Stream Stabilization:

Achieving Diverse Goals Associated with Stormwater Conveyance in the Urban Environment

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Presentation outline

<u>Watersheds</u>

- *Water cycle and the urban watershed*
- *Rate and volume impacts to streams*
- *Stormwater solutions to consider*

<u>Streams</u>

- *The geomorphology of urban streams*
- *Common problems*
- *Solutions to consider*

Stormwater conveyance goals

- Infiltrate when possible – Increase base flows
- Detain if not possible - Reduce peak flows
- Reduce flooding
- Improve stream health
  - *Improve water quality*
  - *Improve habitat*

Stormwater conveyance goals

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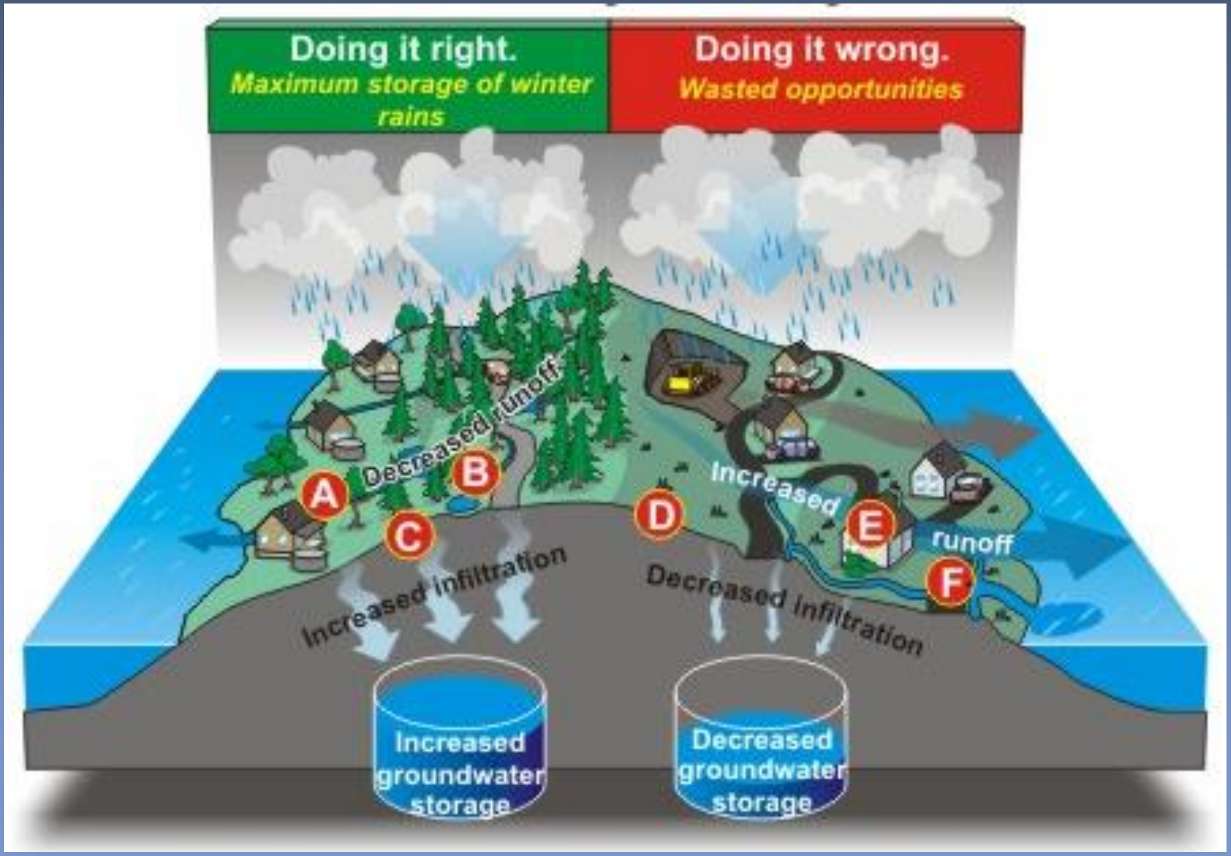
We are creating <u>facsimiles</u> of healthy systems, but are prevented from restoration by constraints of the urban environment

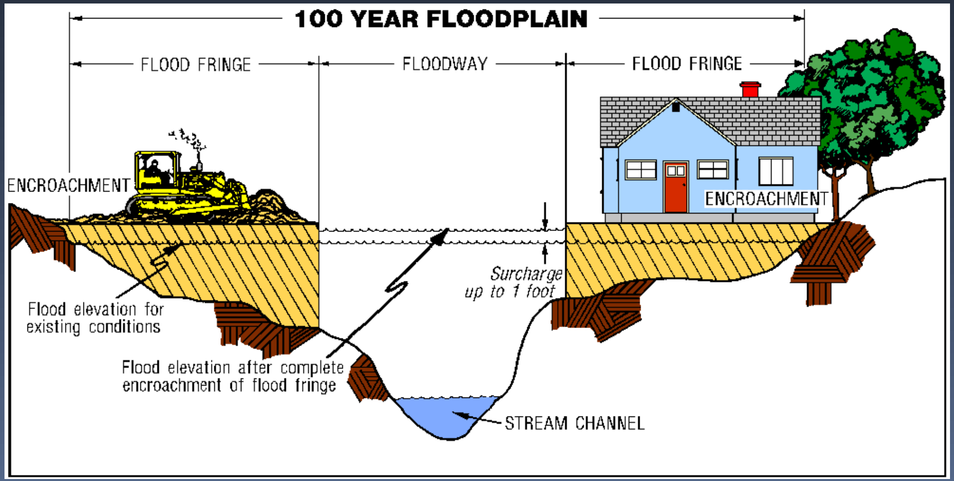
THE WAY IT WAS

- *Pervious watersheds*
- *Significant infiltration/retention*
- *Sinuous stream channels*
- *Native soil and vegetation within system*

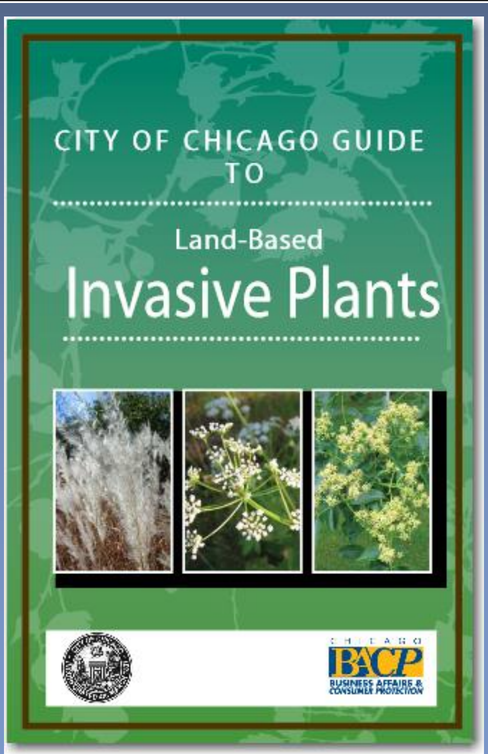


The Way it Is: Urban watershed impacts

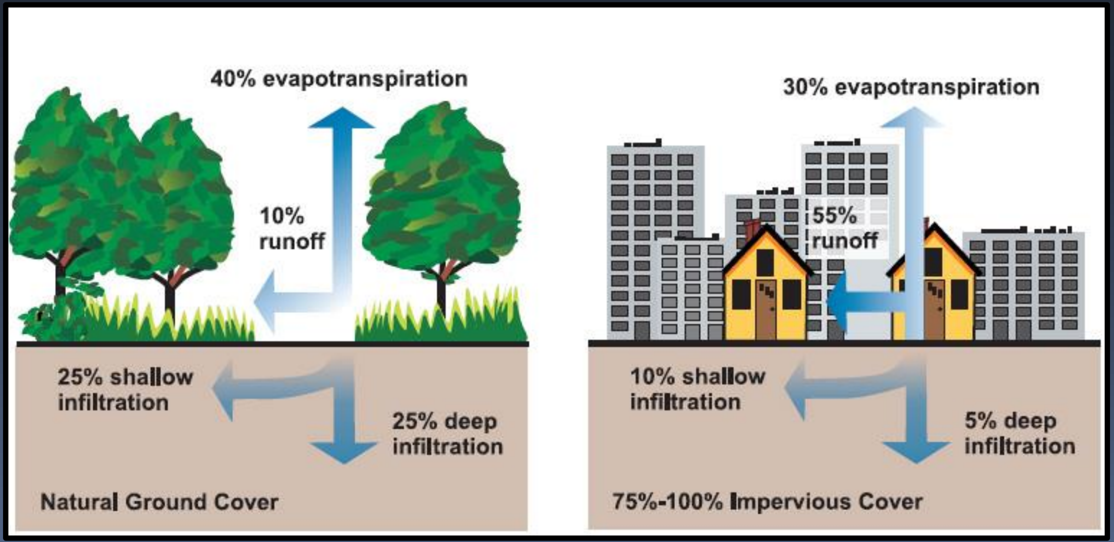
Pavement

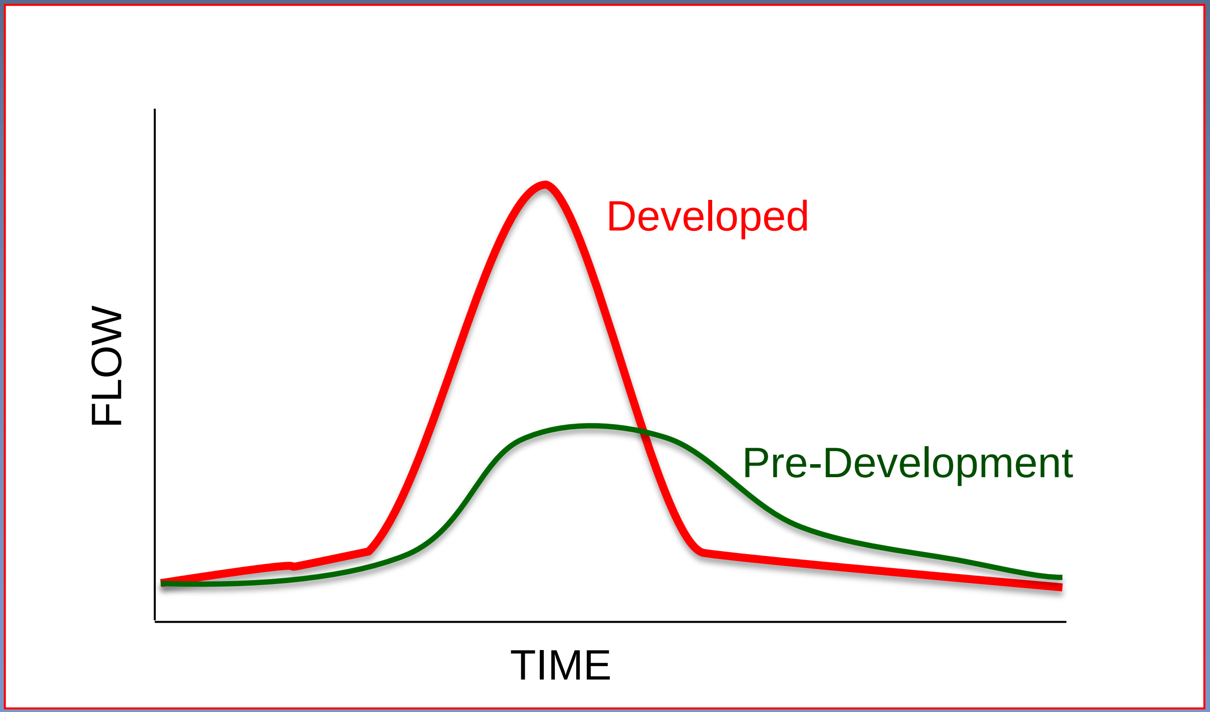


Channelization and hard armor



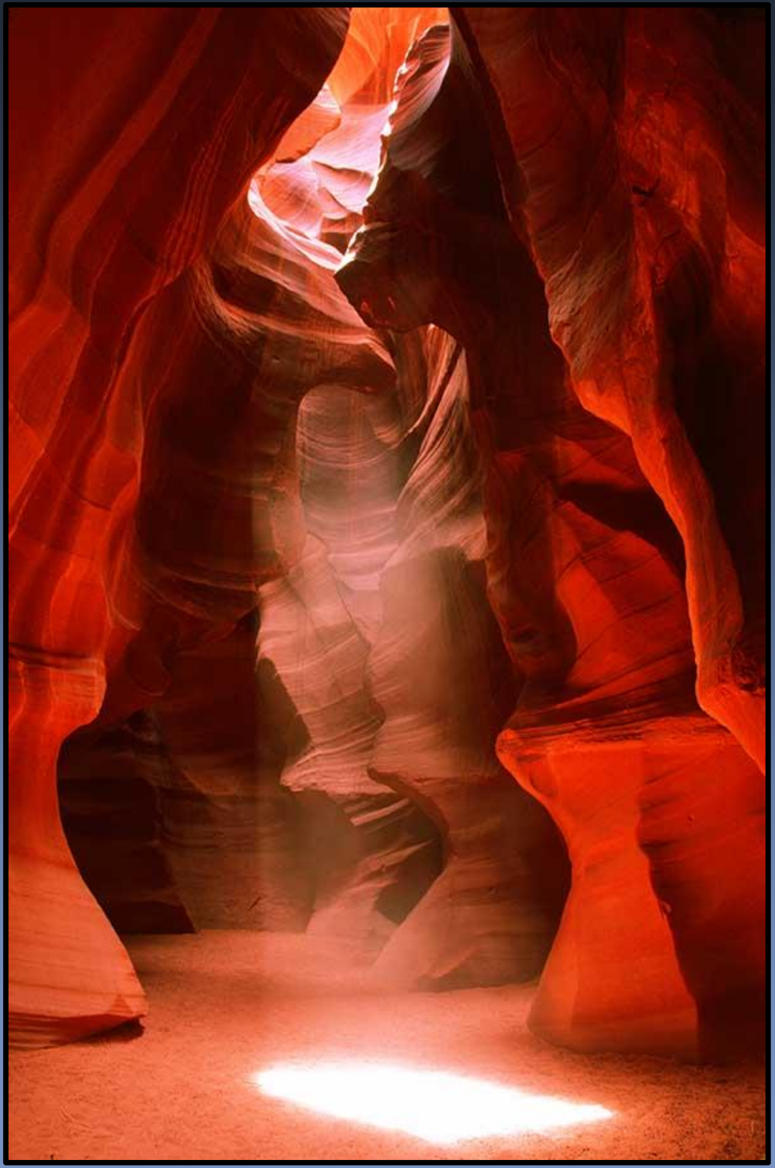
Hydrologic impacts of Impervious cover





Urban hydrology

- *Urban streams act somewhat like desert streams - Low baseflow and high flood flows*



Antelope Canyon, AZ

Why is stream health important?

- Indicator of what we've lost:
  - Historically intolerant biotic communities have been converted to communities tolerant of sediment and pollution
  - Carp or Trout?
- Good water quality (60% depend on surface water for drinking water)

Impact to urban streams and property

- *Soil erosion – reduced water quality and reduction in ecological function*
- *Nutrient loading – downstream algae blooms and reduction of instream ecological diversity*
- *Erosion threatens private and public property*
- *Flooding threats*
- *Impacts to freshwater and coastal marine ecology*

Infrastructure at Risk




Streams at Risk

Impact of no action

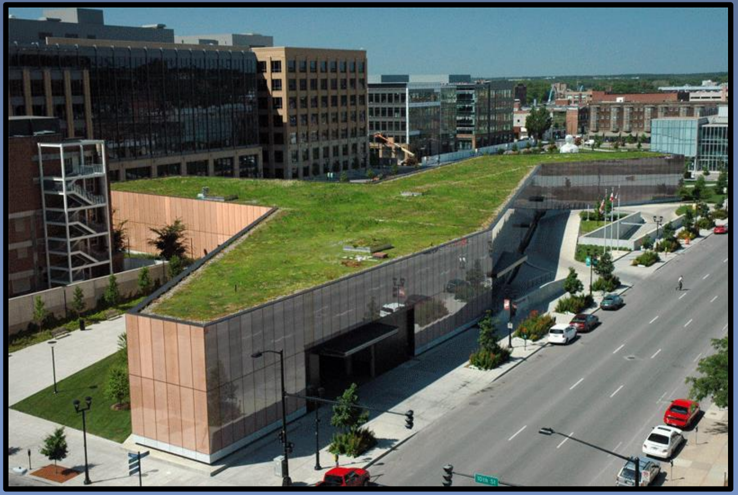
Impact of misapplied action

Achieving primary Stormwater Management Goals

- Retention / Detention
- Infiltration
- Green Infrastructure
  - Roofs, swales, raingardens, rainbarrels, etc.

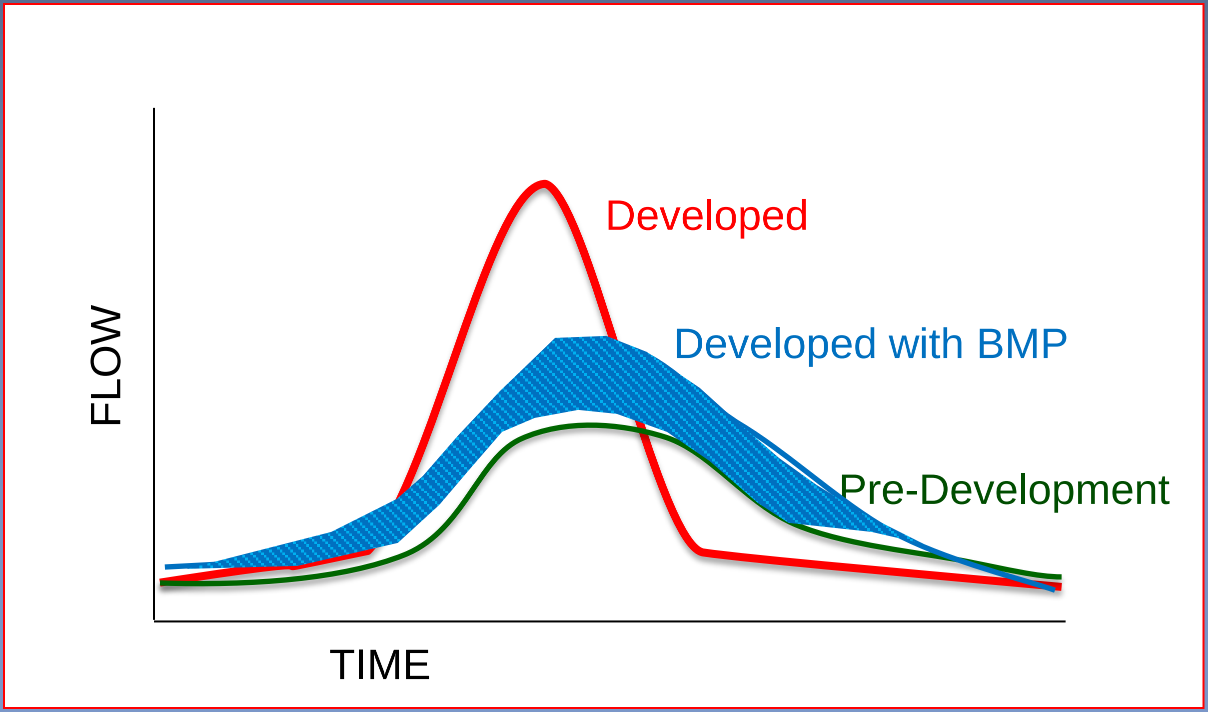
Stormwater Management Options

Stormwater Management Options



Stormwater Conveyance Goals

- *Primary*
  - *Watershed BMPs can mitigate for landuse changes*
  - *We cannot likely return to pre-development hydrology*
- *Secondary – Implications for streams and rivers*



Part 2
Achieving stream and riparian goals

Fundamentals of urban stream geomorphology

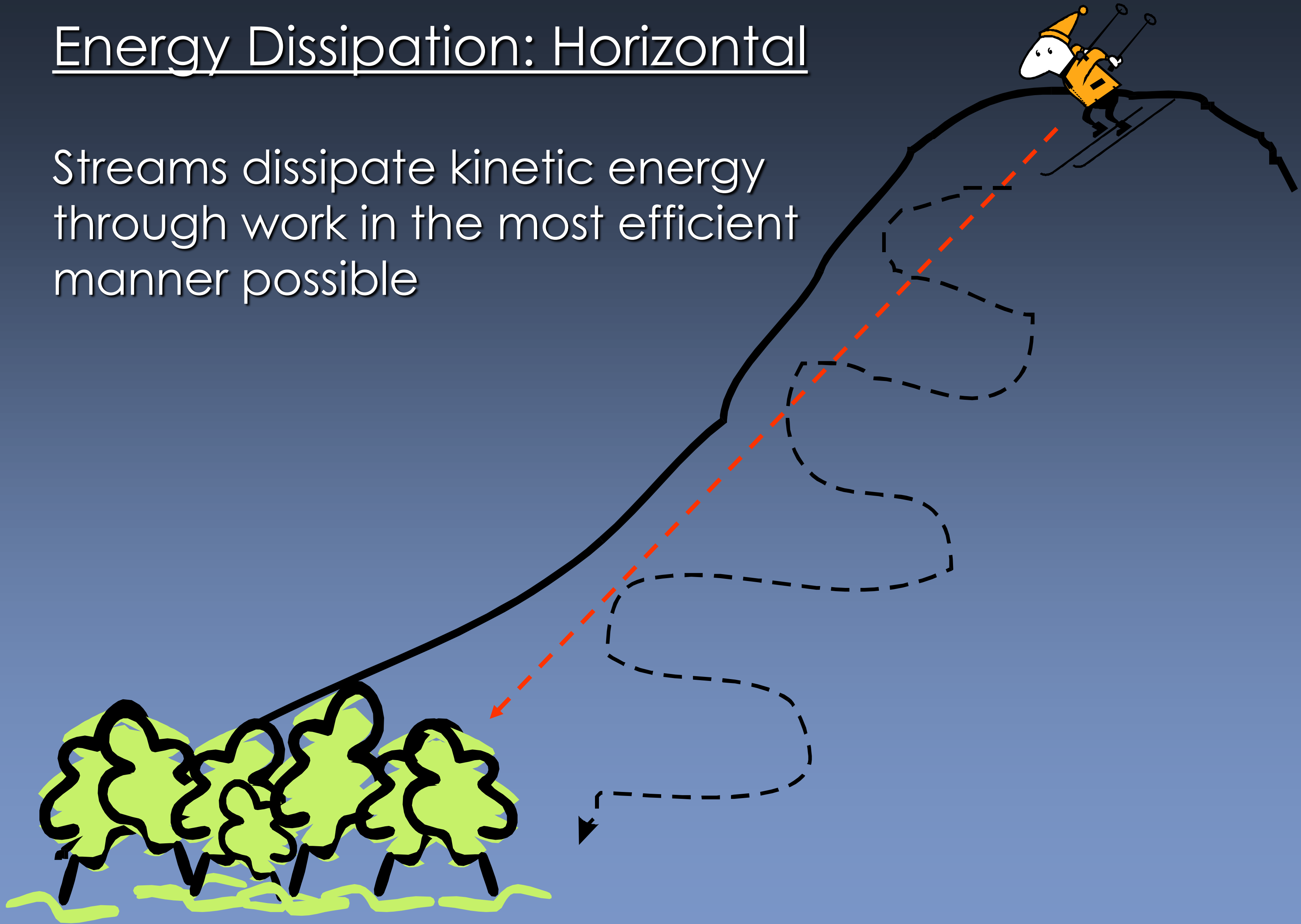
<u>Energy dissipation</u>

- *Streams start with potential energy*
- *Potential energy becomes kinetic energy and streams dissipate this energy in the form of work (moving water and sediment)*

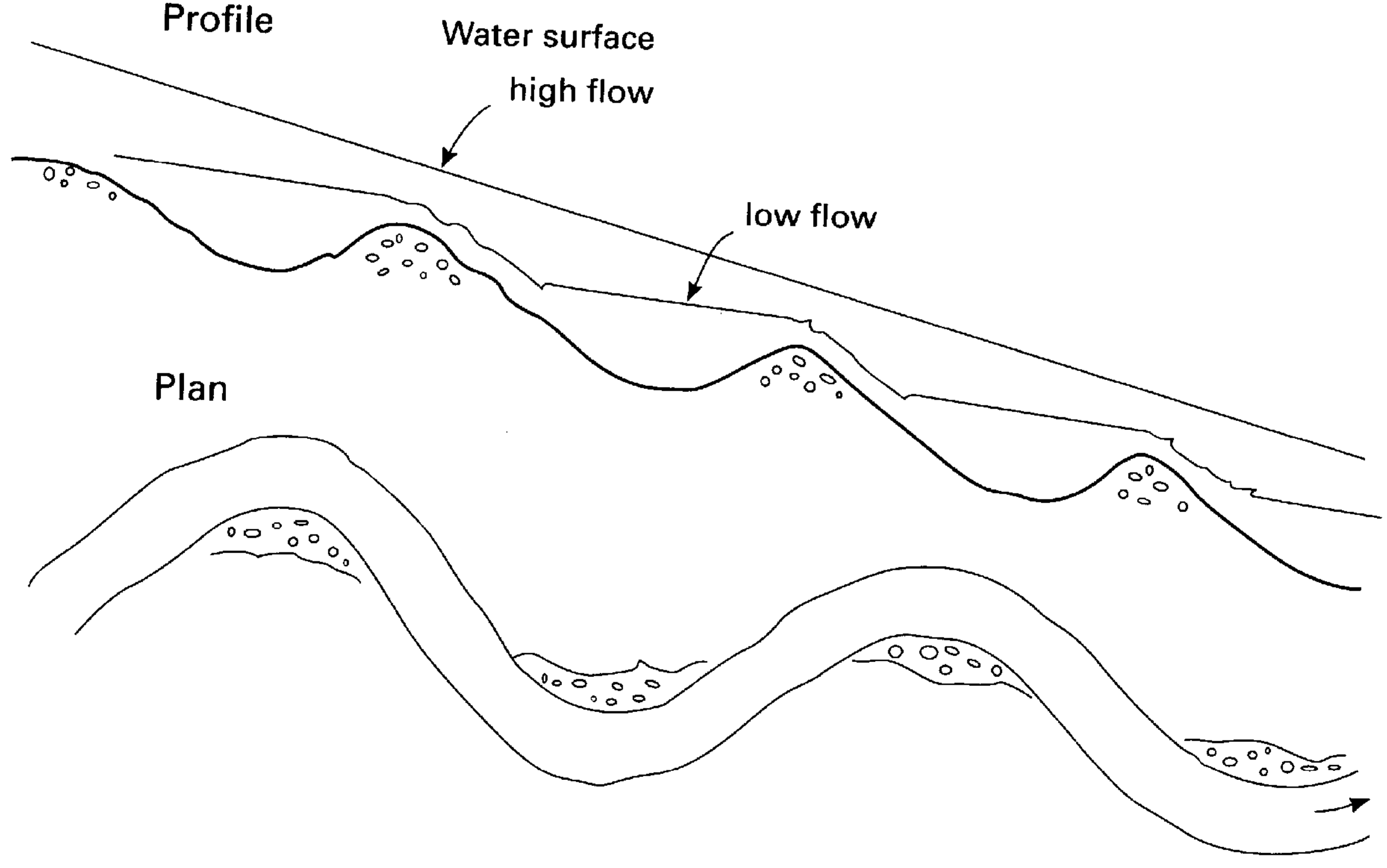
- *Linear systems dissipate energy in two principle ways:*
  - *Sinuosity (meandering)*
  - *Gradient (riffles, steps, waterfalls, headcuts)*

Energy Dissipation: Horizontal

Streams dissipate kinetic energy through work in the most efficient manner possible



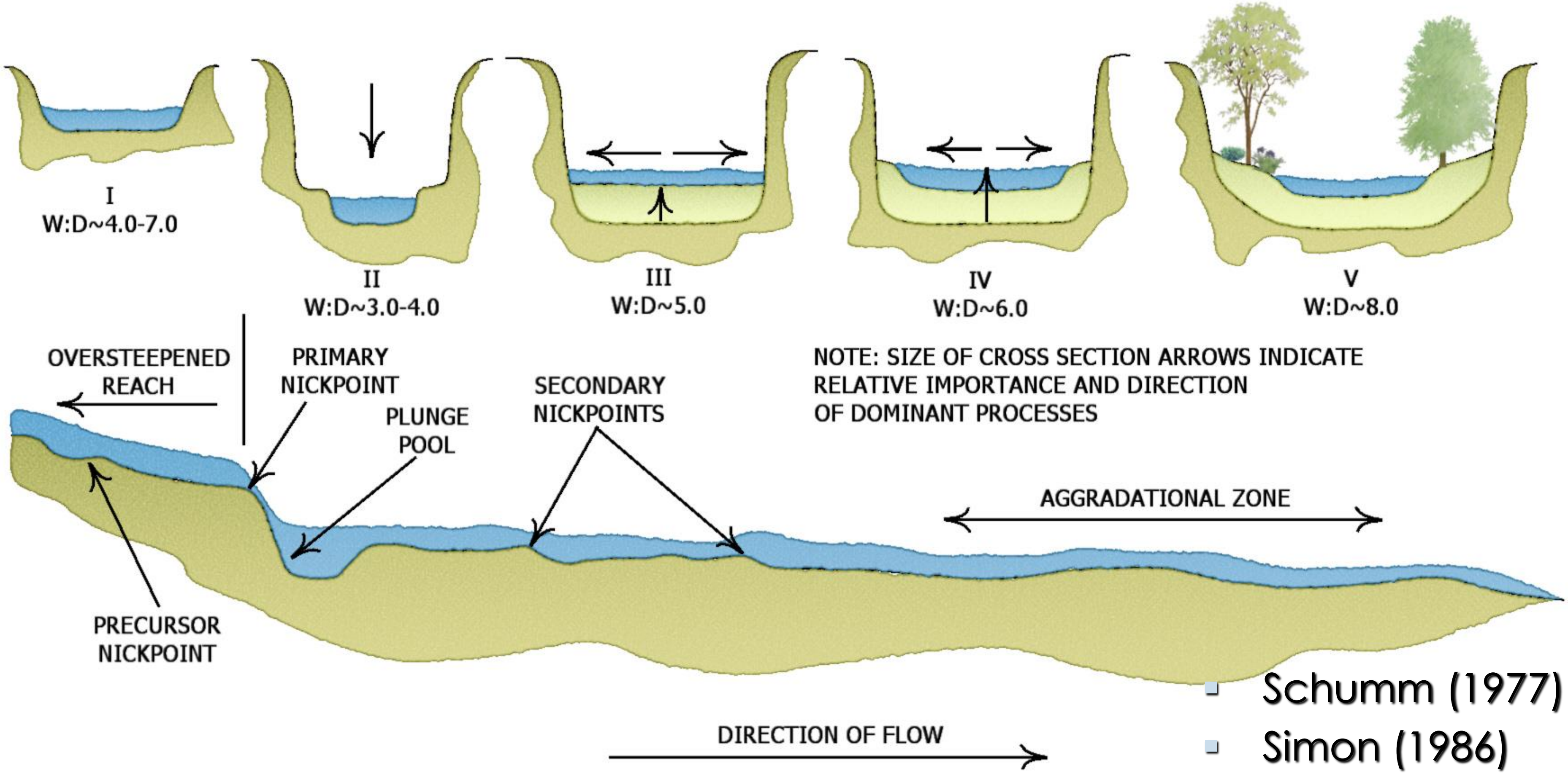
Energy Dissipation: Vertical



Why understand urban stream geomorphology?

- *Changes in hydrology = changes in stream power and form*
- *Understanding these changes can help predict when and where stormwater BMPs should be implemented*
- *Designing a watershed assessment around geomorphology helps target funding*

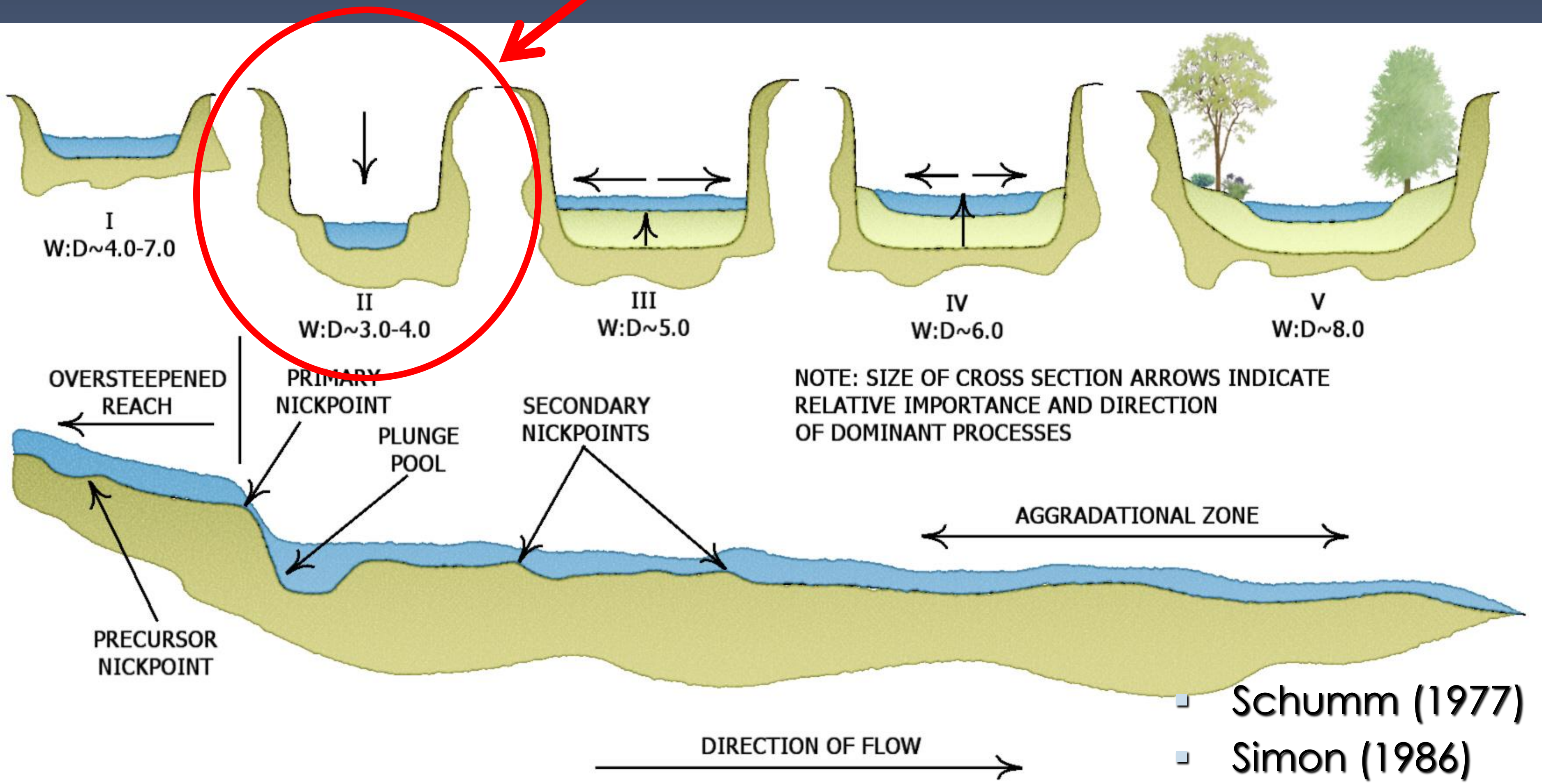
Channel Evolution and instability



- Schumm (1977)
- Simon (1986)

Channel Evolution and Instability

As a <u>temporal</u> model, channel evolution can help pinpoint when and where rapid change is going to occur



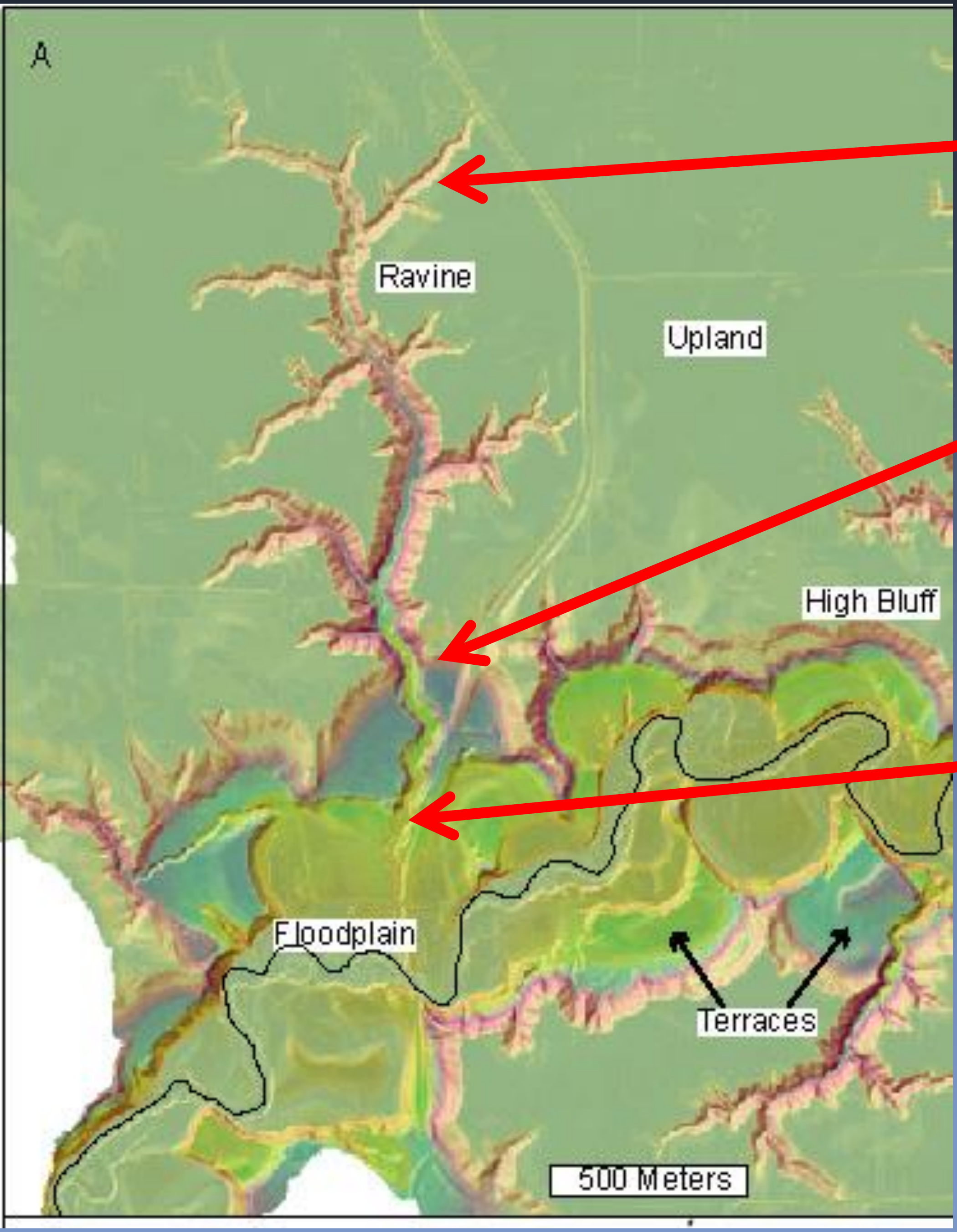
- Schumm (1977)
- Simon (1986)

Impacts: Incision

Impacts: Incision and aggradation

- Upstream incision often accompanied by downstream aggradation





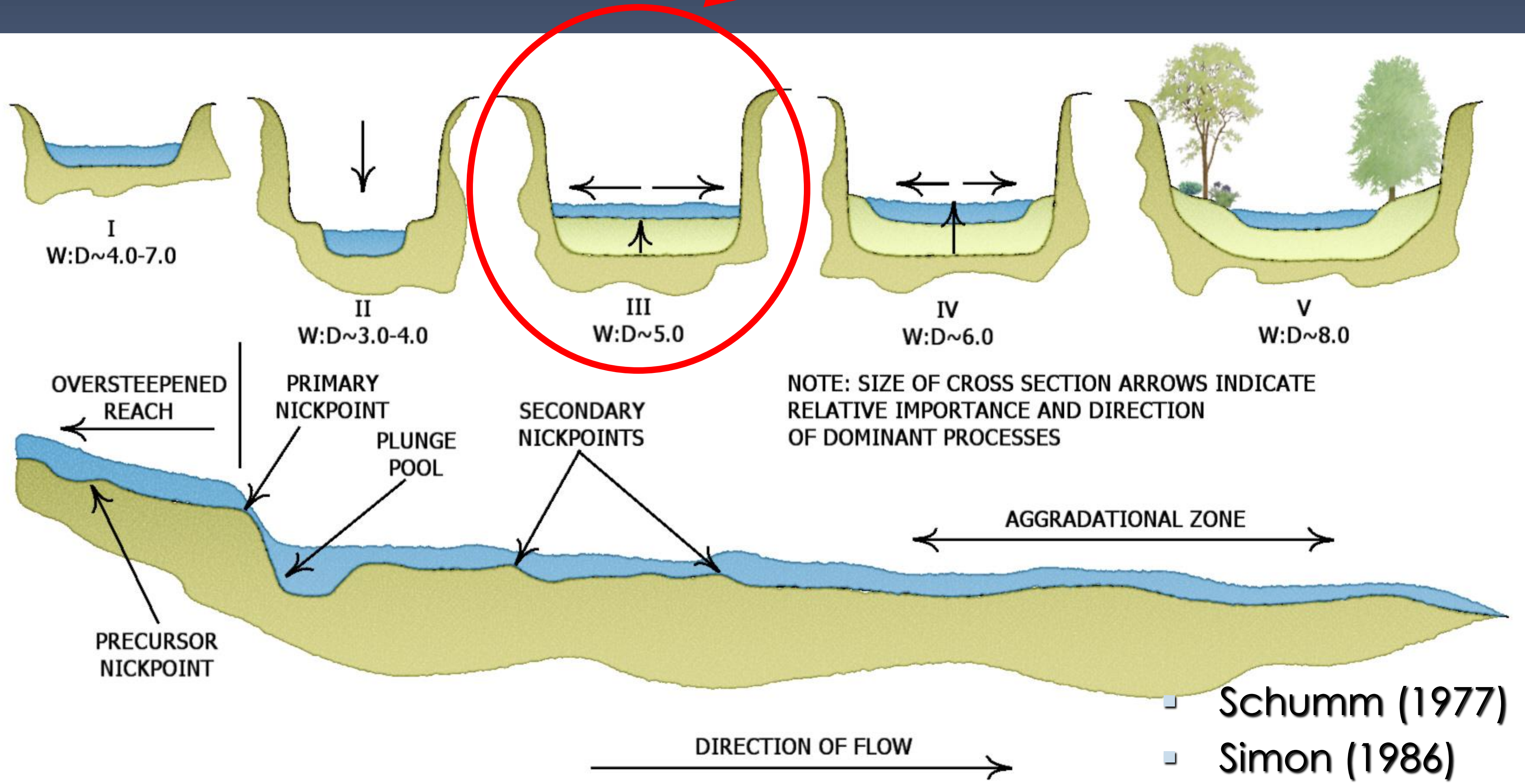
Stage 2 - incision

Stage 3 - widening

Stage 4 - recovery

CHANNEL EVOLUTION AND INSTABILITY

As a spatial model, channel evolution can help pinpoint where lateral erosion is going to occur



- Schumm (1977)
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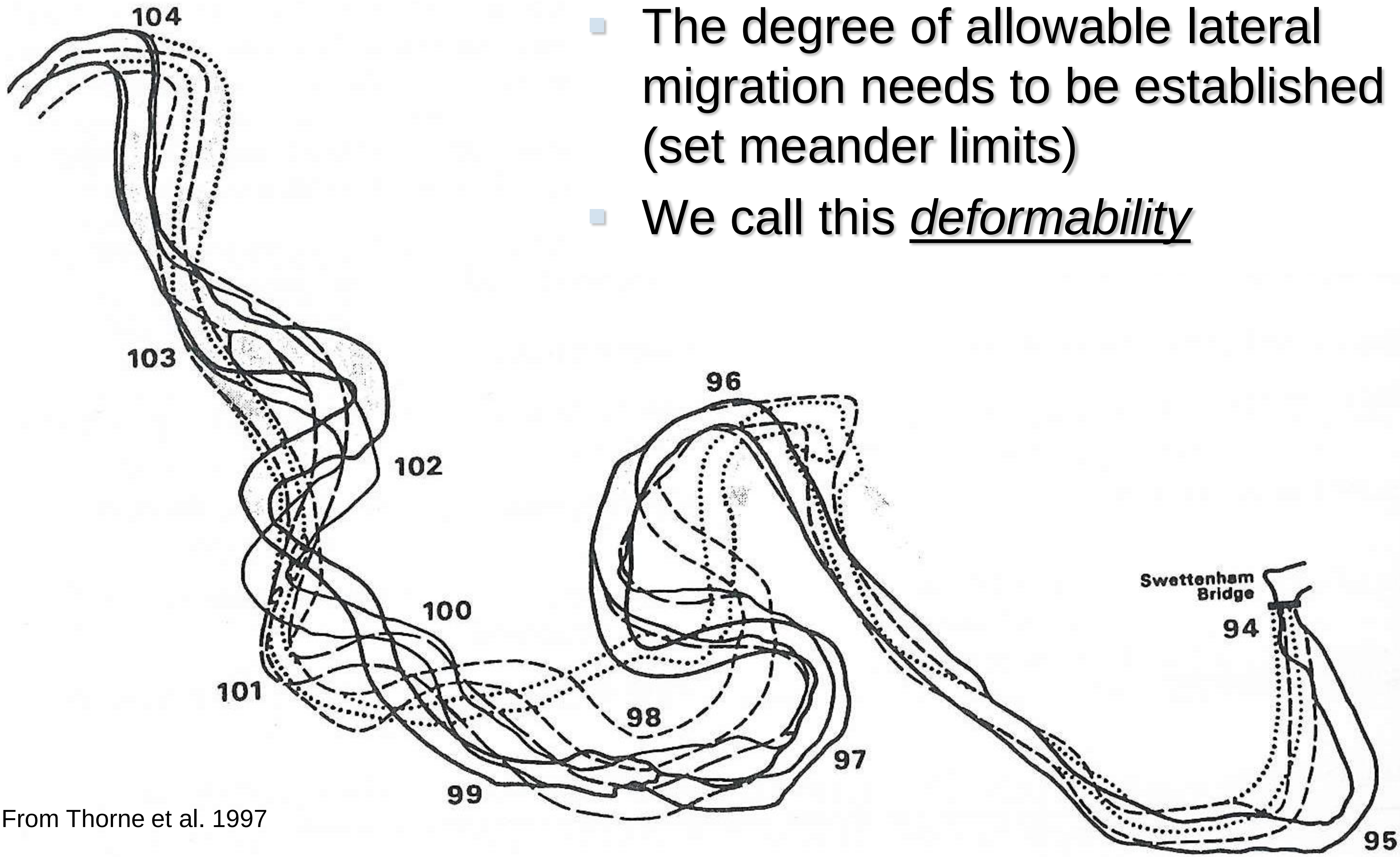
Impacts: Lateral Erosion (widening)

<ins>Lateral stability</ins>

- Obvious signs
- *What is bad erosion versus good erosion?*

Erosion and deposition

- The degree of allowable lateral migration needs to be established (set meander limits)
- We call this *deformability*



From Thorne et al. 1997

Belt width

- Belt width is generally equivalent to the frequent flood boundary

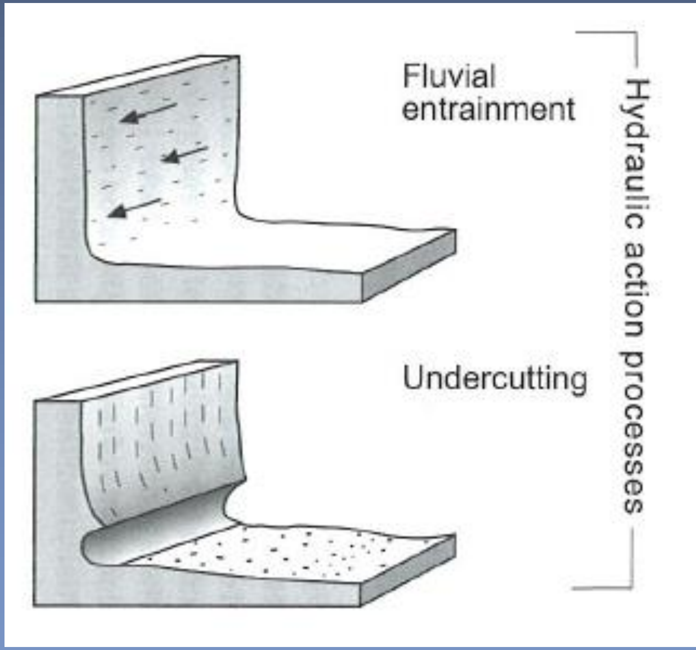
- Belt width (BW)

Meander limits

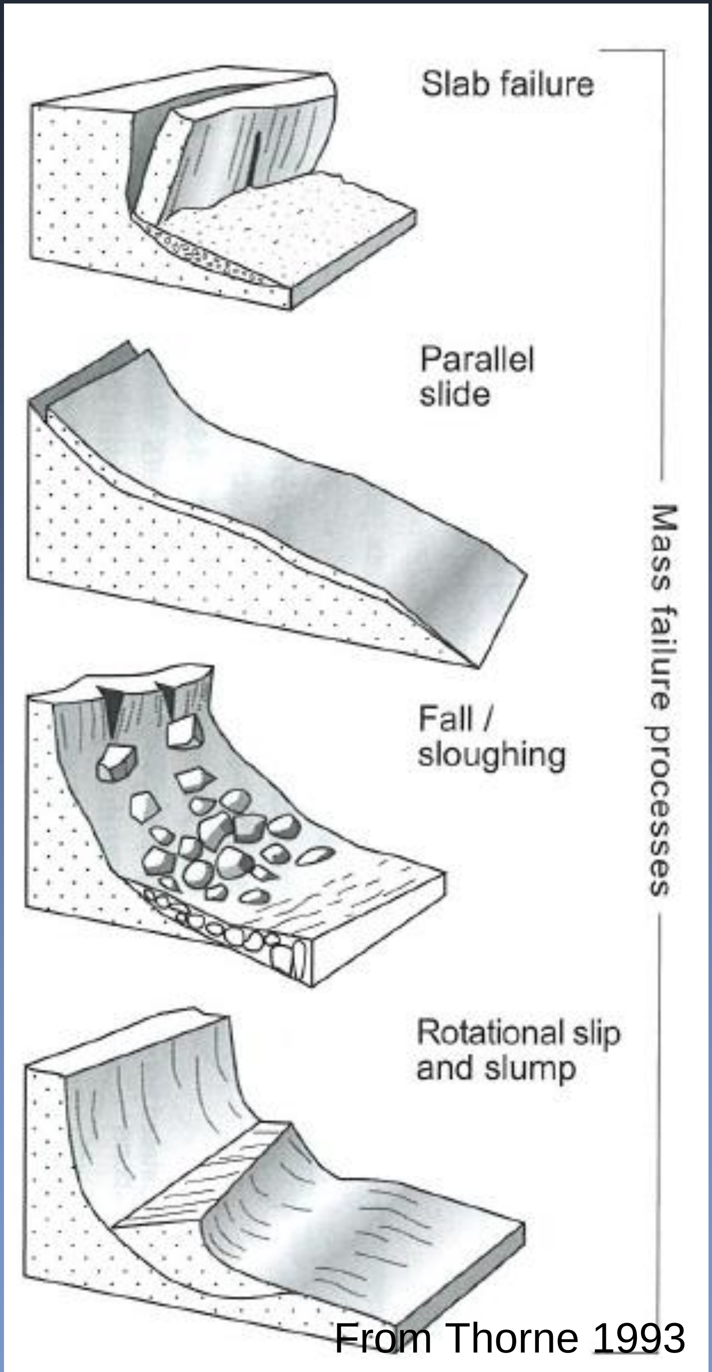
- Sometimes, bank erosion exceeds the equilibrium condition, and sediment becomes a problem
- Infrastructure built *inside the belt width* = problem

Bank erosion

- Its important to know the difference between fluvial and gravitational erosion
- Global vs. localized

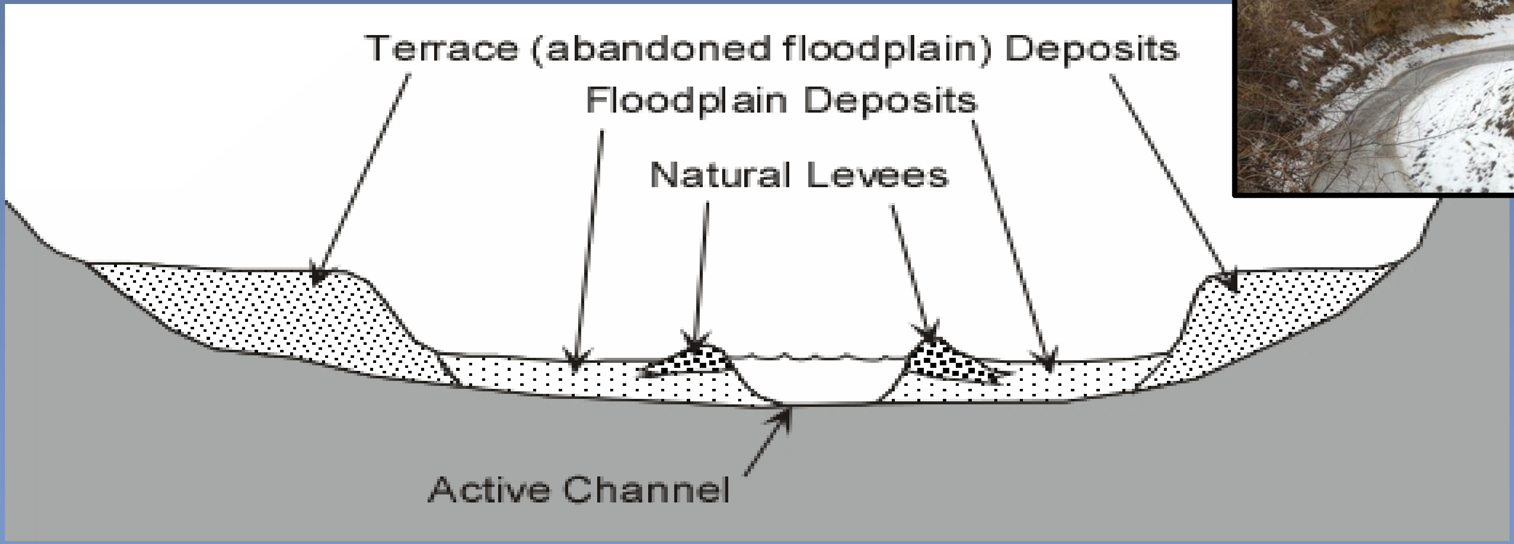


Increased incision



Bluff Erosion

- Bluff vs bank erosion
- Abutting terraces = bluff
- Mass wasting
  - Rotational failure
  - Dry or wet granular flow
  - Cantilever failure



Perceived instability ≠ instability

- Bank erosion is a normal process in an equilibrium channel

Traditional solutions

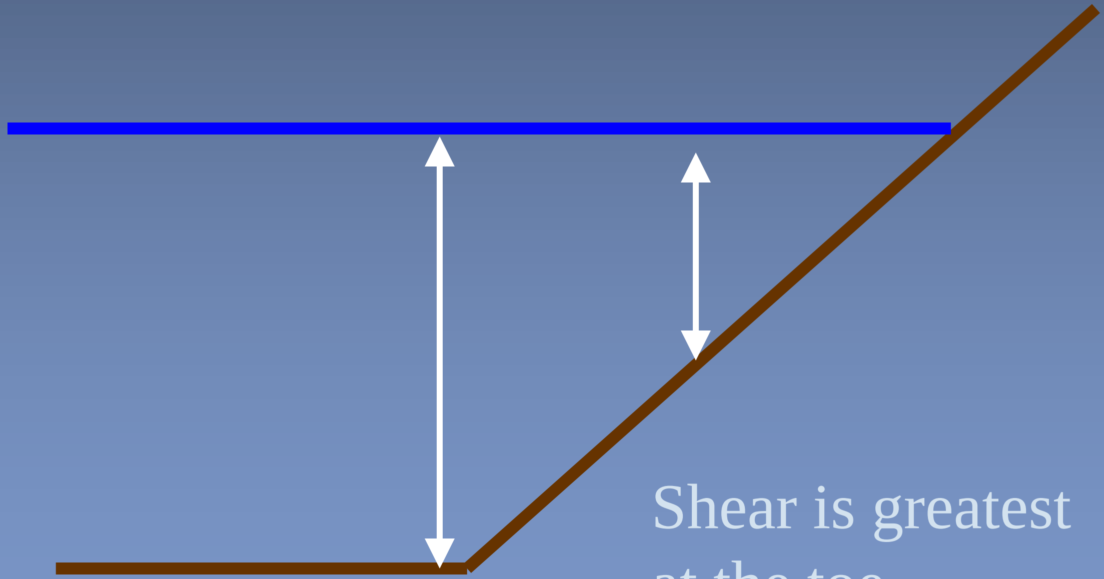
- Traditional solutions involve threshold channel design, whereby the stream is locked in place
- Although engineering goals are met, aesthetic, geomorphic and ecological goals are not

Riprap

Shear stress in cross-section

$$\tau = \gamma DS$$

γ = weight of water
D = depth
S = slope



Shear is greatest at the toe

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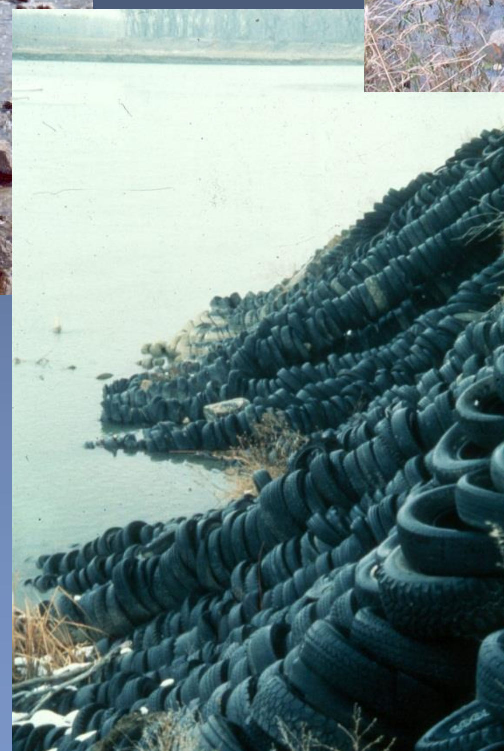
Engineering *waterways*

- All hard engineering solutions have a design life <100 years
- From an ecological perspective, the cure is much worse than the disease


Gabion baskets

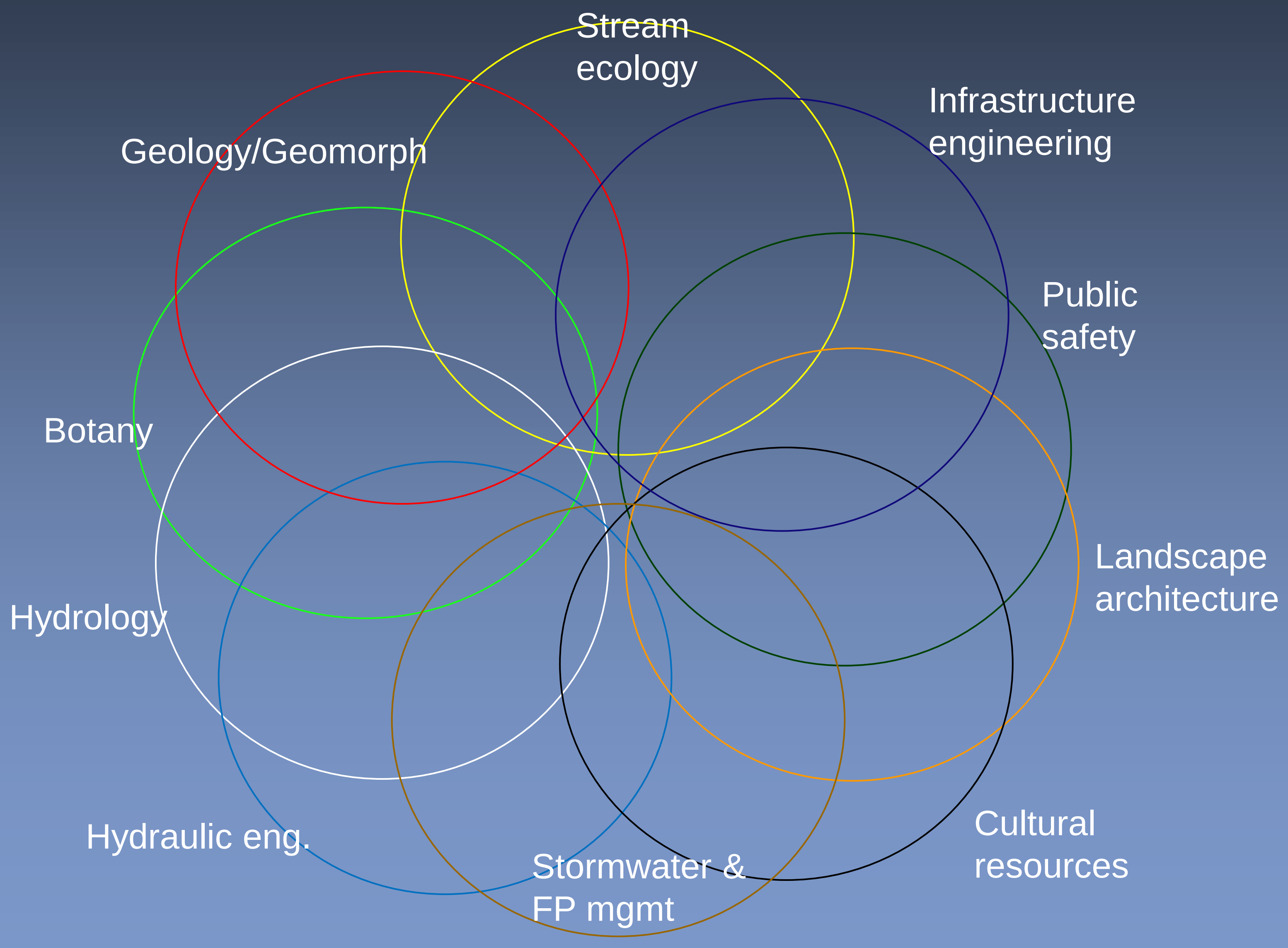
Other methods



- Fortunately, regulations have evolved so that these types of practices are no longer allowed

Urban river restoration solutions

- Urban river restoration expands on required disciplines



Modes of failure
engineering

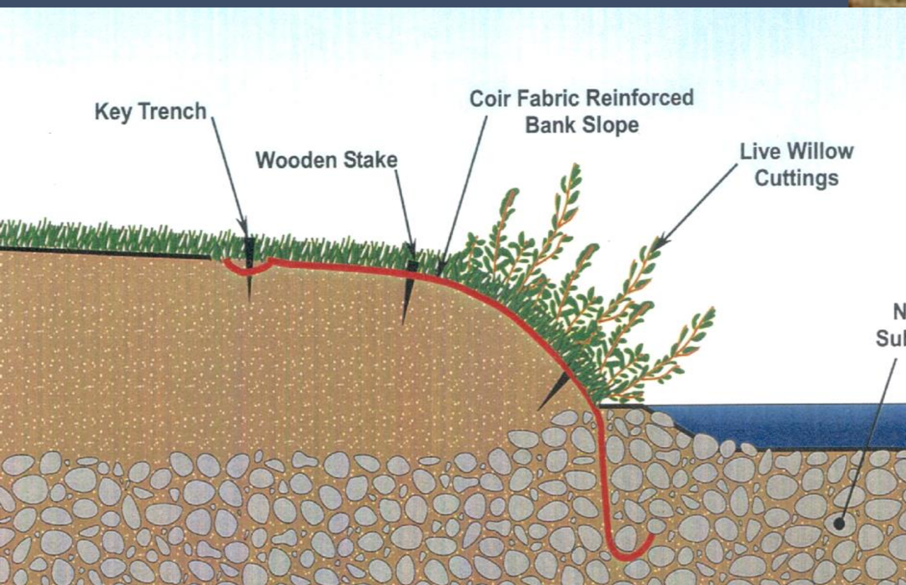
Strength in one discipline (eg. Biology), is not enough. You need an understanding of engineering too

Modes of failure
ecological

Projects may meet simple engineering goals, but could be ecological disasters

Bank Stabilization

Simple grade and shape



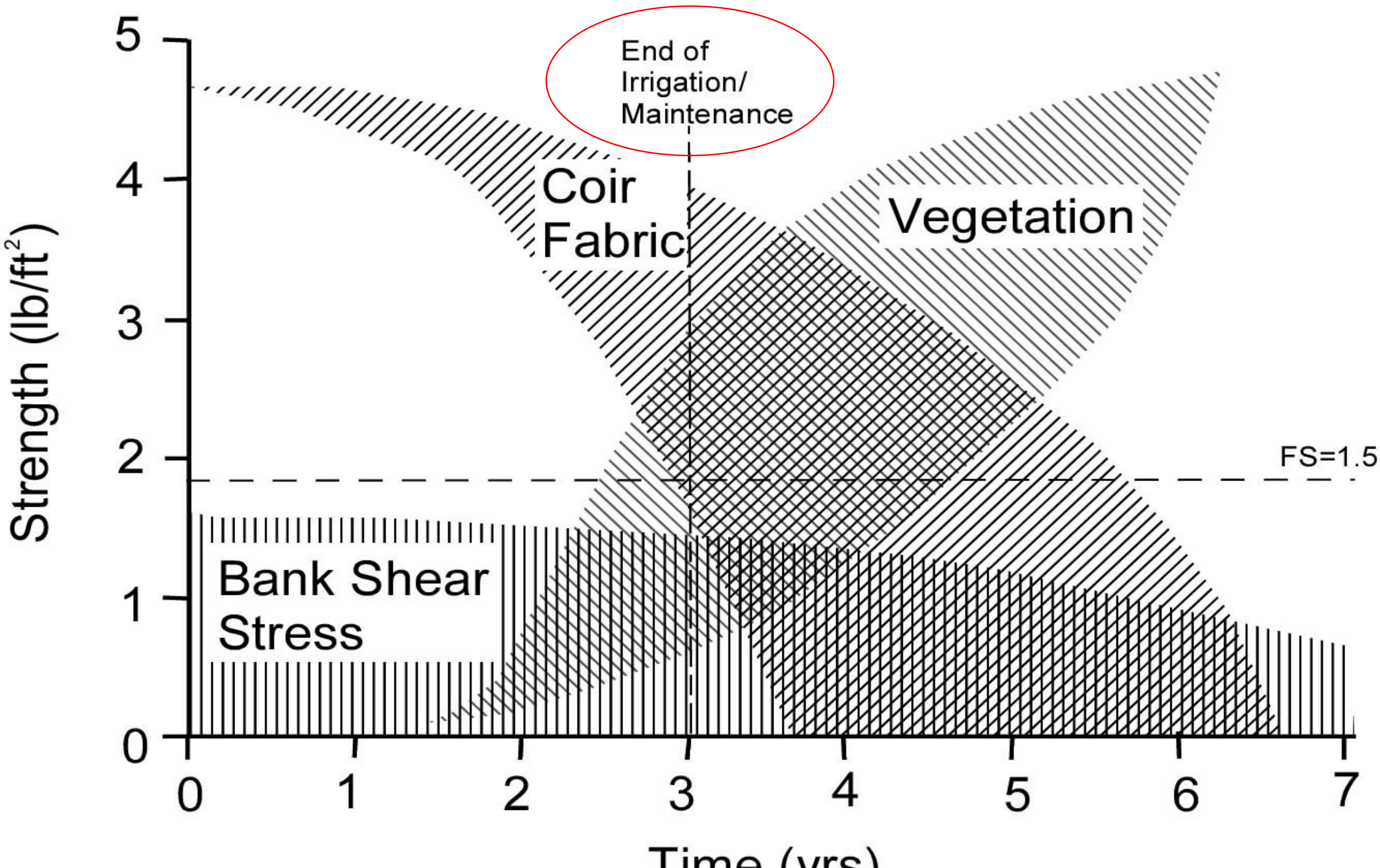
- 15 years post-construction

Simple grading and shaping

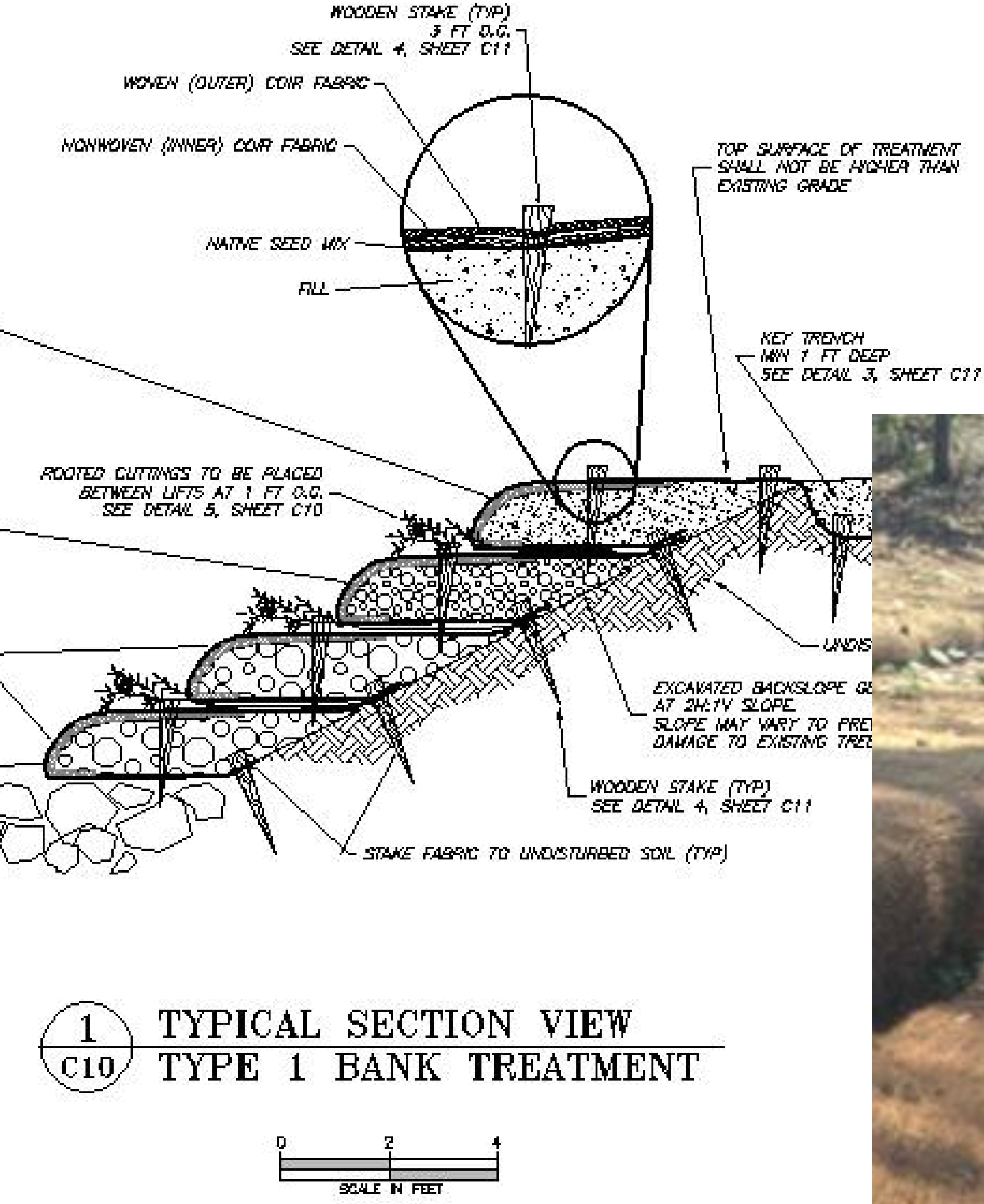
- Hard toe for boat wake protection


1 year post construction

Fabric Degradation and Vegetation Growth Versus Bank Shear Stress Over Time



Soil encapsulation



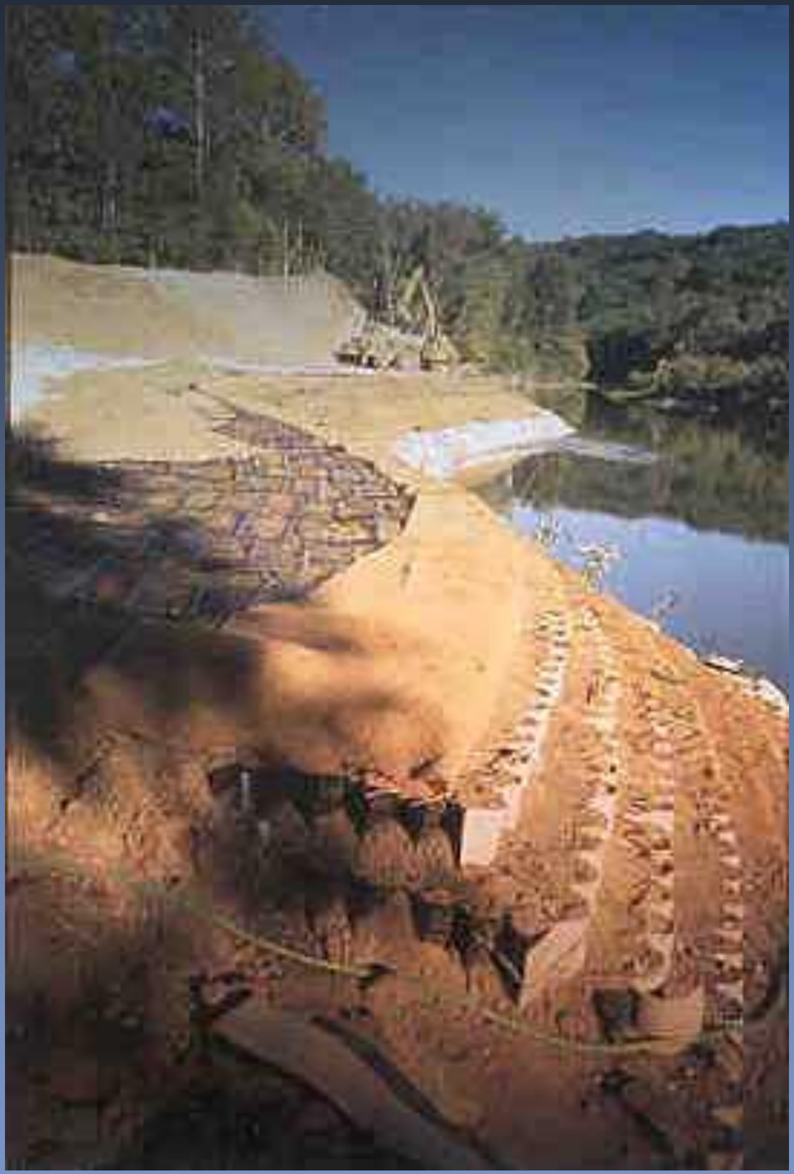
No traffic areas can be incorporated into high traffic parks

3 months post construction

Combination treatments can protect from high toe shear while allowing for green corridors

Combination treatments

- Fish habitat can be incorporated into long term bank protection in a variety of ways



Steep bank treatments can replace sheet pile or WPA-type walls


Steep bank treatment
10 years

Natural Channel Restoration


Step pools and floodplain benches
can replace threshold channels

Wood can be used in urban projects

Complex habitat can be realized together with flood capacity projects in urban streams

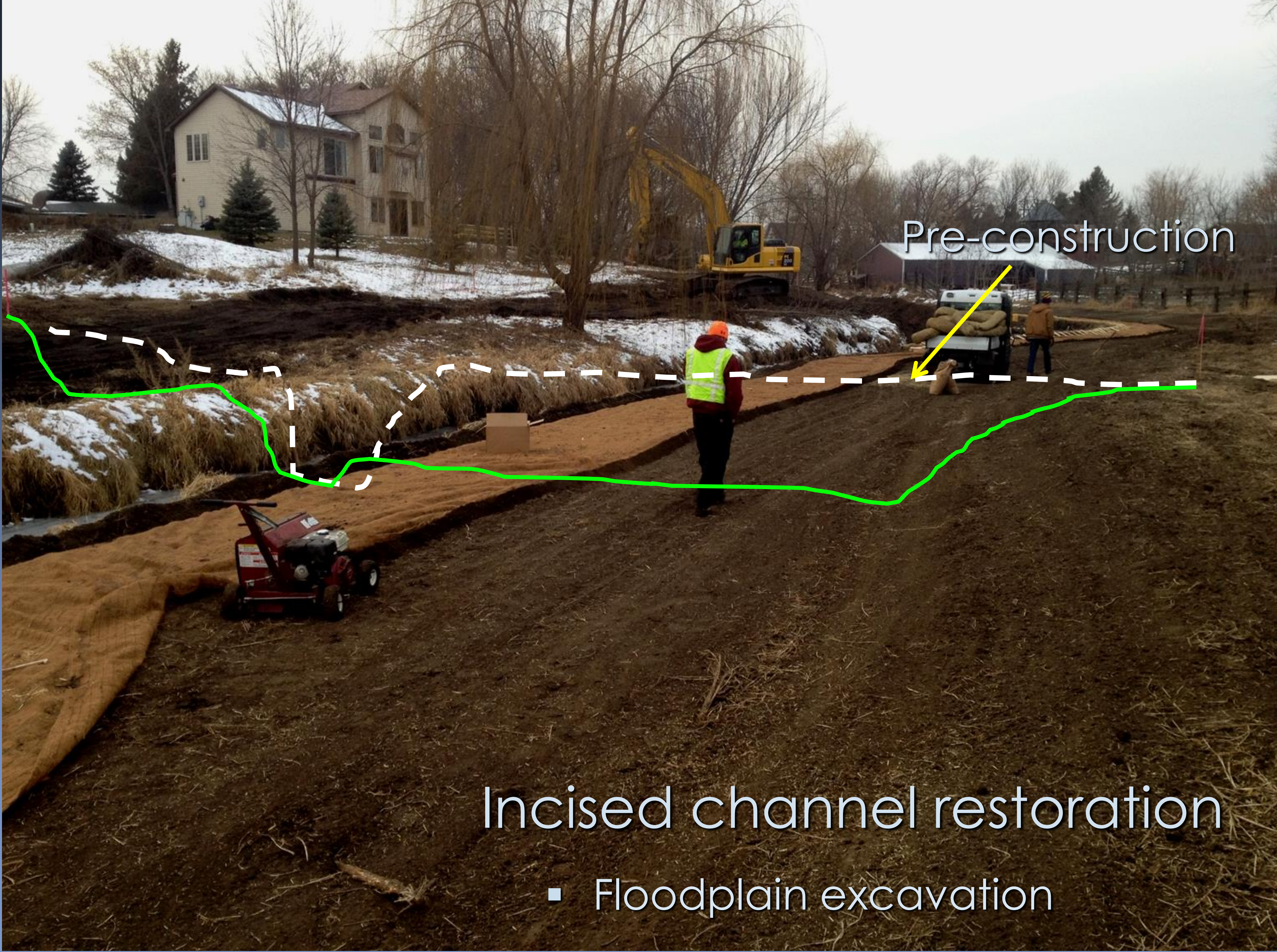
Channel relocation can replace degraded streams with stable, complex habitat


Channel relocation
Deadwood

High energy waterways

- Immobile pool and riffle habitat is better than no habitat at all

Incision repair / prevention



Incised channel restoration

- Floodplain excavation


Incised channel
reclamaton

Incised channel elevation

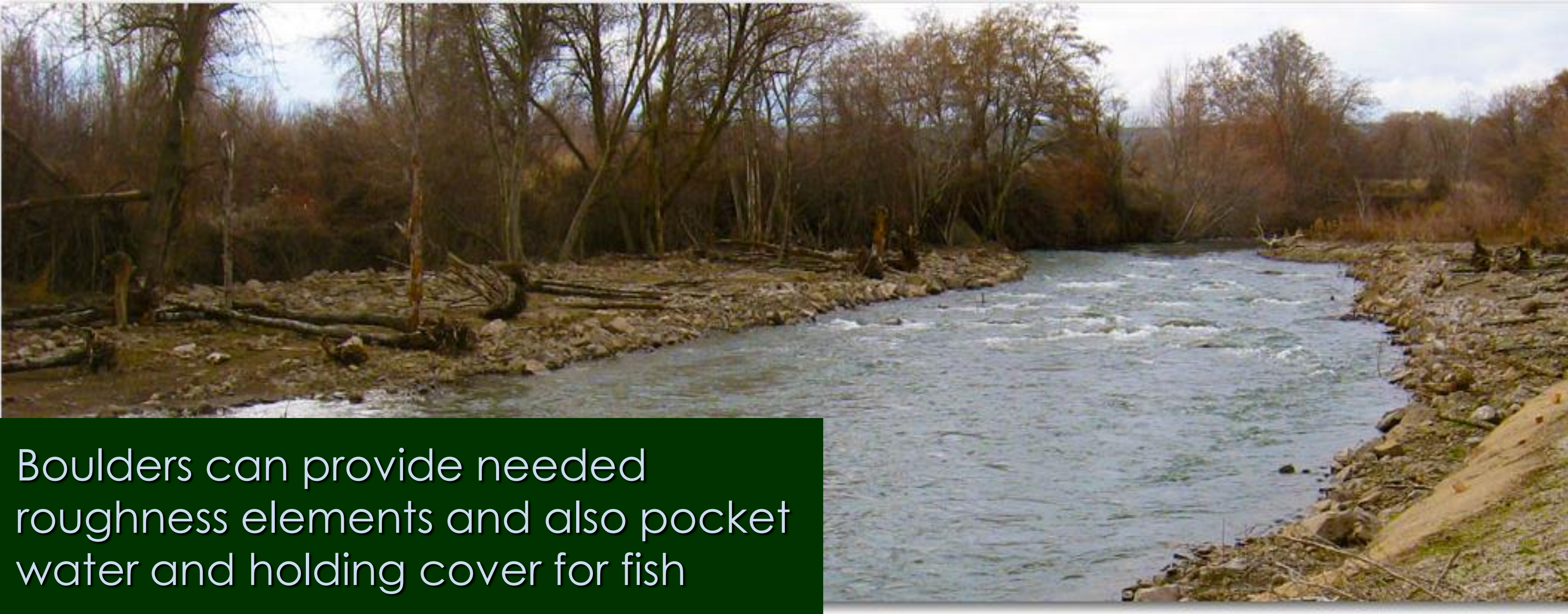
- Incised channels offer opportunities for regenerative stormwater conveyance = in-stream infiltration

Grade control for infrastructure protection

- Drop structures can be replaced with natural looking, immobile riffles

Steep channel elevation/stabilization

- Natural step pool/cascade



Boulders can provide needed roughness elements and also pocket water and holding cover for fish

Dam removals are an excellent way of vastly increasing healthy river habitat in urban systems

Questions?

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