Remote survey of gravel riverbeds: A new view of large braided rivers

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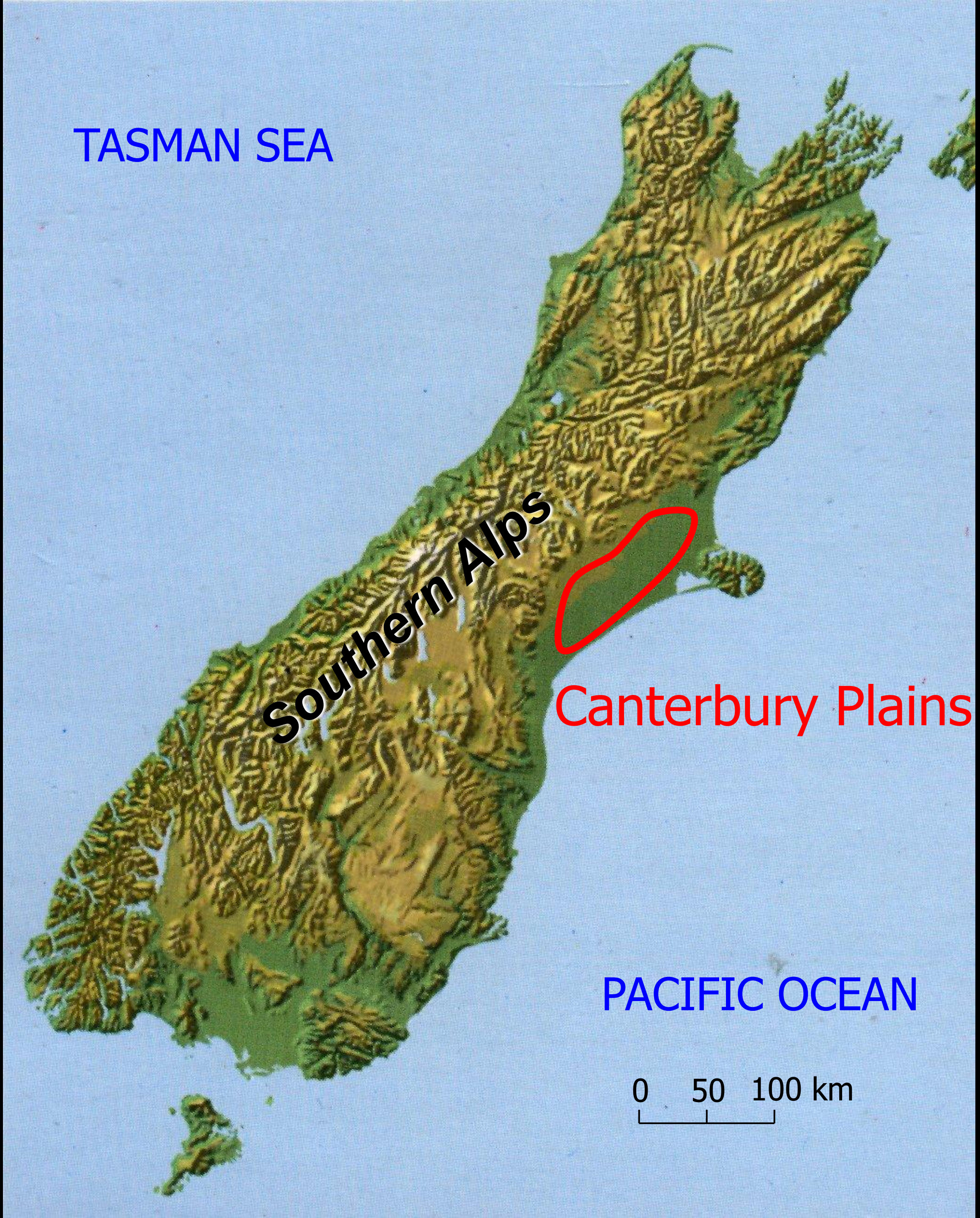
No-one really knows what a large braided river looks like

How to make a braided river

Ingredients:

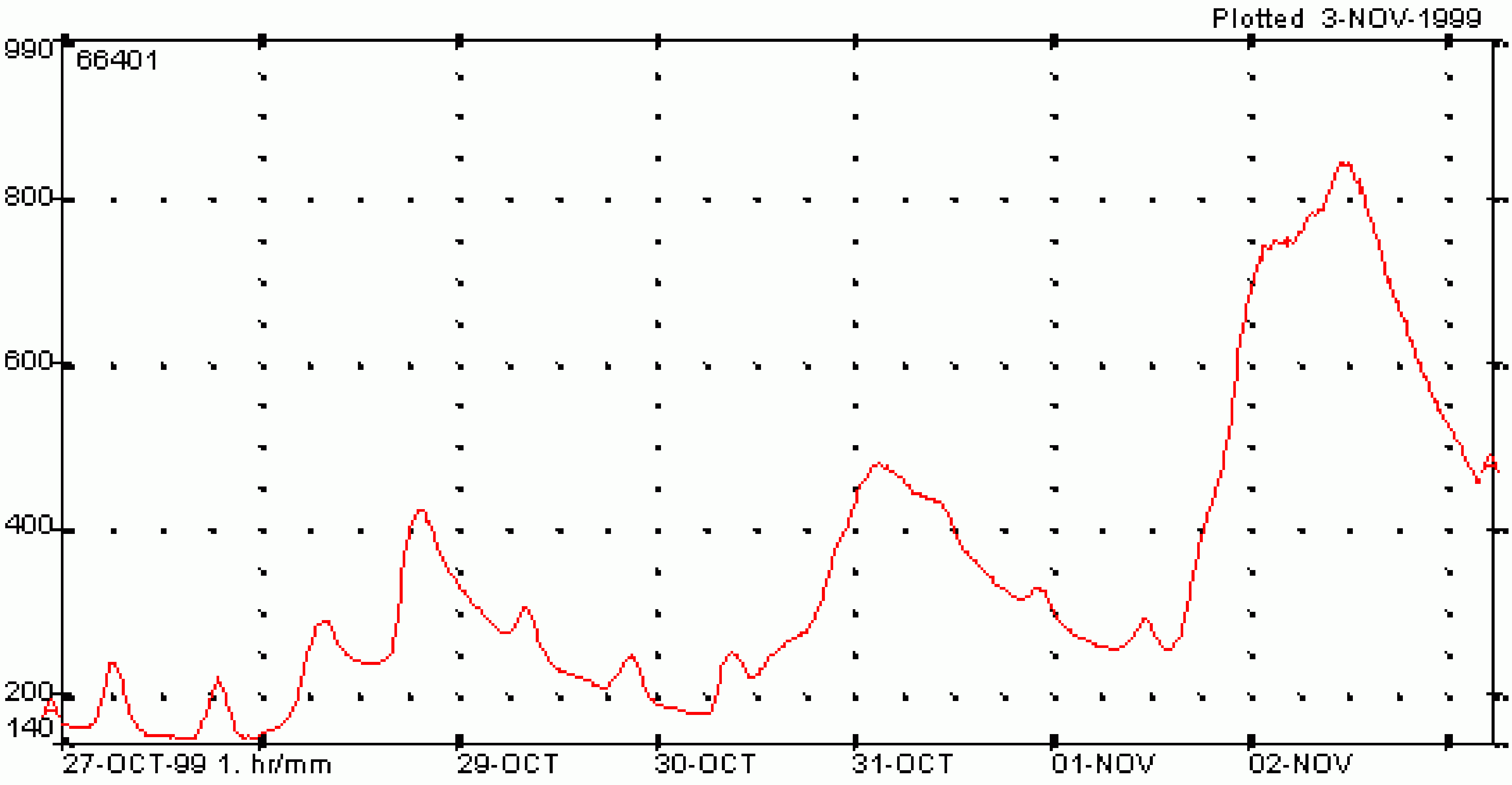
- Large sediment supply
- Low bank strength
- High stream power (=>discharge)
- Space


TASMAN SEA
Southern Alps
Canterbury Plains
PACIFIC OCEAN
0 50 100 km

- Large sediment supply

- Easily erodable banks

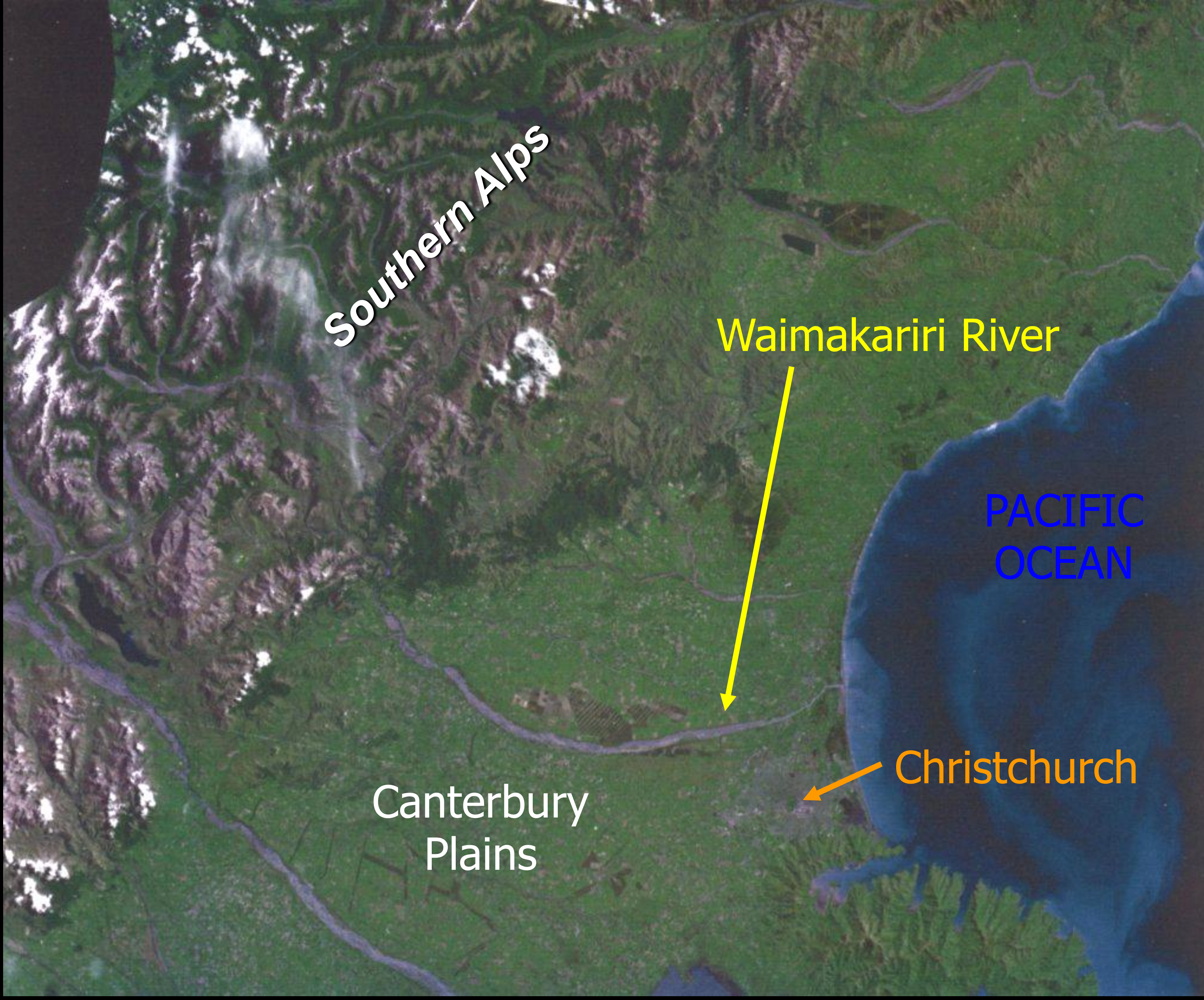
- High(ly variable) discharge


Plotted 3-NOV-1999
66401
990
800
600
400
200
140
27-OCT-99 1. hr/mm
29-OCT
30-OCT
31-OCT
01-NOV
02-NOV

- …and lots of space

Aims

- To attempt to use digital photogrammetry and image analysis techniques to survey wide, braided, gravel riverbeds
- To use the morphological information obtained about to investigate the form and processes of large braided rivers


Southern Alps
Waimakariri River
PACIFIC OCEAN
Christchurch
Canterbury Plains

- Braided

- Big

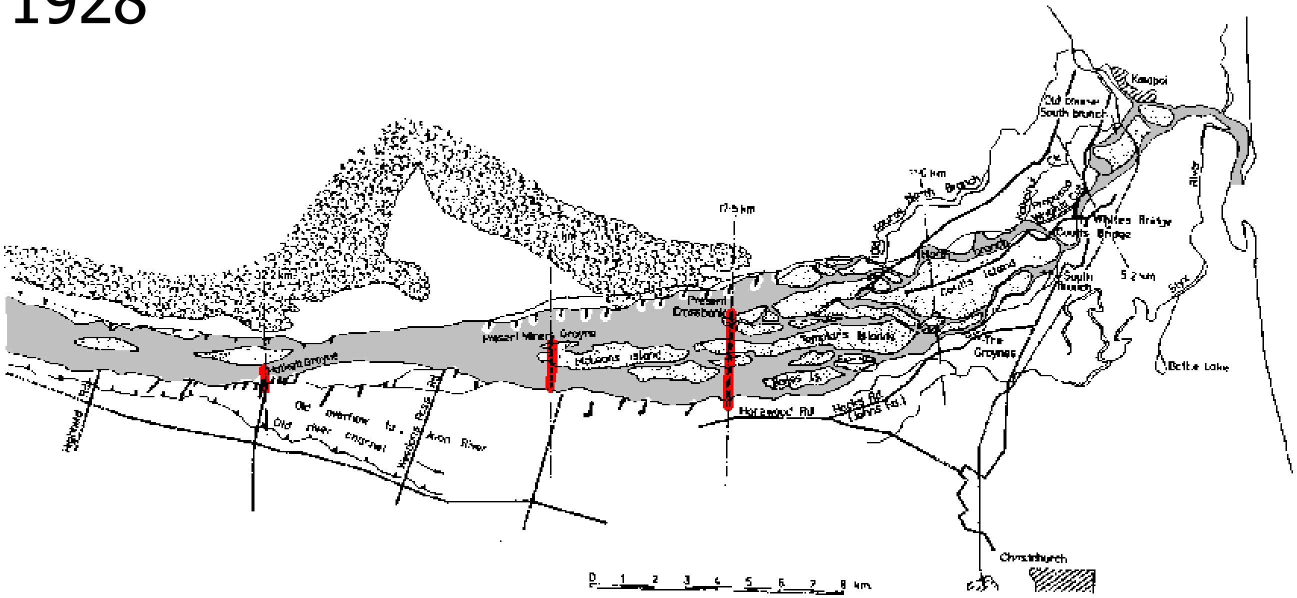
- Flat

- Some vertical relief…

- …causes avulsion

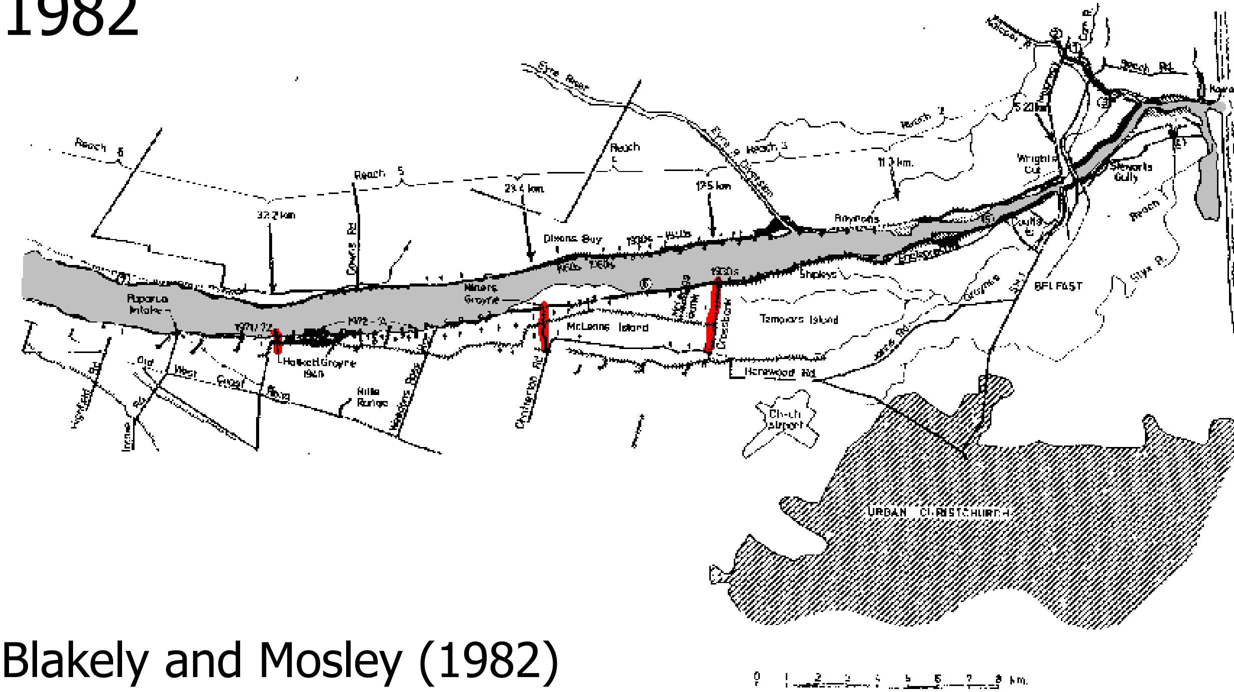
- Frequent flood events

1928



- Managed

1982



Blakely and Mosley (1982)

- Stopbanks

- …and groynes

River monitoring

- River management issues:
  - Sediment storage/movement
  - Impact of control works
  - Likely zones of bank erosion and flooding
  - Gravel extraction volumes
- River science issues:
  - 3D riverbed morphology
  - Drainage patterns
  - Volumes of change during flood
  - Bedload transport rate

Conventional survey methods

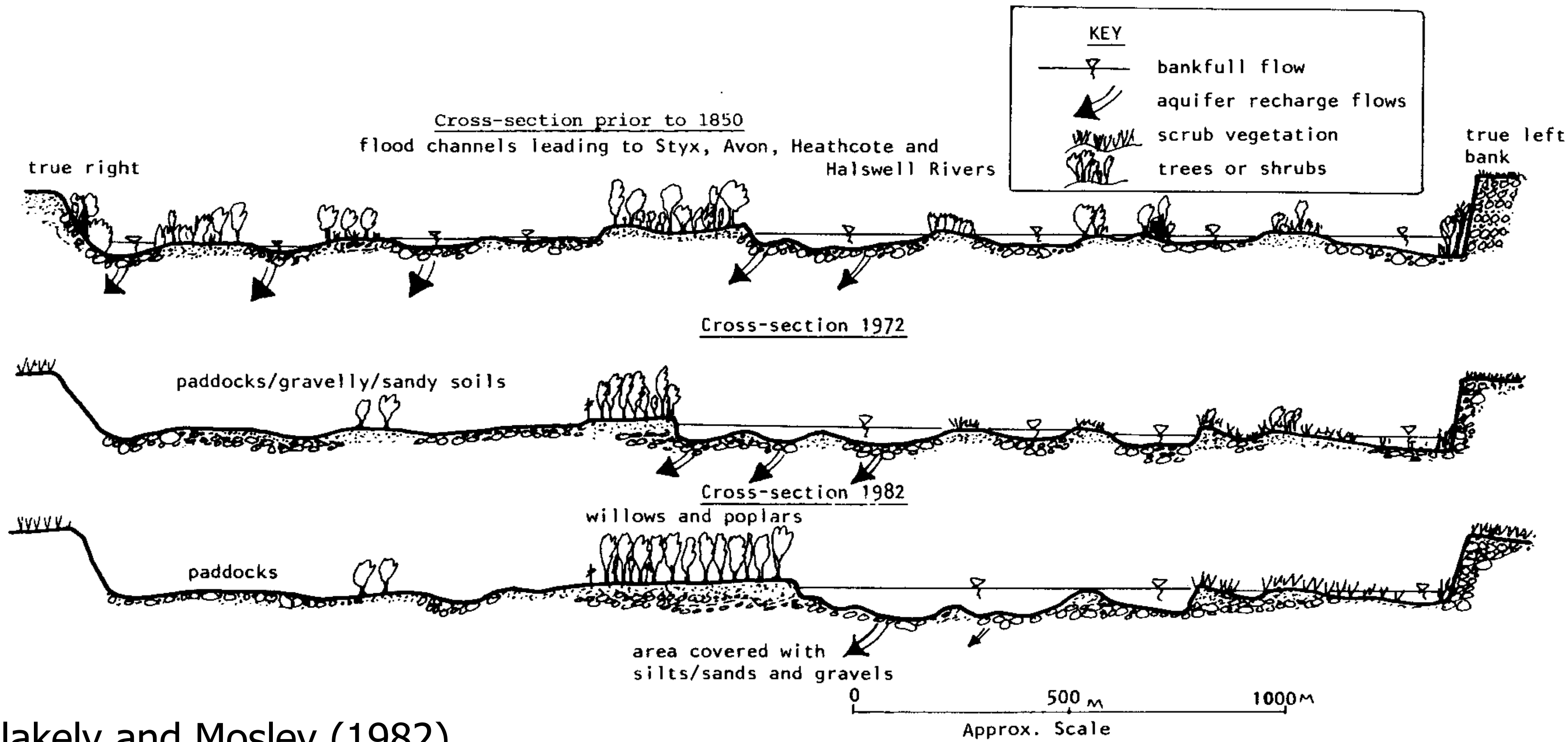
- Ground survey

- Aerial photography (or satellite imagery)

Waimakariri monitoring programme

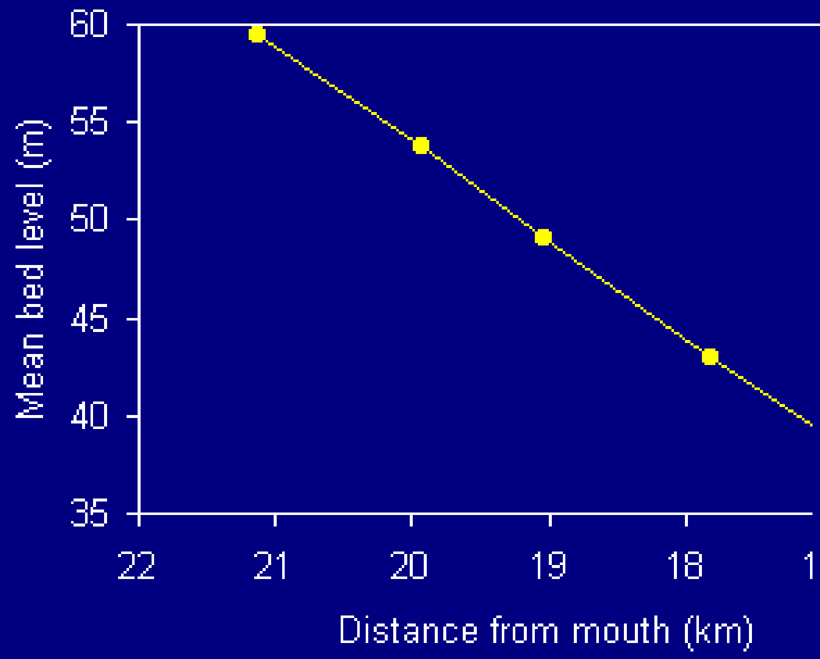
- Waimakariri surveyed by local regional council
- Cross-sections are ‘levelled’
- Spaced every 500 m
- Re-surveyed every 5 years
- Supplemented by aerial photography

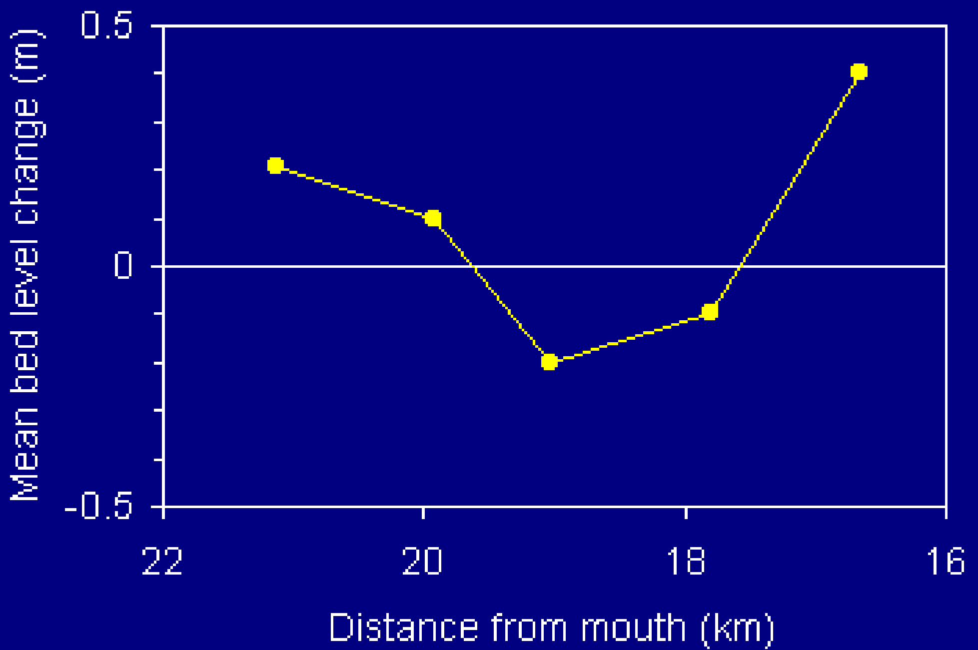
Waimakariri monitoring programme



Blakely and Mosley (1982)

Waimakariri monitoring programme





Problems with conventional methods

- Cross-sectional levelling:
  - – Laborious and slow
  - – Gross estimates of riverbed long-profile
  - – Unreliable estimates morphological change
- Aerial photographs:
  - – Shows where water is but not why it's there
  - – Stage-dependent

Remote survey

- Digital photogrammetry
- Airborne laser scanning
- …and others

Photogrammetry - the basics

(The calculation of 3D topography from overlapping photographs of a landform)

- Every point on a photograph can be described by its (x,y) position
- Every point on-the-ground can be described by its (X,Y,Z) position
- The position of a camera can be described by its position (X_C,Y_C,Z_C), rotation $(\Omega_C,\kappa_C,\Phi_C)$ and focal length (f_C). Here grouped together as C

…and the maths

- With 1 photograph, for each point:

$$(X_1,Y_1,Z_1) = f(x_1,y_1,\cancel{c_1})$$

- With 2 photographs, for each point:

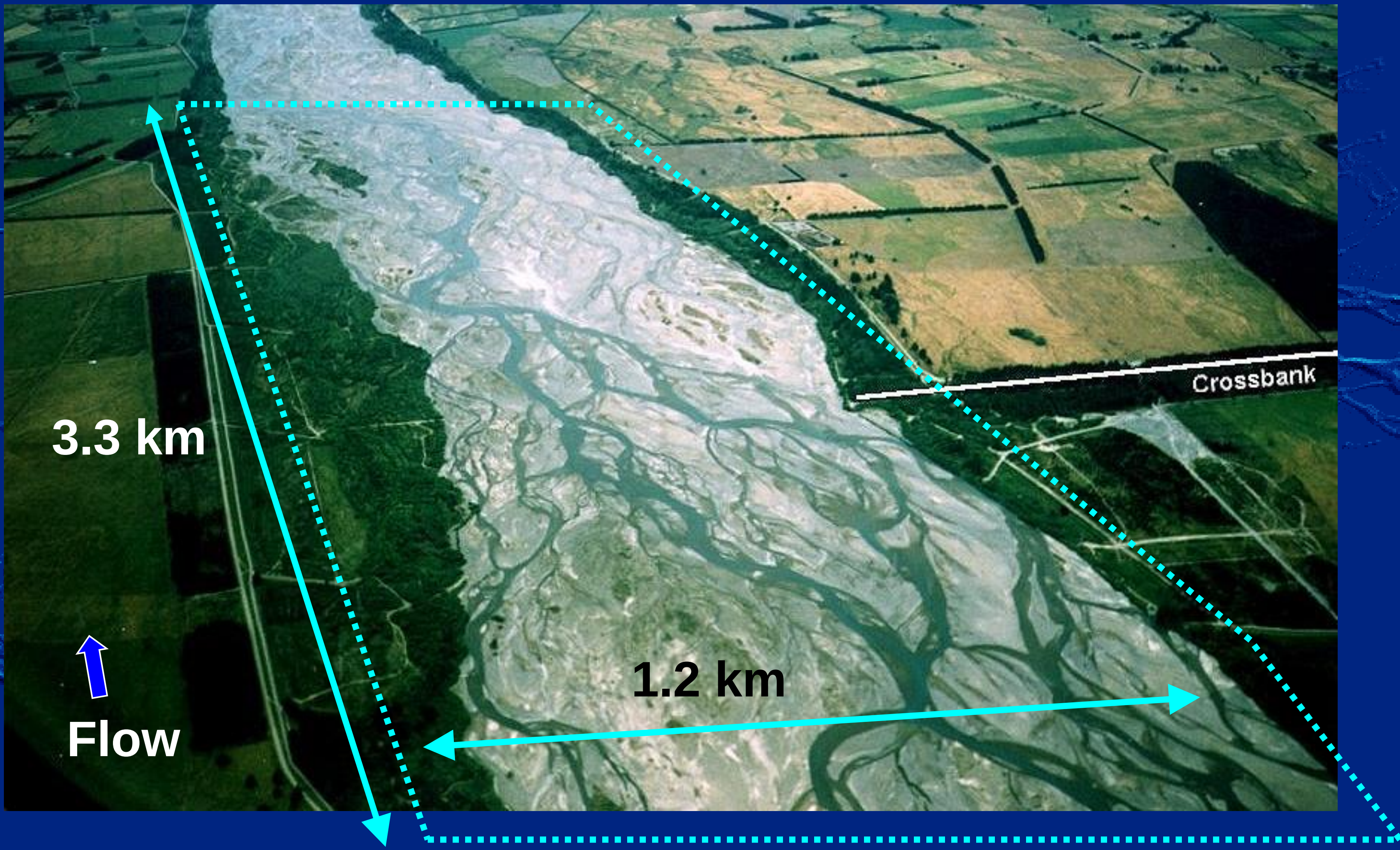
$$(X_1,Y_1,Z_1) = f(x_1,y_1,\cancel{c_1})$$
$$(X_1,Y_1,Z_1) = f(x_2,y_2,\cancel{c_2})$$

So, for each point that can matched on the overlapping photographs, an (X,Y,Z) position can be calculated

Photogrammetry - development

- 10 years ago points had to be matched manually, at around 500 points per hour - Analytical photogrammetry
- Now can be done automatically, at between 100,000 and 1,000,000 points per hour - Digital photogrammetry
- But can it be used to survey large gravel riverbeds?
  - Low relief
  - Water

Waimakariri study area

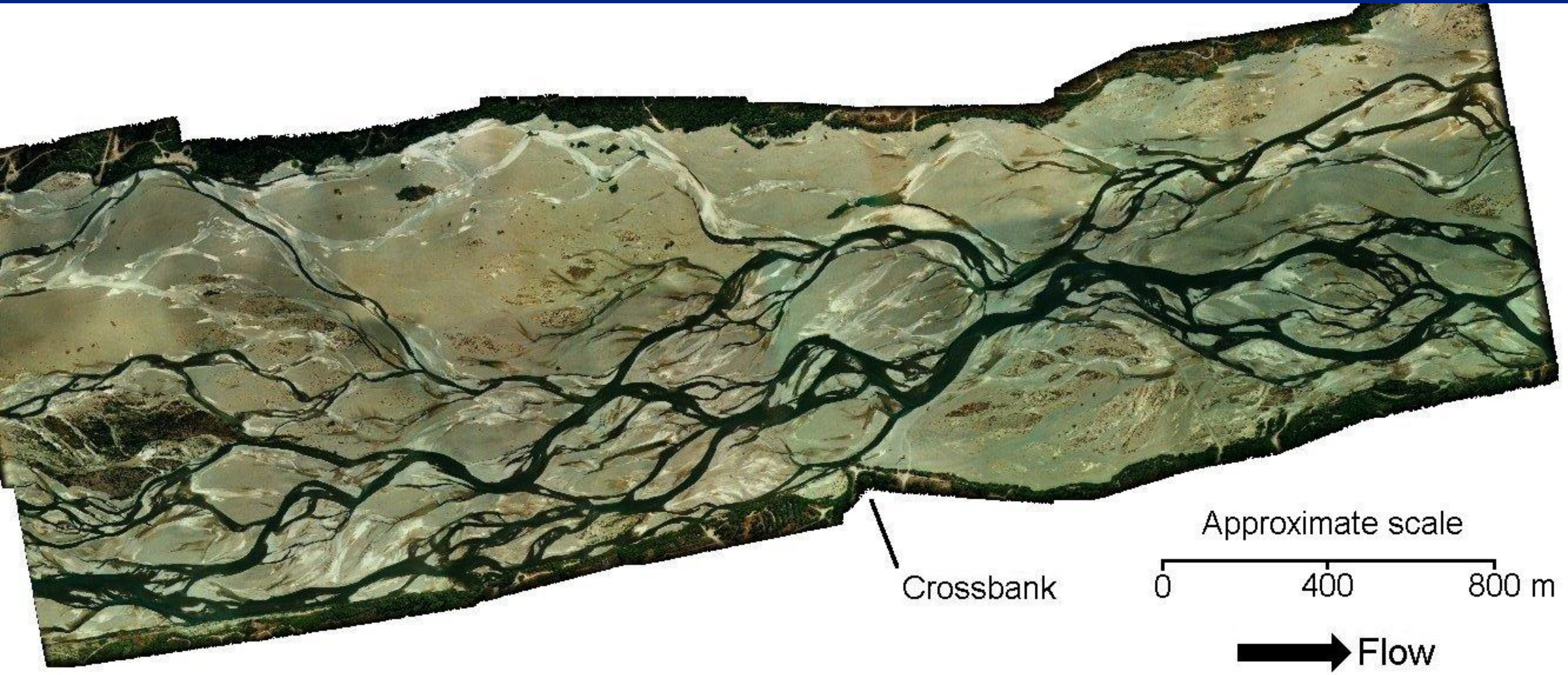


Aerial photographs taken:

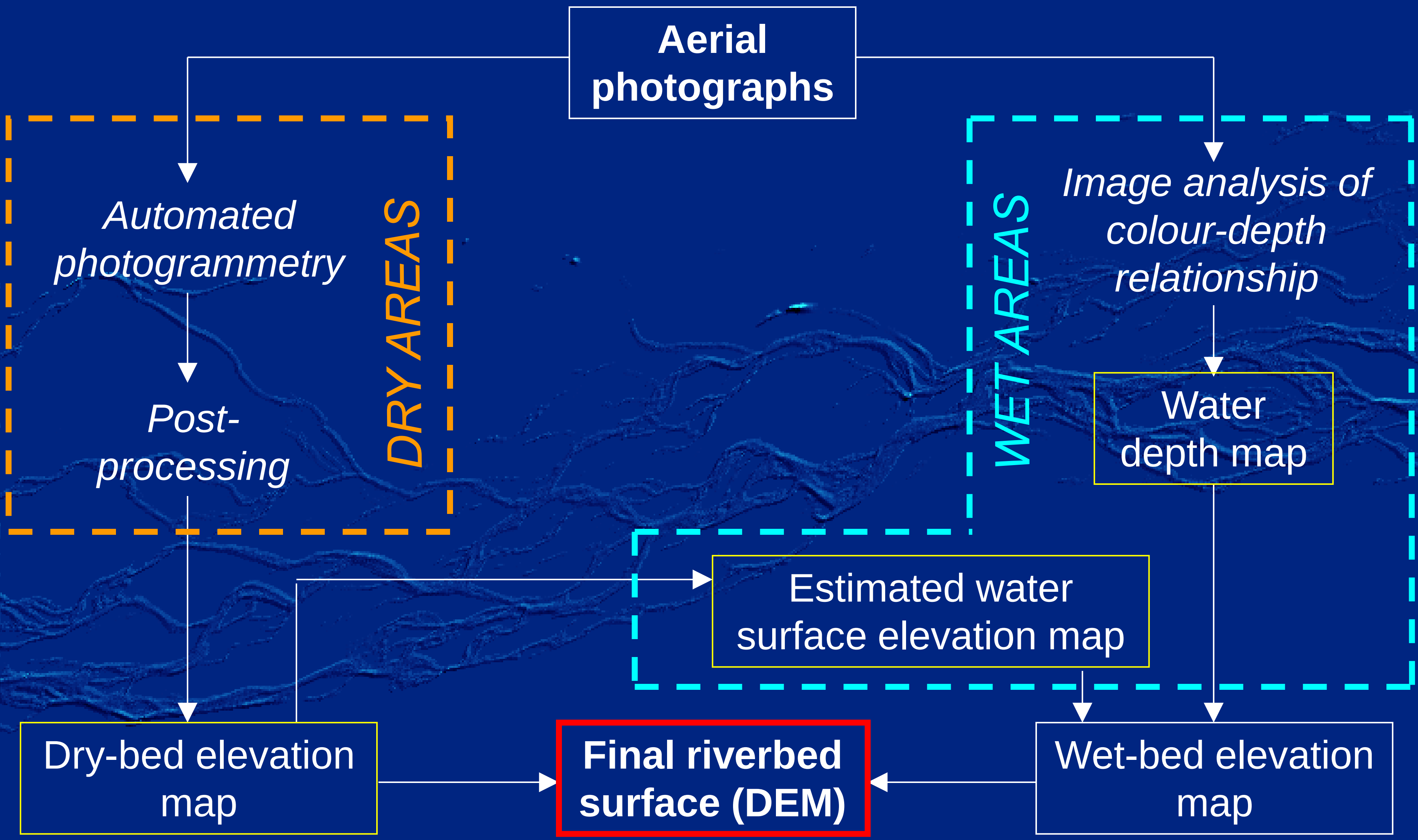
- February 1999
- March 1999
- February 2000

(Plus an airborne laser scanner survey in May 2000)

Aerial photographs - Feb 1999



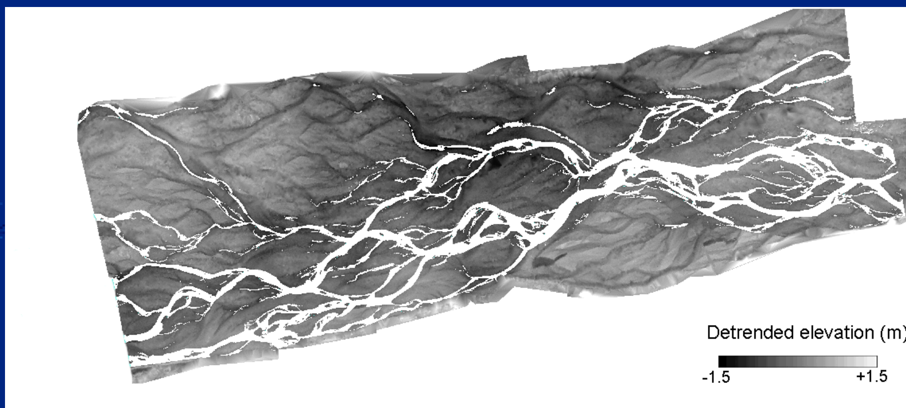
Method

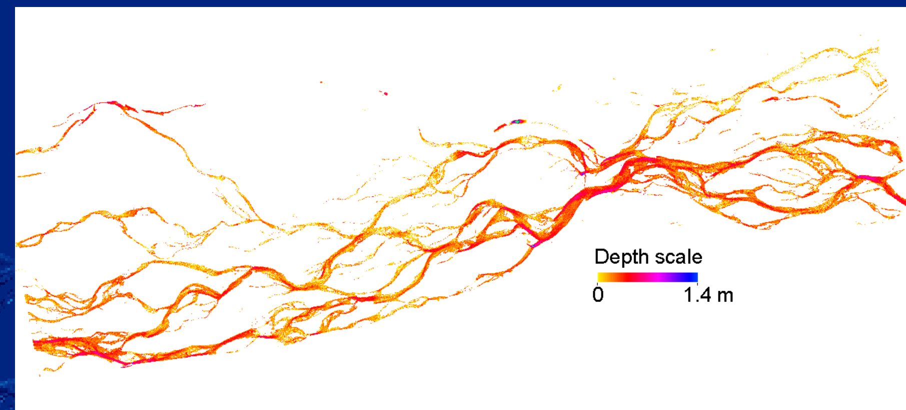


Aerial photographs
Automated photogrammetry
Post-processing
DRY AREAS
WET AREAS
Image analysis of colour-depth relationship
Water depth map
Estimated water surface elevation map
Dry-bed elevation map
Final riverbed surface (DEM)
Wet-bed elevation map

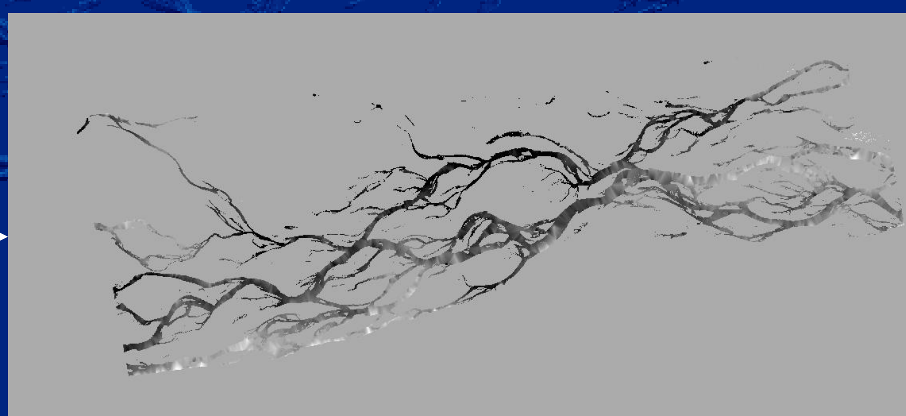
Photogrammetry

Image analysis





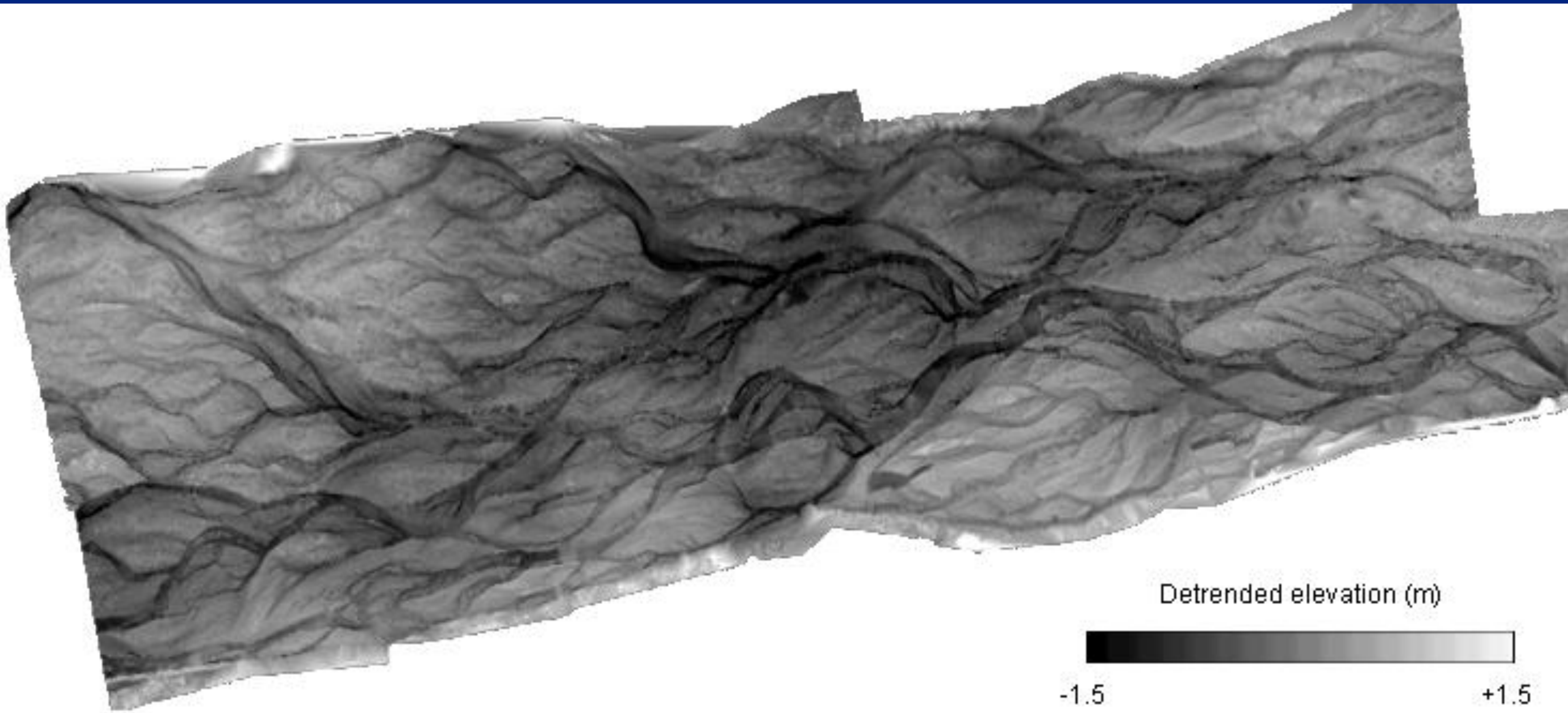
Interpolation across wetted channels



Subtracted from

Merged to give...

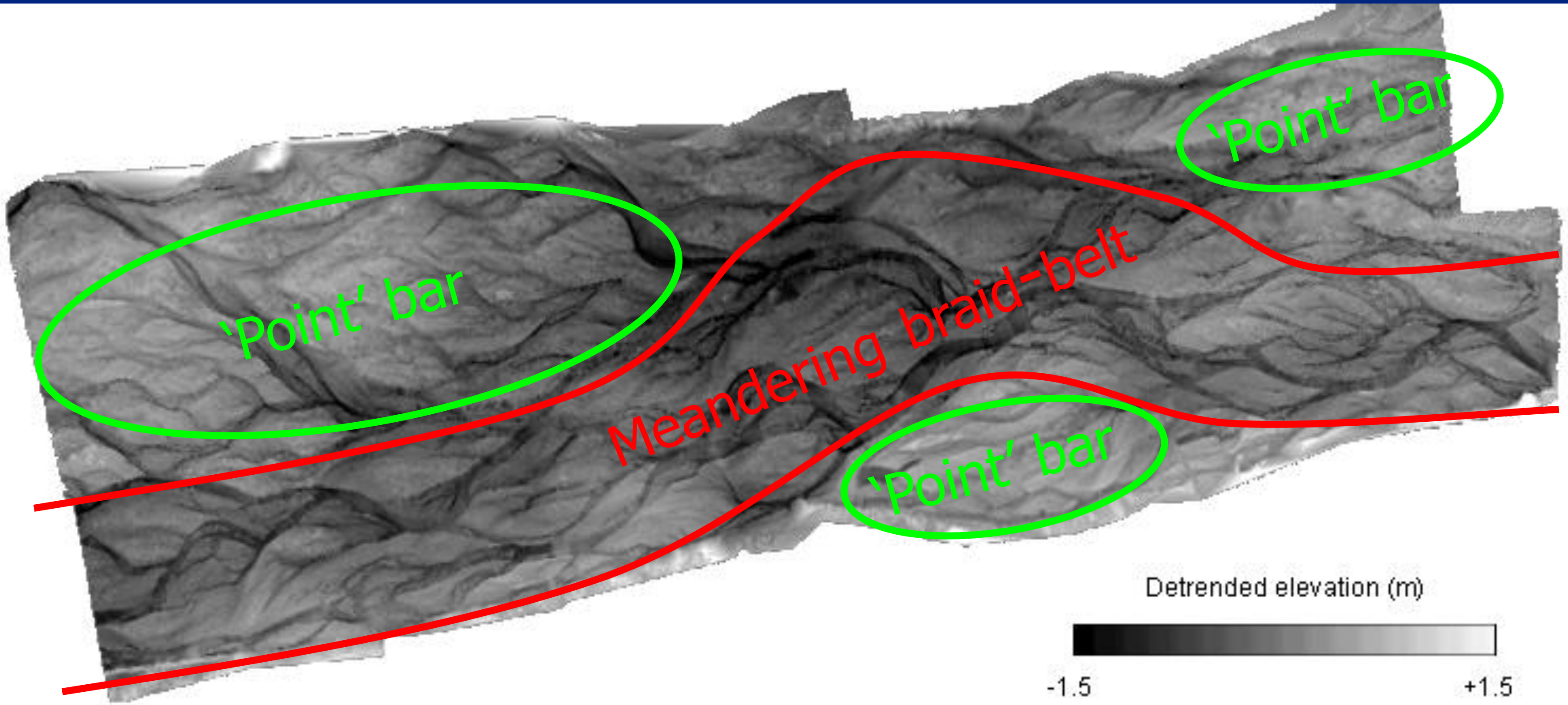
Final riverbed surface: a new view of a large braided river



Surface quality

DEM area	Number of points compared	Mean error (cm)	St.dev. of error (cm)
Dry points	3700	+8.4	±26
Wet points	11202	+26	±32

Broad-scale topography



Where next?

- Aim 1:
  - Repeat method for March 1999 and February 2000
  - Analysis of surface quality
  - Automated versus manual post-processing

Where next?

- Aim 2:
  - At-epoch issues:
    - 2D and 3D topography
    - Drainage patterns
    - Location of active channels
    - Importance of upstream water routing
    - Scaling analysis
  - Between-epoch issues:
    - Quantification of planform changes
    - Spatial patterns of morphological change
    - Estimation of ‘step-length’
    - Volumes of erosion and deposition
    - Morphological estimation of bedload transport rate

Conclusions

- Digital photogrammetry and image analysis can be used to survey large, gravel riverbeds
- Important management and research applications
- Braided rivers far more complex than they appear - aerial photos don't tell the whole story!