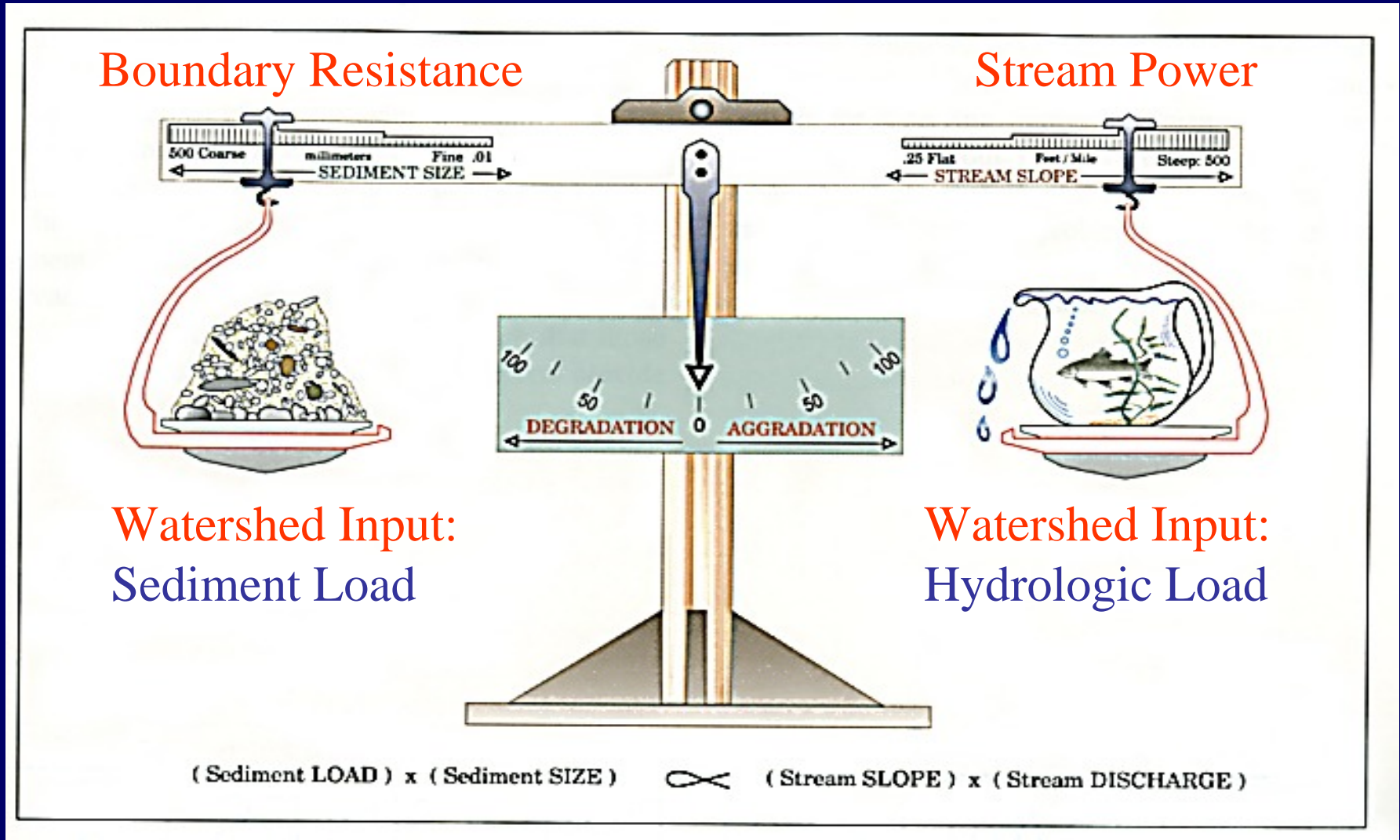


Complex, diverse, and productive habitats derive from the range and distribution of hydraulic units.



The range and distribution of hydraulic units derives from the dynamic equilibrium of a stream.



Habitat simplification is the legacy of dams, drainage, and flood hazard mitigation in New England



Vermont RMP Goal and Objectives

**Public and Private
Property
Protection**

**Water Quality
Improvement**

**River Ecosystem
Restoration**

**Economically and
ecologically sustainable
relationship with rivers
by managing toward
*equilibrium conditions***

**Fluvial Erosion
Hazard (FEH)
Mitigation**

**Protect flood attenuation
assets and adopt municipal
plans and ordinances to
minimize fluvial erosion
hazards.**

**Sediment and
Nutrient Load Reduction**

**Increase floodplain storage,
riparian vegetation, and stream
bank stability to reduce sedi-
ment and nutrient loads in a
watershed.**

**River & Riparian
Habitat Restoration
and Protection**

**Implement watershed and
river corridor strategies and
conserve lands to achieve long-
term protection of riparian
ecological attributes and
processes.**

Given a specific boundary condition, flow and sediment regime, a river will tend toward **equilibrium conditions** or a unique and dynamic combination of cross section, meander pattern, and longitudinal profile.

Open systems work toward simultaneously unattainable conditions

- **of minimum work and**
- **uniform distribution of energy**

The result is a compromise: the variance is minimized in a **most probable form**



When a river is in its most probable form the rate of work (erosion, deposition and migration) is minimized

By allowing streams to adjust in equilibrium, we are working toward a more stable built environment.





Escalating Costs, Risks, and Ecosystem Degradation

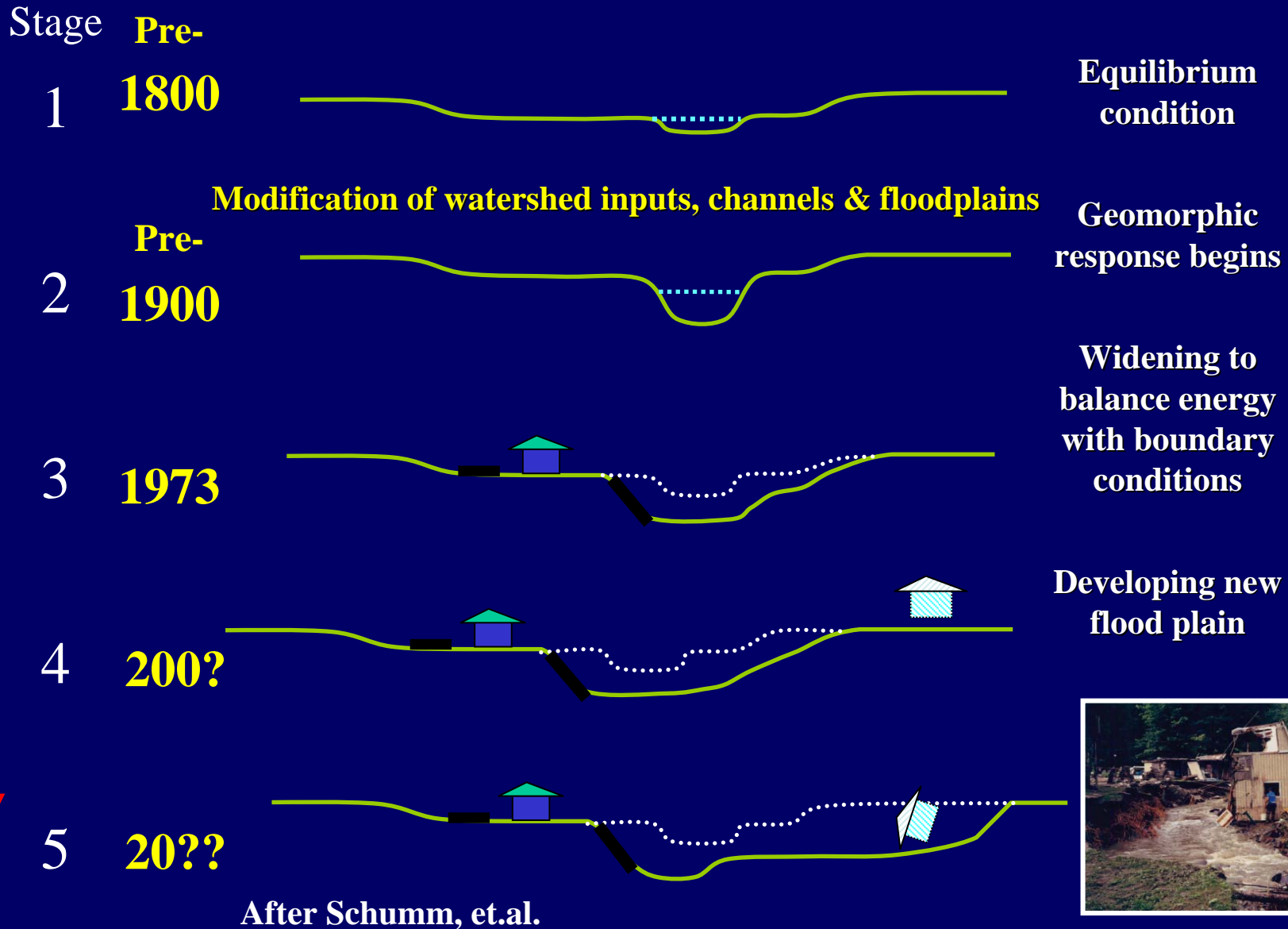
Floods and
Property Damage



Encroachment

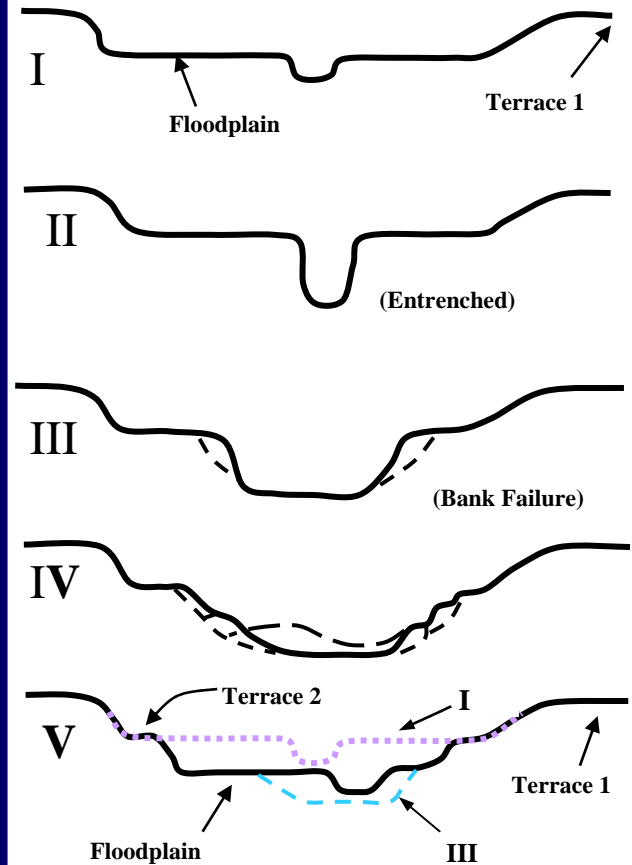
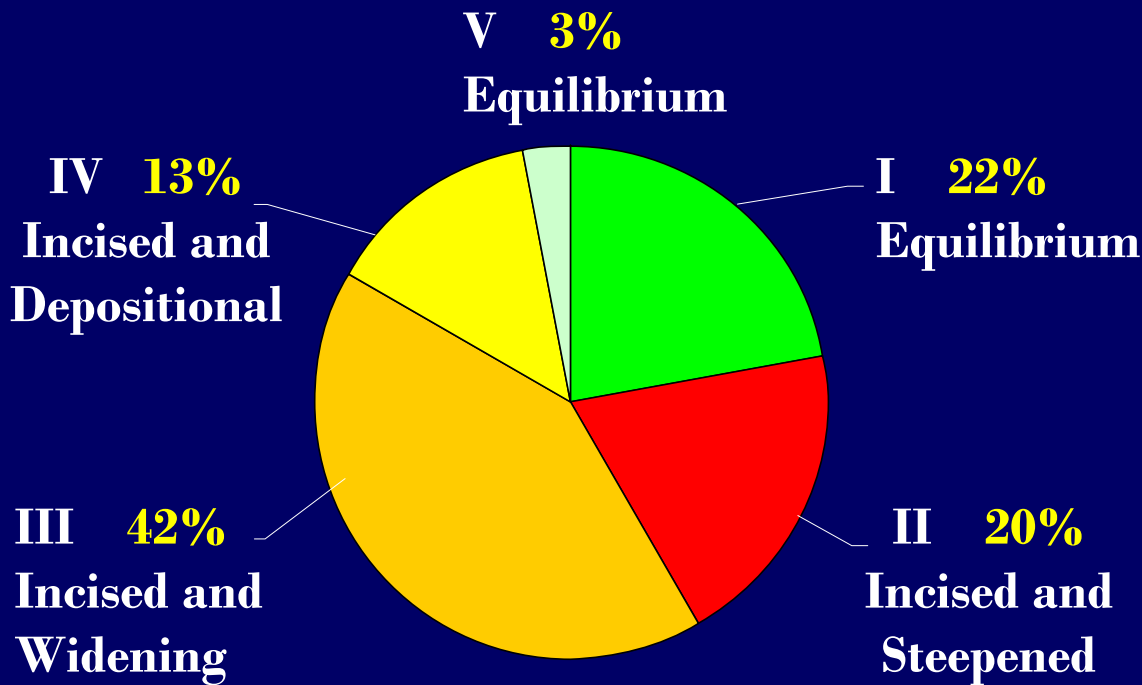
Dredge, Berm
and Armor

Managing Toward Equilibrium and Economic and Ecologic Sustainability



VT Assessed Stream Miles in Various Stages of Evolution

Evolution Stage	Number of Segments	Percent Segments	Number of Miles	Percent Length
I	208.0	19.7%	167.5	22.1%
II	256.0	24.2%	147.5	19.5%
III	415.0	39.2%	316.8	41.8%
IV	139.0	13.1%	102.4	13.5%
V	40.0	3.8%	22.8	3.0%
Total	1,058.0	100.0%	757.1	100.0%



Bankfull Flow



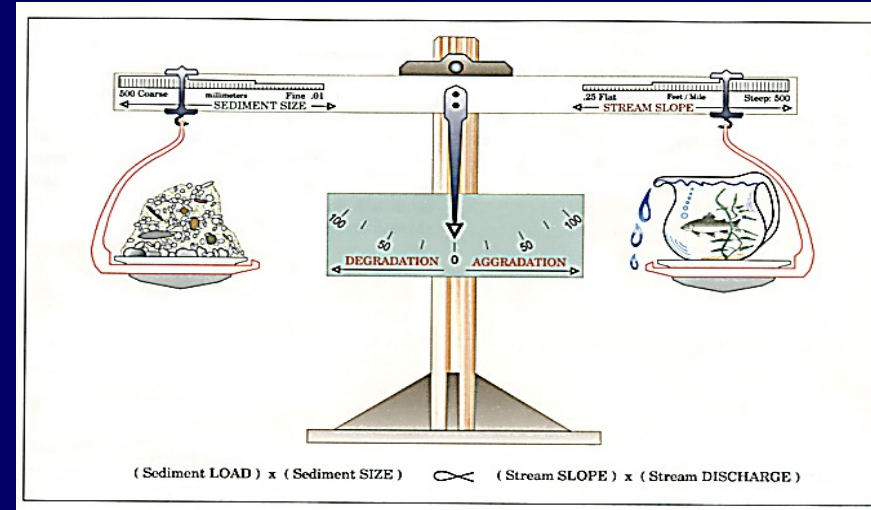
Stage II

**Rock River
Franklin, VT**

20%



Historic Floodplain



Historic Floodplain



Channel Evolution
Stage III
Incision to Widening

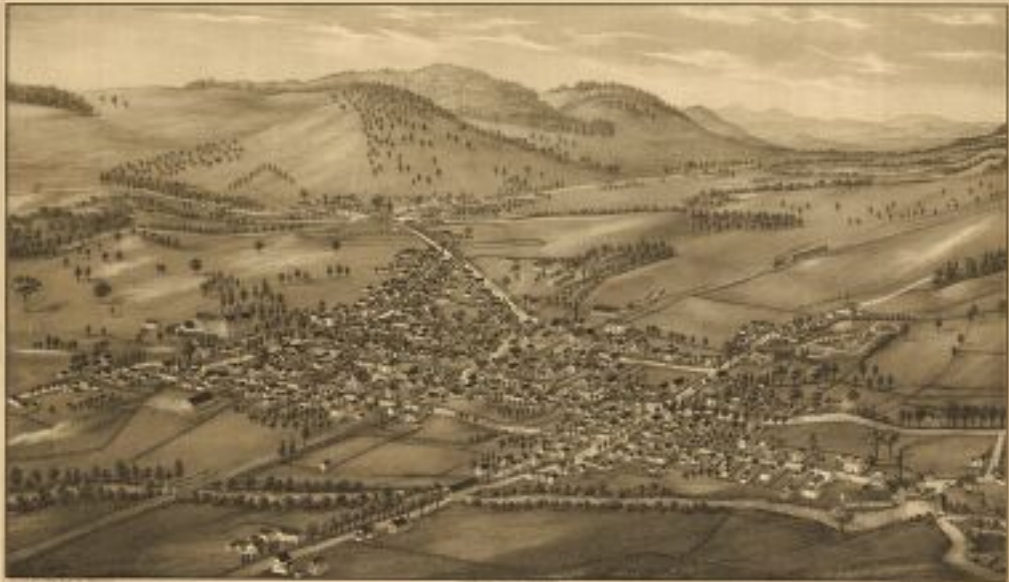
42%

Channel Evolution Stage IV

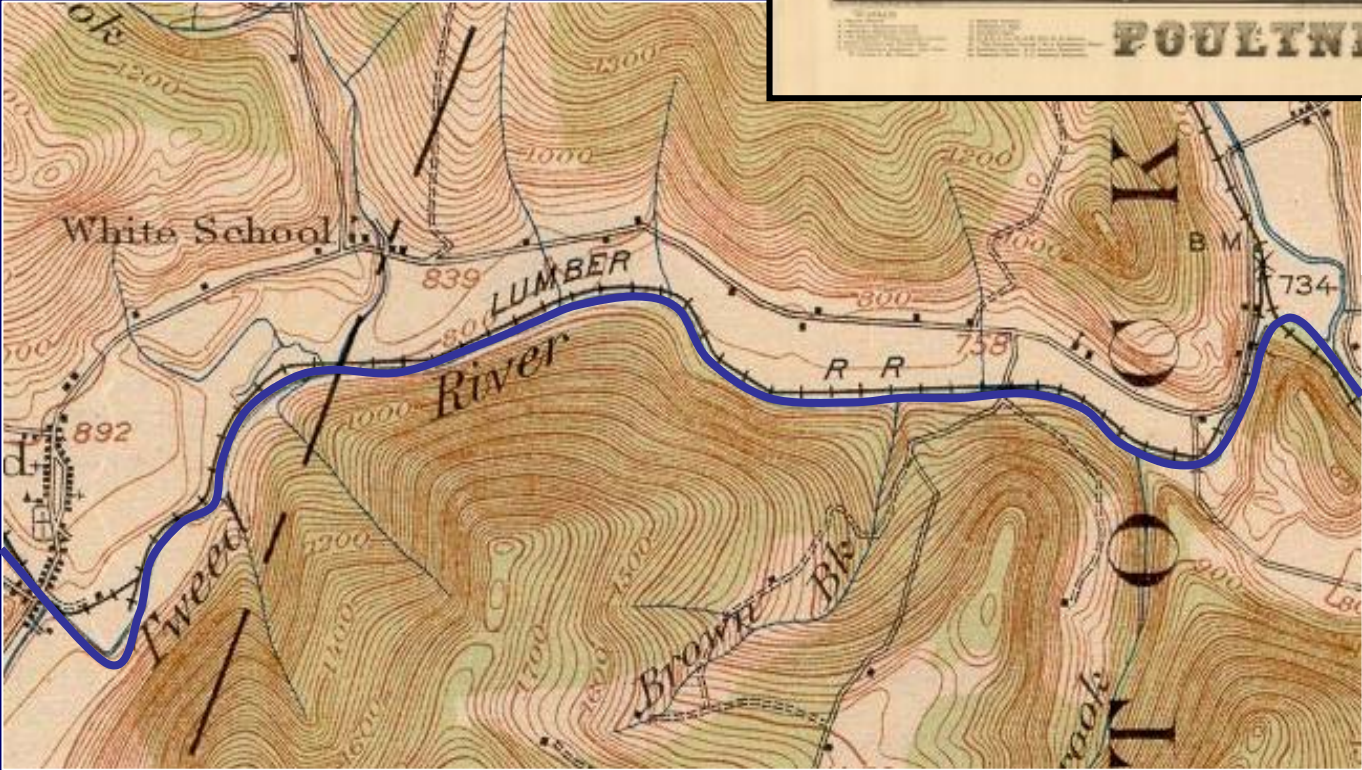
Previously straightened rivers will re-establish meanders during the floodplain development process



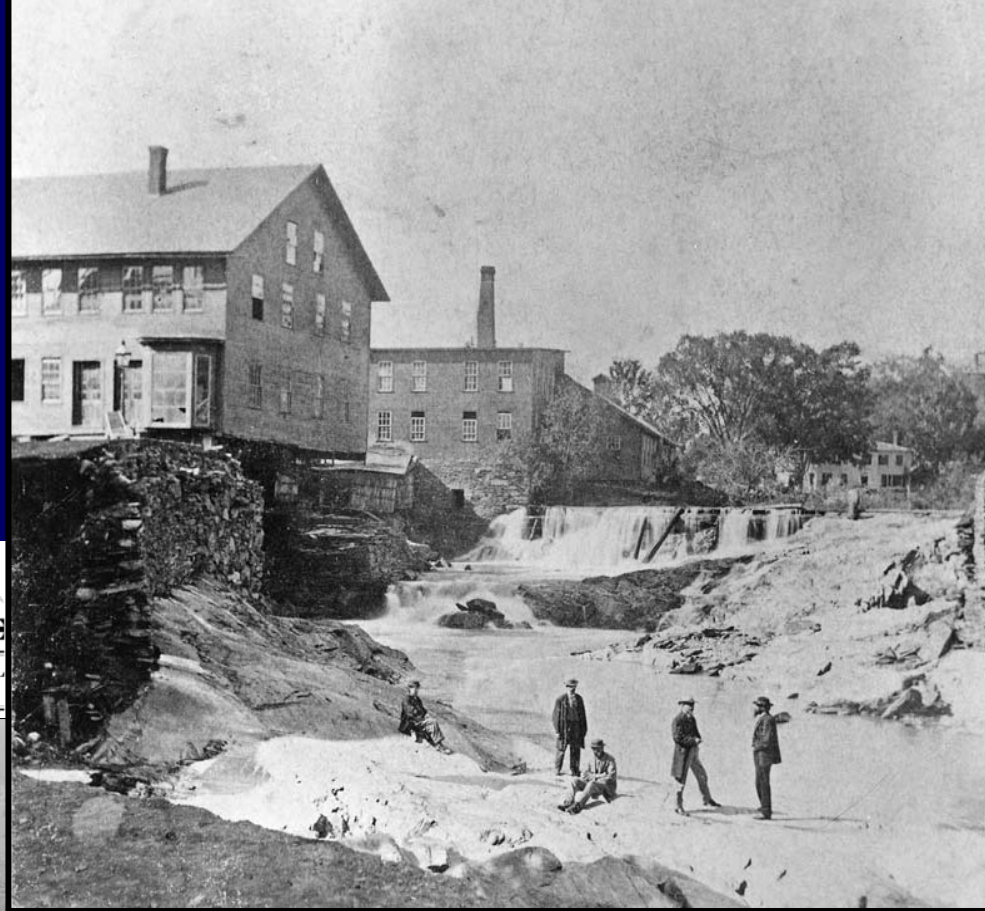
Change in physical regimes and loss of habitat are rooted in our history



POULTNEY, VT.



**Dammed to produce
power and reduce
flooding impacts...**




**...channelized to
transport commercial
goods.**

**Rivers were moved
to accommodate
roads & railroads...**

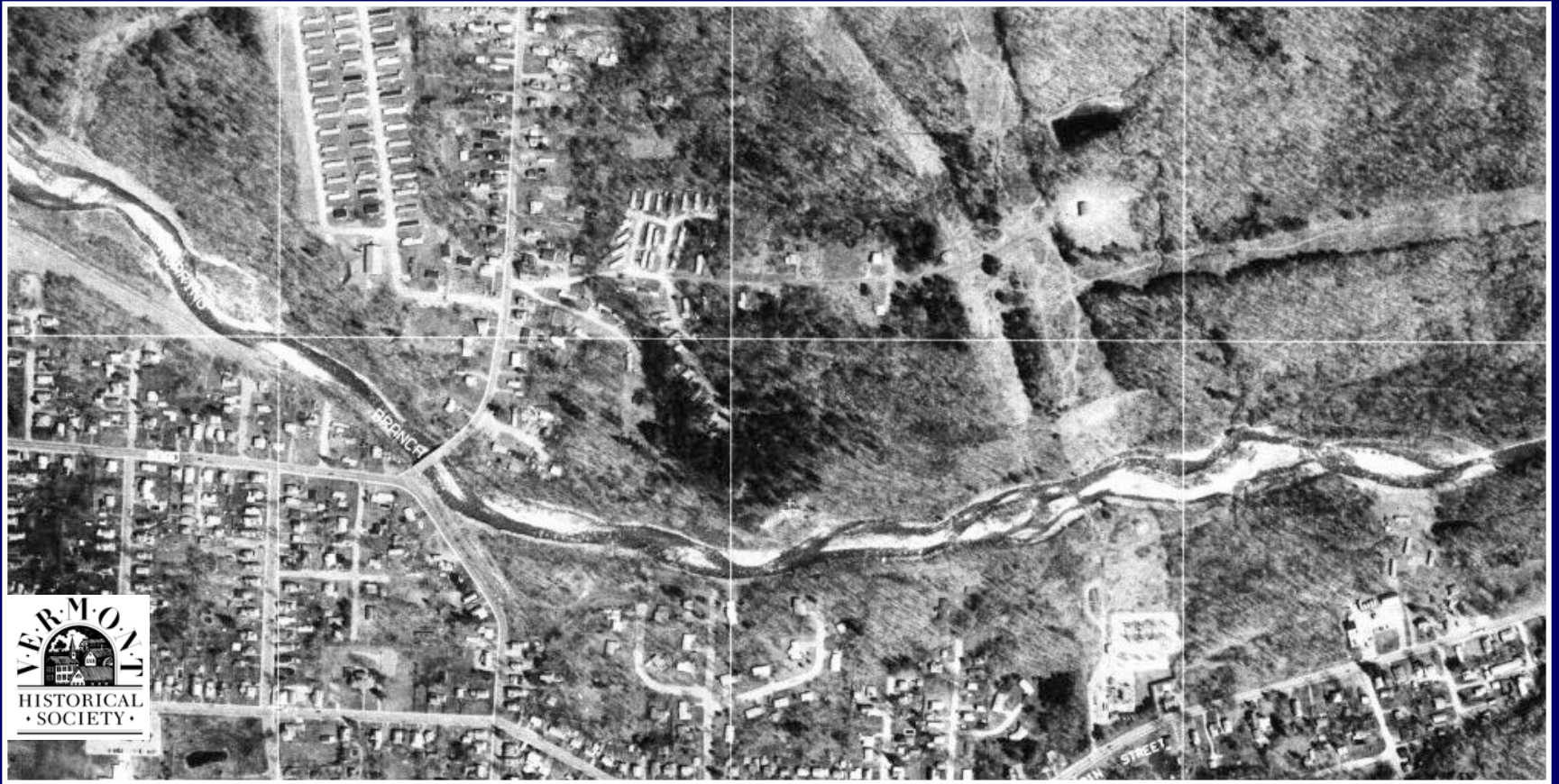


**...straightened to
improve drainage.**

An aerial photograph showing a winter landscape. The top half of the image is dominated by snow-covered agricultural fields, with visible straight lines and patterns from farming. A winding stream flows through the center of the image, starting from the left and curving towards the right. The bottom half of the image shows a dense forest of trees, mostly without leaves, with some evergreens visible. The overall scene is a mix of natural and human-made elements in a cold season.

**Drained for
Agricultural
Production.**

Steepened and confined by development and enlarged by structural storm water conveyance.



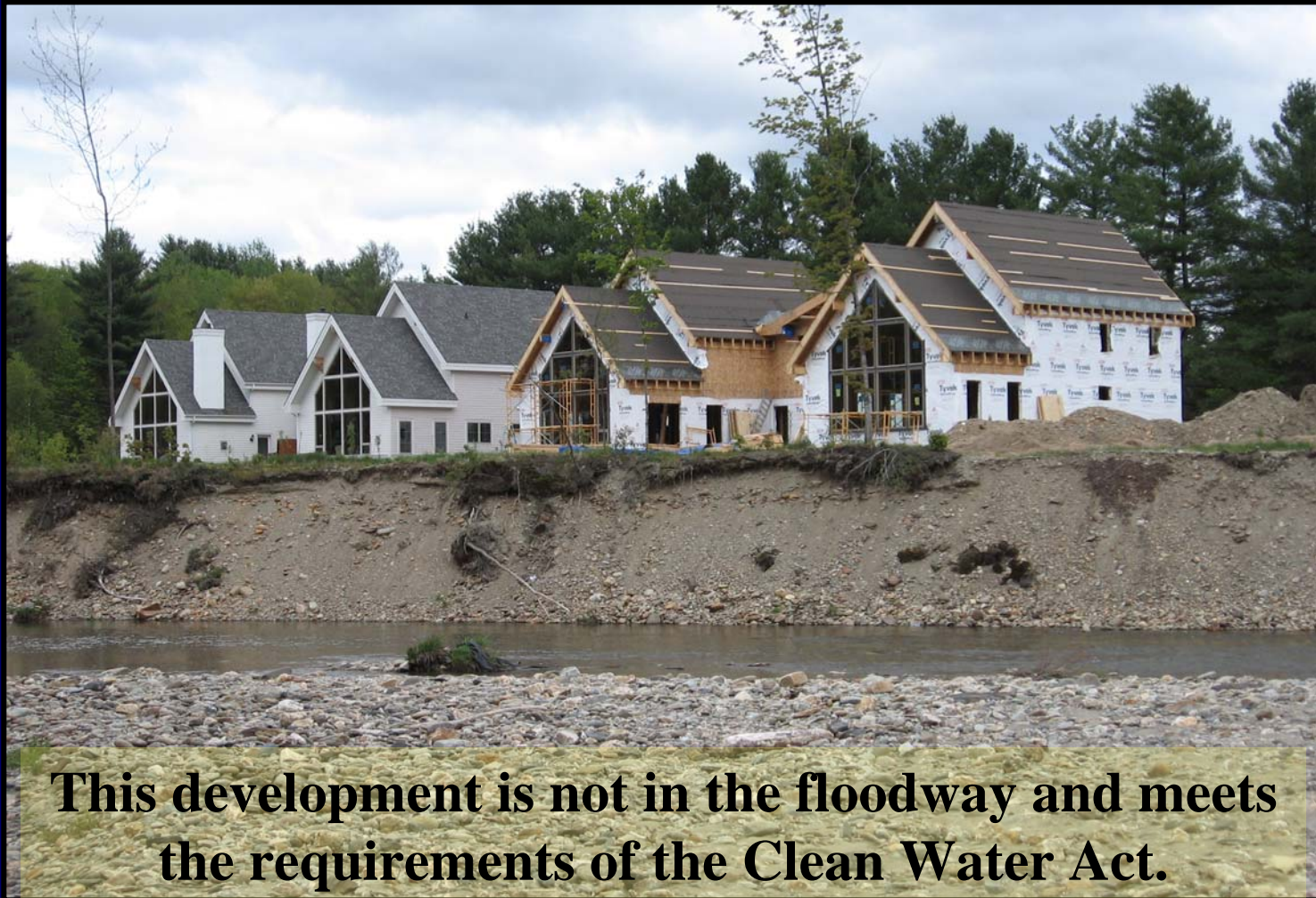
**Current-day
property
protection and
flood hazard
mitigation...**



**...through
gravel mining
& channel
armoring.**

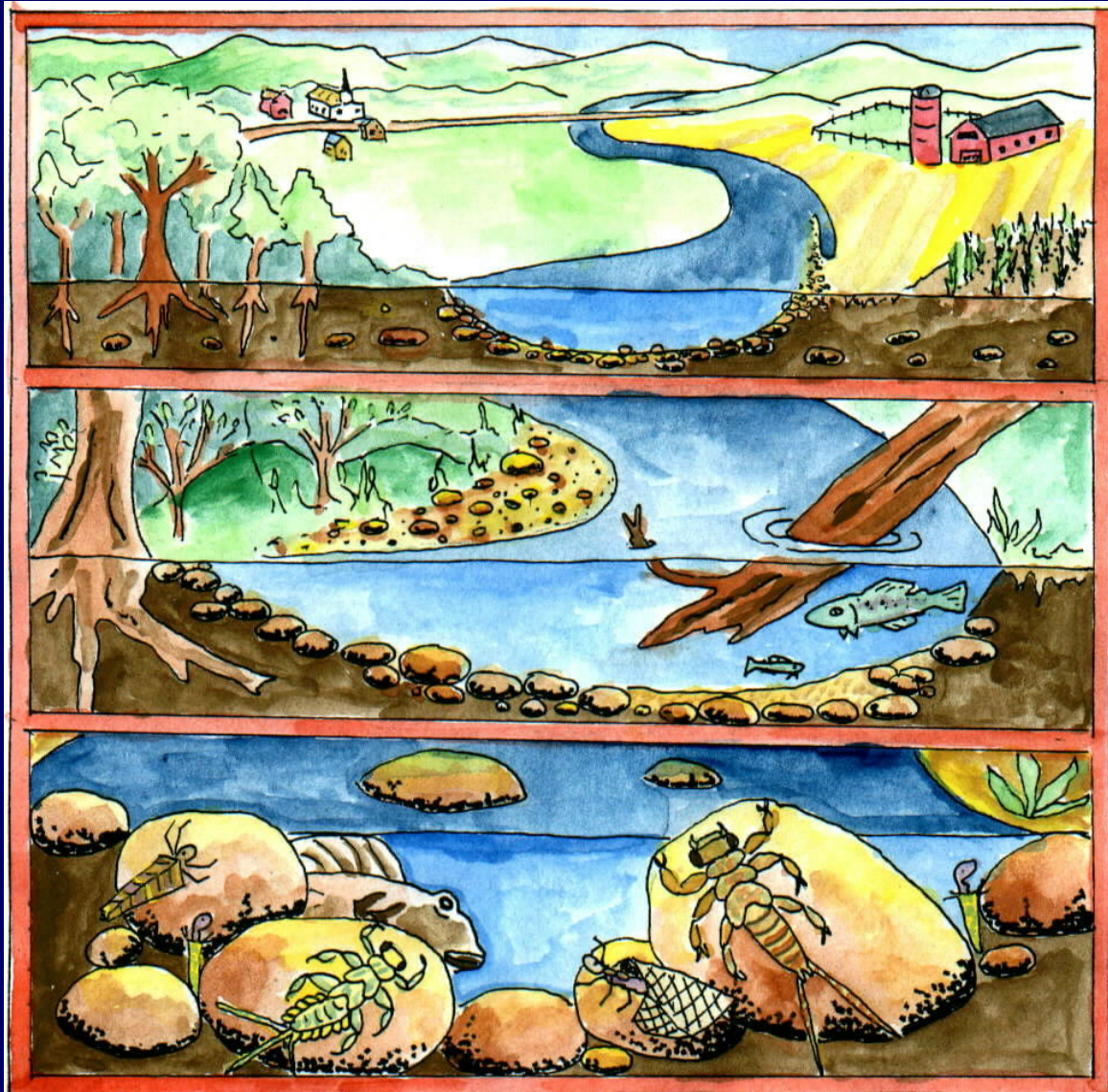
What are the tools we need to break the cycle?

Land use encroachments prevent the maintenance or achievement of the **Equilibrium Condition**



This development is not in the floodway and meets the requirements of the Clean Water Act.

VT ANR Stream Geomorphic Assessment Program



Watershed – Phase 1

Land use, Riparian,
Channel and Floodplain
Modifications

Reaches – Phase 2

Condition - Departure
Adjustments - Evolution
Sensitivity - Rate

Sites – Phase 3

Hydraulics
Sediment Transport

Bridge/Culvert/Dam

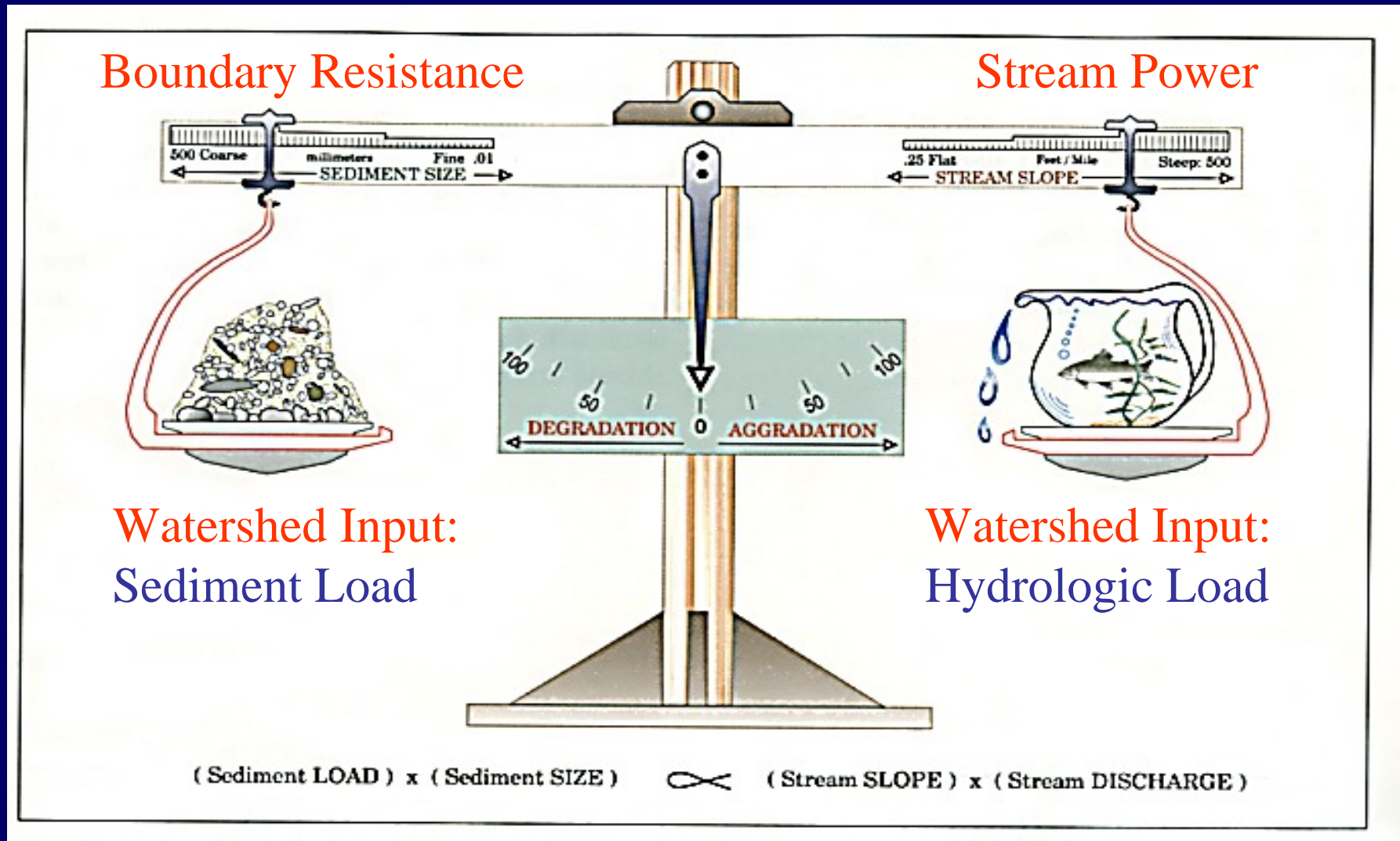
Habitat Assessment

Objectives of Geomorphic Assessment

Identification of:

- **stream condition** a departure analysis of channel form and process
- **adjustment process** or physical change currently underway in the channel
- **sensitivity** of valley, floodplain, and channel to human or natural changes

Stream Equilibrium supports a broad range of ecological processes and services

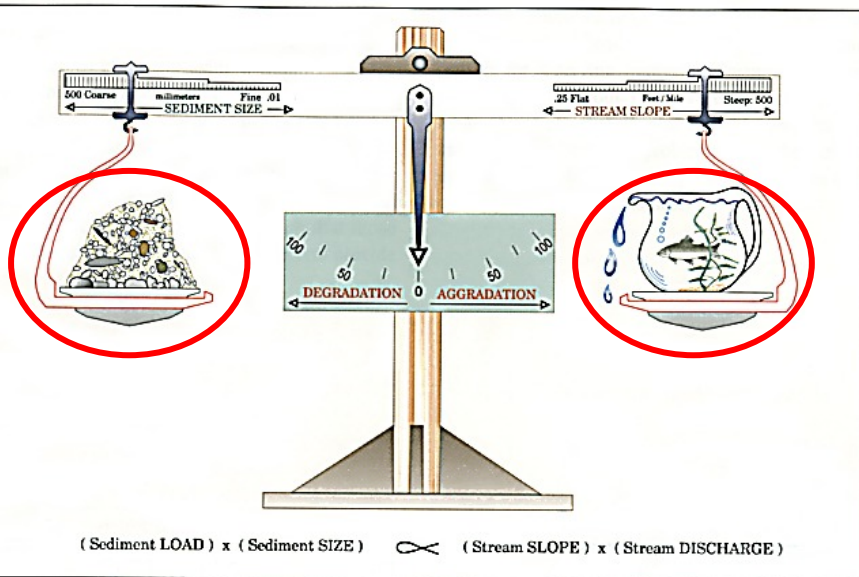
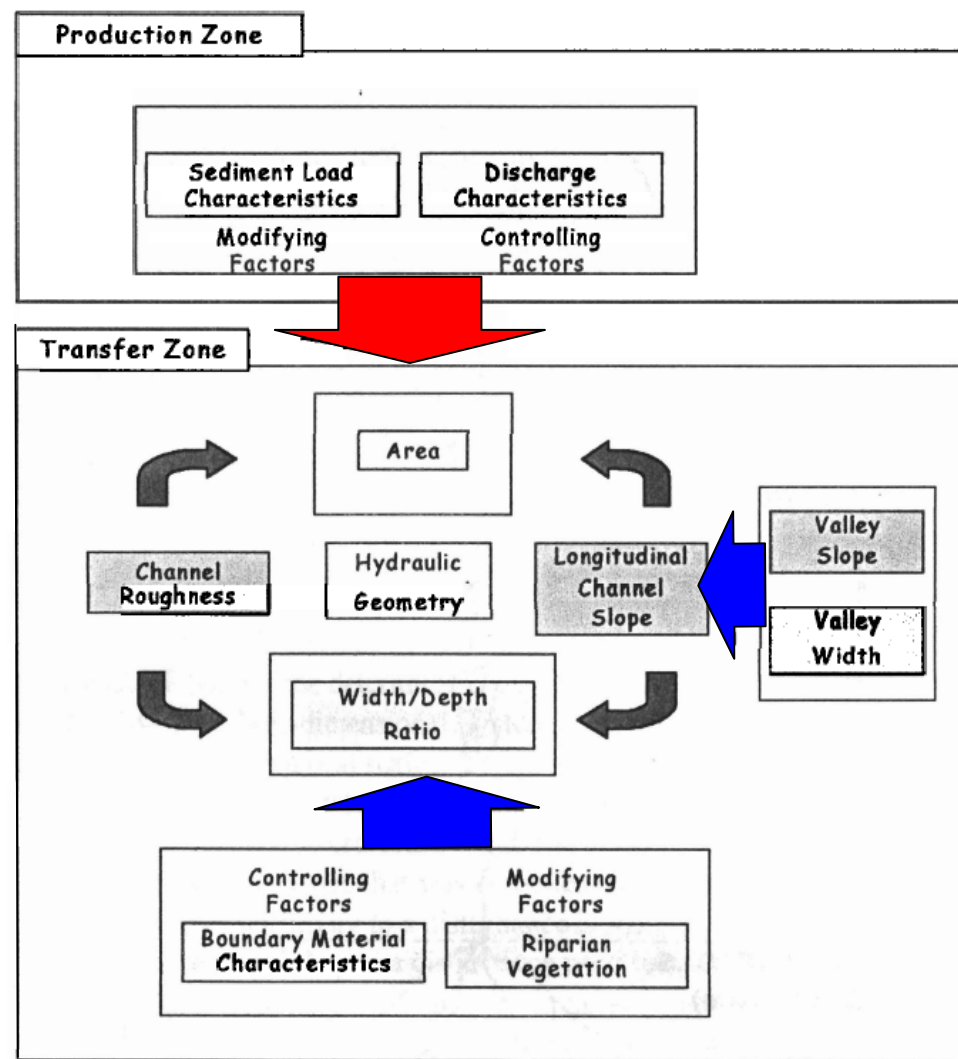


Understanding Channel Adjustment in Response to Watershed Stressors

**Tributary to
Lake Carmi**

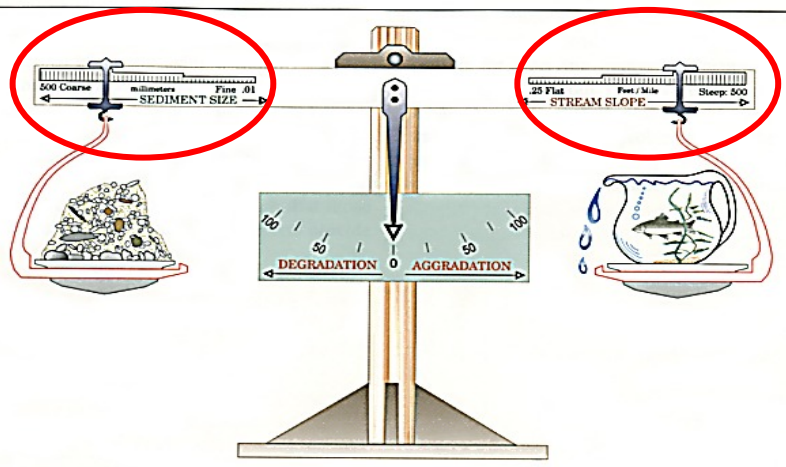
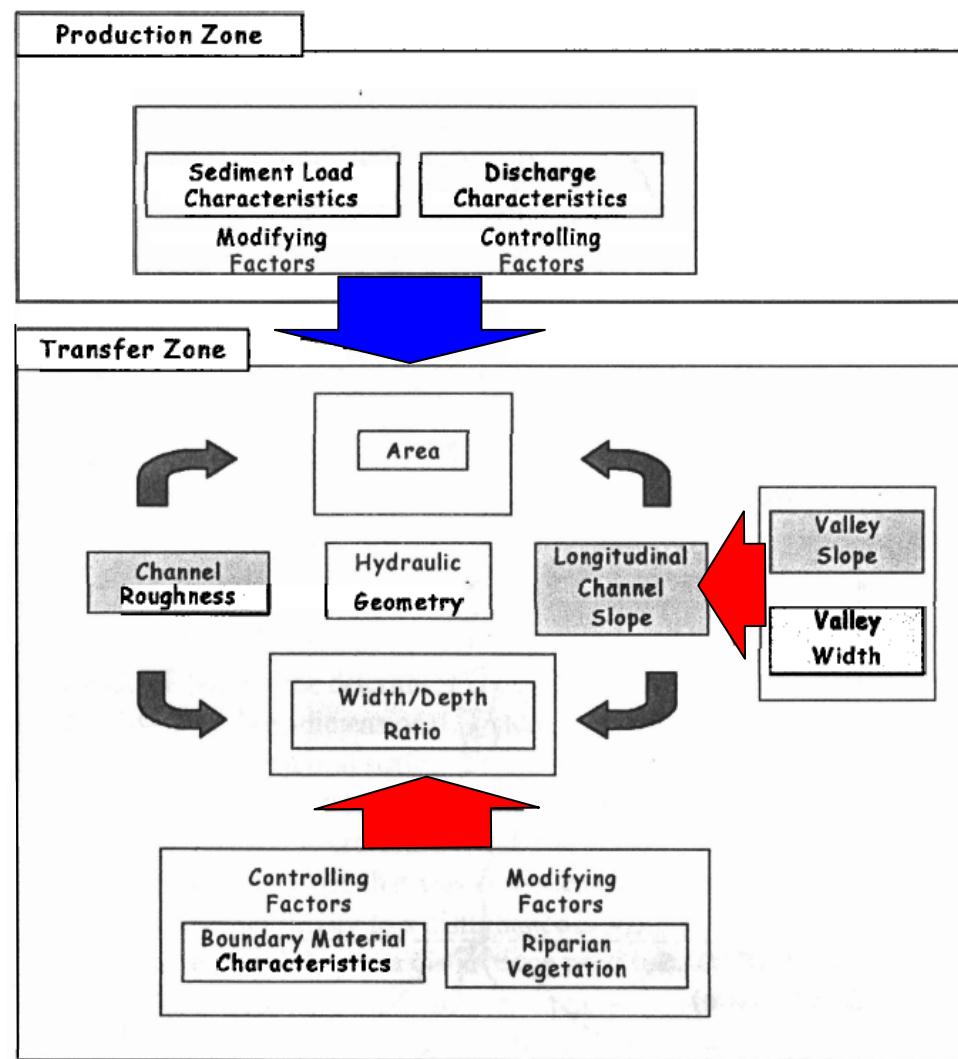


Stream flow and sediment load characteristics are primary controlling factors influencing equilibrium, hydraulic geometry, and stream power.



Watershed-scale Stressors

Depth, slope, and boundary resistance influence hydraulic geometry, stream power, and the sorting and distribution of sediment and organic material.



$$(\text{Sediment LOAD}) \times (\text{Sediment SIZE}) \propto (\text{Stream SLOPE}) \times (\text{Stream DISCHARGE})$$

Reach-scale Stressors

Inherent Sensitivity + Adjustment Processes

- **Sediment Supply**
- **Transport Capacity**
- **Bed and Bank Materials**
- **Channel Evolution Stage**
- **Ongoing Major Adjustments**
- **Ecological Process Changes**



Alluvial Fans as example of inherently sensitive stream type

- Sediment naturally deposits at locations of significant decrease in valley slope.
- Depositional Areas / Alluvial Fans.

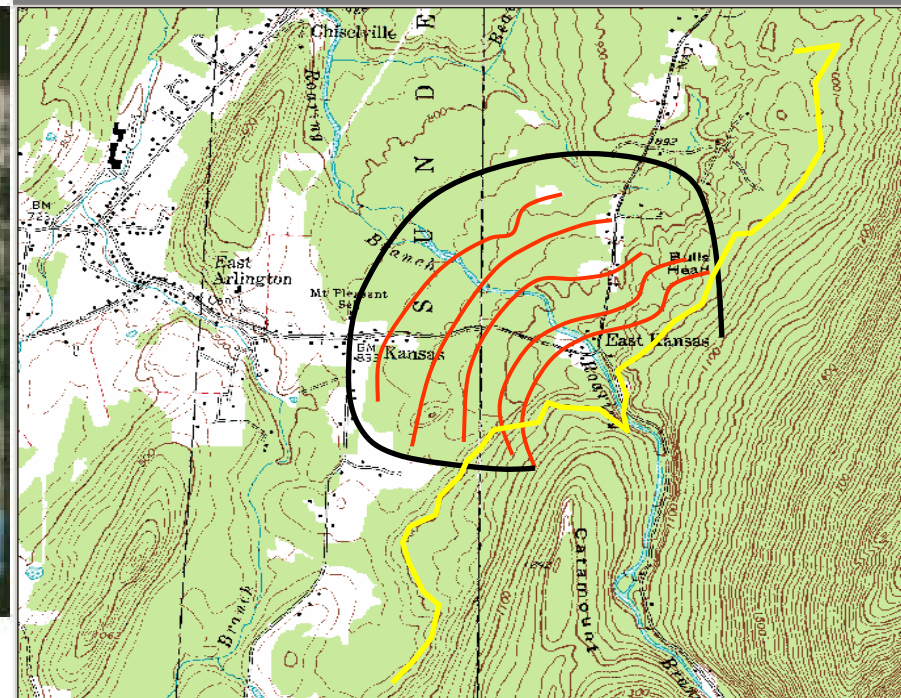
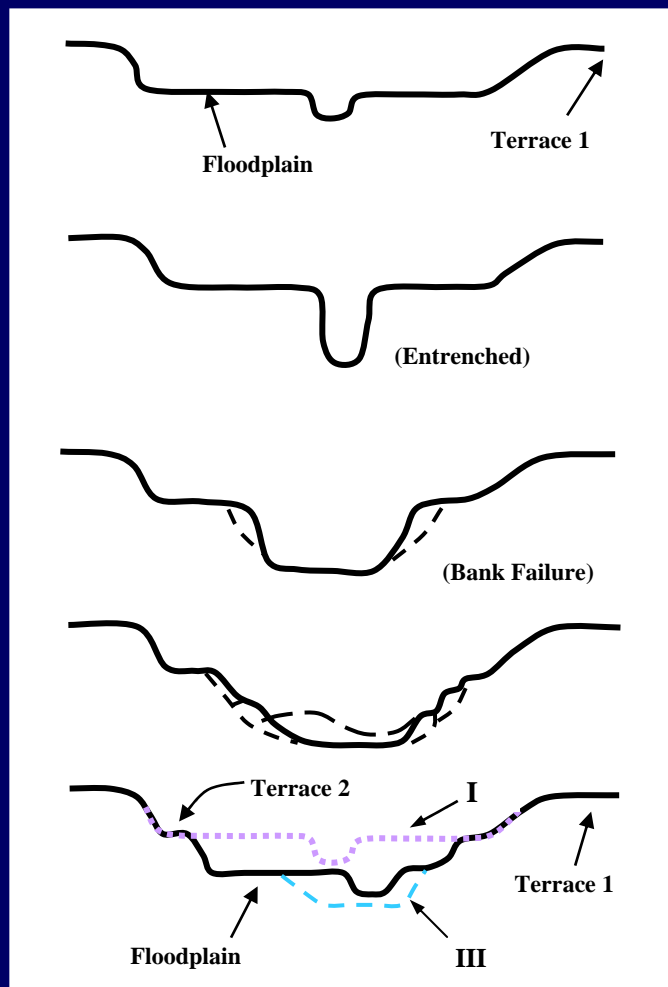
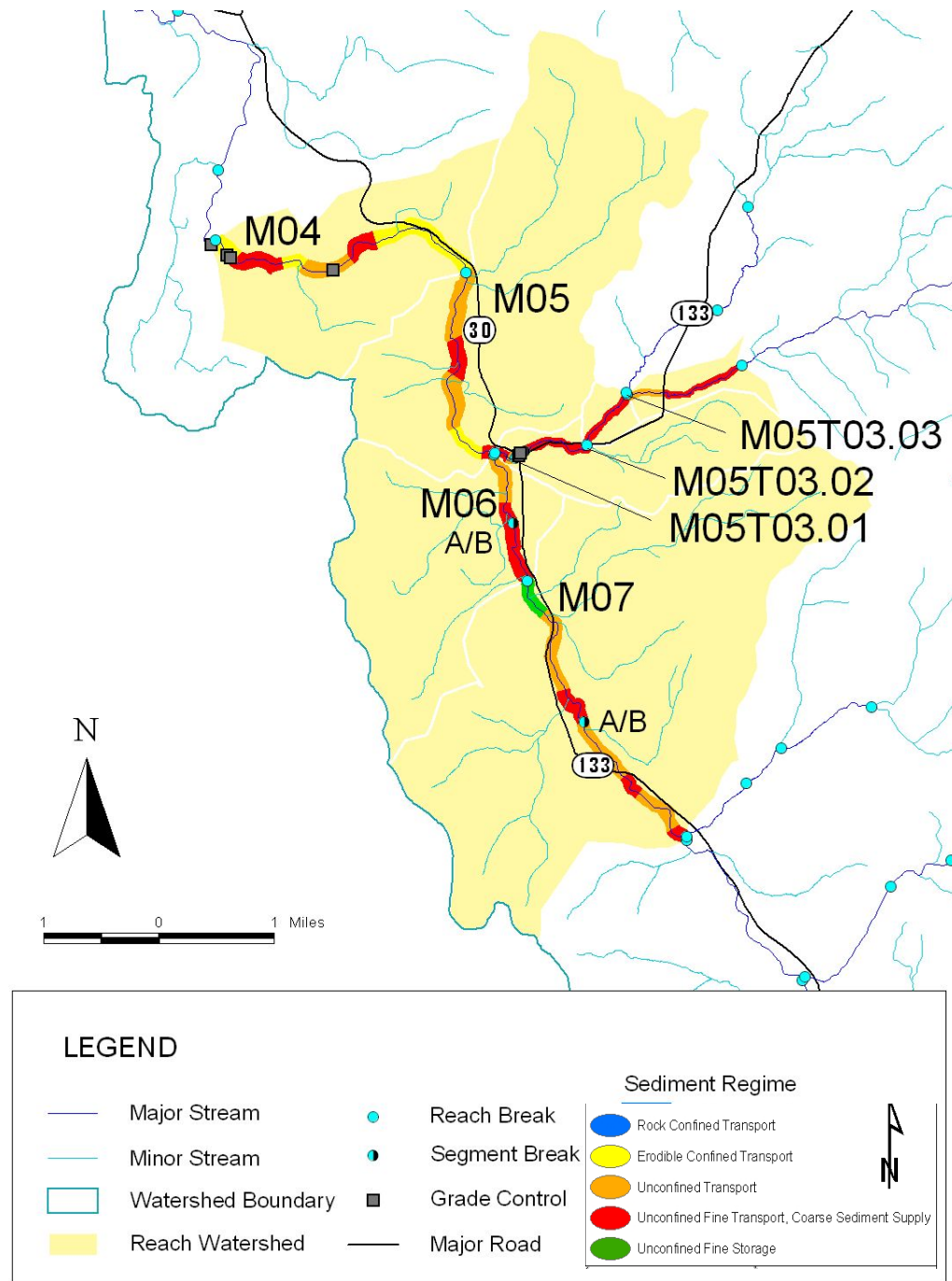


Figure 1.1 A small alluvial fan deposited from a steep tributary due to a change in slope.

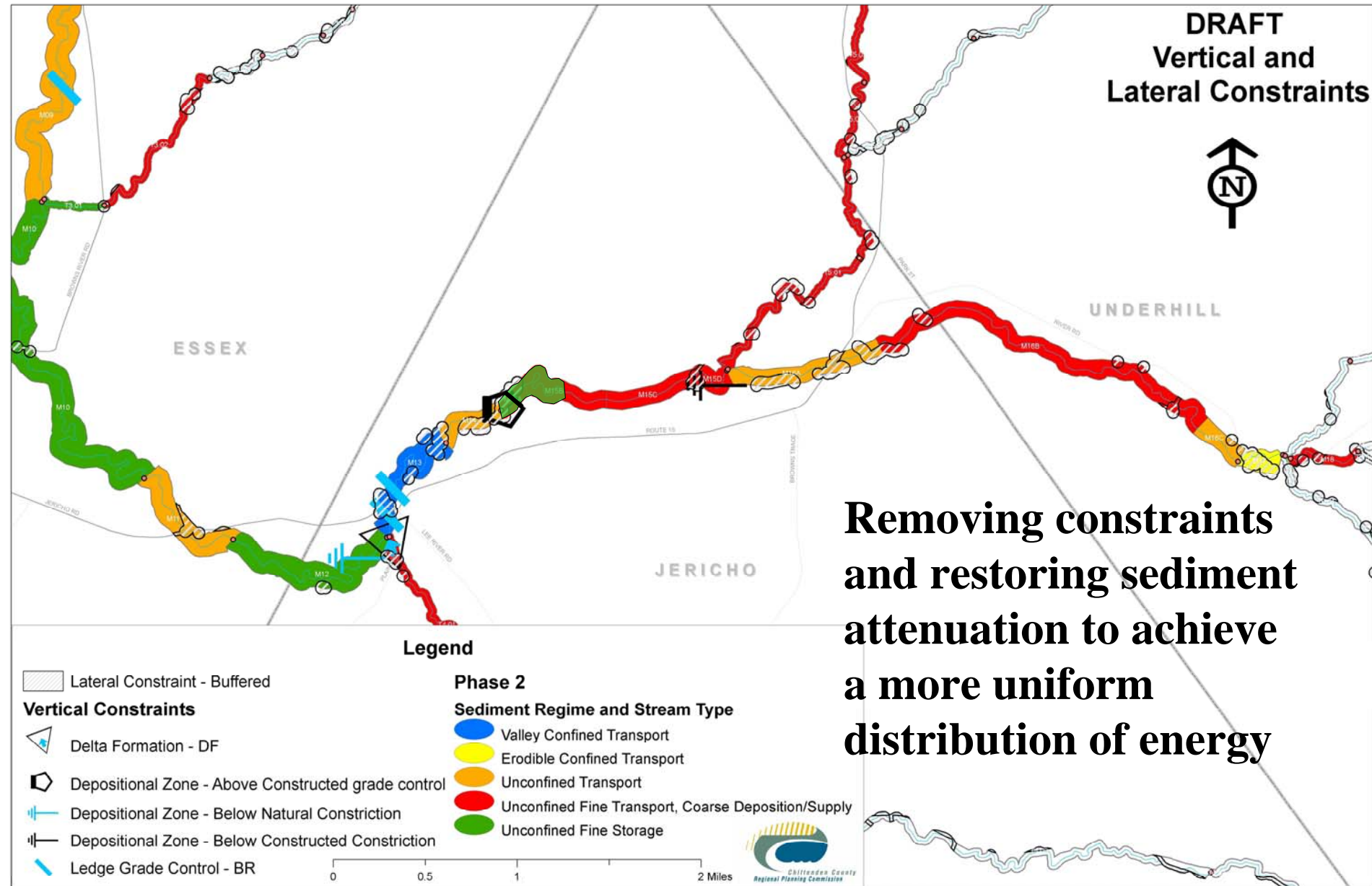
Channel Evolution Model used to indicate sediment storage and transport



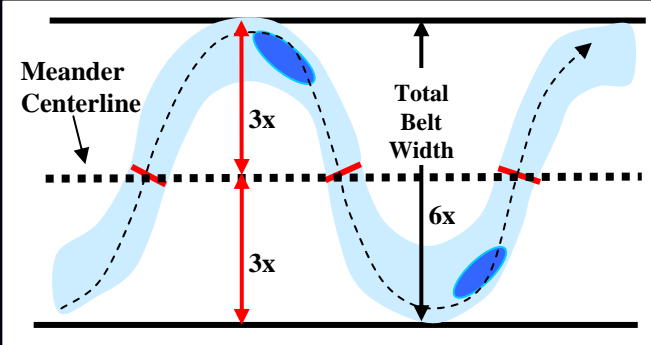
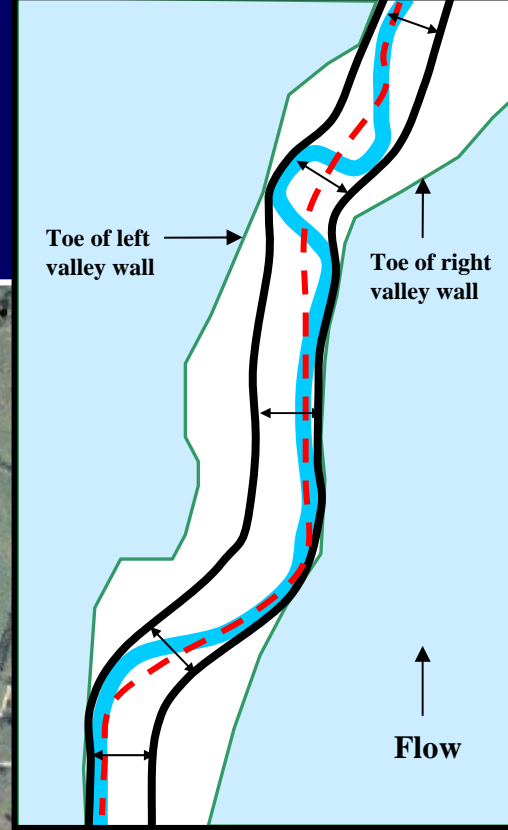
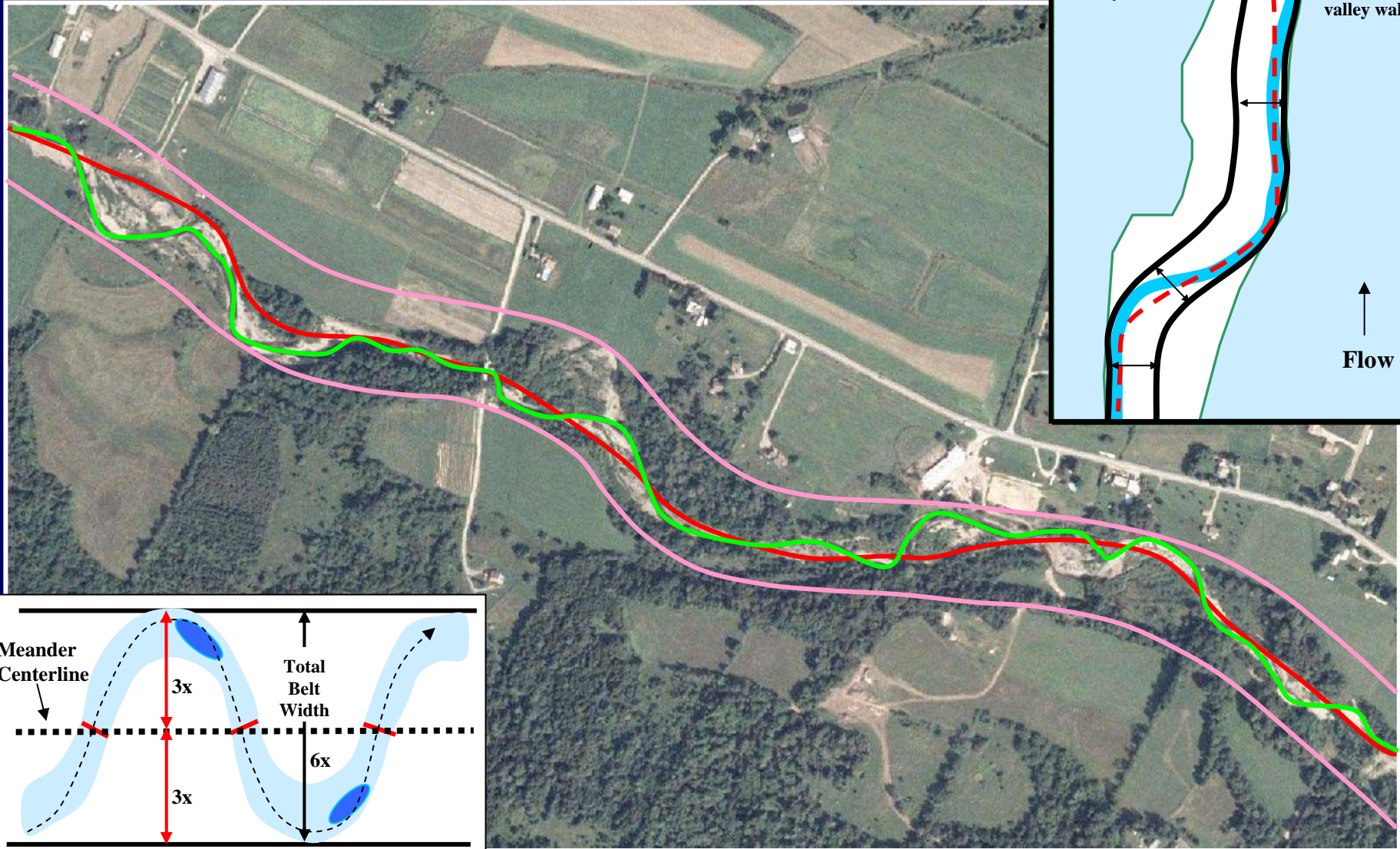
Map Courtesy of Kristen Underwood
and South Mountain Research



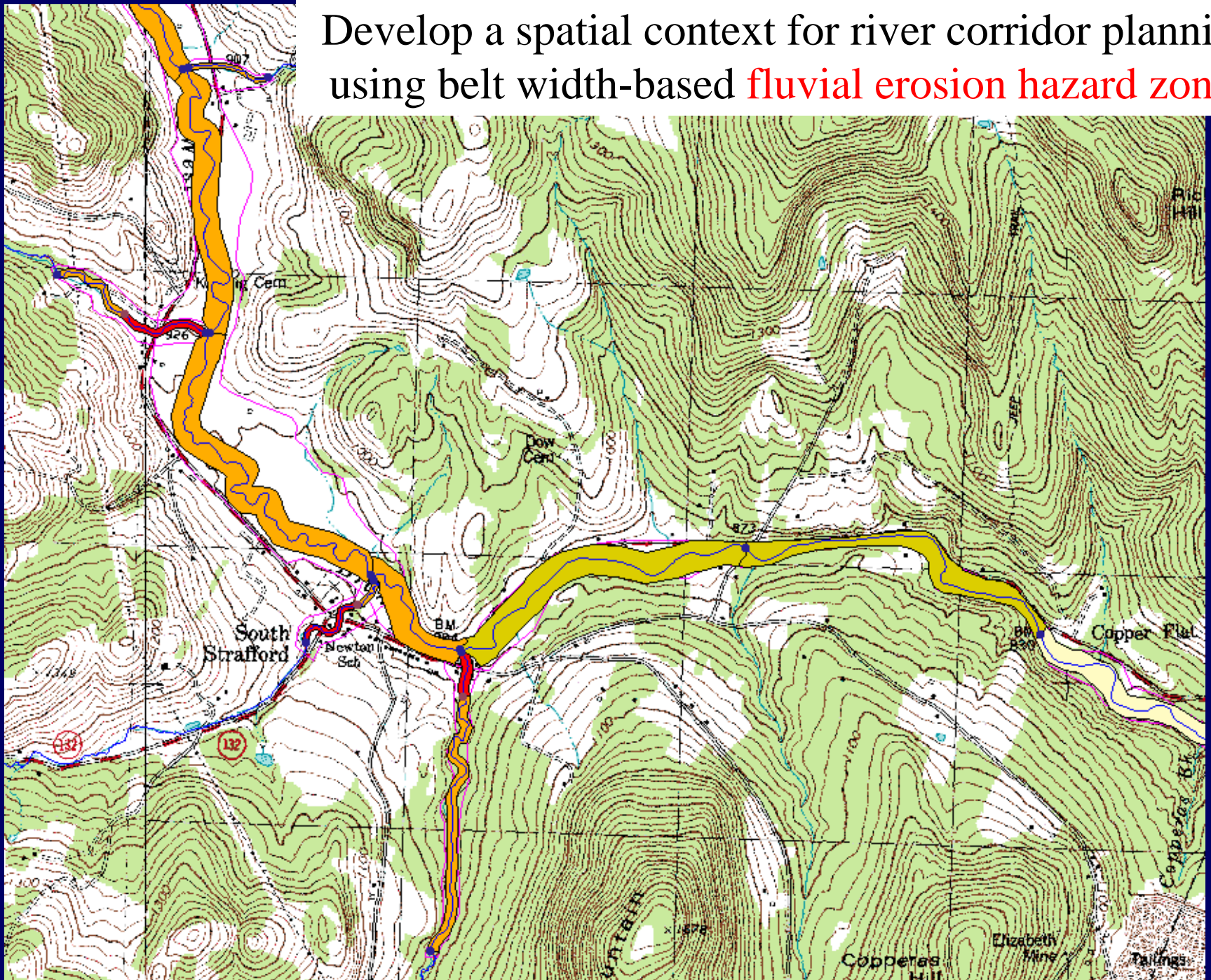
Vertical and lateral constraints on the sediment regime



River Corridors based on derived belt width, valley confinement, erosion and deposition features, and active vertical adjustments



Develop a spatial context for river corridor planning using belt width-based **fluvial erosion hazard zones**



River Corridor Planning



Evolution Stage II – III
Incision to Widening



Identify project and strategies to address sediment regime imperatives in context of vertical and lateral channel constraints and...



Stage III – IV
Widening to
Stabilizing

... ongoing
channel
adjustments
along the
longitudinal
profile.



Active Flood Plain Restoration

Black Creek, Fairfield, VT



Lateral connectivity to riparian areas, floodplains and wetlands lost when channels become incised and bermed



Working to link geomorphic assessments with habitat data:

Extensive alteration of ecological processes in / between wetland and freshwater systems, notably the change in **water, sediment, and nutrient storage patterns, has led to the loss of cover, feeding, and reproductive habitat.**

Assess Sediment and Debris Sorting and Distribution

A photograph of a stream flowing through a wooded area. The stream bed is composed of numerous smooth, rounded rocks of various sizes, ranging from small pebbles to larger boulders. The water is clear and flows over the rocks, creating small rapids and white water. The banks are lined with green grass and fallen branches, some of which are partially submerged in the water. The background shows a dense forest of trees with green foliage.

Vermont's many incised plain bed streams lack a diversity of hydraulic units

Aggradation

Losses in the quantity and quality of habitat due to changes in

Hydrology, Sediment Loading, and Channel Hydraulics



Degradation

Watershed, channel, and floodplain modification have changed velocity/depth patterns and the size, quantity, sorting, and distribution of sediment & organics

Habitat assessments evaluate river and riparian components of cover, feeding, and reproductive habitat



As created and maintained by the physical regimes of:

- **Hydrology**
- **Sediment**
- **Large wood and organics**
- **Lateral and longitudinal connectivity**
- **Temperature**

Exposure to devastating flood events is increasing due to intensifying land development in susceptible areas and by global climate change.



Encroachments on a straightened and incised channel that must now be maintained as a channelized river transferring its erosive energy and sediment load to downstream reaches.

Moving away from the concept that rivers are static systems. Repeated and costly efforts to control long lengths of rivers as static channels is proof that channelization with structural measures is an unsustainable public policy.



Conservation programs spend public funds trying to protect private property and improve water quality, when in the end, neither are served.

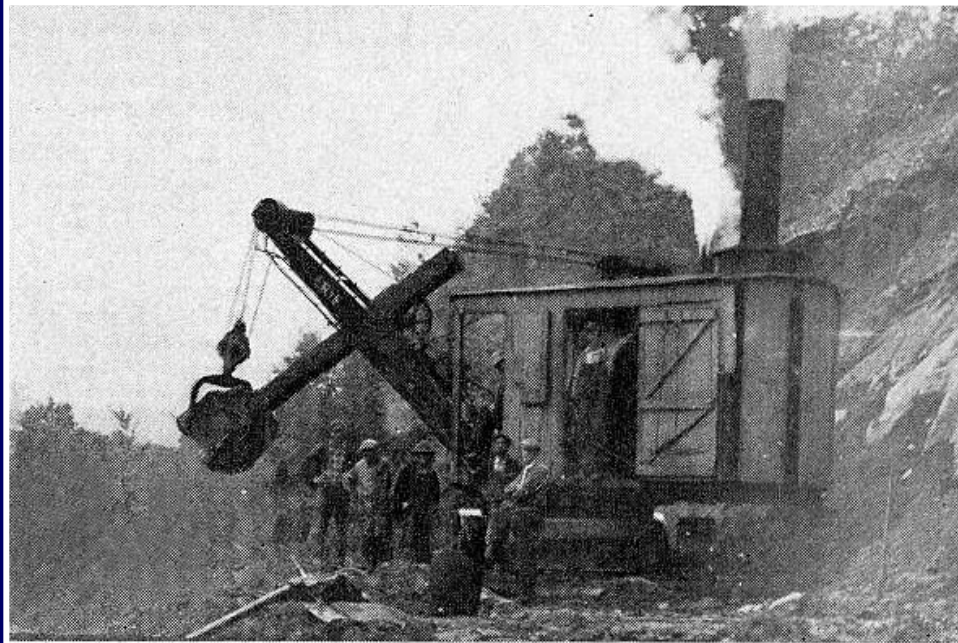
Vermont River Management

Chasing
Rivers



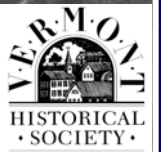
Moving away from projects that miss opportunities to invest public \$\$ in the long-term resolution of systemic problems

Dedicated “restoration” of the modified condition



THE ANSWER

Randolph, VT



Consequences of Failing To Protect River Corridors from Continued Encroachments:

- Local governments and individuals increasingly vulnerable to disastrous flood and erosion loss
- Upward spiral of state and municipal expenditures for flood and fluvial erosion hazard recovery and mitigation
- Ever increasing discharges of sediment and nutrients into downstream receiving waters
- Degradation of flood plain agricultural soils
- Degradation of aquatic and riparian habitats, ecological diversity, water quality and human recreational use
- The only remaining option to be implementation and maintenance of river controls (channelize, dredge, and armor) at enormous, unsustainable public cost.