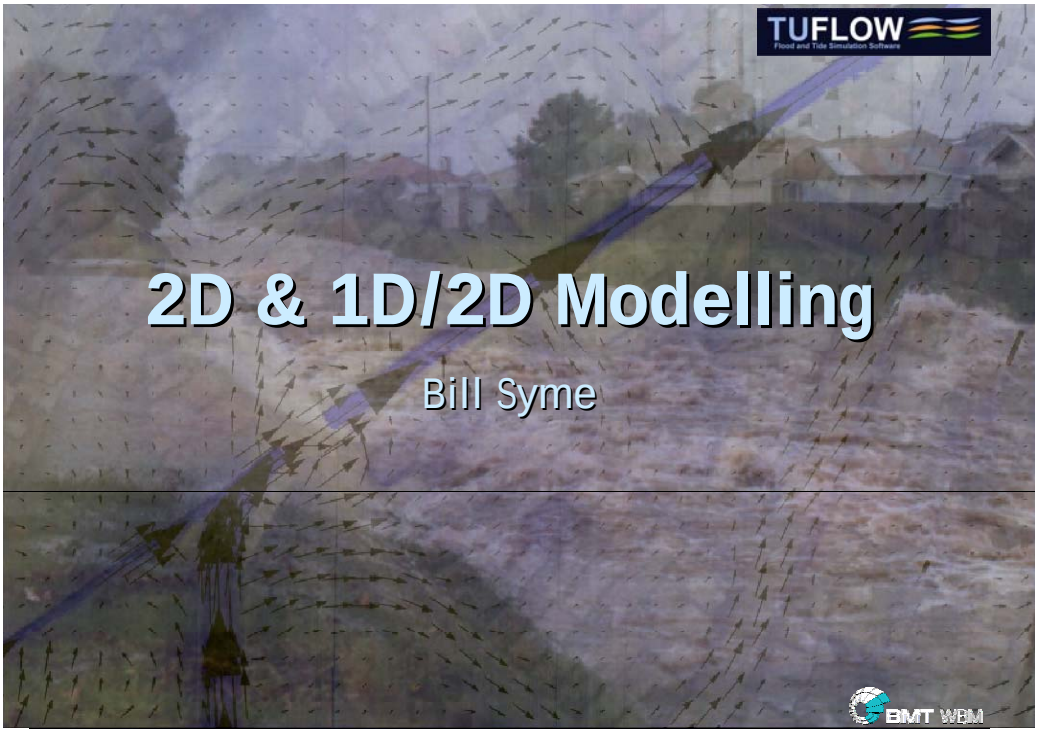
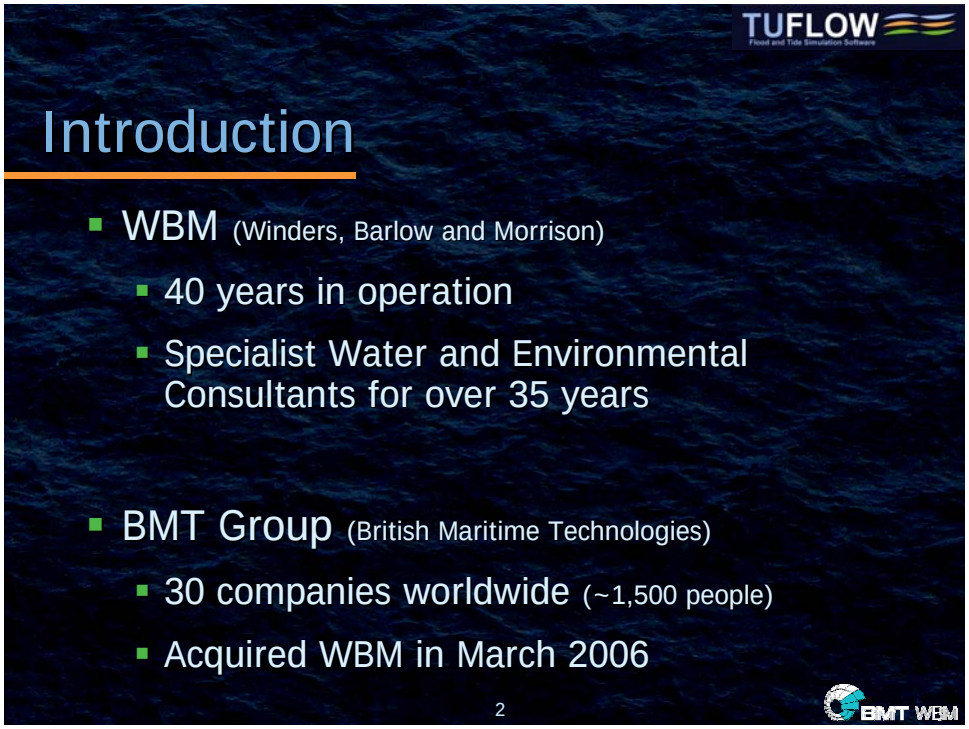




Copyright BMT WBM Pty Ltd

Today

- Introduction to TUFLOW
- Case Studies
- Lunch
- Case Studies...
- Minimising Uncertainties
- The Future

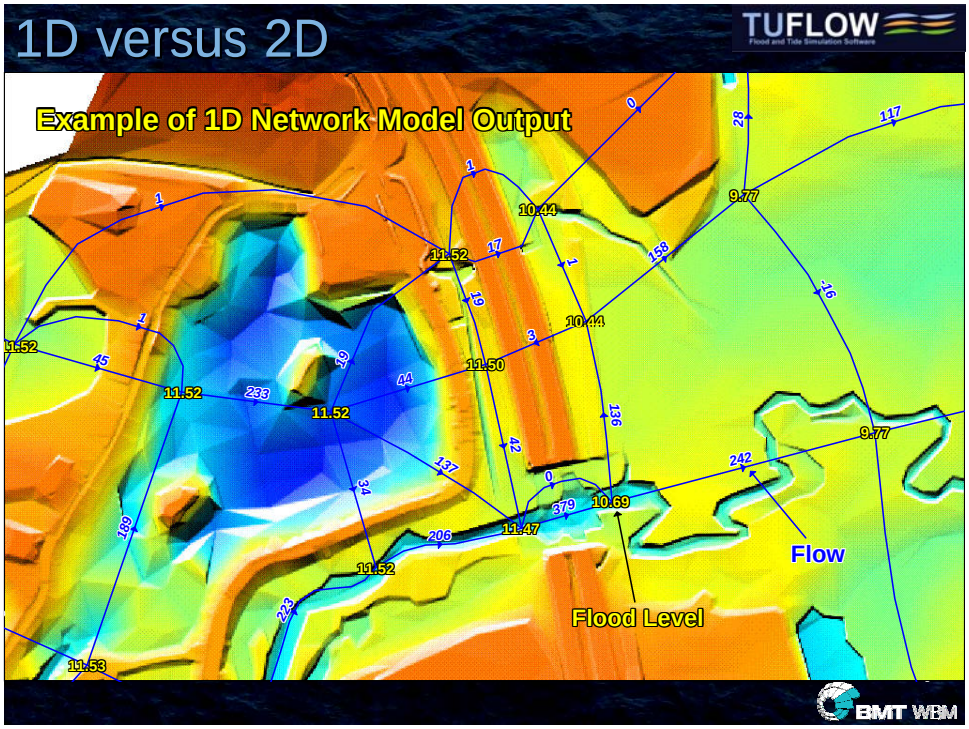
3

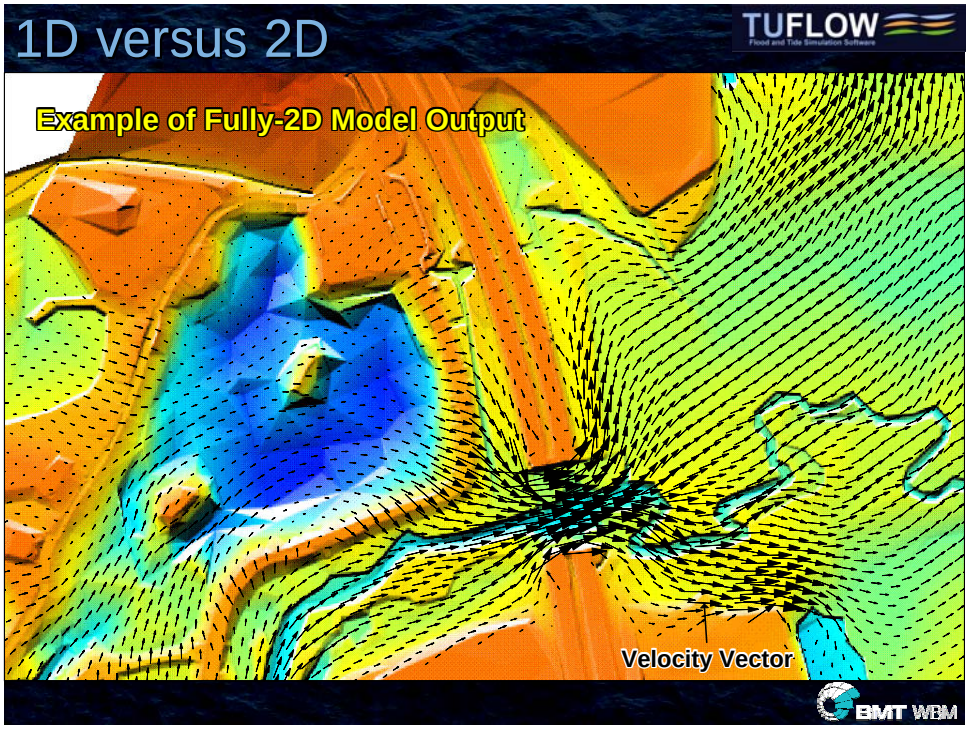
TUFLOW

- Stands for
  Two-Dimensional Unsteady Flow
- Also, solves one-dimensional equations
- Designed for modelling “long waves”
  - Tides , Storm Surges, Tsunamis
  - Floods

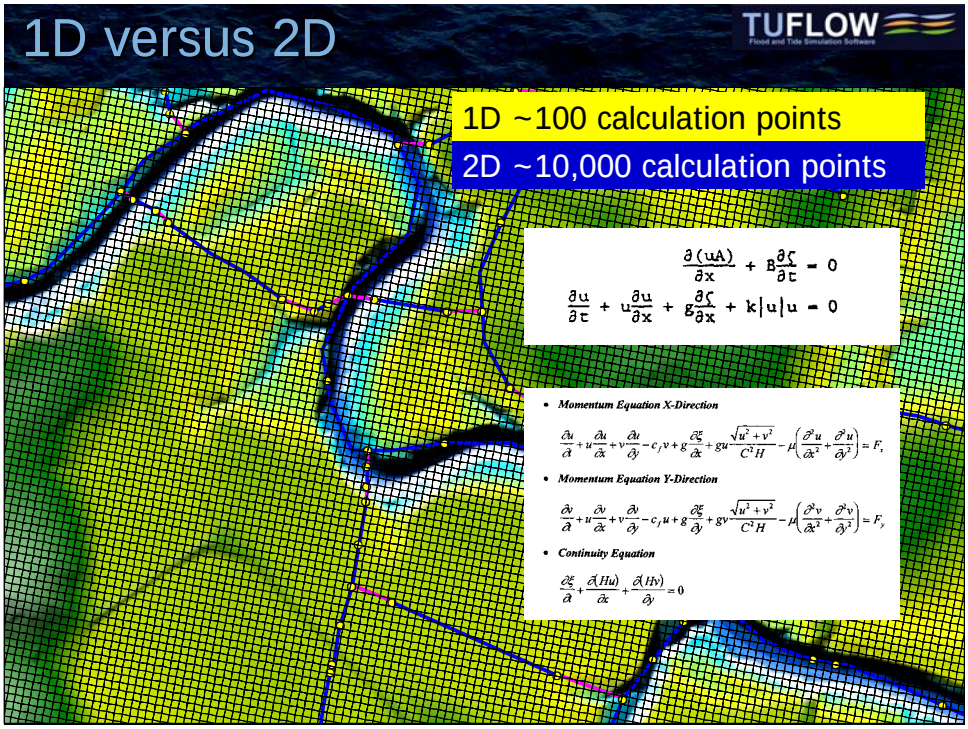
4

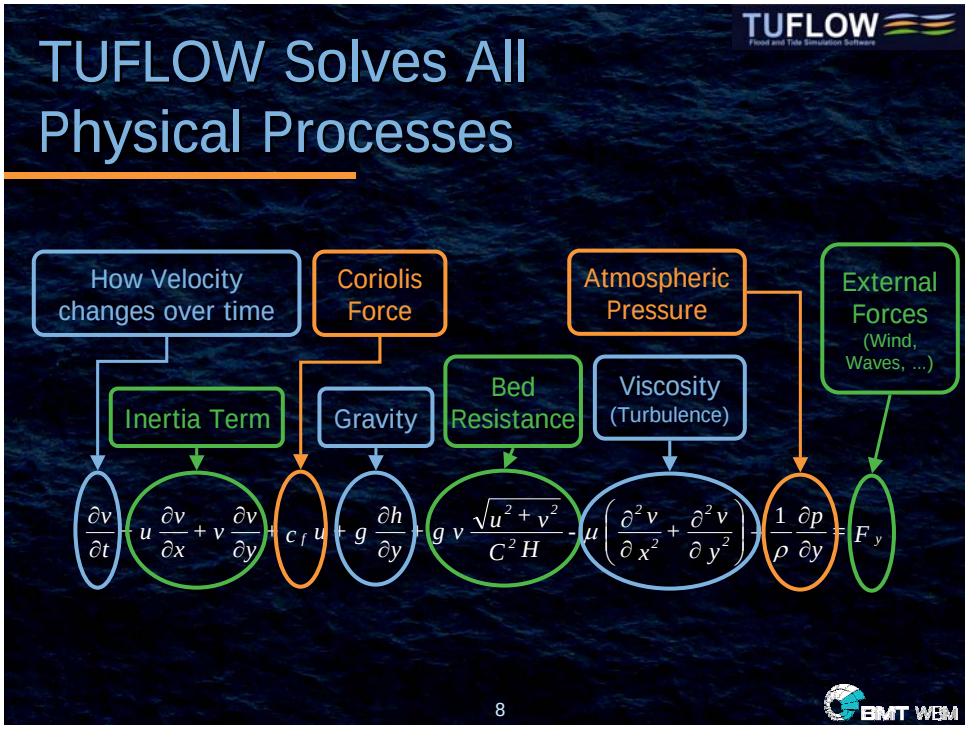
Copyright BMT WBM Pty Ltd





Copyright BMT WBM Pty Ltd

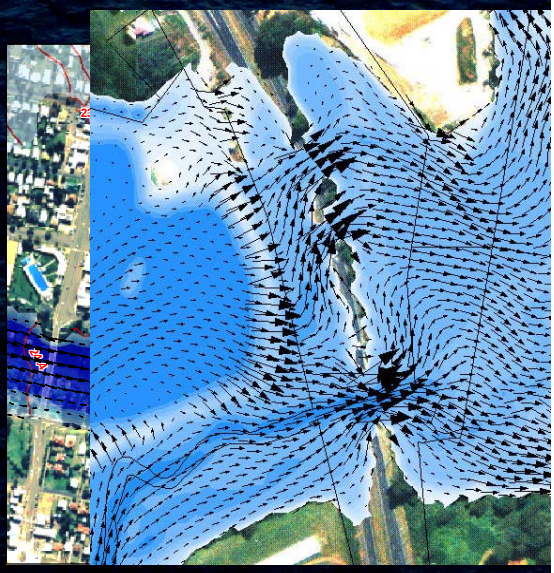




Copyright BMT WBM Pty Ltd

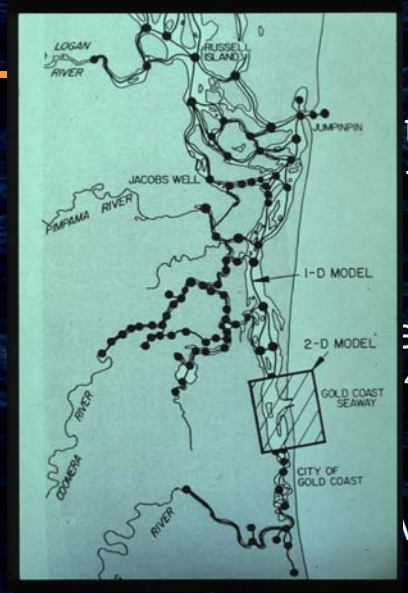
Why 2D?

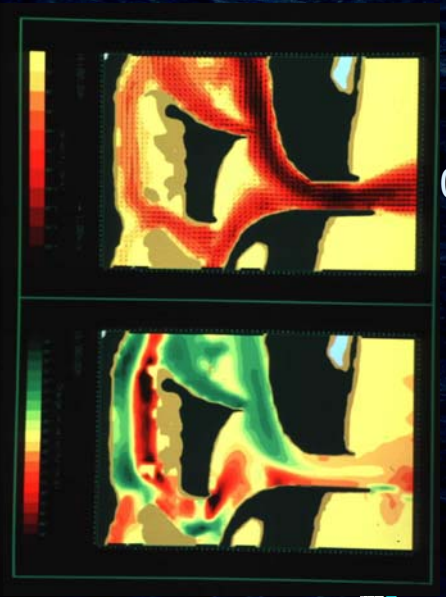
- Very important where velocity
  - Speeds up or slows down
  - Changes direction
- Structures and bends



9

TUFLOW – 1989/90





10

Copyright BMT WBM Pty Ltd

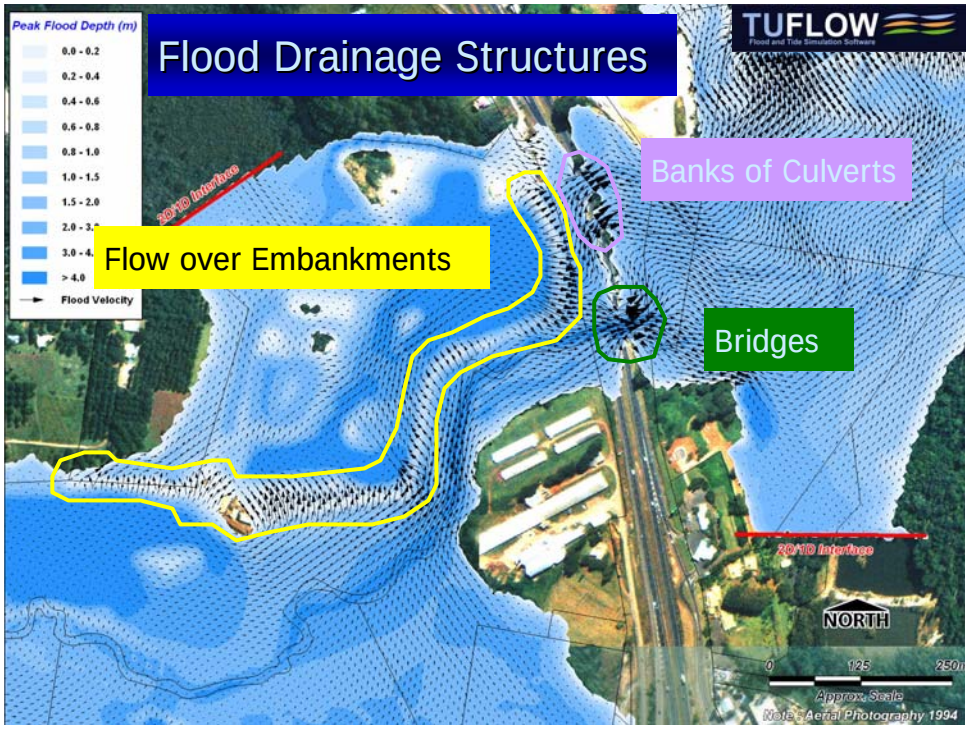
TUFLOW

Milestones Since 1998

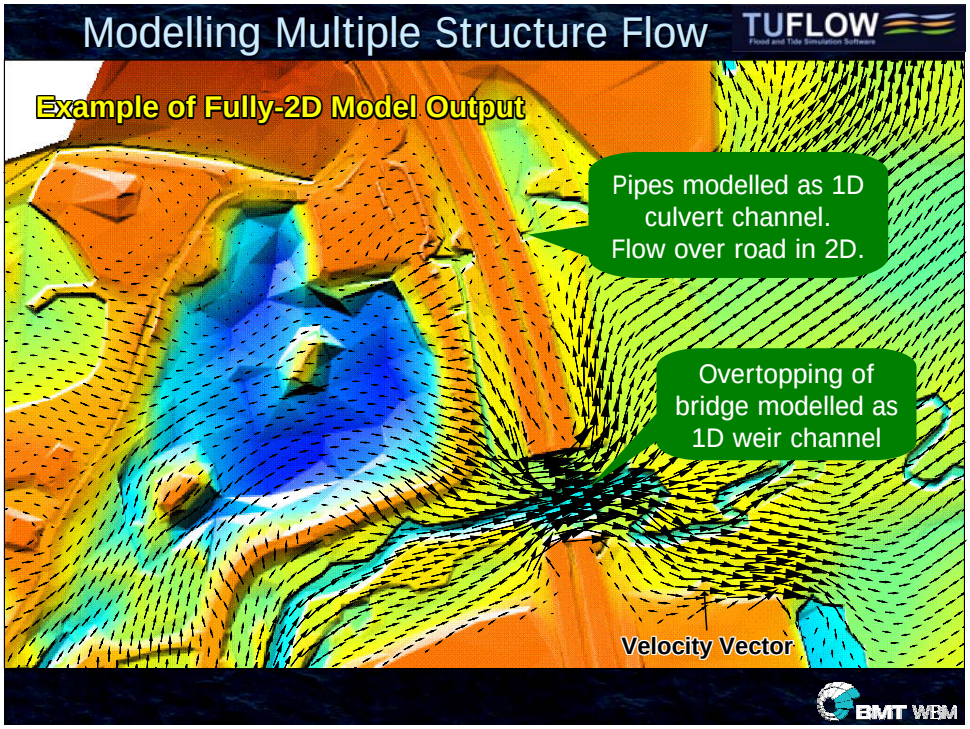
- 1998-2001 Significant enhancements
- 2001 First sale!
- 2004 Selected for the Thames Embayments Study
- 2004 Linked with ISIS and XP-SWMM
- 2006 SMS and XP-SWMM2D Interfaces released
- 2007
  - Sold in 13 countries
  - >150 Organisations

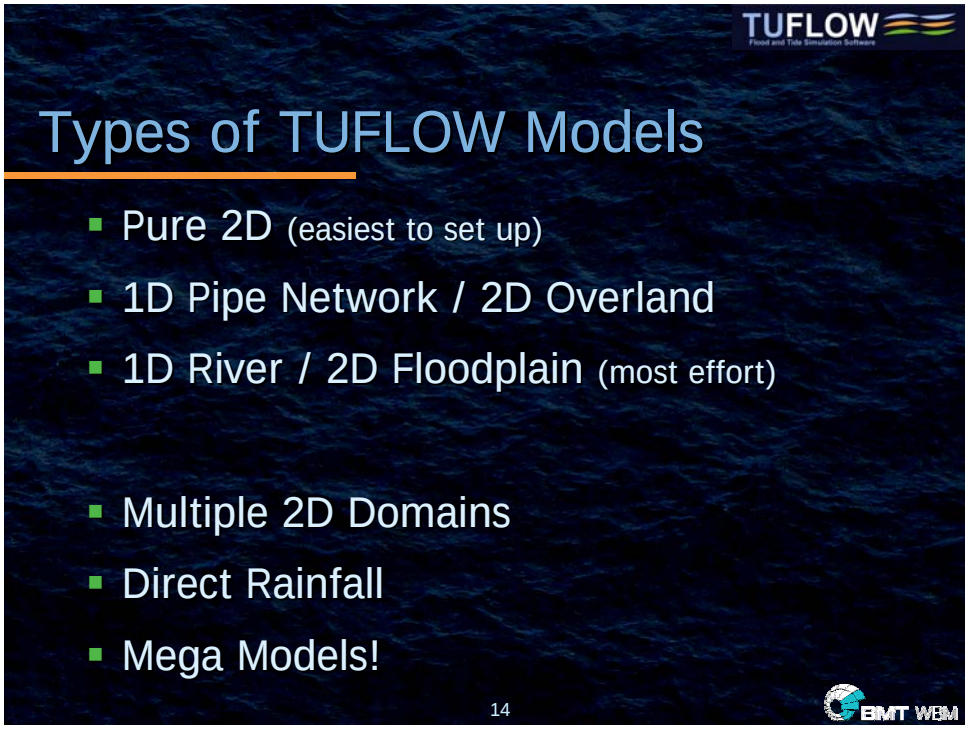
11

BMT WBM



Copyright BMT WBM Pty Ltd

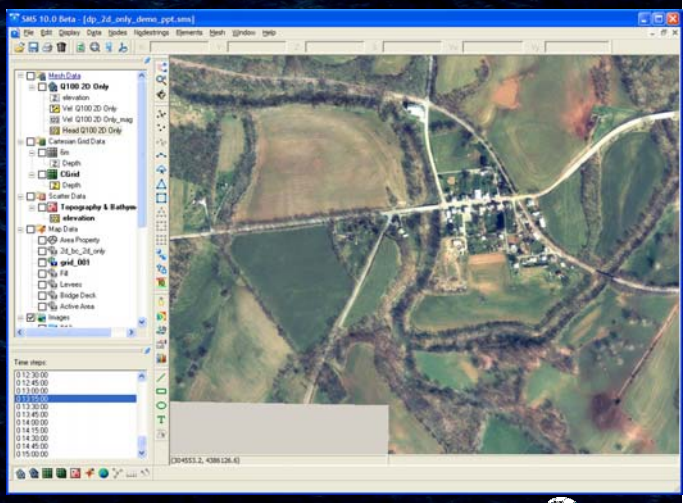




Copyright BMT WBM Pty Ltd

2D Data Input Types
Background Imagery

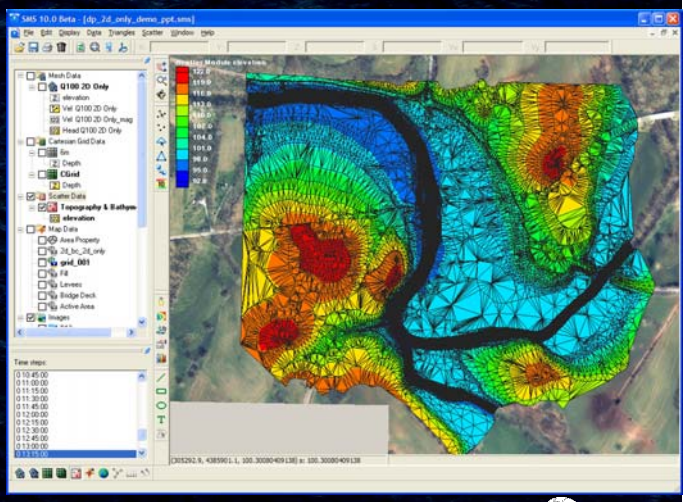
- Needed as a background for developing the 2D model
  - Aerial Photos
  - Topo Maps
- Need to be geo-referenced



15

2D Data Input Types
DTM

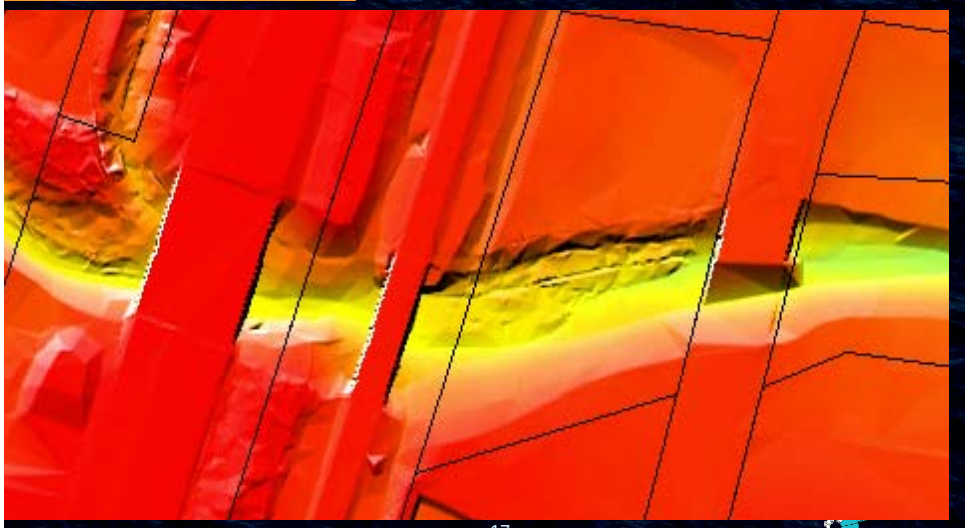
- Ground or bathymetric elevations sampled from the DTM
- TUFLOW allows inputs from any number of DTMs



16

Copyright BMT WBM Pty Ltd

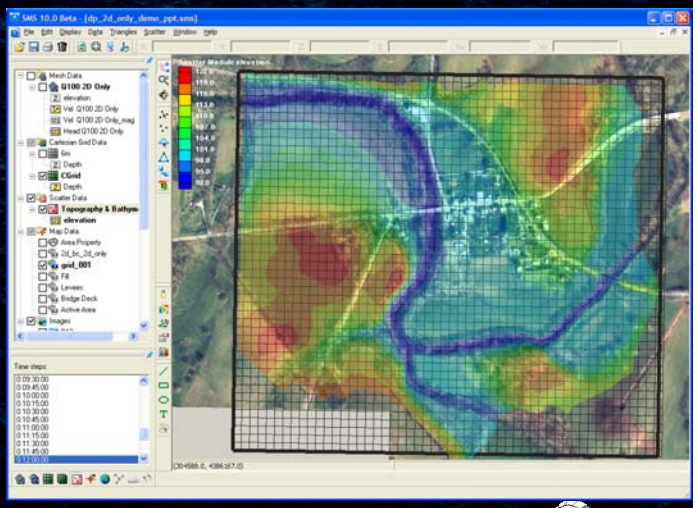
DTM and 2D Modelling
Garbage In, Garbage Out



17

2D Data Input Types
2D Domain Extent

- 2D Domain Outer Extent (Rotated Rectangle)
- Used to create 2D cells

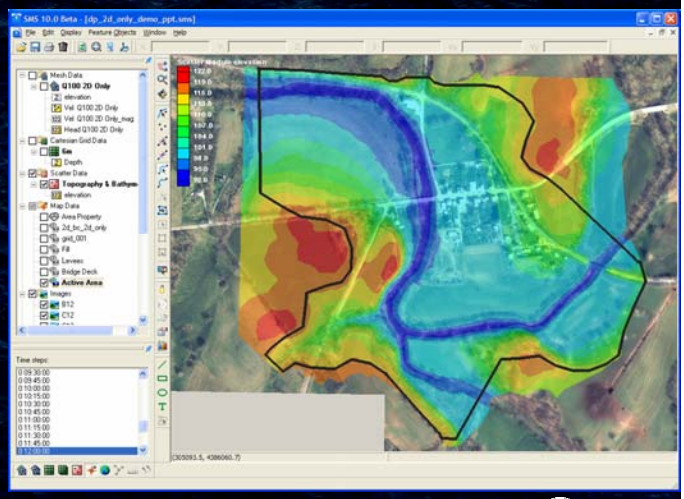


18

Copyright BMT WBM Pty Ltd

2D Data Input Types
Active/Inactive Areas

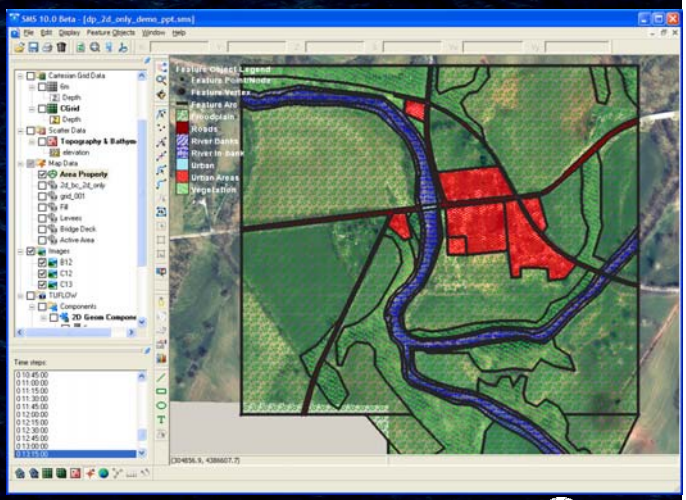
- Can use polygons to activate or deactivate areas of the 2D domain
- Reduces output file sizes
- Reduces run-time



19

2D Data Input Types
Land-use (Materials)

- Polygons of Land-use Categories (Materials)
- Each material
  - Manning's n
    - Fixed, or
    - Varies with Depth
  - Rainfall infiltration losses

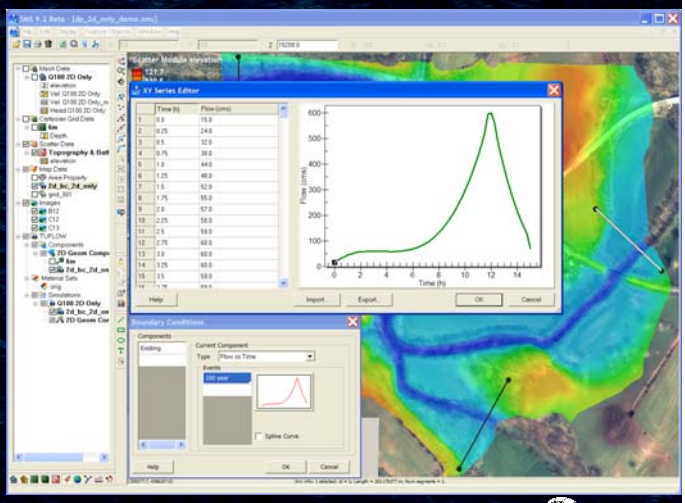


20

Copyright BMT WBM Pty Ltd

2D Data Input Types
Boundaries

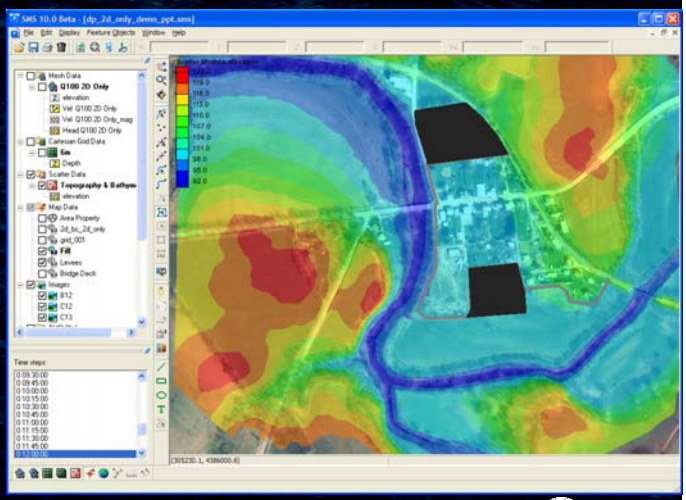
- Flow vs Time
  - Side Inflow
  - Area Inflow
- Water Level
  - vs Time
  - vs Discharge
- Direct Rainfall
- Flow vs h
- Z vs Time



21

2D Data Input Types
Geometry Modifications

- Embankments (Levees, Roads, Railways)
- Landfill
- Excavations
- Land-use

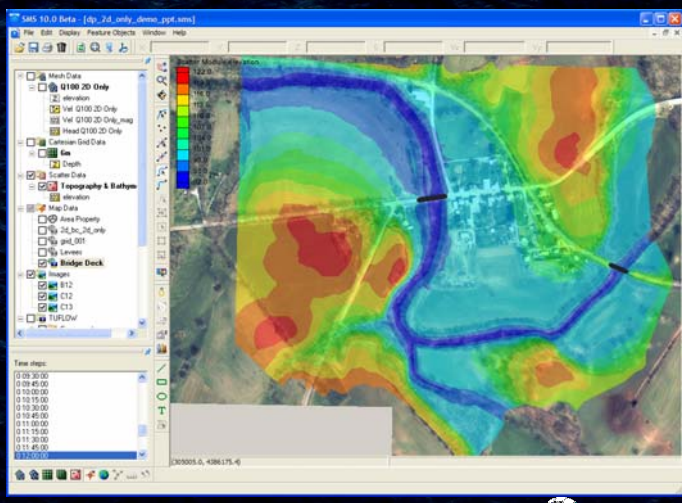


22

Copyright BMT WBM Pty Ltd

2D Data Input Types
Flow Constrictions

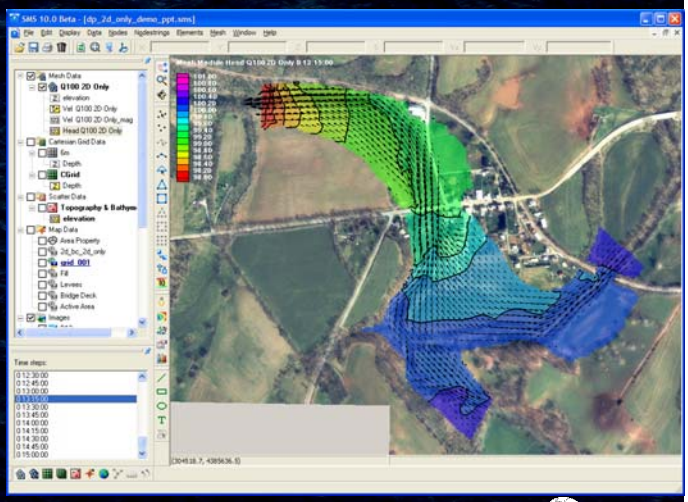
- Modify 2D cells
  - Soffit/Obvert
  - Adjust cell-side flow widths
  - Additional energy losses (eg. from piers)
  - Side wall friction (box culverts)
- Bridges
- Box Culverts
- Floating Decks



23

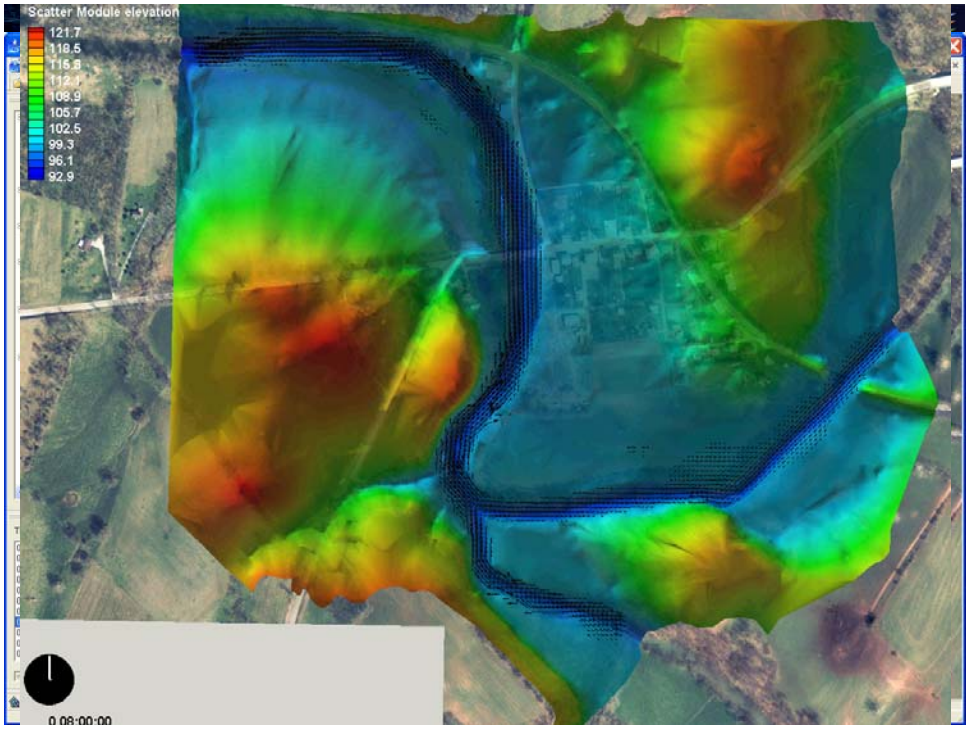
2D Data Output Types

- Water Levels (h)
- Velocities (V)
- Depths (d)
- Unit Flow (q)
- Several Hazard Categories (Zx)
- Energy (E)
- Froude No. (F)
- Flow Regime (R)
- Mass Error (MB1)
- and more...

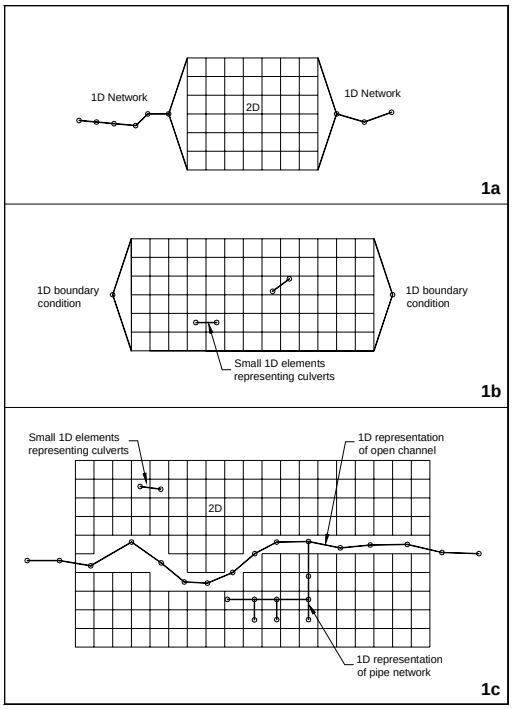


24

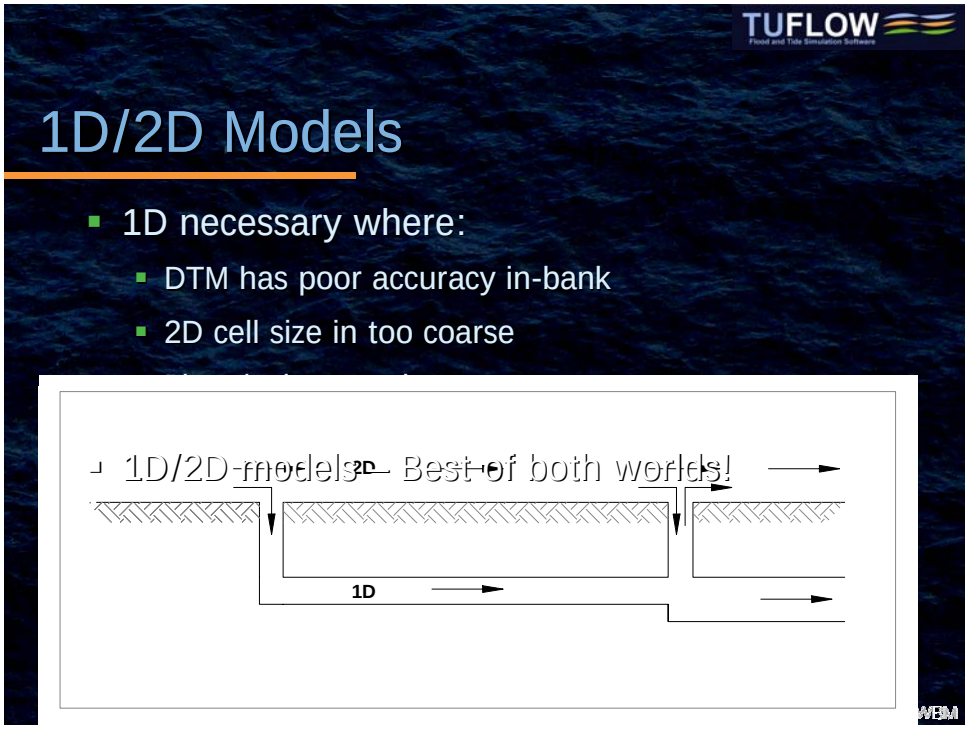
Copyright BMT WBM Pty Ltd

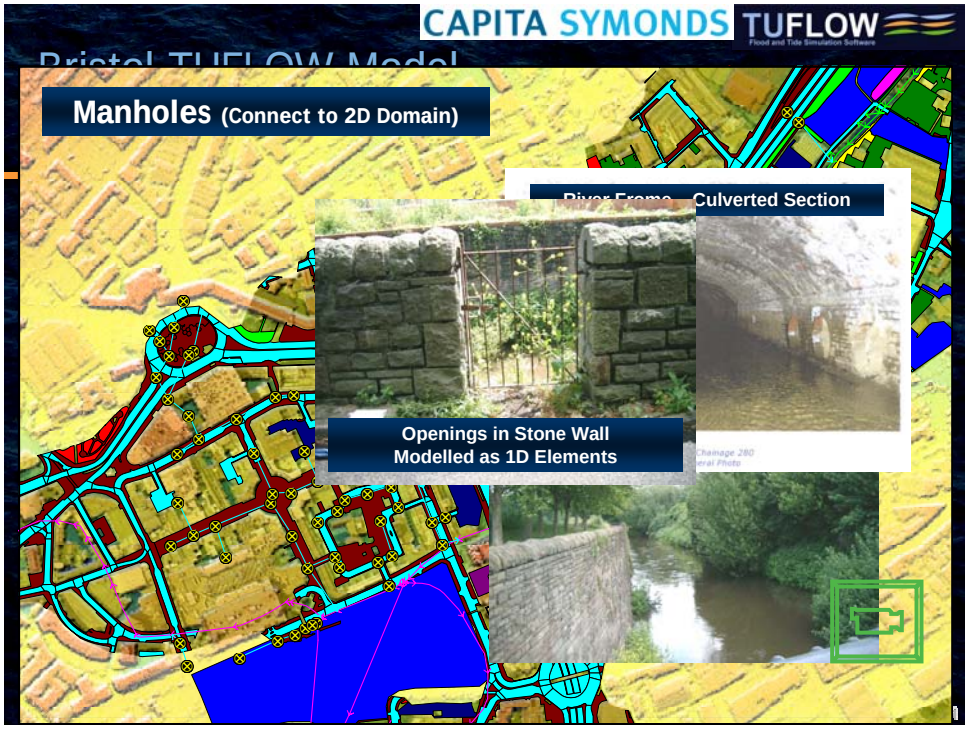


1D/2D Models



Copyright BMT WBM Pty Ltd





Copyright BMT WBM Pty Ltd

TUFLOW

ISIS Link

- ISIS dynamically linked with TUFLOW 2D
- ISIS (1D)
  - Between river banks
    (DTM poor and/or 2D grid too coarse)
  - Far-field
    (2D take too long to simulate)
- TUFLOW (2D)
  - Floodplains / Urban areas
- Value adds to existing investment in ISIS models

29

BMT WBM

Halcrow

Croston

Copyright BMT WBM Pty Ltd

Halcrow

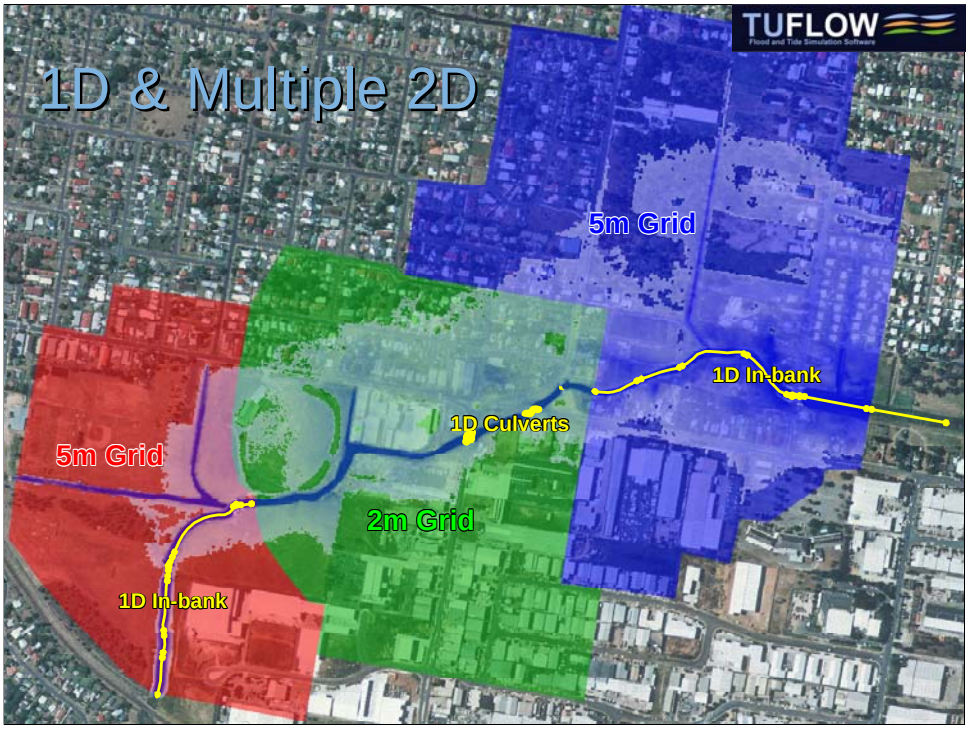
Cors Fochno

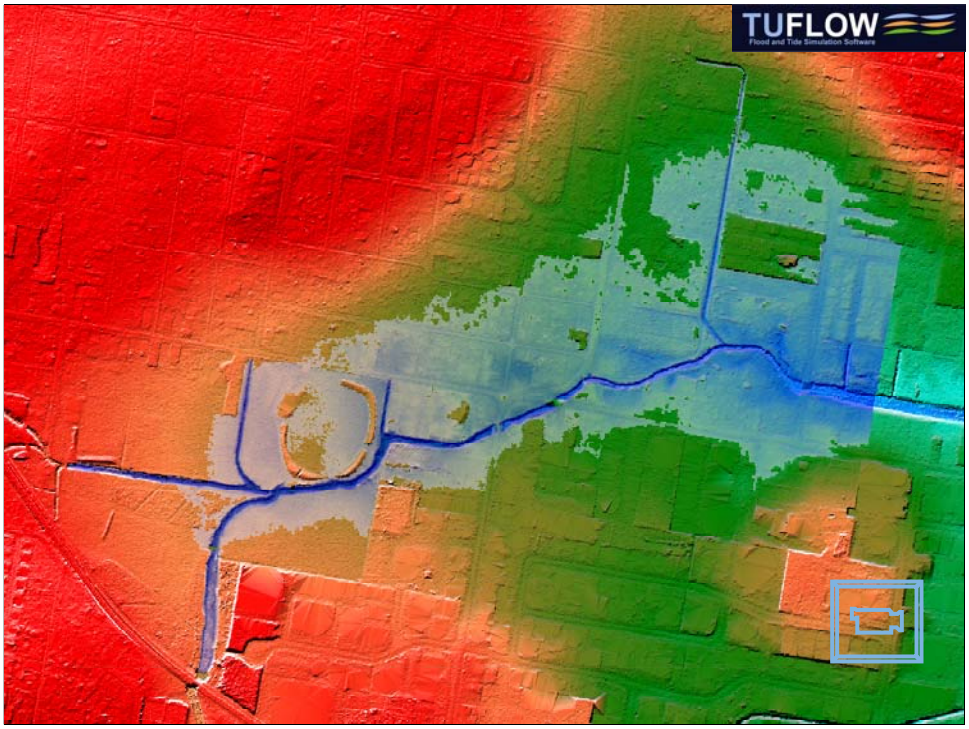
Multiple 2D Domains

- Allows variation in cell size
  (overcomes fixed cell size constraint)
- Can link any number of 2D domains
- No constraints on
  - Different cell sizes
  - Different orientations
  - Can link 2D-1D-2D or 2D-2D
- Grafton, Clarence River

32

Copyright BMT WBM Pty Ltd

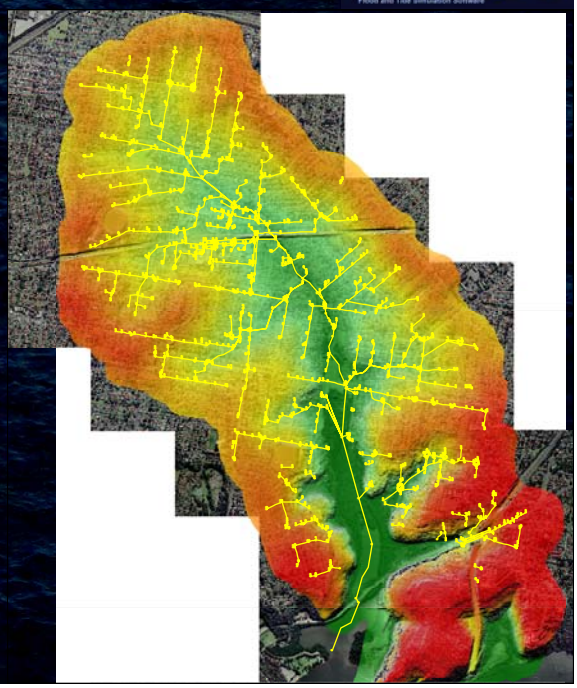




Copyright BMT WBM Pty Ltd

Direct Rainfall Modelling

- Replaces hydrologic modelling
- Trialled on urban catchments
- Developing field



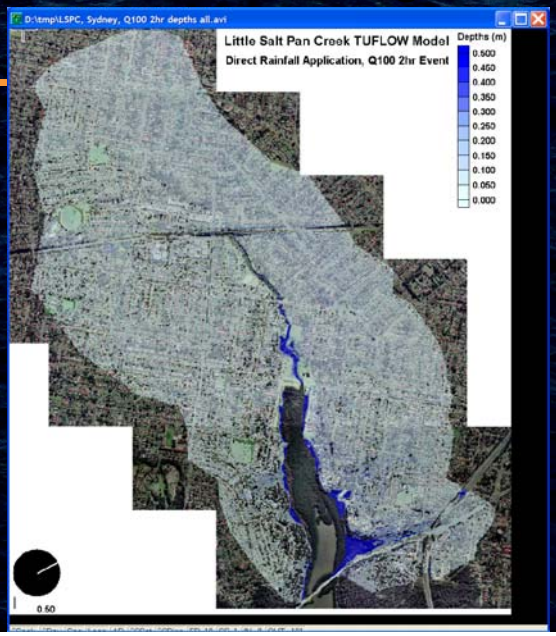
Closer View

- Pipes and Gully Traps
- Land-Use Categories
- Building Outlines

Copyright BMT WBM Pty Ltd

Direct Rainfall Modelling

TUFLOW

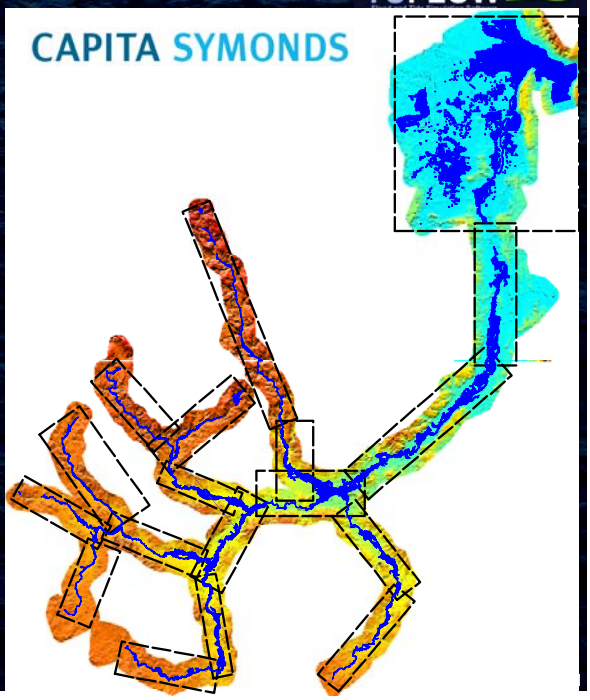


BMT WBM

Mega Models!

TUFLOW

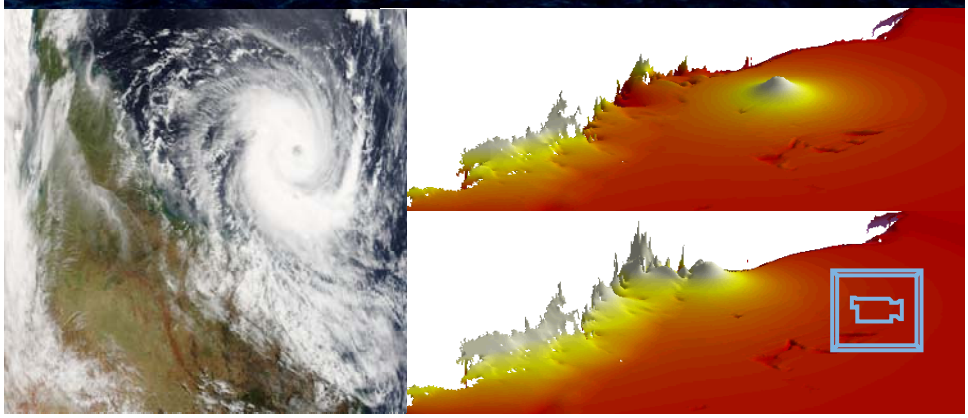
- River Trent
  - Third largest catchment in the UK
  - Catchment 10,000km^2
  - 150km in 1D
  - 25 2D Domains (15m to 200m)
  - 141 Inflow Hydrographs
  - 1.8Gb RAM
  - 1hr takes 0.4hr



Copyright BMT WBM Pty Ltd

Cyclone/Hurricane Modelling

- Storm Surge Inundation Studies



Flood Impact Assessments

Copyright BMT WBM Pty Ltd

Benchmarking

- Extensively benchmarked over the last 17 years to
  - Theoretical solutions and hypothetical models
  - Numerous calibrations to recorded flood behaviour
  - Comparisons with other models

41

Benchmarking to Theory

- 1991: My Thesis on TUFLOW
- 1998: Syme, et al – Comparison of 2D Software
- 2001: Barton – Flow Through an Abrupt Constriction
- 2001: Syme – Modelling of Bends and Hydraulic Structures
- 2004: Chris Huxley – TUFLOW Validation and Testing

42

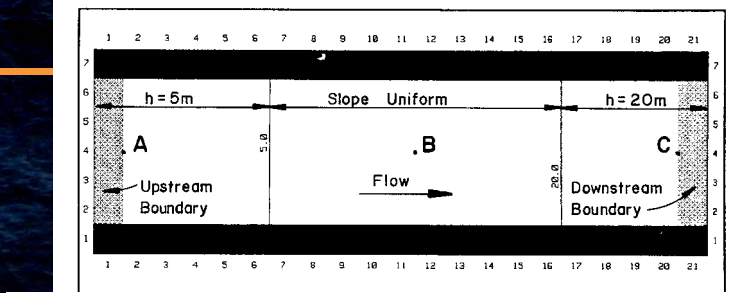
Copyright BMT WBM Pty Ltd

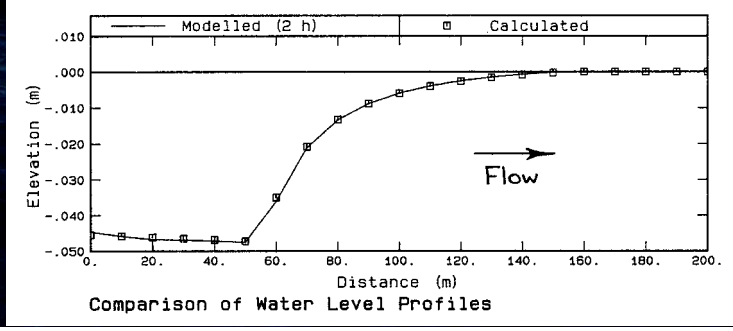
TUFLOW Thesis – Syme 1991

- Rigorous testing of 2D scheme
  - Bed Resistance
  - Inertia
  - Viscosity (Sub-grid turbulence)
  - Mass Balance
- Numerous tests with varying flow rates, timesteps, boundary conditions, etc

43

Inertia Term

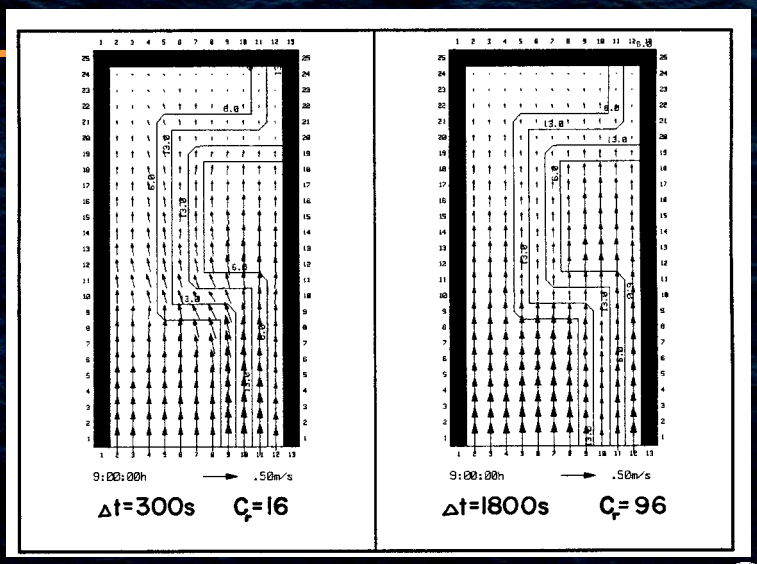




Comparison of Water Level Profiles

Copyright BMT WBM Pty Ltd

Courant Number



45

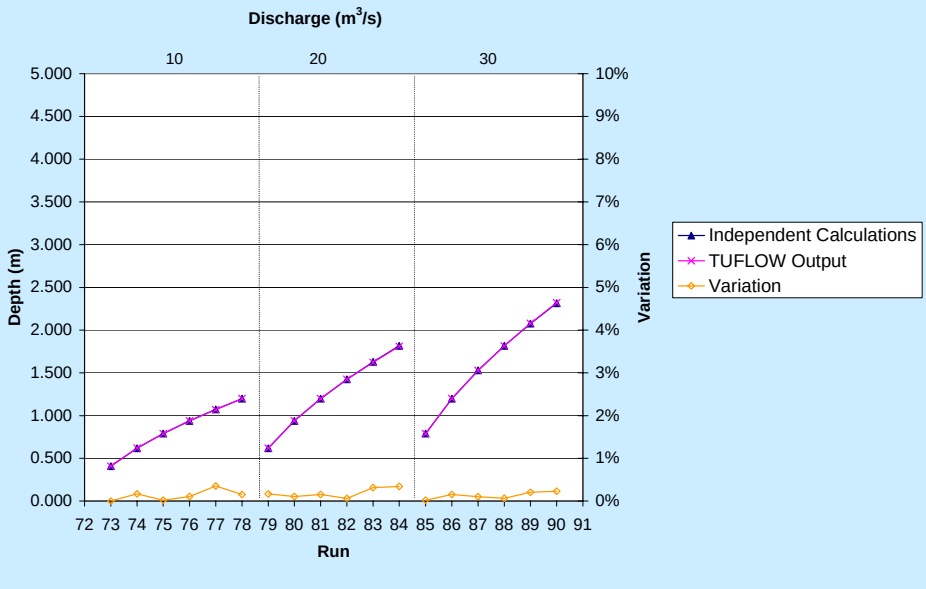
Huxley – TUFLOW Validation and Testing

- Hundreds of 1D and 2D Tests
  - Culvert Flow (10 regimes)
    (1.7% error cf nomographs)
  - BC Weir Flow
    (0.2% error cf theory)
  - Supercritical to Subcritical Flow
    (0.15% error cf theory)
- Probably holds record for number of TUFLOW runs in one day!

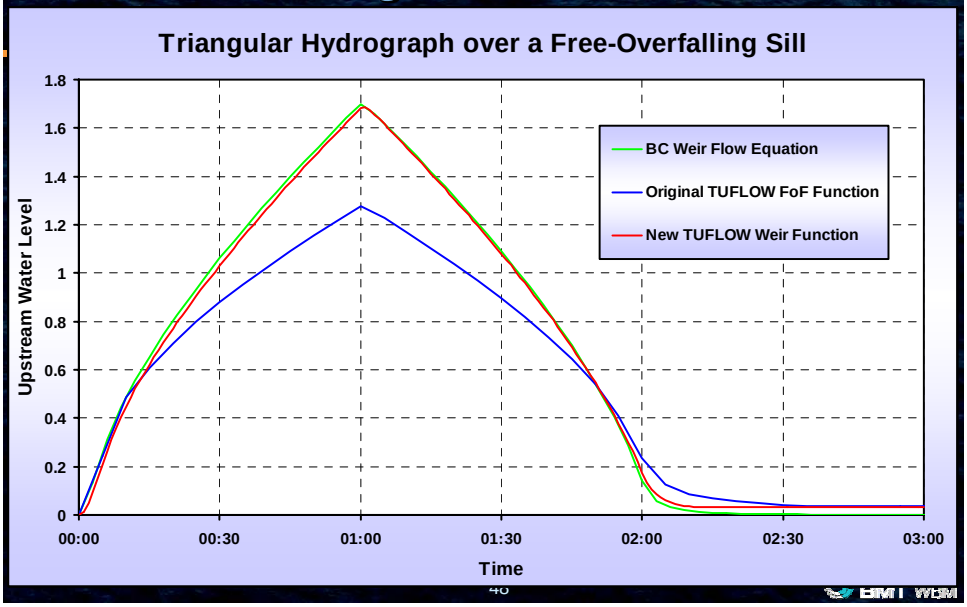
46

Copyright BMT WBM Pty Ltd

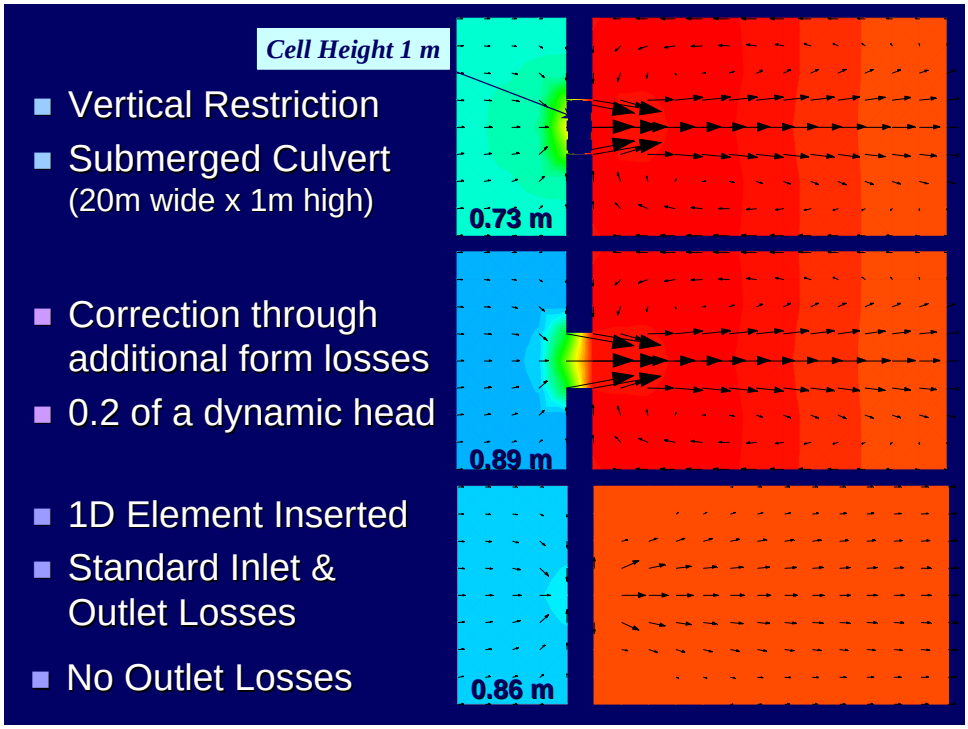
Huxley – TUFLOW Validation and Testing

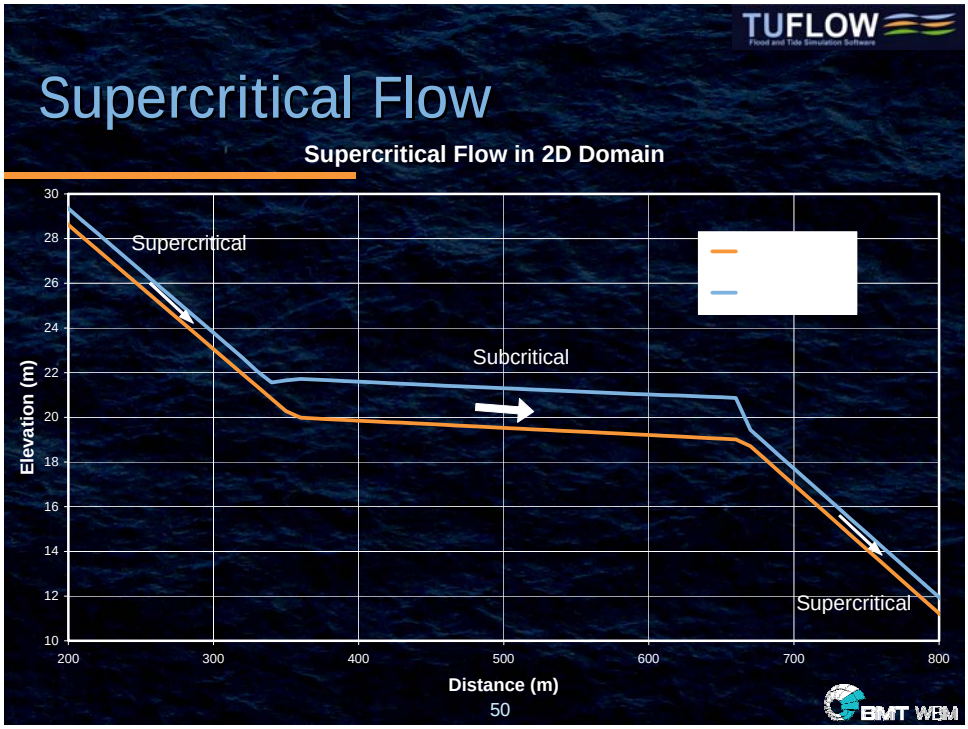


Benchmarking – 2D Weir Flow



Copyright BMT WBM Pty Ltd





Copyright BMT WBM Pty Ltd

Limitations

- Hydraulic jumps are not modelled, but the transition from supercritical to subcritical is
- At very small cell sizes (<1 to 2m), all 2D codes based on the SWE can give inaccurate results, especially where turbulence is important
  (this is the domain of CFD codes)
- 2D may look impressive and be closer to reality, but it's still not perfect
  – Modeller's still need to cast a critical eye

51

TUFLOW Interfaces

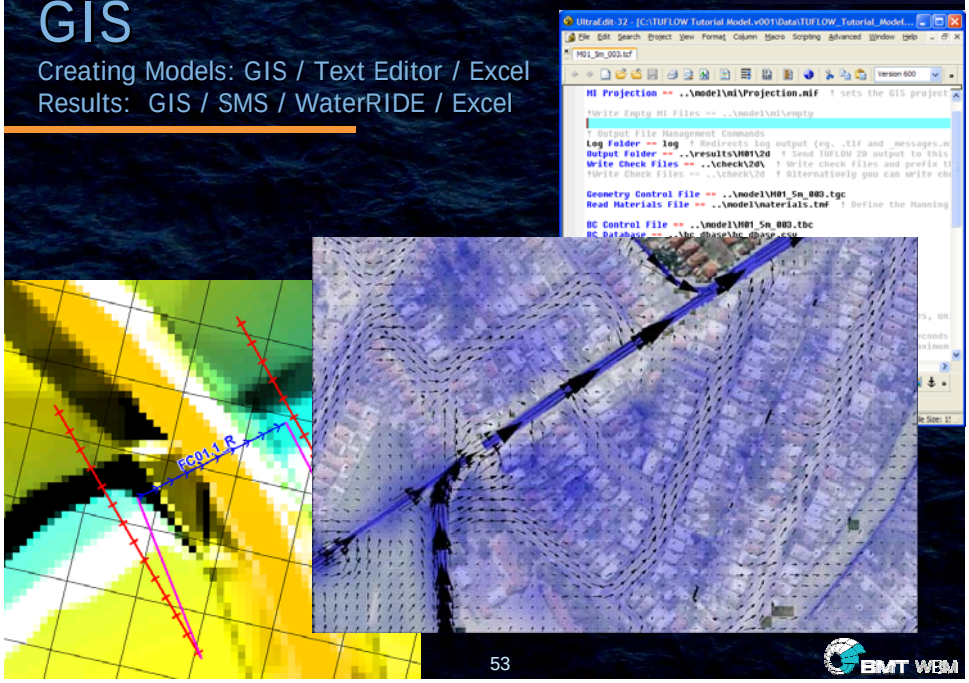
- TUFLOW is purely an "engine"
- Three Interface Options to the Engine
  - GIS
  - SMS TUFLOW Interface
  - XP-SWMM2D

52

Copyright BMT WBM Pty Ltd

GIS

Creating Models: GIS / Text Editor / Excel
Results: GIS / SMS / WaterRIDE / Excel



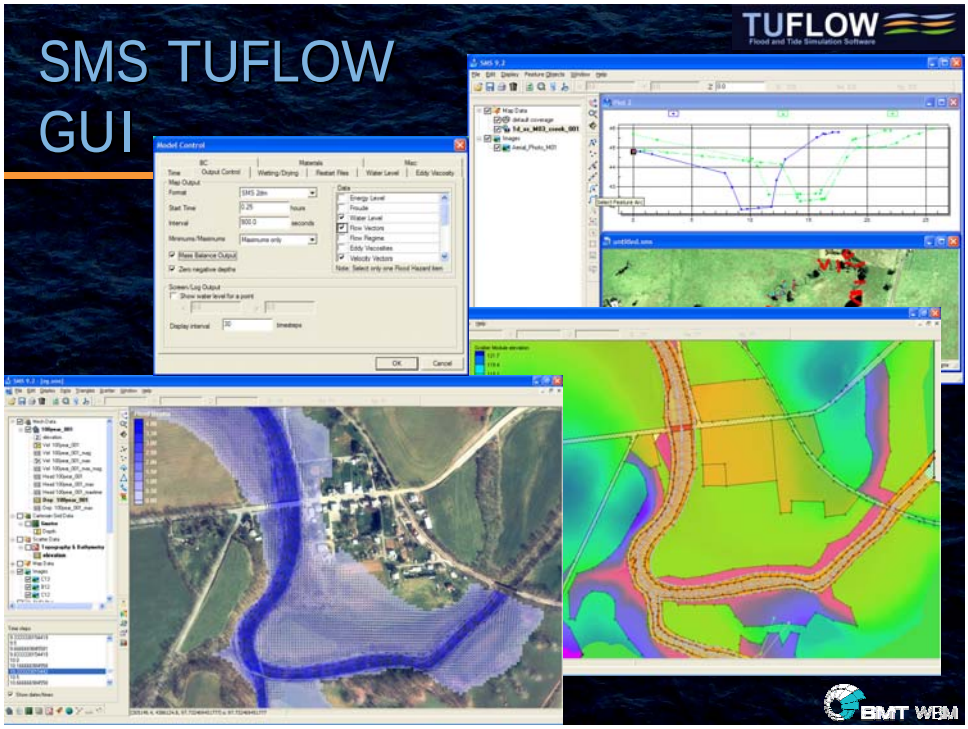
53

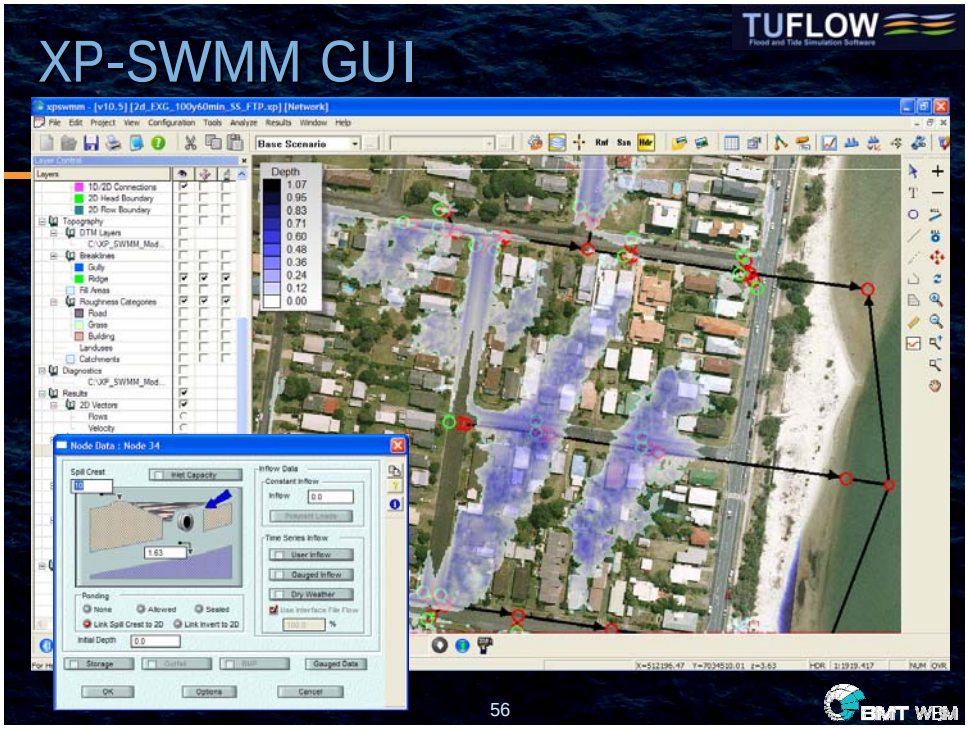
GIS Input Data Approach

- Layer upon layer upon layer
- For example:
  - Layer 1: DTM Ground Elevations
  - Layer 2: Road Crests as 3D Breaklines
  - Layer 3: Landfill polygons
  - Layer 4: Proposed Levee as 3D Breakline
- You do not have to modify the original data to make a change – you just override it with another layer.

54

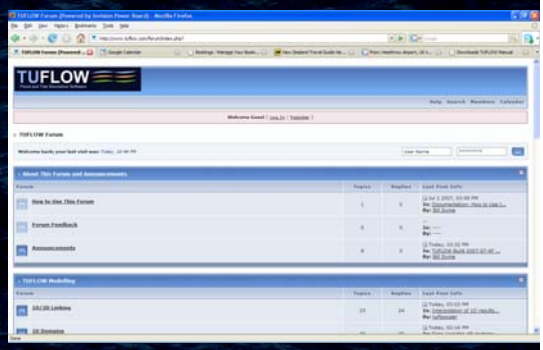
Copyright BMT WBM Pty Ltd





Copyright BMT WBM Pty Ltd

TUFLOW Forum



- Post and reply to topics
- Receive emails of TUFLOW updates and announcements
- www.tuflow.com\forum

57

Tutorial Model

- Useful for in-house training
- Can simulate model without a licence
- Presently designed for MapInfo/VM
- Version 1 covers TUFLOW fundamentals
- Download from www.tuflow.com

58

Copyright BMT WBM Pty Ltd

TUFLOW In Summary

- Successfully applied to:
  - Estuaries / Coastal Waters / Storm Surges
  - Major Rivers
  - Broad-scale models (River/Streams 1D; Floodplain 2D)
  - Urban Flooding (Overland 2D; Pipe Network 1D)
- 2D Linked with ISIS and XP-SWMM 1D Schemes
- GIS / SMS / XP-SWMM2D Interface Options
- Extensively benchmarked

59

Future Challenges

- To focus on the major uncertainties
  - Hydrologic flow estimates
  - DEM (LIDAR) data quality
  - Calibration data and calibration of models
  - Training and mentoring of modellers
- Proven hydraulic modelling software is not a major uncertainty if correctly and appropriately applied

61

Copyright BMT WBM Pty Ltd

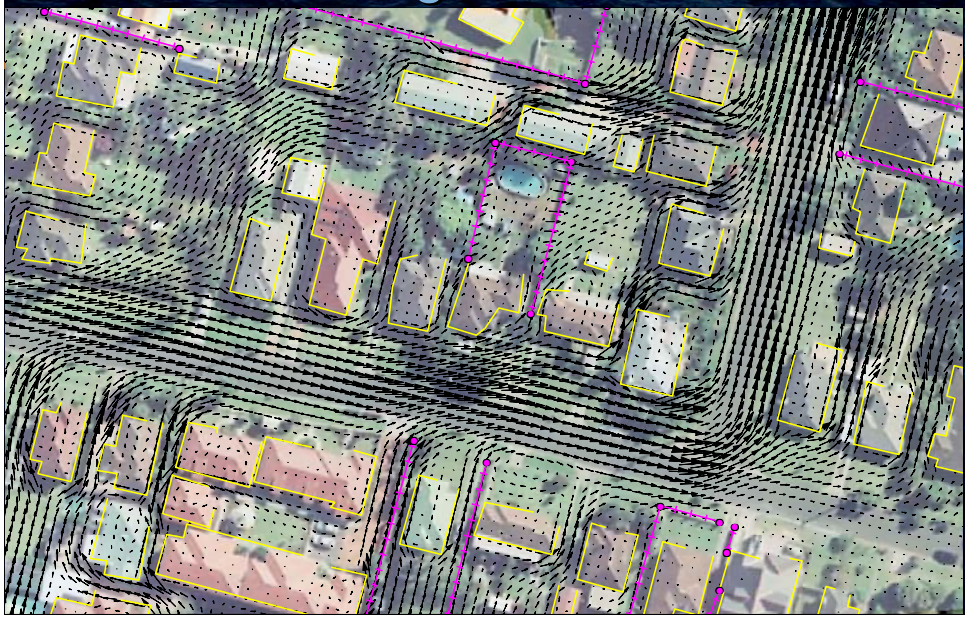
Future Challenges
Understand Applicability of "2D" Software

- Raster routing
- Simplified "Full" Momentum
  (excludes turbulence and some other terms)
- Full Momentum
  (TUFLOW)

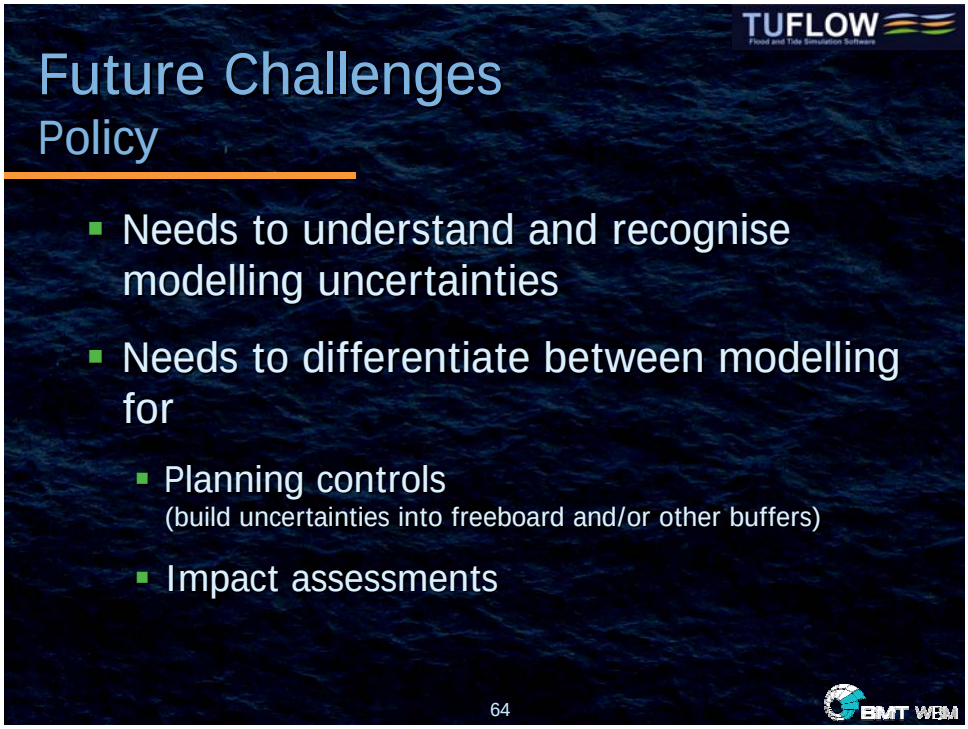
Increasing Range of Application

62

Future Challenges – Urban Areas



Copyright BMT WBM Pty Ltd



Copyright BMT WBM Pty Ltd