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2D Modelling Workshop
-
Sydney
16 June 2015

Assessment of Bridge Losses using a Range of 2D Modelling Tools
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Introduction

Two types of losses considered:

- Blockage and flow separation losses
  - hypothetical case
- Losses caused by individual bridge piers
  - case study – Gold Coast light rail bridge

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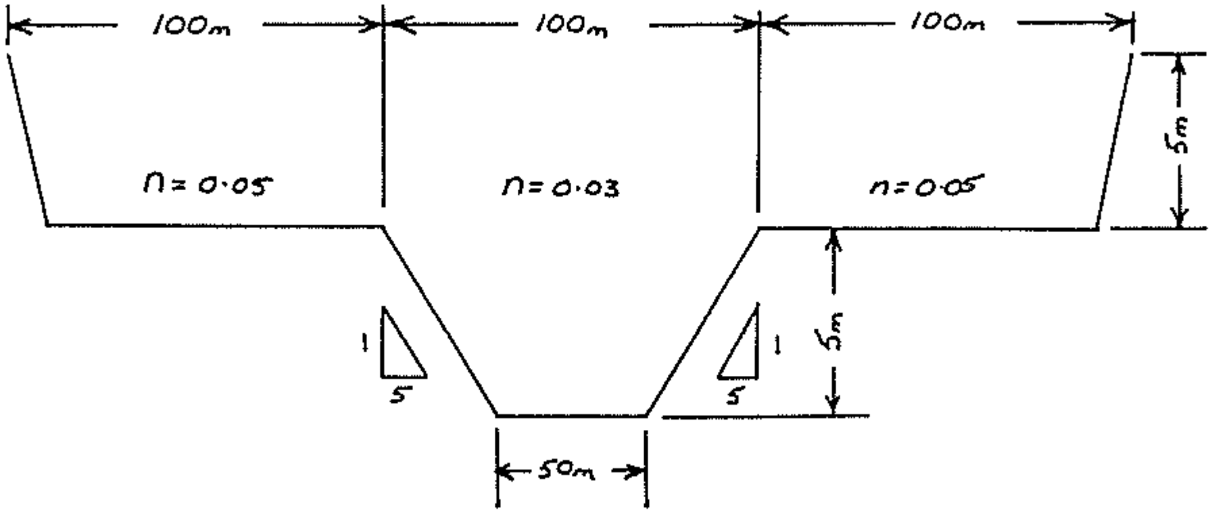
Hypothetical river - flood plain system

- Long straight trapezoidal channel and floodplain
  - channel 100m wide, 5m deep, side slopes 5:1
  - floodplain 100m wide on either side
  - Mannings 'n' = 0.03 channel, 'n' = 0.05 floodplain
- Length 10.0 km
- Longitudinal slope 0.0005
- Q = 2,000 m^3/s

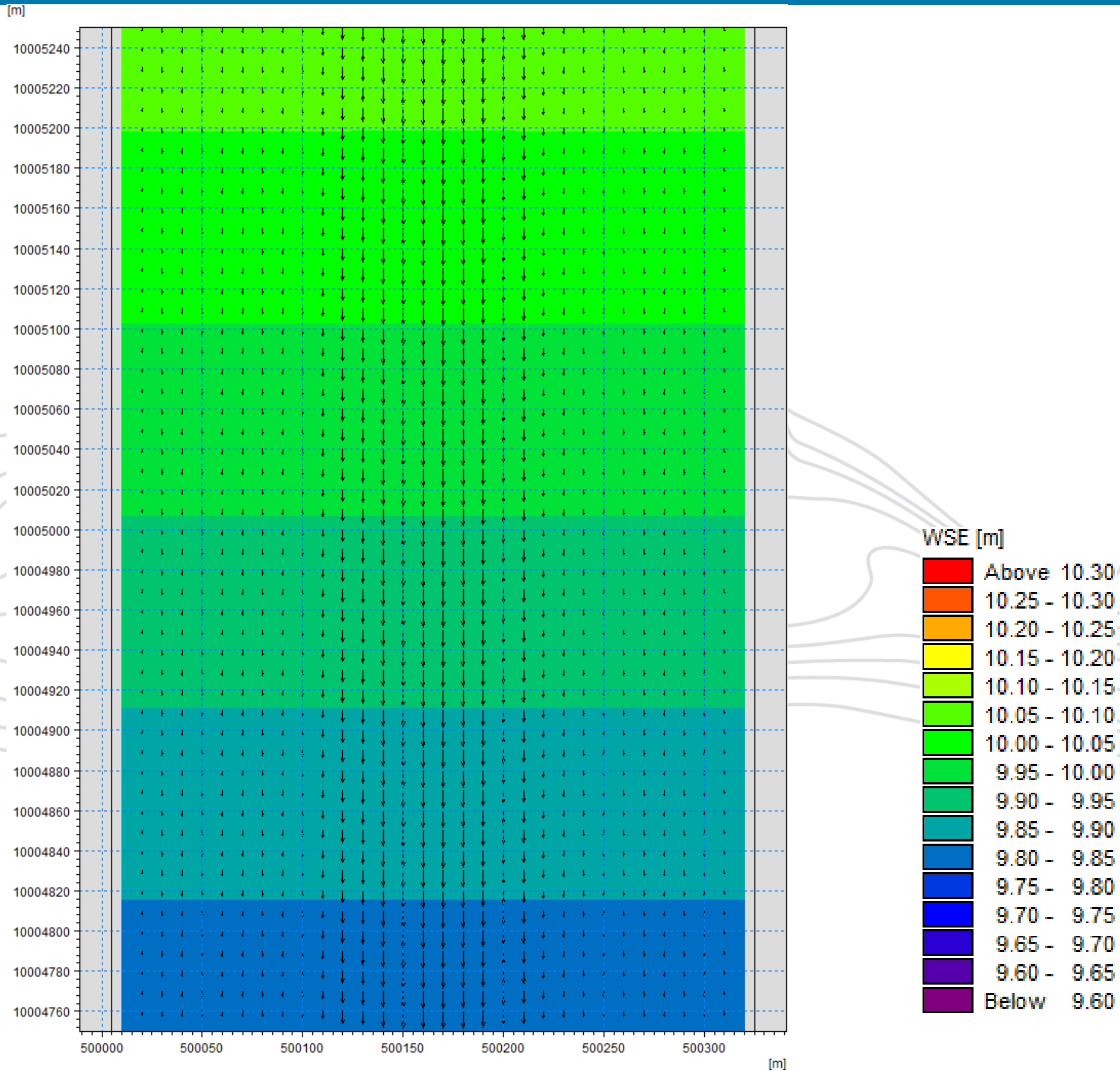


Test Cases

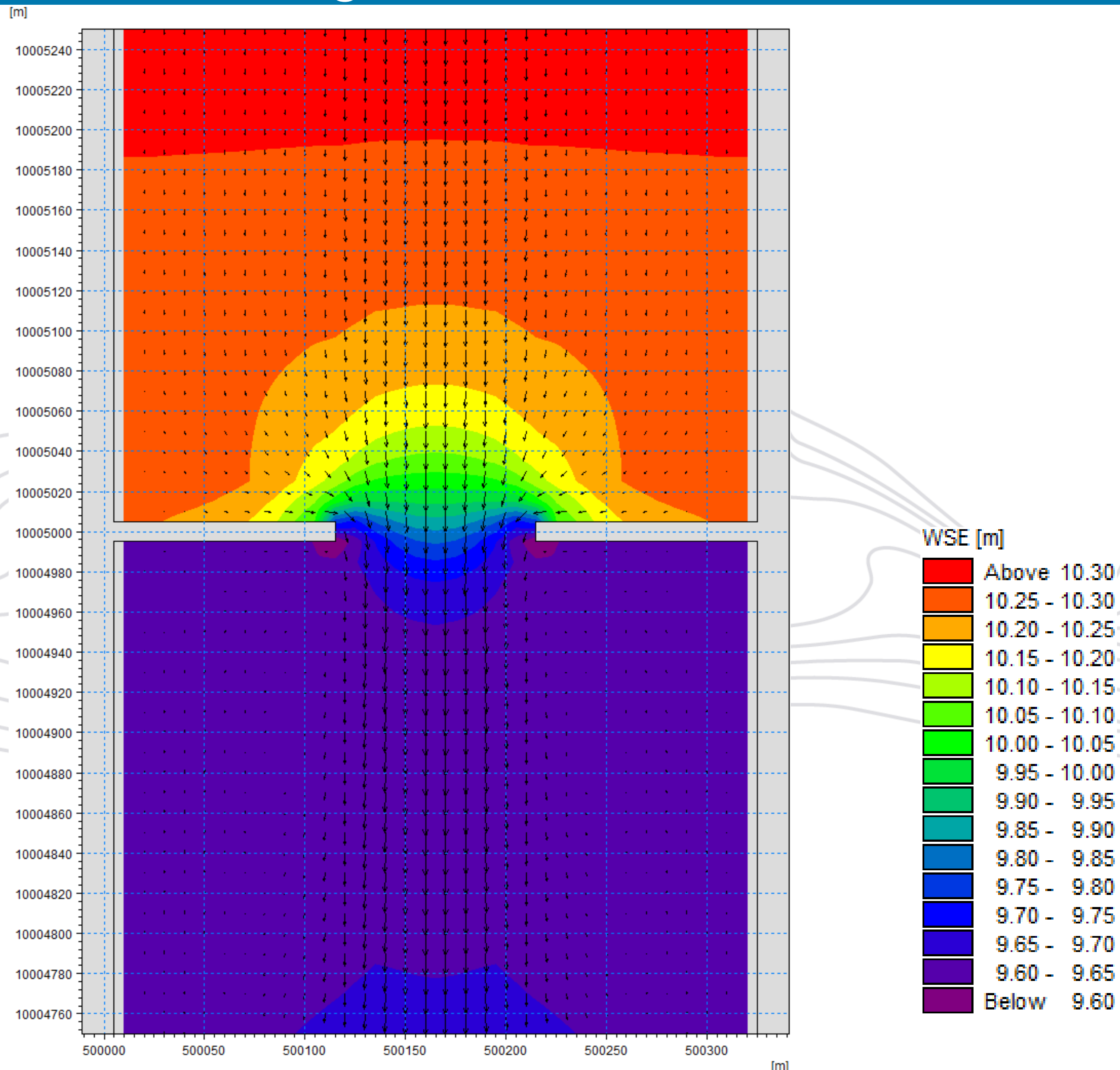
Four main test cases:

- Natural channel – no constrictions
- Bridge section at 5.0 km
  - clear span of channel
  - both floodplains fully blocked by bridge abutments
- Bridge section with 20m wide culvert on left abutment
- Bridge section with 20m wide culverts on both abutments

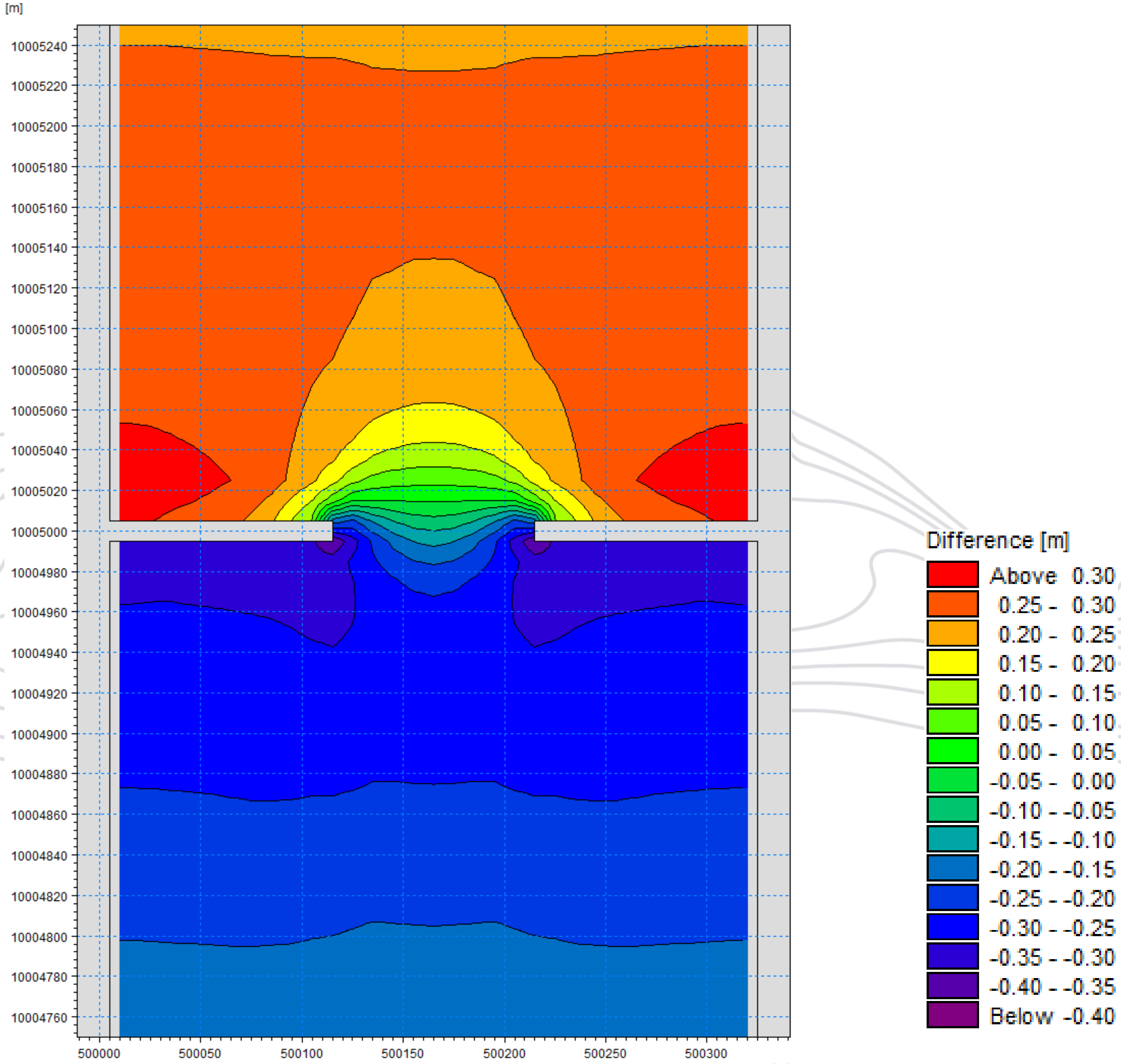
Flood Flow – Natural Channel



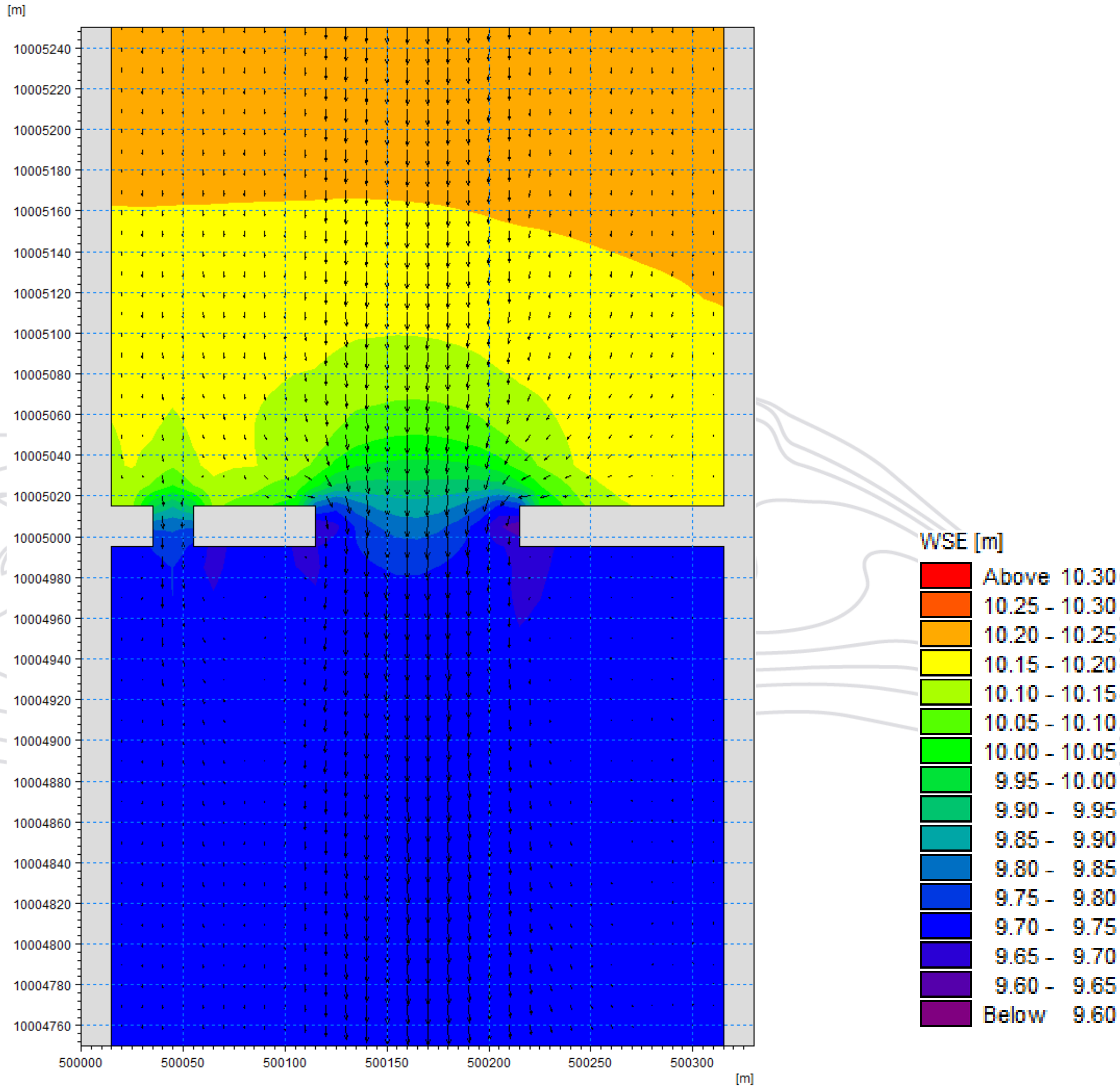
Flood Flow – Bridge Section



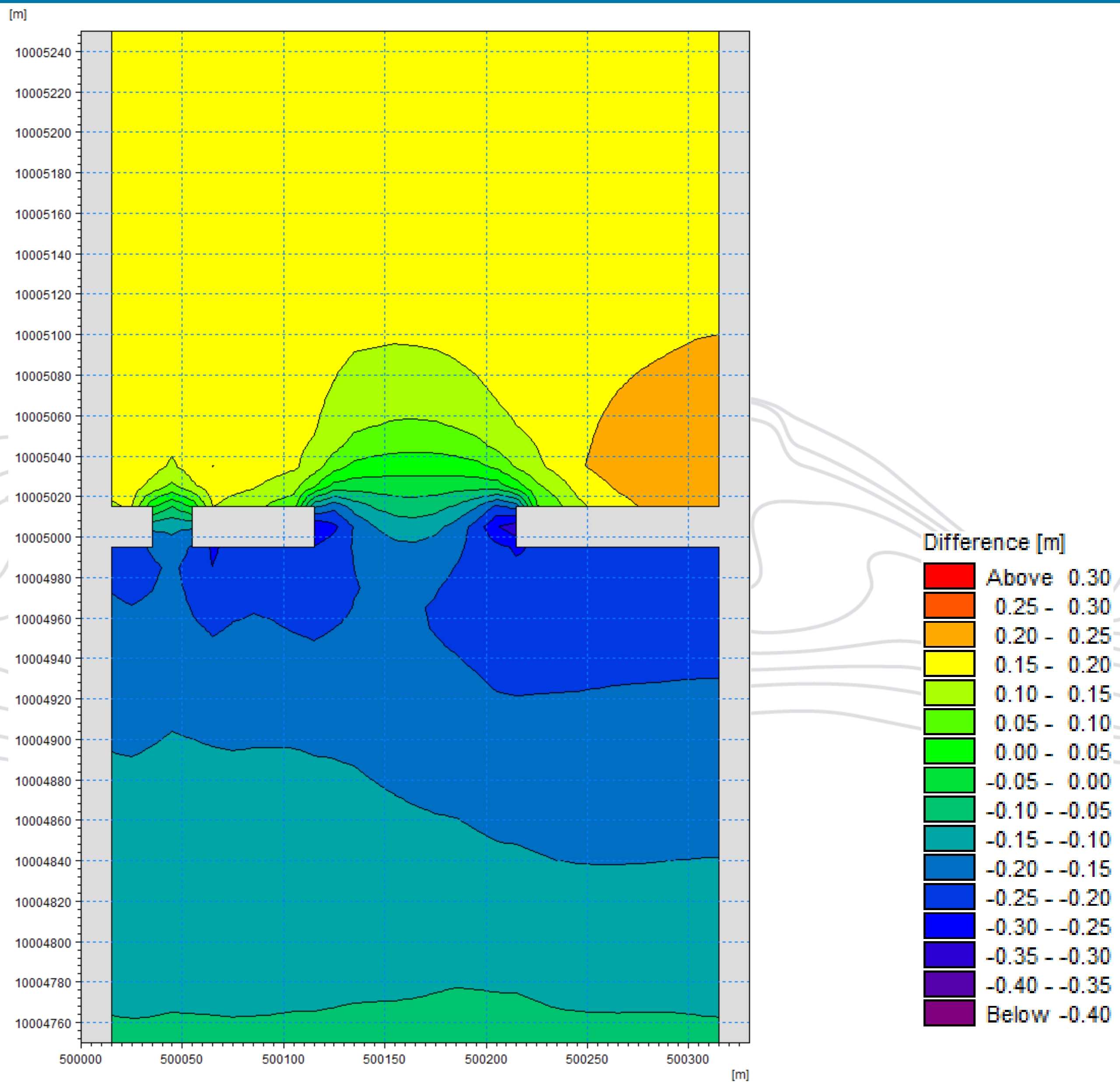
Bridge Section - Differences



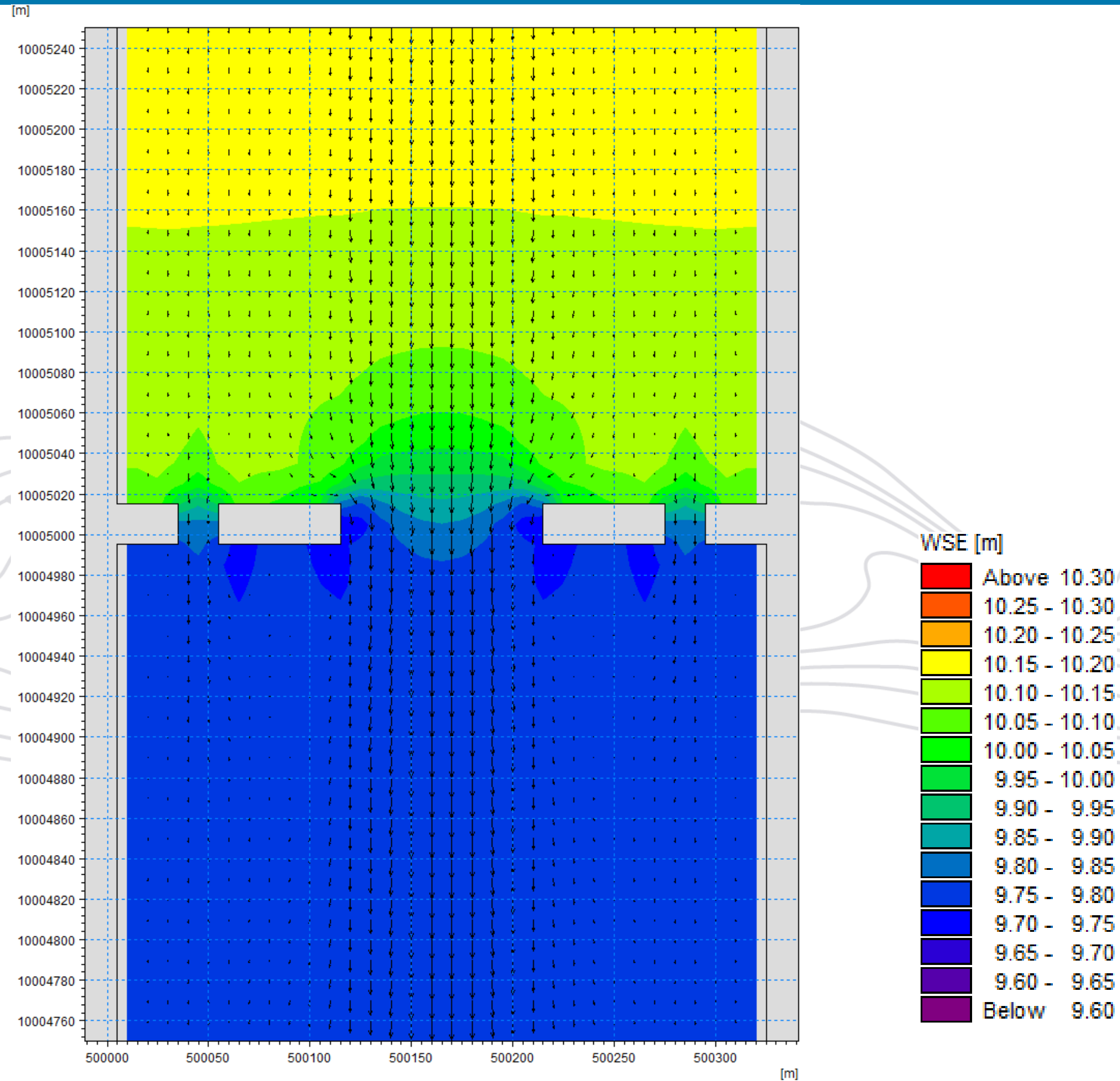
Bridge Section with 1 culvert



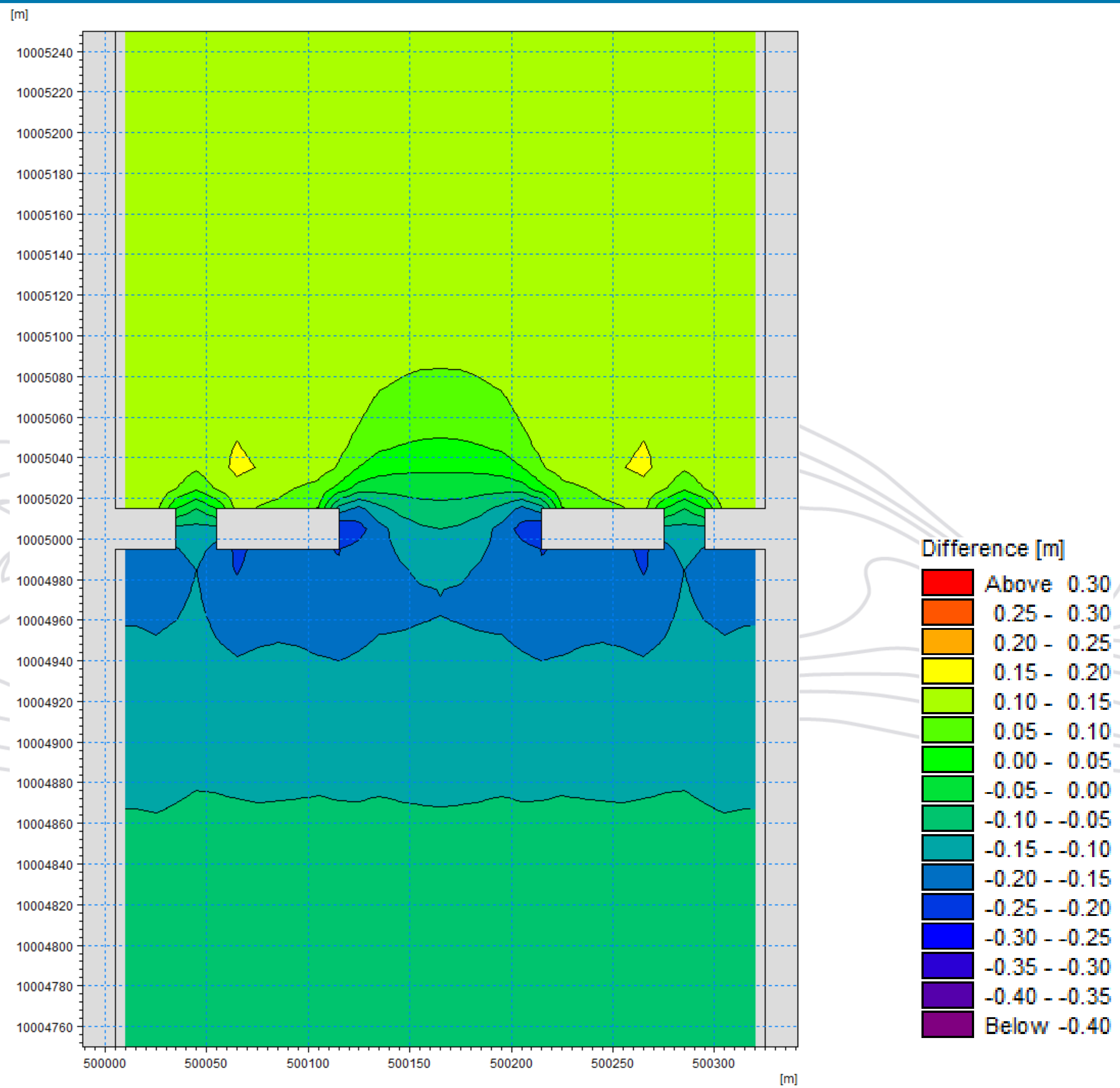
Bridge Section with 1 culvert - Differences



Bridge Section with 2 culverts



Bridge Section with 2 culverts - Differences



Summary

Case	Afflux
1. Natural Channel	0.00m
2. Bridge with abutments	0.33m
3. Bridge with 1 culvert	0.27m
4. Bridge with 2 culverts	0.15m

- Afflux with full abutments consistent with results from "Hydraulics of Bridge Waterways"
- Selective placement of culverts in bridge abutments can be used to reduce flow separation and thereby expansion losses (in this case by more than 50%)

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Case Study – Gold Coast Rapid Transit Bridges

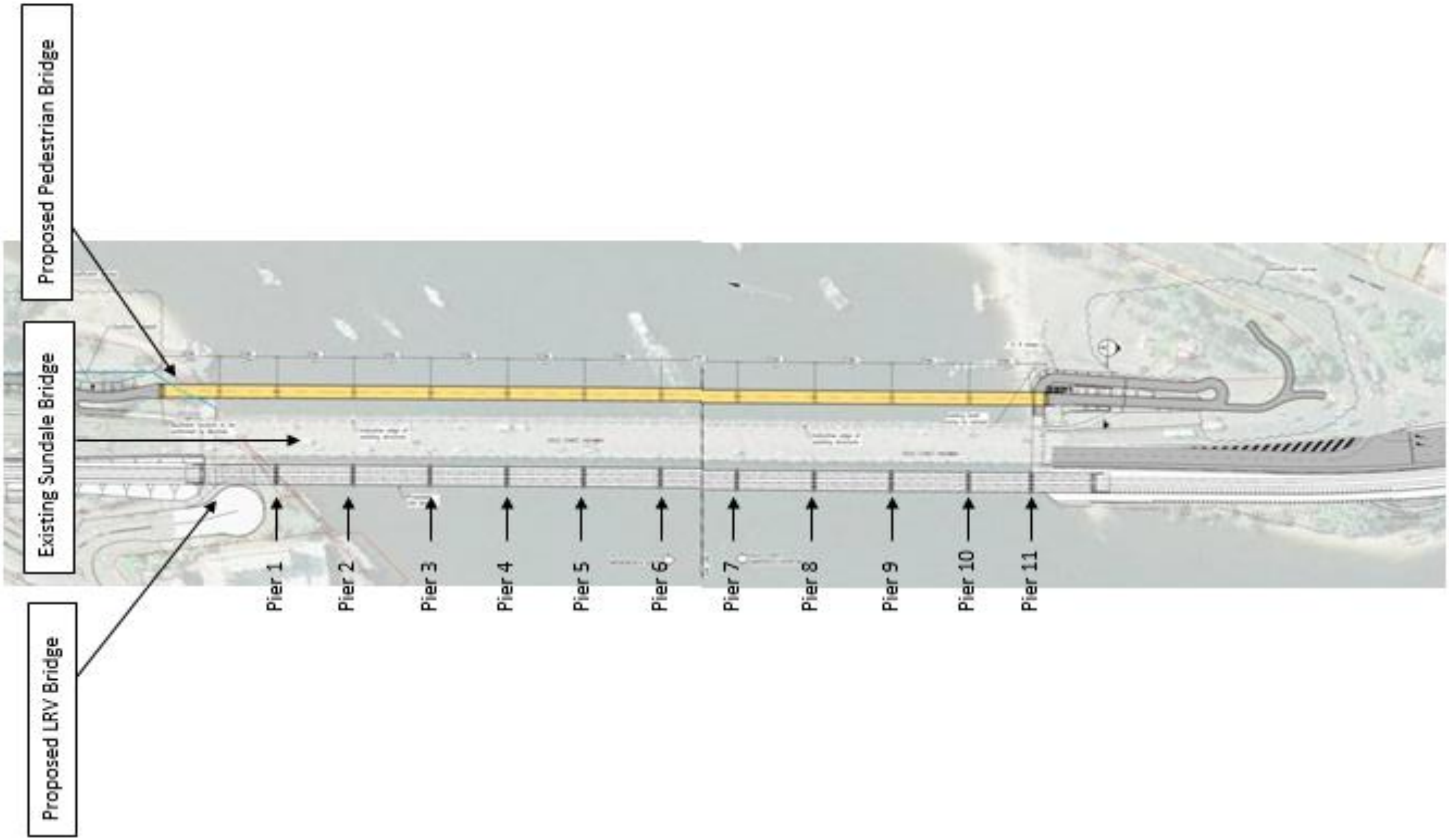
- Gold Coast Rapid Transit Project
- Two new bridges across the Nerang River adjacent to the existing “Sundale” bridge
  - Pedestrian bridge immediately downstream
  - Light Rail Vehicle bridge immediately upstream
- Required to satisfy:
  - Project specific conditions
  - General design standards

Case Study – Gold Coast Rapid Transit Bridges

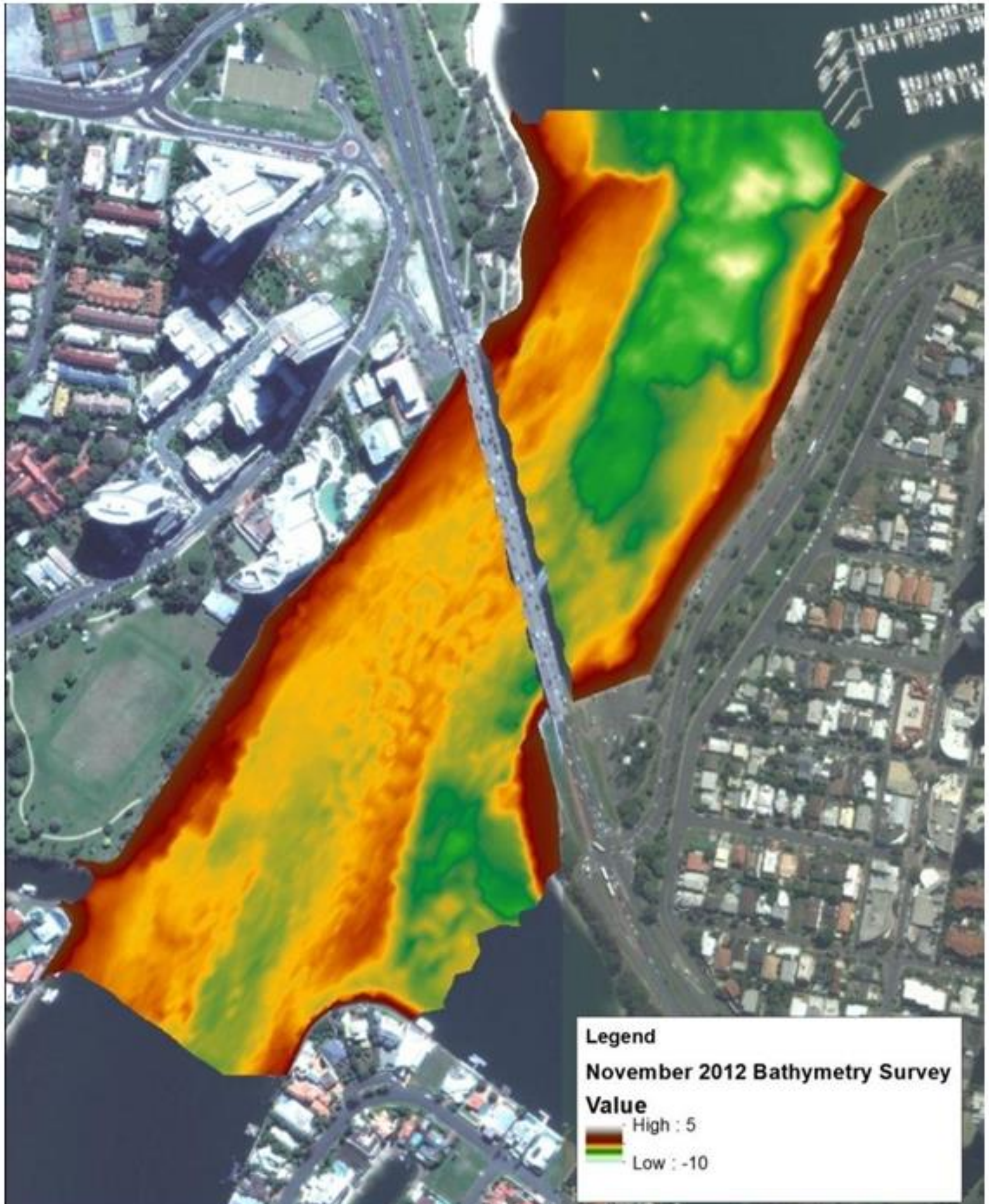
General Locality

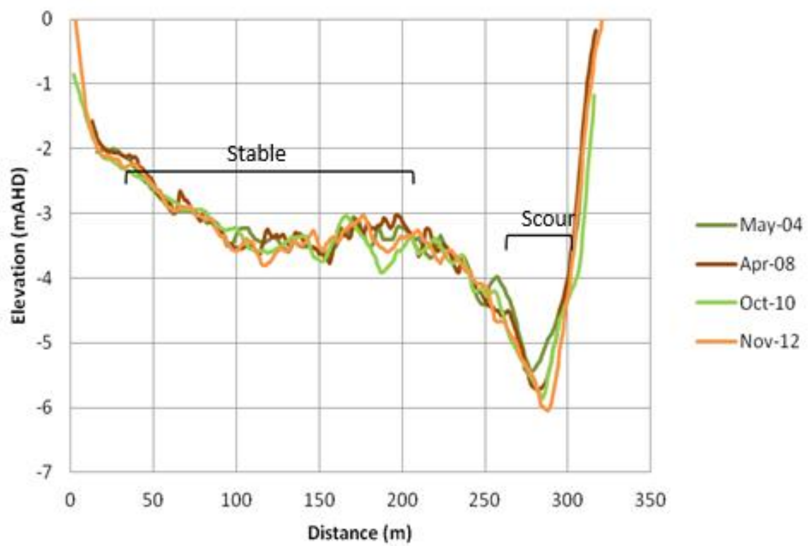
Existing Sundale Bridge and location of proposed LRV and pedestrian bridges

Bridge Layout



Available Survey





Flood Modelling

- Debate between proponent and approval authorities
- Multiple model approaches investigated

System	M21 FD			M21 FM		TUFLOW
Bridge approach	Coarse (20m) Grid + piers	Fine (5m) Grid + piers	Fine grid to resolve piers explicitly	Pier module	Resolving piers explicitly	Fine (5m) Grid + layered flow constriction

- Multiple design scenarios including:
  - – Defined flood event
  - – Varying tailwater
  - – Climate change scenarios

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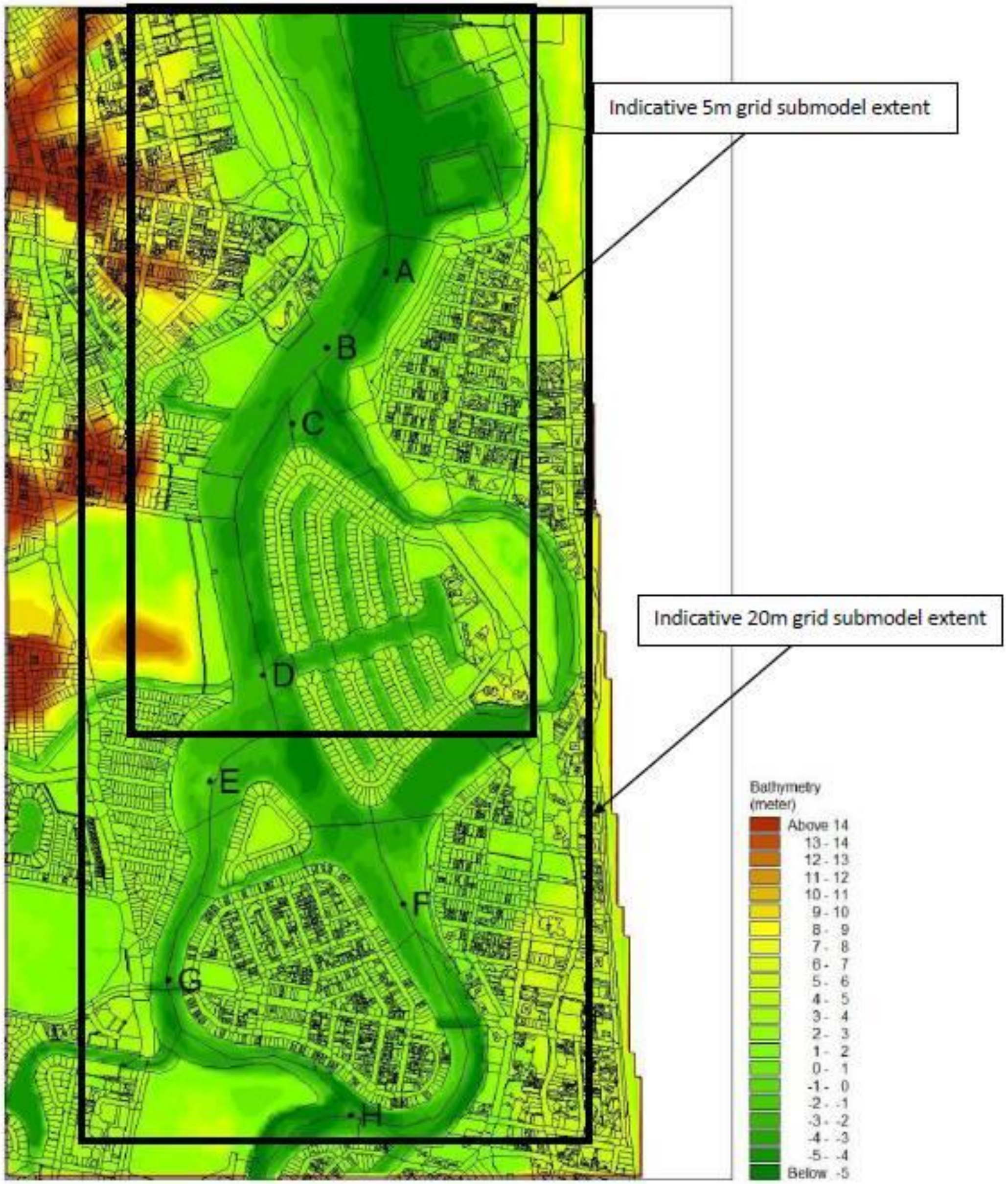
Overview of Models



Model Set-up – Very Fine Grid

- 2D Finite Difference (FD) grid
- Explicit representation of piers in 2D FD grid
- Requires extremely fine grid sizes (0.1m) (long run times for even small grid areas)
- Doubtful that the results were worth the effort

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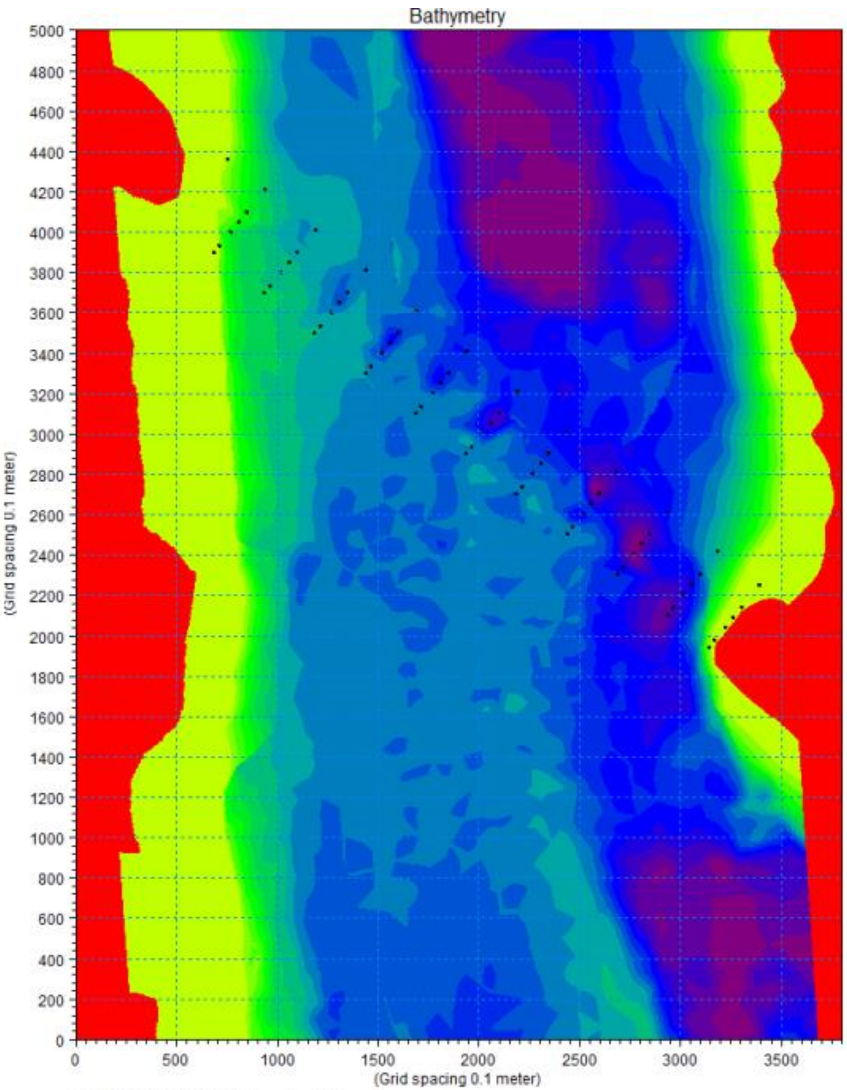
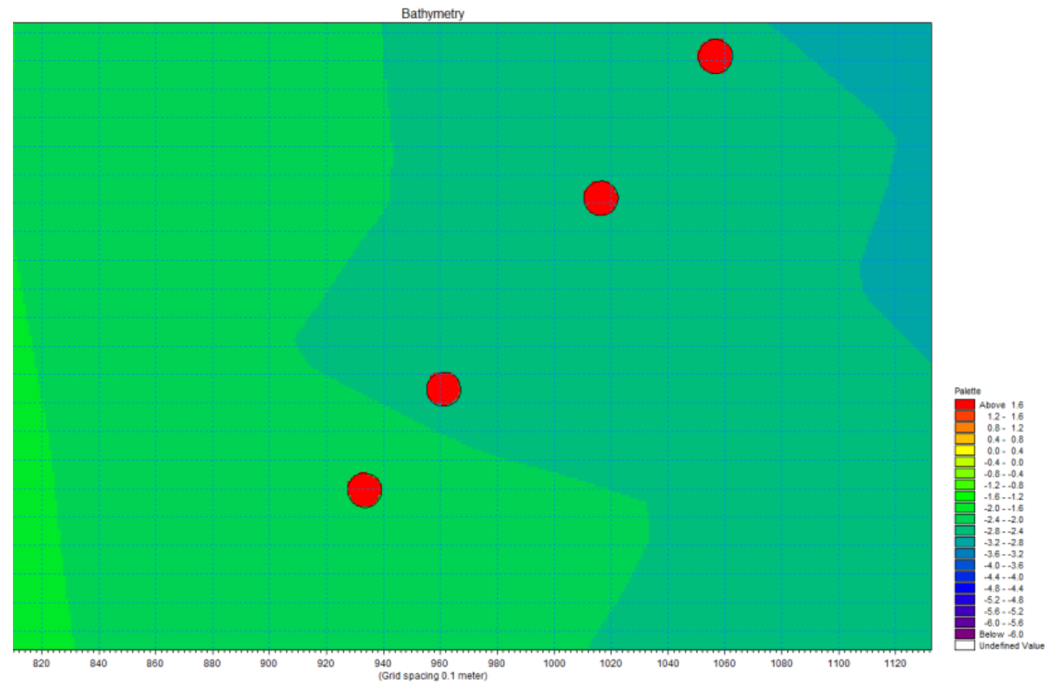
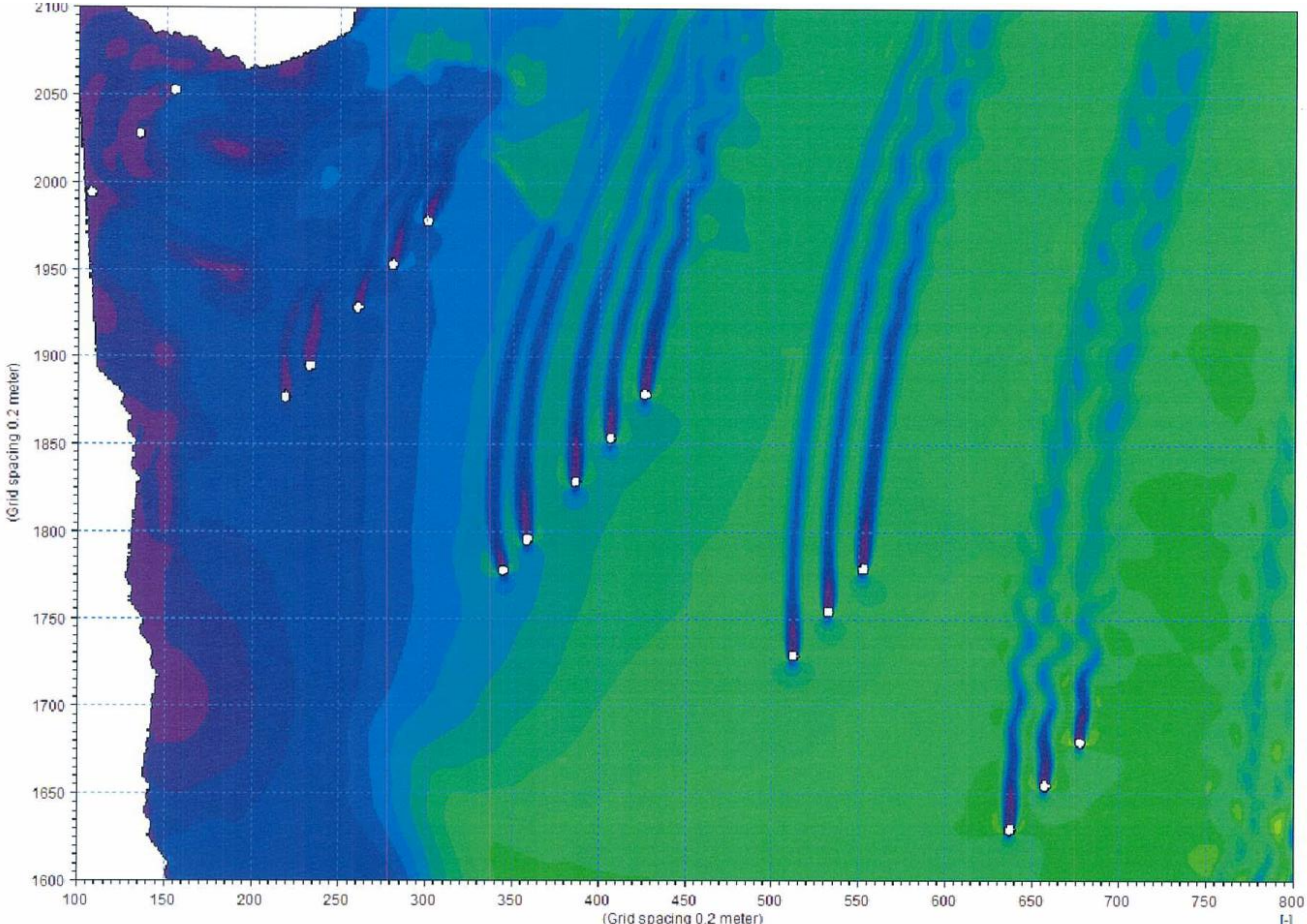
Model Set-up – Very Fine (0.1m) Grid





Very Fine (0.2m) Grid – Early Results



Model Set-up – Flexible Mesh

- 2D Finite Volume Flexible Mesh (FM) model
- Explicit representation of piers in 2D FM mesh
- Fine mesh only required around individual piers
- Significant improvement in run times with similar resolution individual piers

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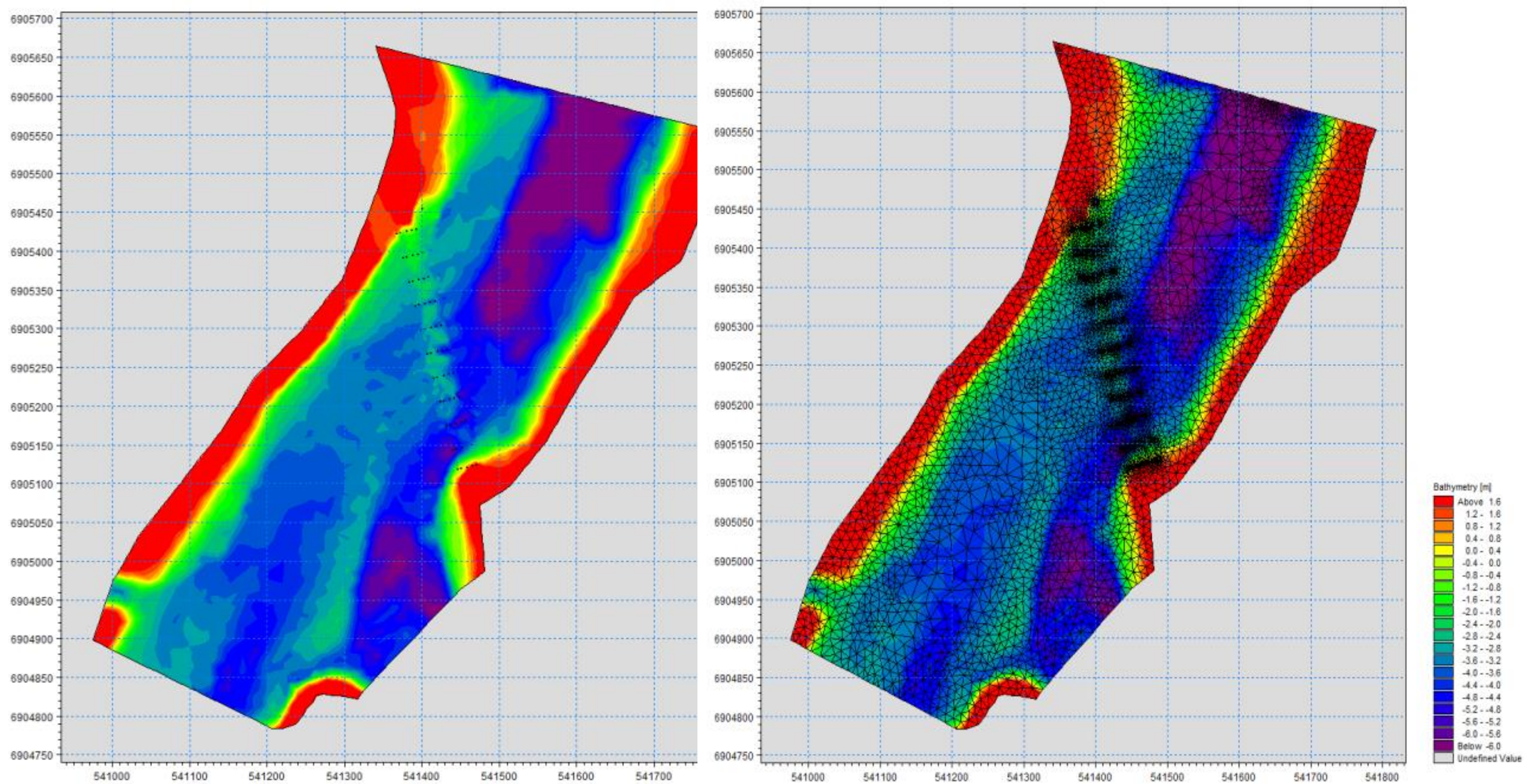
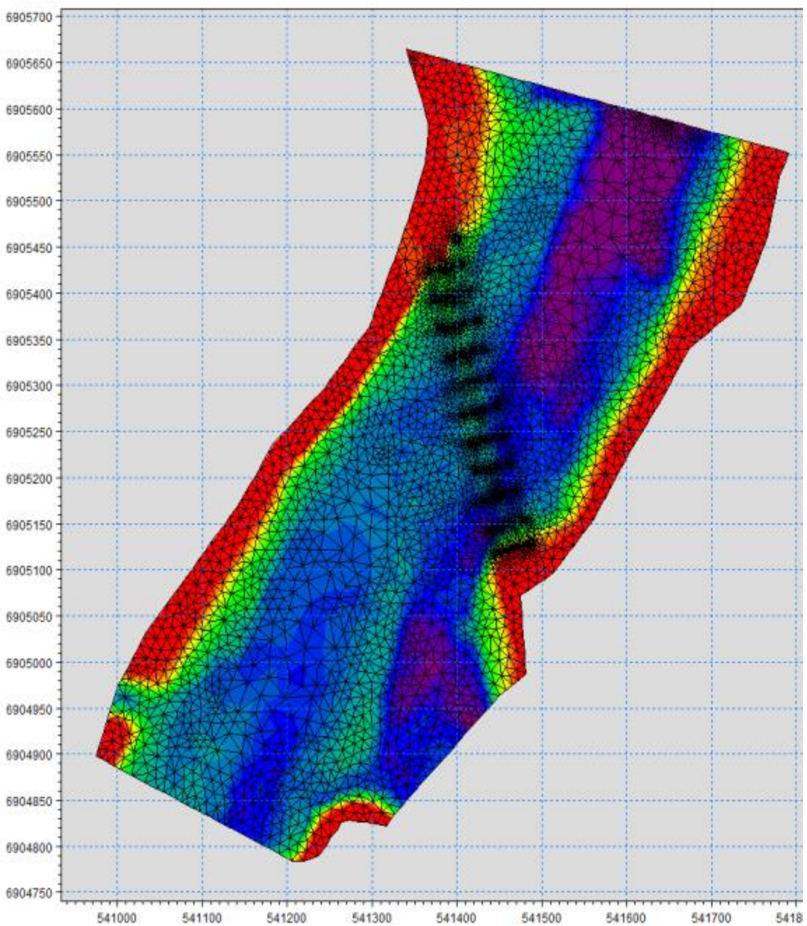
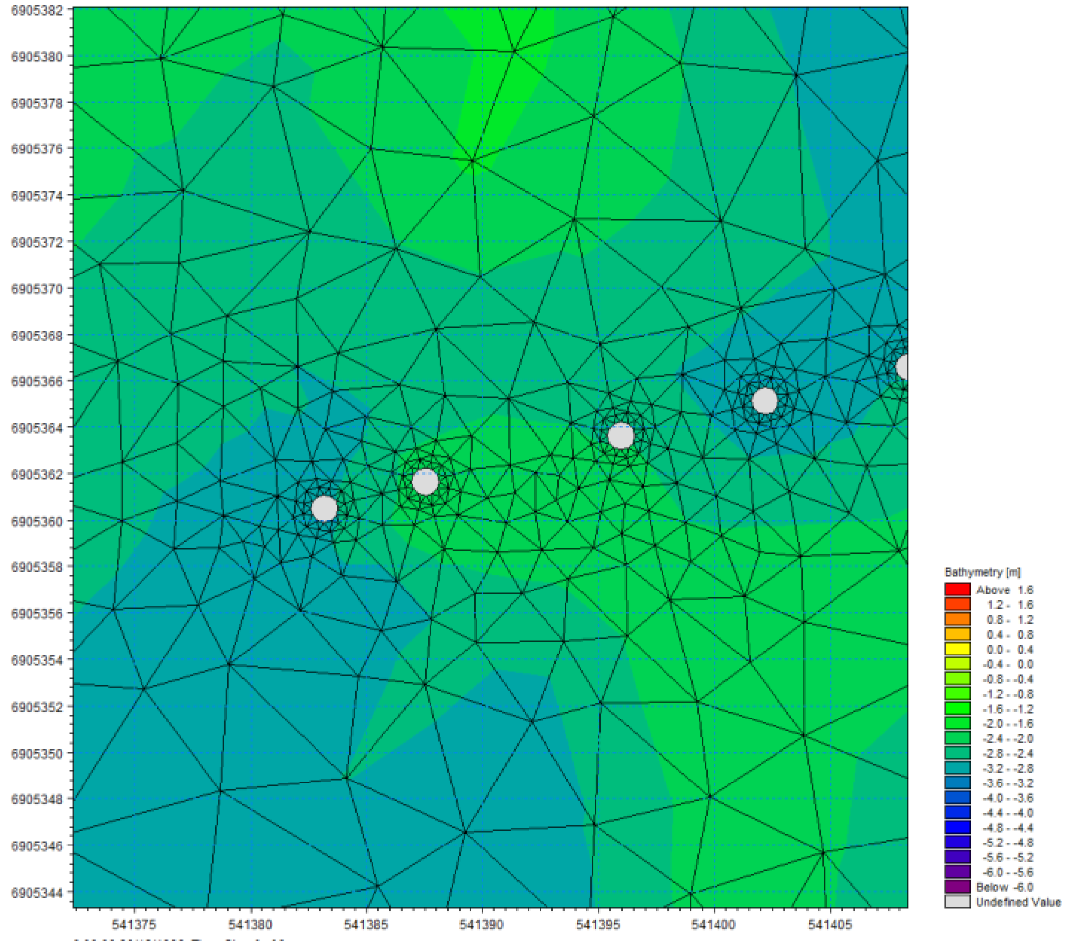
Model Set-up – Flexible Mesh



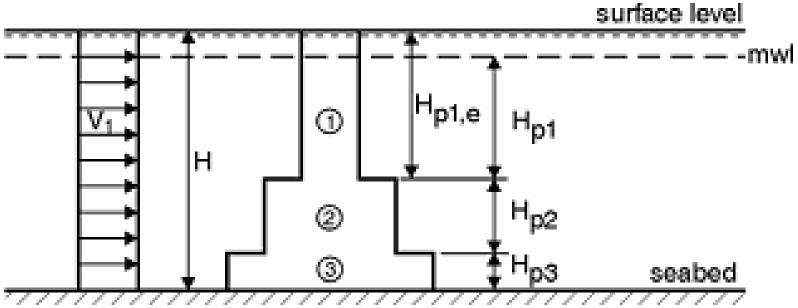
Model Set-up – Flexible Mesh





Model Set-up – MIKE 21 Pier Module

- Sub-grid scale representation of piers
- Calculates current induced drag on individual piers
- Representation of piers is independent of grid size
- Can be applied to either FD grids or FM meshes



Example : Effective height for pier section:

$$H_{p1} = \max\{(H - H_{p2} + H_{p3}), 0\}$$

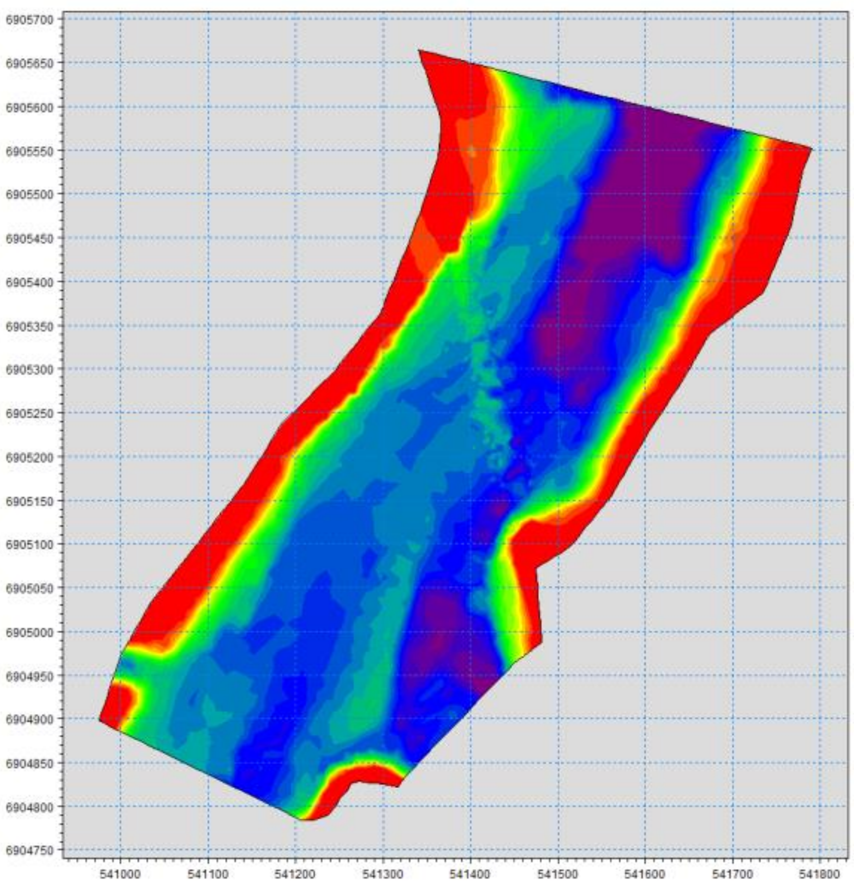
$$H_{p2} = \max\{(H - H_{p3} - H_{p1e}), 0\}$$

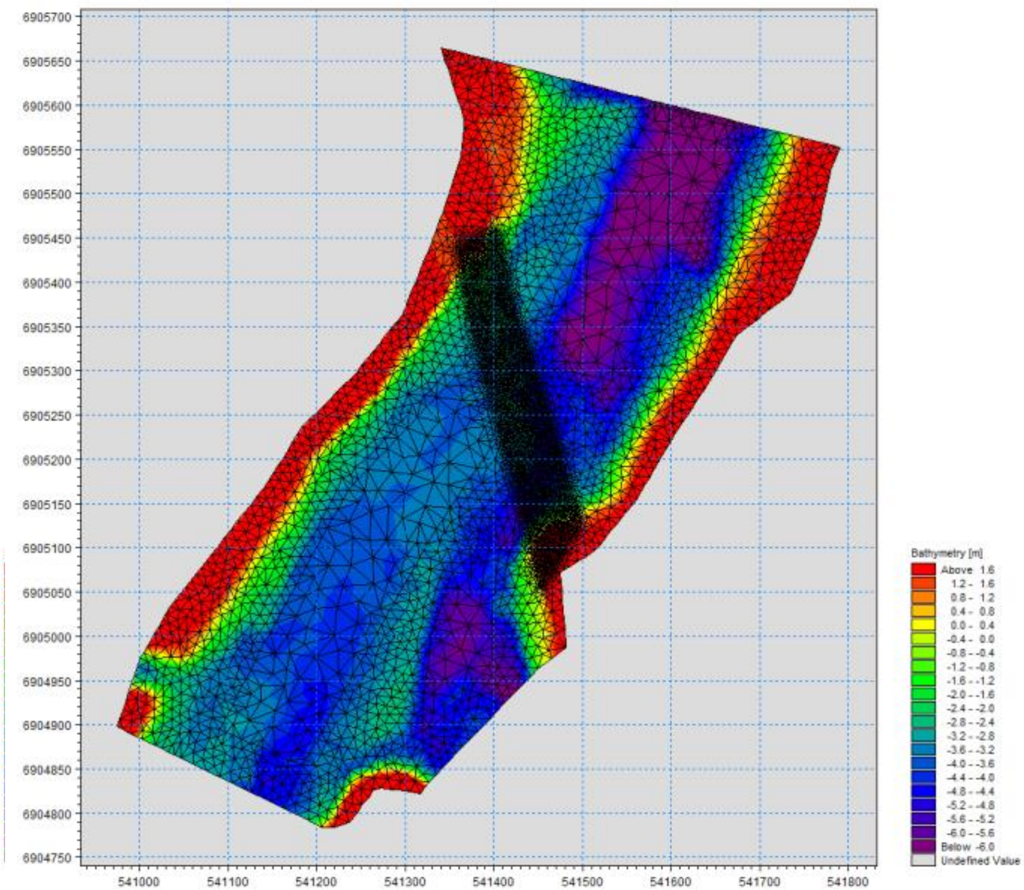
$$H_{p3} = \min\ (H_{p3}, H)$$

Figure 2.9•Definition of pier sections

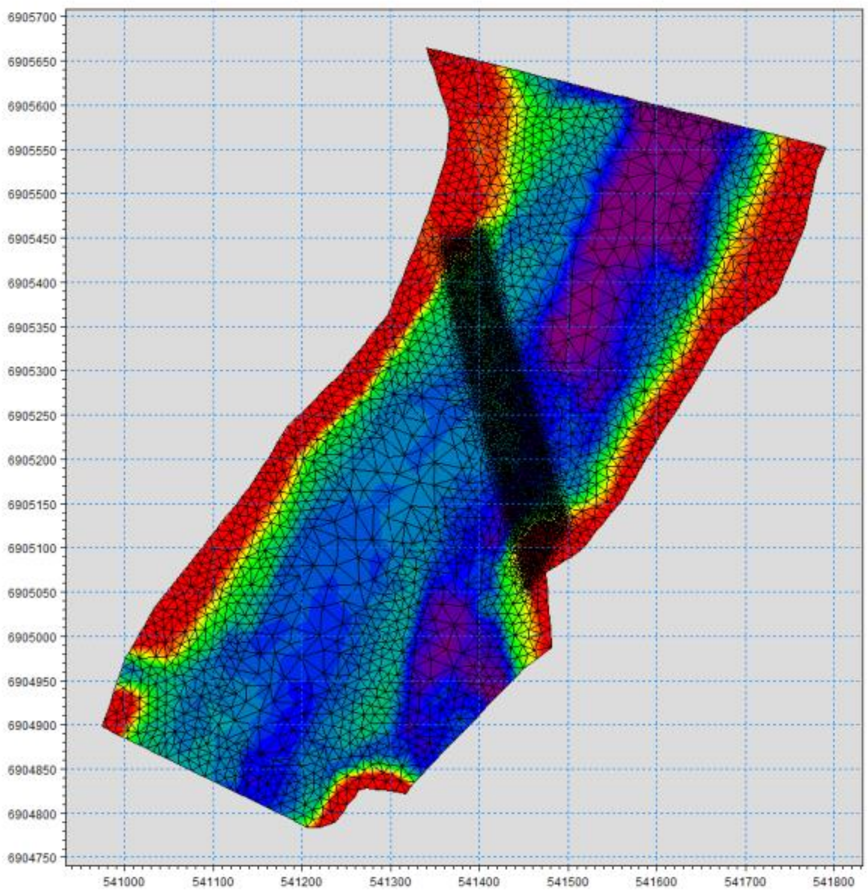
MIKE by DHI

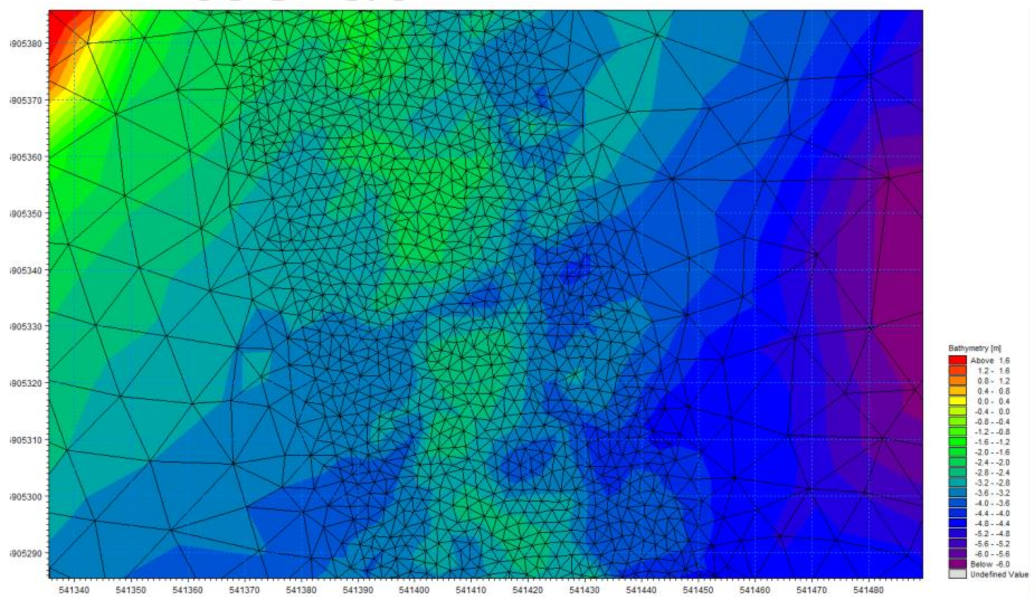
Model Set-up – Pier Module in FM



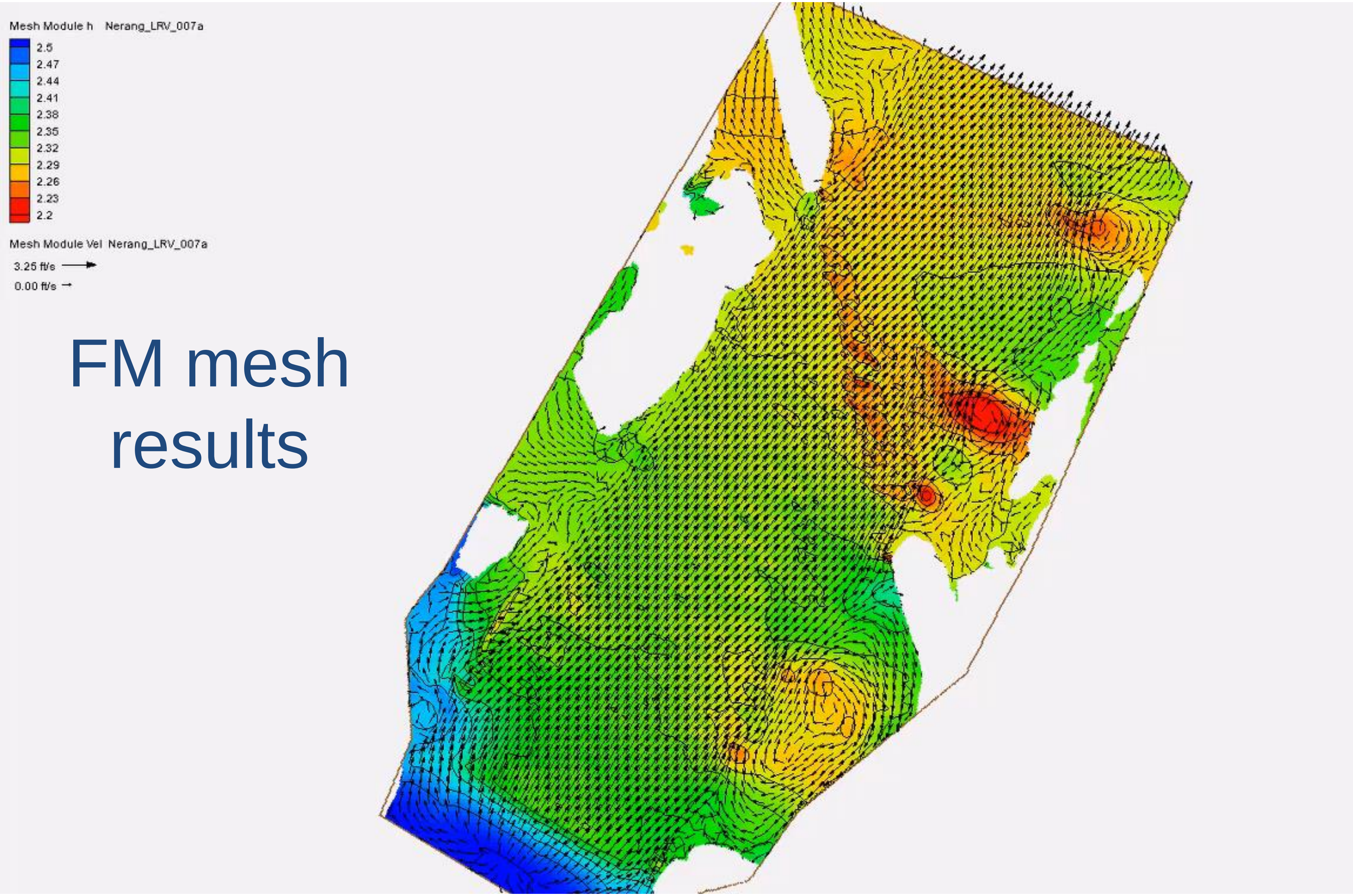


Model Set-up – Pier Module in FM

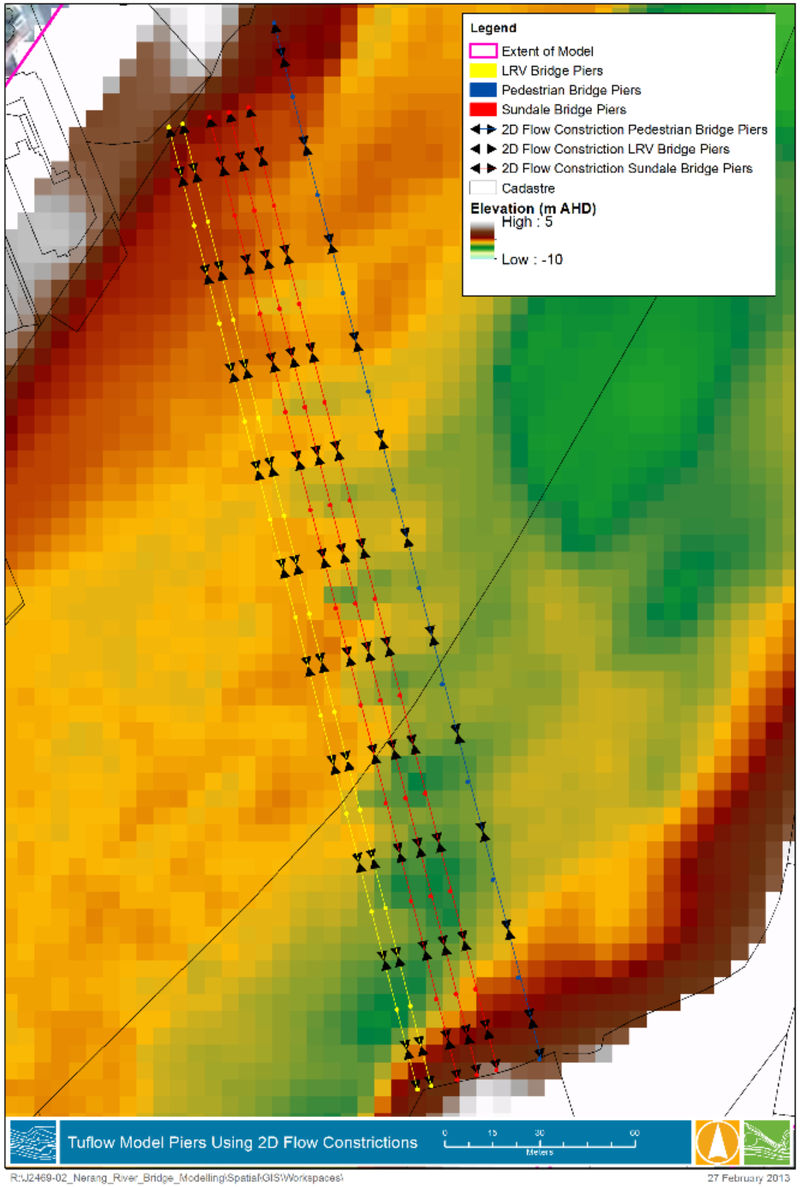




FM mesh results



Tuflow Set-up – Layered Flow Constriction



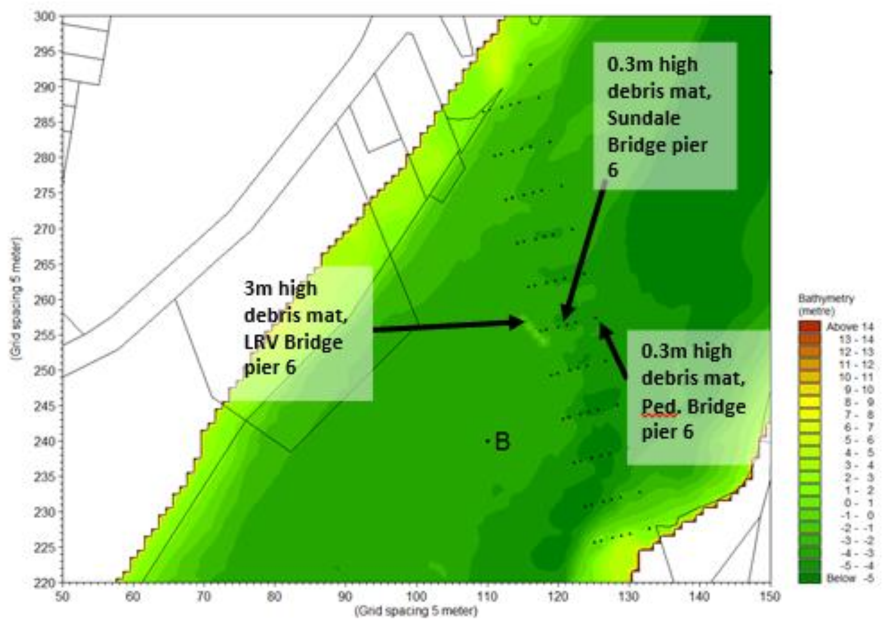
Debris Modelling

- Significant debate around debris allowance
- Adopted an approach consistent with AS 5100 – Bridge Design, i.e.,
  - *In the absence of more accurate estimates, the minimum depth of debris mat for design shall be 1.2m and the maximum depth shall be 3m* (Section 15.5.1), and
  - *The length of the debris mat shall be taken as one half the sum of the adjacent spans or 20m, whichever is the smaller* (Section 15.5.2).
- M21 – modelled by increasing bed level
- TuFlow – modelled using layered flow constriction

Debris Modelling (cont'd)

Three debris cases adopted for testing

- 20m wide by 3m deep blockage on Sundale Bridge, pier 6 (existing conditions)
- 20m wide by 3m deep blockage on LRV Bridge, pier 6 (single debris mat)
- 20m wide by 3m deep (100%) blockage on LRV Bridge, pier 6, 20m wide by 0.3m deep (10%) blockage on Sundale Bridge, pier 6, and 20m wide by 0.3m deep (10%) blockage on Pedestrian Bridge, pier 6 (multiple debris mats)

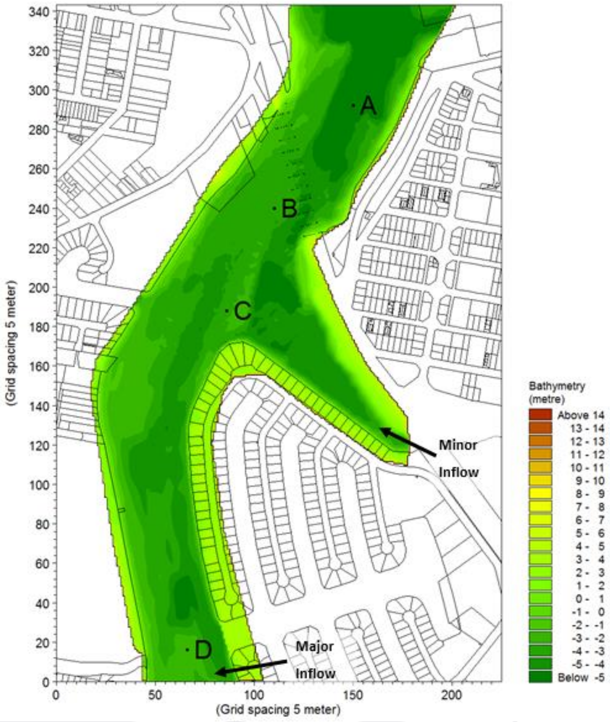


Results

Multiple configurations, scenarios and design events

"Like for like" comparison:

- Q100, MHWS with no allowance for climate change
- No debris blockage



Location	Predicted Afflux (m)		
	M21 Coarse (20m) FD with Piers	M21 Fine (5m) FD with Piers	Tuflow (5m) with Layered flow constrictions
B	0.018	0.011	0.016
D	0.011	0.008	0.013

Conclusions

- Attempting to resolve individual piers in FD models is not recommended:
  - Predicted afflux dependant on grid size i.e., as grid size reduces, predicted afflux reduces
- Use of the pier module in MIKE:
  - Produces consistent results (in FD and FM) where significant inundation of superstructure does not occur
  - Is relatively independent of FD grid size
- Resolving individual piers in MIKE FM produces results consistent with the pier module in MIKE FD and MIKE FM
- TuFlow layered flow constrictions:
  - Offer advantages where superstructure is impacted
  - Are highly dependent on flow area assumptions