Fraser River Gravel Reach – Lessons From A Large, Free-Flowing System

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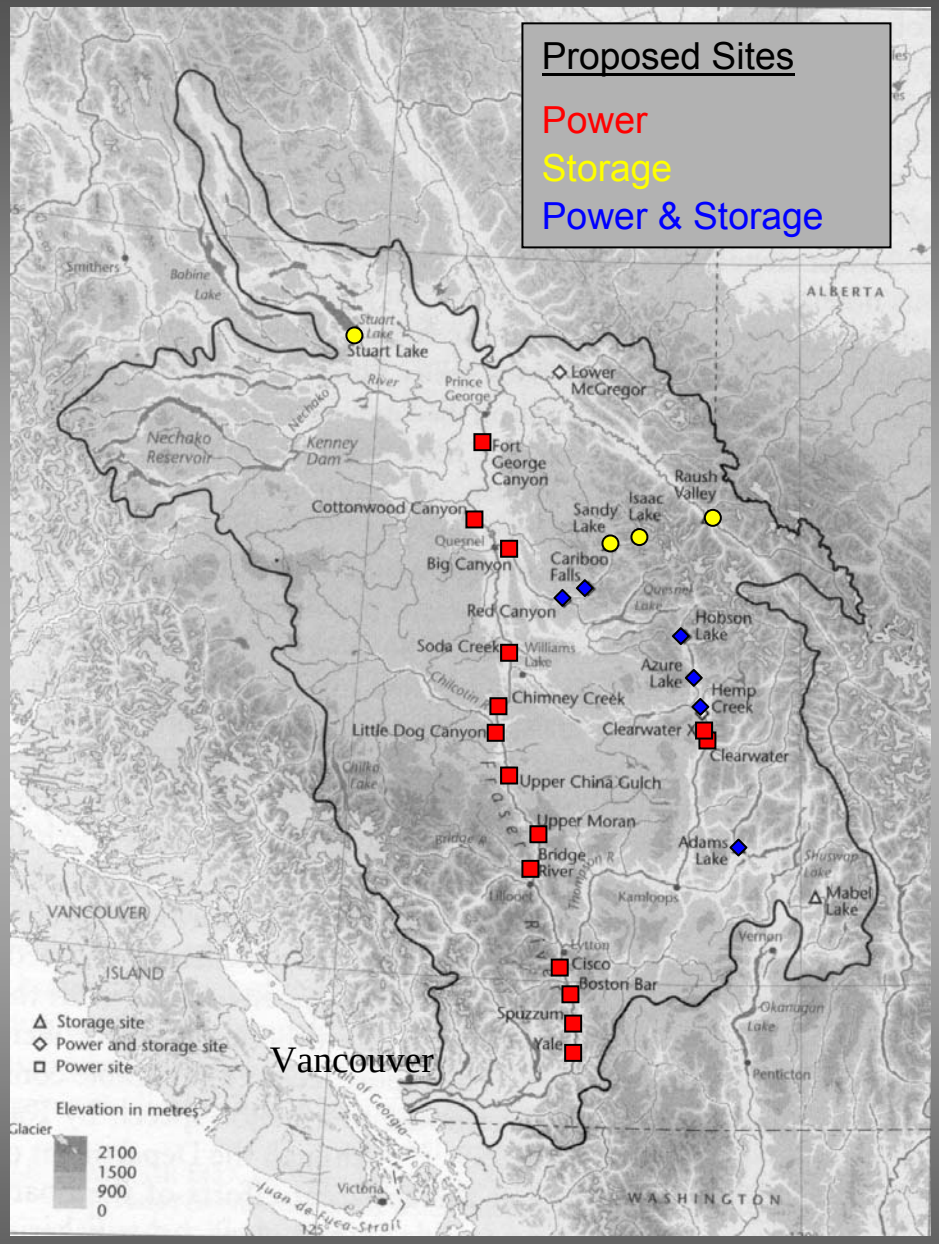
Fraser River, British Columbia

- 235,000 km^2 basin
- 1400-km mainstem length, unregulated
- Fraser Basin is home to 65% of BC's population (2.5 million)
- >2 million live in lower reach within 160 km of Pacific Ocean

★ CALFED



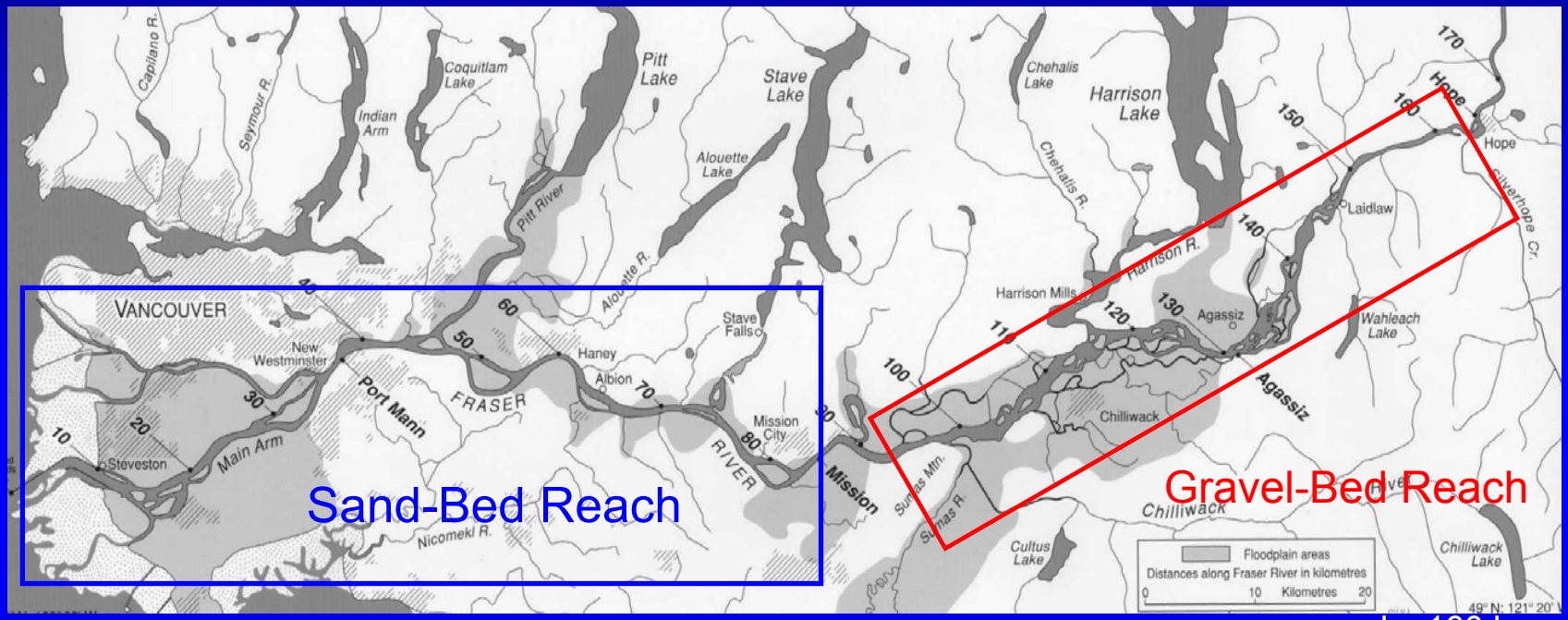
Source: Fraser Basin Power Board (1958), in "Fish Versus Power" by M. Evenden (2004)

A bit of history…

- Strong lobbying in 1940s and '50s to dam the Fraser mainstem
- "…all of the Northwest's rivers are going to be dammed and we should not kid ourselves."
  - USFWS Director A. Day (1951)
- "…weigh the value of the salmon against the value of electricity… the choice is obvious."
  - Canadian B. Hutchinson (1950) "*The Fraser*"

➢ all Fraser mainstem dam proposals rejected in 1960s based on scientific review by IPSFC that predicted extirpation of Pacific Salmon

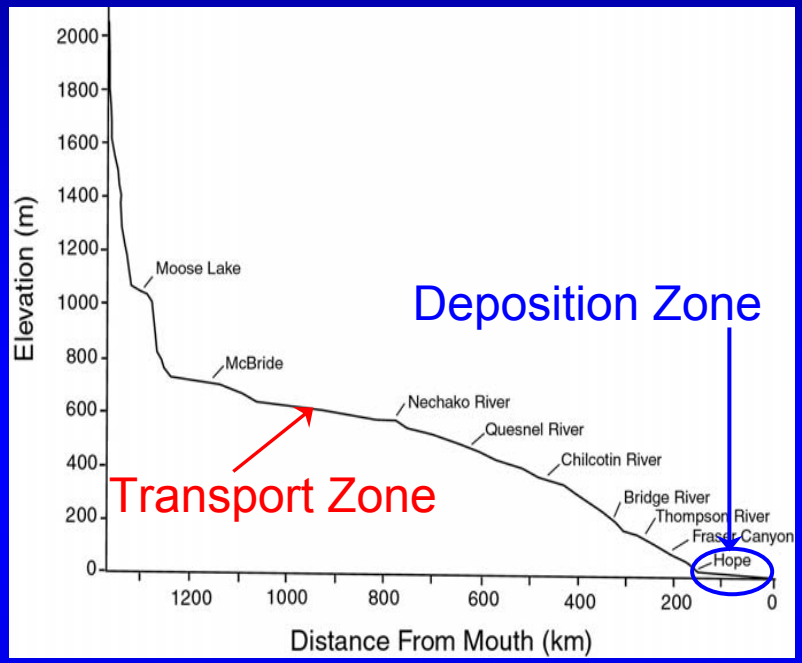
Lower Fraser River

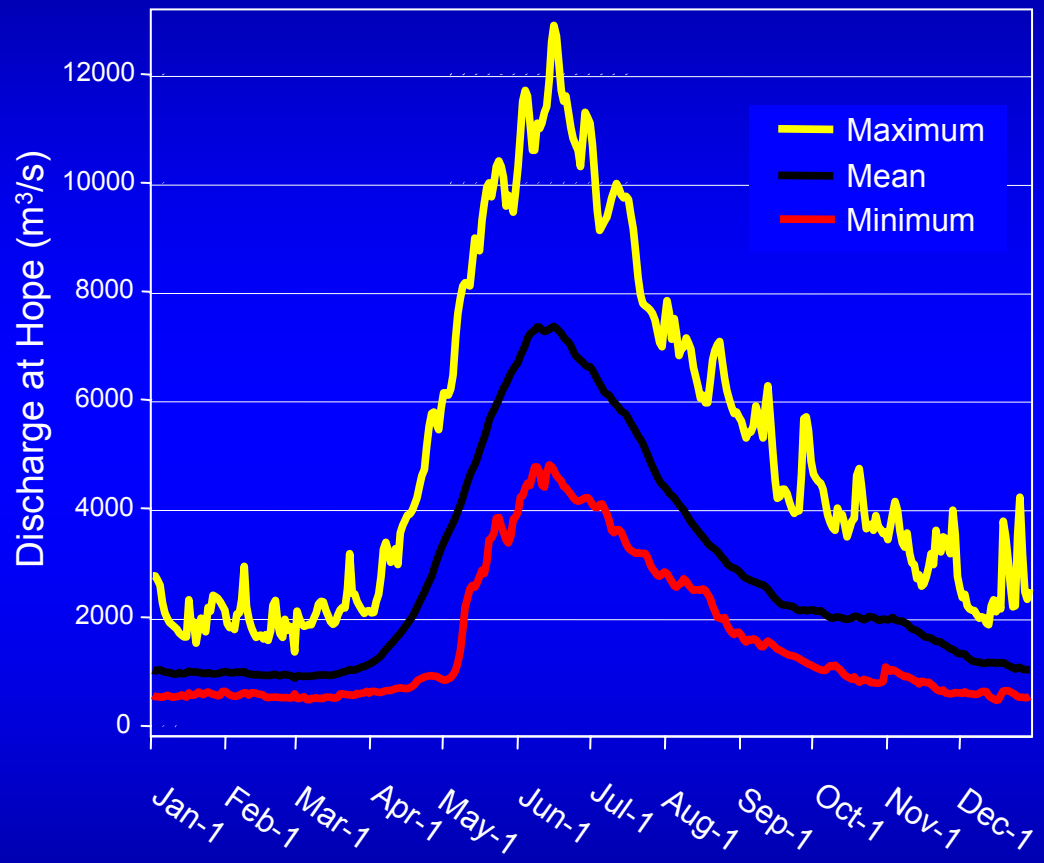


scale: 160 km

- 75-km “wandering” gravel-bed reach between Hope and Mission
- sediment transport from steep, upper basin delivers ~340,000 t/yr of gravel to reach
- reduced gradient at Mission forces gravel deposition upstream; hence, the reach is aggrading

Sediment Delivery

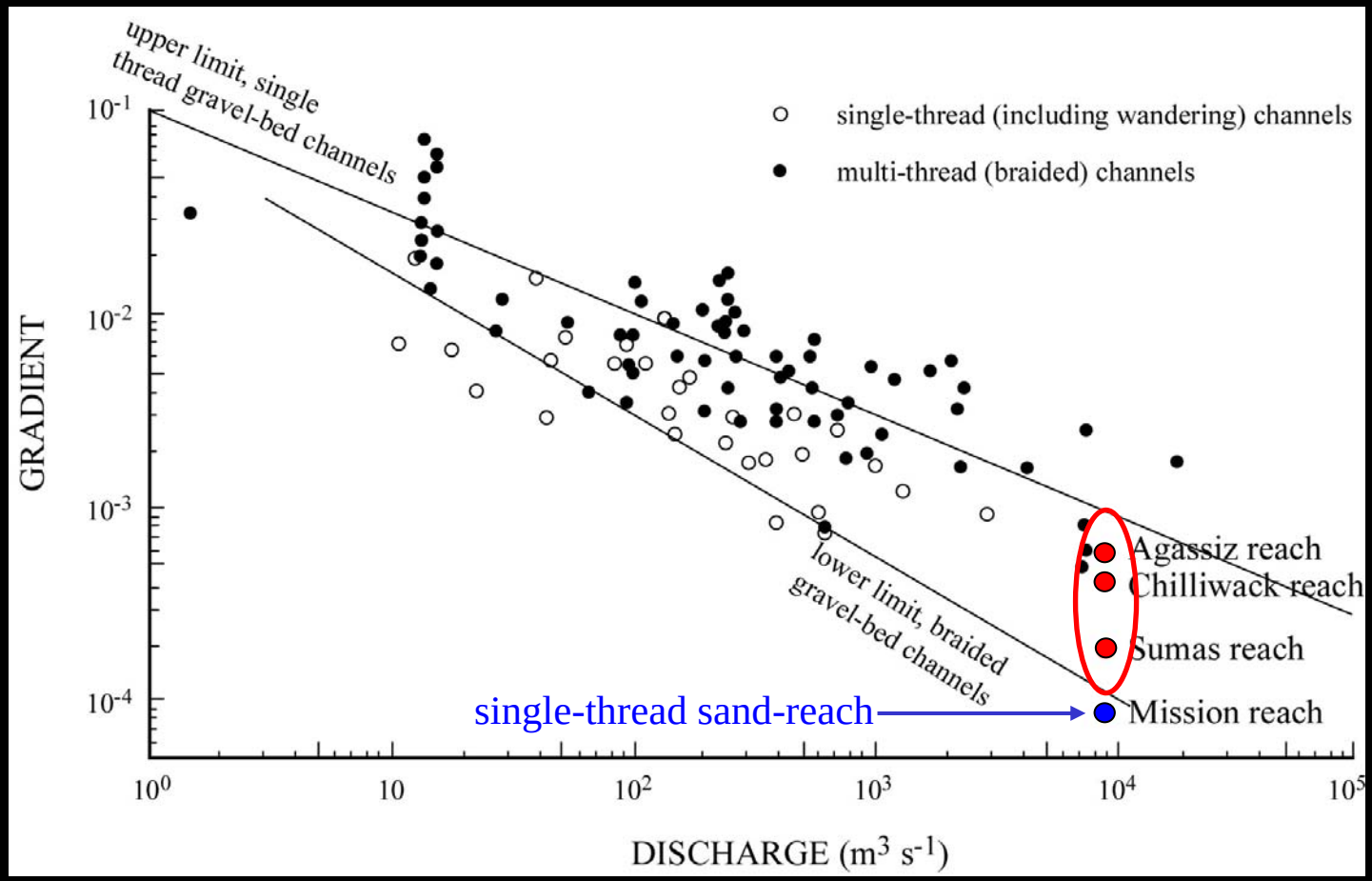




- channel gradient forces gravel deposition below Hope
- annual freshet (snow-melt) delivers gravel; gravel recruitment correlated with annual peak Q

Wandering Channel Morphology

- transition between single-thread meandering and multi-thread braided channel
- dependent upon modest volume and temporally irregular movement of sediment

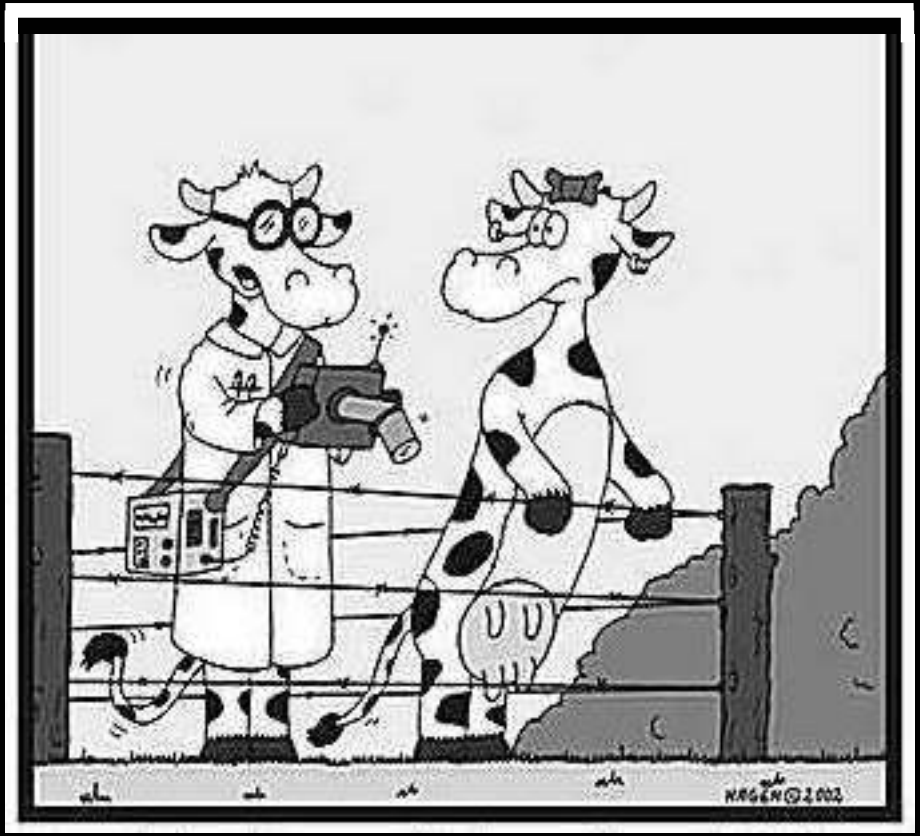


Gravel Reach of Fraser River

- wandering morphology
- extensive network of perennial, seasonal and abandoned channels
- gravel accumulates in localized ‘sedimentation’ zones (gravel bars)

- sediment deposition creates exceptional habitat for at least 28 fish species
    - including six “listed” species
    - all 5 Pacific Salmon species
        - *pink and chinook salmon*

- $1.7 billion/yr to provincial revenue
- significant First Nations values



Yes Daisy, according to my Chromatic Analyzer the grass is greener on the other side

but…

The Pr

Managers warn public, government ignore 'bastard child' of the mineral

B.C. faces

The Steelheader Salmon & Trout News Sept-Oct. 15, 2000 vol. 6 #9

SSTN 7

Fraser gravel removal: Is it all about money?

Vic Carrao
Steelheader Contributor

Recently I spent a few minutes talking with a senior fishery biologist while fishing the Fraser. He had pointed out to me that there were hundreds of juvenile Chinook right at my feet, feeding on discarded fish guts and salmon eggs. This led to a brief conversation on Fraser gravel removal which is being looked at right now by the Fraser Basin Council.

On June 28th the first of many meetings to come was held at the University College of the Fraser Valley. The Fraser Basin Council is facilitating the development of a Management Plan for the Fraser River between Hope and Mission, a section of the river often referred to as the Gravel reach. (Also know to us anglers as the most productive angling

LUHR·JENSEN

Photo courtesy of STS guiding

talling 50 million tonnes a year — about 15 tonnes annually for each B.C. resident — even a seemingly minor increase, say $5 a tonne, adds up quickly.

For a homebuyer, it would

BILL KEAY/Vancouver Sun

KNOBBLY TREASURE: Jim Allard, vice-president of Allard Contractors Ltd., says the industry has to do more to show the public the importance of gravel to reduce opposition to new mines.

- Actions taken to mitigate flood hazard and river instability must reckon with possible consequences to fish habitat

Gravel Management

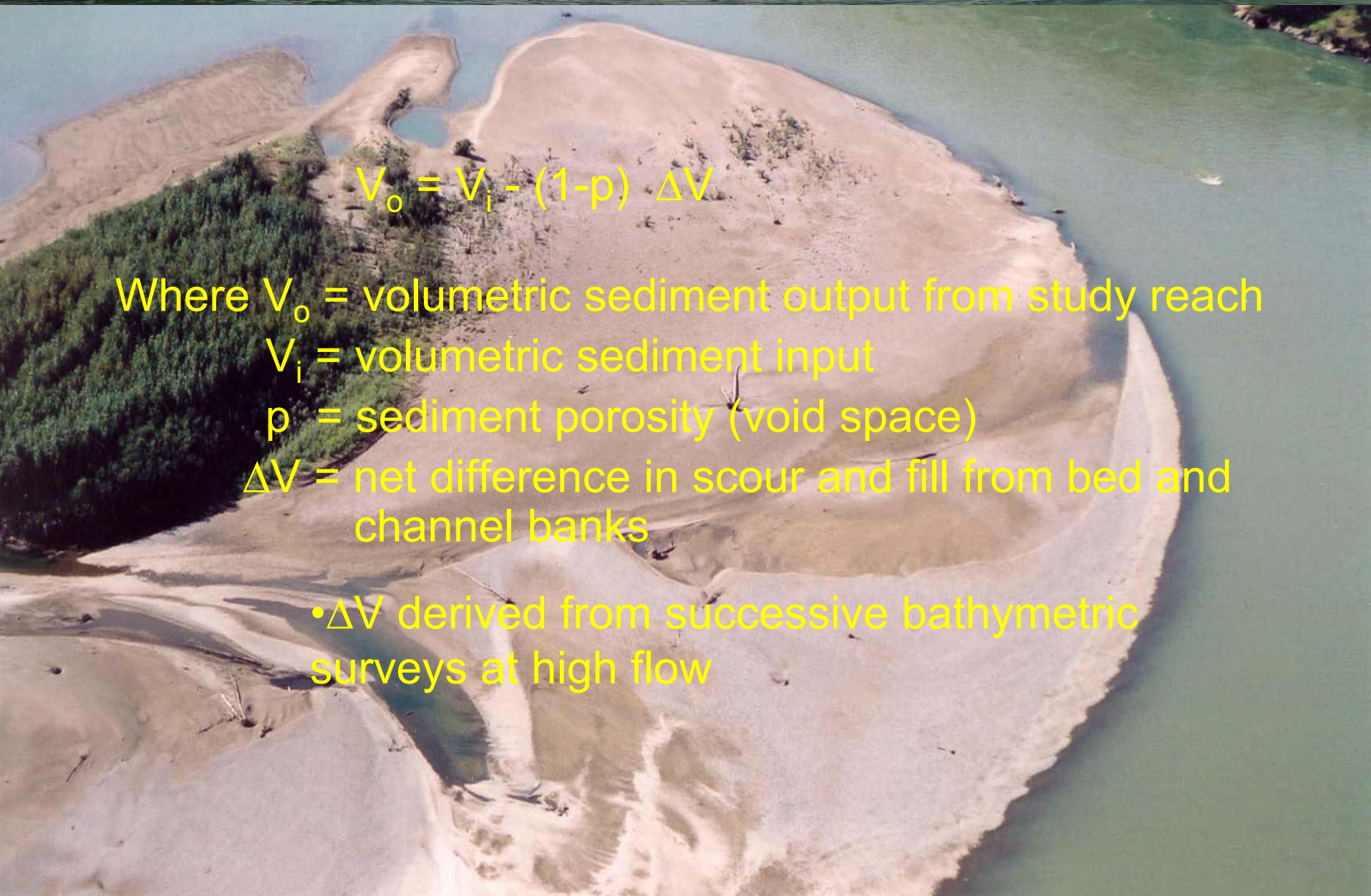
- current political mandate supports in-stream mining
- science-based gravel management needs answers to:
    - how much gravel is recruited annually?
    - what is the spatial pattern of gravel deposition?
    - what is the ecological role of gravel in the reach?
    - where to remove? what method? what time of year? how much? how often?

Presentation Outline

Tools Used to Answer These Questions:

1. Reach-scale sediment budget *(D. Ham, UBC)*
2. Bar-scale sediment transport and habitat development
3. Habitat-scale use of gravel bars by fish
4. Gravel mining impact study – *brief results highlighting role of fluvial processes in habitat recovery*

Sediment Budget –*Volumetric Method*



$$V_o = V_i - (1-p)\ \Delta V$$

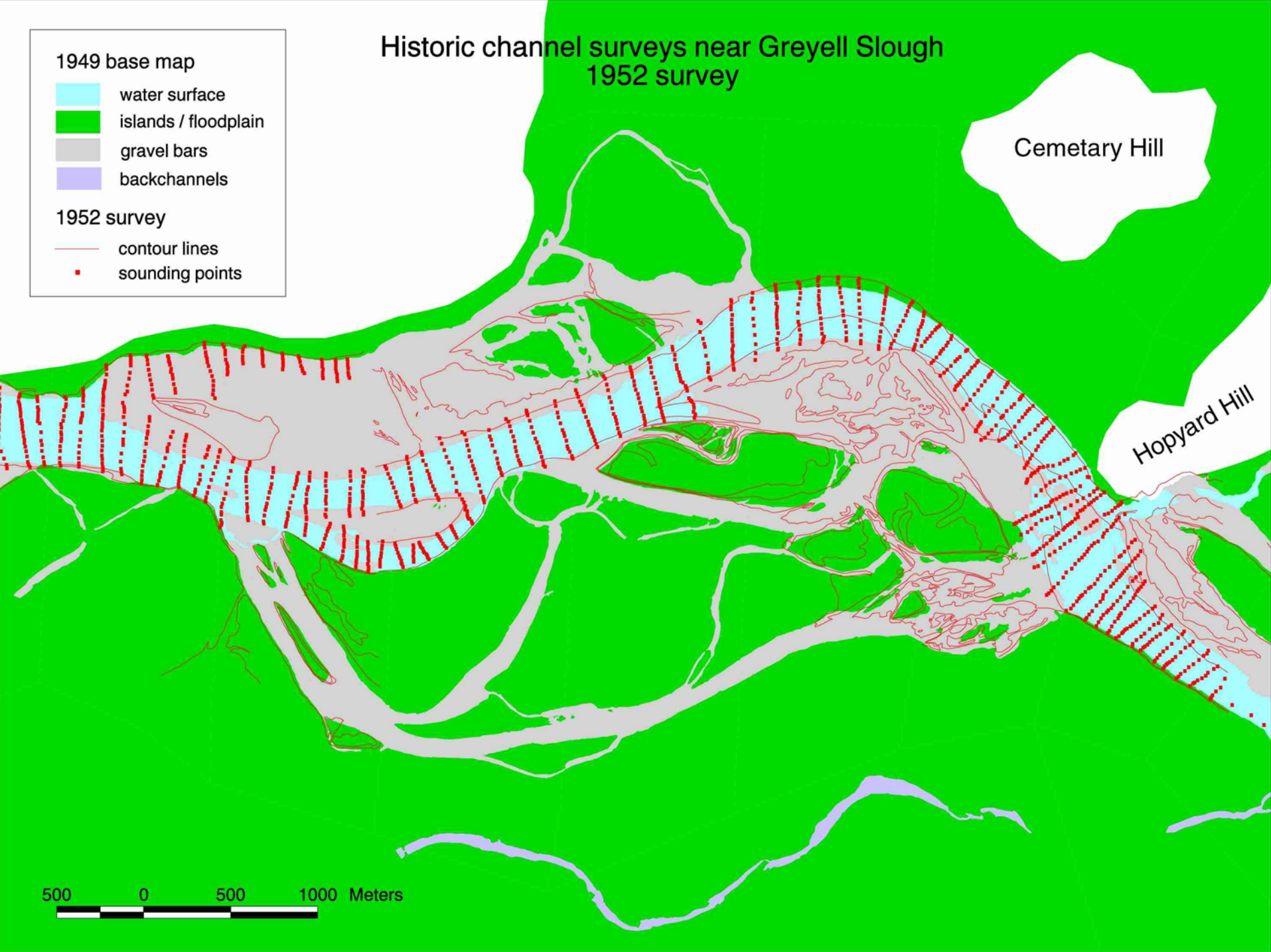
Where V_o = volumetric sediment output from study reach

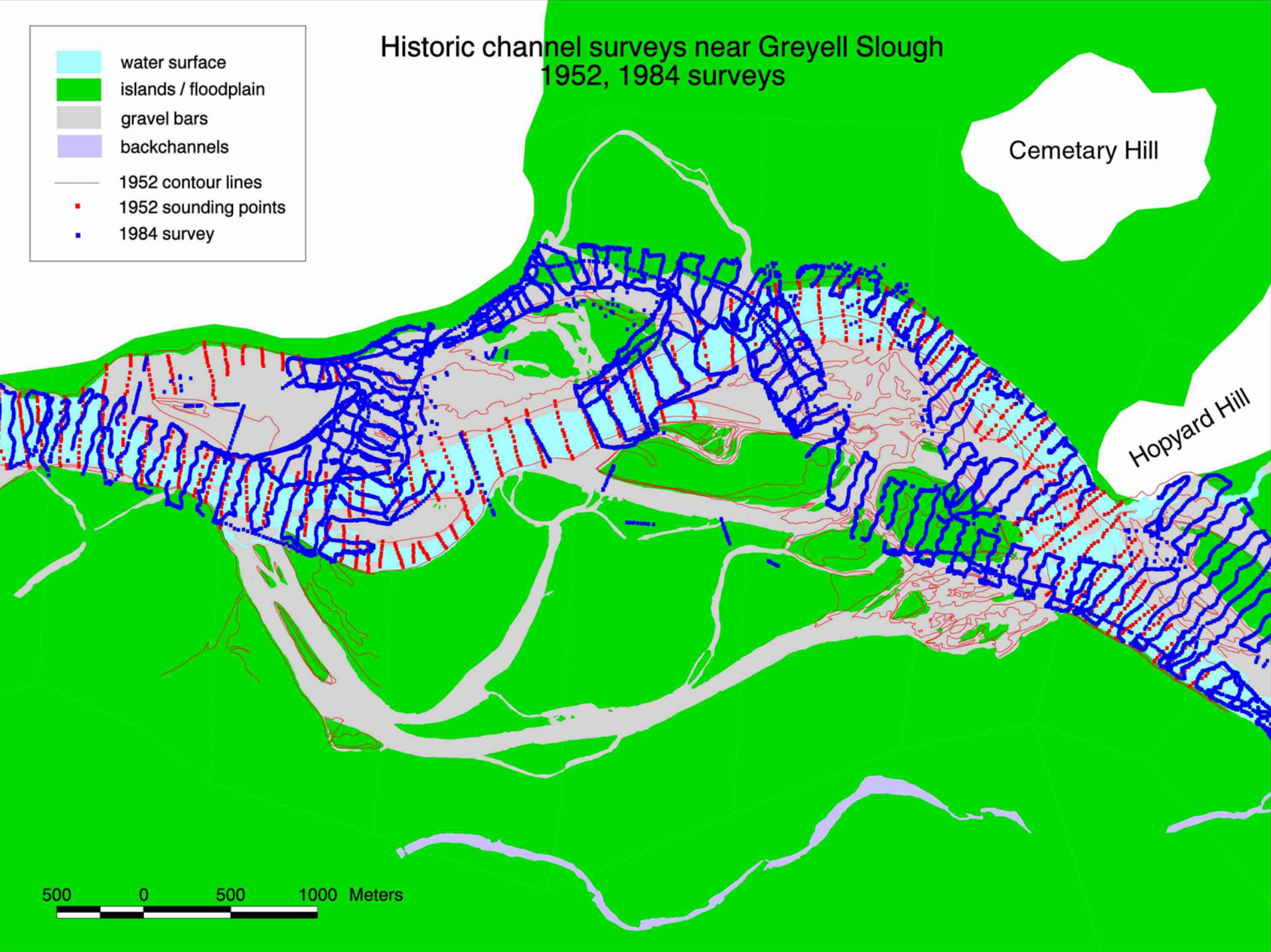
V_i = volumetric sediment input

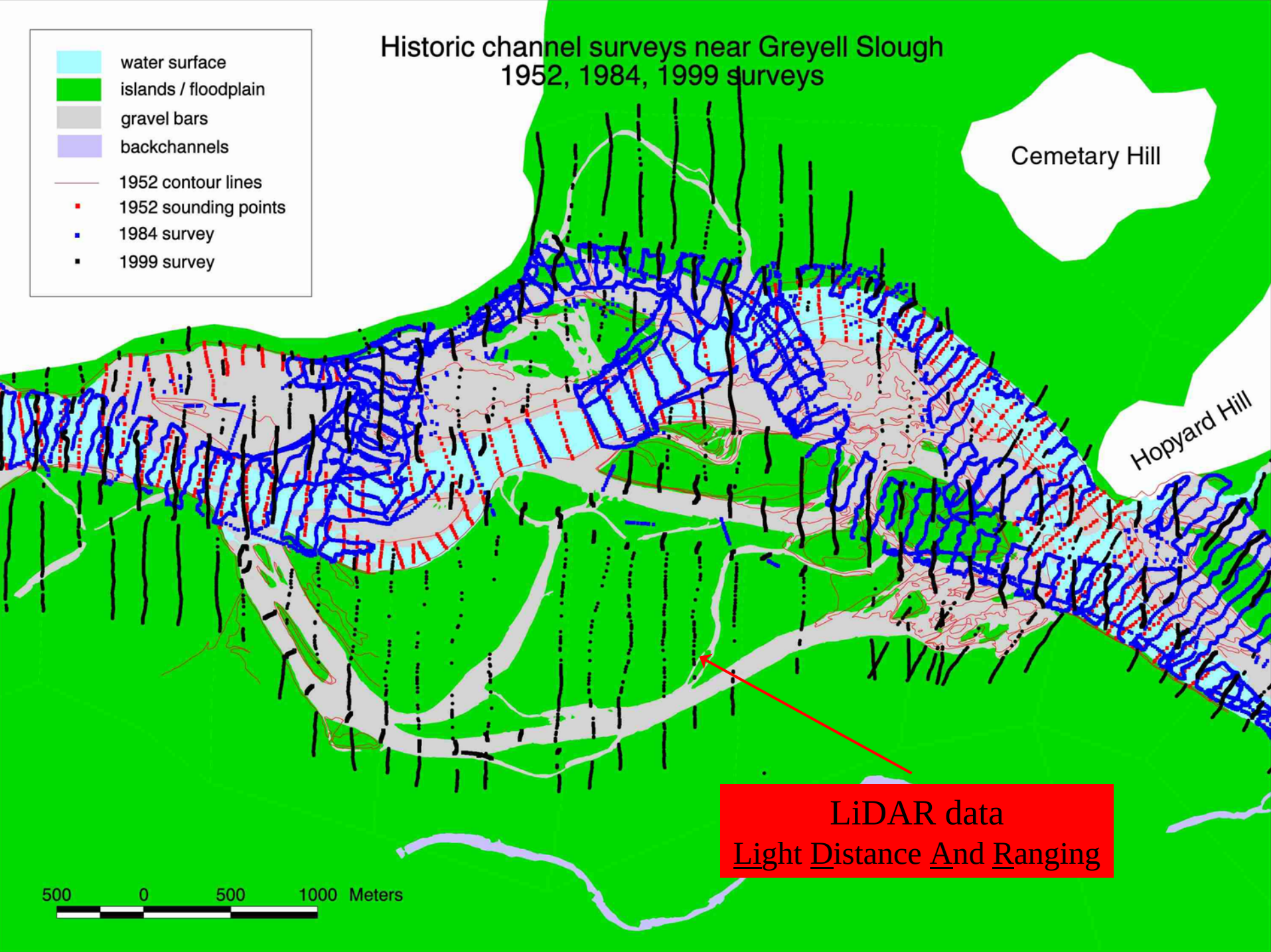
p = sediment porosity (void space)

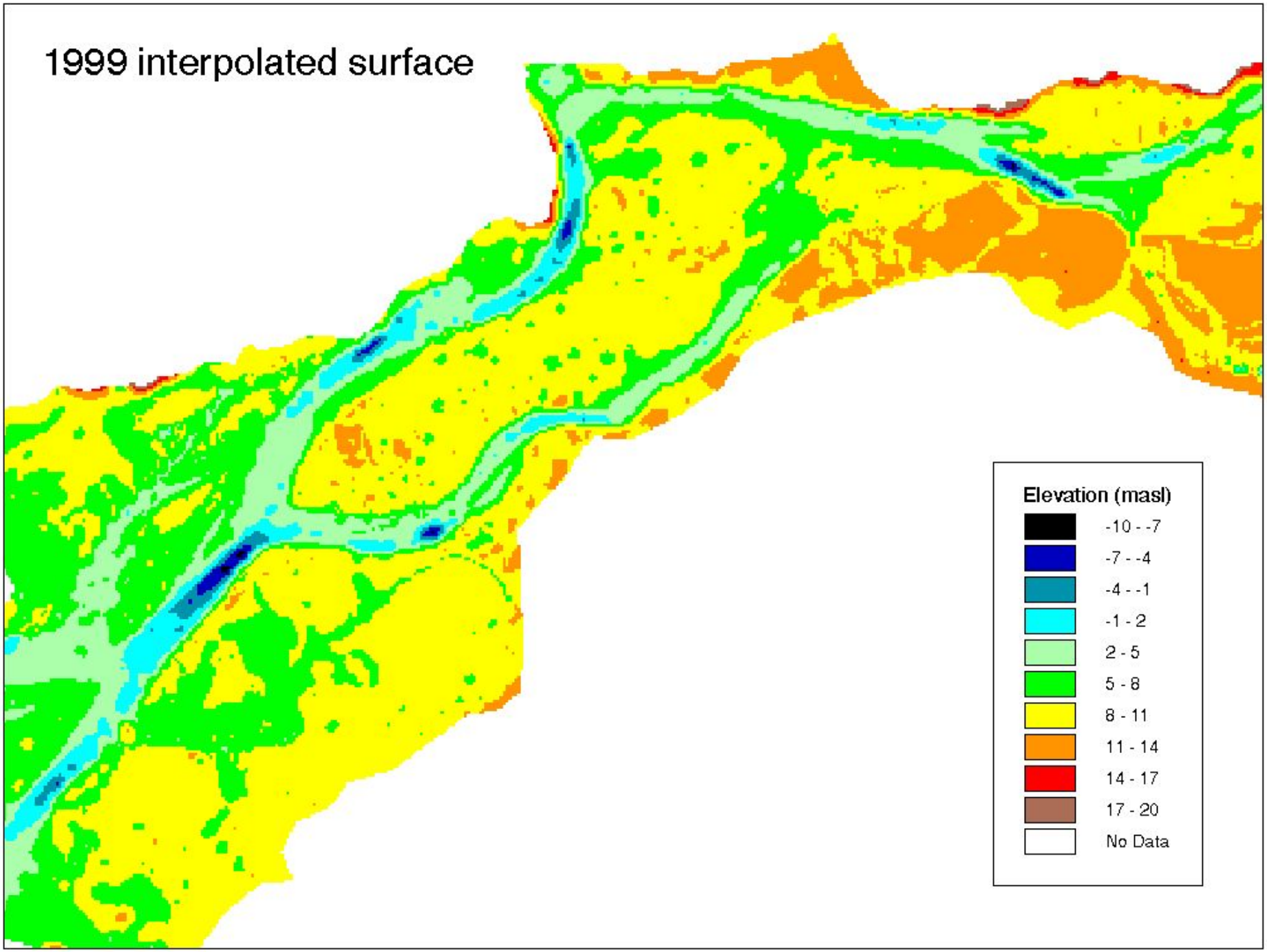
ΔV = net difference in scour and fill from bed and channel banks

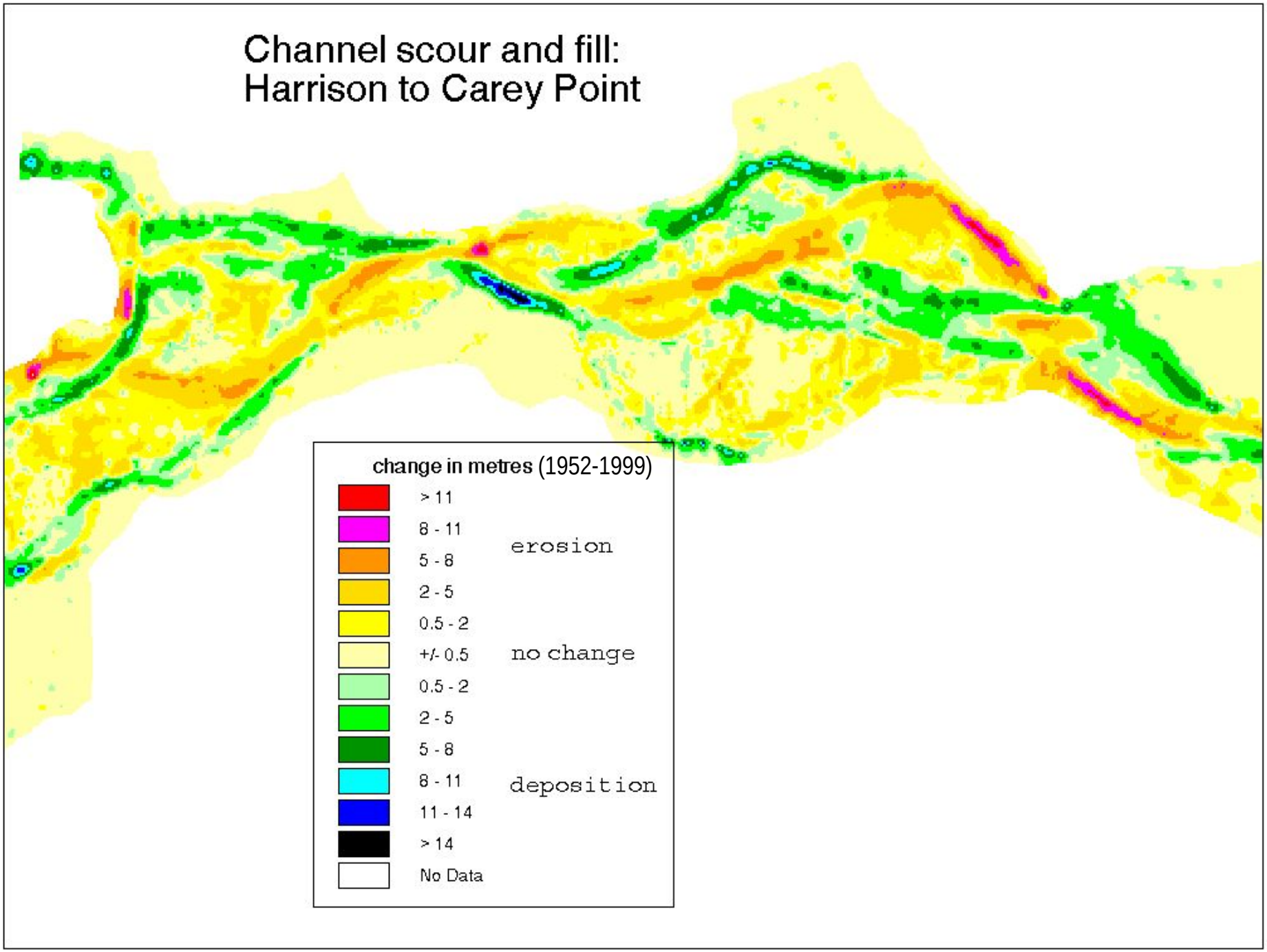
- ΔV derived from successive bathymetric surveys at high flow


Historic channel surveys near Greyell Slough
1952 survey
1949 base map
water surface
islands / floodplain
gravel bars
backchannels
1952 survey
contour lines
sounding points
Cemetary Hill
Hopyard Hill
500
0
500
1000
Meters

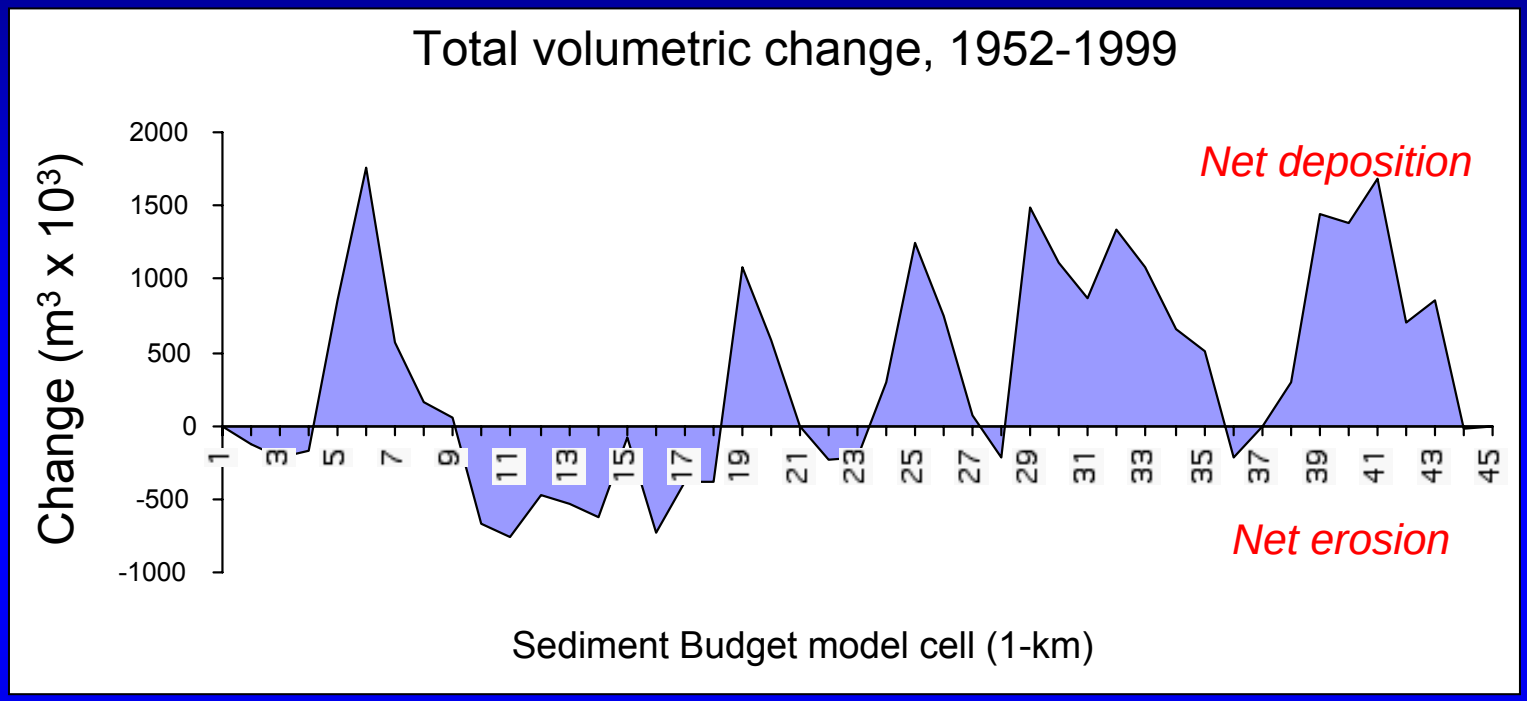

Historic channel surveys near Greyell Slough
1952, 1984 surveys
water surface
islands / floodplain
gravel bars
backchannels
1952 contour lines
1952 sounding points
1984 survey
Cemetary Hill
Hopyard Hill
500
0
500
1000
Meters


Historic channel surveys near Greyell Slough
1952, 1984, 1999 surveys
water surface
islands / floodplain
gravel bars
backchannels
1952 contour lines
1952 sounding points
1984 survey
1999 survey
Cemetary Hill
Hopyard Hill
LiDAR data
Light Distance And Ranging
500
0
500
1000
Meters


1999 interpolated surface
Elevation (masl)
-10 - -7
-7 - -4
-4 - -1
-1 - 2
2 - 5
5 - 8
8 - 11
11 - 14
14 - 17
17 - 20
No Data


Channel scour and fill:
Harrison to Carey Point
change in metres (1952-1999)
> 11
8 - 11
5 - 8
2 - 5
0.5 - 2
+/- 0.5
0.5 - 2
2 - 5
5 - 8
8 - 11
11 - 14
> 14
No Data
erosion
no change
deposition

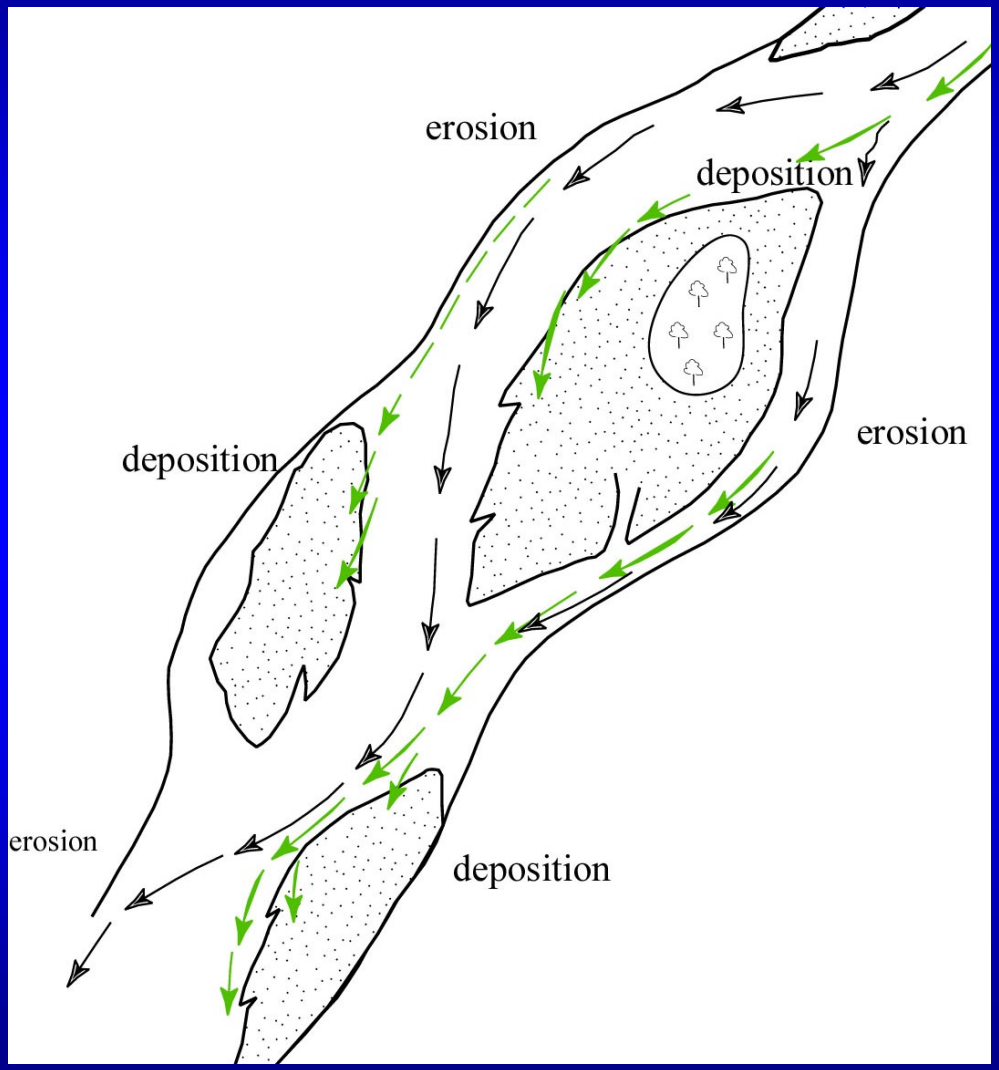
Aggradation on Lower Fraser River



- net annual gravel recruitment: 340,000 t/yr
- <2 mm/yr over entire 75-km reach
- up to 2.7 m net deposition in some locations over 50 yr

➢ sediment deposition is spatially and temporally variable

Pattern of Gravel Movement



- gravel moves during freshet in steps, not continuously (<3 km step distance)
- 340,000 t/yr recruited, but 3-5 million t/yr shift locally
- bar morphology produced by long-term aggradation at the reach scale and flood-event processes of erosion and deposition at the bar scale

Bar-Scale Processes of Habitat Development

- reach-scale sediment transport processes are preserved as sedimentary features on gravel bars
  - ➢ building blocks of fish habitat

- repeat surveys of bar complexes after flood events
- detailed surveys of small-scale features
- sediment characterization (surface and subsurface)

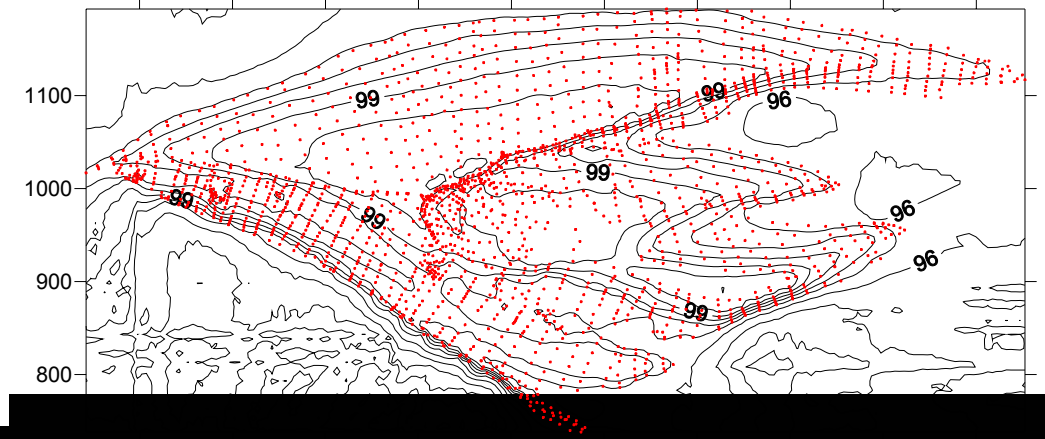
Gravel Bar Morphology

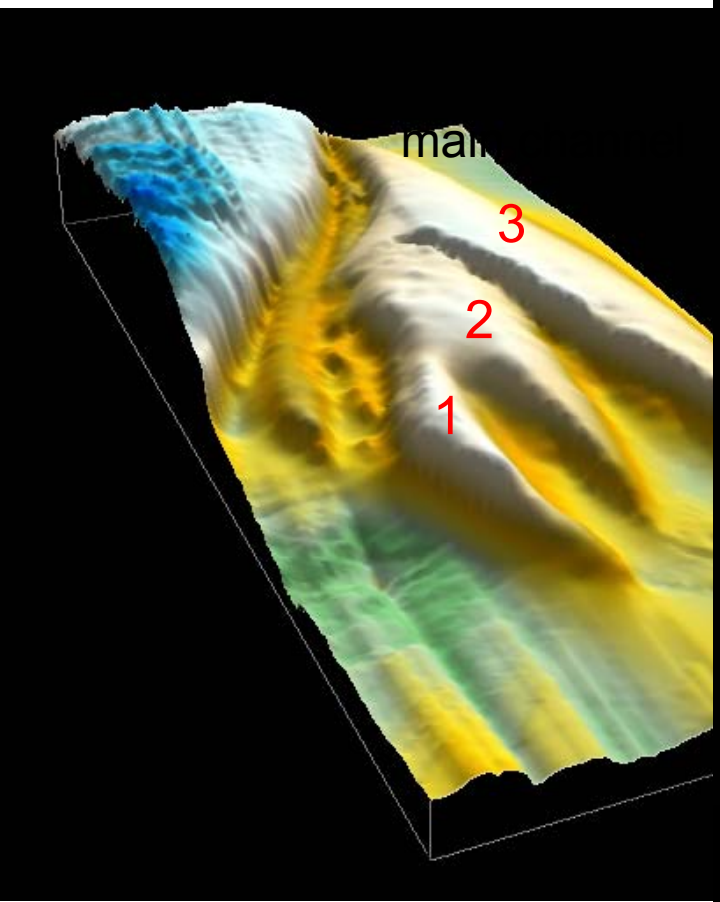
- gravel bars made up of sedimentary units produced from deposition and erosion
  - the building blocks of fish habitat

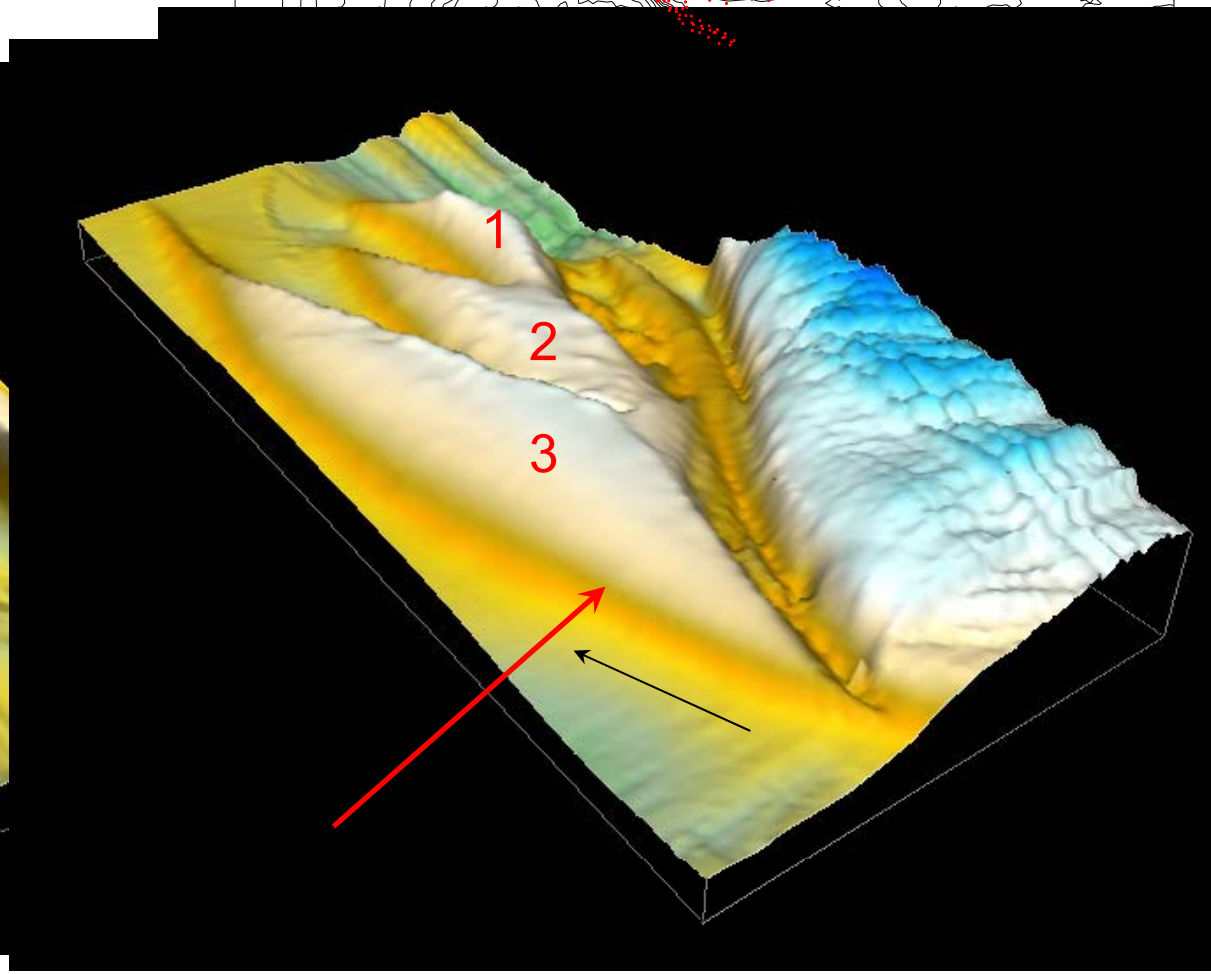
Sedimentary Units - *Habitat Development*

Calamity Bar March 2002

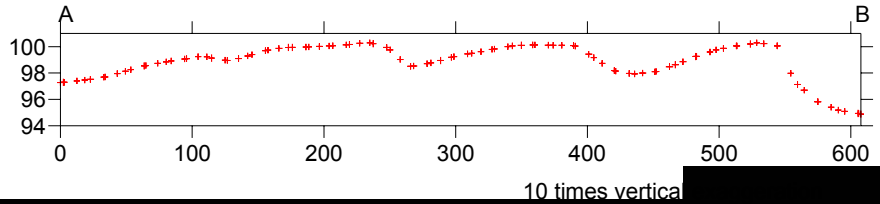
- bar consisting of 3 sediment lobes

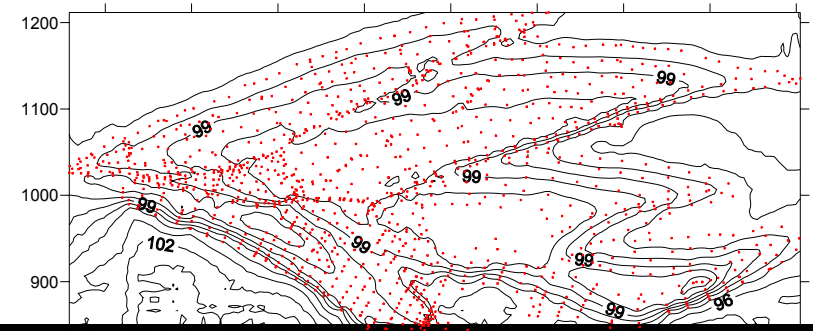


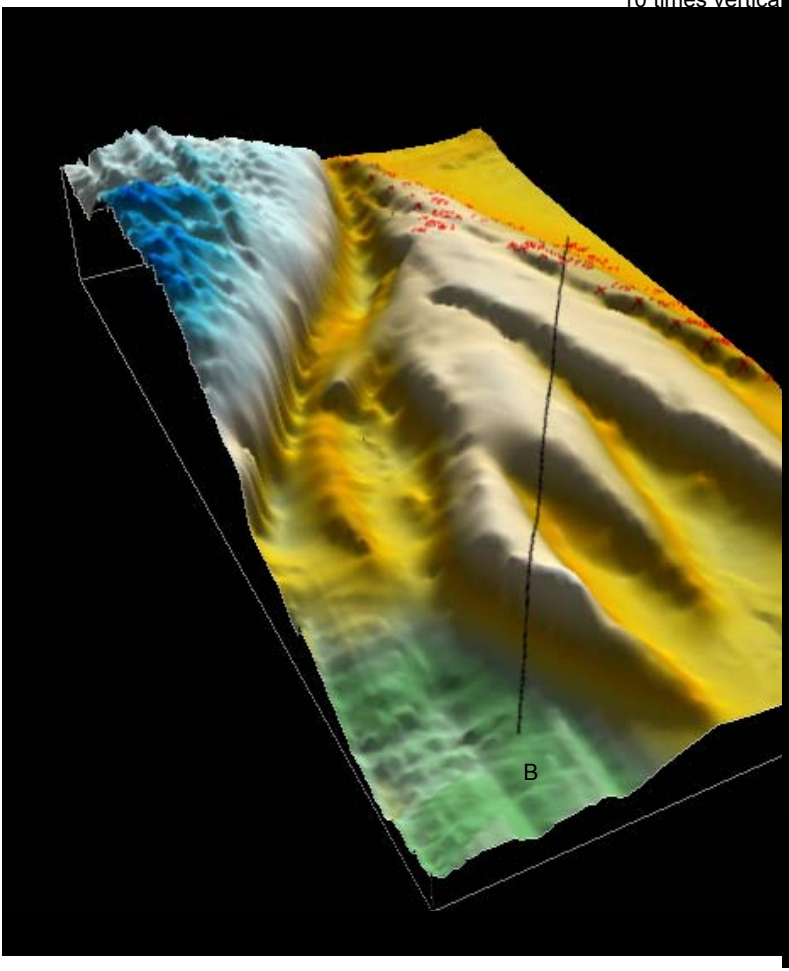


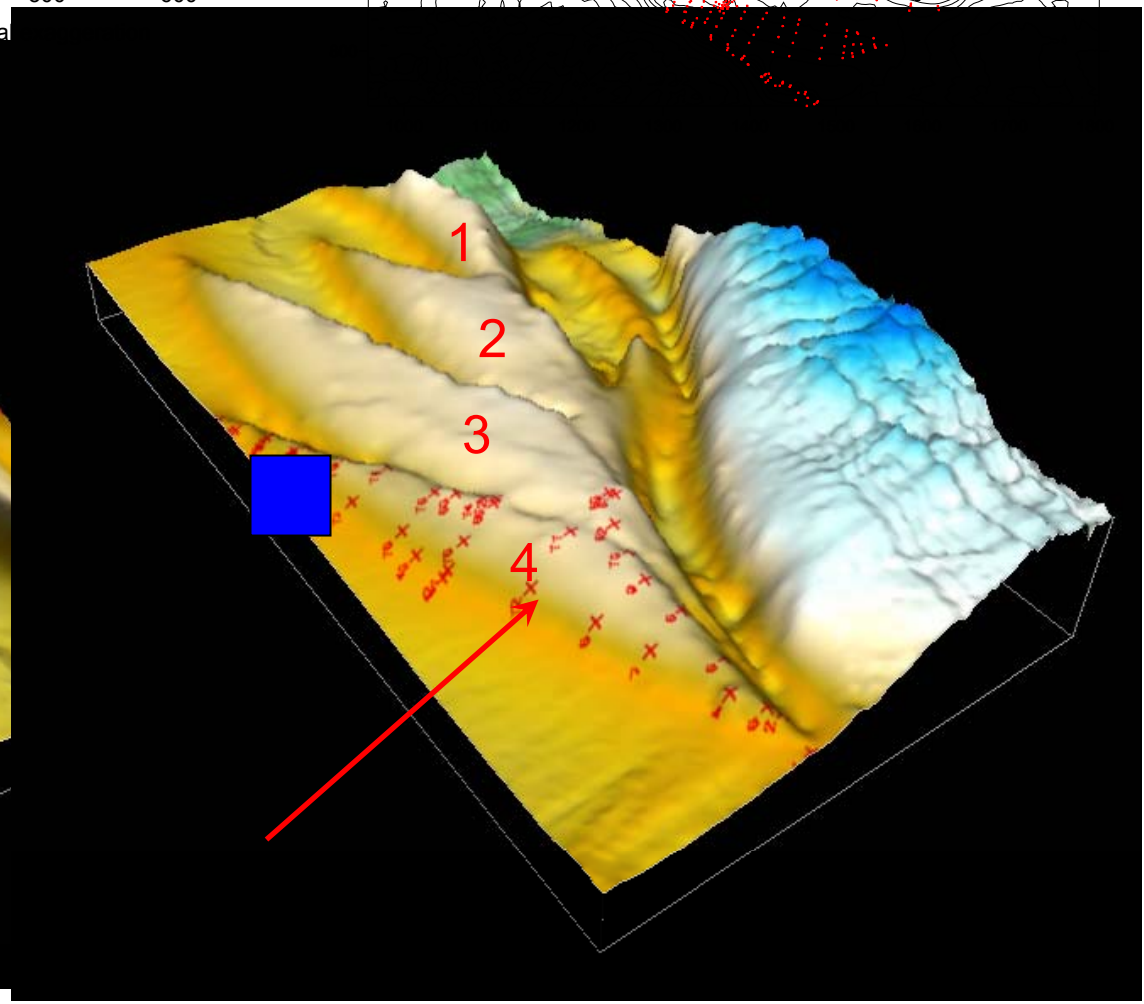


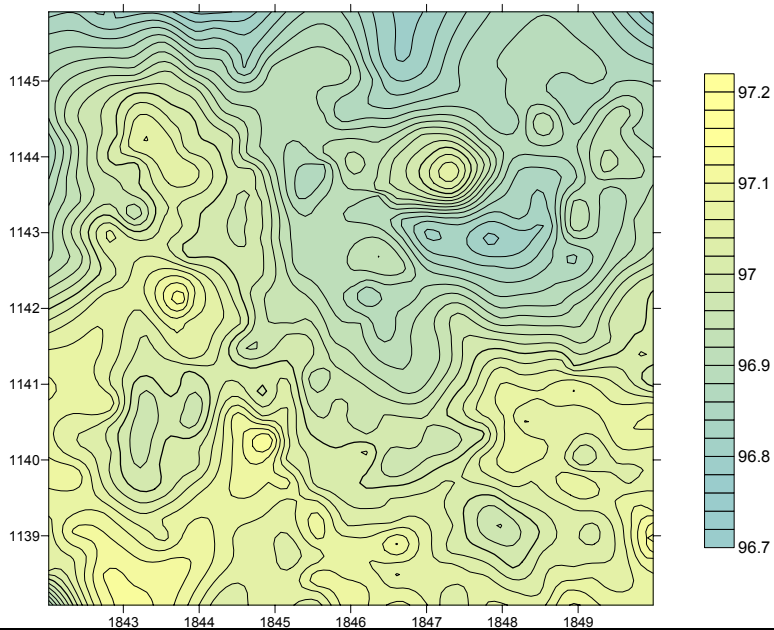
Calamity Bar March 2003

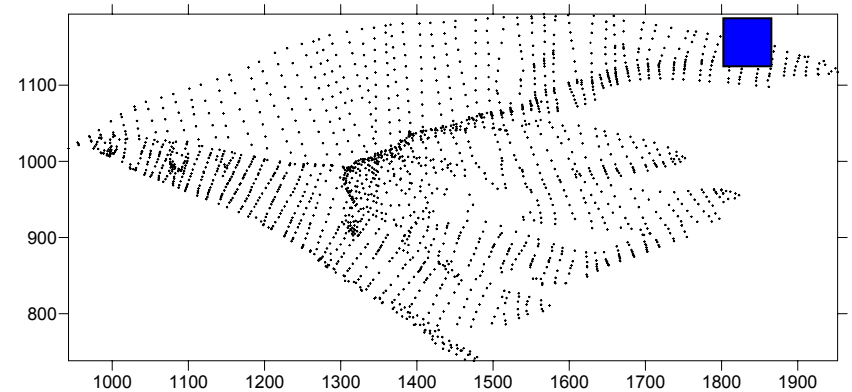


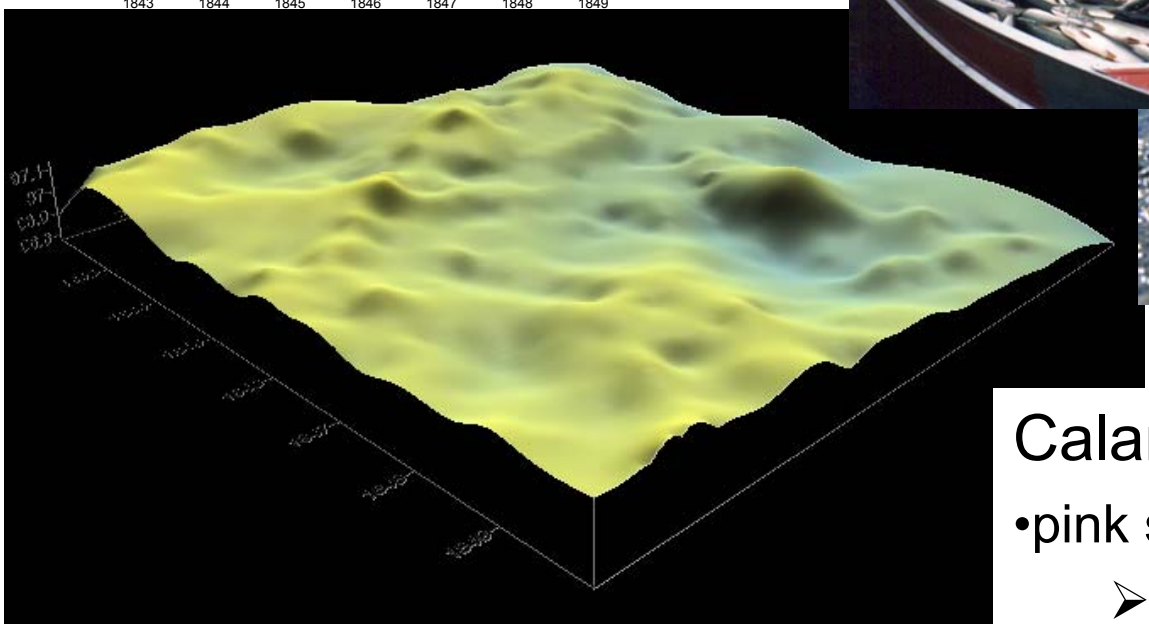










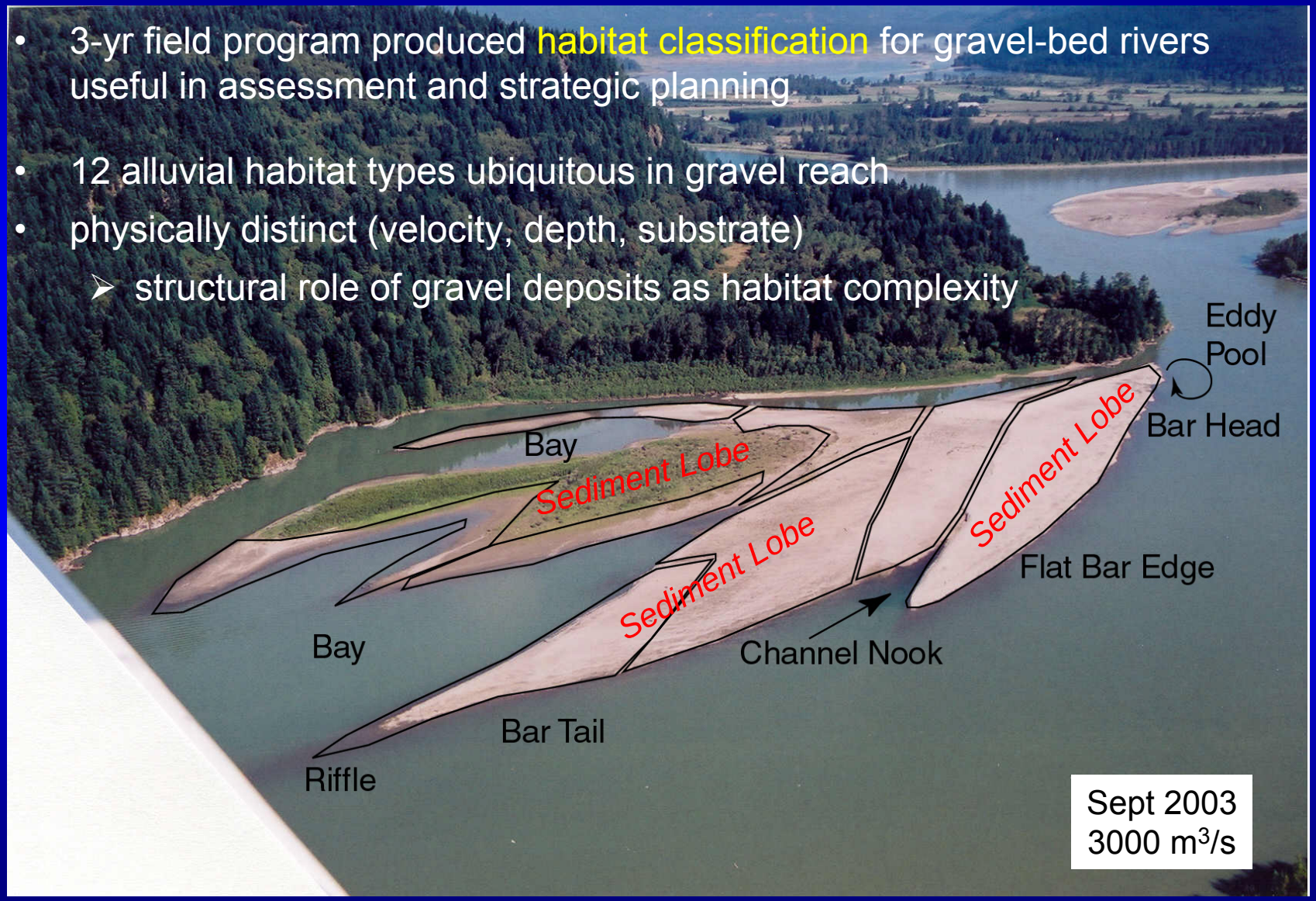


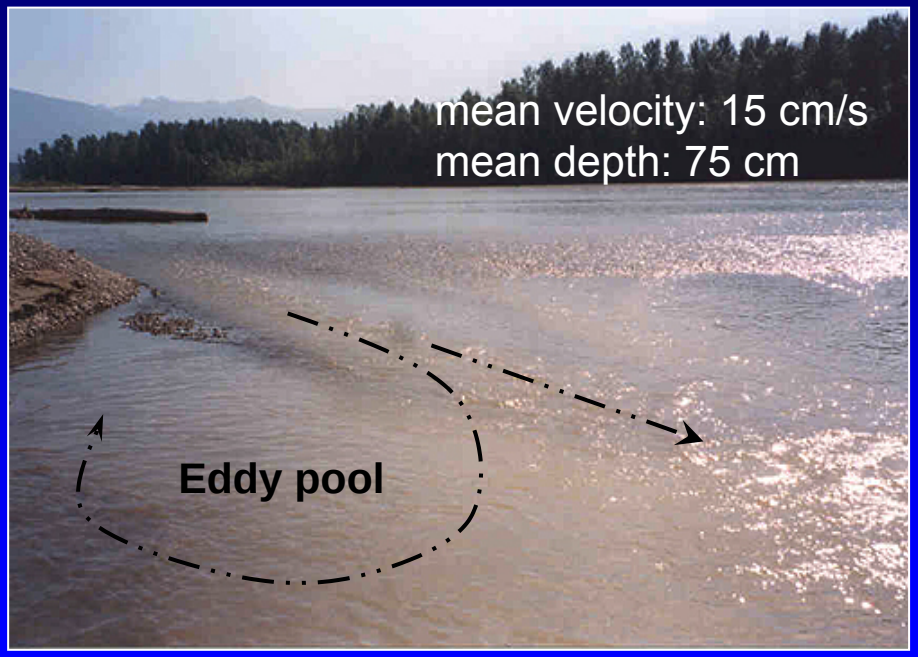
Calamity Bar March 2002

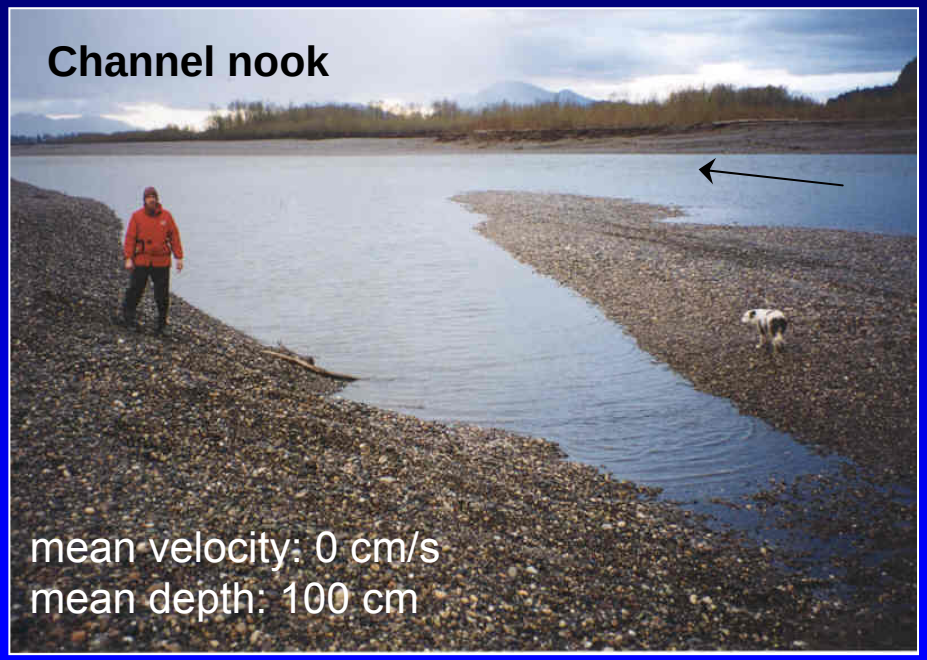
- pink salmon redds
  - functional role of gravel

Gravel Bars As Fish Habitat

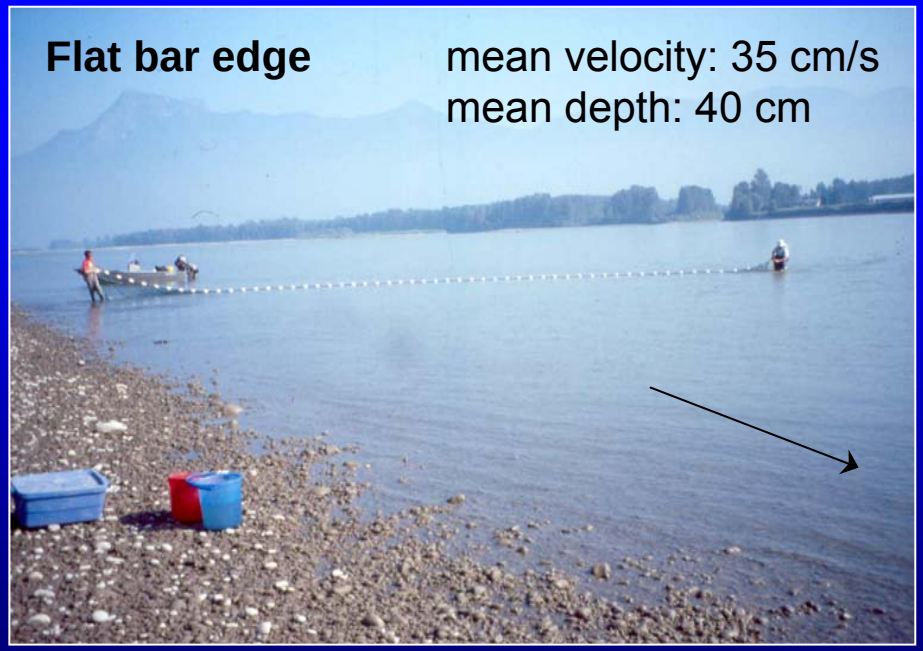
- 3-yr field program produced habitat classification for gravel-bed rivers useful in assessment and strategic planning
- 12 alluvial habitat types ubiquitous in gravel reach
- physically distinct (velocity, depth, substrate)
  - structural role of gravel deposits as habitat complexity




mean velocity: 15 cm/s
mean depth: 75 cm
Eddy pool


Channel nook
mean velocity: 0 cm/s
mean depth: 100 cm

Steep bar edge
mean velocity: 65 cm/s
mean depth: >100 cm

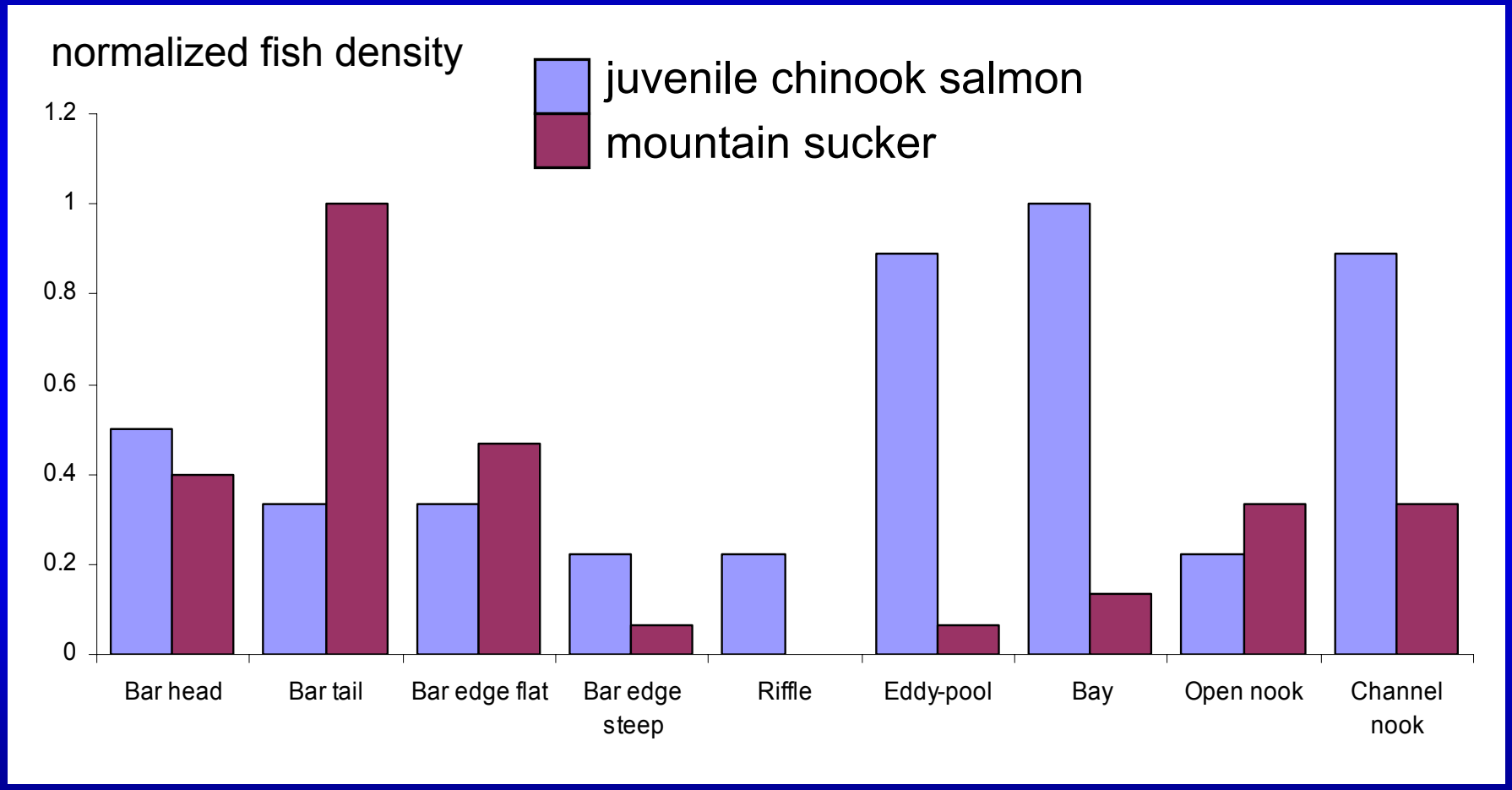

Flat bar edge
mean velocity: 35 cm/s
mean depth: 40 cm

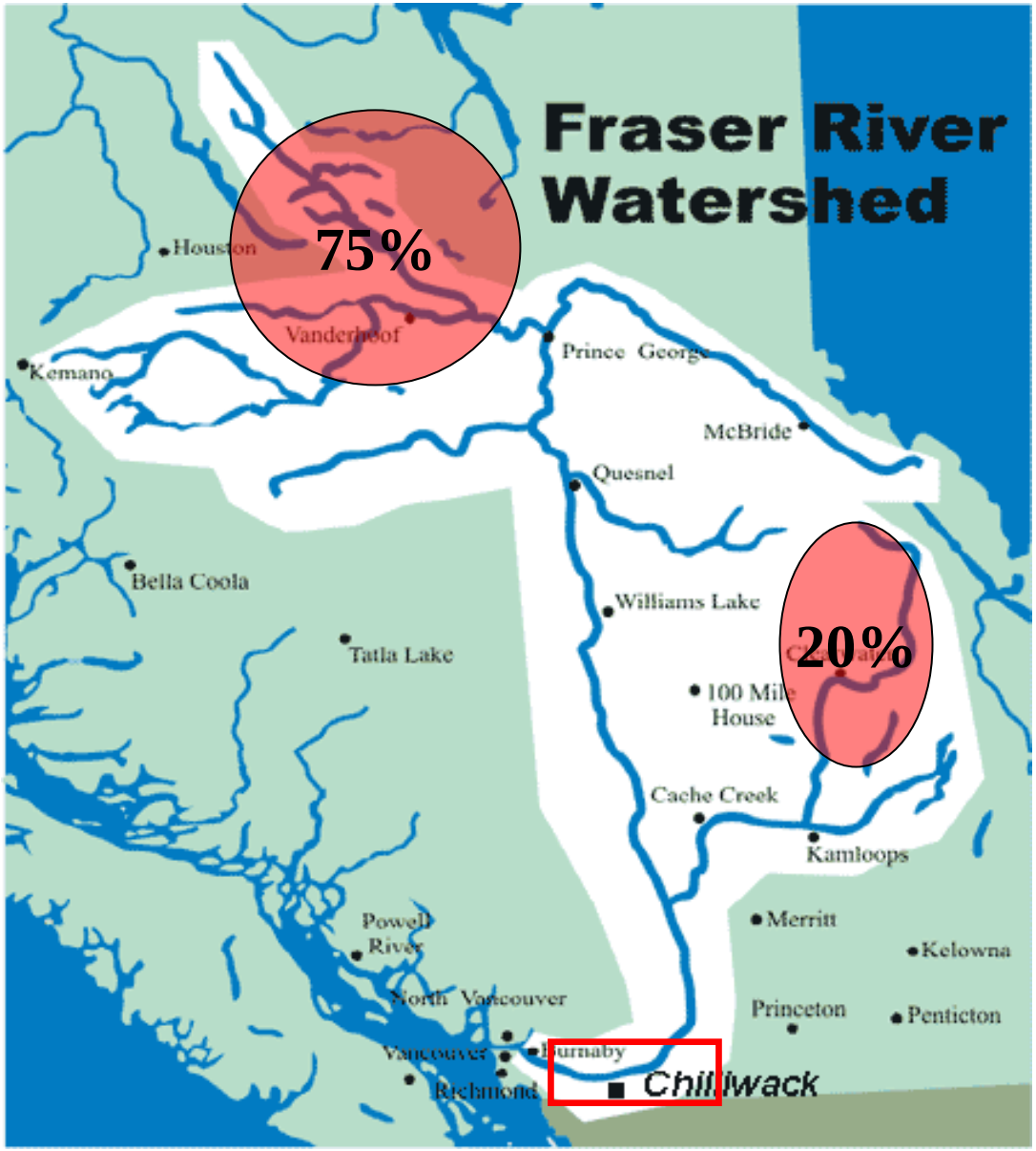
Fish Sampling

Do fish discriminate among habitats?

- stratified sampling effort among habitats using various methods
  - beach seine most effective in Fraser
    - 960 seines (341,800 m^2)
    - 55,000 fish identified and measured
      - 21% juvenile chinook salmon
    - 1100 fish stomachs analysed
  - invertebrate sampling using a Surber net (shallow) or Shipek Grab (deep)
    - 525 samples processed

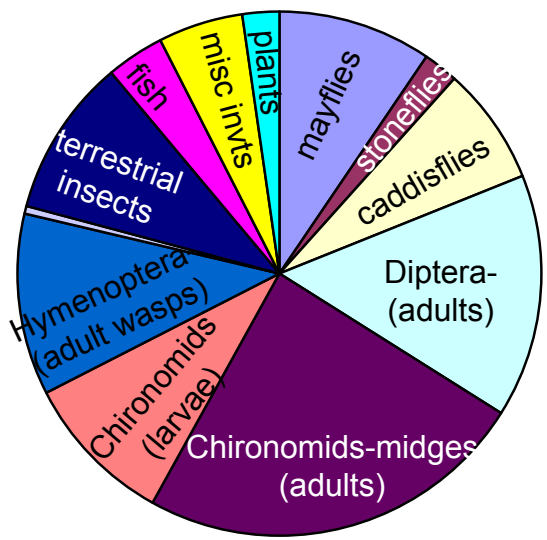
Ecological Significance of Habitat Units





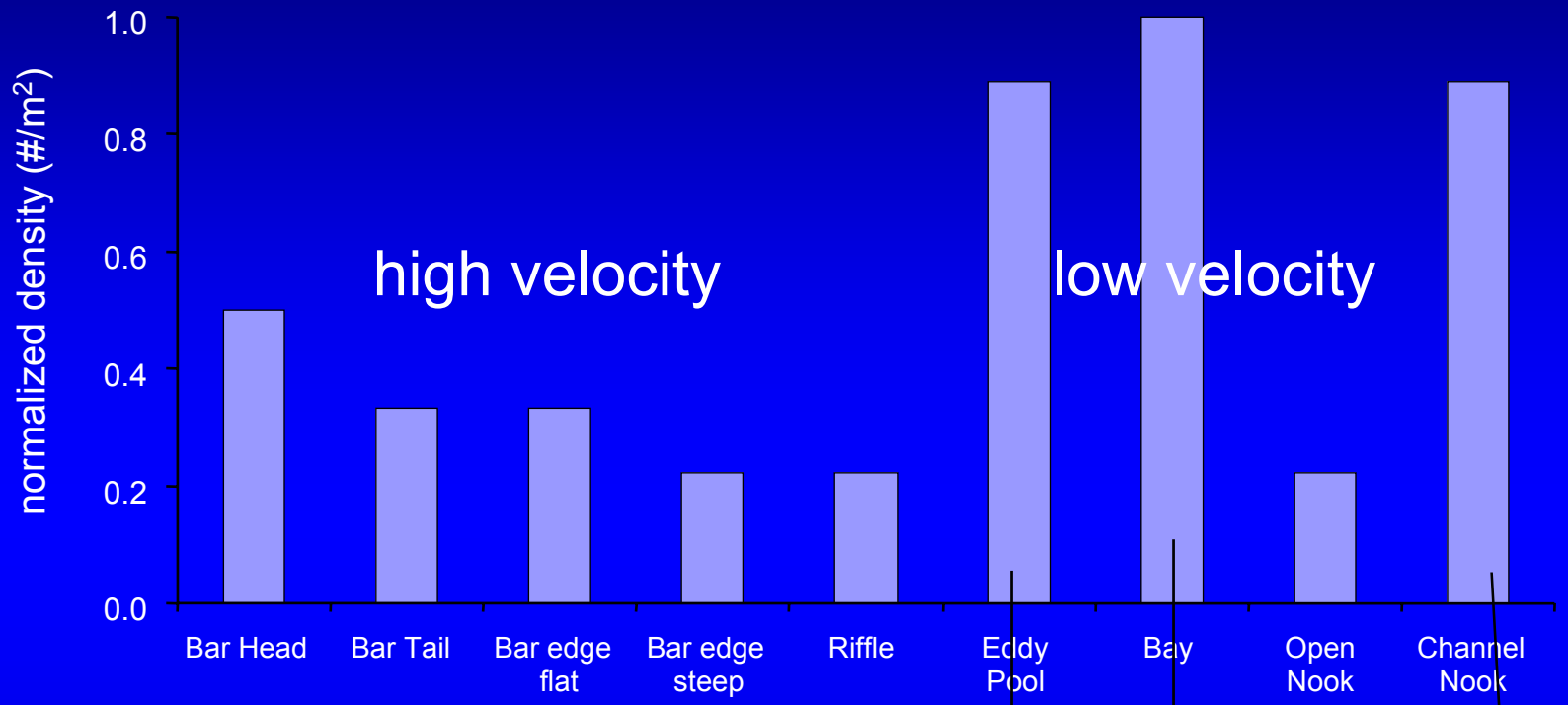
Chinook Juveniles

- DNA analysis shows juveniles 30-40 mm migrate >600 km to gravel reach for rearing up to 1 year
- predominantly spring-run chinook
- evidence of habitat quality in gravel reach



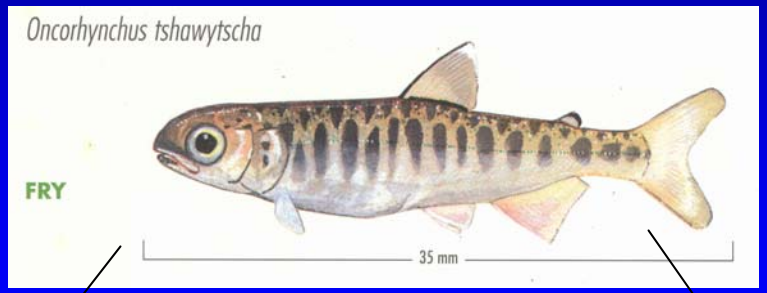
Diet Analysis (n=447)

Juvenile Chinook Habitat Associations



Bio-Physical Linkage

goal: increase chinook rearing density



requires habitat availability

- structural complexity

requires food availability

- functional value

<u>geomorphic process</u>: modest sediment transport to build habitat units and rework surface materials

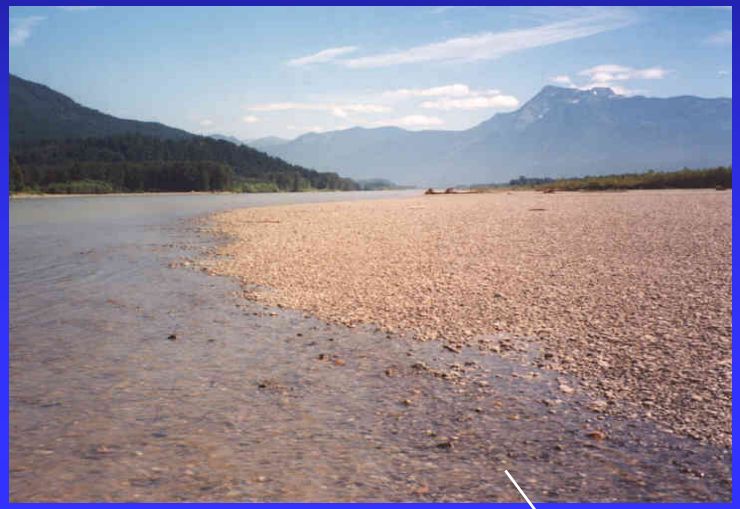
Lessons From Gravel Mining

- Experimental bar scalping in February 2000 to determine habitat and biological impacts (125,000 t)
- Sampling carried out over 6 months prior and 18 months post-scalping, including 3 reference sites

- Biological metrics: fish and invertebrate density, biomass, diversity, richness, evenness
- Physical metrics: surface sediment texture, habitat availability, rate of sediment replenishment (repeated surveys), topographical complexity

- Asymmetrical ANOVA used to assess impacts (Underwood, 1993)
  - rigorous analysis for non-replicated treatments with reference sites (e.g., evaluating restoration project success?)

Sediment Transport Facilitates Site Recovery



pre-removal Aug 99
cobble/gravel
D_{50} = 30 mm

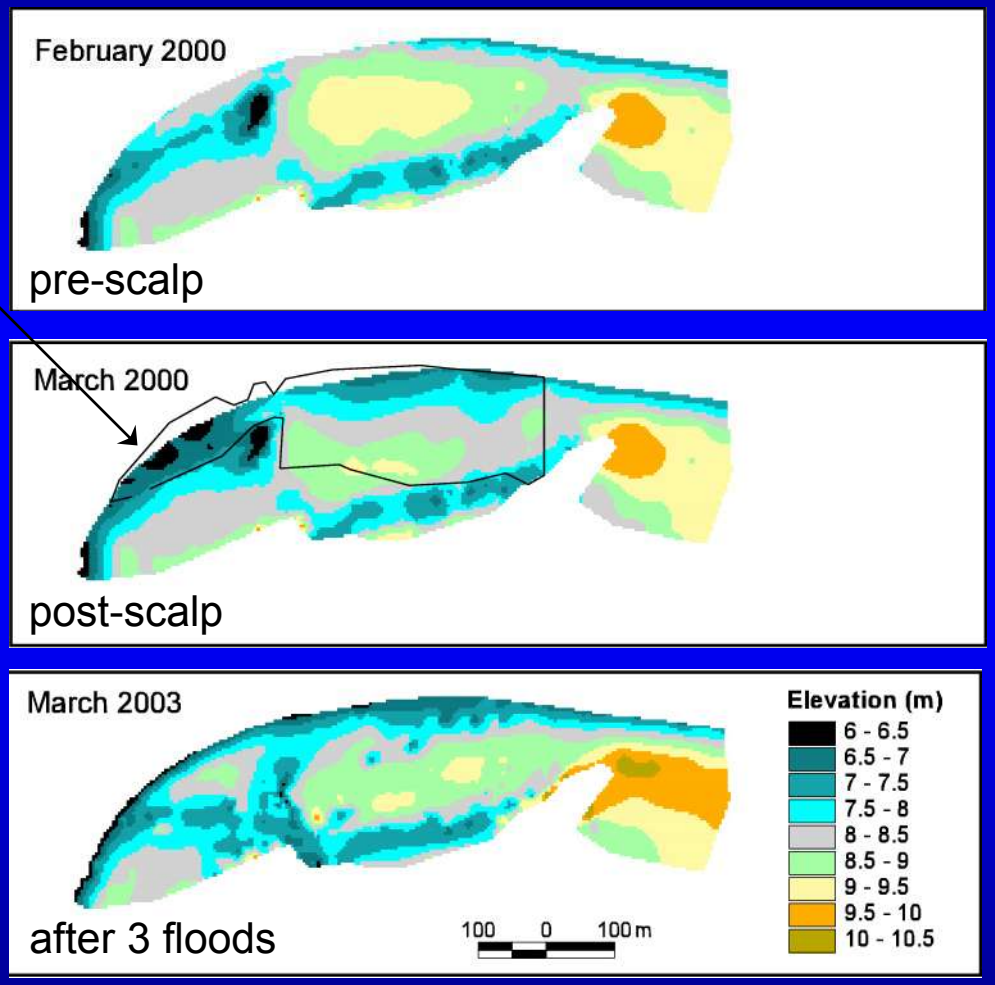
post-removal Nov 00
cobble/gravel
D_{50} = 28 mm

post-removal Apr 00
loose sand/gravel
D_{50} = 12 mm

- grain size recovery after one flood event (ANOVA, $p>0.1$)

Topographical Complexity

- 125,000 t scalped
- After 3 flood events:
  - 30% sediment volume replenished
  - gradual rebuilding of high bar habitat, facilitated by flooding
  - increased topographical complexity and habitat diversity
  - ➢ supports range of species and life stages
- one above-average flood responsible for majority of geomorphic work



Useful Lessons Learned…

- physical recovery dependent on sediment transport processes
- short-term reduction in macroinvertebrate density related to change in sediment texture; recovery after one freshet
- large, natural variance in fish abundance reduced statistical power to detect an impact
- invertebrate sampling had greatest statistical power to detect change ($+^{ve}$ or $-^{ve}$)

Summary and Issues To Consider

- both reach- and bar-scale processes of deposition and erosion are responsible for producing structural complexity (fish habitat units) and reworking sediment for functional value as spawning habitat and for invertebrate production
- fish benefit from structural complexity which provides a range of functional opportunities to exploit
  - also supports a range of species and life stages over range of flows
- need to confirm that habitat complexity begets diversity and productivity (what is complexity??)
- important to select appropriate physical and biological metrics that afford sufficient statistical power for assessment and monitoring
  - macroinvertebrates are link between gravel conditions and fish
  - highly sensitive to site conditions, less mobile than fish

Thank you to…

Darren Ham, University of British Columbia (sediment budget)
Stephen Rice, Loughborough University, UK (bar morphology)

- BC Habitat Conservation Trust Fund
- NSERC
- Fisheries and Oceans Canada
- BC Provincial Flood Protection Assistance Fund
- BC Land, Water, Air Protection
- BC Fisheries

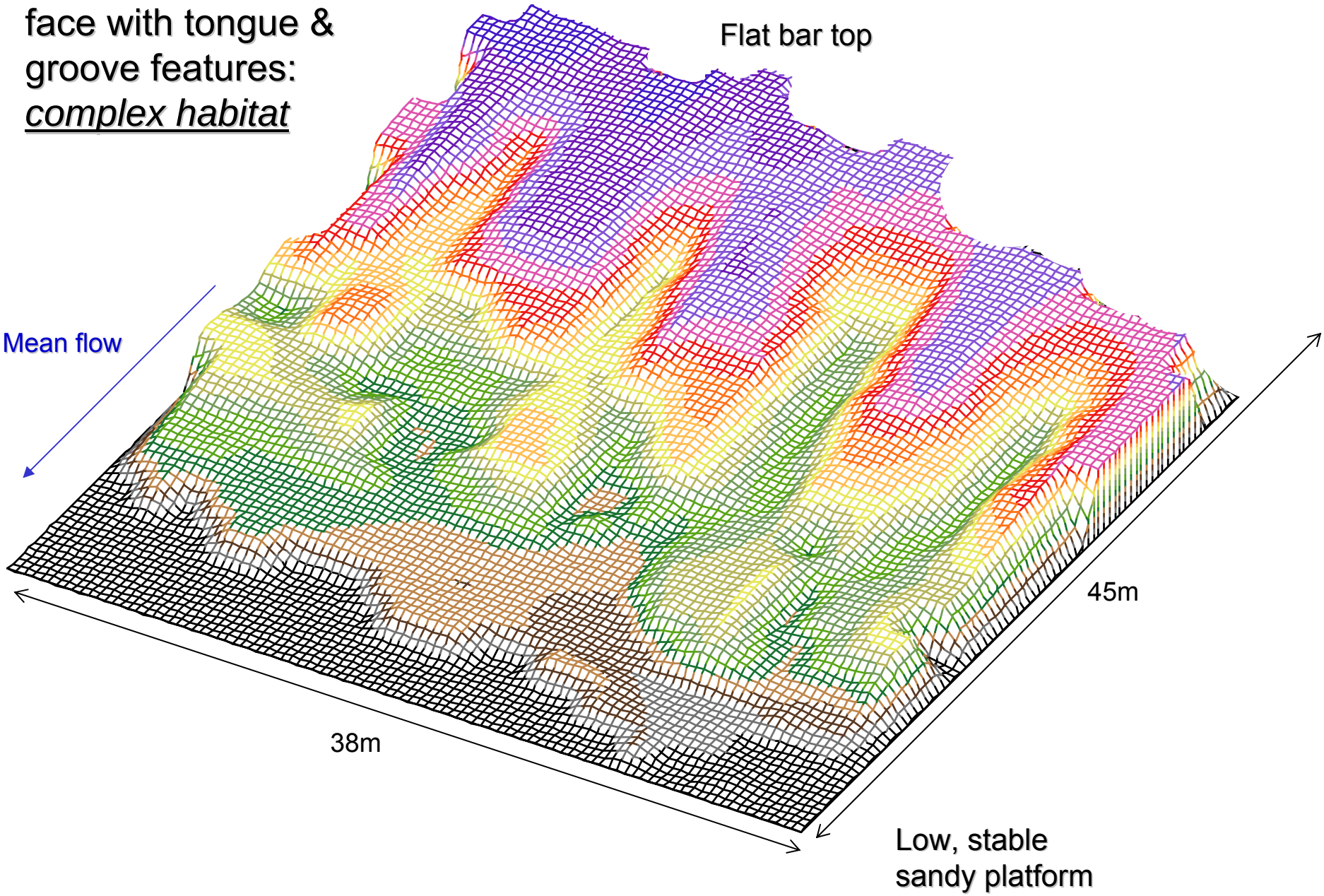
http://www.geog.ubc.ca/fraserriver

HCTF

NSERC CRSNG

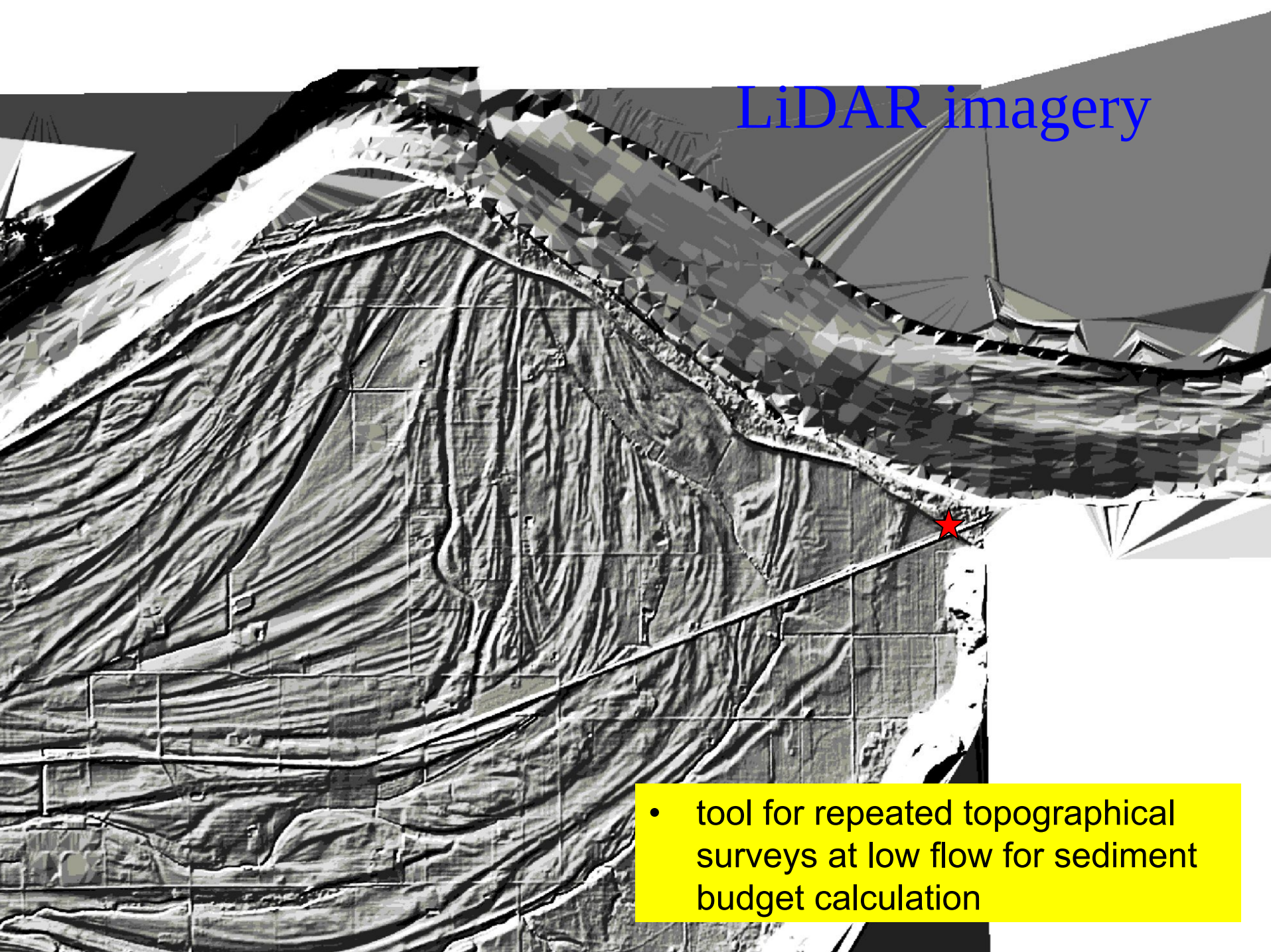
Chute and Lobe Couplets

Degraded avalanche face with tongue & groove features: *complex habitat*



LiDAR base photo

LiDAR imagery



- tool for repeated topographical surveys at low flow for sediment budget calculation