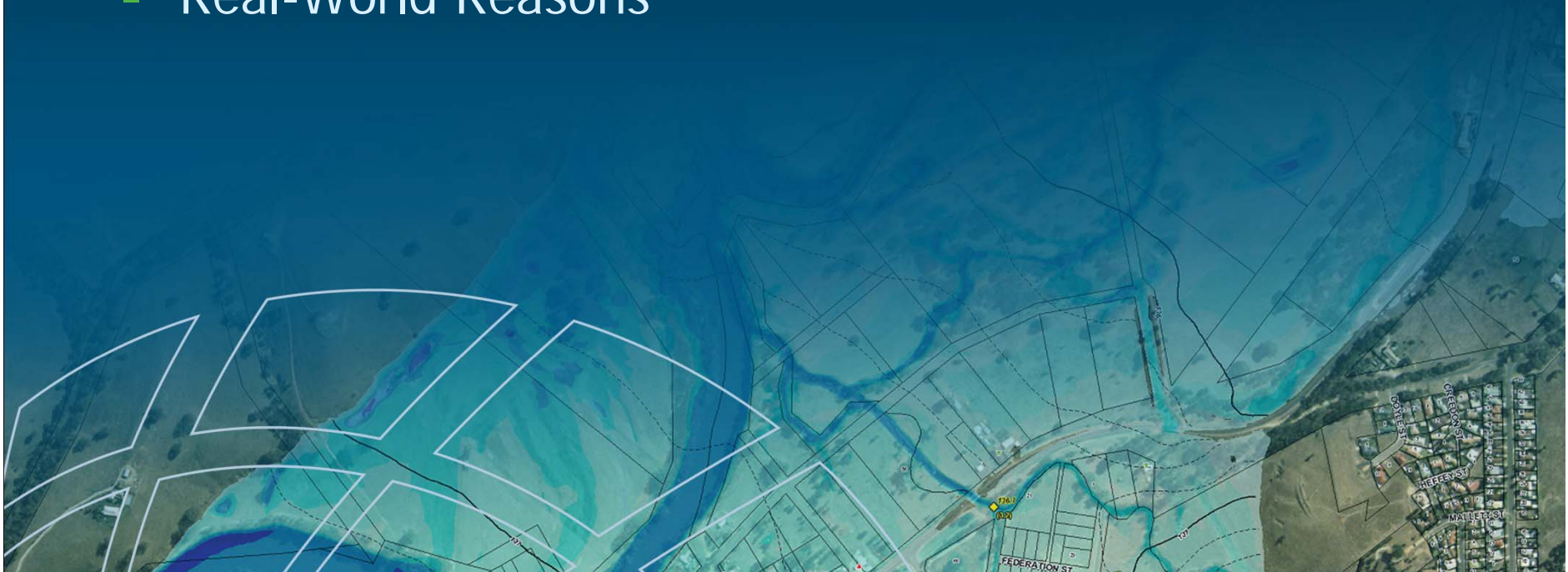


2D or Not 2D?

Bill Syme

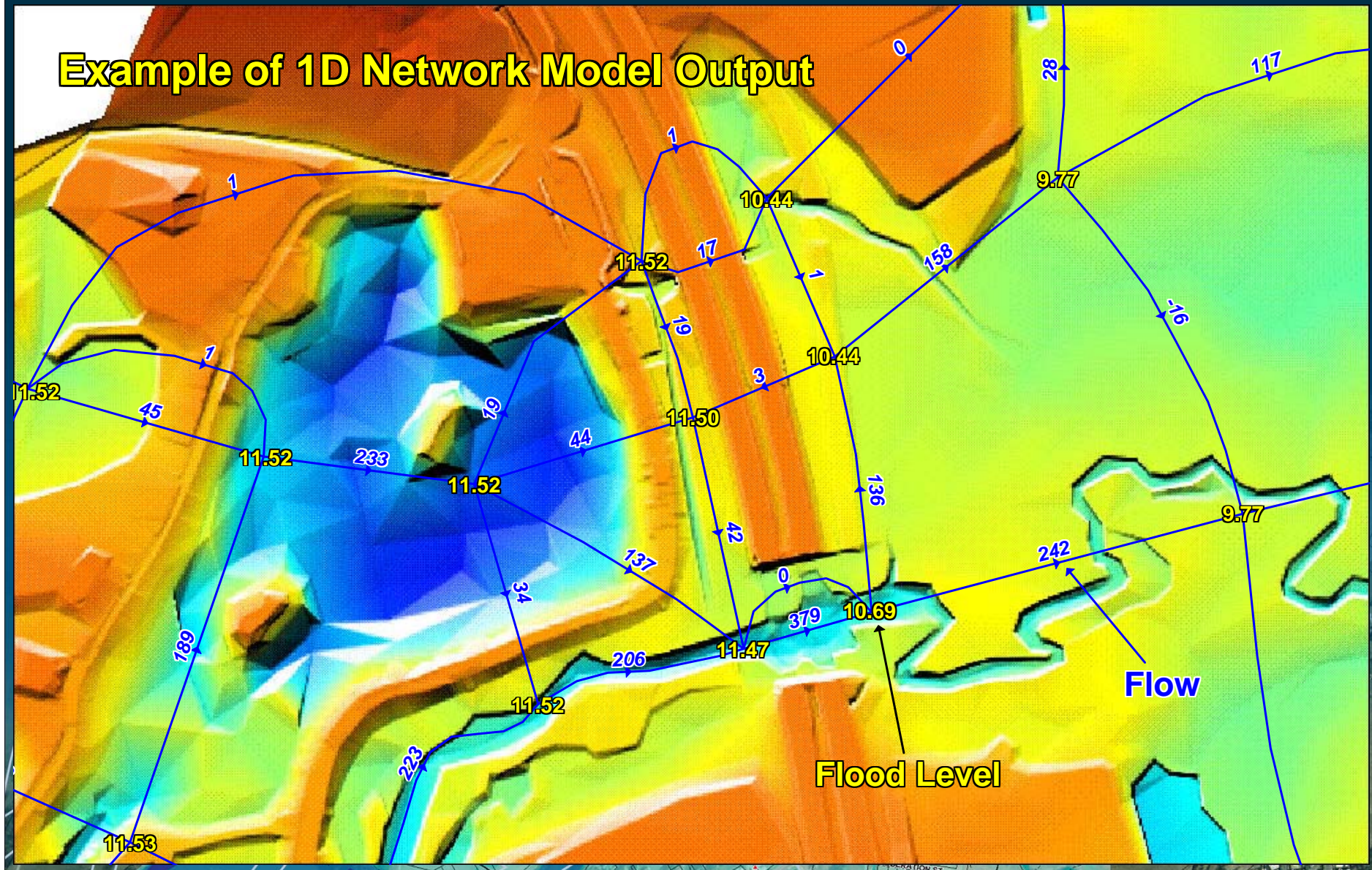
2D or Not 2D?

- Mathematical Reasons
- Real-World Reasons



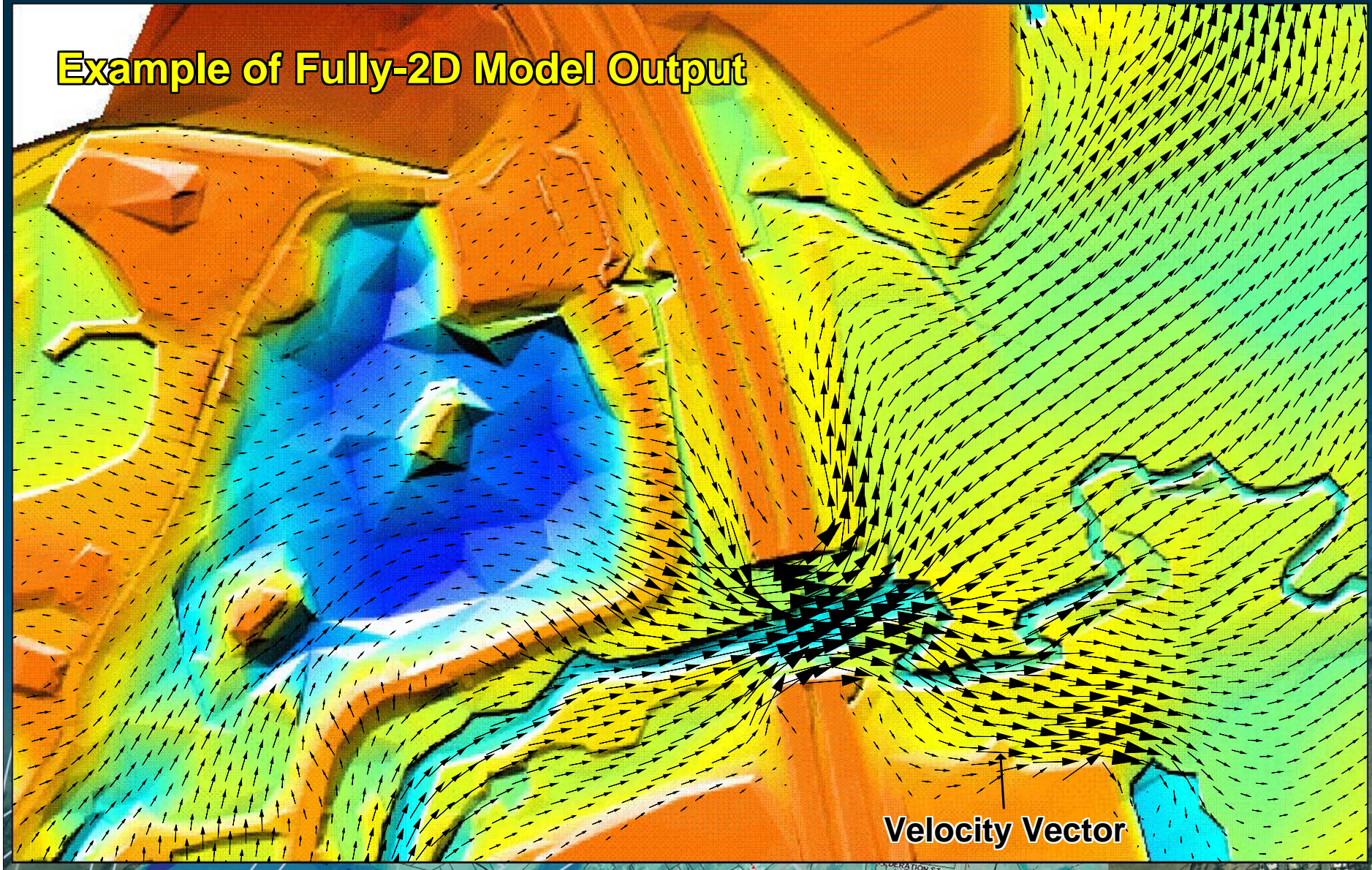
1D versus 2D

Example of 1D Network Model Output



1D versus 2D

Example of Fully-2D Model Output



1D versus 2D

1D ~100 calculation points

2D ~10,000 calculation points
(and longer simulation times)

$$\frac{\partial(uA)}{\partial x} + B \frac{\partial \zeta}{\partial t} = 0$$

$$\frac{\partial u}{\partial t} + u \frac{\partial u}{\partial x} + g \frac{\partial \zeta}{\partial x} + k|u|u = 0$$

- Momentum Equation X-Direction**

$$\frac{\partial u}{\partial t} + u \frac{\partial u}{\partial x} + v \frac{\partial u}{\partial y} - c_f u + g \frac{\partial \zeta}{\partial x} + g u \frac{\sqrt{u^2 + v^2}}{C^2 H} - \mu \left(\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} \right) = F_x$$

- Momentum Equation Y-Direction**

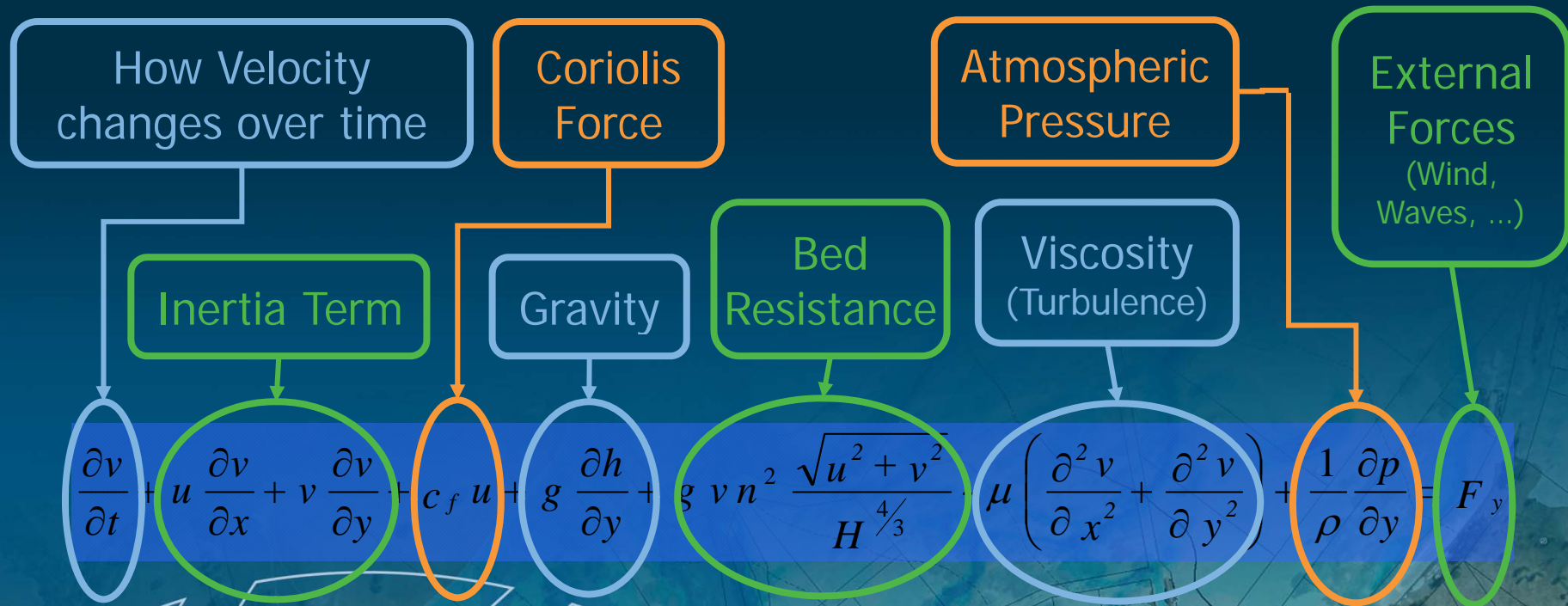
$$\frac{\partial v}{\partial t} + u \frac{\partial v}{\partial x} + v \frac{\partial v}{\partial y} - c_f v + g \frac{\partial \zeta}{\partial y} + g v \frac{\sqrt{u^2 + v^2}}{C^2 H} - \mu \left(\frac{\partial^2 v}{\partial x^2} + \frac{\partial^2 v}{\partial y^2} \right) = F_y$$

- Continuity Equation**

$$\frac{\partial \zeta}{\partial t} + \frac{\partial(Hu)}{\partial x} + \frac{\partial(Hv)}{\partial y} = 0$$

Key Physical Processes

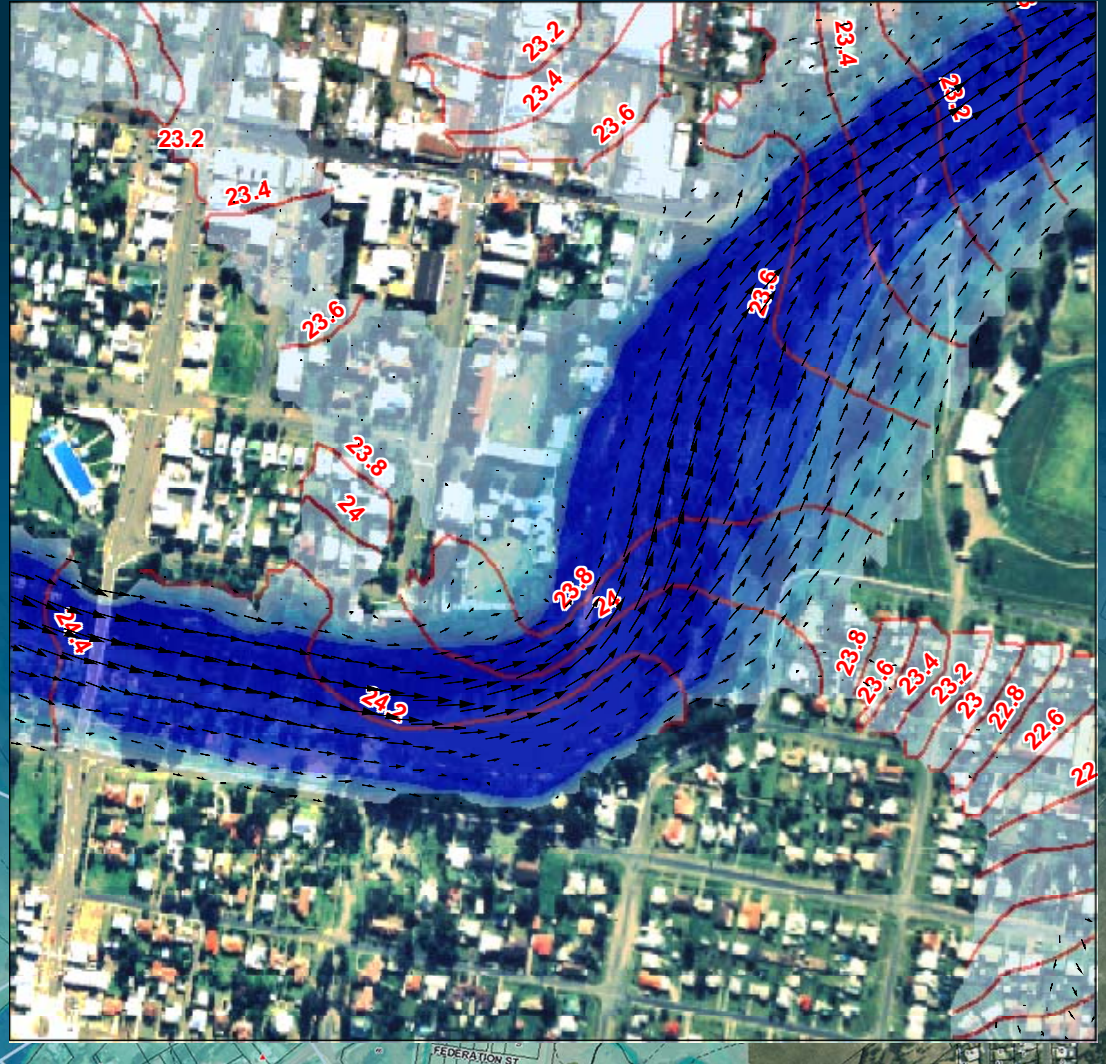
(What does your 2D scheme solve?)



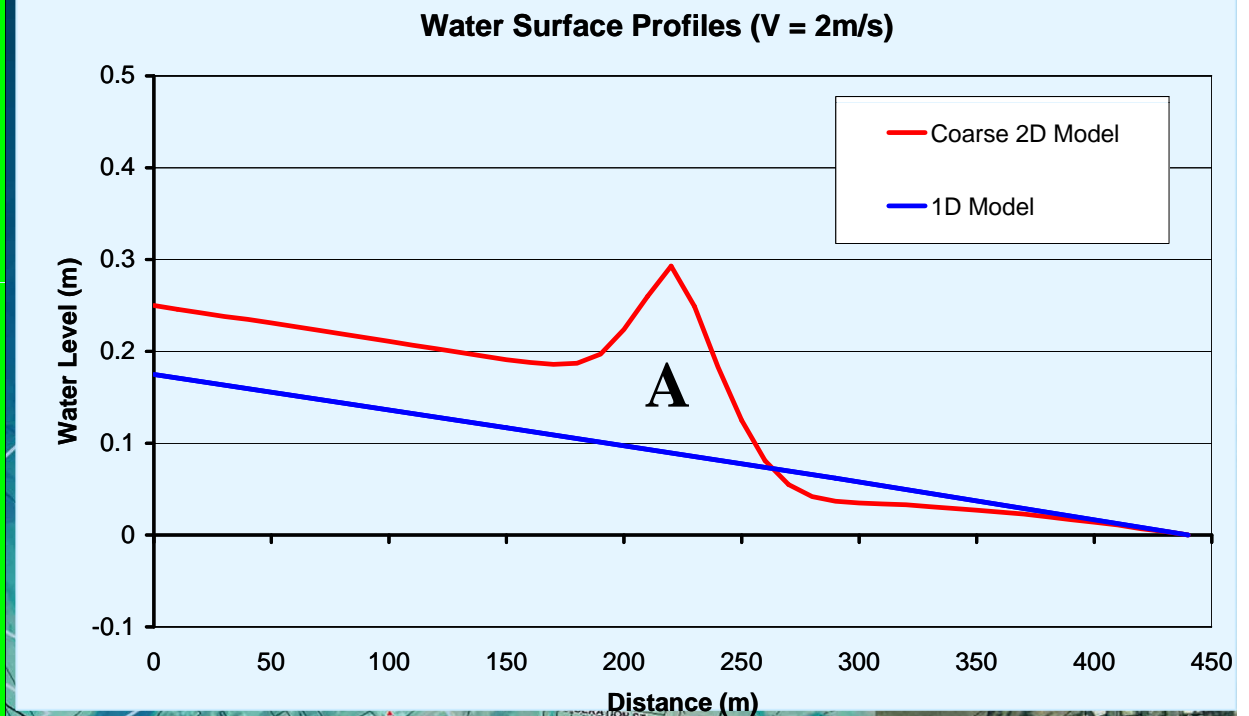
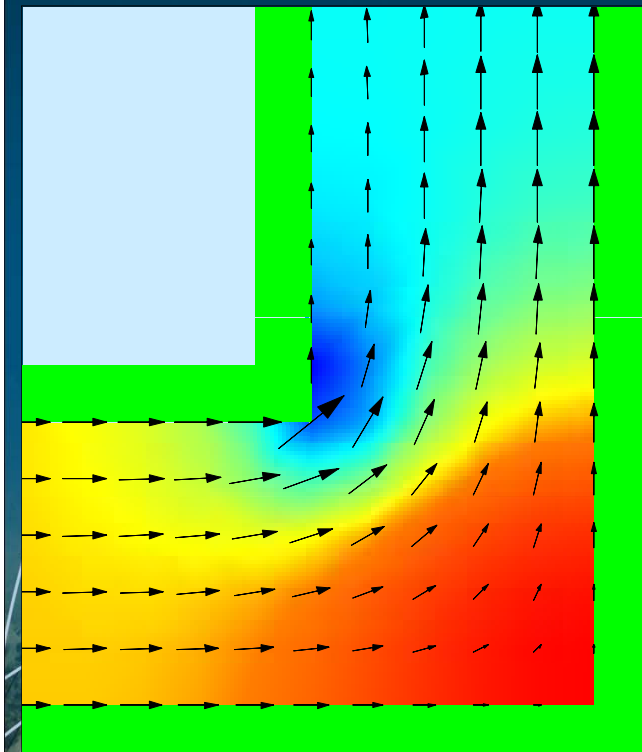
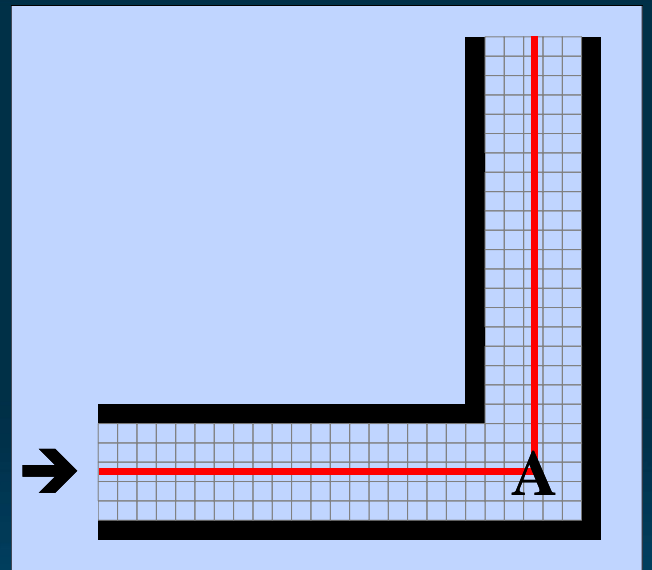
What does your 2D scheme need to solve?

Inertia

- Very important where velocity
 - Speeds up or slows down
 - Changes direction
- Essential at structures and bends

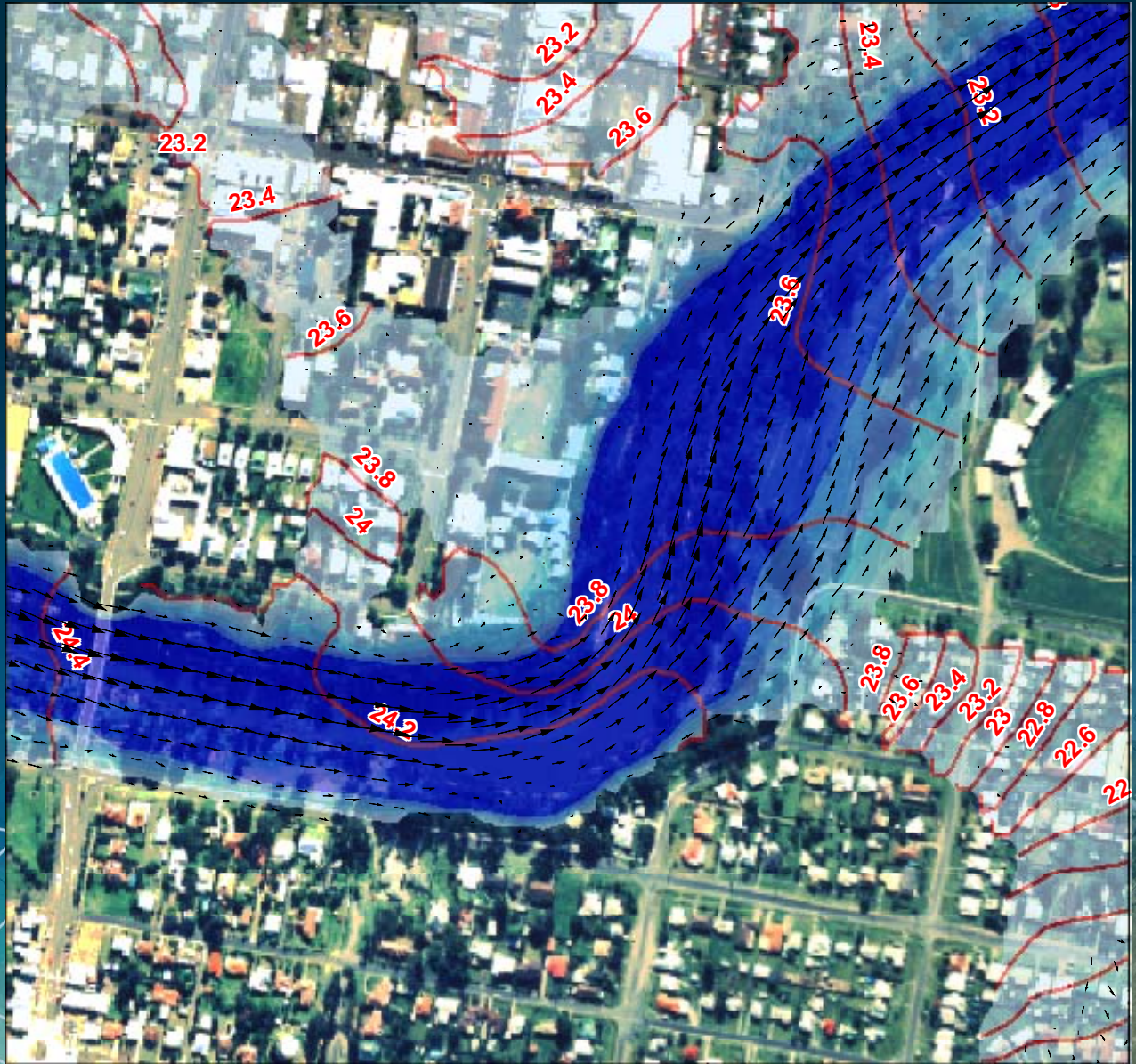


Right-Angled Bend 1D vs 2D



River Bends

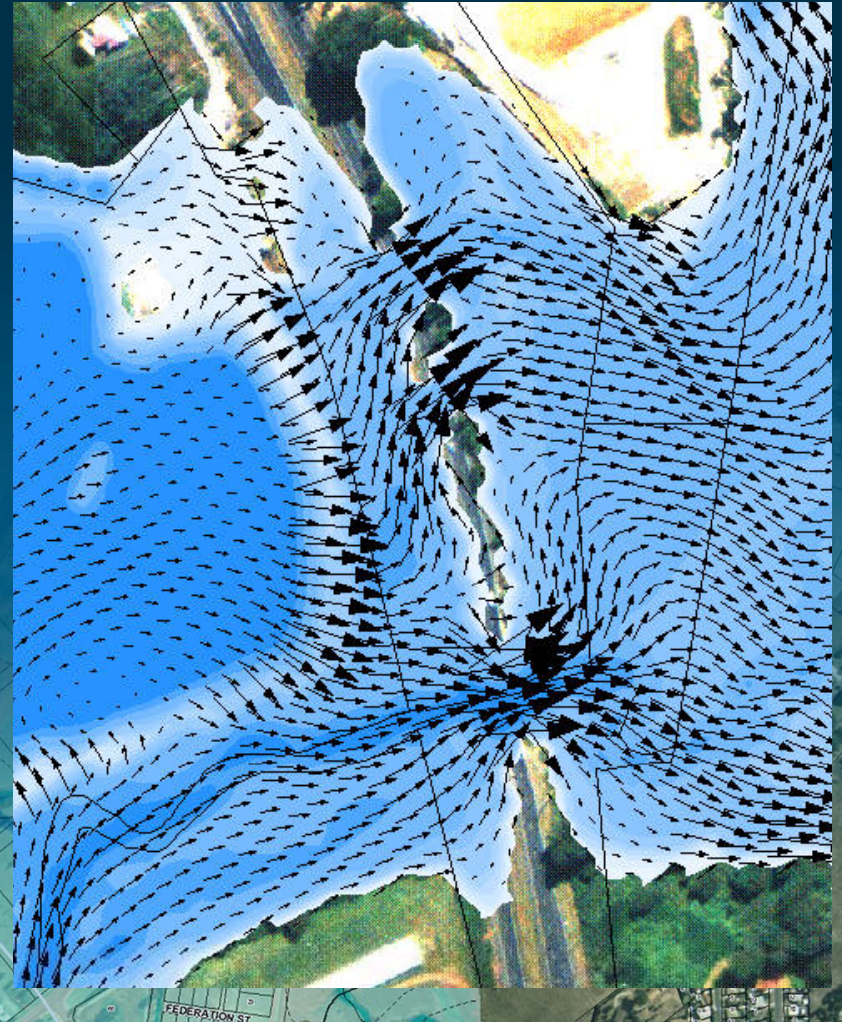
- 4 m/s
- 20 m deep
- 0.4m superelevation
- 1D:
 - Need additional losses
 - No superelevation



Viscosity

Sub-Grid Scale Turbulence

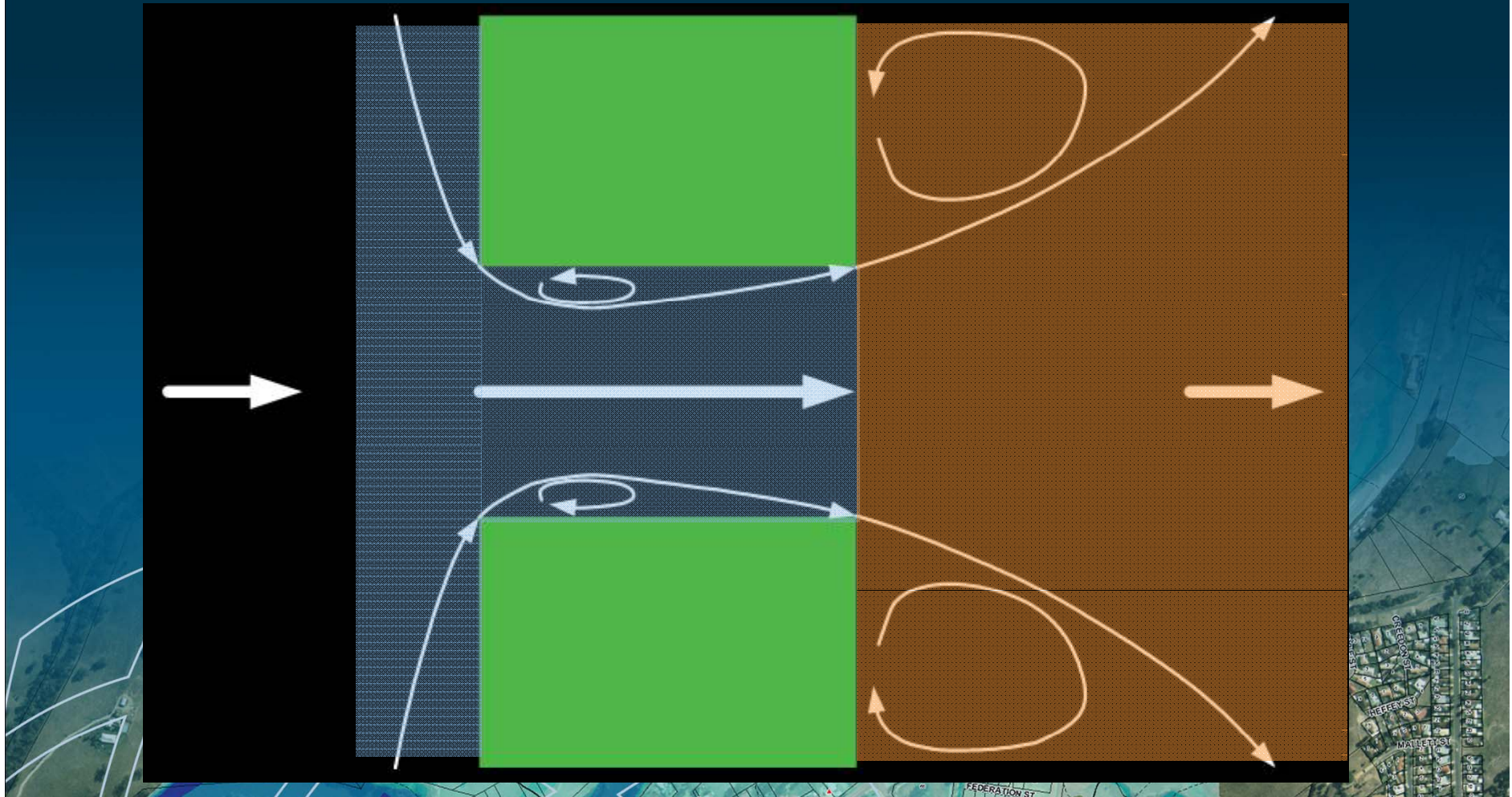
- Important where bed resistance term not dominant and/or rapid changes in velocity gradient
 - Low Manning's n values and/or deep water
 - Flow constrictions
- Smagorinsky formula preferred (varies coefficient based on velocity gradient)
- Many 2D schemes omit this term (Computationally intensive and difficult to solve)
- Don't artificially increase viscosity to stabilise models – distorts results



1D Structures

Contraction/Expansion Losses

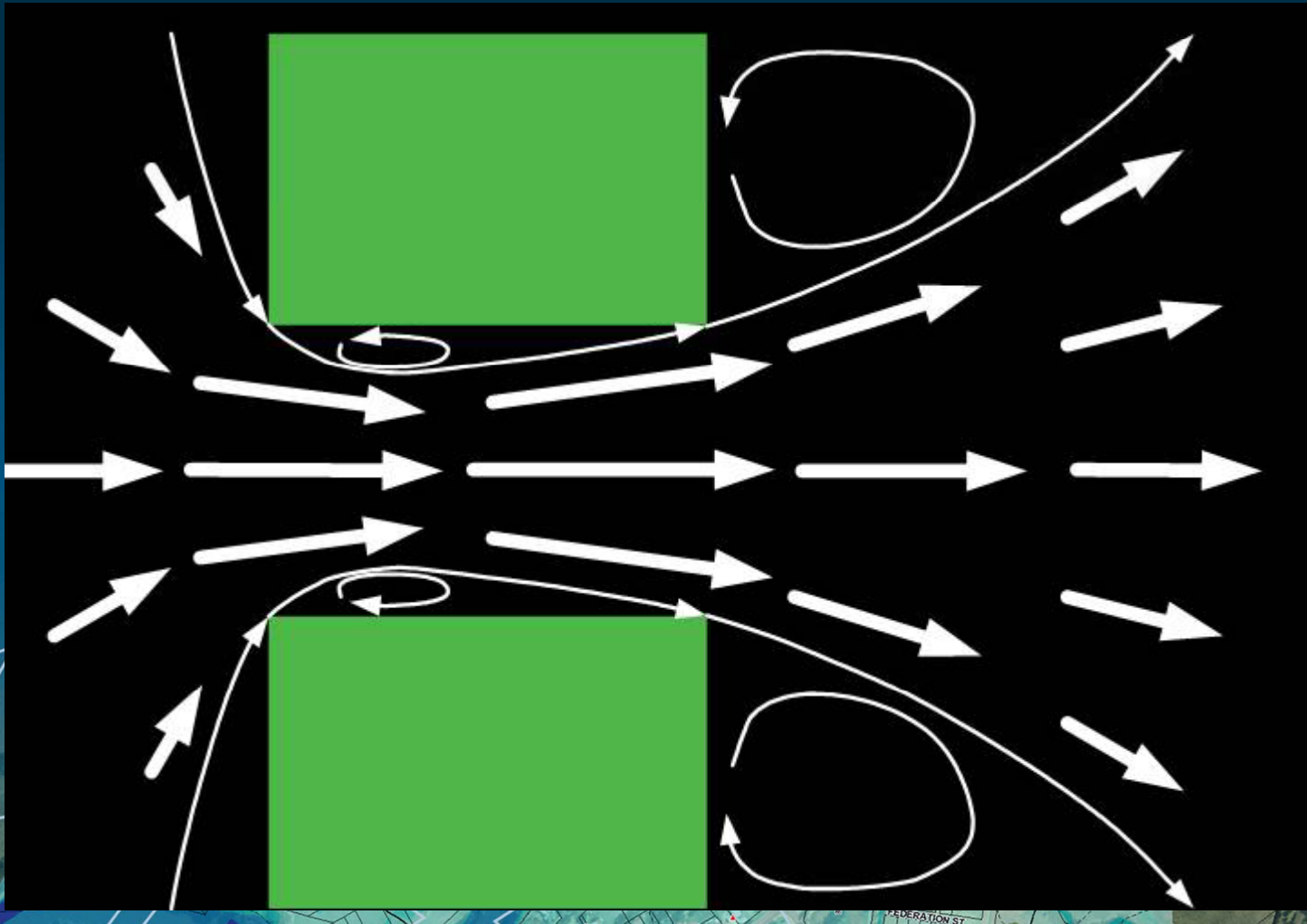
Simplified representation of complex flows



2D Structures

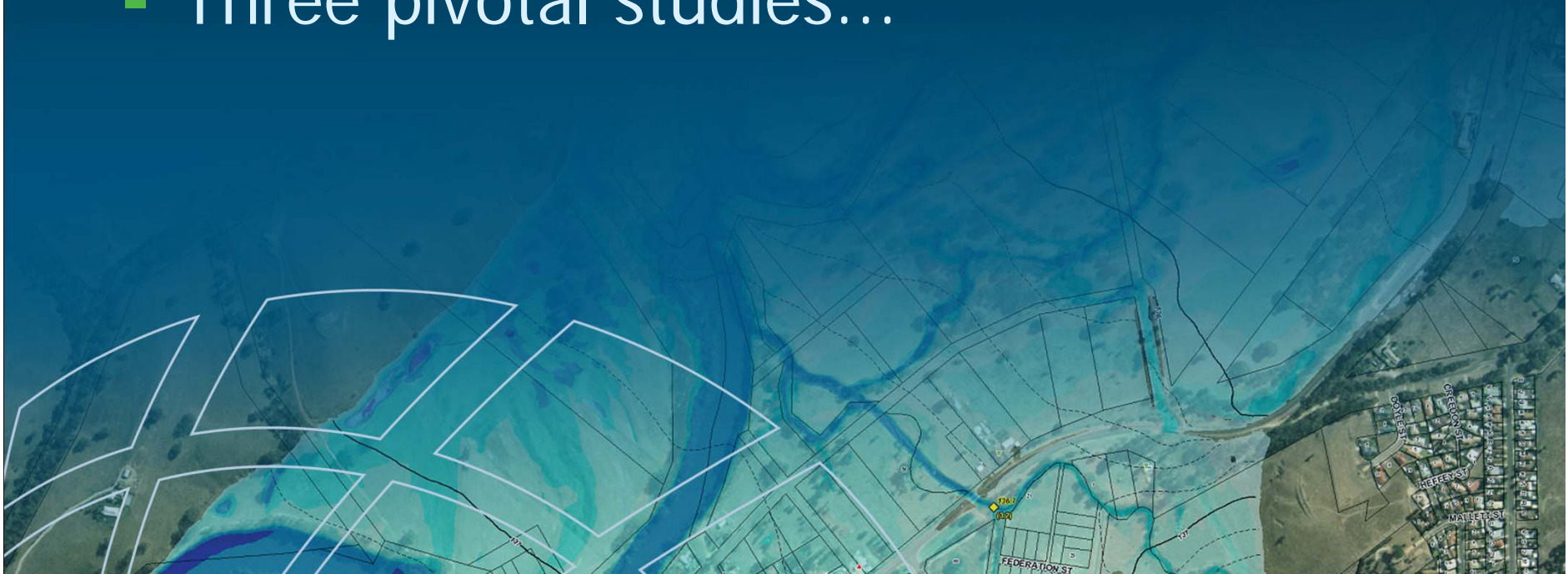
No Contraction/Expansion Losses

But need inertia/viscosity, ability to add fine-scale losses for bridge piers, etc



Real-World

- In Australia and UK
2D or 1D/2D modelling now standard
- Three pivotal studies...



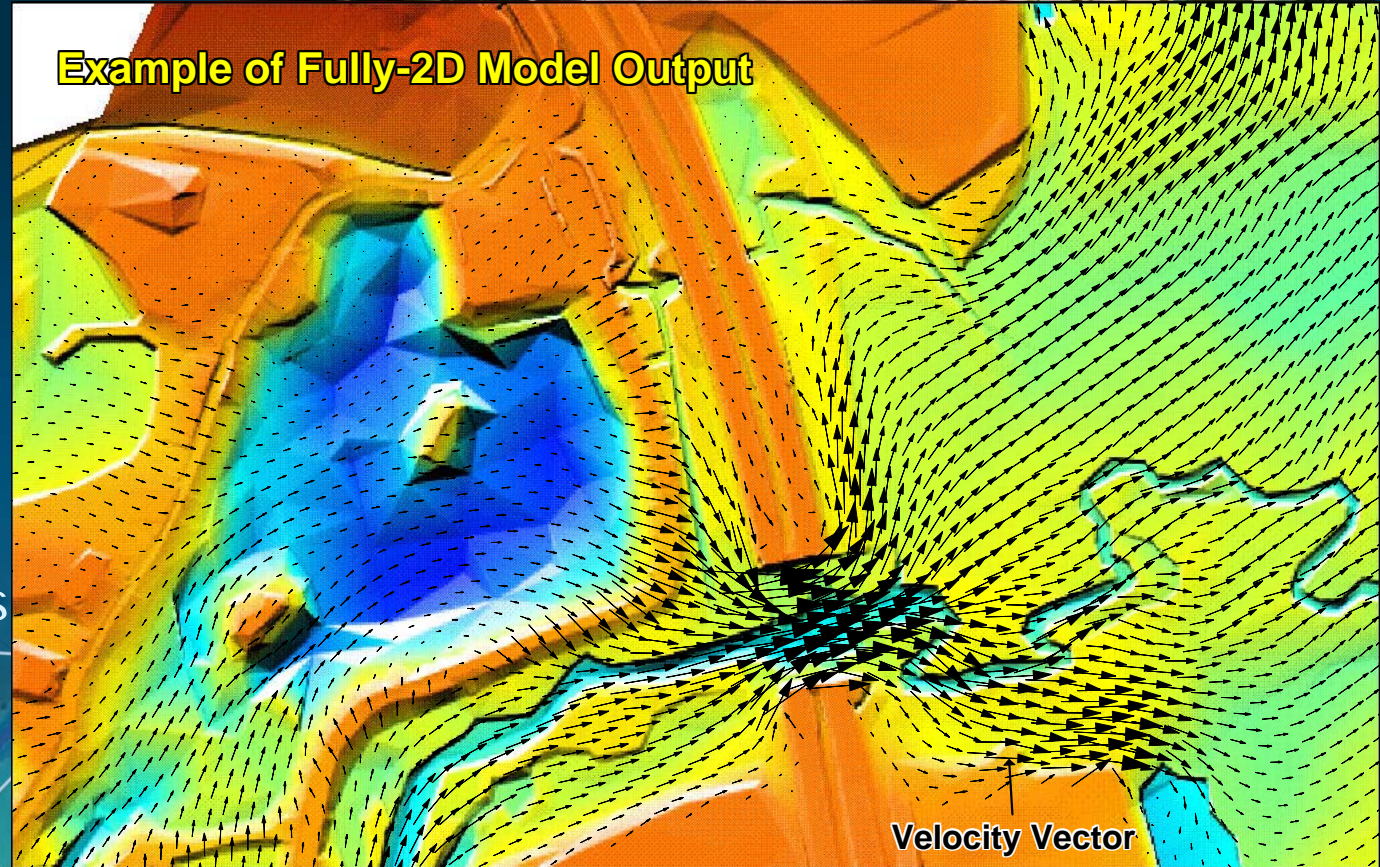
Eudlo Creek Hydraulic Investigations, Qld, 1998-2003

Which Model?

- Exhaustive Investigations
- \$4m damages claim
- Physical Model
- Four 1D Models
- Three 2D Models



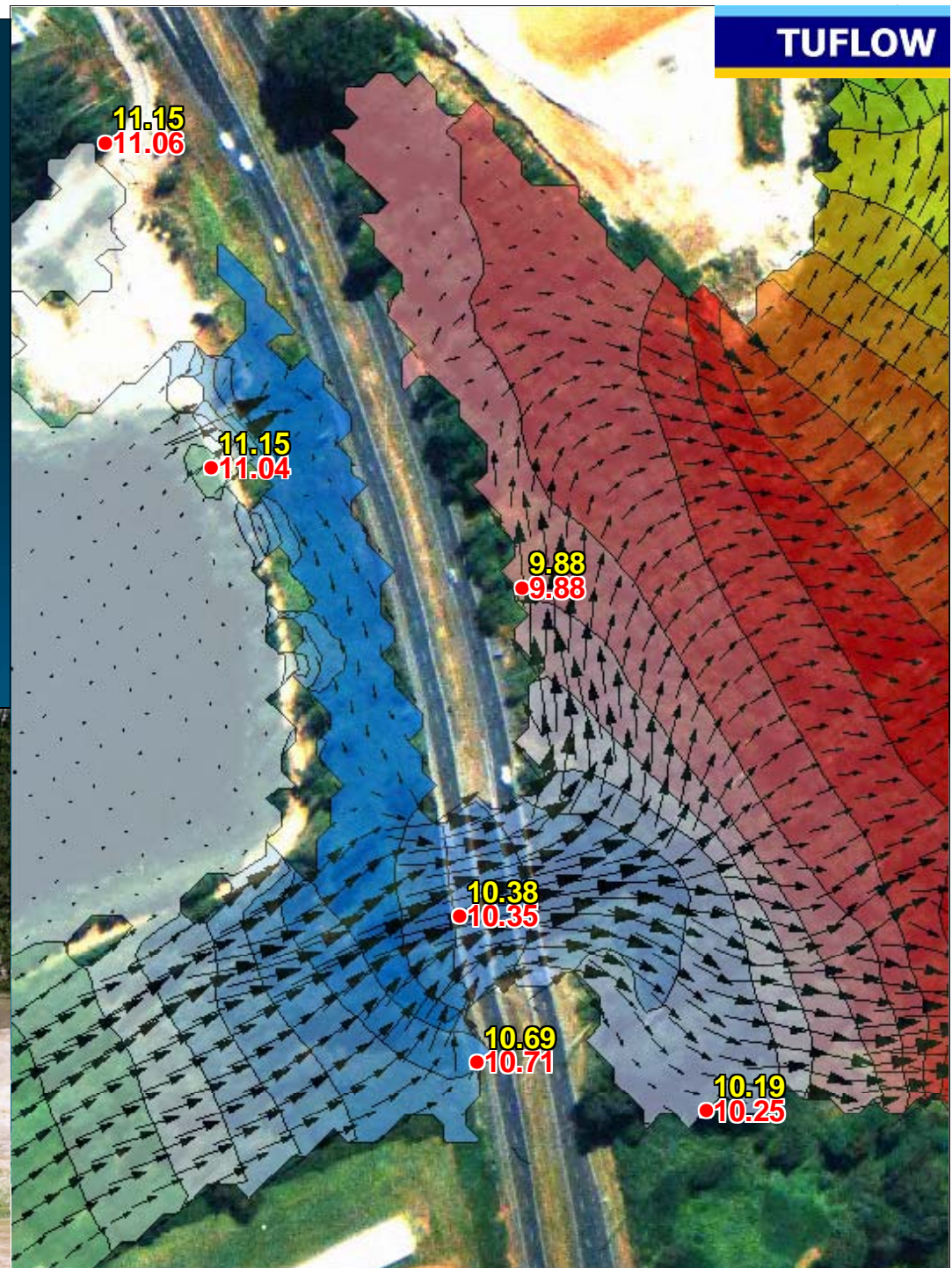
Example of Fully-2D Model Output



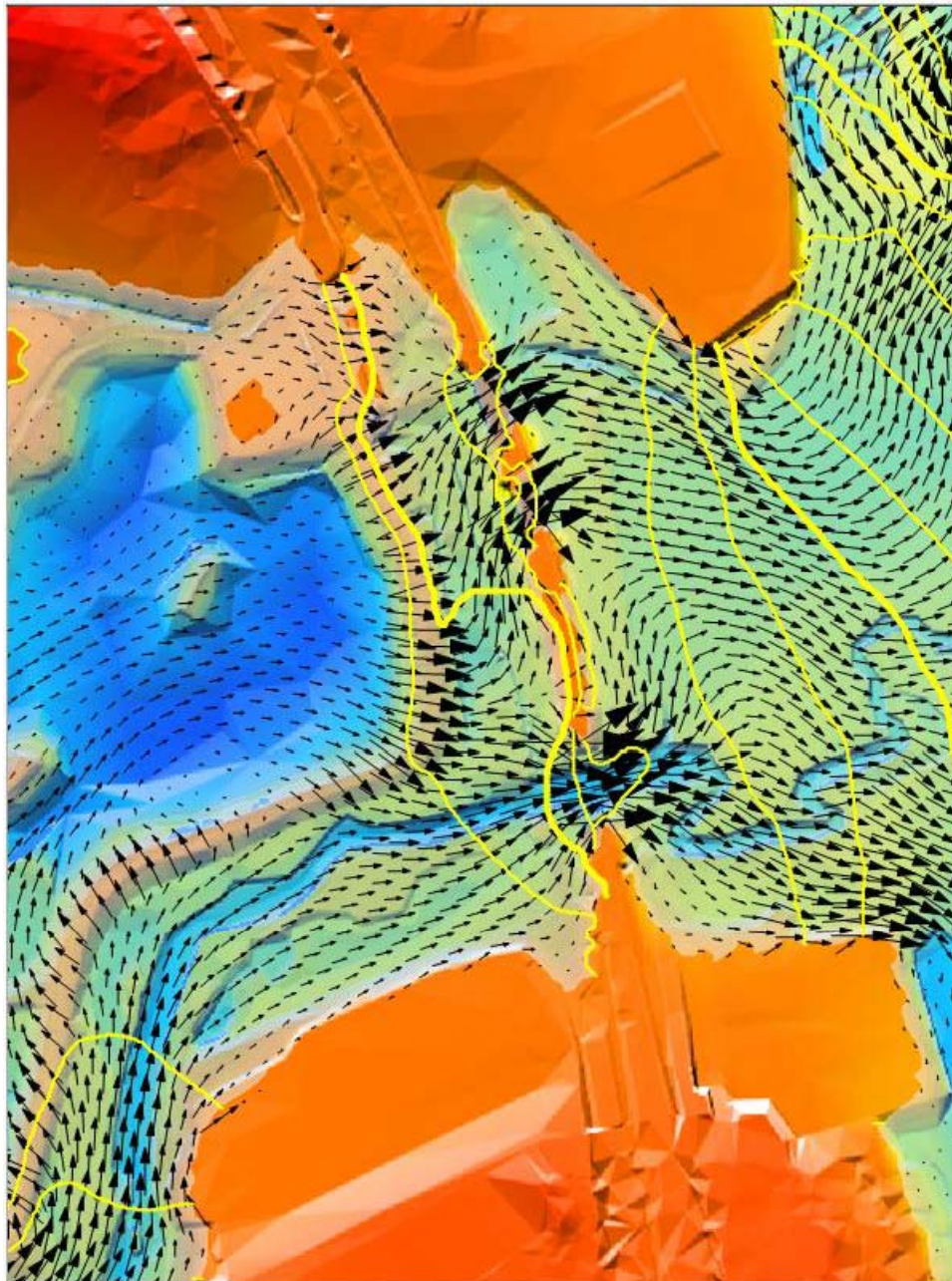
Eudlo Creek, Qld, 1998-2003

Calibration

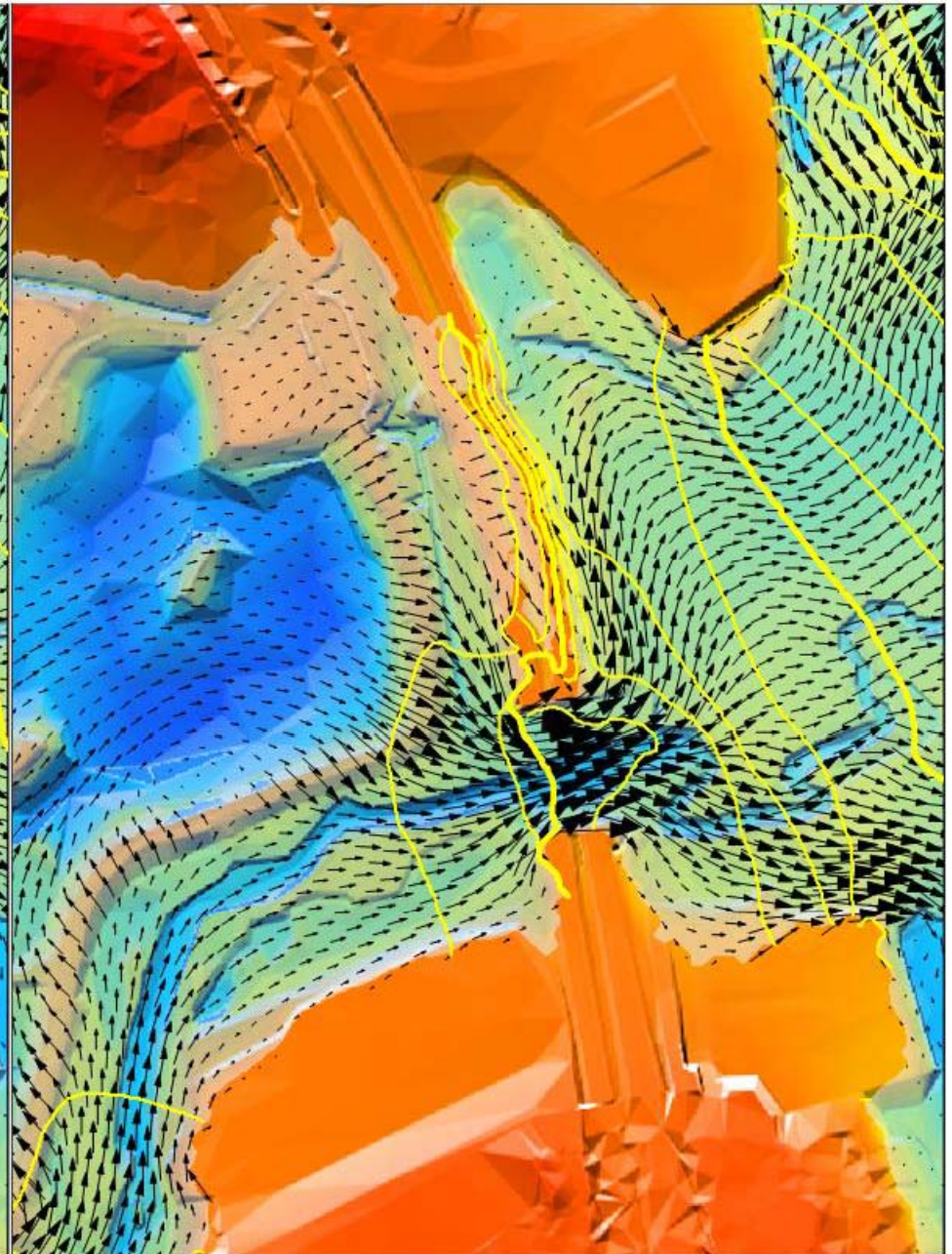
- Three floods
 - 1983, 1992, 1999
 - One during study
- Good data sets



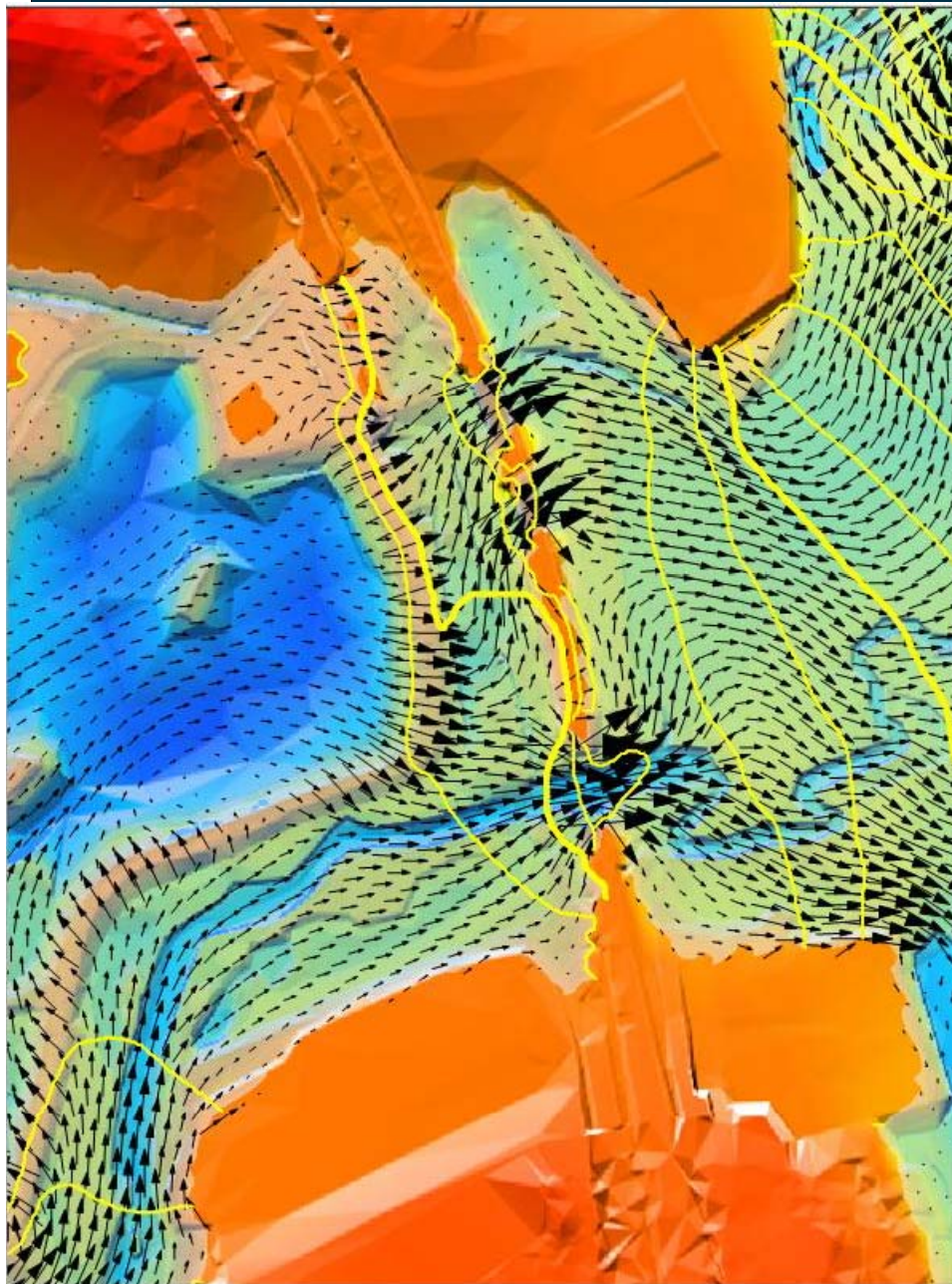
Pre-Duplication



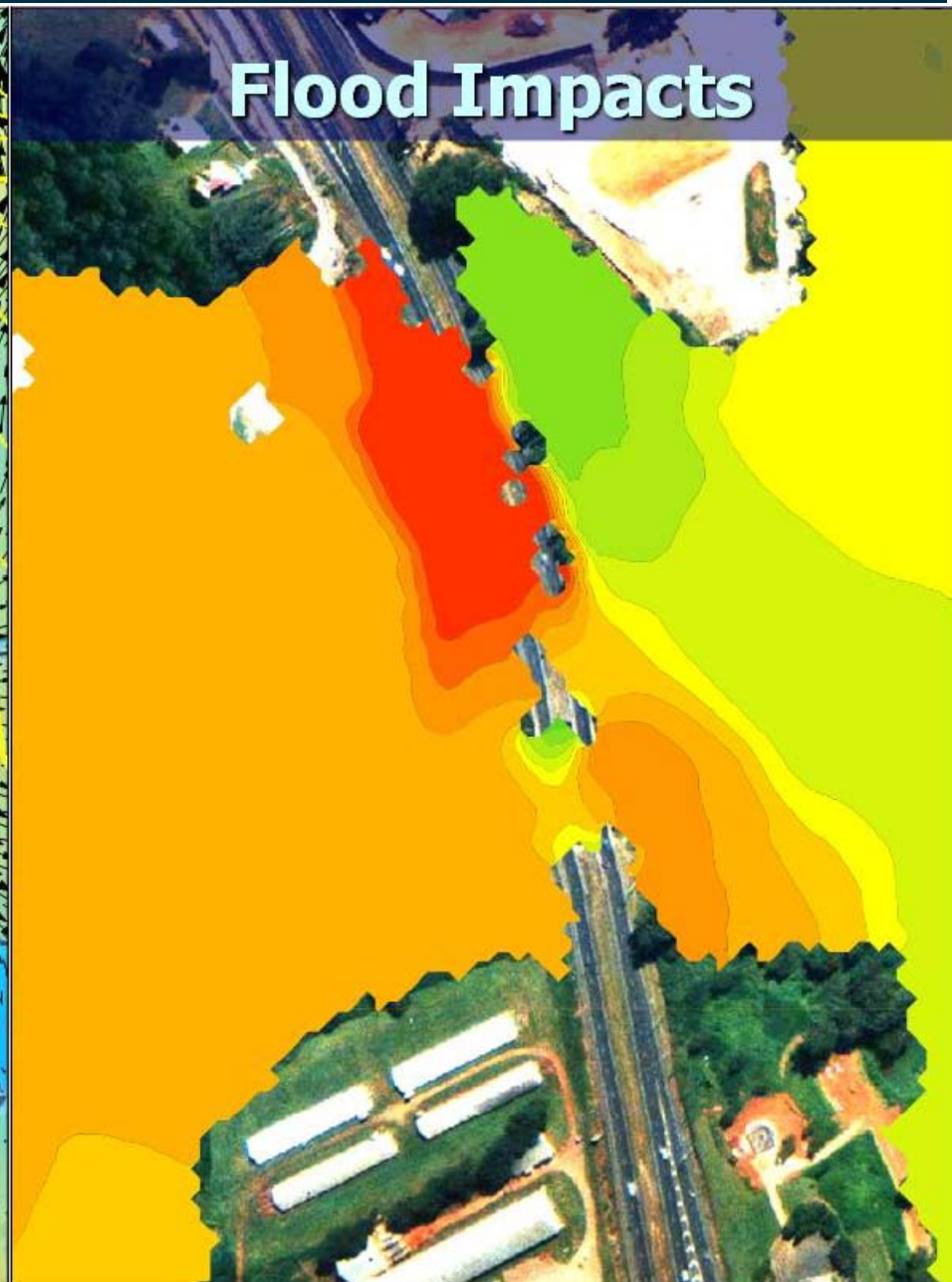
Post-Duplication



Pre-Duplication



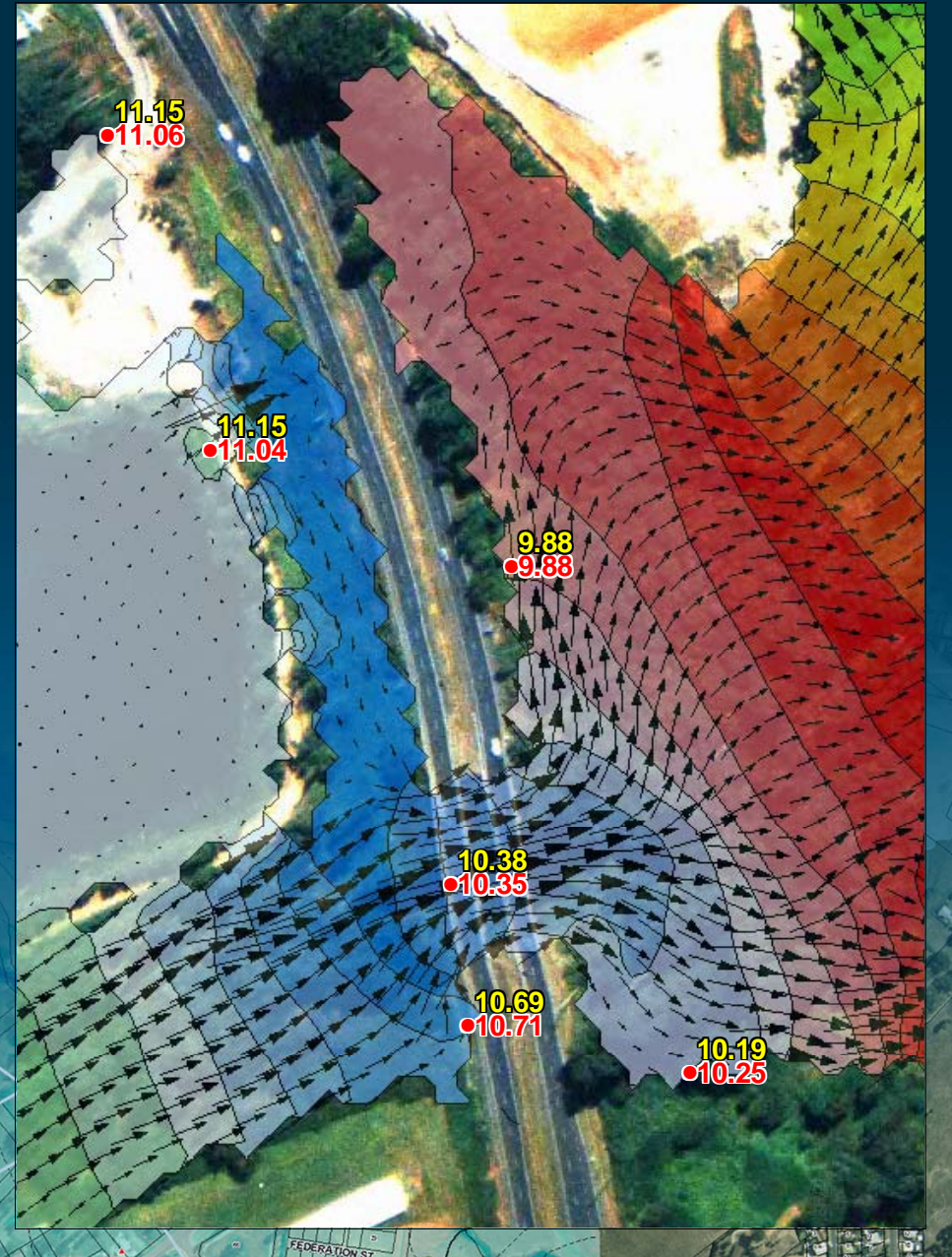
Post-Duplication



Eudlo Creek, Qld, 1998-2003

Key Findings

- 1D models very poor
(Could not reproduce recorded affluxes using standard parameters – did not dissipate enough energy)
- 2D models performed well
(Calibration data helped fine-tune models)
- Physical Model
(once “rough” enough, ie. calibrated) performed well



Throsby Creek Newcastle (2006)

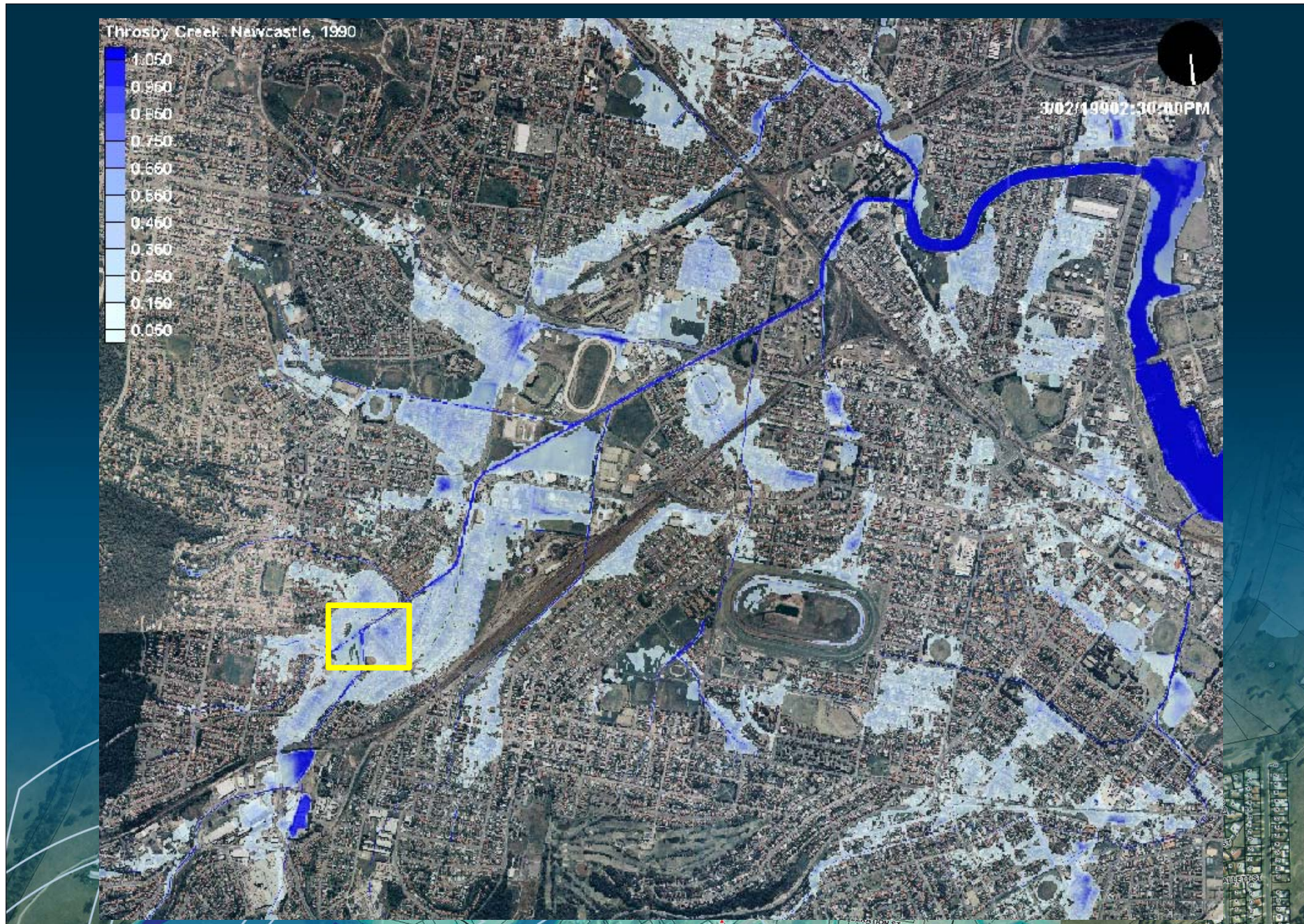
- 1D
 - Sub and super critical flow
 - 700 structures
 - Major pipes, pits, manholes
- 2D
 - Complex overland flows



Throsby Creek, Newcastle, 1990

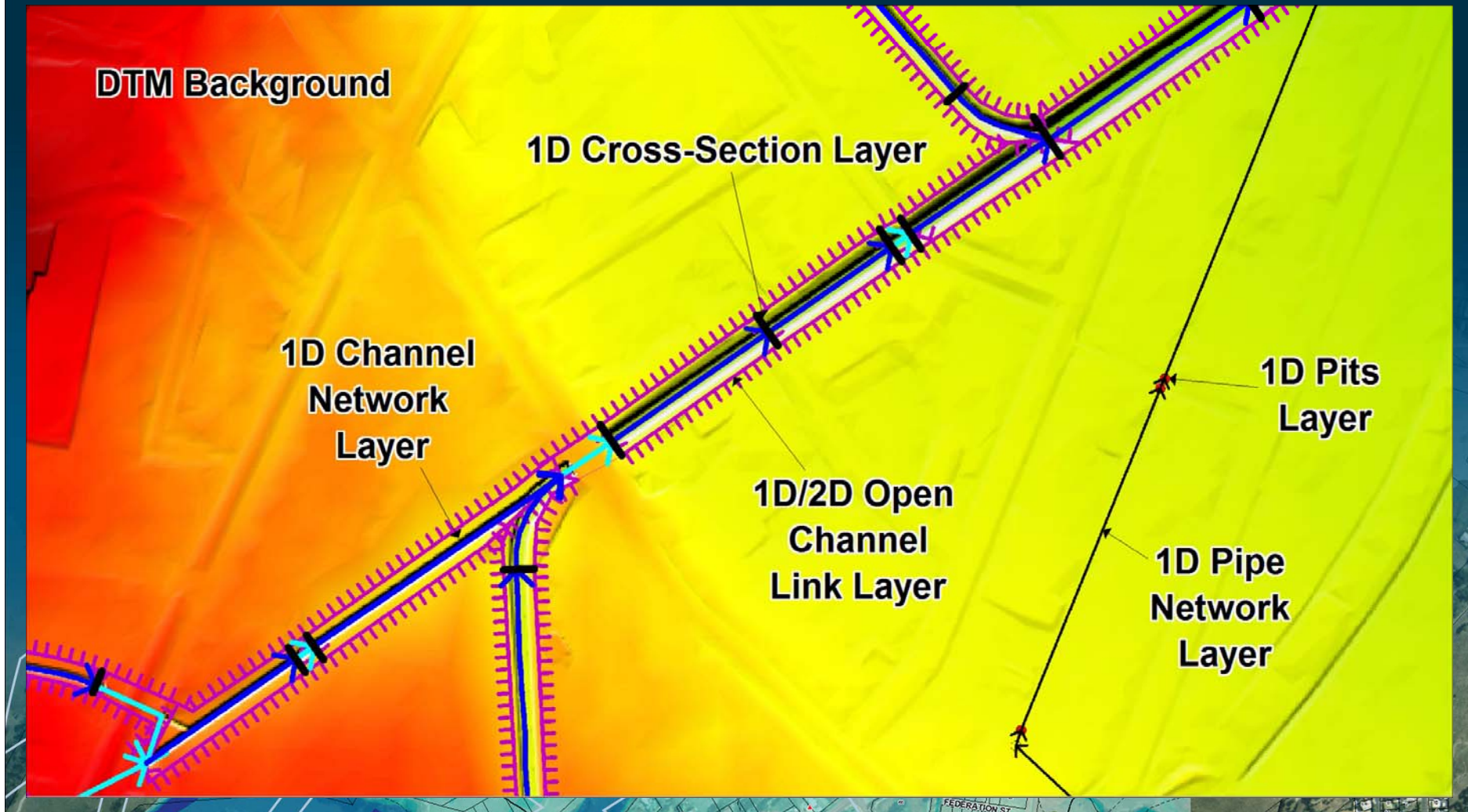


3/02/1990 2:30 PM



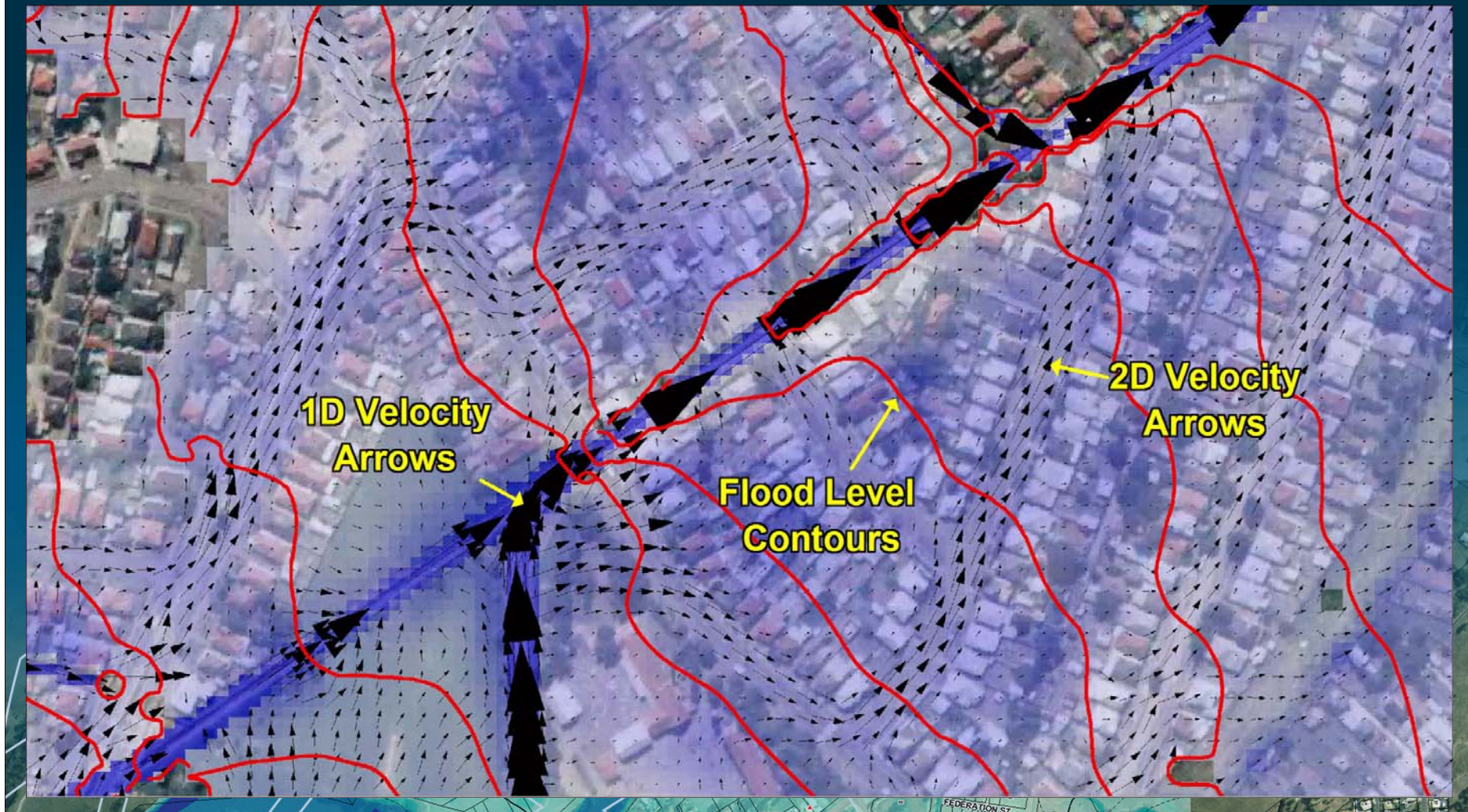
Throsby Creek, NSW, 2006 - 2007

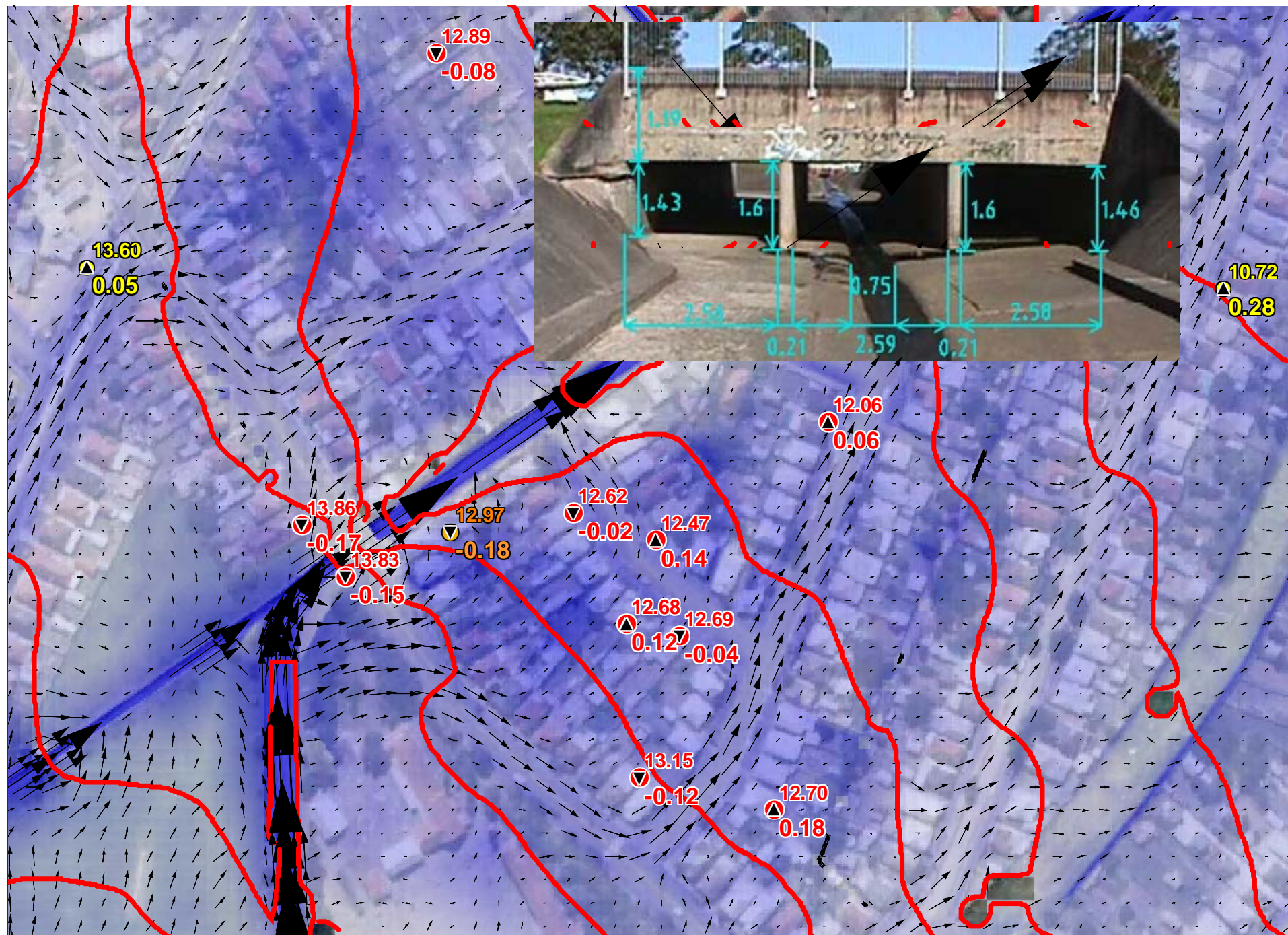
1D/2D Model Development



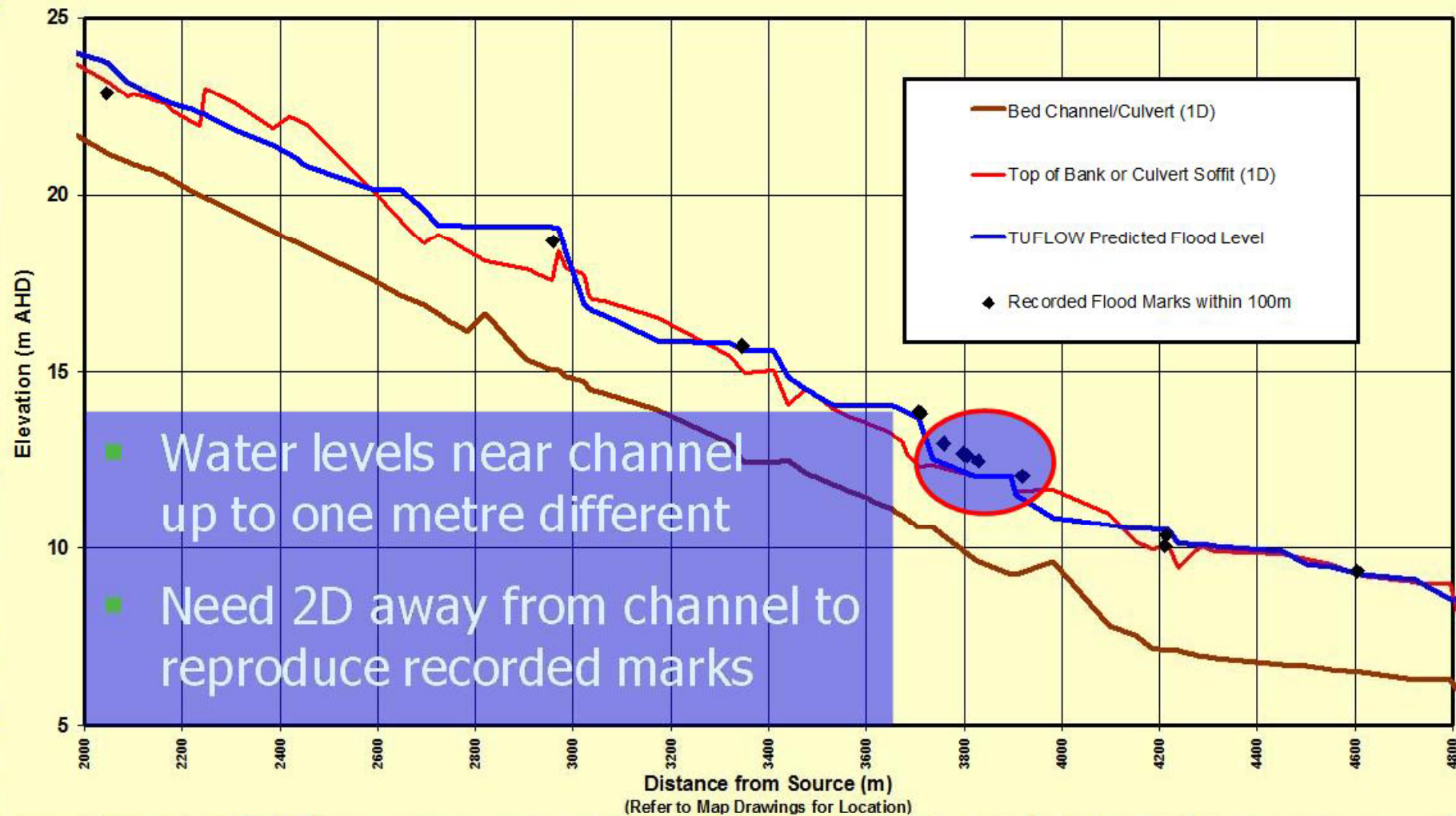
Throsby Creek, NSW, 2006 - 2007

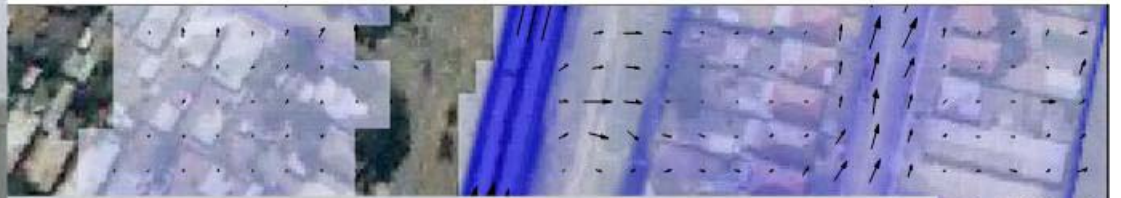
1D/2D Model Results





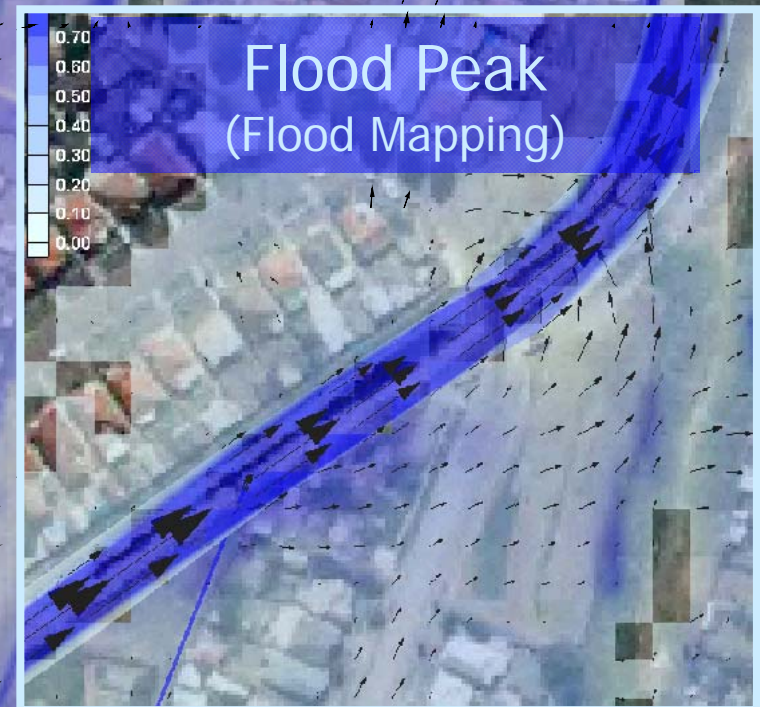
TUFLOW Feb 1990 Calibration Profile - Throsby Main Branch







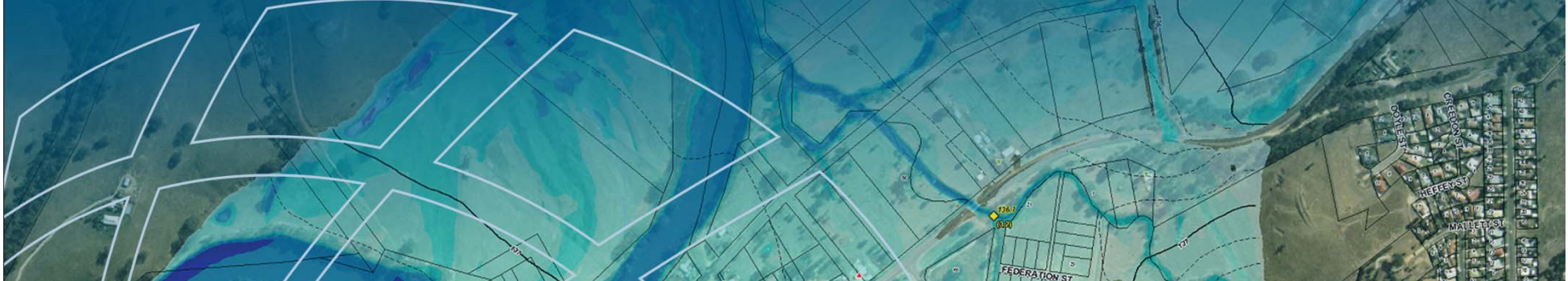
- Client questioned modelling
- Client very happy 😊



Throsby Creek, NSW, 2006 – 2007

June 2007

- ~100 year flood
(1 week after submitting 100 year flood maps!)
- \$700 million in damages
- 5,000 cars written off
- Thousands of homes inundated
- >1,200 flood marks to verify model!
- Field observations indicate an excellent comparison with modelling except...



June 2007 Throsby Creek Flood

- Newcastle CBD
 - 1m deep – should be dry!
 - Outlet to harbour blocked by shipping container
- New housing estate flooded
 - Should be dry
 - Two cars blocked main drain d/s
- When blockages modelled, excellent comparisons resulted

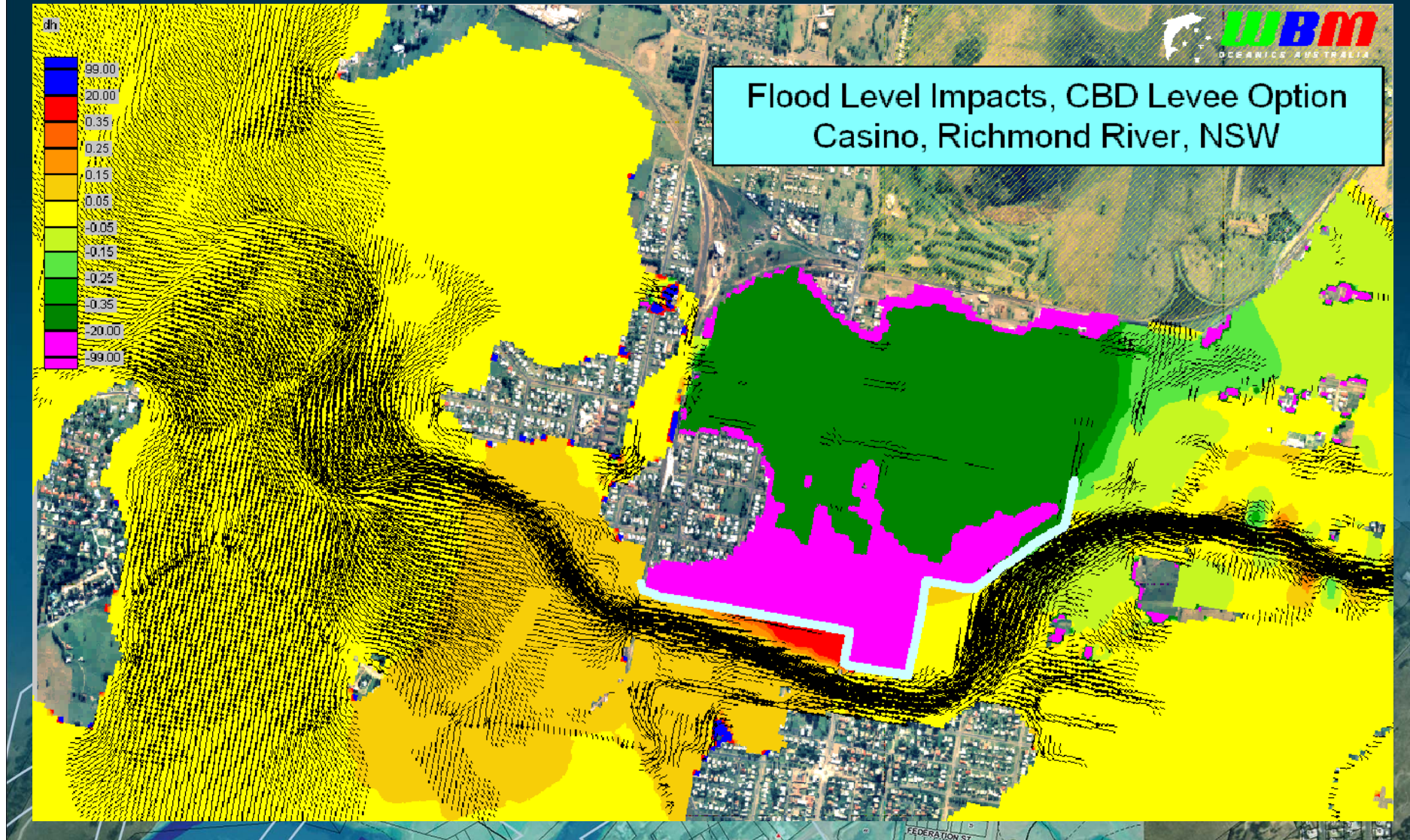


Casino Floodplain Management Study, NSW, 1999 – 2001

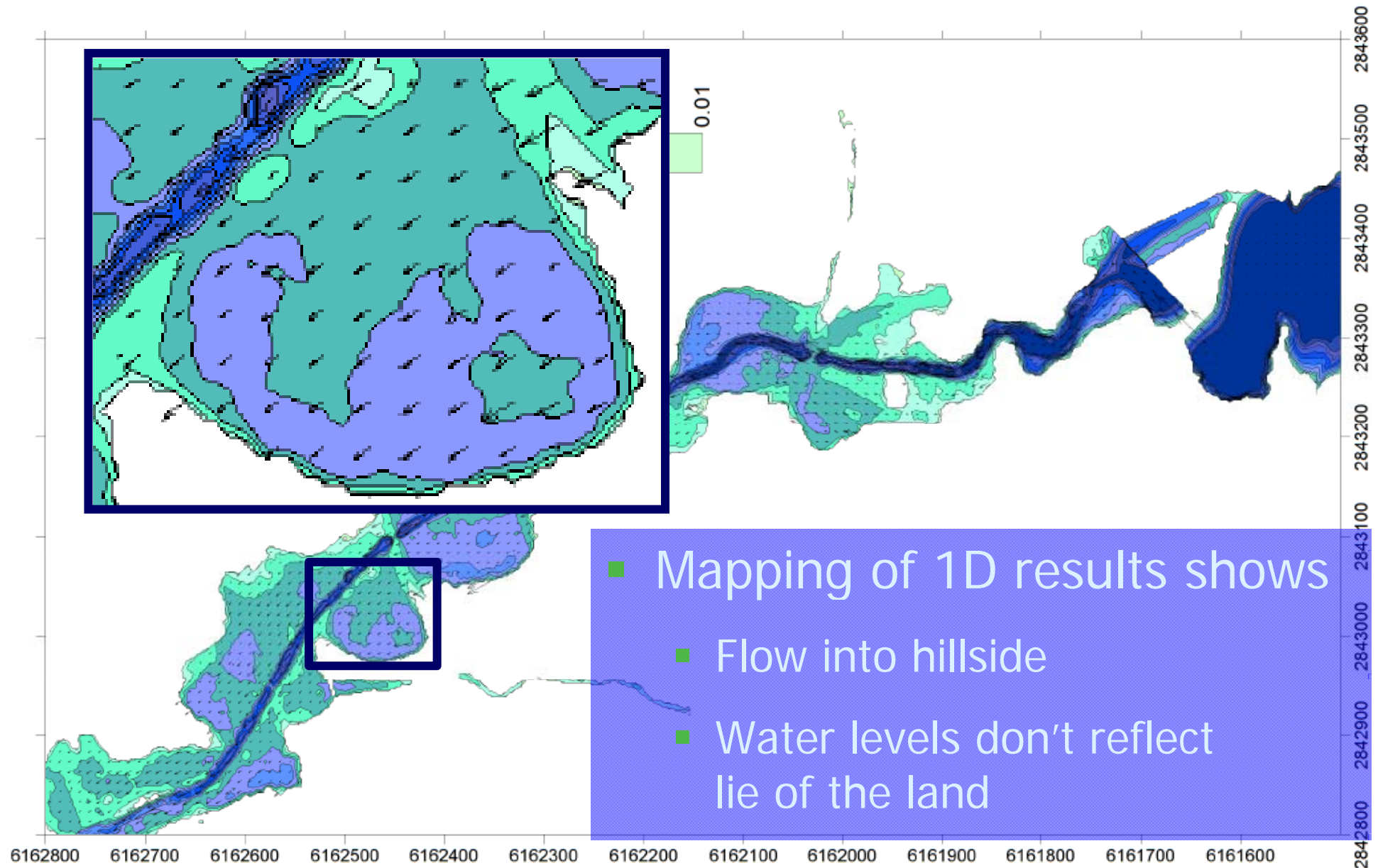


Casino Floodplain Management Study, NSW, 1999 – 2001

Switching to 2D no longer made the community skeptical about modelling



Mapping 1D Results



Notes

- All flood level contours are to Australian Height Datum (AHD).
- Flood levels shown are those expected to be reached during a typical flood event and under the physical and topographic conditions prevailing at the time of preparation.
- The approximate extent of land liable to flooding has been based on survey data available at the time of preparation. These include survey based on low level aerial photography flown March 2000. Conditions may have changed since that time. The exact extent of flooding for individual properties can only be determined by a licensed surveyor.
- Floods greater than the largest shown can occur. During such floods an area greater than that shown would be inundated. Conversely floods of lesser magnitude can affect properties within the area shown.
- Local flooding of other areas, or in excess of levels shown, may occur. The extent of flooding shown relates primarily to flooding from the Goulburn River and Sandey Creek. Some effect may be seen from other local drainage areas.
- Flooding in Whiteheads Creek is highly dependent on local conditions. While Whiteheads Creek is taken into consideration, the primary aim of these maps is not to present detailed flooding characteristics for Whiteheads Creek and its surrounds.
- Local increases in flood levels, depths and/or velocities shown may result from local factors such as drain blockages, and obstructions to overland flows such as fences, buildings and cars.
- Gatehead boundaries, alignment numbers, street names and drain locations have been supplied by Mitchell Shire Council and have not been independently verified.
- Mitchell Shire Council and its consultants do not warrant that individual properties not shown on these maps as inundated, are not flood liable.

LEGEND

Flood Depth

- 0 to 0.5m
- 0.5 to 1.0m
- 1.0 to 2.0m
- 2.0 to 3.0m
- 3.0 to 5.0m
- Greater than 5.0m

Building Inundated above Floor

- Building Floor not Inundated
- Hospital
- Police

Flood Level Contour (Metres AHD) - Interval 1.0m

- Intermittent Contours - 0.2m Interval
- Limit of Flood Mapping

Flow Velocity

- 0.5m/s
- 1.0m/s
- 1.5m/s
- 2.0m/s

Scale 1:2000 @ A4

DRG NO. FM-01-G7.0

6. All flood level contours are to Australian Height Datum (AHD);
7. Flood levels shown are those expected to be reached during a 100 year return period flood event, based on the topographic conditions prevailing at the time of preparation.
8. The approximate extent of land liable to flooding has been determined by the use of the following assumptions:
 - a. The floodable area is based on low level aerial photography and the 100 year return period flood level.
 - b. The exact extent of flooding for individual properties is determined by the use of the following assumptions:
 - i. Floods greater than the largest shown can occur. During such floods an area greater than that shown would be flooded.
 - ii. Floods less than the largest shown would not inundate properties within the area shown.
9. Land flooding of other areas, or in excess of levels shown, may occur as a result of the following:
 - a. The effect of wind on waves, especially on the beach, resulting from the Gullford River and Sanday Creek. Same as for the Gullford River and Sanday Creek.
 - b. The effect of wind on waves, especially on the beach, resulting from the Gullford River and Sanday Creek. Same as for the Gullford River and Sanday Creek.
10. Flooding in Whitehead Creek is highly dependent on local conditions. Whitehead Creek is likely to be flooded in the following circumstances:
 - a. The effect of wind on waves, especially on the beach, resulting from the Gullford River and Sanday Creek. Same as for the Gullford River and Sanday Creek.
 - b. The effect of wind on waves, especially on the beach, resulting from the Gullford River and Sanday Creek. Same as for the Gullford River and Sanday Creek.
11. Increase in flood levels, depth and/or velocities may occur as a result of the following:
 - a. The effect of wind on waves, especially on the beach, resulting from the Gullford River and Sanday Creek. Same as for the Gullford River and Sanday Creek.
 - b. The effect of wind on waves, especially on the beach, resulting from the Gullford River and Sanday Creek. Same as for the Gullford River and Sanday Creek.
12. Coastal boundaries, allotment numbers, estate names and land locations have been supplied by Mitchell David Council and are not warranted.
13. Mitchell David Council and its consultants do not warrant that individual properties not shown on these maps are inundated.

Flood Depth

- 0 to 0.5m
- 0.5 to 1.0m
- 1.0 to 2.0m
- 2.0 to 3.0m
- 3.0 to 5.0m
- Greater than 5.0m

Building Status

- Building inundated above floor
- Building Floor not inundated
- Hospital
- Police

Flood Level Contour (Metres AFD) - Interval 1.0m

- Intermediate Contours - 0.2m Interval
- Limit of Flood Mapping

Flood Level (mAHD)

Flood Depth (m)

Flow Velocity

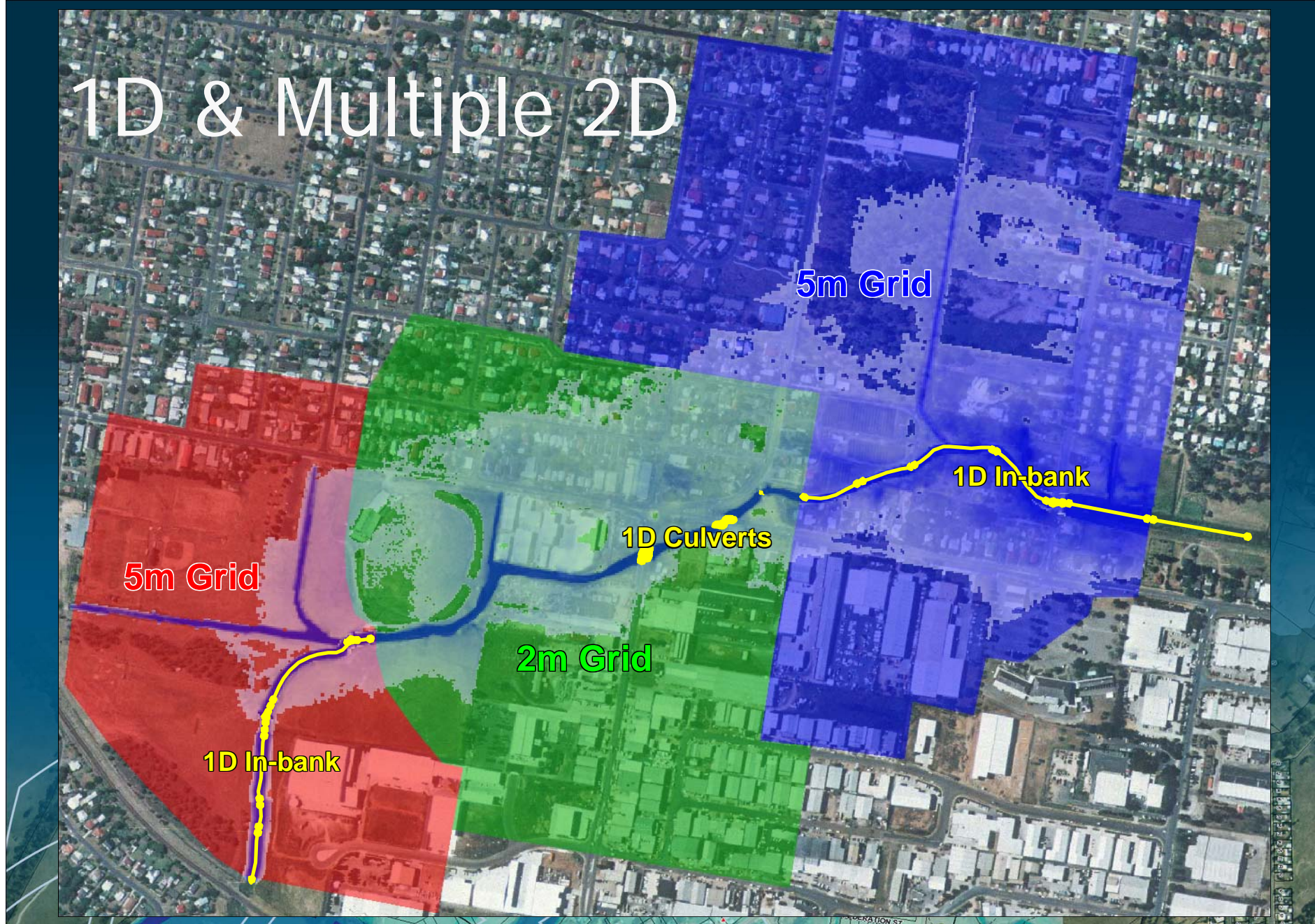
- 0.5m/s
- 1.0m/s
- 1.5m/s
- 2.0m/s

WVDE does not warrant that this map is definitive nor free of error and does not accept liability for any loss caused or arising from reliance upon information provided herein.

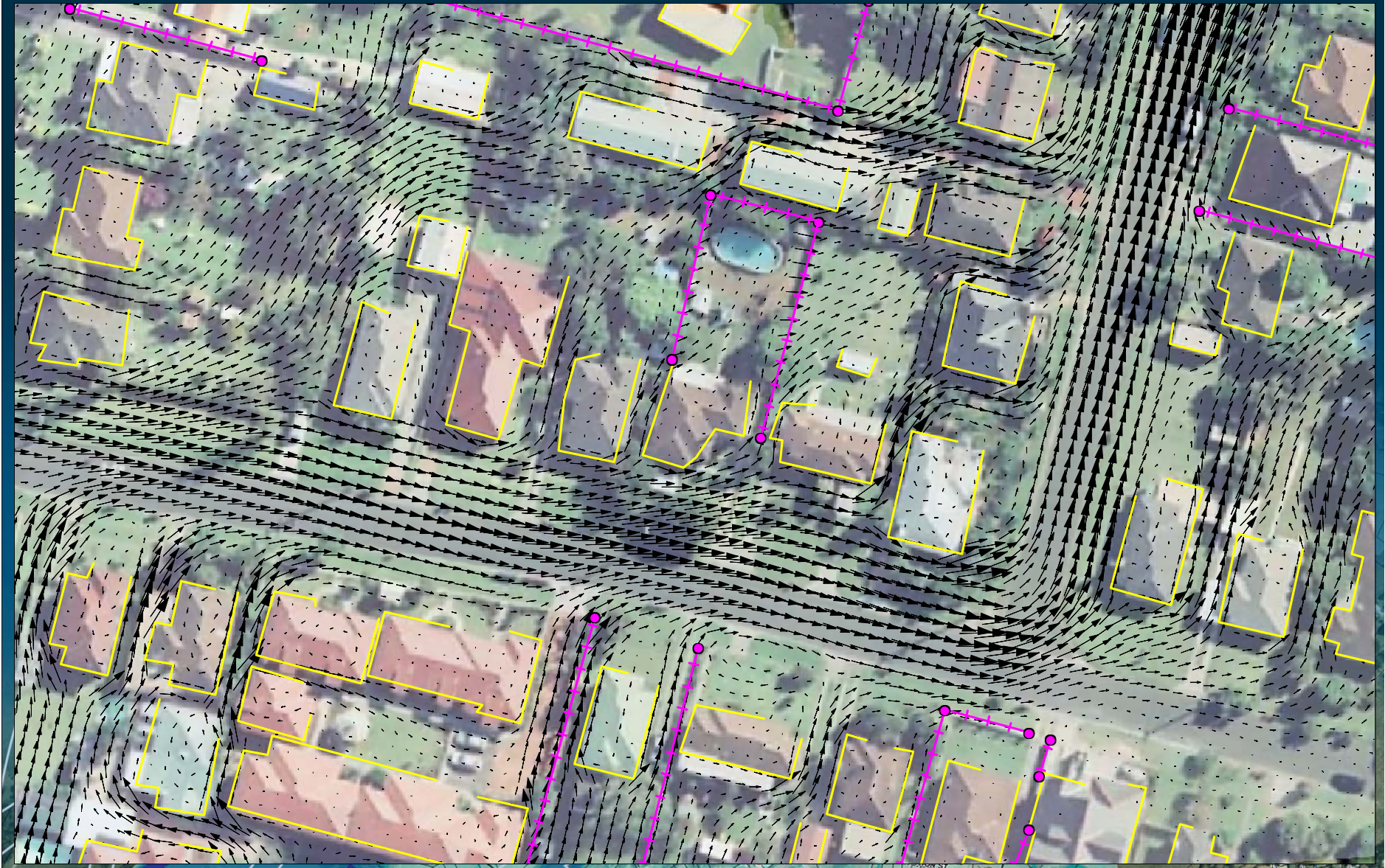


FM-01-G7.0

1D & Multiple 2D

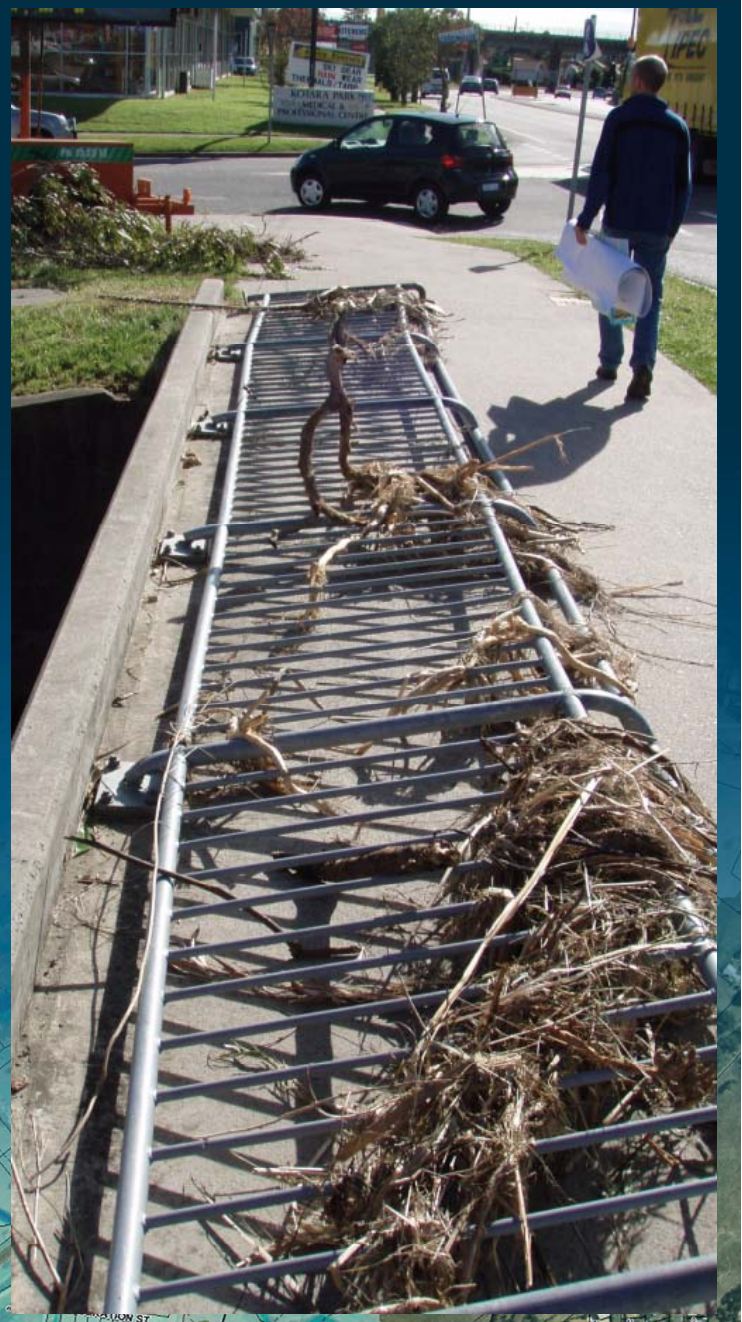


Urban Areas – Buildings and Fences

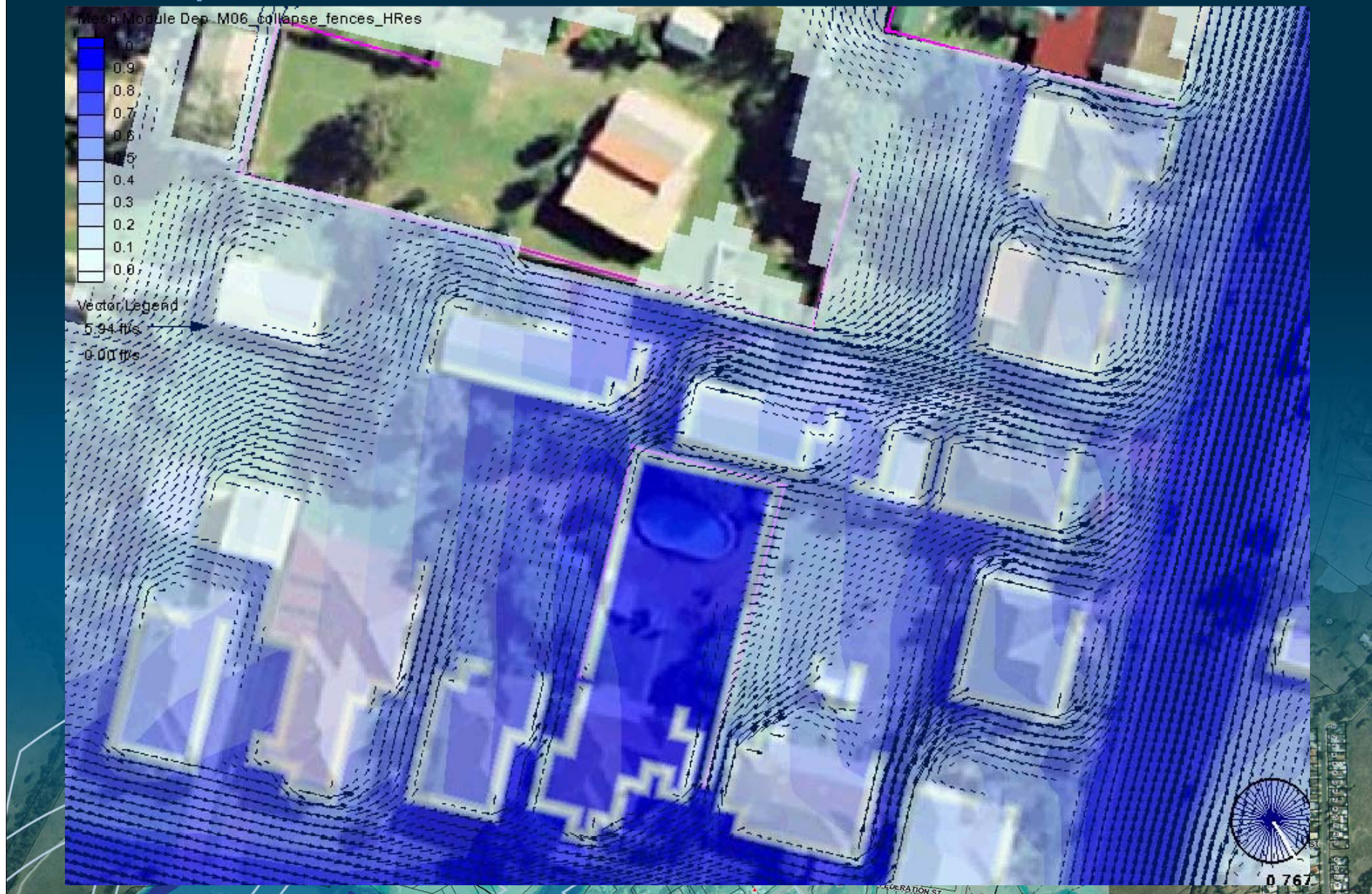


Modelling Fences!

- Able to raise element sides
- Element sides wet and dry
- Layered parameters
 - eg. vary blockage and losses with height
- Collapse element sides
- Switch between u/s and d/s controlled weir flow



Collapsible Fences Animation



Modelling Blockages!?

(These rails are recommended because they don't collect debris...)



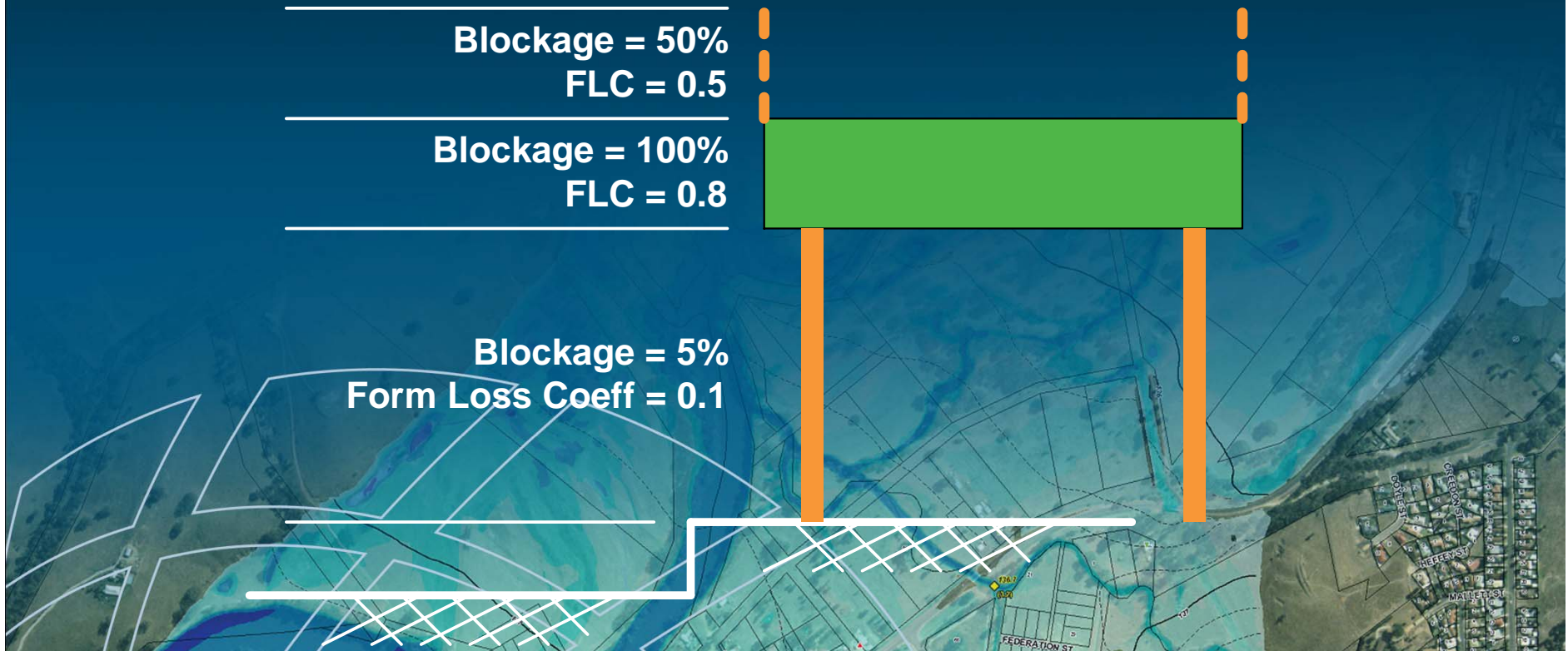
2D Layered Adjustments

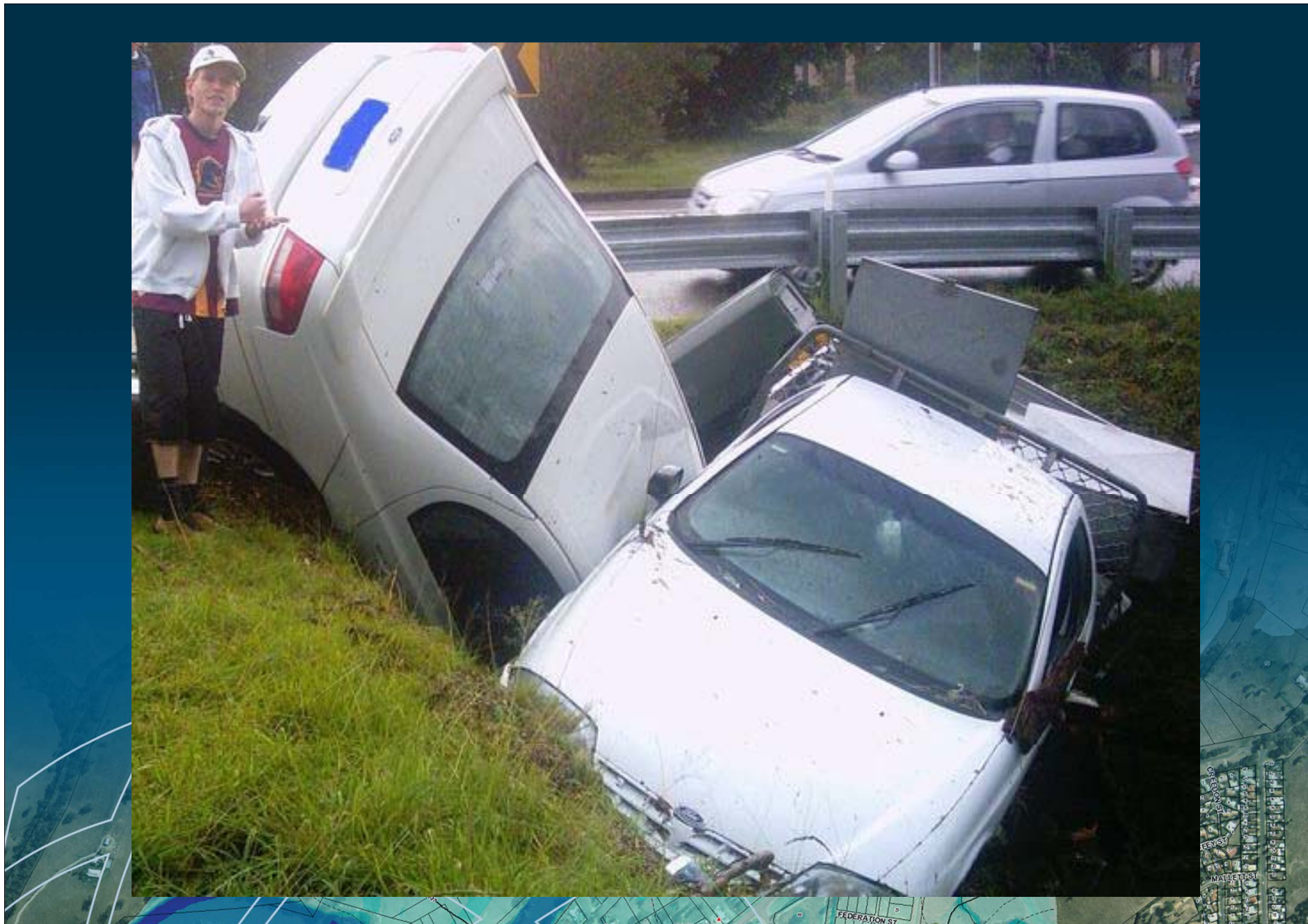
Blockage = 0%
FLC = 0

Blockage = 50%
FLC = 0.5

Blockage = 100%
FLC = 0.8

Blockage = 5%
Form Loss Coeff = 0.1





Detailed Urban Models (2008)

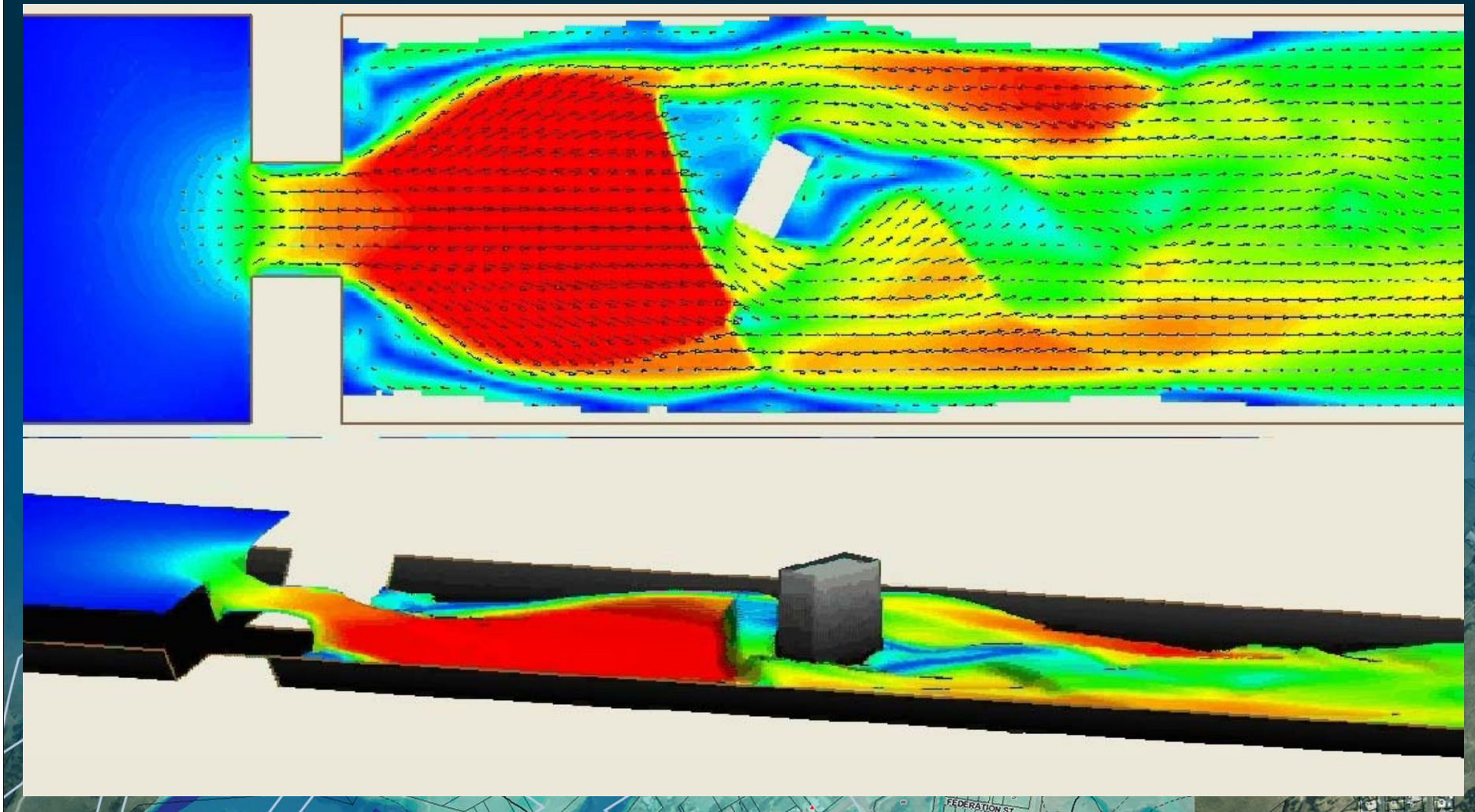


Detailed Urban Models (2008)

- 1,600 pipes / culverts
- 900 pits (drains)
- 600 manholes
- 1.8 million wet cells at peak

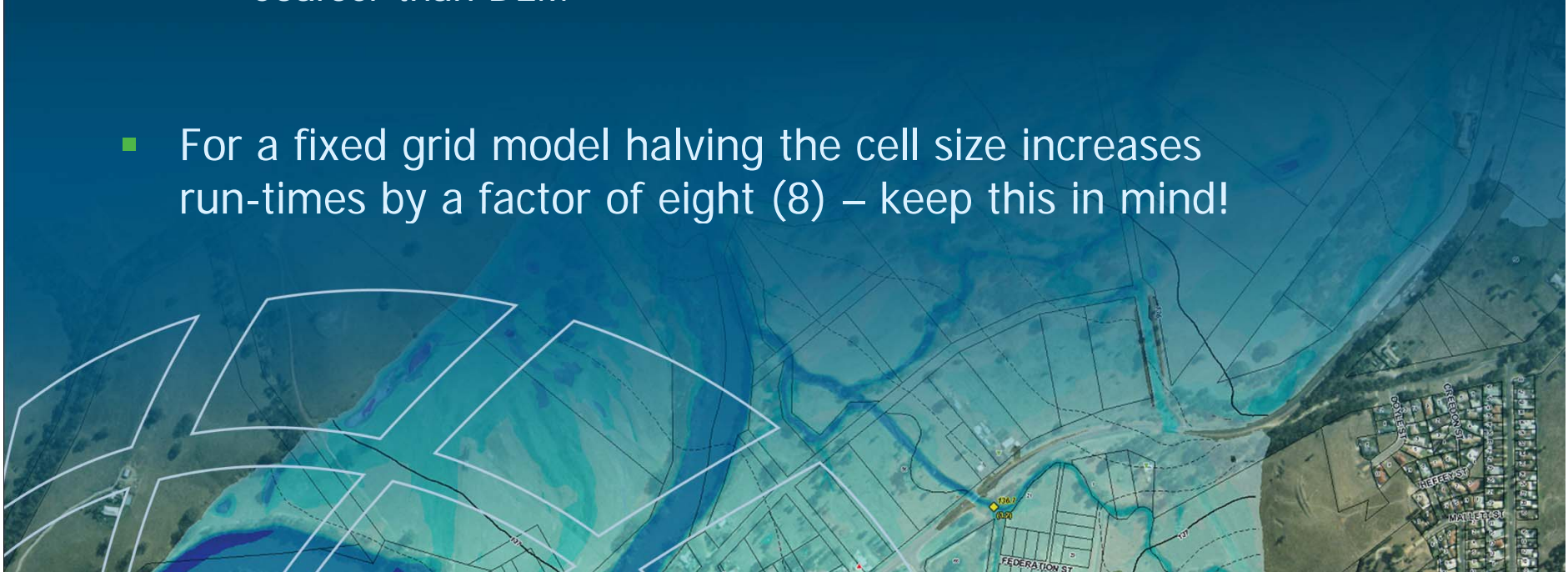
Fine-Scale Modelling

(TUFLOW FV Flexible Mesh Engine)



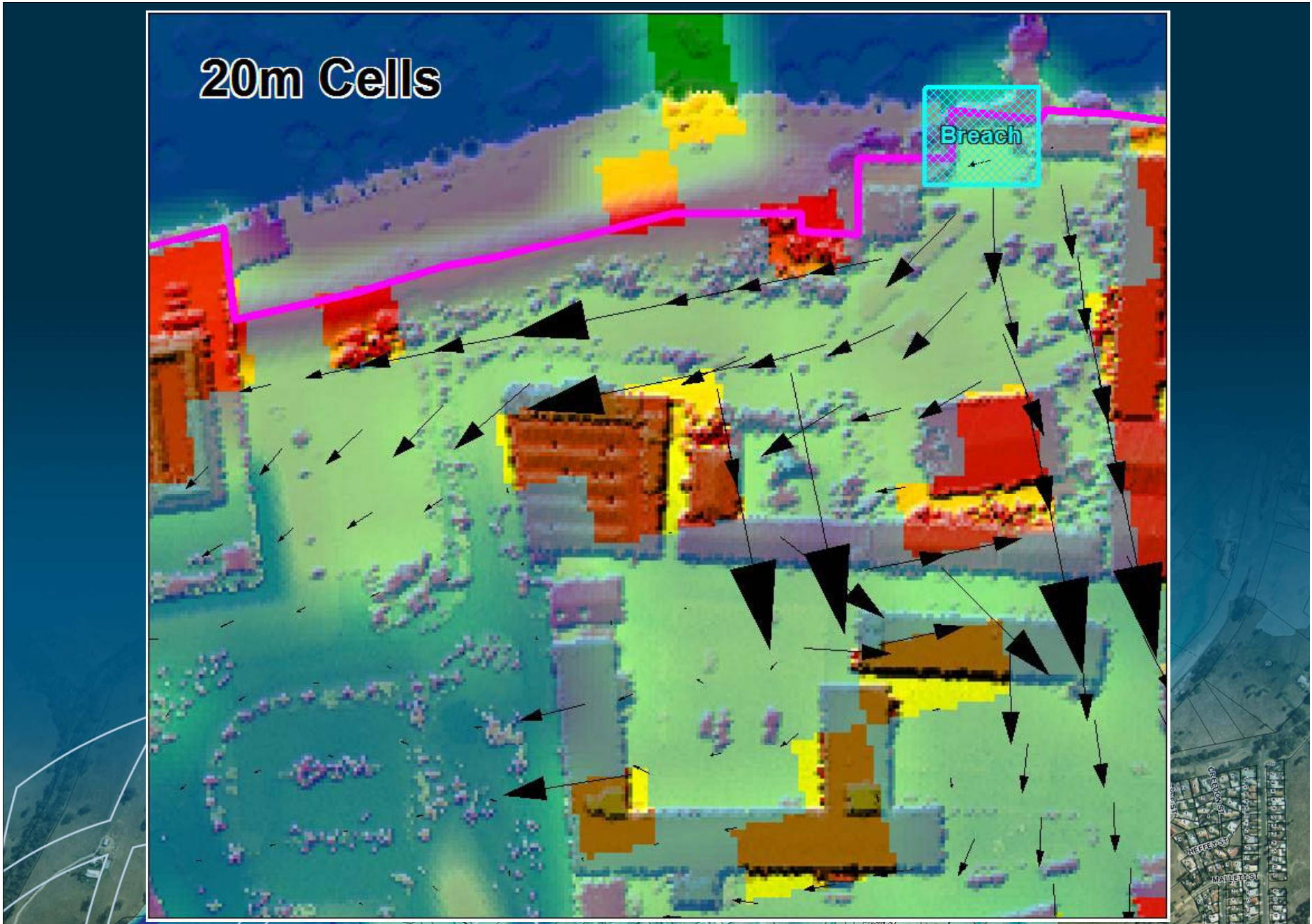
Influence of Cell Size

- Cell/Element Size(s)
 - Small enough to meet hydraulic objectives
 - Large enough to minimise run-times
 - Coarser than DEM
- For a fixed grid model halving the cell size increases run-times by a factor of eight (8) – keep this in mind!



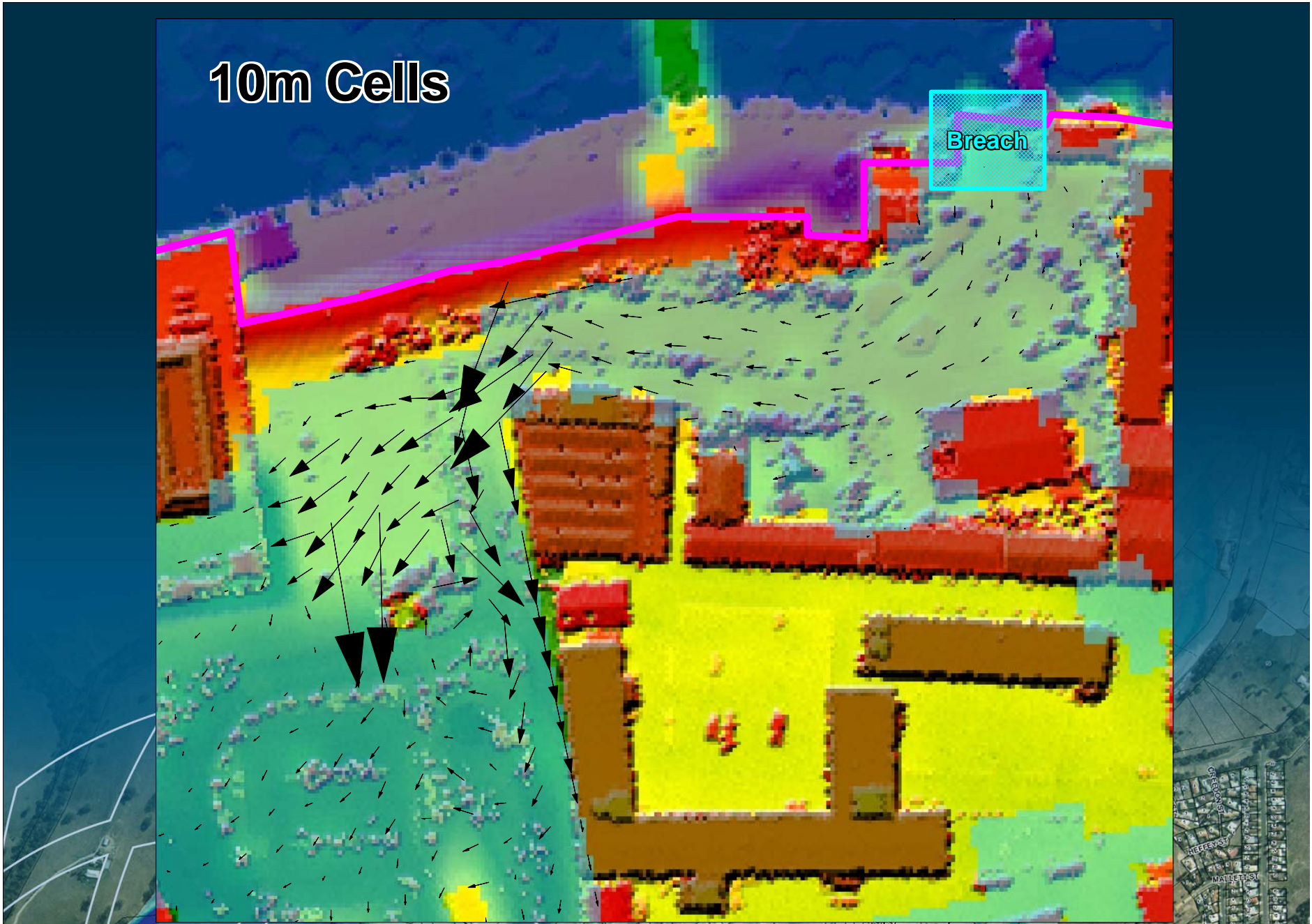
20m Cells

Breach



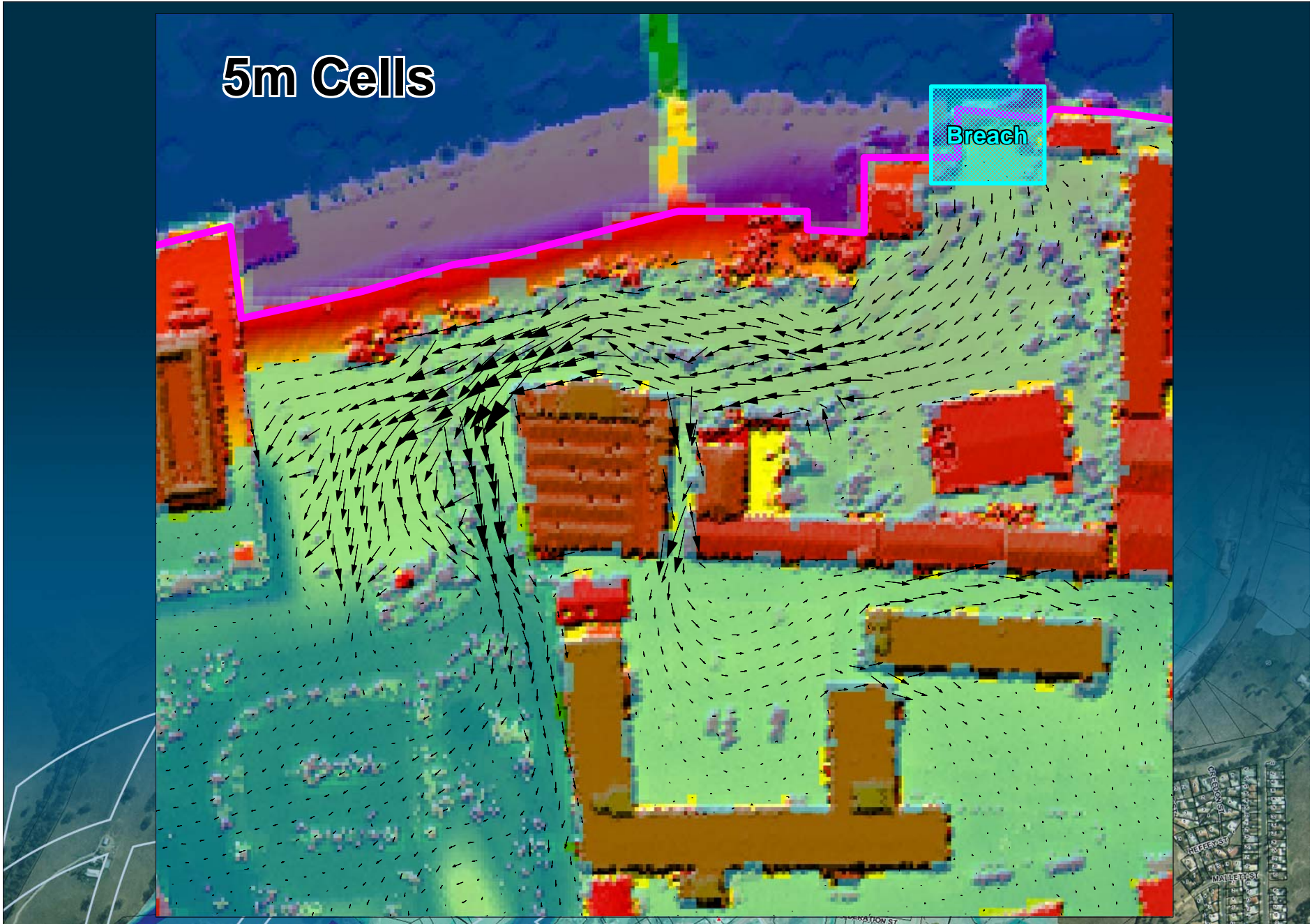
10m Cells

Breach



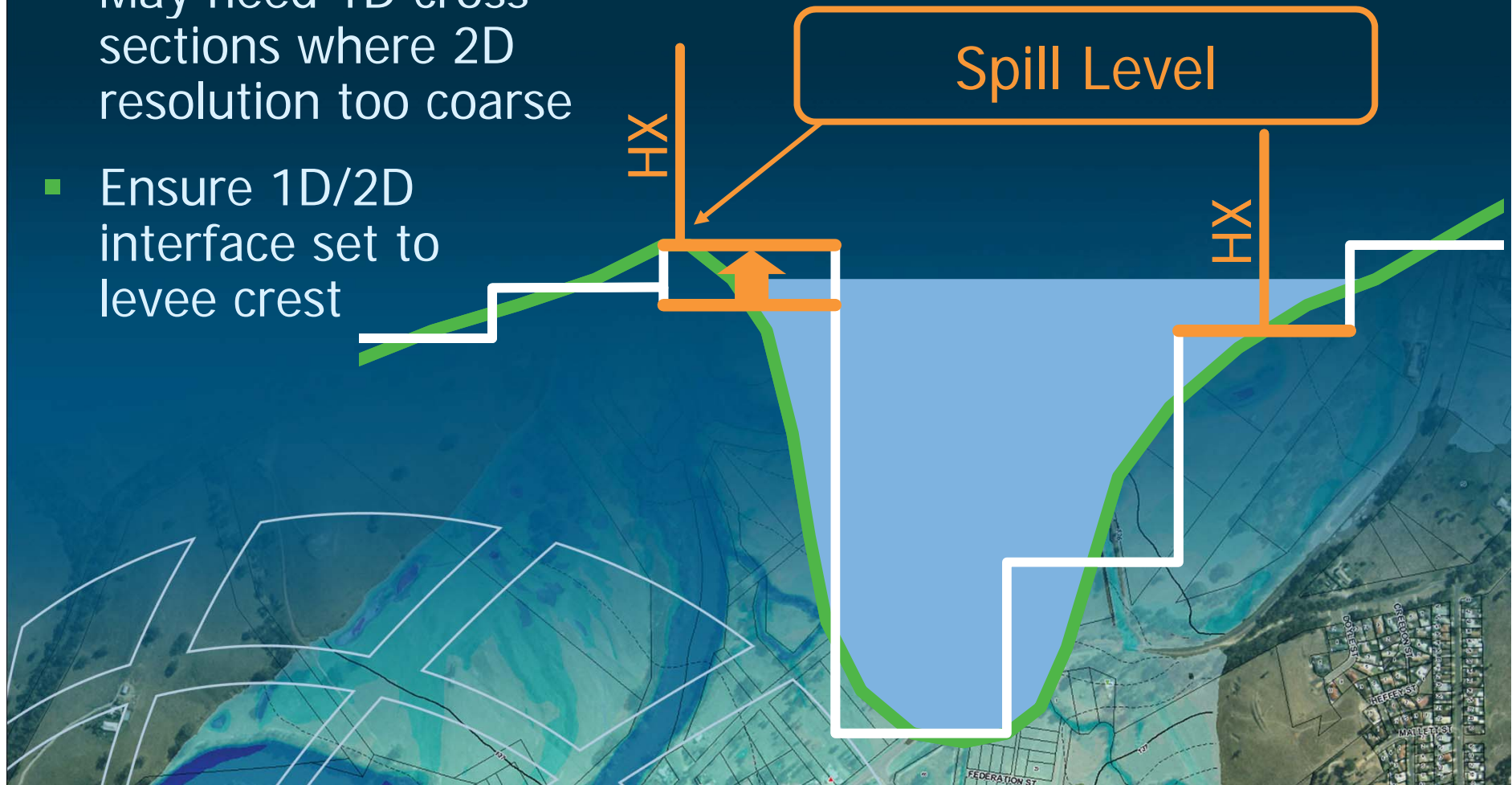
5m Cells

Breach



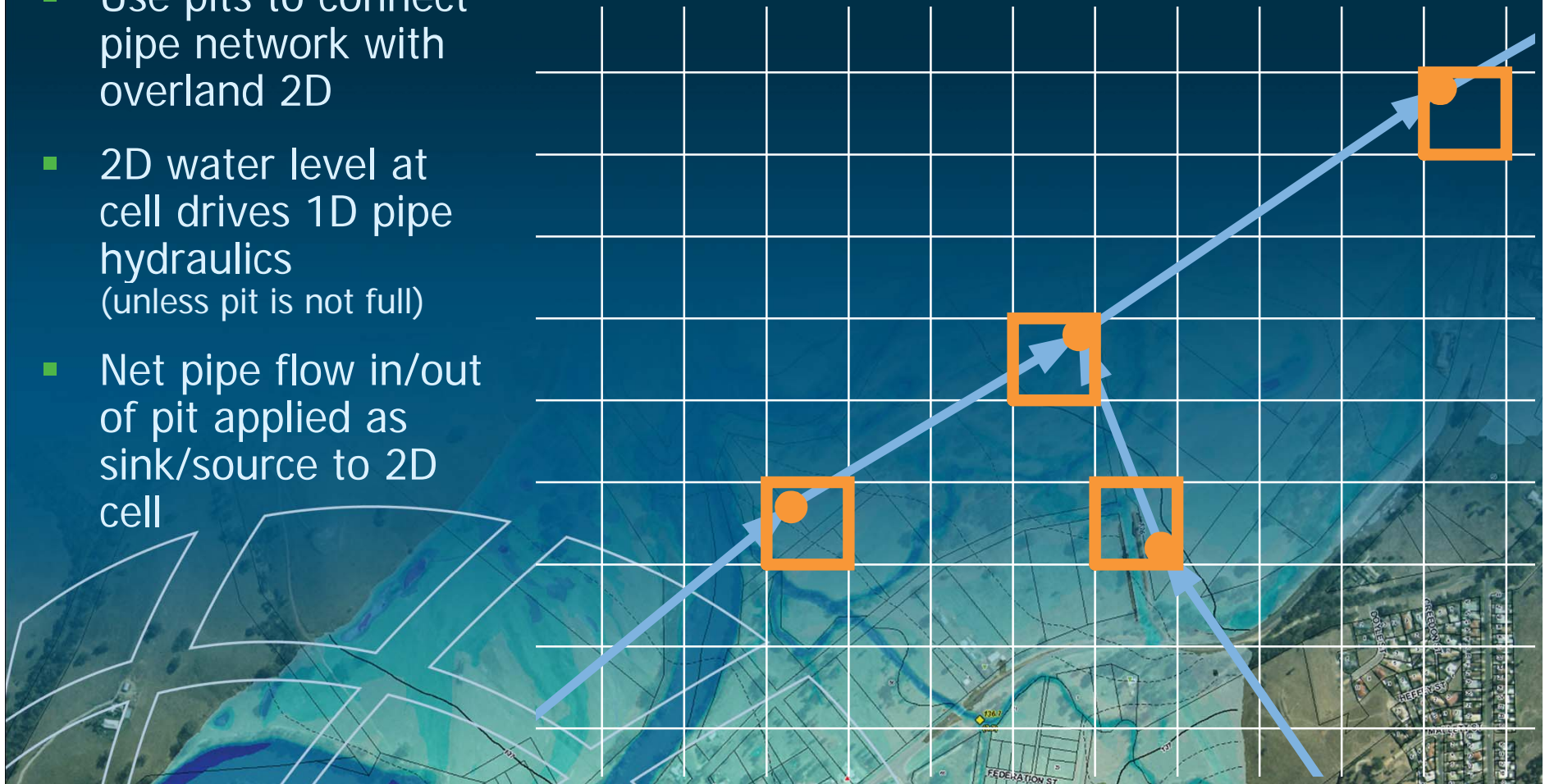
Use 1D Cross-Sections Where 2D Resolution Too Coarse

- May need 1D cross-sections where 2D resolution too coarse
- Ensure 1D/2D interface set to levee crest



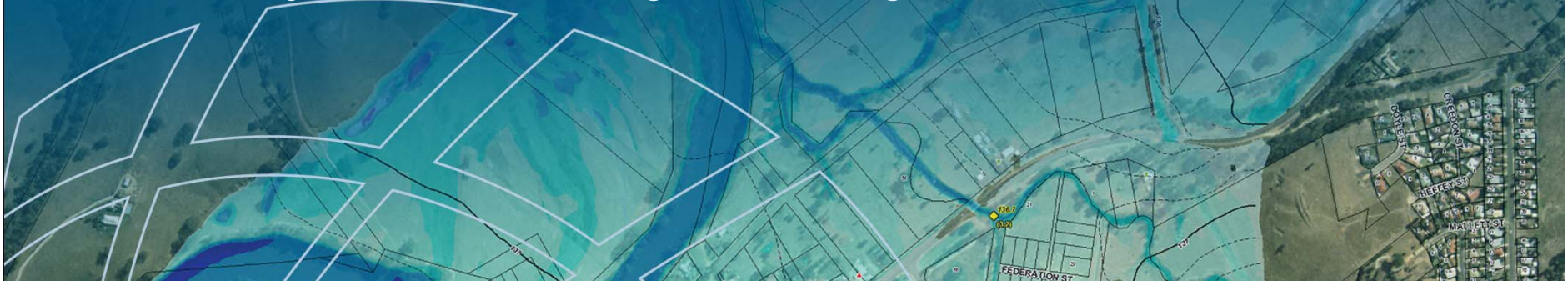
1D Underground Pipe Networks

- Use pits to connect pipe network with overland 2D
- 2D water level at cell drives 1D pipe hydraulics (unless pit is not full)
- Net pipe flow in/out of pit applied as sink/source to 2D cell



Conclusions

- 2D or 1D/2D models offer significant gains
 - in accuracy of flood modelling, risk and flood affect predictions
 - in stakeholder understanding and acceptance
- Need experience to operate/understand software
 - Make sure your 2D scheme solves key physical processes correctly
- Models still need to be
 - Calibrated where possible
 - Quality Controlled: Garbage In / Garbage Out



Eudlo Creek, 1952

Thank You