Developing Skills in TUFLOW

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Workshop topics

1. Conceptualisation and schematisation in model building:
   - Aims and objectives, project constraints
   - Model suitability
   - Model stability
   - Grid sizing, model extent, boundary locations
   - Simulation times (timestepping, data output)
2. Schematisation of TUFLOW boundary conditions
   - Types of boundary
   - 1D-2D linking (high level)
   - Linkage to structures in the 1D domain

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Conceptualisation and schematisation

- Establish clear aims and objectives for your modelling study
- Establish project budget (potentially impacts upon available time & data)
- Develop an understanding of the study area hydraulics, with specific reference to study aims & objectives
- What data is available?
- Define areas to be modelled and approach to representing the relevant hydraulics in these areas
- Simulation considerations (timing, number of simulations, available hardware)
- Justify your chosen approach

- Giving the above some thought at project startup is time well spent!

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Define aims and objectives

- Why has the study been commissioned? (Strategic level model, model requested to address concerns at a specific location, site specific FRA, update to FWA / ABD studies etc.)
- What are the required outputs?
  - Flood extents
  - Hazard / depth / velocity mapping
  - Visualisation of flooding
  - Timing of inundation
  - Impact comparisons
- Be an intelligent modeller. Can the model do more? Where can we add value?

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Study area hydraulics

- Visit the study area (if at all possible)
- Research observed relevant mechanisms of flooding
- Refer to past studies, maps, LiDAR and other topographic datasets, aerial photography etc.
- Understand the relevance of study reach hydraulics to your specific study aims

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Available data

- Previous modelling studies (BEWARE of legacy issues!). Check calibration / sensitivity / sensibility.
- Topographic data (extent):
  - LiDAR DTM
  - Topographic surveys – sites, defences, key obstructions to flow
  - DTMs from other sources – vertical accuracy?
- Mapping data (OS MasterMap or other mapping in UK, aerial photography)

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Define approach: 2D domain extent

- Domain extent – establish suitable boundary locations for the model
- Must capture all relevant hydraulics
- These will be influenced by:
  - Data constraints
  - Locations which suitably capture hydraulics
  - Number of wet cells in simulation / simulation times
- 1D-2D linking provides flexibility in location of boundaries
- Move uncertainty away from areas of interest

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Define approach: 1D - 2D linking

- 1D approaches may be better suited to representing clearly defined flow paths
- Check for available data and relevant flow routes
- 1D-2D linking allows boundaries to be moved upstream and downstream without significant impact on simulation times

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Define approach: 2D grid sizing

- Grid should be suitably sized so as to effectively represent key mechanisms of flooding
- Aim for 3-4 cells across major flow paths
- Must result in a workable simulation time (halving 2D cell size typically increases simulation time by a factor of eight - four times as many cells & half the timestep).
- TUFLOW model builds are independent of grid size, so coarser grids can be used during model build before using the final grid size on final design simulations

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Simulation Considerations

- Model schematisation is important not only in capturing mechanisms of flooding, but also in:
  - Stability of model
  - Workable simulation times
  - Delivery of project (timescales!)
- Again, giving the above some thought at the beginning of projects is time well spent!

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Simulation times and stability

- TUFLOW offers an implicit solution of the full 2D free-surface wave equations
- Solver based on the Stelling finite difference, alternating direction implicit (ADI) scheme
- Courant number is a measure of stability
- 2D implicit schemes stable when Courant numbers B 10 (typically ~ 5)
- Examples - timestep 5 secs, grid 10m:
  - Depth 1m, Courant number = 2.2
  - Depth 5m, Courant number = 5.0
- 2D timestep as a rule of thumb should be between half to a quarter of grid size

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Simulation times and stability

- Time for simulation to complete depends on:
  - Timestep
  - Number of wet cells
  - Storm duration
  - Computer speed
  - Frequency of writing output (and size of output files)
- Bear in mind:
  - Number of simulations required
  - Project timescales

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Simulation times and stability

- AVOID the temptation to 'fix' an unstable model by reducing the timestep
- If the Courant numbers are reasonable, instability is unlikely to be a timestep issue
- Review 2D Courant numbers in _Cr.dat file (as of build 2008-08-AA) – specify as output in *.tcf or *.trd file
- Reducing timestep can increase run times substantially, so…
- Investigate the reason for instability (poor input data, schematisation errors etc.)
- If model is operating at high Courant numbers, run simulations assessing the sensitivity of model output to smaller timesteps
- Watch out for high MB errors as an indicator of too high a timestep (console window / *.tlf/) – aim for ±10% - output to _MB.csv files

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Simulation Considerations

- Simulation times can be LONG and will impact upon project delivery
- Ideal run times:
  - 2 to 3 hours, allows for review of 3 simulations per day, per core
  - 6 to 7 hours – time for review of 2 simulations per day, per core
  - > 7 hours – all day / overnight simulation – review of one simulation per day, per core

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Model Output

- Model outputs specified in the TUFLOW control file (*.tcf / *.trd)
- Example output types:
  - Water level, hazard, velocity, flow, depth
- Frequency of output impacts upon simulation times (dependant on destination folder)
- Frequency of output also influences output file size
  - Large output files may soon fill up hard drive and server space
  - Difficult to share

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Justify your approach

- Recap
- Justify your chosen approach in relation to:
  - Modelling study aims and objectives
  - Project budget (can this be used as justification?)
  - Study area hydraulics and perceived mechanisms of flooding
  - Available data
  - Simulation considerations
- Demonstrate that a considered approach has been taken to modelling

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Justify – (repeat slide) Link back to:

- Establish clear aims and objectives for your modelling study
- Establish project budget (potentially impacts upon time & data)
- Understand the hydraulics in the study area, with specific reference to study aims & objectives
- Available data
- Define areas to be modelled and approach to representing the relevant hydraulics in these areas
- Simulation considerations
- Justify your chosen approach
- Giving the above some thought at the beginning of projects is time well spent!

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Example: Boundary conditions

- Boundary conditions and links to 1D and 2D domains are applied through 2d_bc GIS layers
- Boundaries can be:
  - Water level - 2D – 2D to 2D linking, HS (Tidal water level), HQ (head v flow), HT (head v time), HX (Head from an eXternal source)
  - Flows – QT (flow v time), QC (constant flow), VC (constant velocity), VT (velocity v time),
  - Sources – RF (rainfall v time), SA (rainfall/flow v time over a specified area), SH (flows v head, pumps/abs), ST (Flow v time), SX (source from a linked 1D domain)
- Boundaries may be applied directly to the 2D domain, or may involve 1D-2D linking

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1D-2D Linking

- Two modes of linking:
  - Level / HX
    - 1D domain sends levels to the 2D domain
    - 2D domain sends flows back
- Flow / SX
  - 1D domain sends flow to 2D domain
  - 2D domain sends levels back

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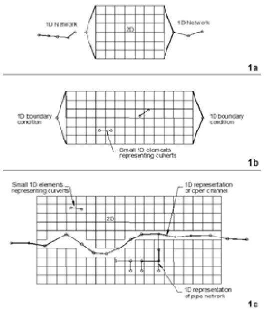
1D-2D Linking

- Both can be used inline, embedded or laterally
- Inline – usual configuration is SX US boundary and HX DS boundary
- Embedded – SX boundary link usually applied
- Lateral – HX or SX appropriate, depending on bank / floodplain geometry



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Linkage to structures in the 1D domain – structure decks

- Common cause of problems in model reviews
- Focus on linking structure decks represented in 2D domain to 1D domain (although representing decks in 1D domain as weir/spill unit is also valid)
- Approach:
  - 2D cells represent topography of structure deck i.e. Road
  - 2D cells must be linked to the upstream and downstream faces of structure (HX boundary), with appropriate elevations applied (3D breaklines / Z shape layers)
  - Important bank elevations upstream and downstream are also correctly applied

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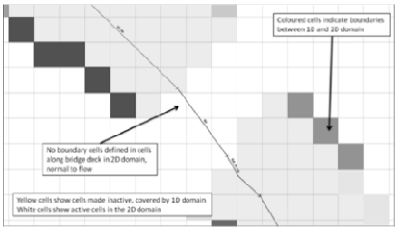
Linkage to structures in the 1D domain – bridge decks



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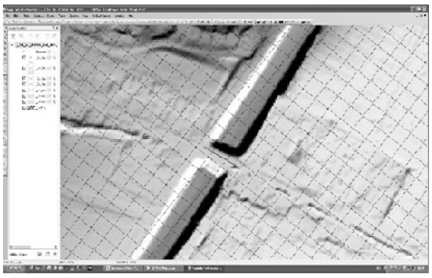
ESTRY Culvert Example



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ESTRY Culvert Example

- Common error is 2D boundary width
- Culvert modelled in ESTRY (1d_nwk layer)
- Linked to 2D domain using SX boundary (designated by SX point in 2d_bc layer)
- Cell size = 20m
- Structure width comparable or less than cell size, therefore 1 cell selected as boundary is suitable
- Cell size selected must be comparable to structure geometry
- In this example, should structure be 40m width, 2 cells should be highlighted as boundary cells

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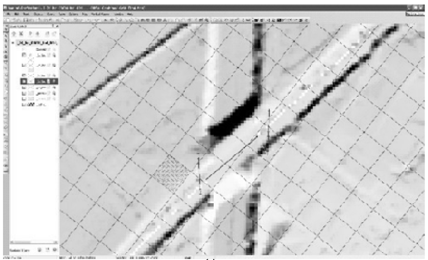
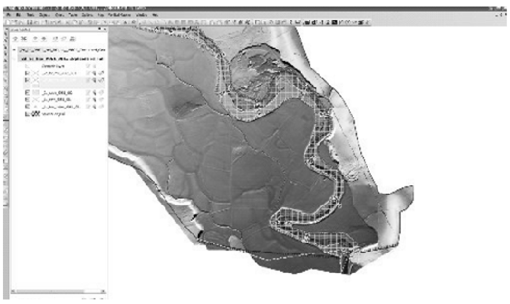
ESTRY Culvert Example



1D-2D Downstream Boundary Example

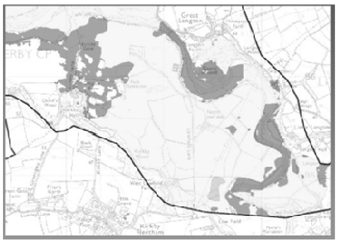
- Example DS boundary error (surprisingly common)
- 1D-2D linked reach
- 1D domain represented in ISIS, linked to 2D domain via HX and CN lines in 2d_bc layer
- DS boundary incorporates HX line along width of the floodplain linked to 1D domain ‘collecting’ flow from the 2D domain into the continuing 1D domain

1D-2D Downstream Boundary Example



1D-2D Downstream Boundary Example

- Baseline and proposed events modelled showing inclusion of new bridge structure US in model reach
- Outputs show significant variation between 1000yr design event simulations
- (Yellow indicates up to 0.25m increase in peak level 3km DS of bridge
- Does this look right?



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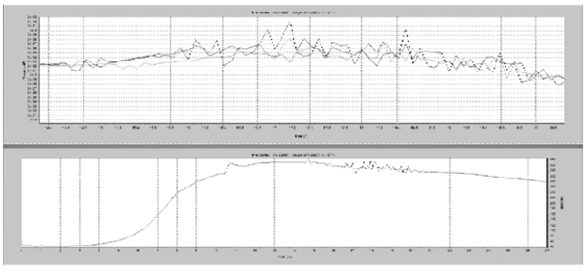
1D-2D Downstream Boundary Example



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Any Questions?

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