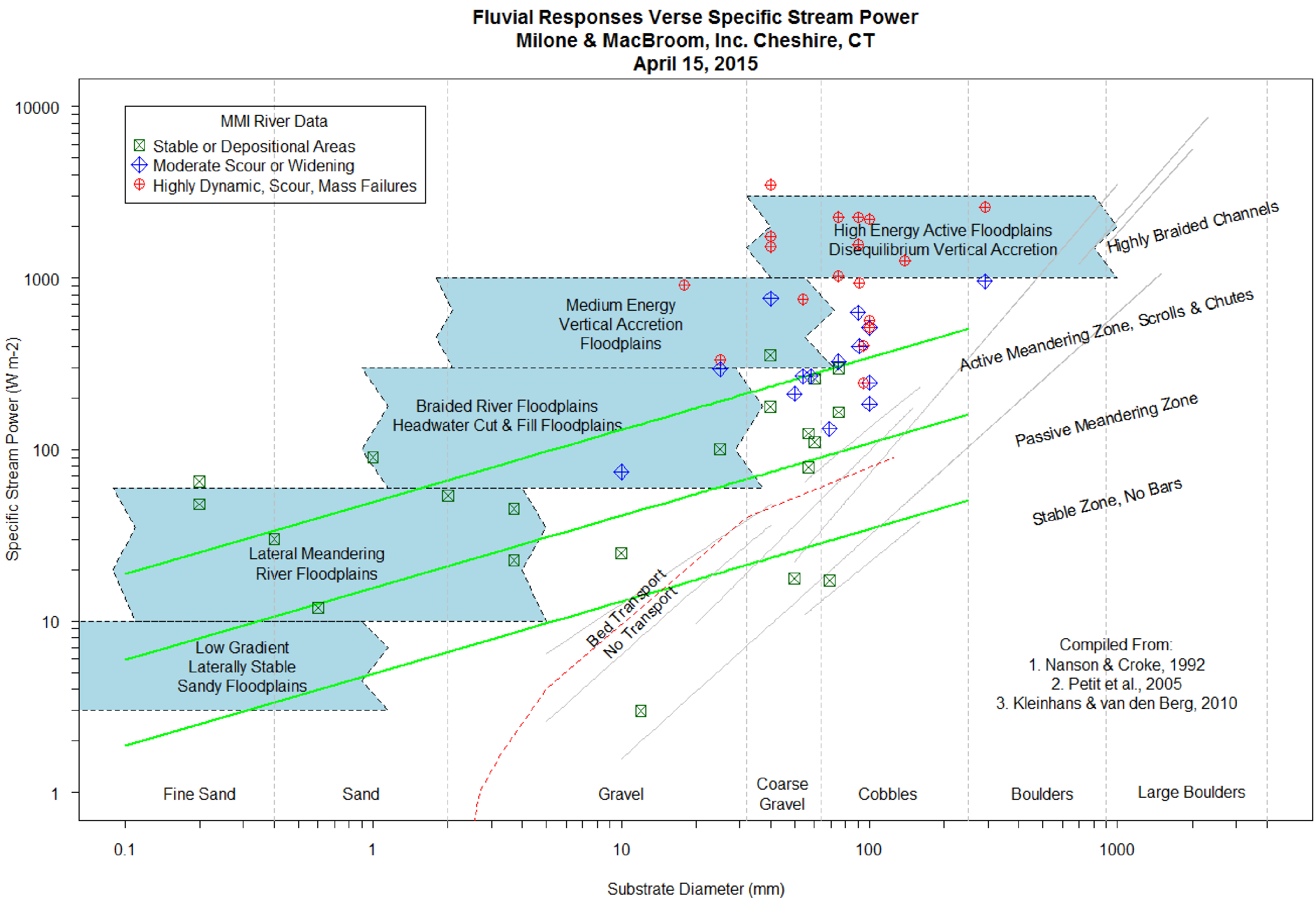
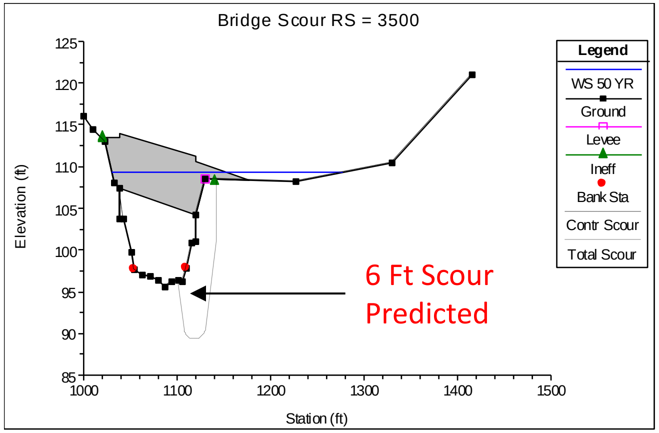
Bridge Aggradation & Emergency Response

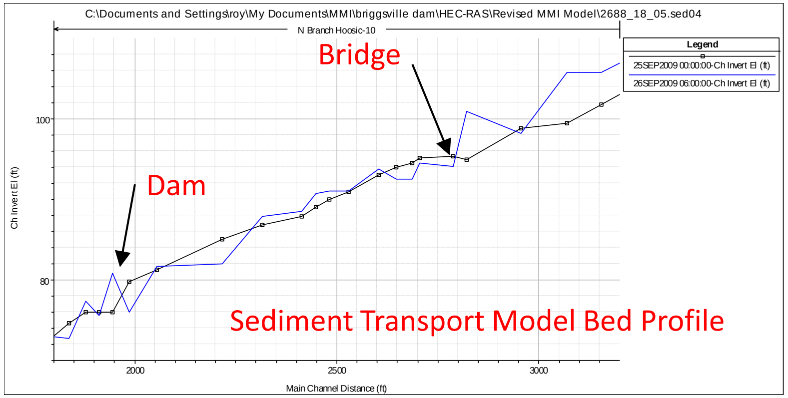
Phoenicia, SSP = 258 / 101



Fluvial Responses Verse Specific Stream Power
Milone & MacBroom, Inc. Cheshire, CT
April 15, 2015
MMI River Data
Stable or Depositional Areas
Moderate Scour or Widening
Highly Dynamic, Scour, Mass Failures
High Energy Active Floodplains
Disequilibrium Vertical Accretion
Medium Energy
Vertical Accretion
Floodplains
Braided River Floodplains
Headwater Cut & Fill Floodplains
Lateral Meandering
River Floodplains
Low Gradient
Laterally Stable
Sandy Floodplains
Highly Braided Channels
Active Meandering Zone, Scrolls & Chutes
Passive Meandering Zone
Stable Zone, No Bars
Bed Transport
No Transport
Compiled From:
1. Nanson & Croke, 1992
2. Petit et al., 2005
3. Kleinhans & van den Berg, 2010
Specific Stream Power (W m-2)
10000
1000
100
10
1
Fine Sand
Sand
Gravel
Coarse
Gravel
Cobbles
Boulders
Large Boulders
0.1
1
10
100
1000
Substrate Diameter (mm)

Channel Prediction for Briggsville Dam Removal





The Issue;

1. Preliminary design (by others) proposes unnatural step pool grade controls, over looking channel type

2. HEC-18 predicts deep bridge scour, ignoring bed load sediment

3. MMI finds large upstream in-channel sediment sources

4. MMI develops dynamic sediment transport model, predicting high sediment bedload (but model is quite expensive)

5. MMI designs for high bedload and minimal scour, no step pools

6. Hurricane Irene validated MMI design assumptions

Goal-Need simple ways to predict complex things

Interpretation*: *Confined high energy, gravel and cobble substrate channel.

Design: ***Create: stable straight plane bed (run) channel, active bed, with supplemental roughness and grade control riffles, plus local bridge scour counter measures***

Stream Power Analysis

Q2 = 2360 CFS
S = 0.014-0.022
W=60 Ft
D50=100 mm
SSP = 800 WM^{-2}
EU Type 6

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Channel Prediction for Off-Billington St Dam Removal

Q2 = 80 CFS

S=0.014

W=25 FT

D50 < 0.1 mm, anticipated 1 mm

SSP=25 WM^{-2}

EU type 17

Interpretation: Unconfined medium energy, silty sand substrate
Create: stable sinuous pool riffle channel, minimal point bars, with supplemental gravel bed for habitat and roughness

The End