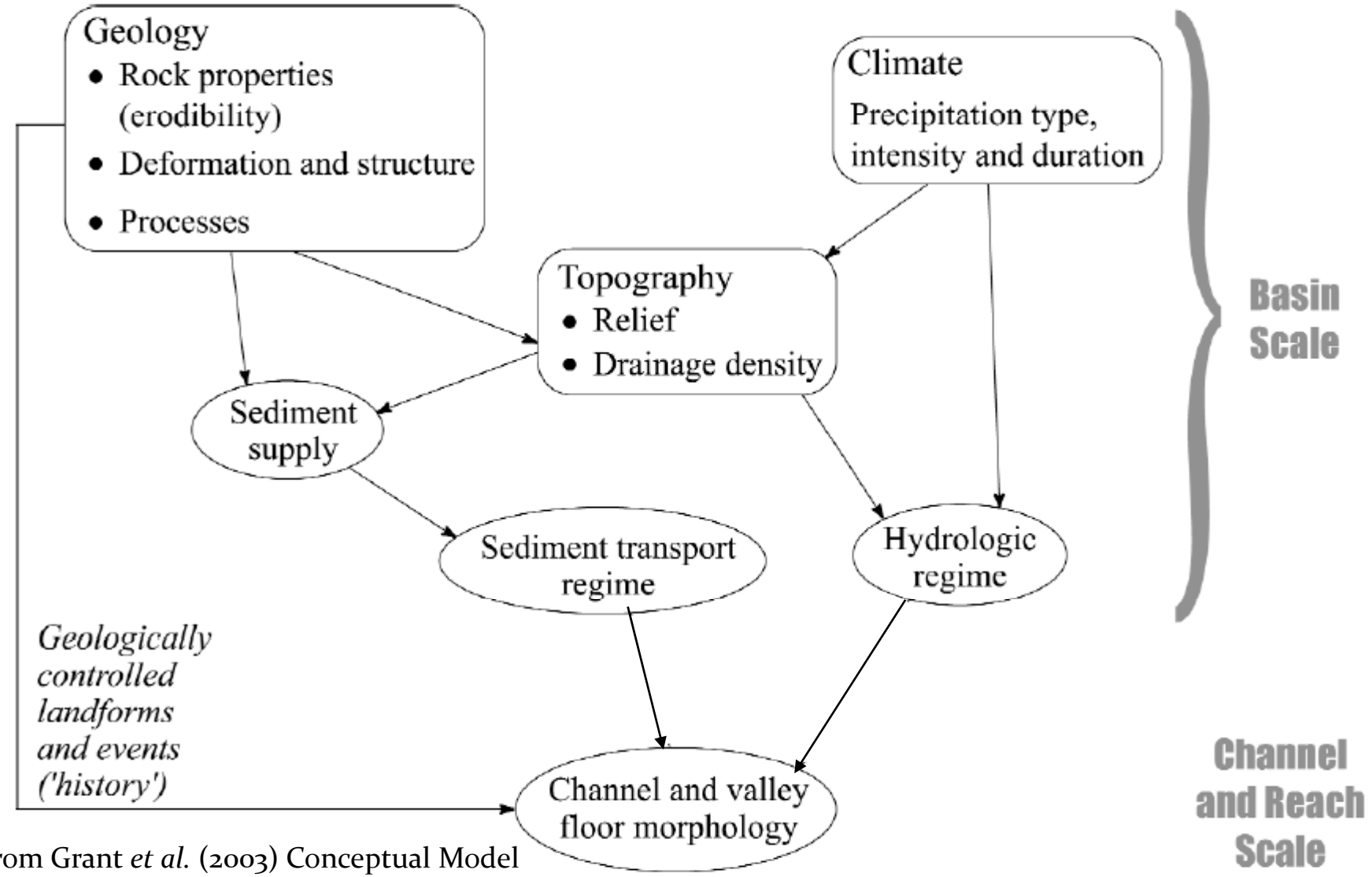
Studying the geomorphic aspects of changes to fish habitat below hydro dams: changes to bed substrate characteristics as well as changes to size and morphology of channels.

Fabien HUGUE and Michel LAPOINTE (McGill University),*
Brett EATON (UBC)

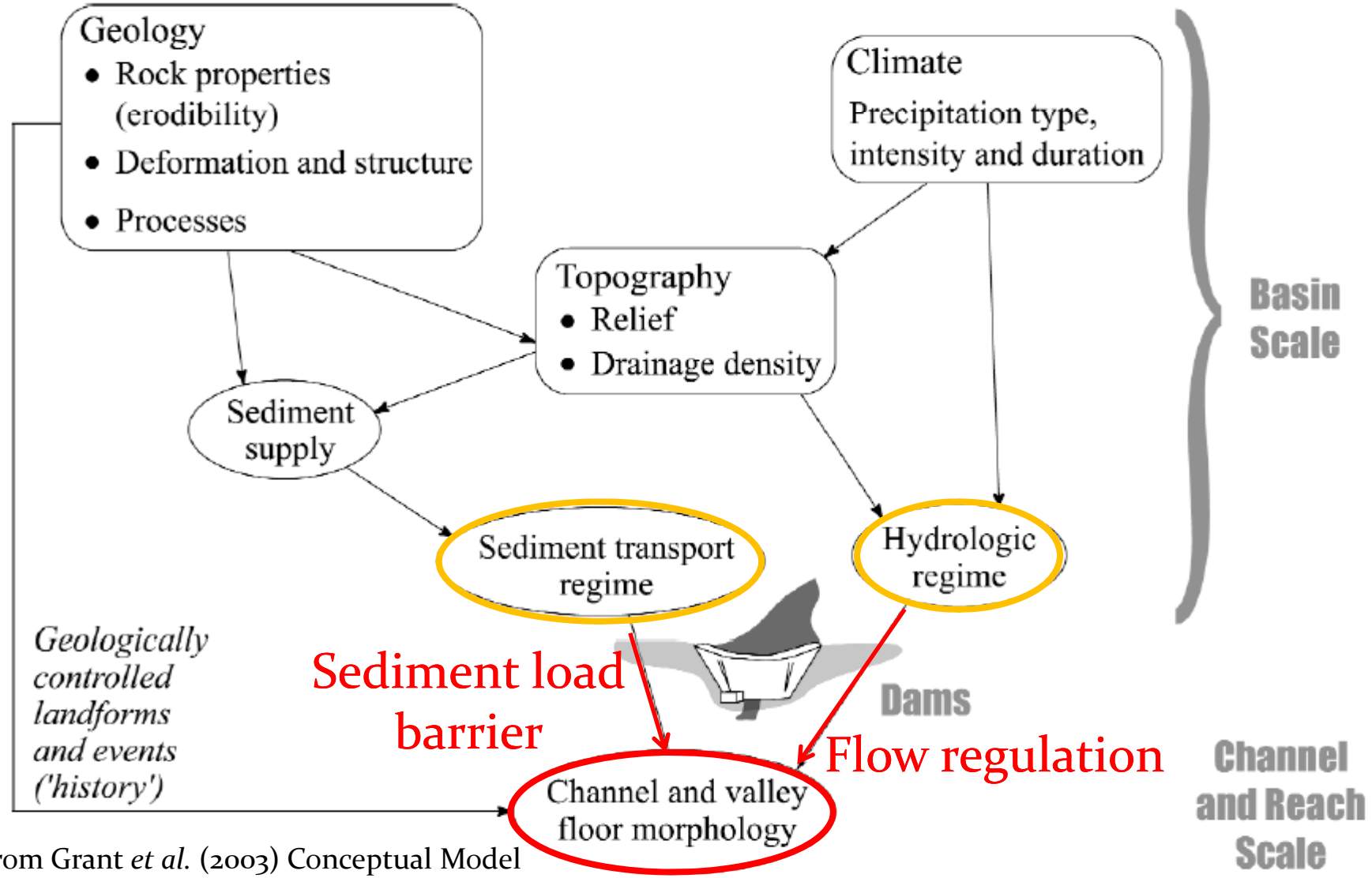
McGill

NSERC
ydroNet
CRSNG



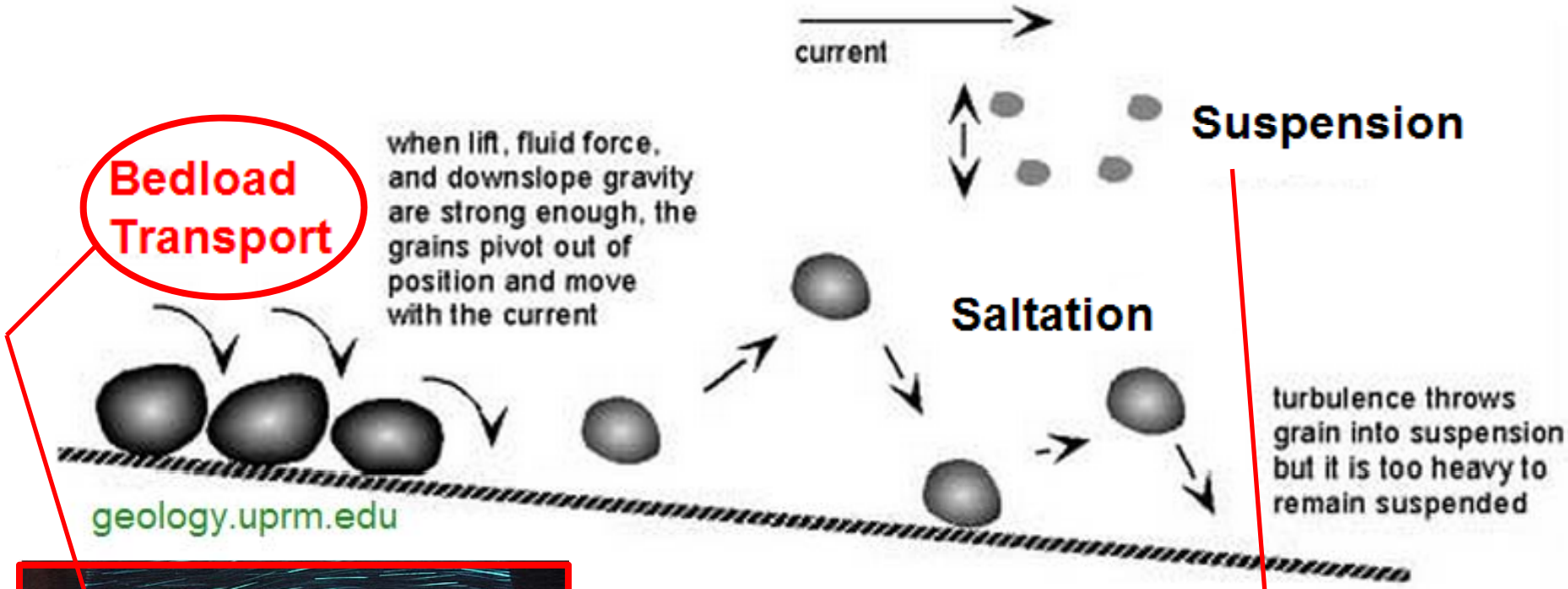
From Grant *et al.* (2003) Conceptual Model

Long term Morpho-sedimentologic impacts on habitat



From Grant *et al.* (2003) Conceptual Model

2- Sediment Transport



No Motion

Sediment Transport

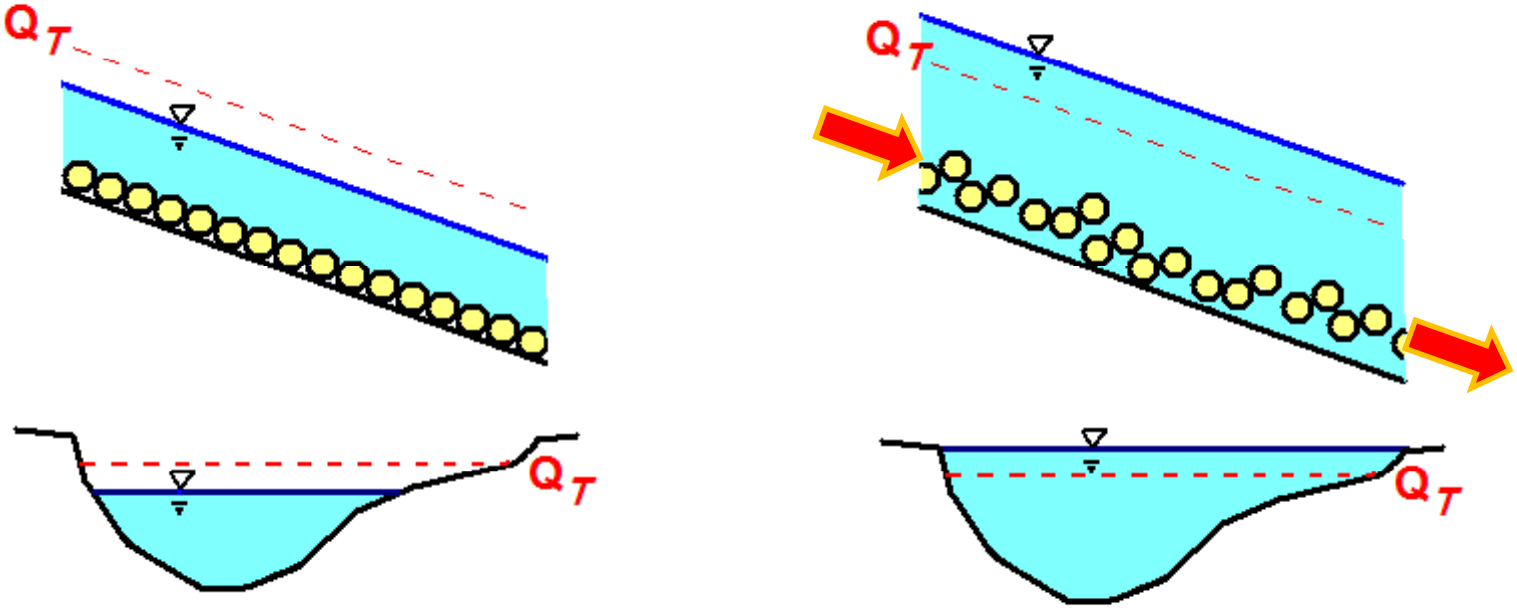
Q

$Q < Q_T$

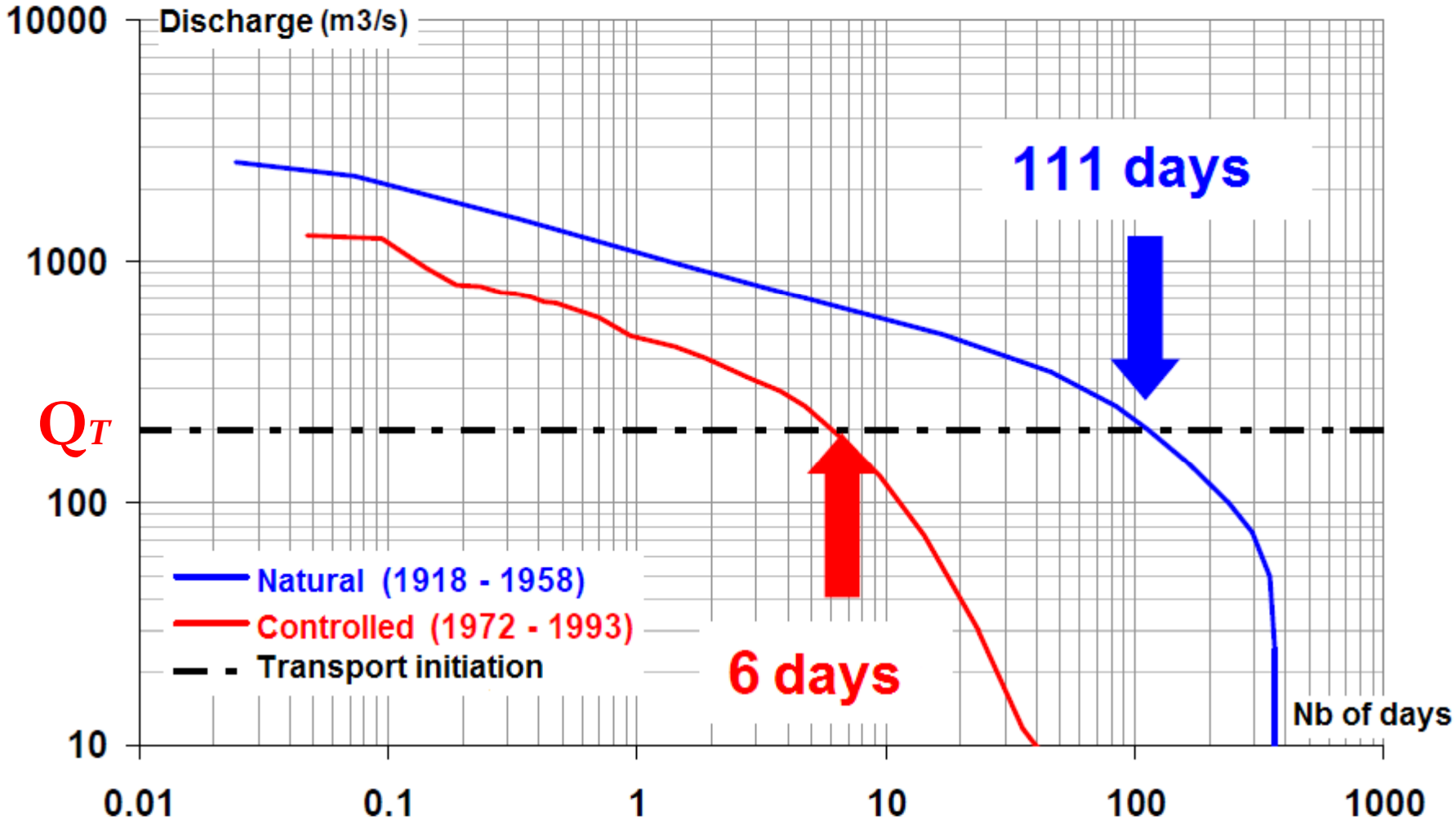
Q_T ***(Threshold)***

$Q > Q_T$

Q_T = discharge that initiates bed particle transport



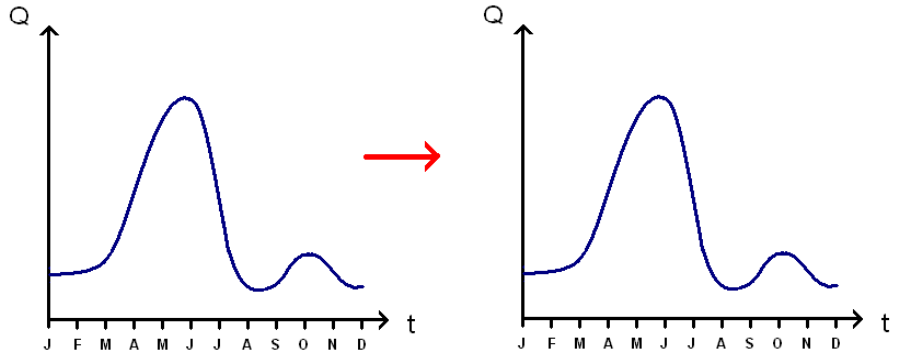
River **Transport capacity** attenuation



Ranked discharge on the *Durance* river (France)

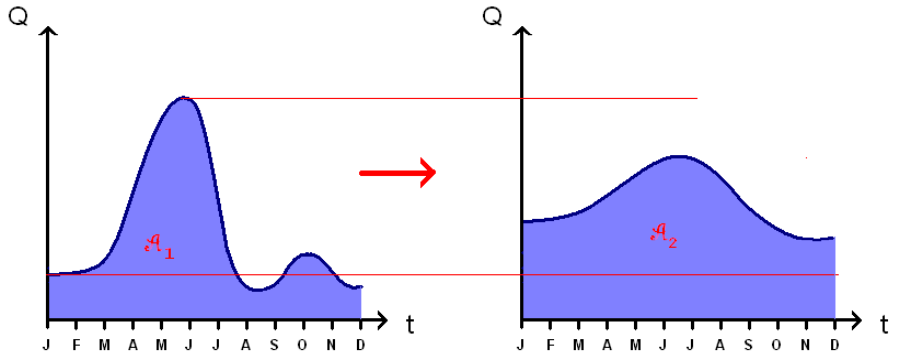
•Run of the river dams

- No flow attenuation
- Small reservoir



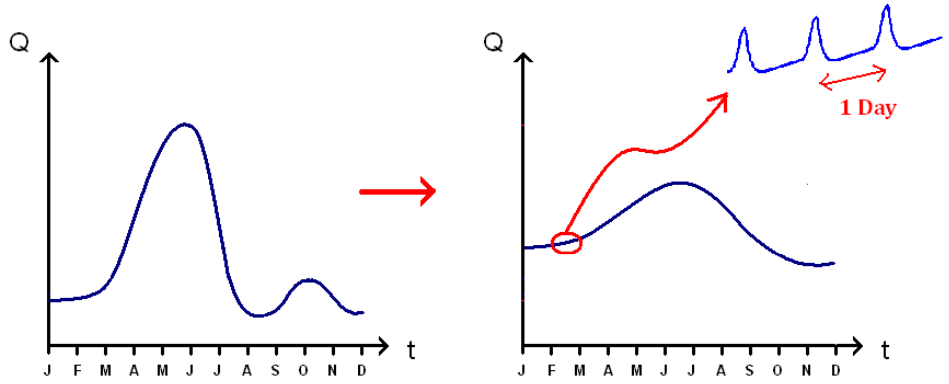
•Storage dams

- Peak flow attenuation
- Base flow modification



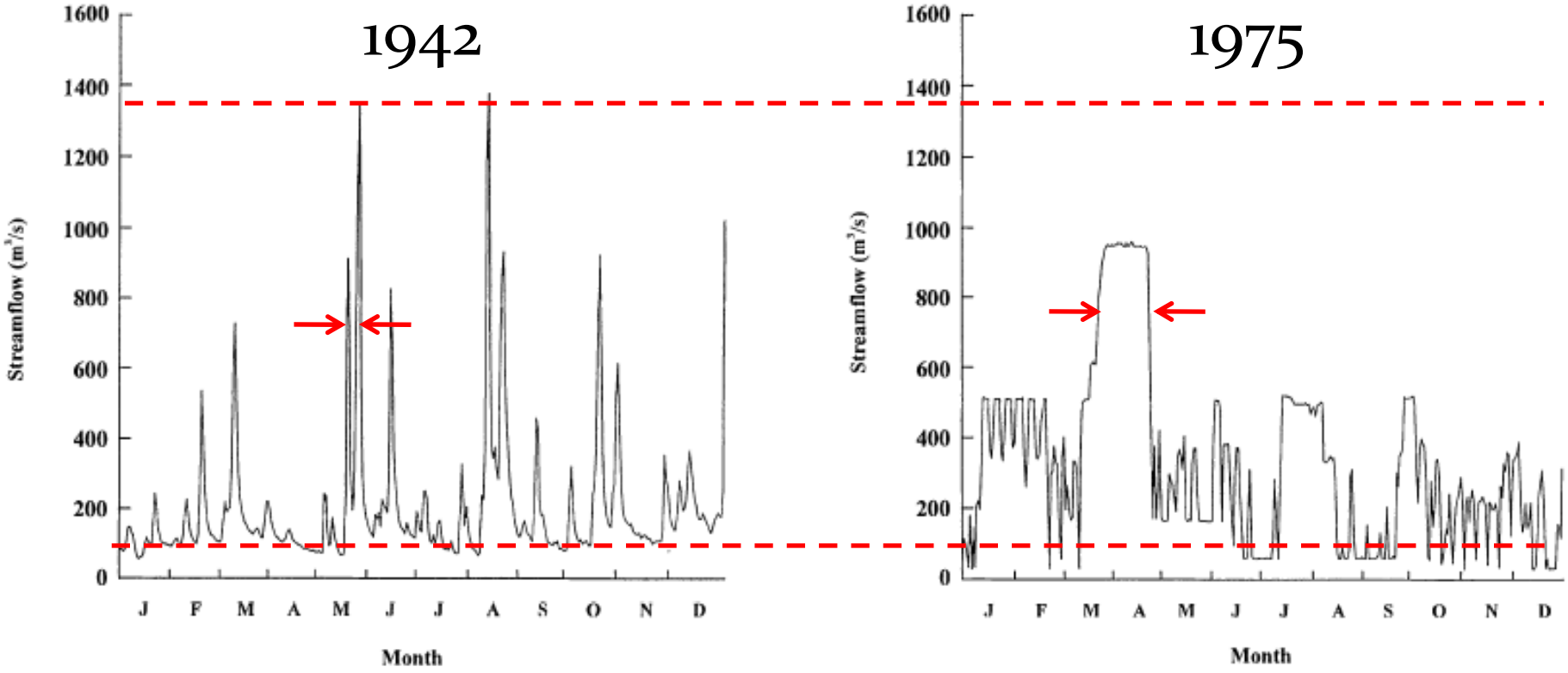
•"Peaking" dams

- Hourly major variation



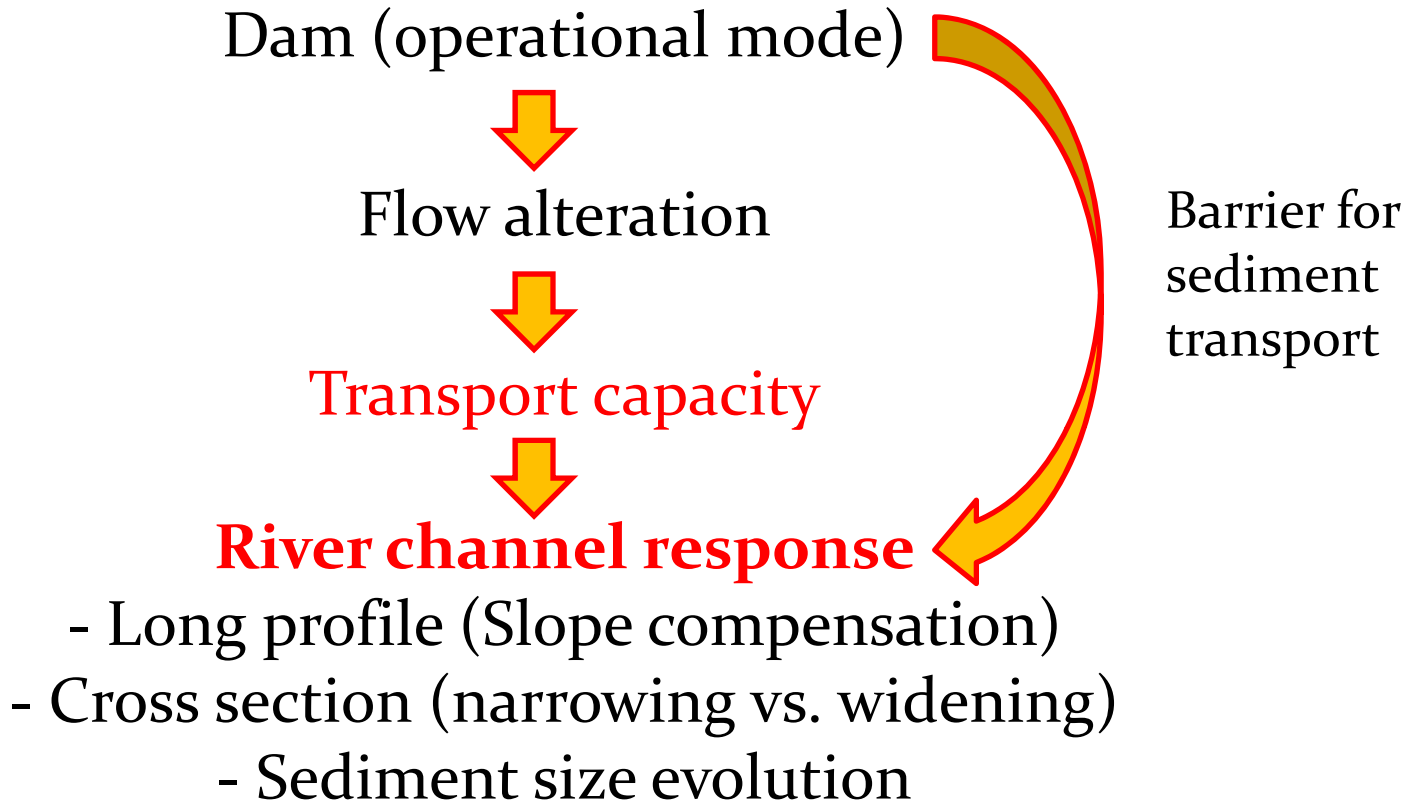
Hydrographs: Roanoke River (North Carolina, USA)

Richter et al. (1996)



- Peak flows attenuation (magnitude & Frequency)
- Base flow changes
- Modification of Floods (duration & timing)

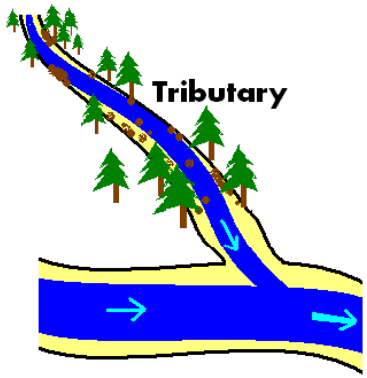
IHA



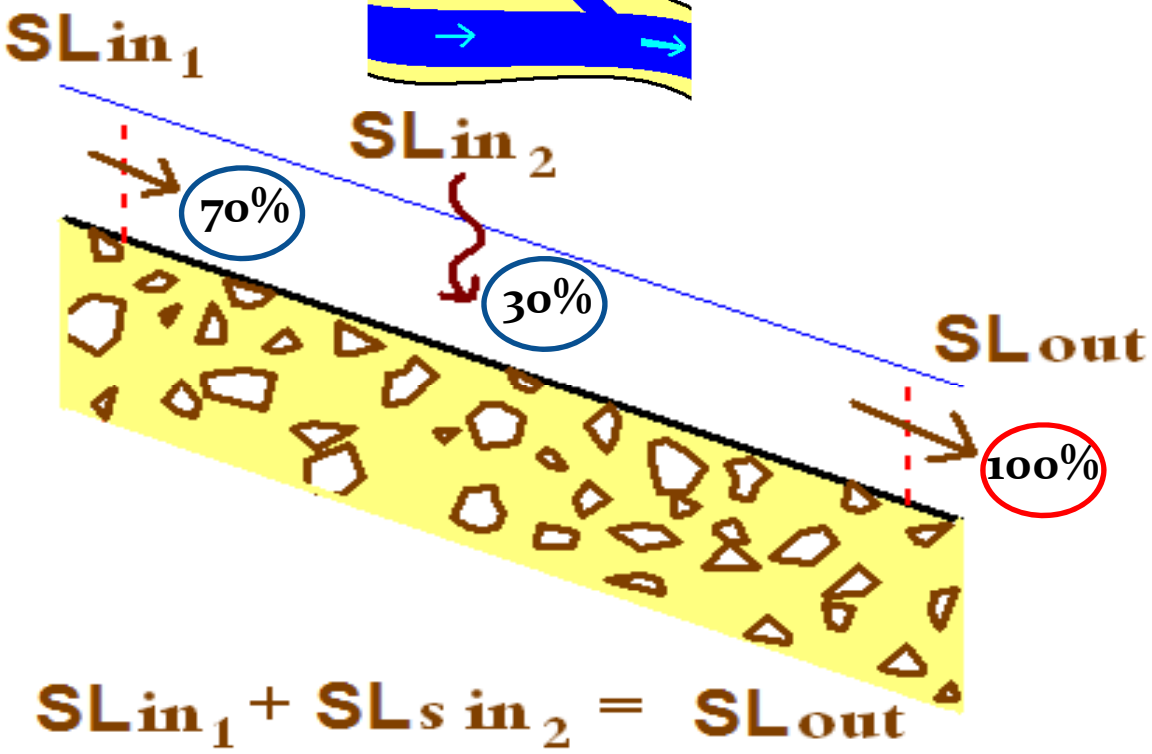
- Grant (2003; 2010) → Ratio downstream / upstream sediment supply
- Schmidt& wilcock (2008) → Quantitative prediction tools
- Brandt (2000) → Identified 9 styles of change below dams

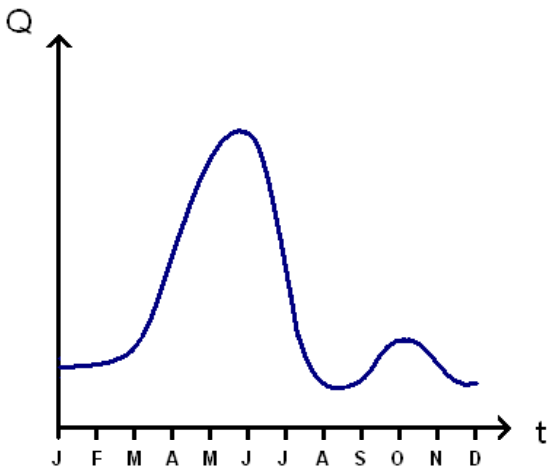
"**<u>At Grade</u>**" system

= Equilibrium between Sediment Load (SL) **inputs** and **output**



- SL in_1 = sediment input from upstream
- SL in_2 = sediment input from tributaries
- SL out = sediment output

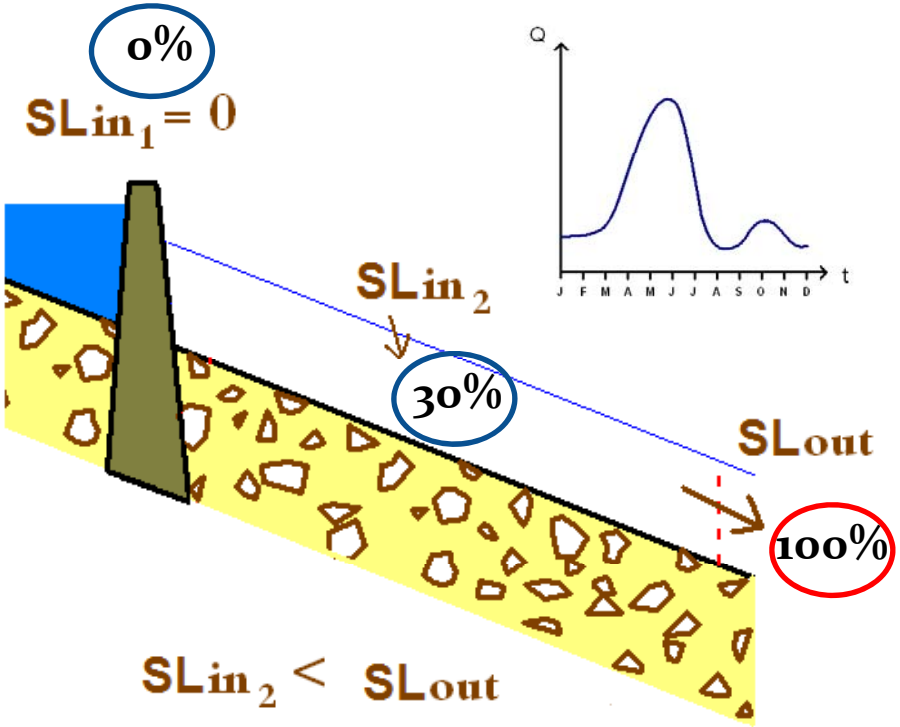




Run of the river dam

- Same transport capacity
$(Q > Q_T)pre \approx (Q > Q_T)post$
- (SL_{out}) is unchanged

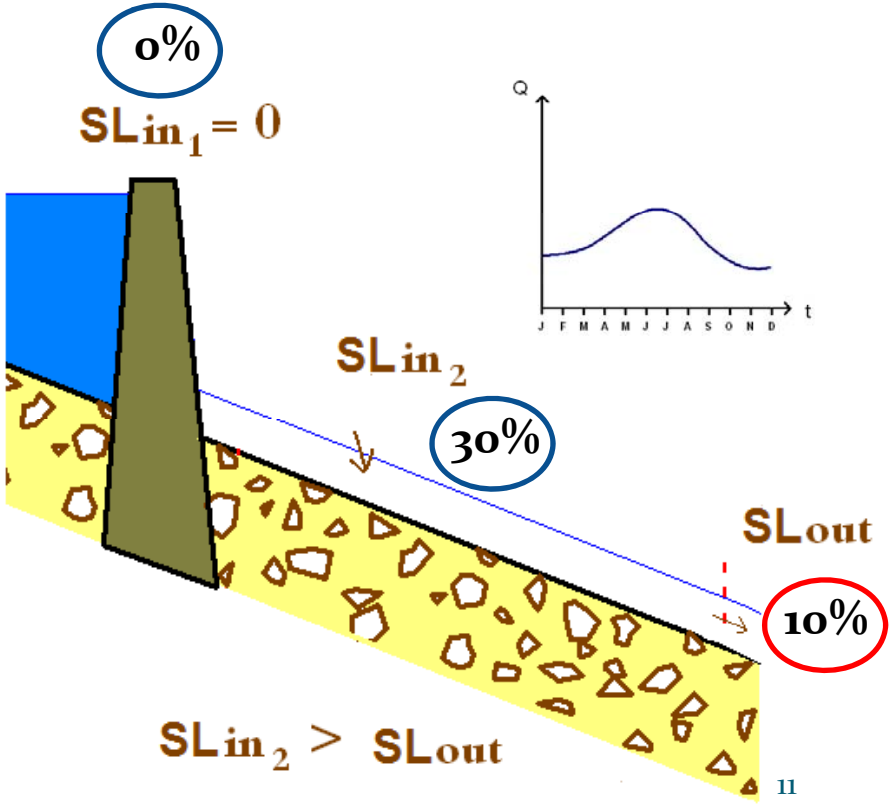
Deficit of 70% of sed. inputs



Storage dam

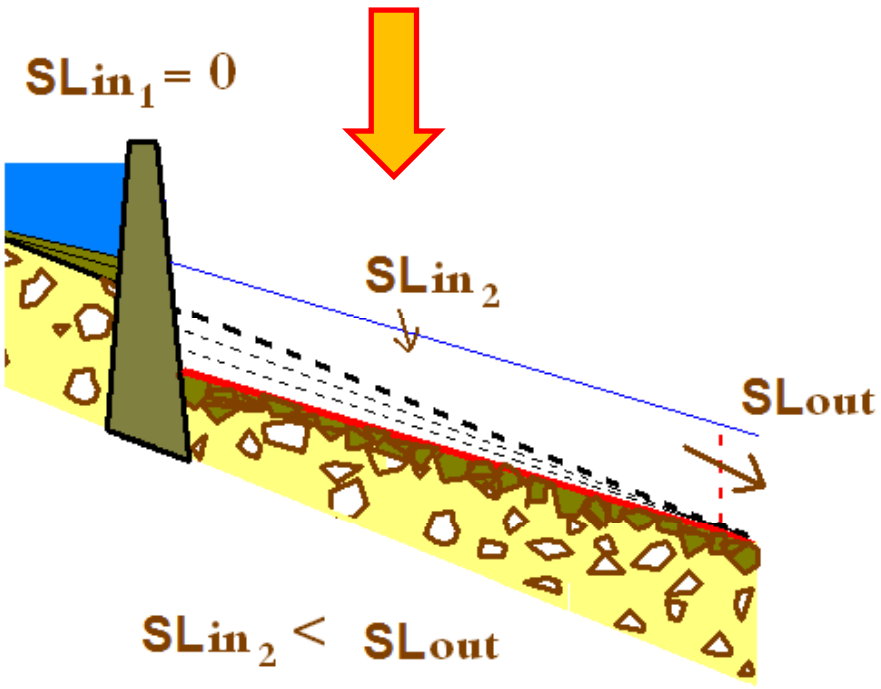
- Lowers transport capacity
$(Q > Q_T)pre > (Q > Q_T)post$
- (SL_{out}) is less

Excess of 20% of sed. inputs

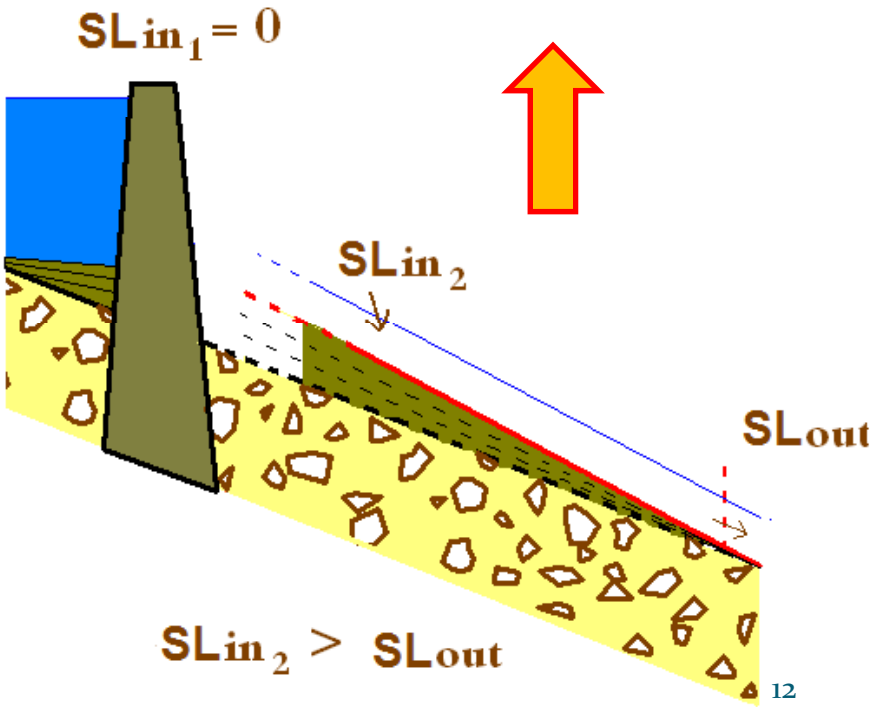


Long-term response of the channel bed to reach the new equilibrium morphology (slope, width, bed texture, etc…)

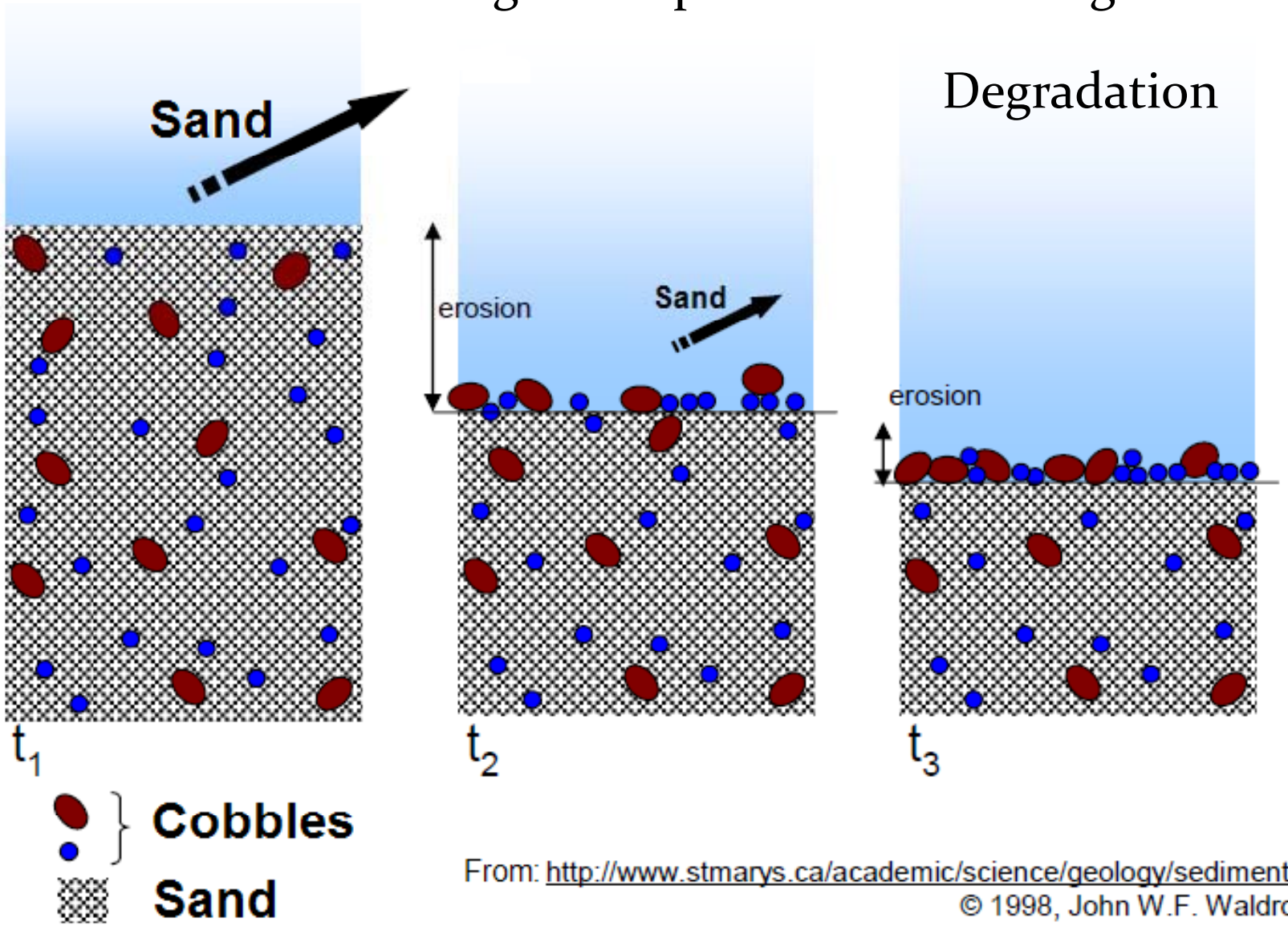
Bed Degradation (thus, slope reduction)



Aggradation (bed rise, slope increase)



Surface coarsening accompanies bed lowering



From: http://www.stmarys.ca/academic/science/geology/sediments/

4- River Channel Responses – Sediment size

→ *Degradation*

Coarsening of channel bed and/or Armouring

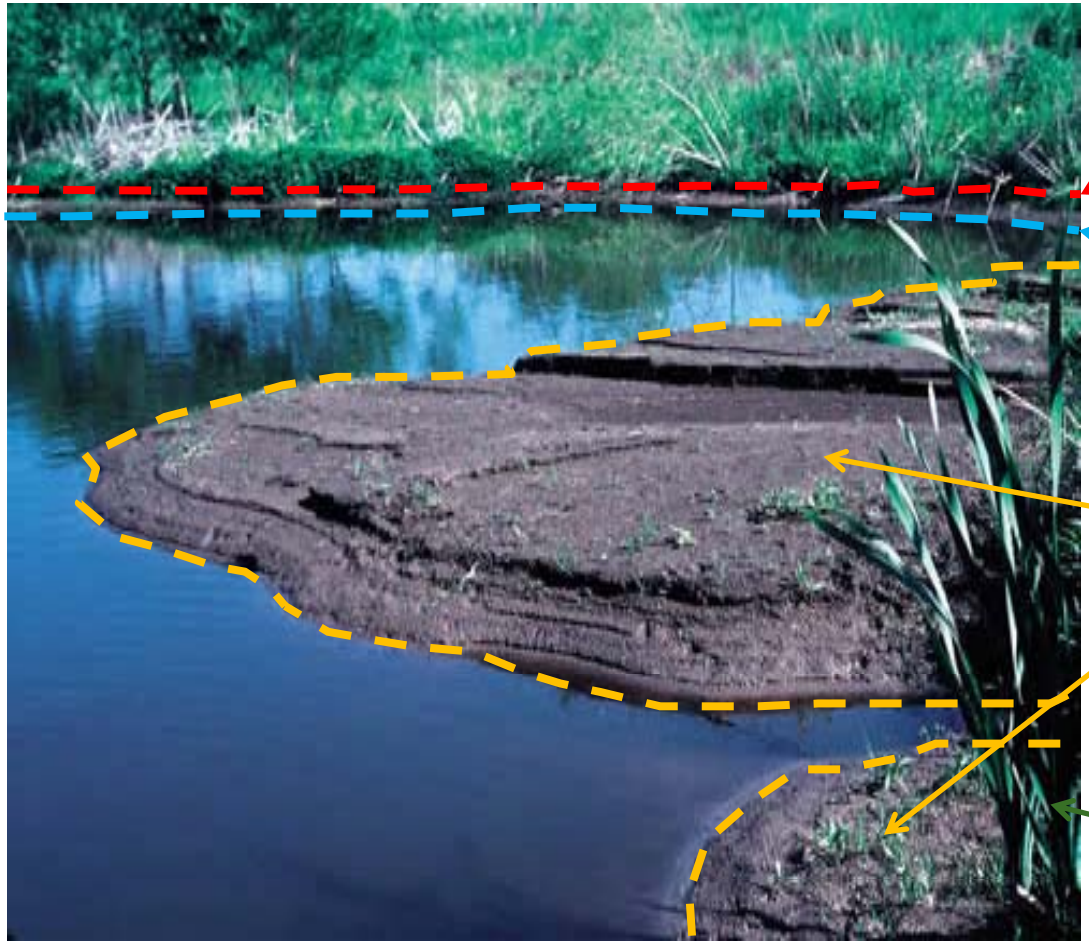
Spawning habitat changes

→ *Aggradation*

Silting-up of channel bed

- Changes to benthic invert communities (fish food)
- Entombment and choking of salmonid embryos

Aggradation



In long term the modifications of Flow / Sediment transport can lead to:

- changes to substrate and spawning habitat in main channel,
- habitat disappearence in back-channels,
- changes to riparian sediments and habitat, etc…

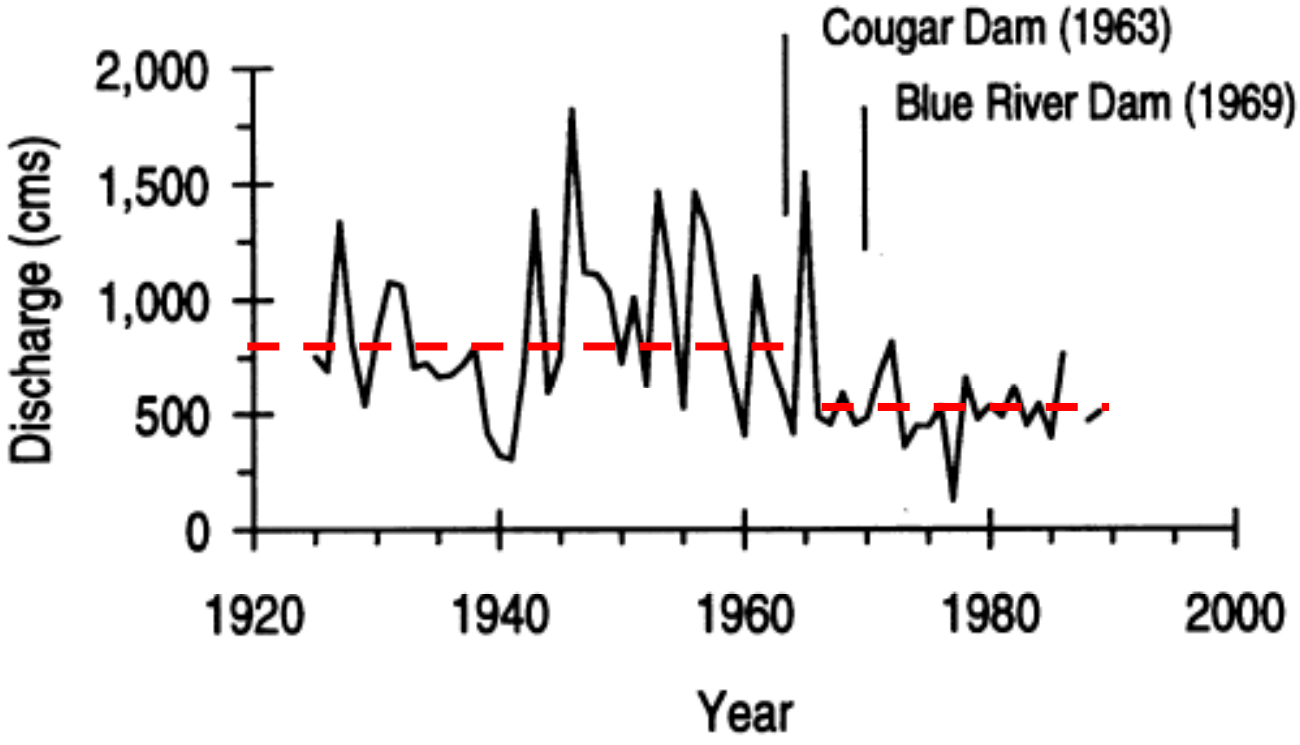
Downstream Ecological Effects of Dams

A geomorphic perspective

Franklin K. Ligon, William E. Dietrich, and William J. Trush

BioScience, Vol. 45 No. 3 - 1995

Annual maximum instantaneous peak discharges



Mackenzie river (Ligon et al. 1995)

5- Impacts on Fish Habitats – Back-channel abandonment

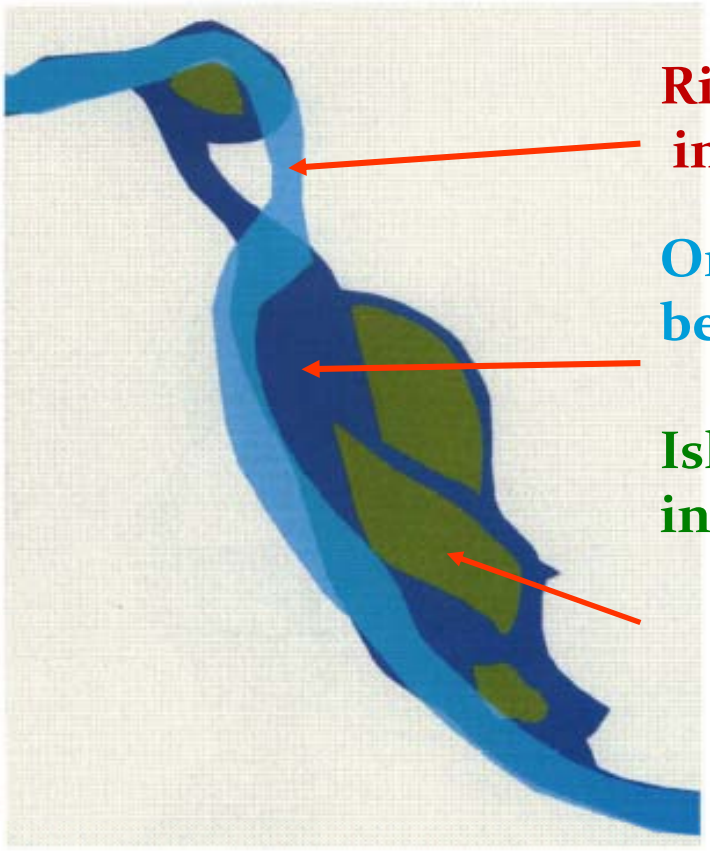


Figure 5. This reach reflects the loss of islands between 1967 and 1990 in the McKenzie River. River path is shown in dark blue for 1967 and in light blue for 1990. Islands in 1967 are green; there were no islands in 1990.

River bed in 1990

Original River bed in 1967

Islands in 1967

Mackenzie river (Ligon et al. 1995)

Loss in channel complexity

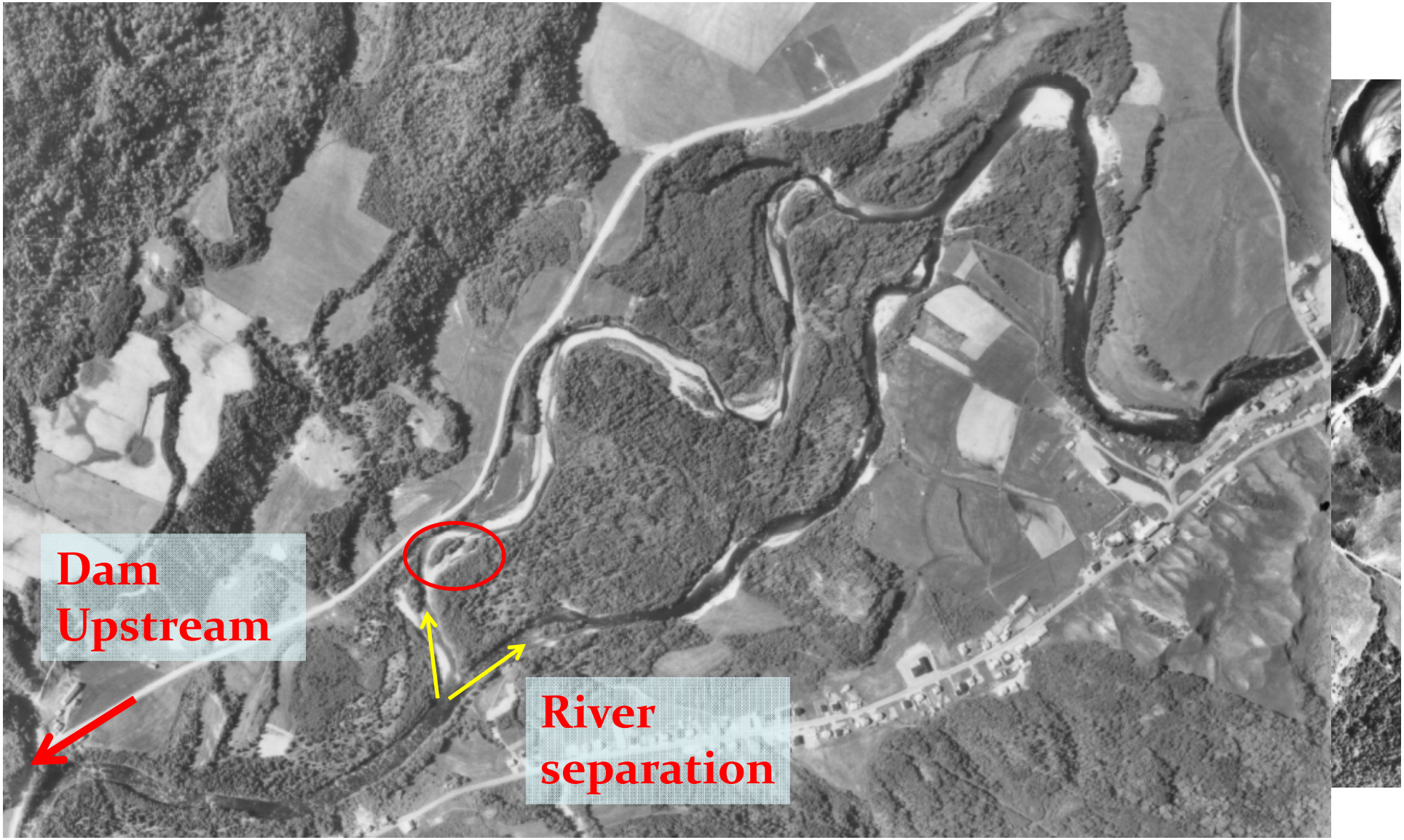
Spawning habitat disappearance in Mackenzie R.

Features	Year 1930	1990
Islands (number)	60	28
Island area (m^2)	2,260,000	1,110,000
Island perimeter (m)	44,000	18,000
Wetted area of river (m^2)	4,020,000	2,930,000

5- Impacts on Fish Habitats – Back-channel abandonment

Anse St Jean Dam (St Jean River, Quebec)

1972



5- Impacts on Fish Habitats – Back-channel abandonment

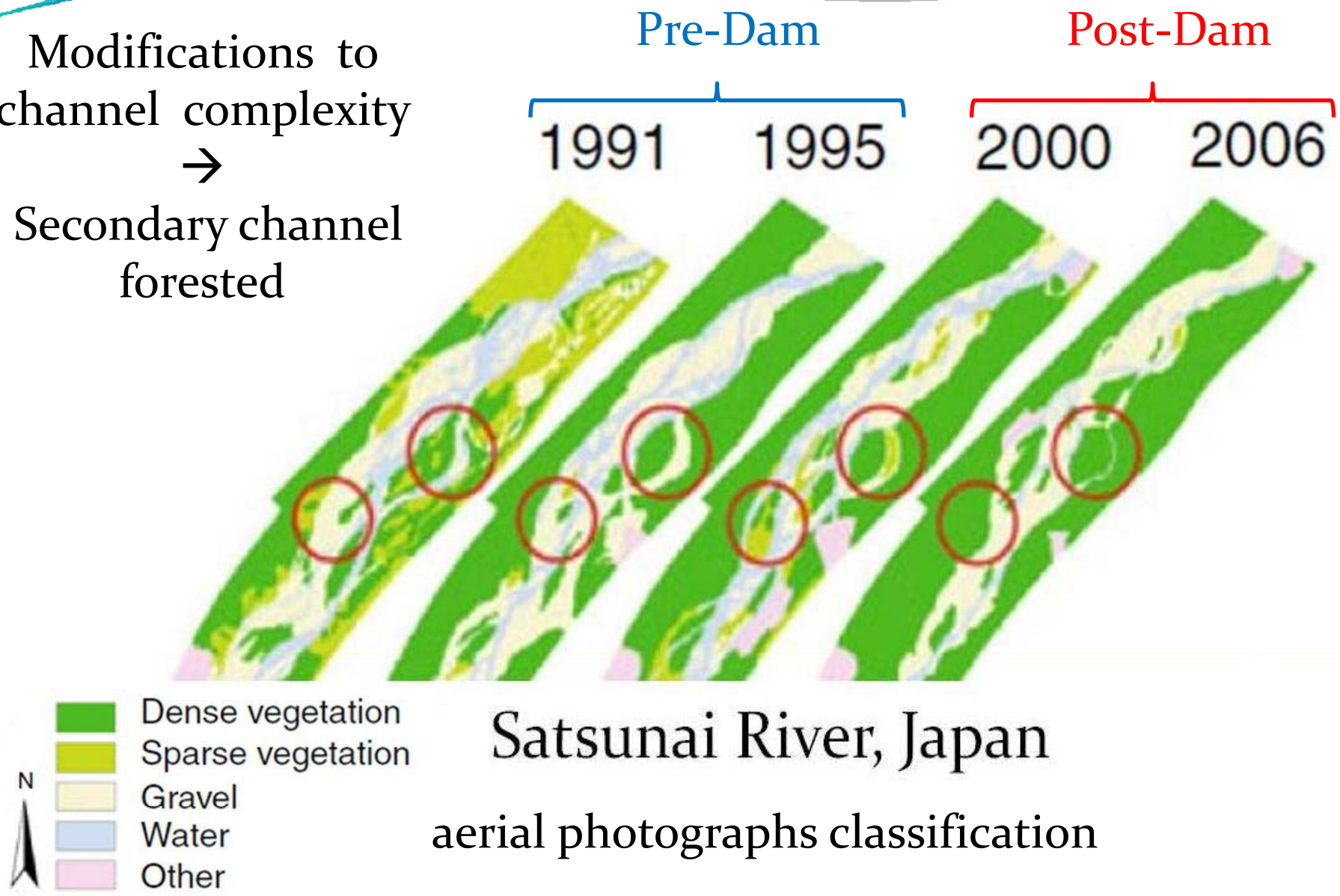
Anse St Jean Dam (St Jean River, Quebec)

1964 1972

Modifications to channel complexity

→

Secondary channel forested

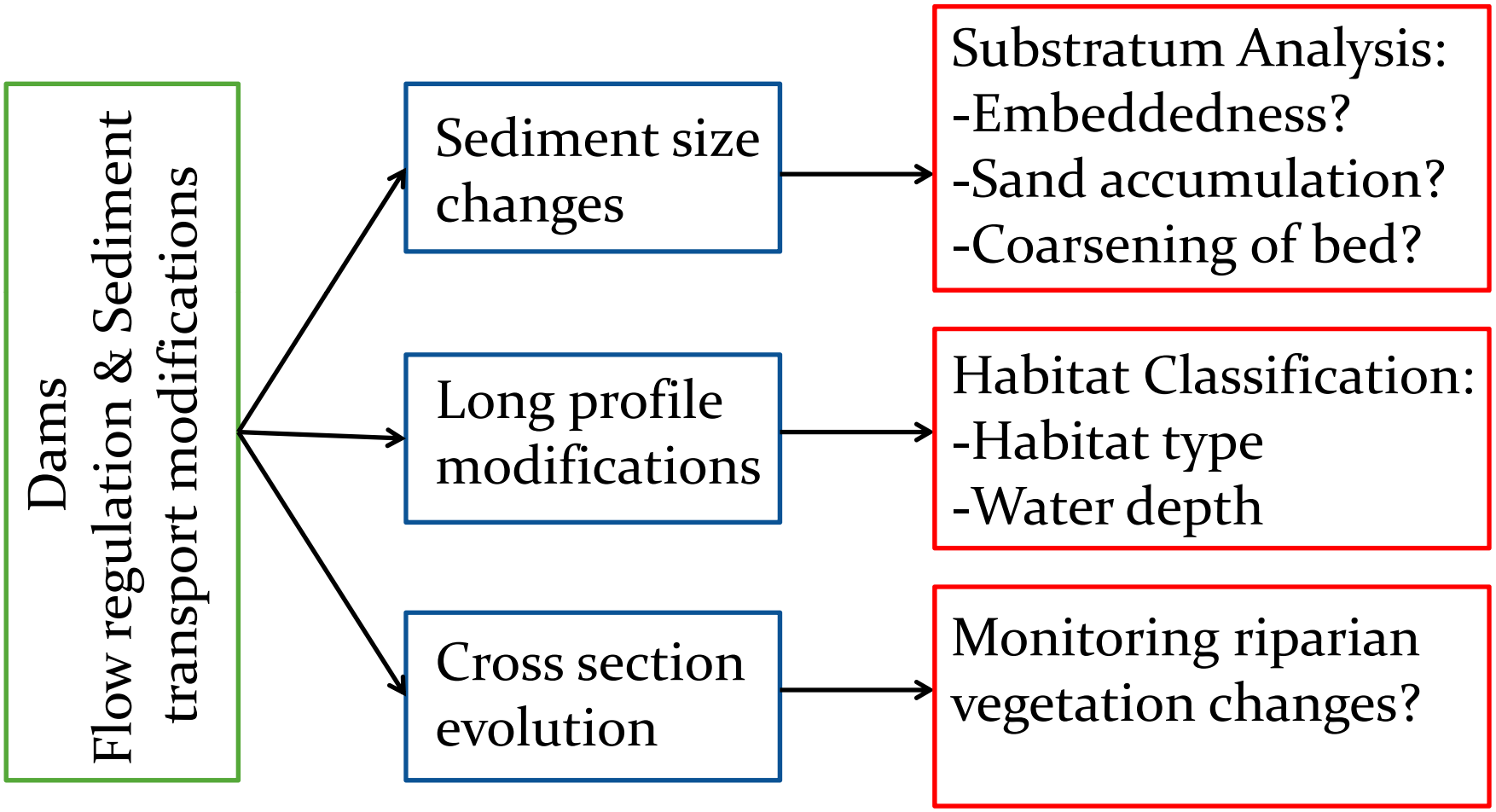


Satsunai River, Japan

aerial photographs classification

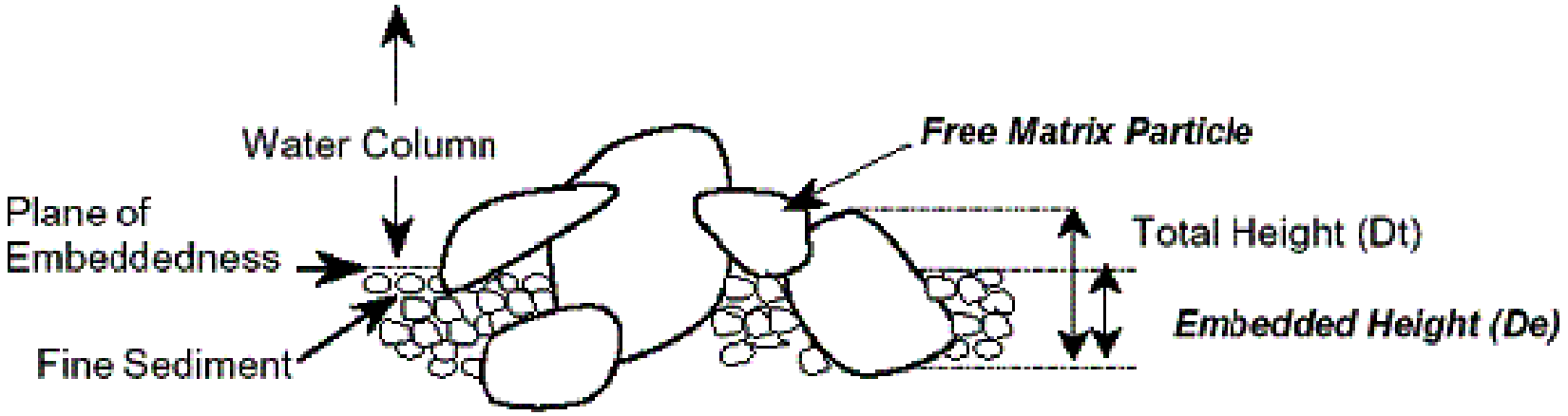
Takahashi & Nakamura (2010)

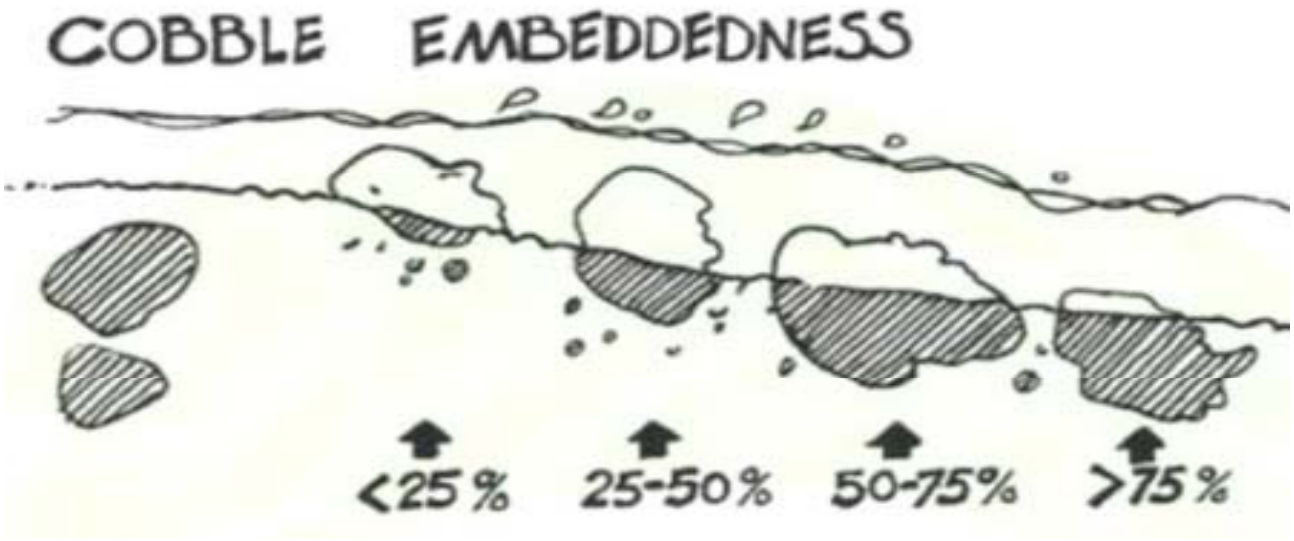
6- METHODS: Surveying the Morpho-Sedimentologic Changes



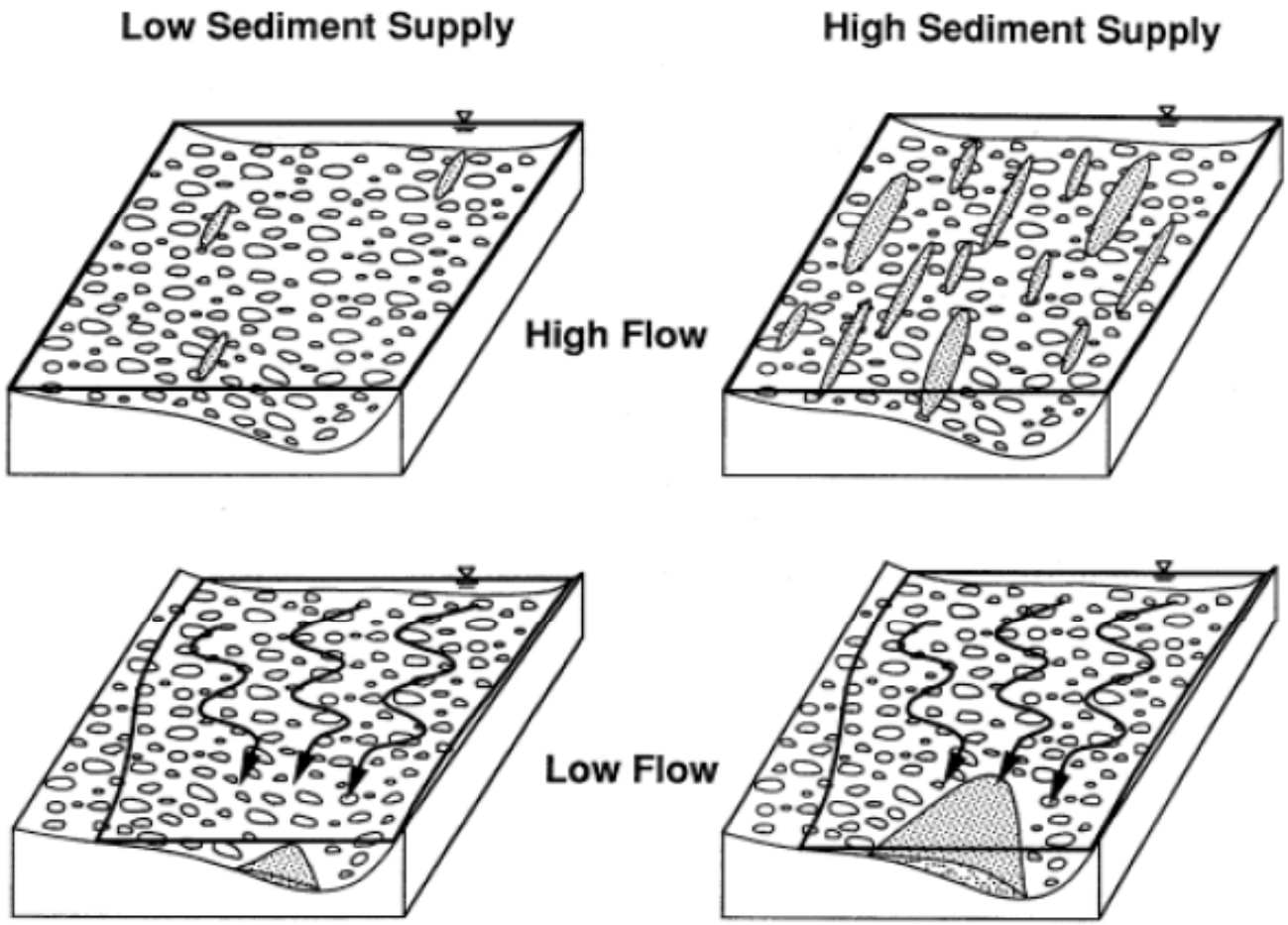
Indicators of aggradation and benthic habitat degradation:

Embeddedness measurement / estimation



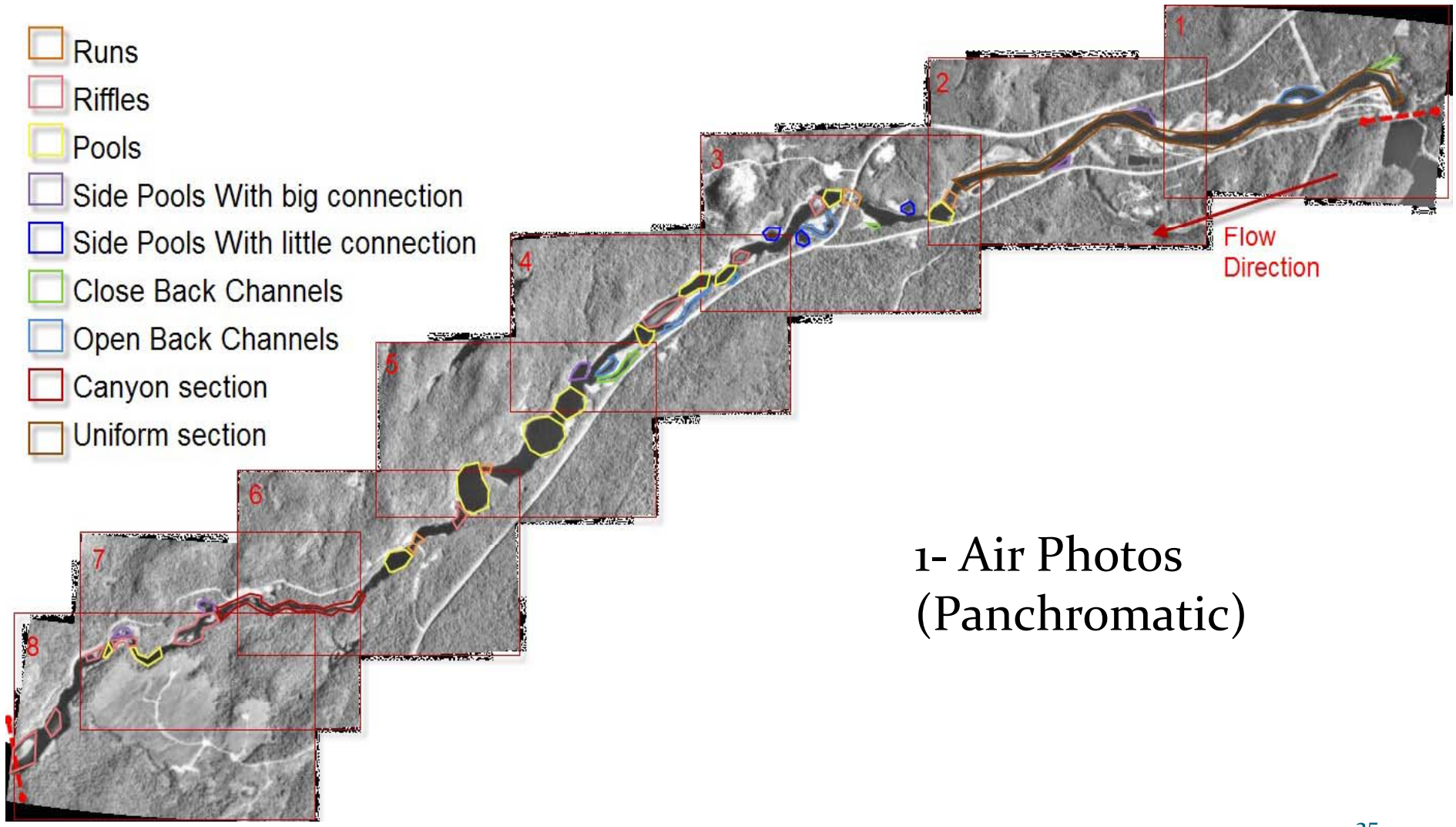


The volume of fine sediment in pools (Index of **sand supply** in Gravel bed rivers)



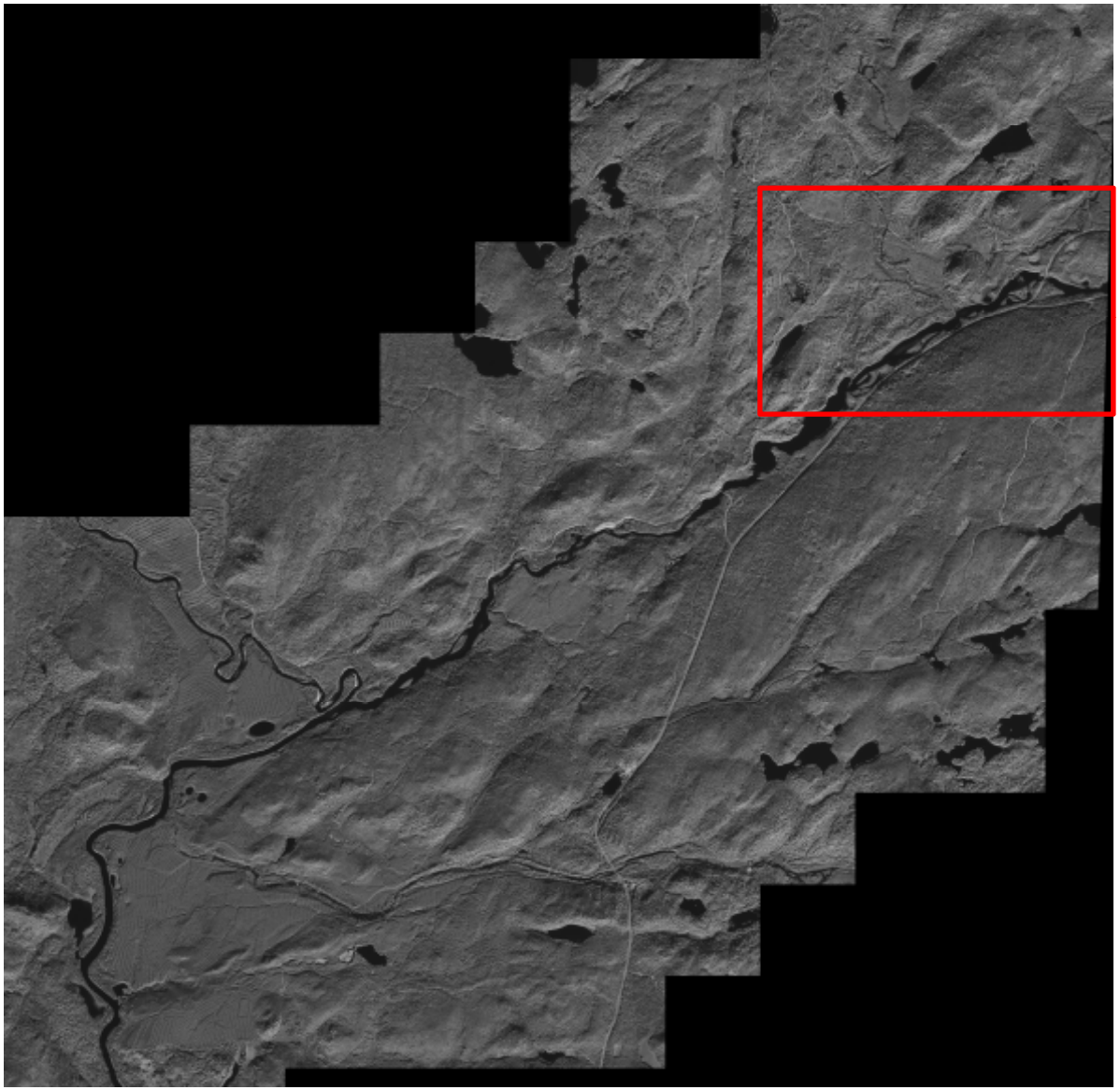
Lisle & Hilton (1992)

Fish Habitat description and classification



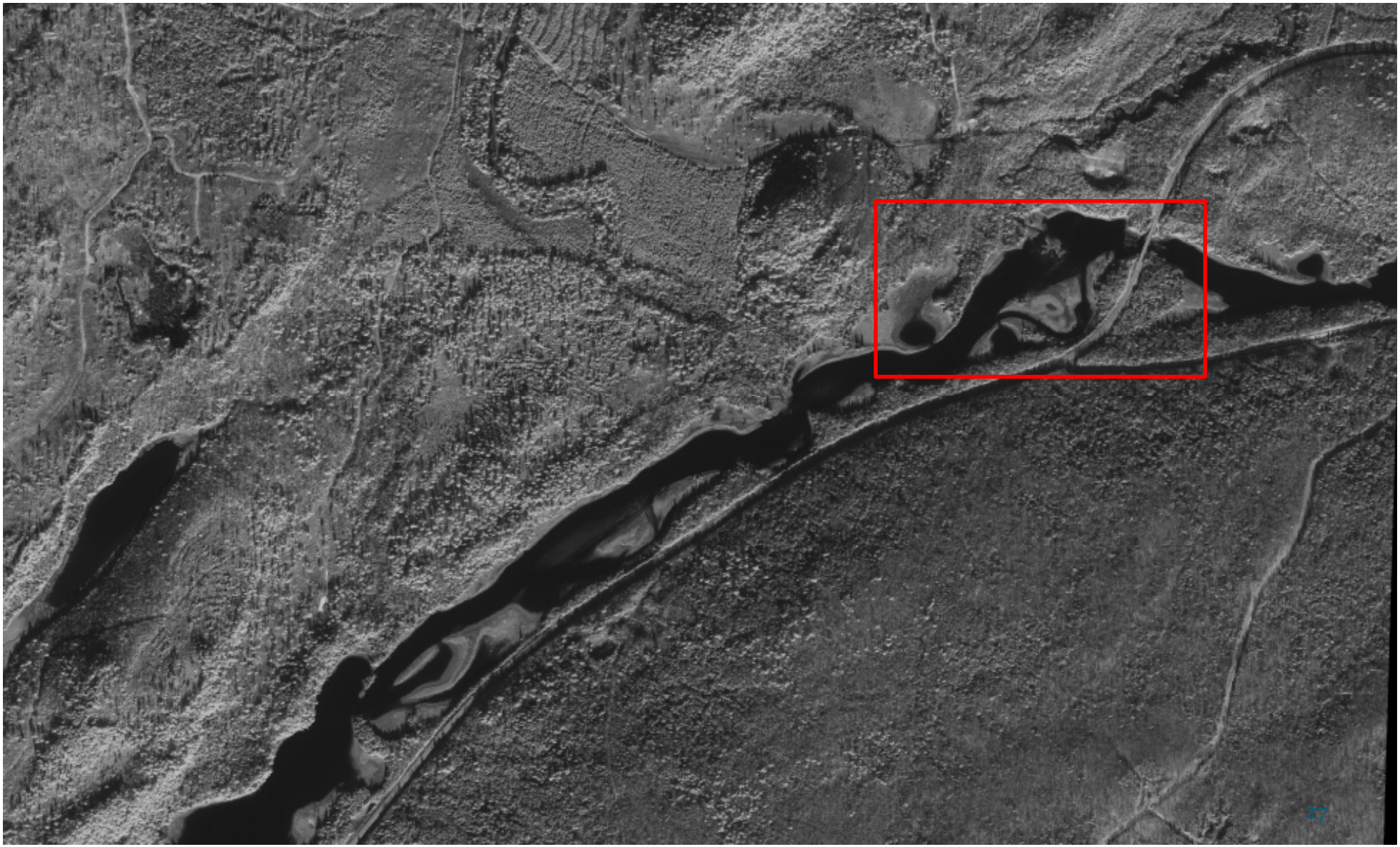
1- Air Photos (Panchromatic)

2- Satellite multispectral image archives (4 bands, 1-4m resolution)

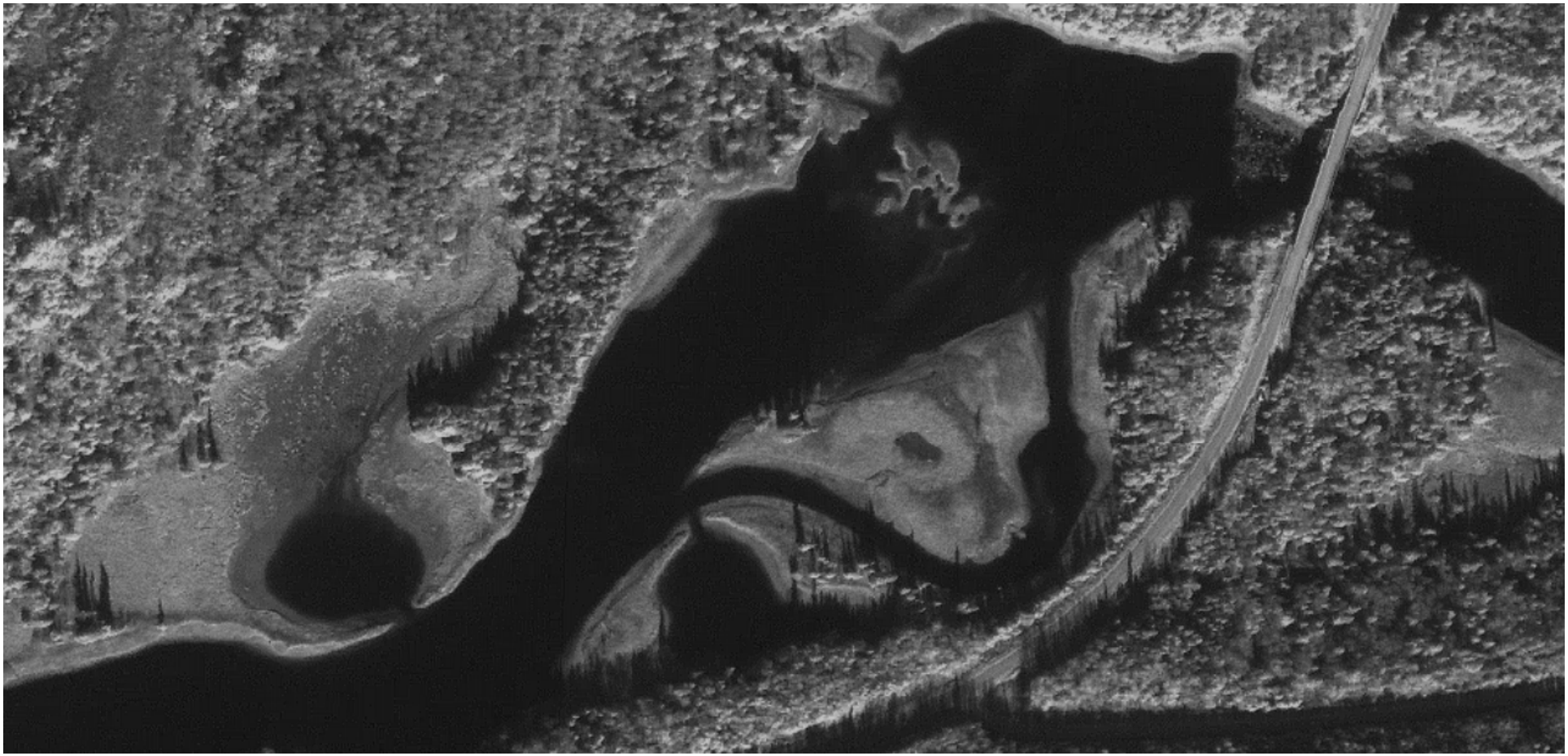


Ikonos panchromatic image of the Mississagi river (Aubrey Falls dam, Ontario)

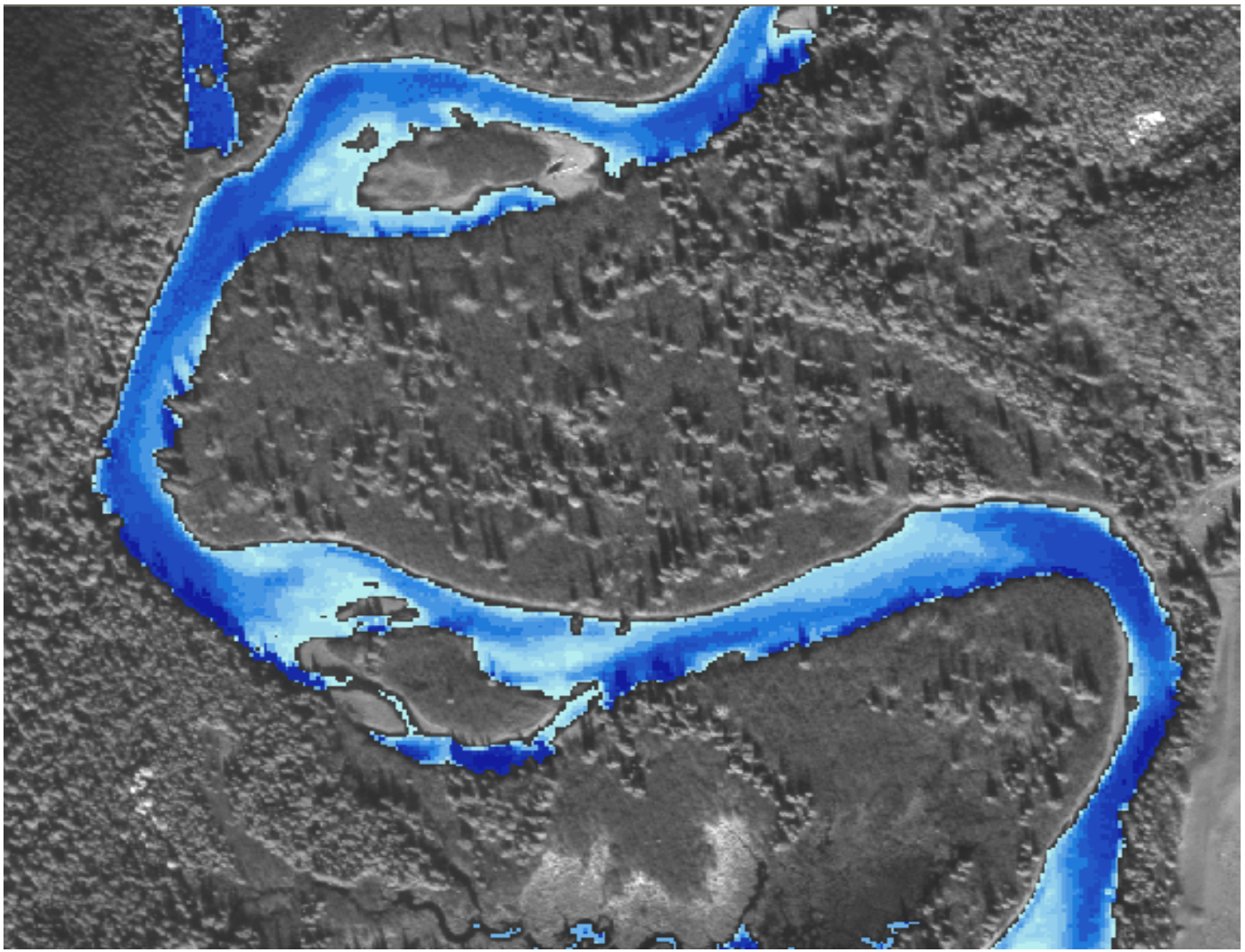
2- Satellite multispectral image archives (4 bands, 1-4m resolution)



2- Satellite multispectral image archives (4 bands, 1-4m resolution)



3- Recent satellite multispectral images (8 bands, 0.5 – 1.8 m resolution)

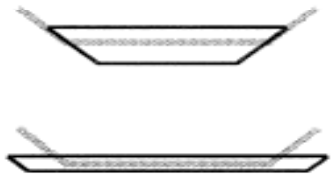
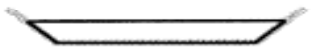
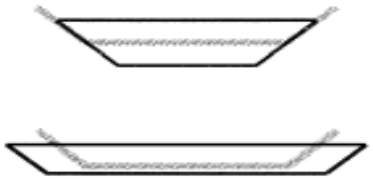
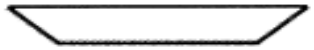
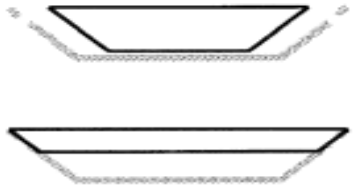
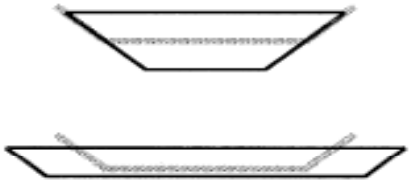
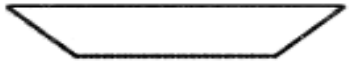
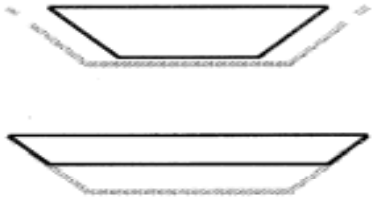


Depth classification using 8 spectral bands (Worldview-2 Image from the Magpie river, Ontario)

4- low altitude flights (Fourchue river, Morin site)
visible + hyperspectral acquisition, type Casi-2 (288 spectral bands)


Questions ?
Lower Pocatera Reservoir,
Kananaskis river

Brandt (2000) → Identified 9 styles of change below dams

	Load<Capacity	Load=Capacity	Load>Capacity
Decreased Q	Case 1 	Case 2 	Case 3 
Equal Q	Case 4 	Case 5 	Case 6 
Increased Q	Case 7 	Case 8 	Case 9 

Degradation

Incision through finer non-alluvial sediments = increase rate of degradation

doc.Ph.Lefort

Channel scour and general destabilization

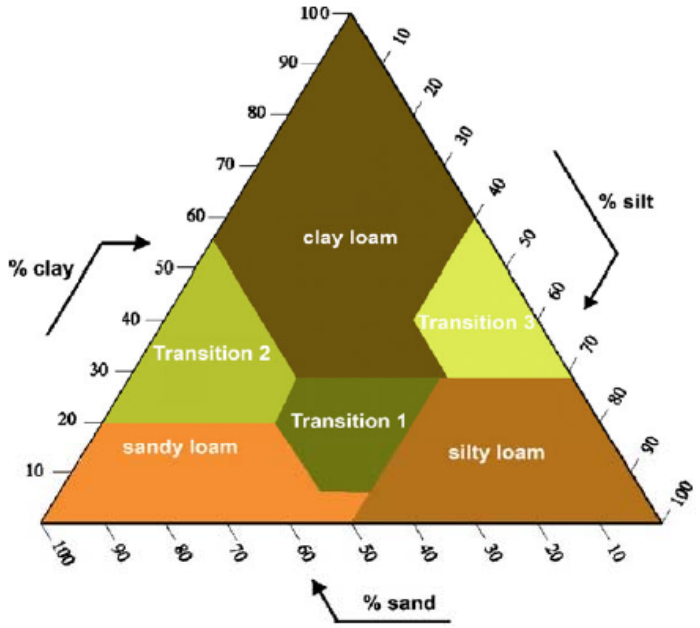
Remote Sensing

Grain size identification :

Accumulation of sand in pools…

• Castillo (2010) → Sediment grain size estimation using airborne remote sensing, field sampling, and robust statistic

• Gilvear (2006) → Remotely sensing river water depth and substrate



CASI-2 Sensor