Automated monitoring of submerged topography using remote-sensing techniques

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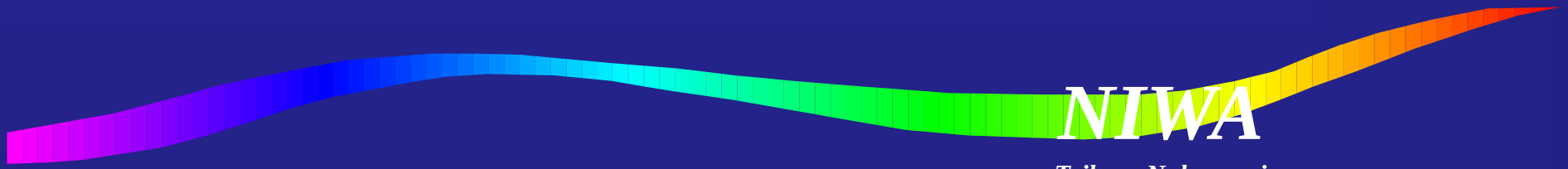


NIWA

Taihoro Nukurangi

Digital photogrammetry

- Increasingly used in Earth Sciences to supplement or replace conventional, manual survey techniques
- Rapid, high-resolution, accurate topography in the form of a dense grid of point elevation values
- Ideal for monitoring large, inaccessible or dangerous landforms

However...

- Relatively untested in fluvial geomorphology due to uncertainty over the treatment of submerged topography
- When used, conventional survey methods retained in wetted channels to supplement photogrammetric measurements

Aim: To develop an automated method to estimate submerged topography at a spatial density similar to that obtained from photogrammetry

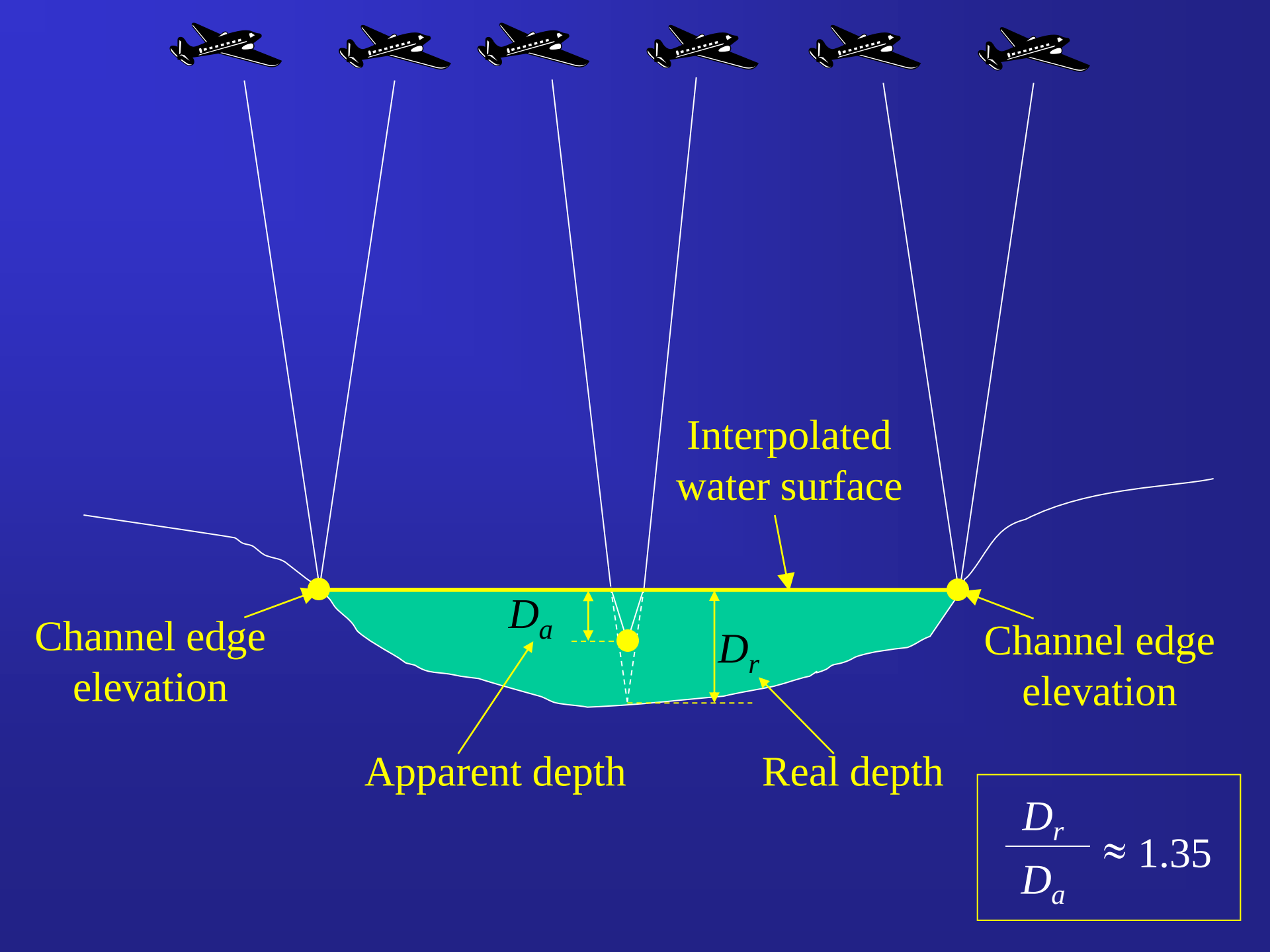
- Two cases require different treatment:

  (a) Clear water (‘*transparent*’)

  (b) Slightly turbid water (‘*translucent*’)

(a) Clear water: ‘Corrected photogrammetry’

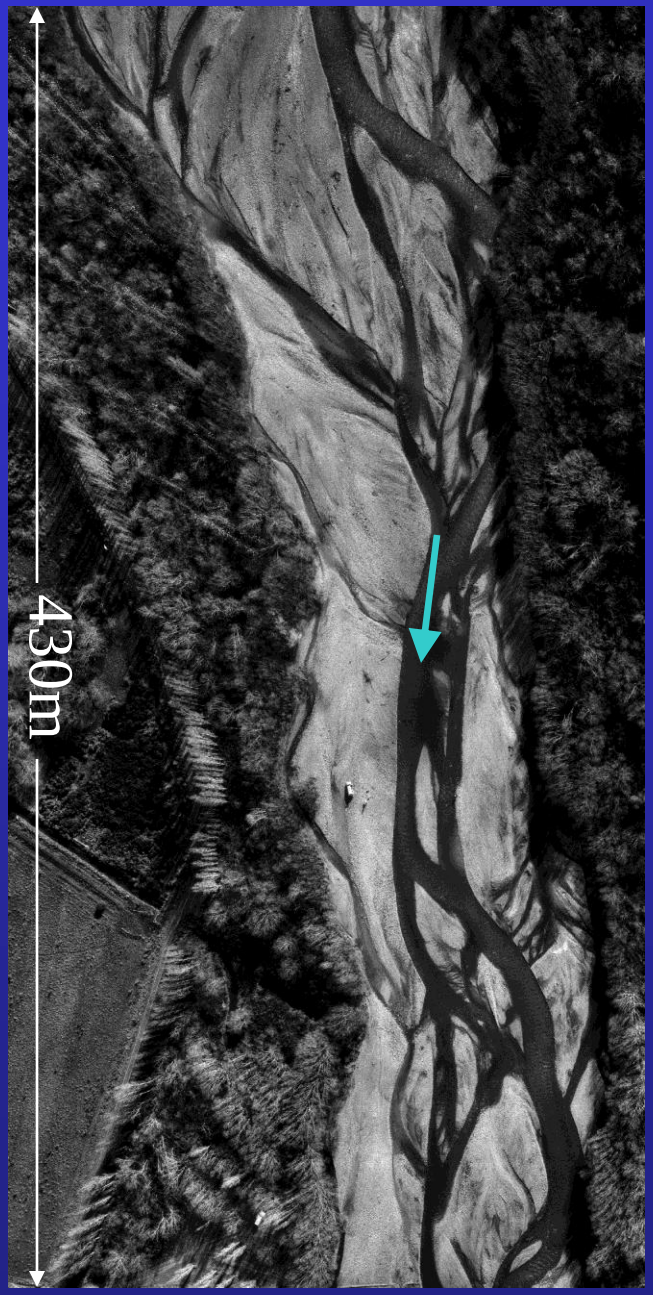
- Based on correcting for refraction of light in water
- Where there is water, there is a systematic positive bias in estimated elevations
- This bias can be ‘eliminated’ by multiplying apparent depth by the refractive index for water (≈1.35)



$$\frac{D_r}{D_a} \approx 1.35$$

The North Ashburton River

- Refraction correction method developed and tested on 430 m reach
- Aerial photos flown May 1995
- Intensive ground survey (2m spacing in wetted channel) allows comparison of photogrammetric and ‘actual’ bed elevation

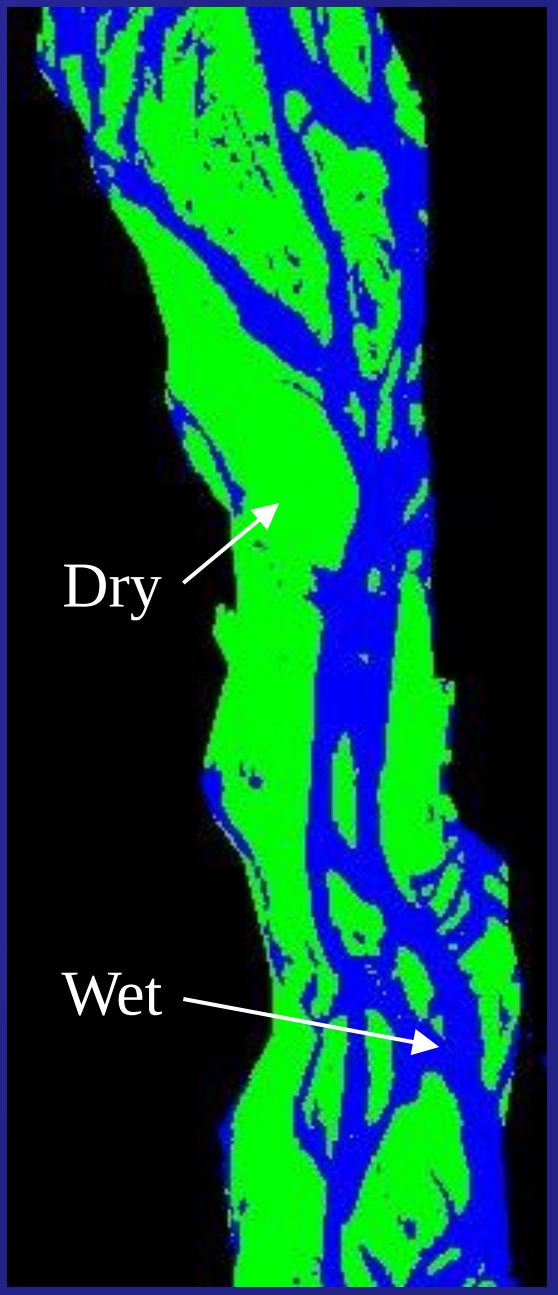


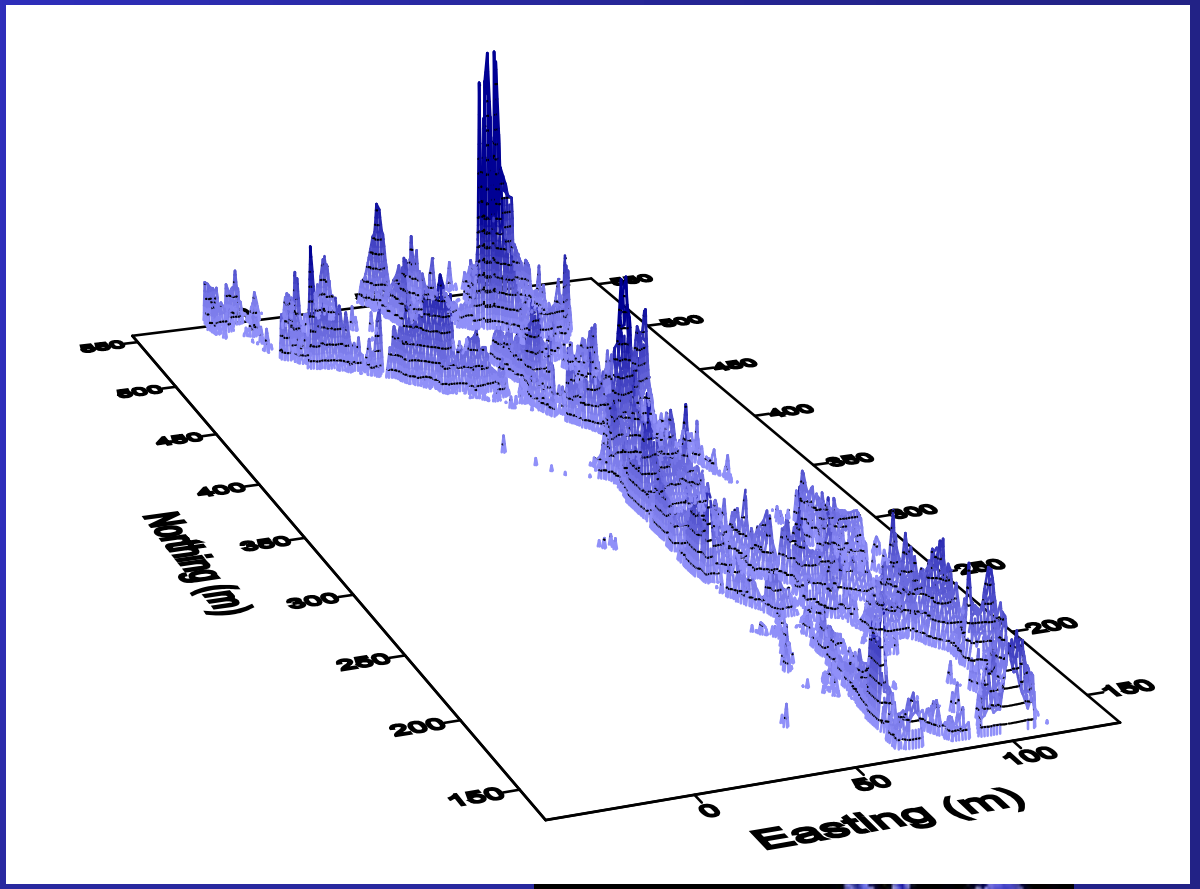
Step 1: Classification of riverbed into ‘wet’ and ‘dry’ areas

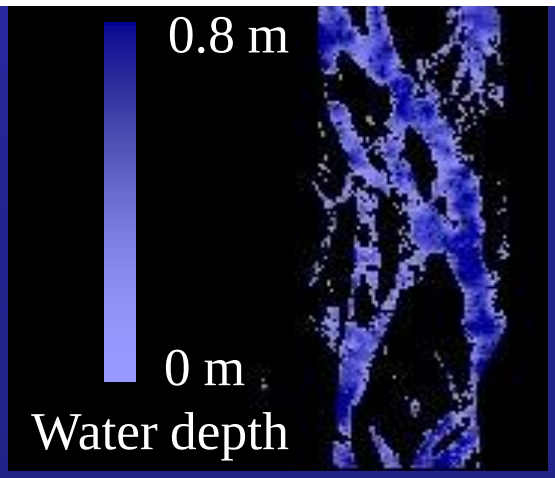
Step 2: Calculation of interpolated water surface

Step 3: Calculation of apparent water depths in wetted channels

Step 4: Correction for refraction (×1.35)




Northing (m)
550
500
450
400
350
300
250
200
150
0
50
100
150
200
250
300
350
400
450
500
Easting (m)

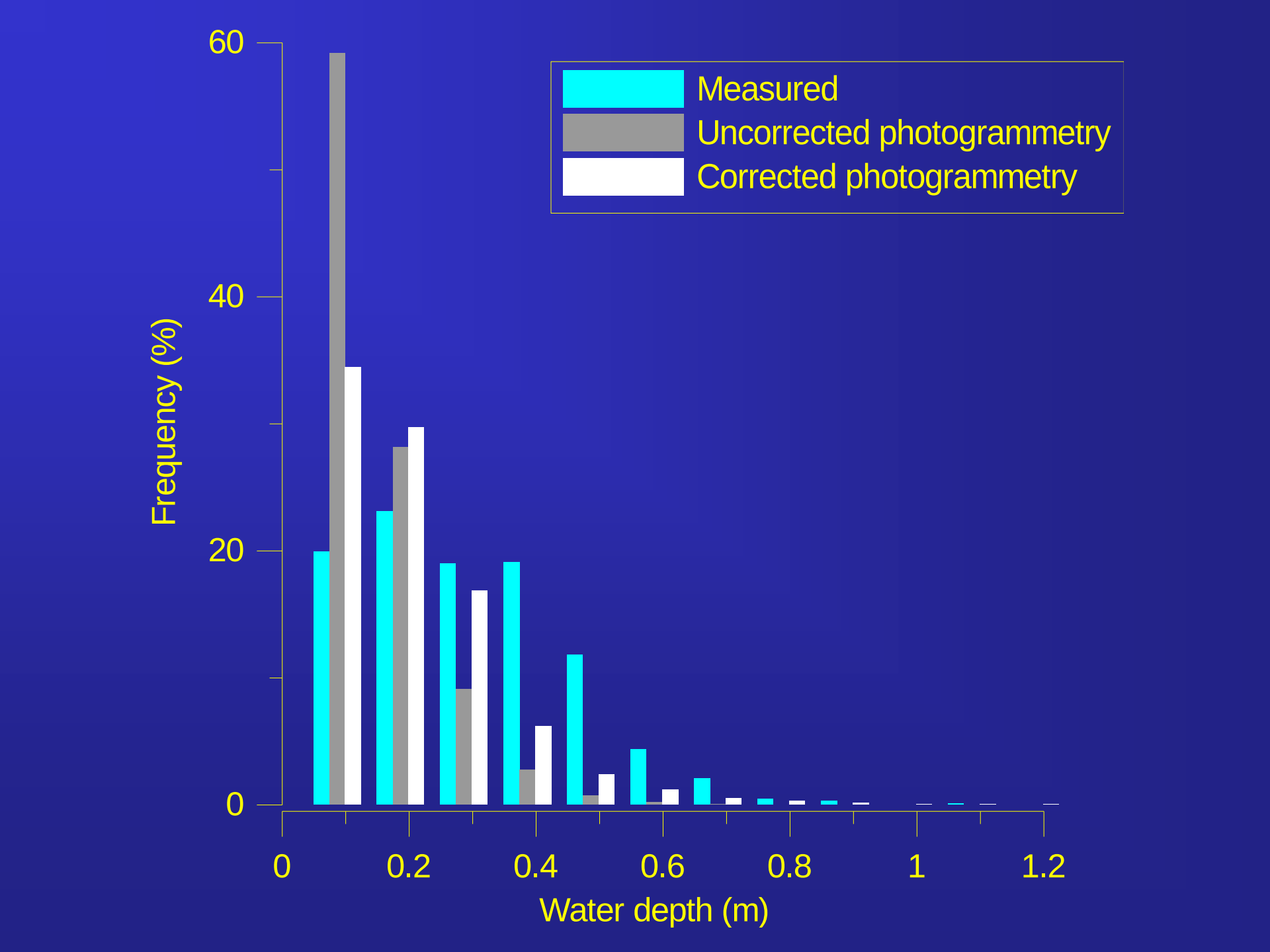

0.8 m
0 m
Water depth

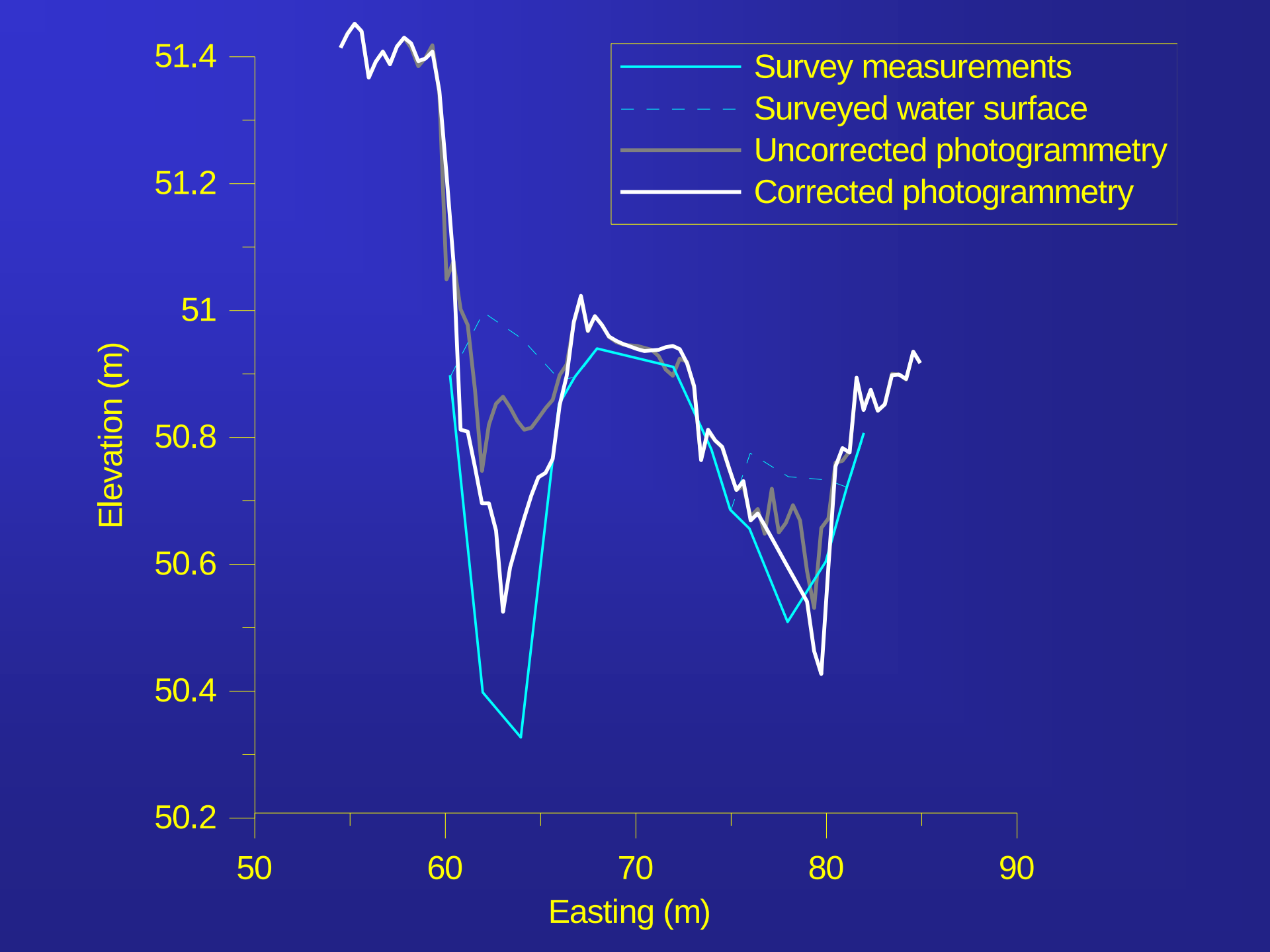
Step 5: Water depth subtracted from estimated water surface to give submerged topography

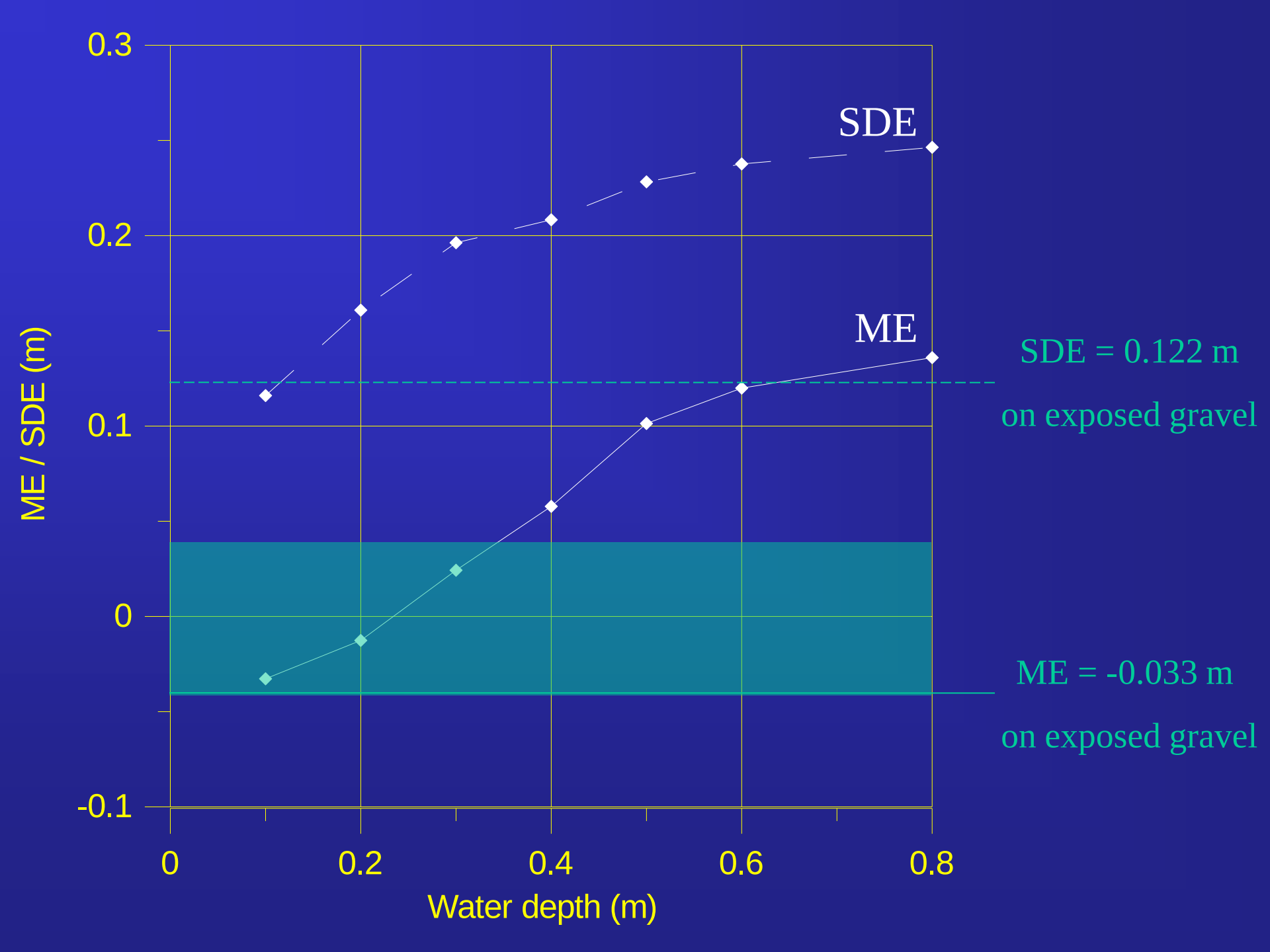
Elevation

53 m

48 m

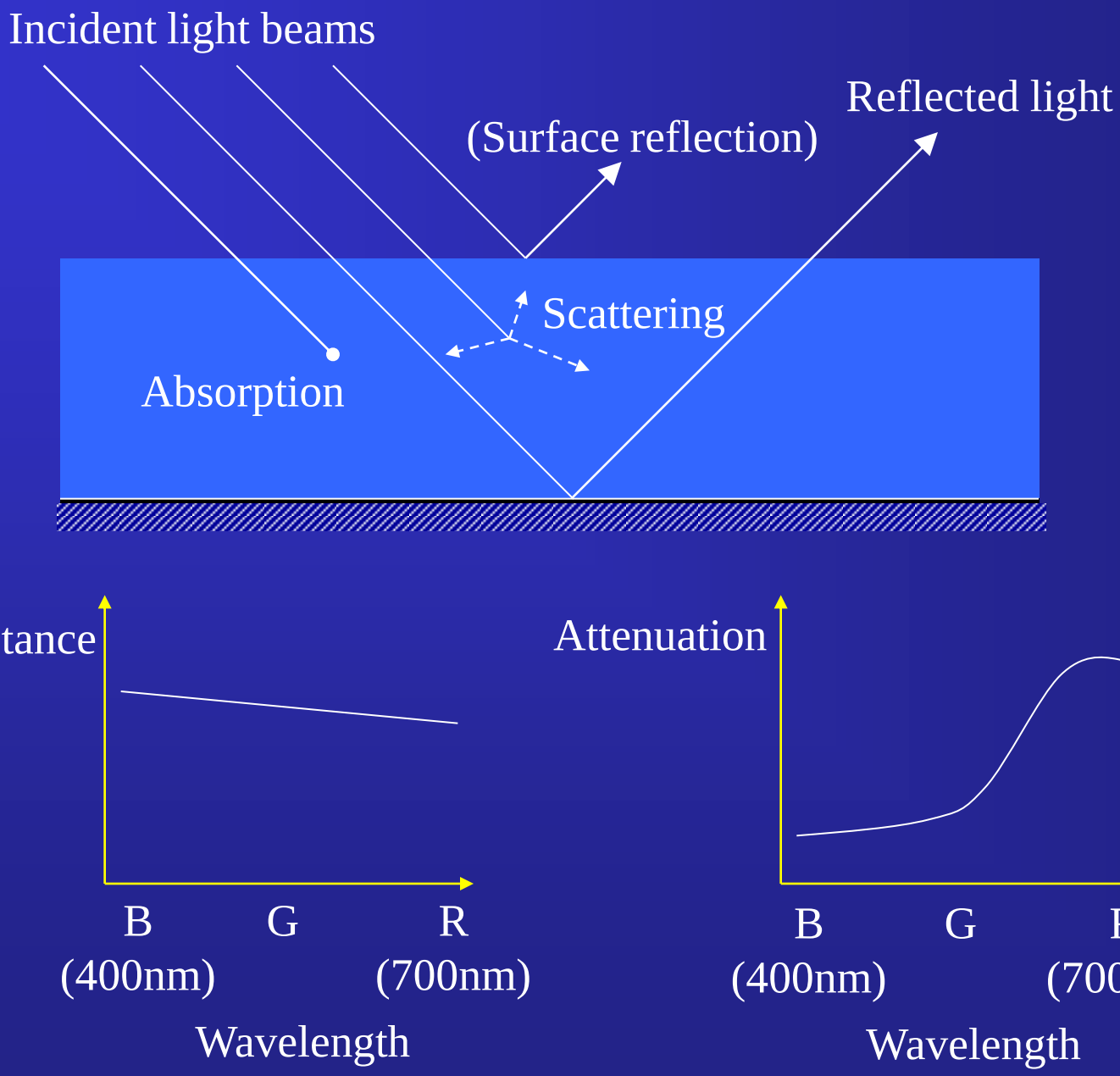

Measured
Uncorrected photogrammetry
Corrected photogrammetry
Frequency (%)
60
40
20
0
0
0.2
0.4
0.6
0.8
1
1.2
Water depth (m)


Survey measurements
Surveyed water surface
Uncorrected photogrammetry
Corrected photogrammetry
Elevation (m)
51.4
51.2
51
50.8
50.6
50.4
50.2
50
60
70
80
90
Easting (m)


0.3
0.2
0.1
0
-0.1
ME / SDE (m)
0
0.2
0.4
0.6
0.8
Water depth (m)
SDE
ME
SDE = 0.122 m
on exposed gravel
ME = -0.033 m
on exposed gravel

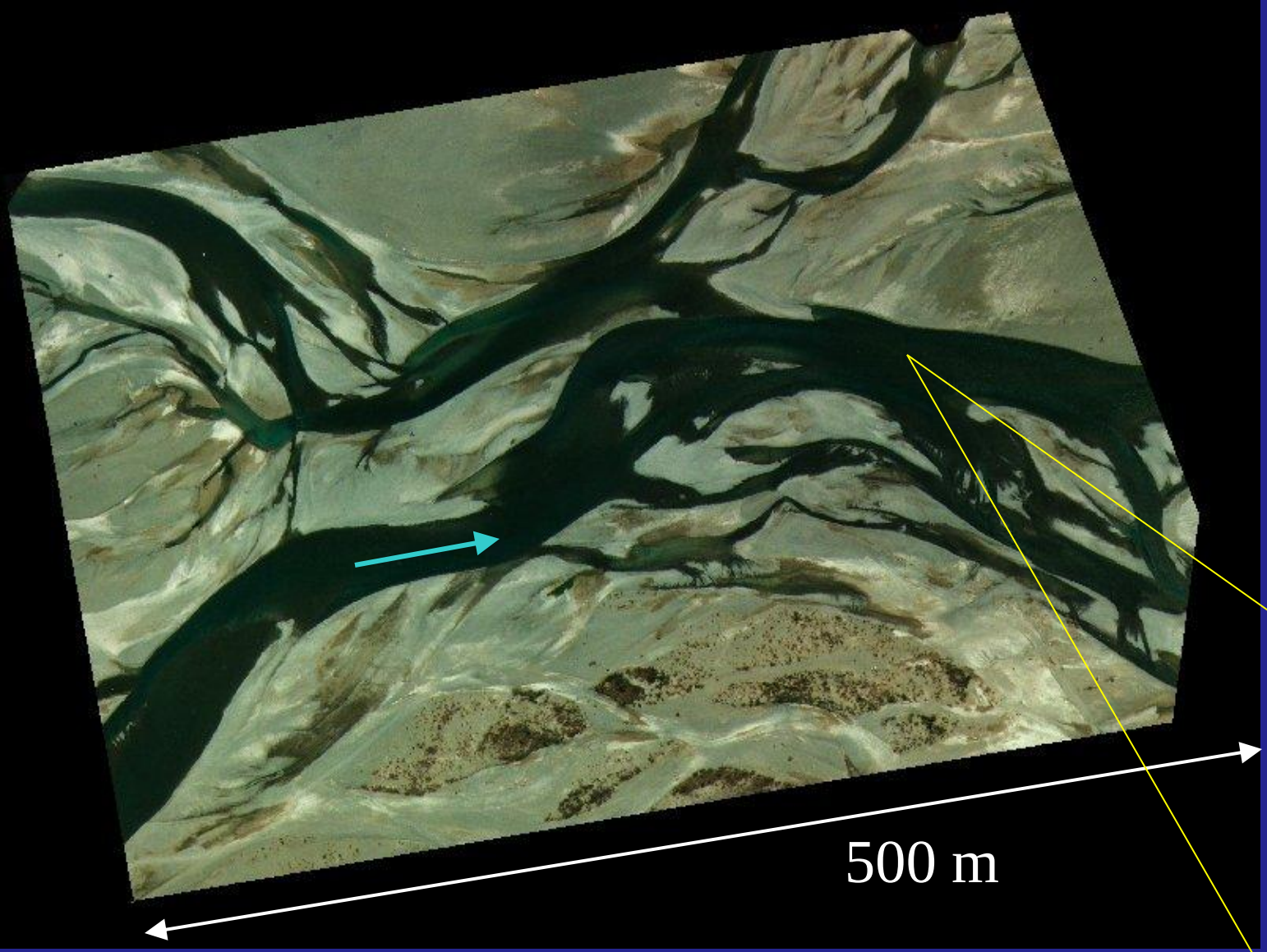
(b) Slightly turbid water: Image analysis

- Water colour is related to how well photons of different wavelengths (i.e. colour) are transmitted through water
- ‘Intrinsic’ colour of water is blue-green, as red light is more readily absorbed and less likely to be reflected
- Colour of shallow water determined by both depth (how much light reaches bed) and substrate (bed colour)


Incident light beams
(Surface reflection)
Reflected light
Scattering
Absorption
Reflectance
B
G
R
(400nm)
(700nm)
Wavelength
Attenuation
B
G
R
(400nm)
(700nm)
Wavelength

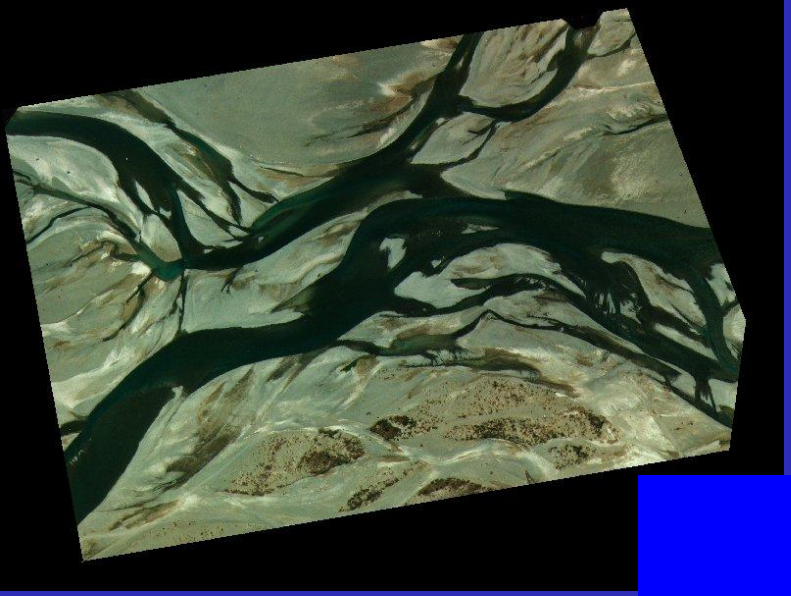
The Waimakariri River

- Colour-depth relationship method calibrated and tested using a 500m section
- Aerial photographs flown in February 1999 and scanned
- Depth measurements made both manually and by jet boat-mounted echo-sounder
- Half used for model calibration; half retained for model testing

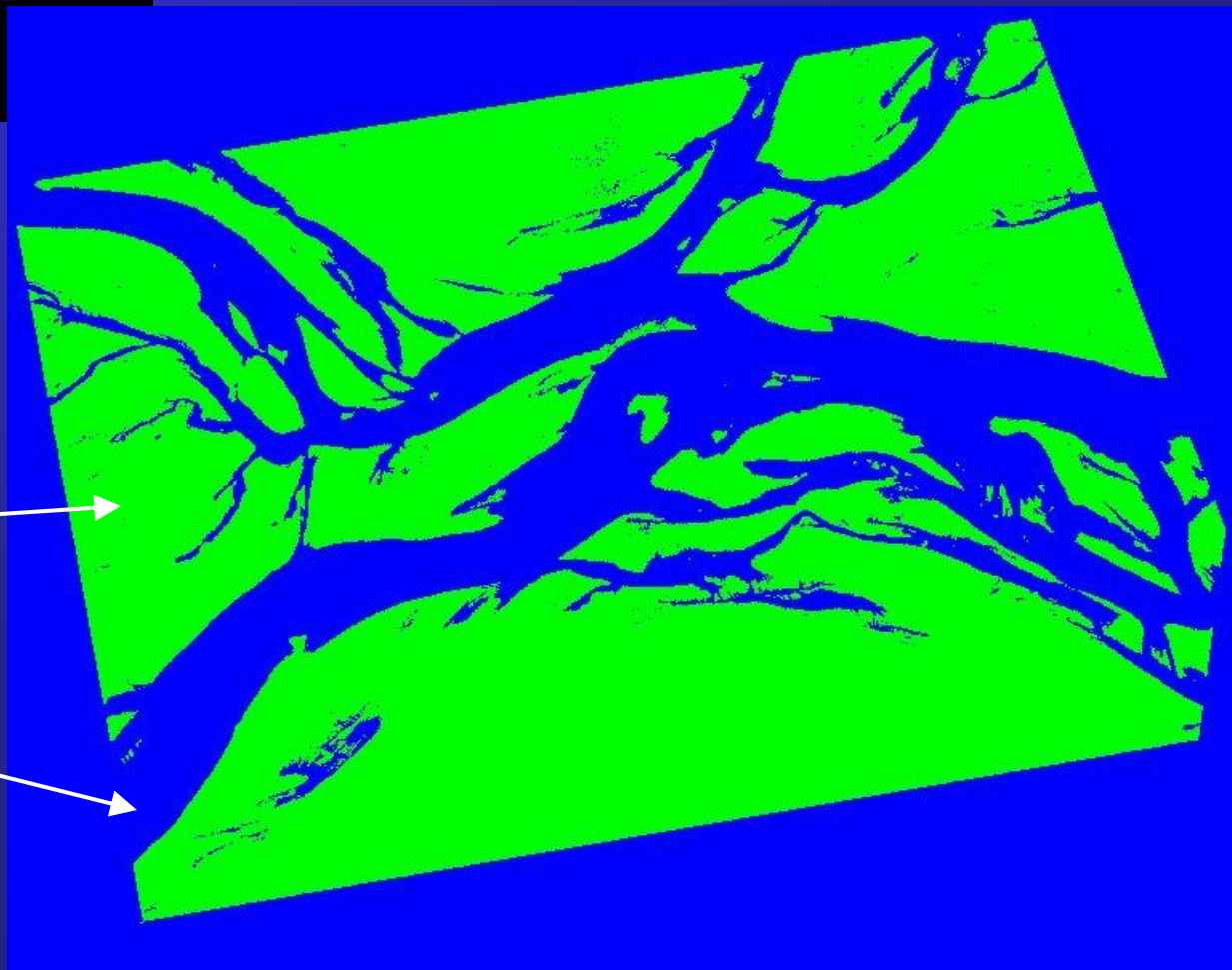


Reflected light ≡ RGB values
from each pixel (0-255)

0.5 m

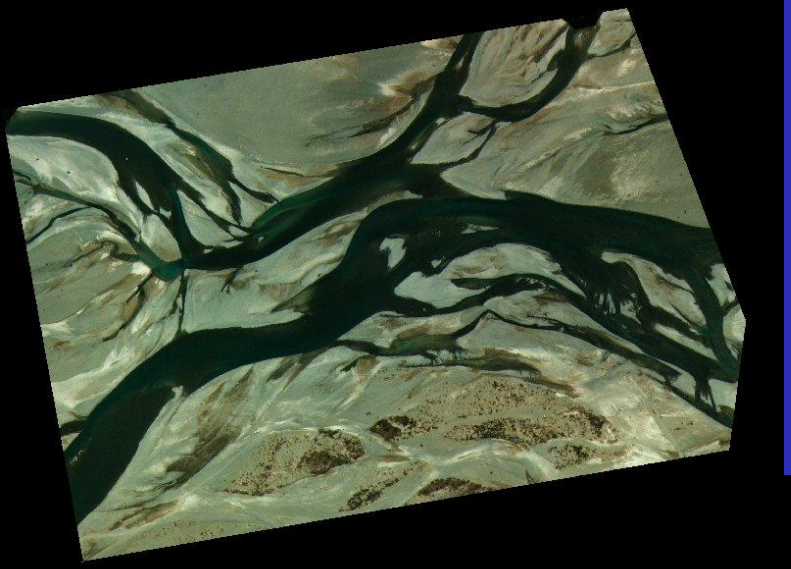


Step 1 - Classification of riverbed into ‘wet’ and ‘dry’ areas

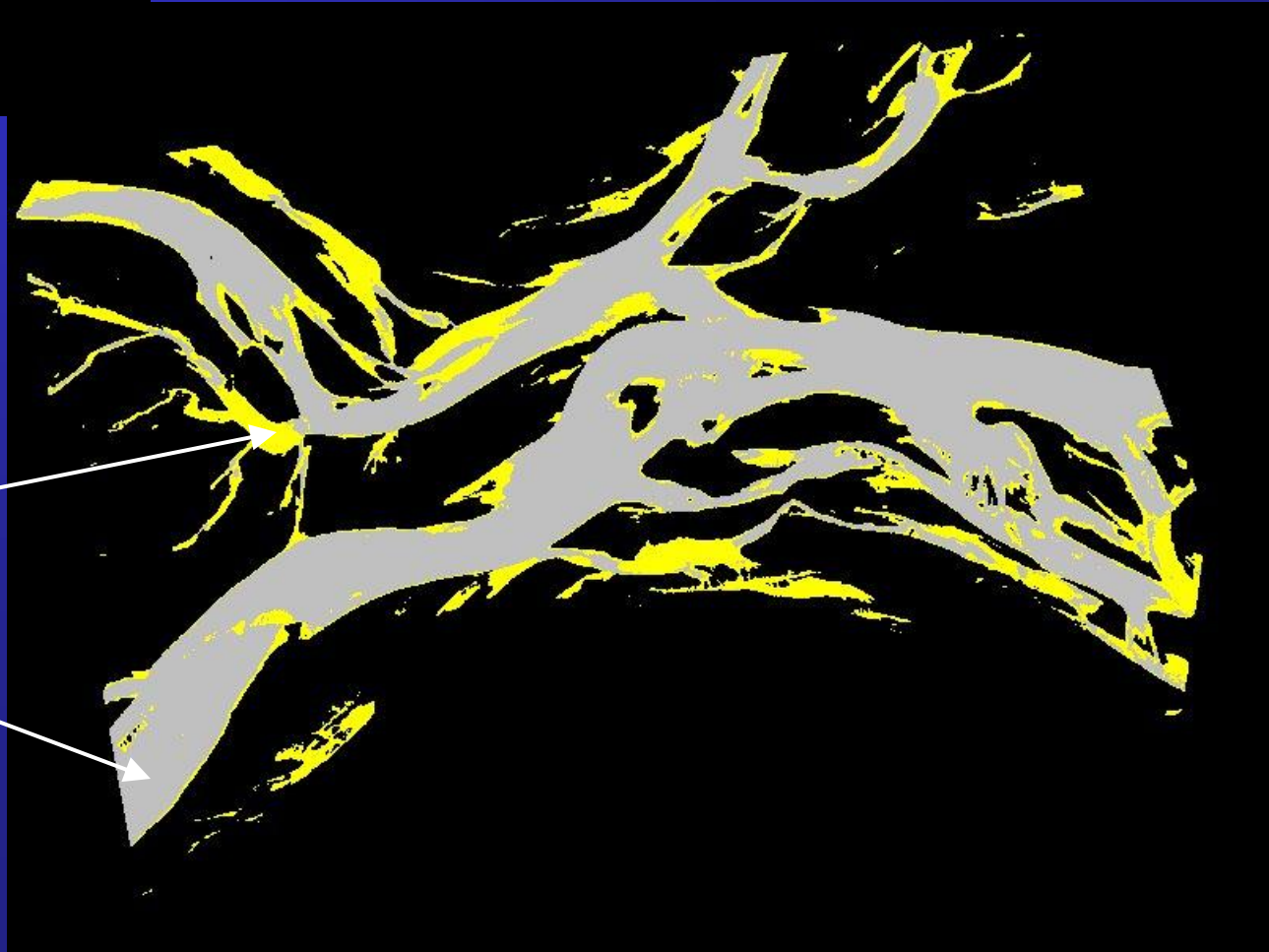


Dry areas

Wet areas



Step 2 - Classification of wetted channels into ‘gravel’ and ‘sand’ substrates

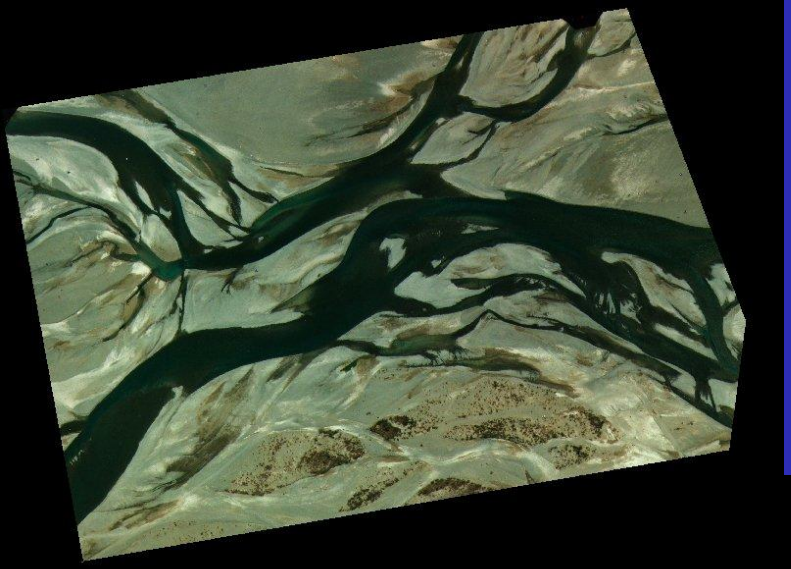


Step 3: Derivation of an empirical depth-colour relationship for each substrate class

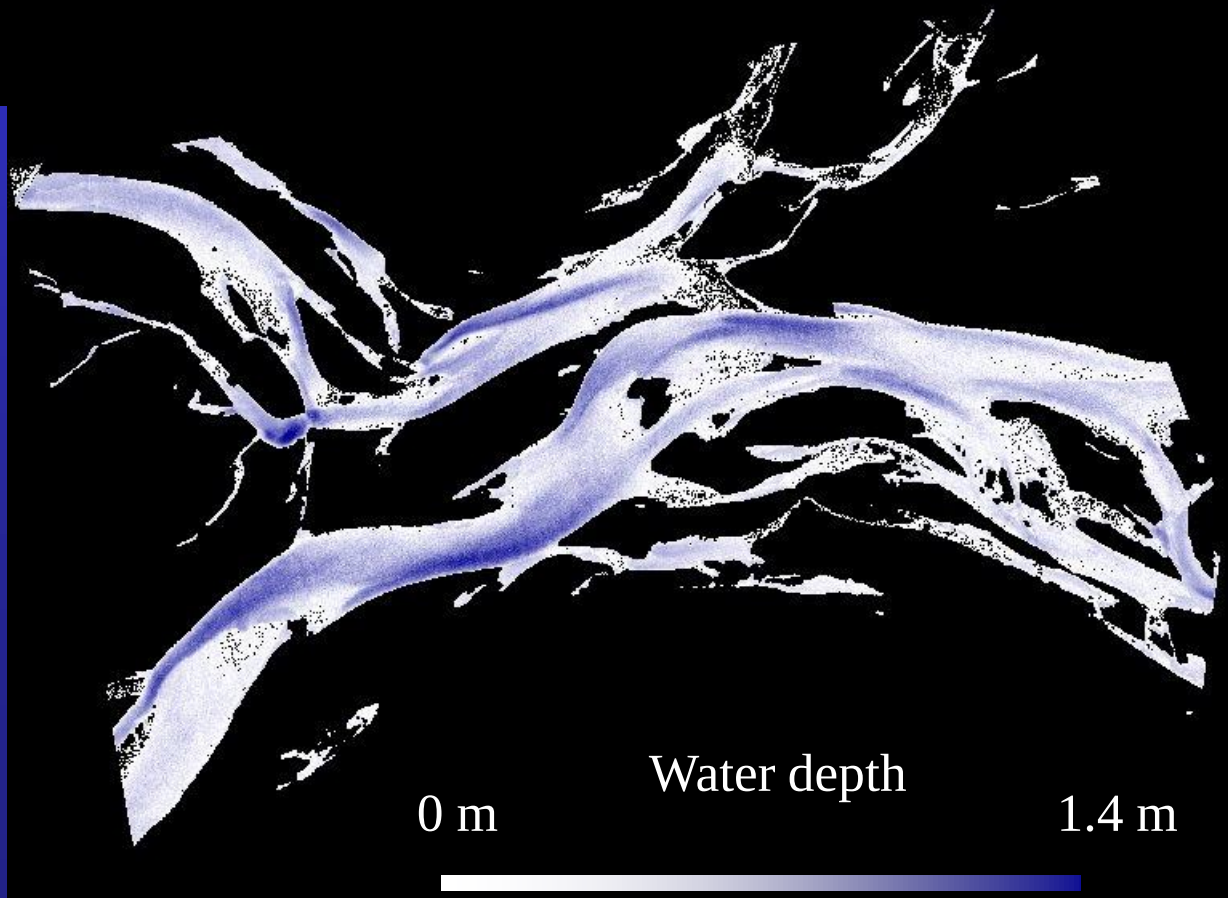
- Reflectance decreases exponentially with depth, therefore:

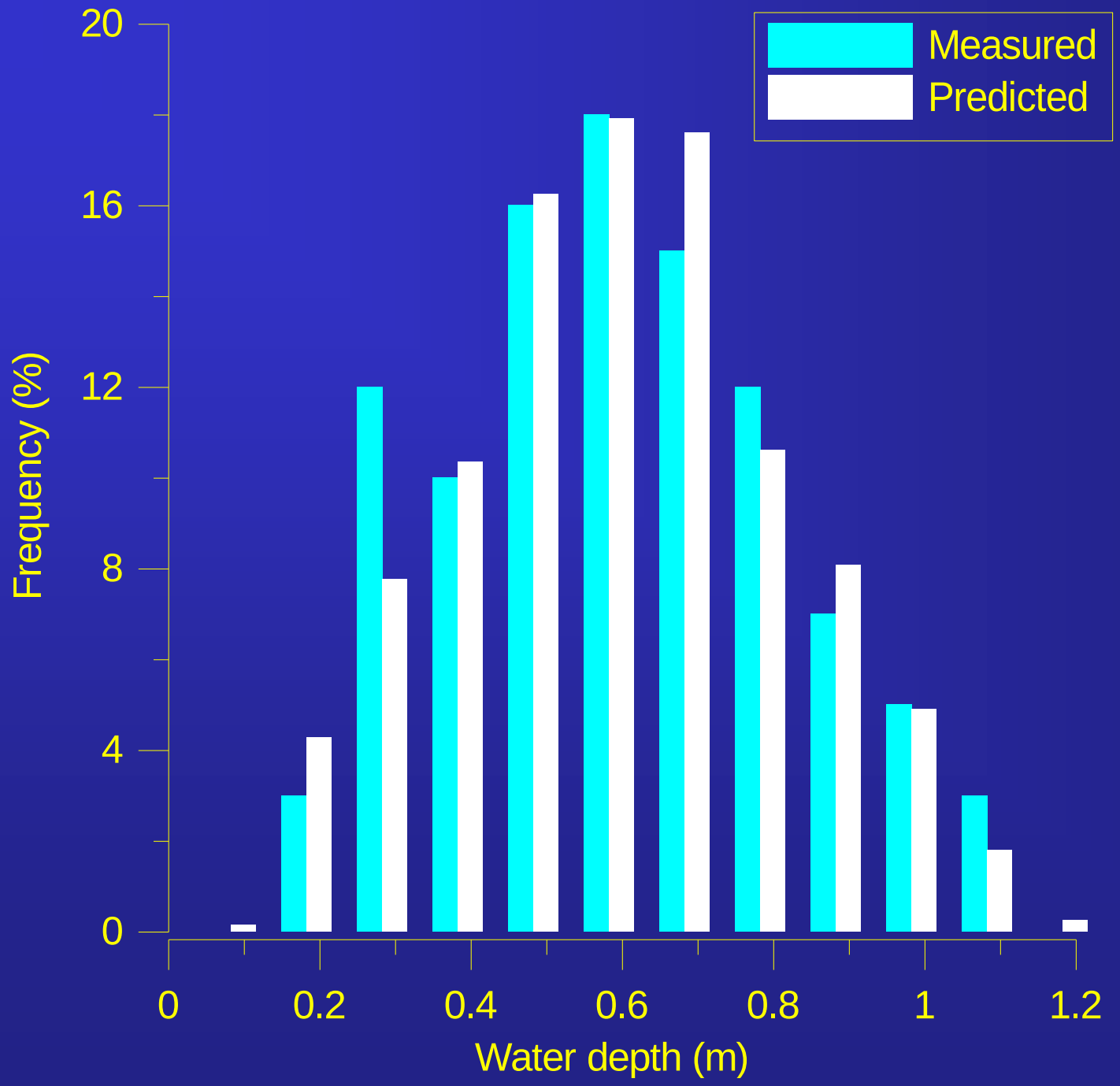
$$\text{Depth} = a \times \ln(R) + b \times \ln(G) + c \times \ln(B) + d$$

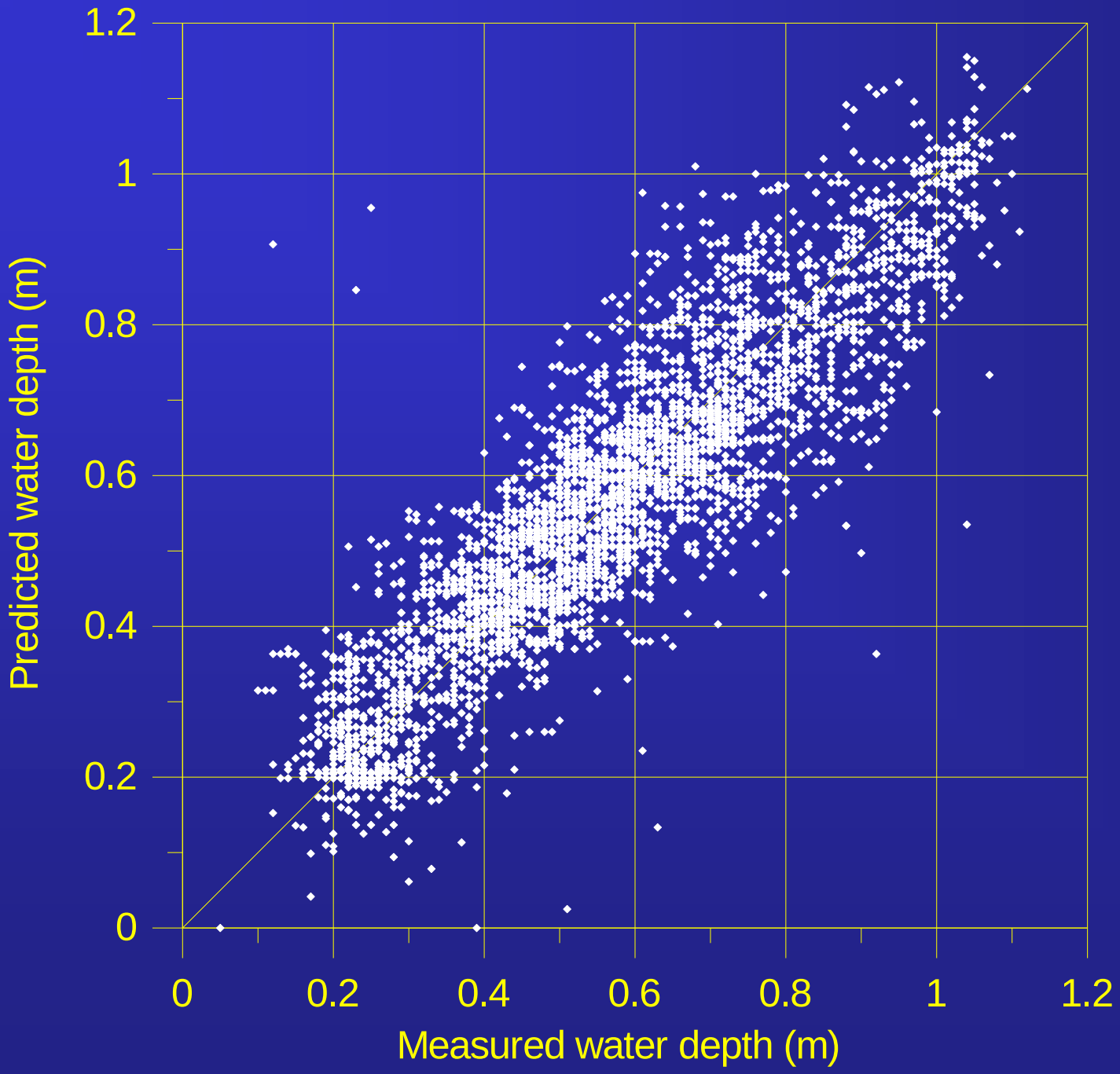
Substrate	***a***	***c***	***d***	**n**	**R^2**	**SDE (m)**
Gravel	-0.44	0.74	-0.94	4083	83%	0.09
Sand	-0.39	0.58	-0.42	94	60%	0.08



Final water depth map




Measured
Predicted
Frequency (%)
20
16
12
8
4
0
0
0.2
0.4
0.6
0.8
1
1.2
Water depth (m)

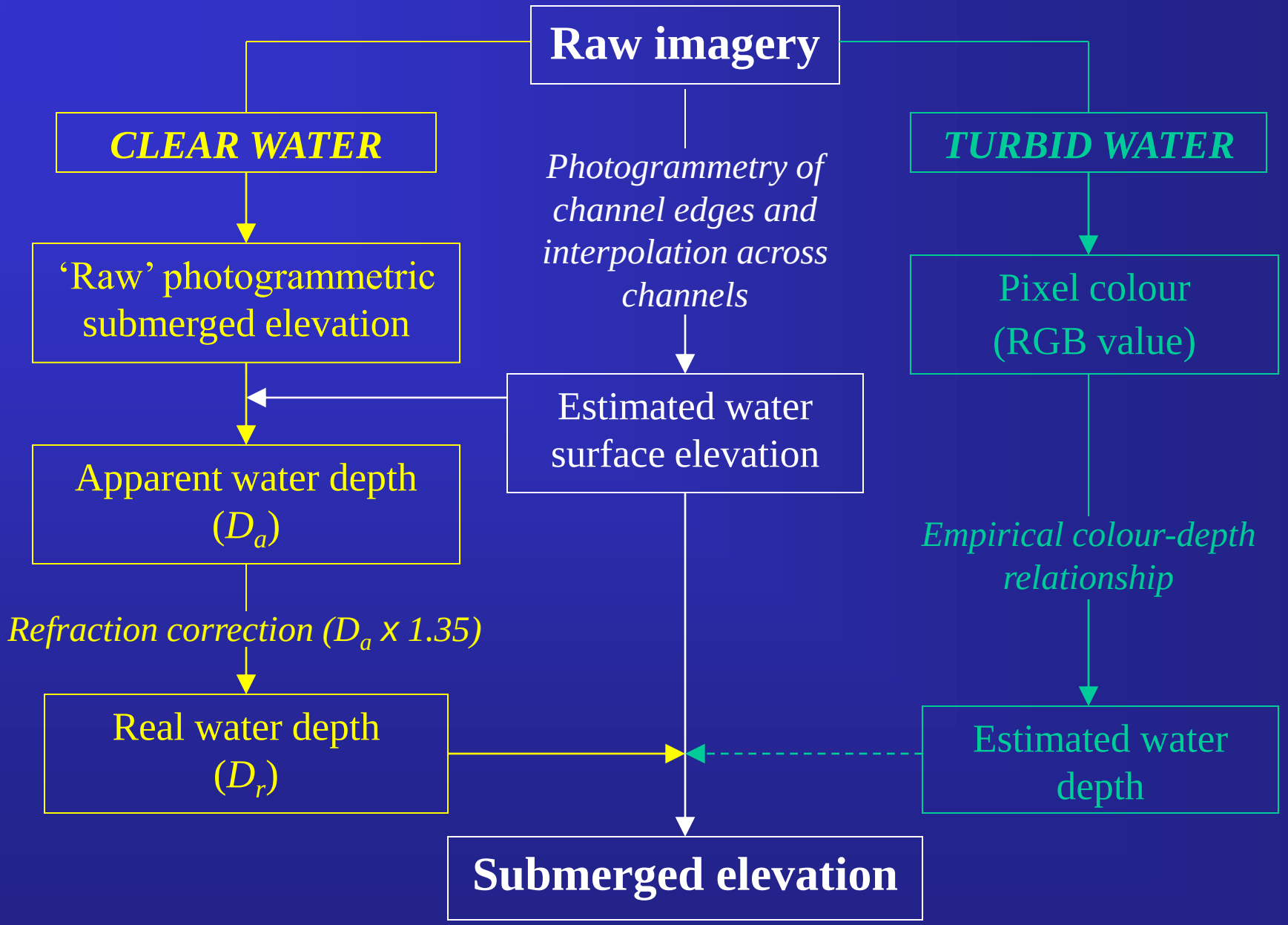


n = 3902

R^2 = 80%

ME = 0.00 m

SDE = 0.10 m


Raw imagery
CLEAR WATER
TURBID WATER
Photogrammetry of channel edges and interpolation across channels
'Raw' photogrammetric submerged elevation
Pixel colour (RGB value)
Estimated water surface elevation
Apparent water depth (D_a)
Empirical colour-depth relationship
Refraction correction (D_a x 1.35)
Real water depth (D_r)
Estimated water depth
Submerged elevation

Conclusions

- It is possible to estimate bed topography of shallow river channels using automated methods
- The point errors associated with submerged topography as a whole are greater than with photogrammetry of exposed areas...
- …but they scale with water depth
- For clear water, corrected photogrammetry of submerged topography in very shallow water (<0.4m) is no less accurate than photogrammetry of dry areas in terms of ME

Conclusions (2)

- Image analysis of colour for slightly turbid water needs careful calibration due to variations in image tone between adjacent images
- *E.g. for whole 2.5 km reach where depth measurements made, ME ↑ from 0.00 to 0.05 m and SDE ↑ from 0.10 to 0.25 m*
- Time and place (and photograph?) specific
- Both methods can be used to contribute toward 'total' topographic coverage of riverbeds
- Used in a variety of reach-scale applications to inform (e.g. optimum cross-section spacing) or replace (e.g. sediment storage calculations) conventional field survey methods