Rapid and Accurate Flood Modeling Fully 2D GPU Solver

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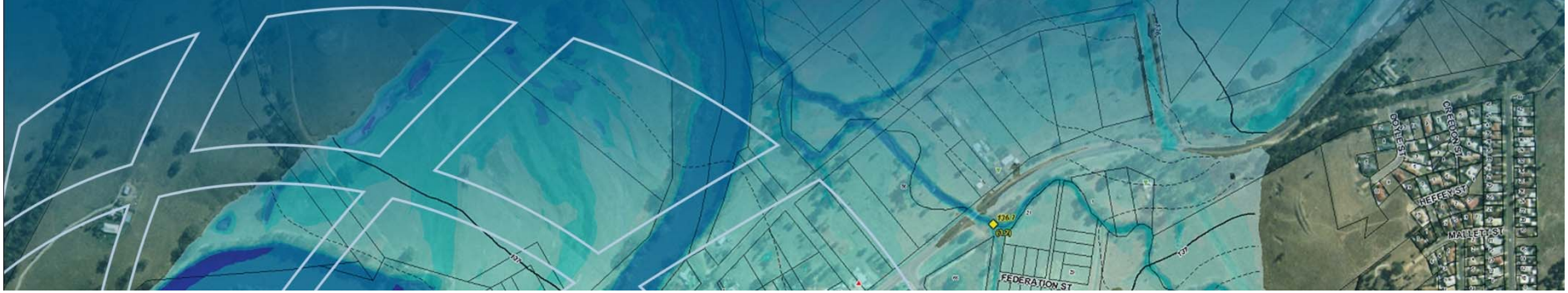
Bill Syme
Greg Collecutt
Phillip Ryan

BMT WBM

TUFLOW

What is a GPU?

- Graphics card Processing Unit
- New cards have over 1,000 cores
- Cores are slower than CPU cores
- Up to 6 Gb on-board memory

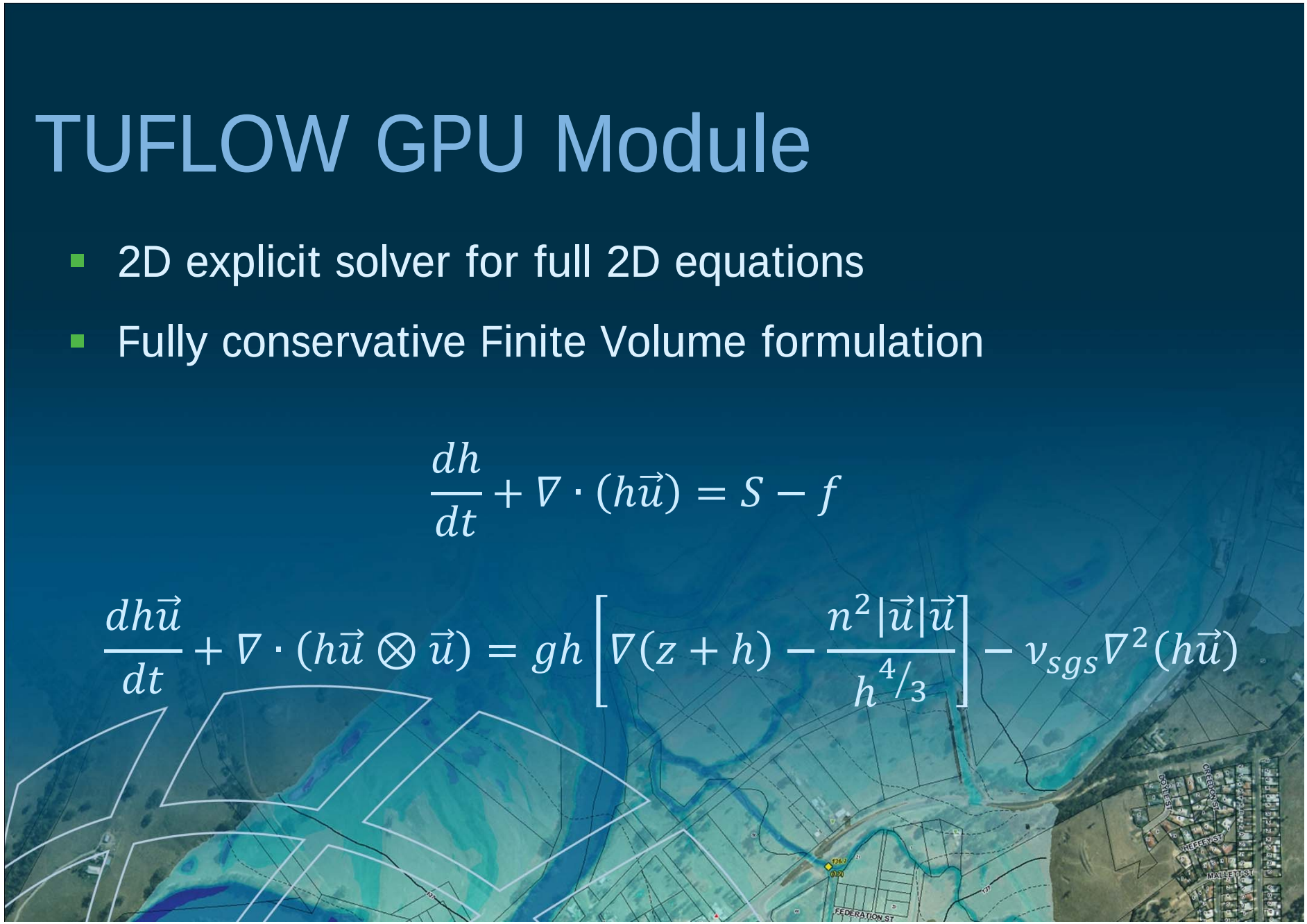


TUFLOW GPU Module

- 2D explicit solver for full 2D equations
- Fully conservative Finite Volume formulation

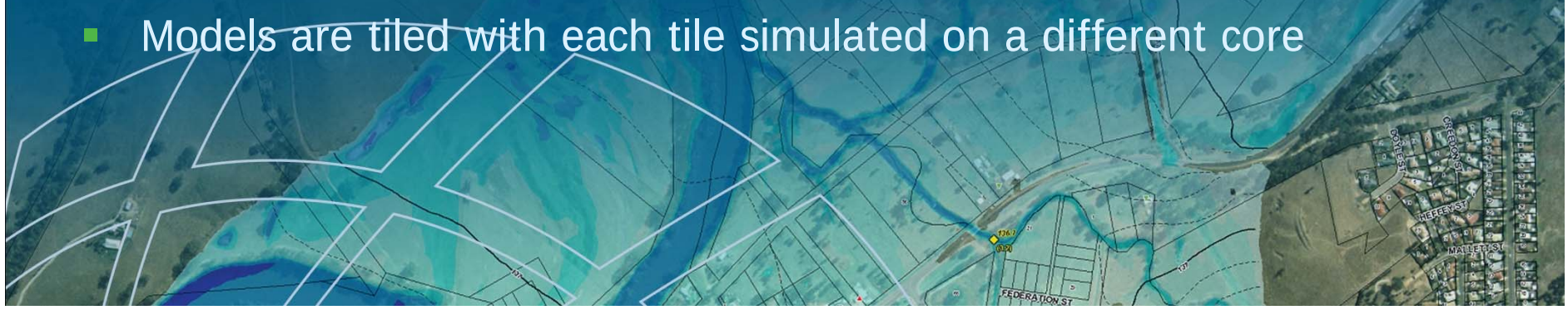
$$\frac{dh}{dt} + \nabla \cdot (h\vec{u}) = S - f$$

$$\frac{dh\vec{u}}{dt} + \nabla \cdot (h\vec{u} \otimes \vec{u}) = gh\left[\nabla(z+h) - \frac{n^2|\vec{u}|\vec{u}}{h^{4/3}}\right] - \nu_{sgs}\nabla^2(h\vec{u})$$



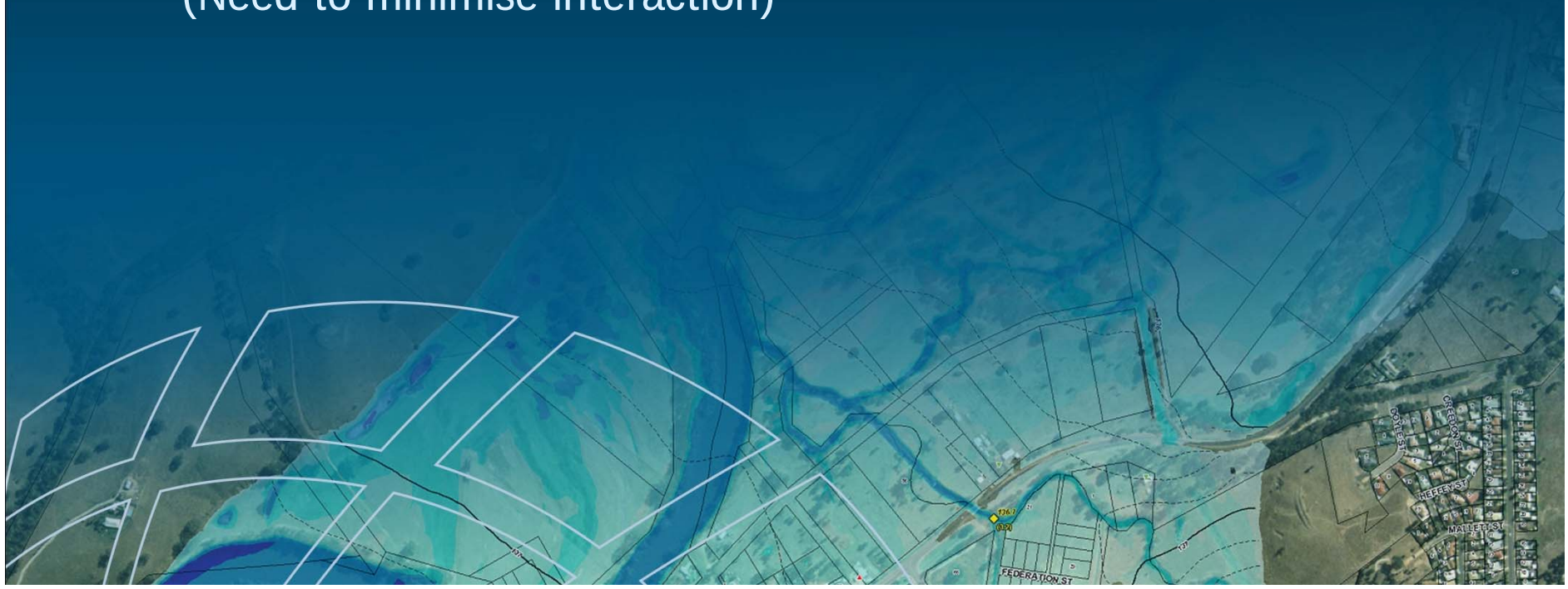
TUFLOW GPU Module

- ODE solver up to 4th order in time
- Mass and momentum conserving to numerical precision
- Unconditionally stable adaptive time step
- Smagorinsky sub-grid-scale eddy viscosity
- nVidia CUDA implementation
- 75 million cell models possible on current GPUs
  (Current GPU memory limitation)
- Models are tiled with each tile simulated on a different core

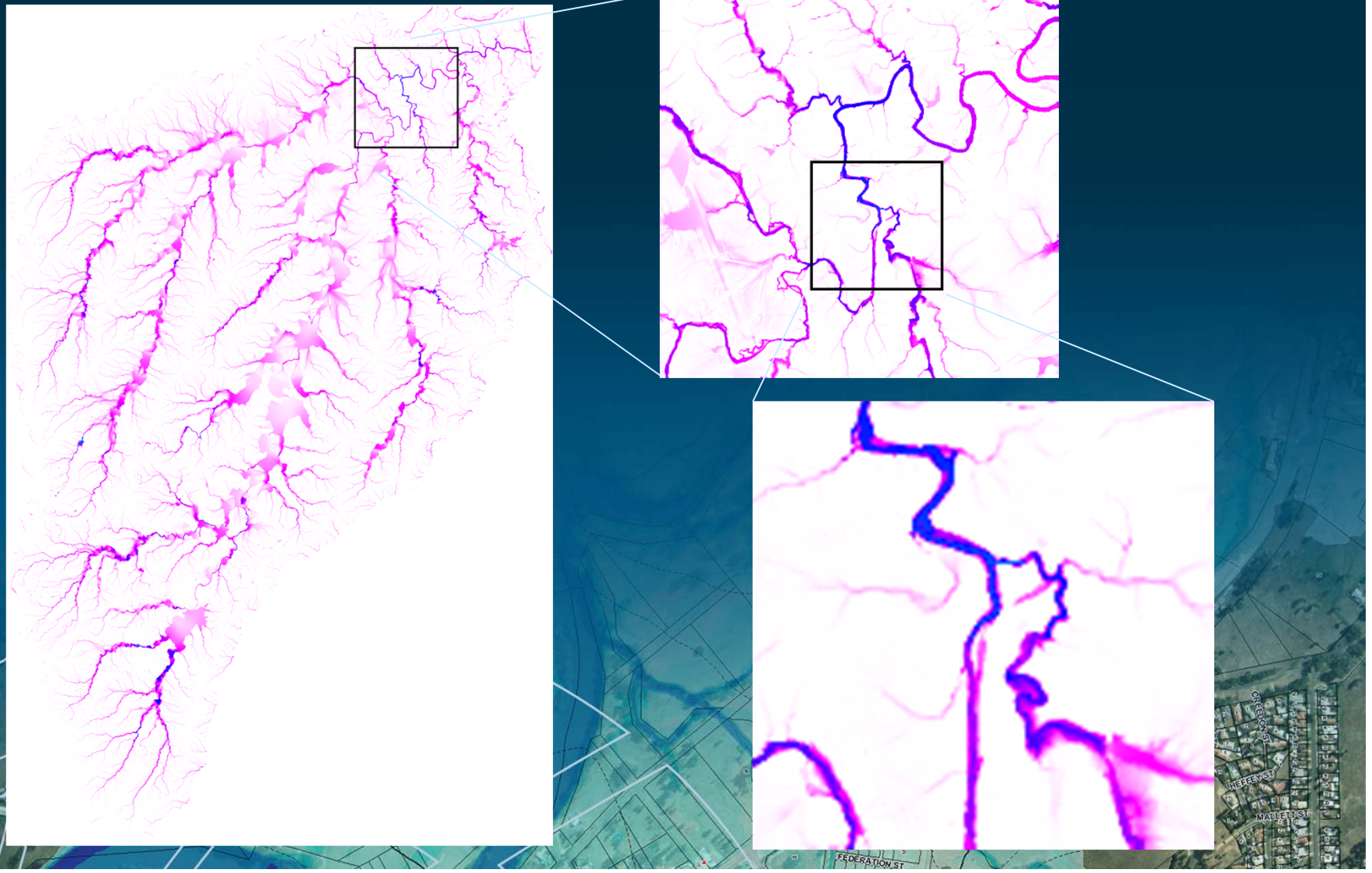


GPU Solver Integration into TUFLOW

- TUFLOW does all the pre-processing and writing of output
- Push model on to the graphics card
- TUFLOW and GPU only communicate when writing map output (Need to minimise interaction)

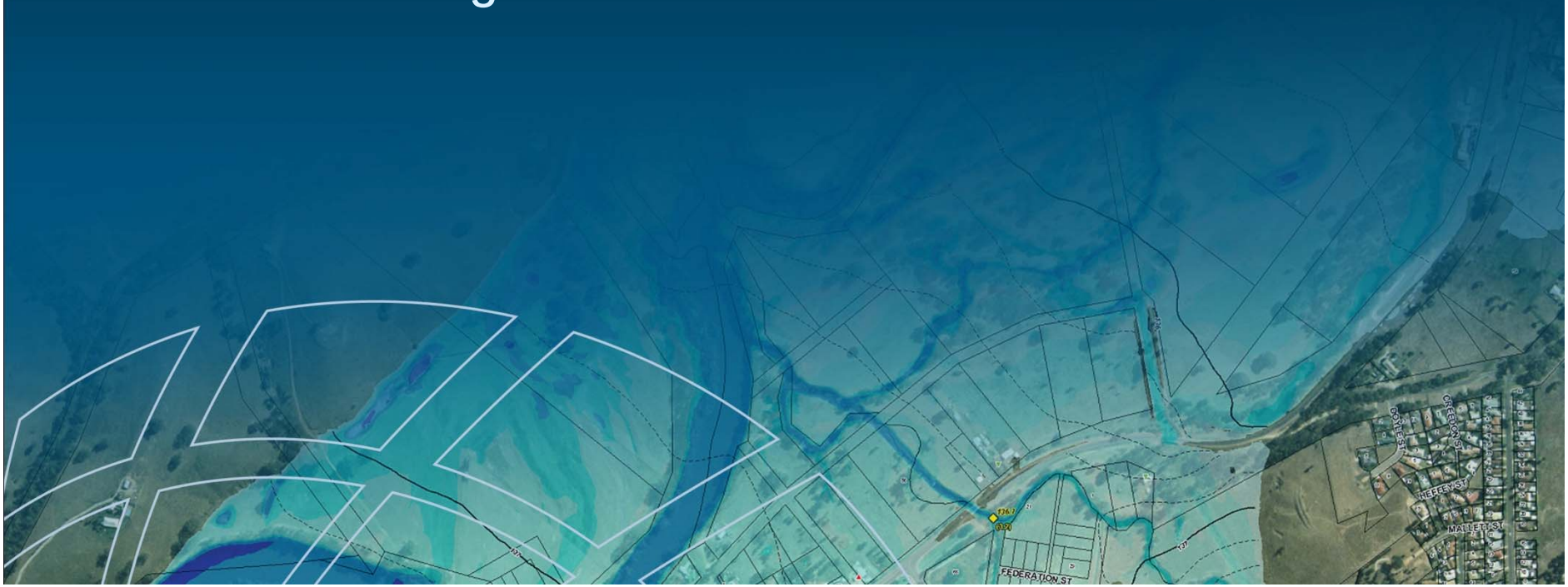


TUFLOW GPU 10m Cell Model



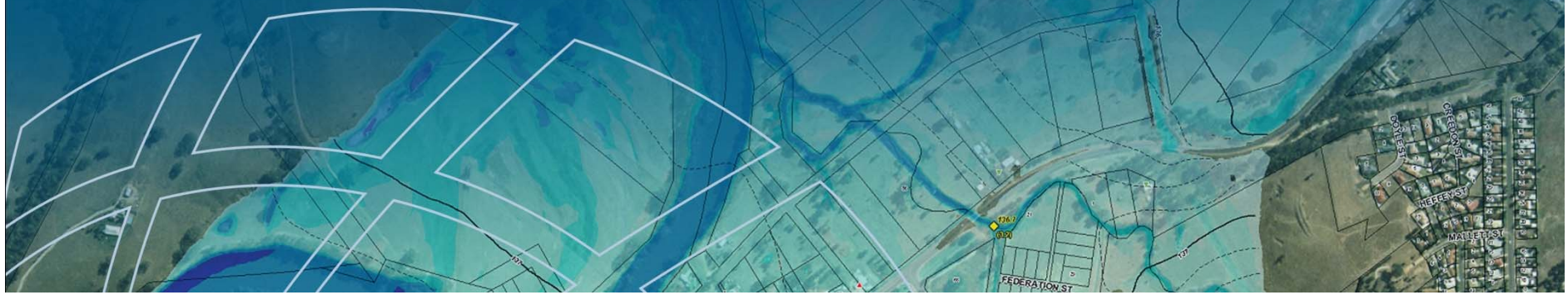
Benchmarking

- Verification testing
- UK EA 2D Benchmarking
- FMA Challenge 2



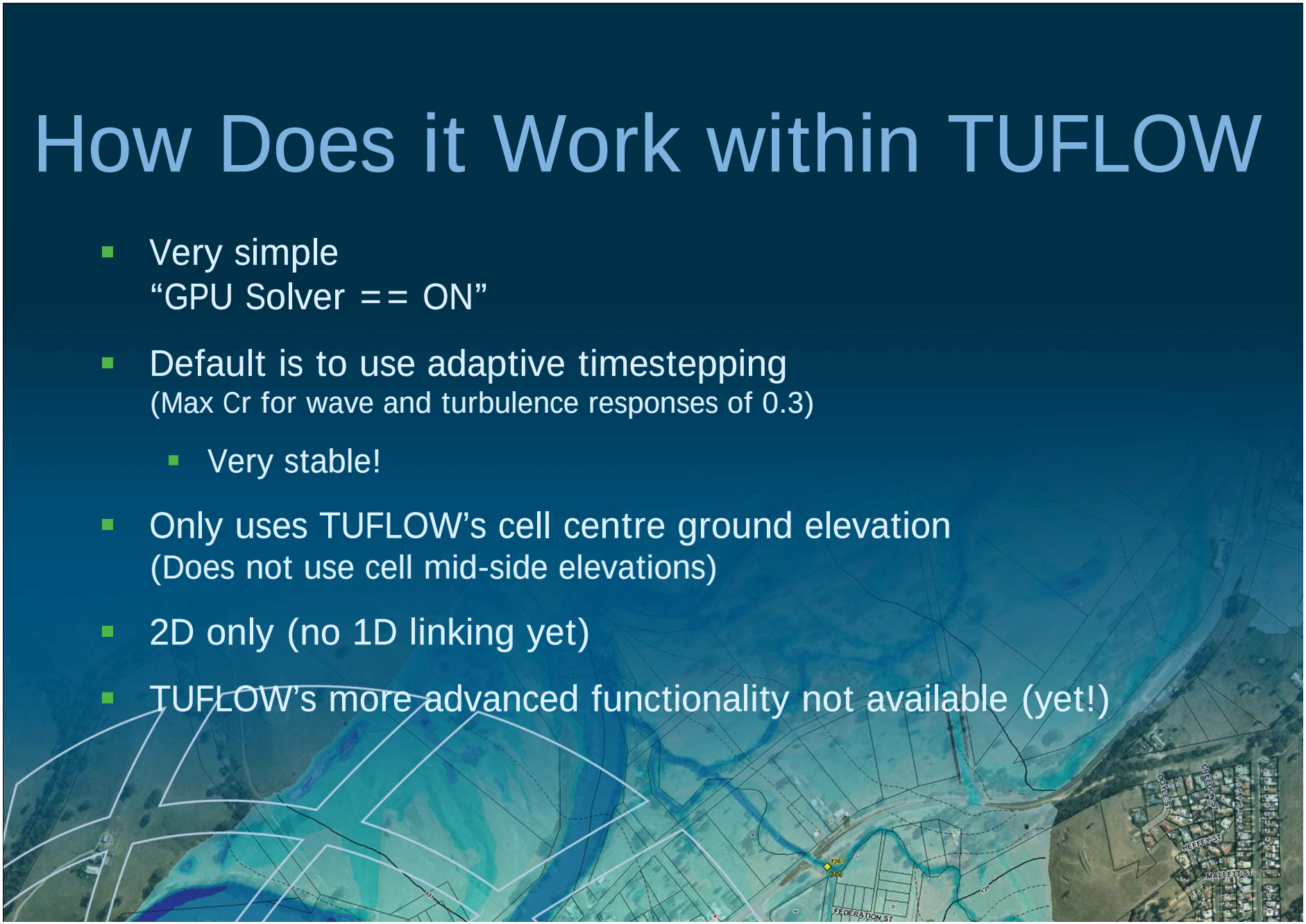
2012 UK EA 2D Benchmarking

- Update to the 2010 benchmarking
- Submissions closed
- Due to be released later this year
- TUFLOW GPU Module submitted along with TUFLOW and TUFLOW FV
- Performed well



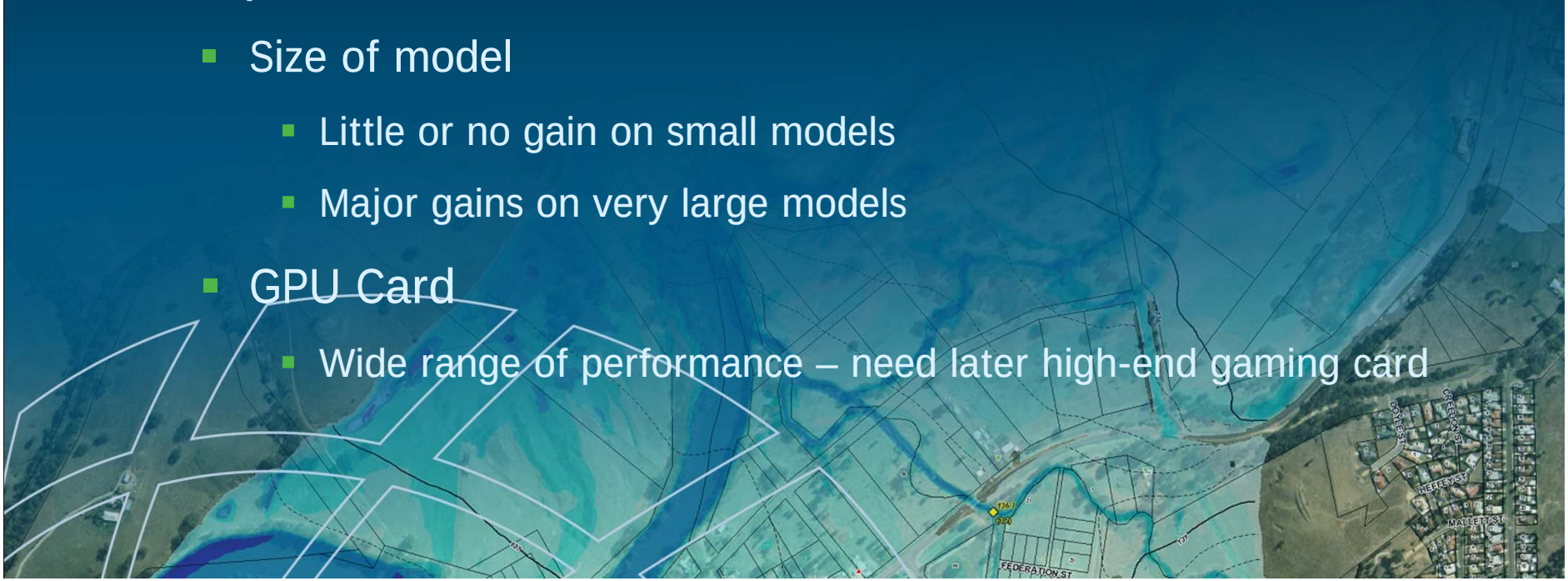
How Does it Work within TUFLOW

- Very simple
  "GPU Solver == ON"
- Default is to use adaptive timestepping
  (Max Cr for wave and turbulence responses of 0.3)
  - Very stable!
- Only uses TUFLOW's cell centre ground elevation
  (Does not use cell mid-side elevations)
- 2D only (no 1D linking yet)
- TUFLOW's more advanced functionality not available (yet!)



Run-times Compared with CPU

- From <1 to 100 times faster
- Typically 10 to 30 times for large models on top end GPU
- Depends on:
  - Size of model
    - Little or no gain on small models
    - Major gains on very large models
  - GPU Card
    - Wide range of performance – need later high-end gaming card



Run-Times GPU Cards

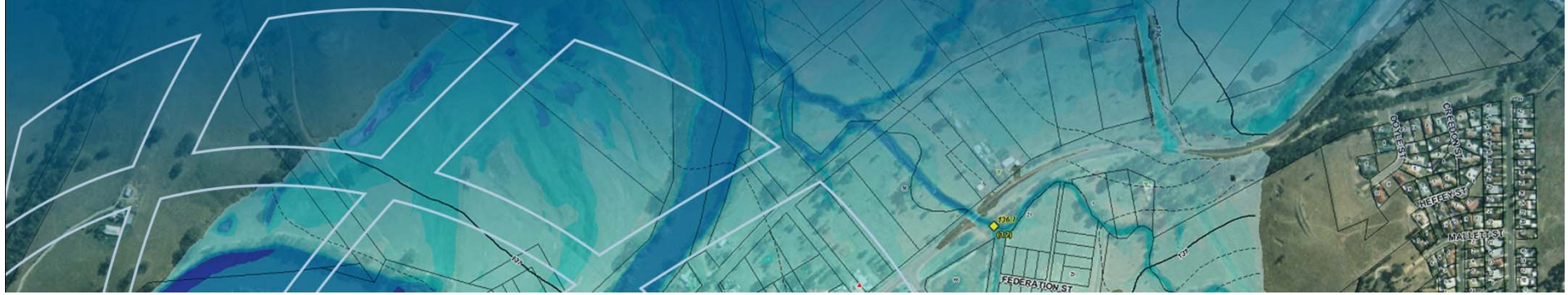
Card	Time (hours:min:sec)
GeForce GTX 680 (overclocked to ~1260MHz)	0:15:55
GeForce GTX 690	0:18:51
Tesla C2075	0:27:50
GeForce GTX 670	0:28:56
NVS 5200M	2:43:04
Nvidia Quadro 600	2:49:39
GeForce GT 220	3:08:53

FMA Challenge 2

2D Model	Typical Run time (dd:hh:mm:ss)	CPU Cores Used / GPU
TUFLOW 15m Grid 791,000 cells with 323,000 active	00:03:30:00	1 Core, 3GHz
TUFLOW 30m Grid 198,000 cells with 81,000 active	00:00:25:00	1 Core, 3GHz
TUFLOW FV Flexible Mesh 17,500 elements	00:00:50:00	8 Cores, 2.8GHz
TUFLOW GPU 10m Grid 1,780,000 cells with 728,000 active	00:01:43:00	NVidia Tesla C2075
TUFLOW GPU 15m Grid 791,000 cells with 323,000 active	00:00:30:00	NVidia Tesla C2075
TUFLOW GPU 30m Grid 198,000 cells with 81,000 active	00:00:05:00	NVidia Tesla C2075

Issues Encountered

- Model size!
  - No input issues
  - Viewing output of >10,000,000 cells an issue
  - Added direct ESRI grid output in TUFLOW
    - GIS only real current option for viewing model results
    - SMS can be used but is slow with a 10,000,000 element mesh
- Power supplies!



Boundaries

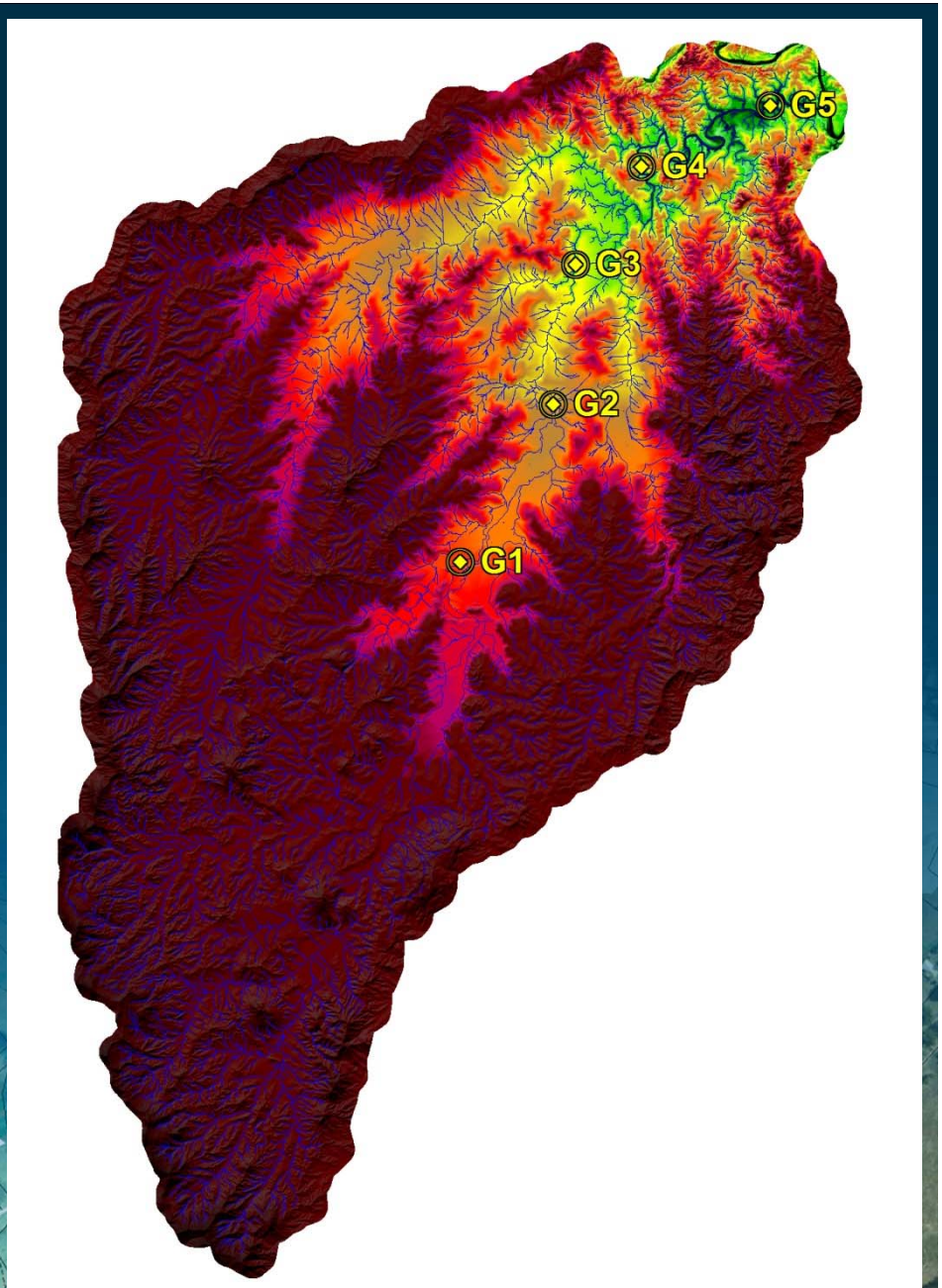
- In/Outflows
  - Have to be known or pre-processed at boundary cells
  - Direct rainfall easily applied
  - Presently building in infiltration (Green-Ampt, IL/CL)
- Downstream water level
  - By default, normal flow applied around model perimeter
  - Can apply time varying water level (can be a storm tide)
- Boundaries that have dependency across tiles not available

Applications

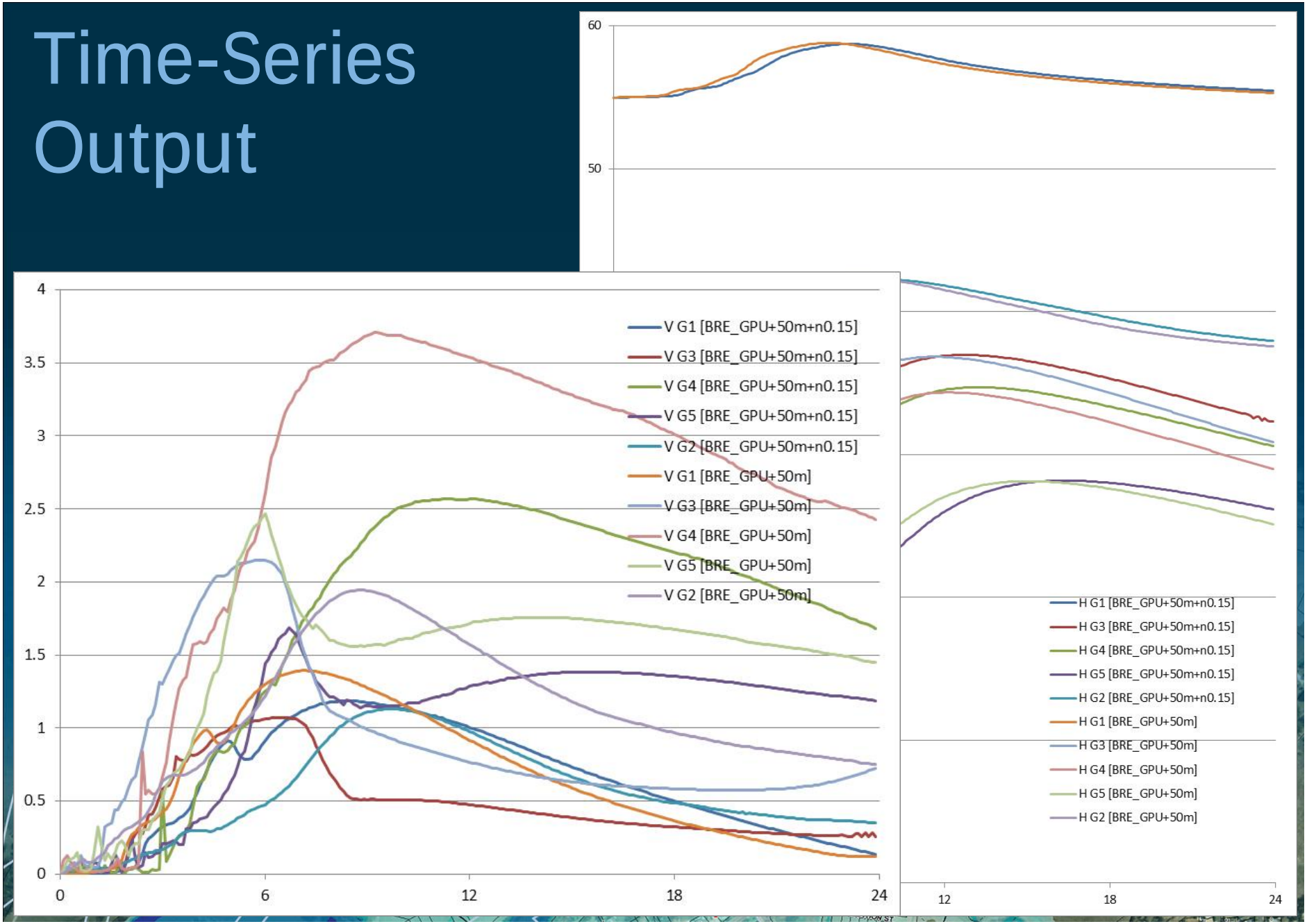
- Broad-scale whole of catchment (Direct rainfall inflow)
- 2D flood forecasting
- High resolution 2D models

Bremer River
(Our first one)

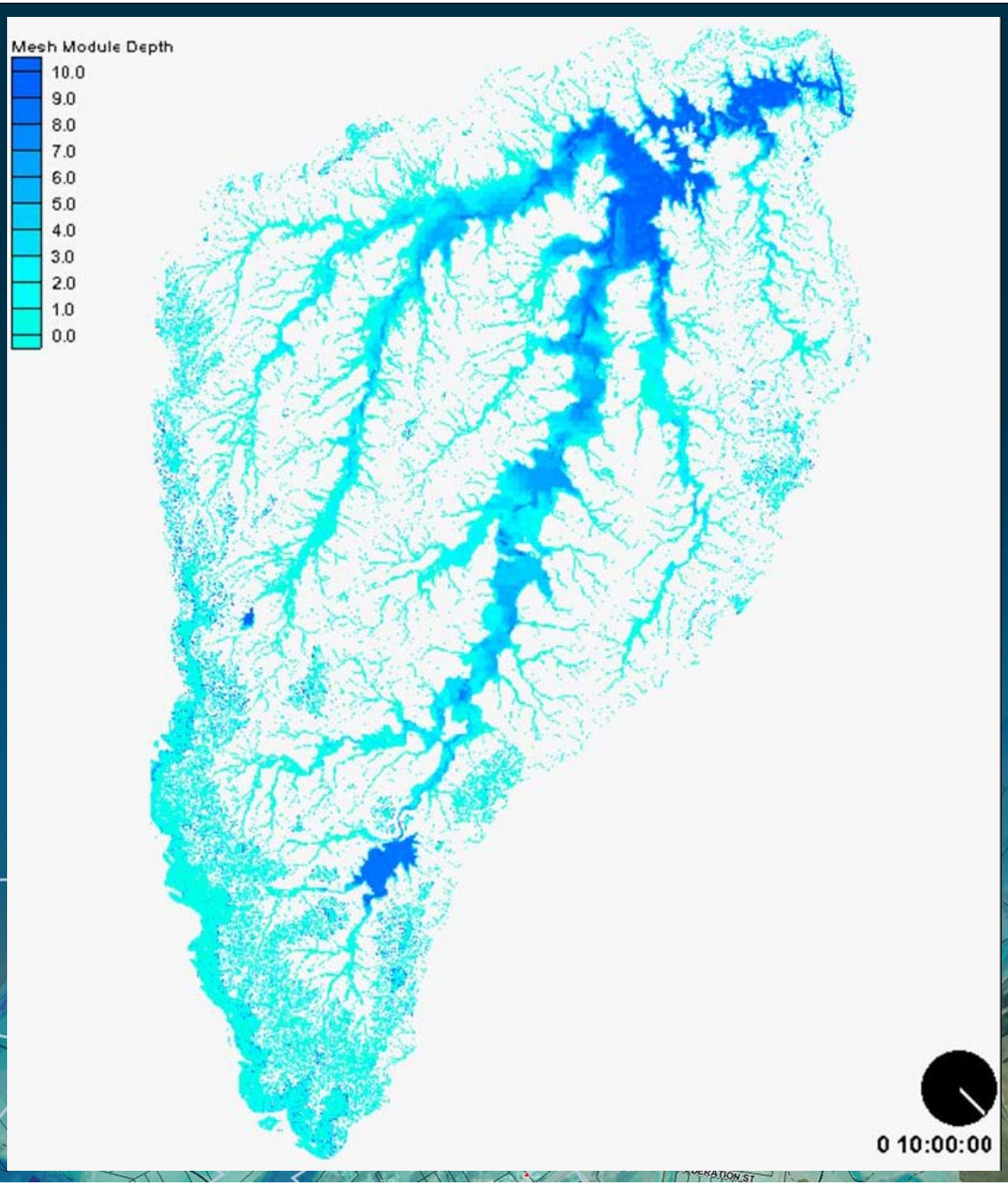
- 1 million active cells
- 50m grid
- 30 mins to run 24 hour duration flood



Time-Series Output

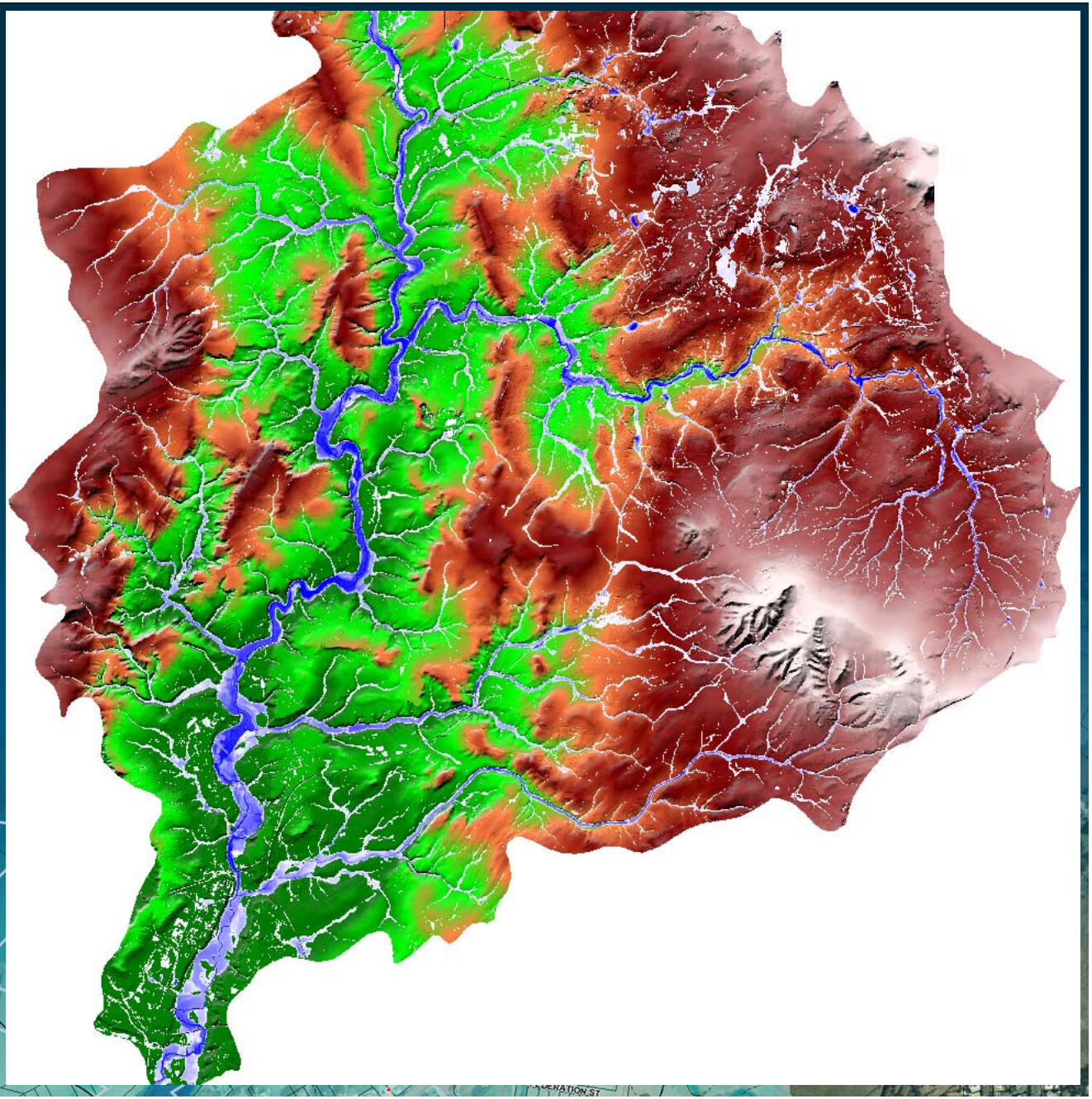


Bremer River

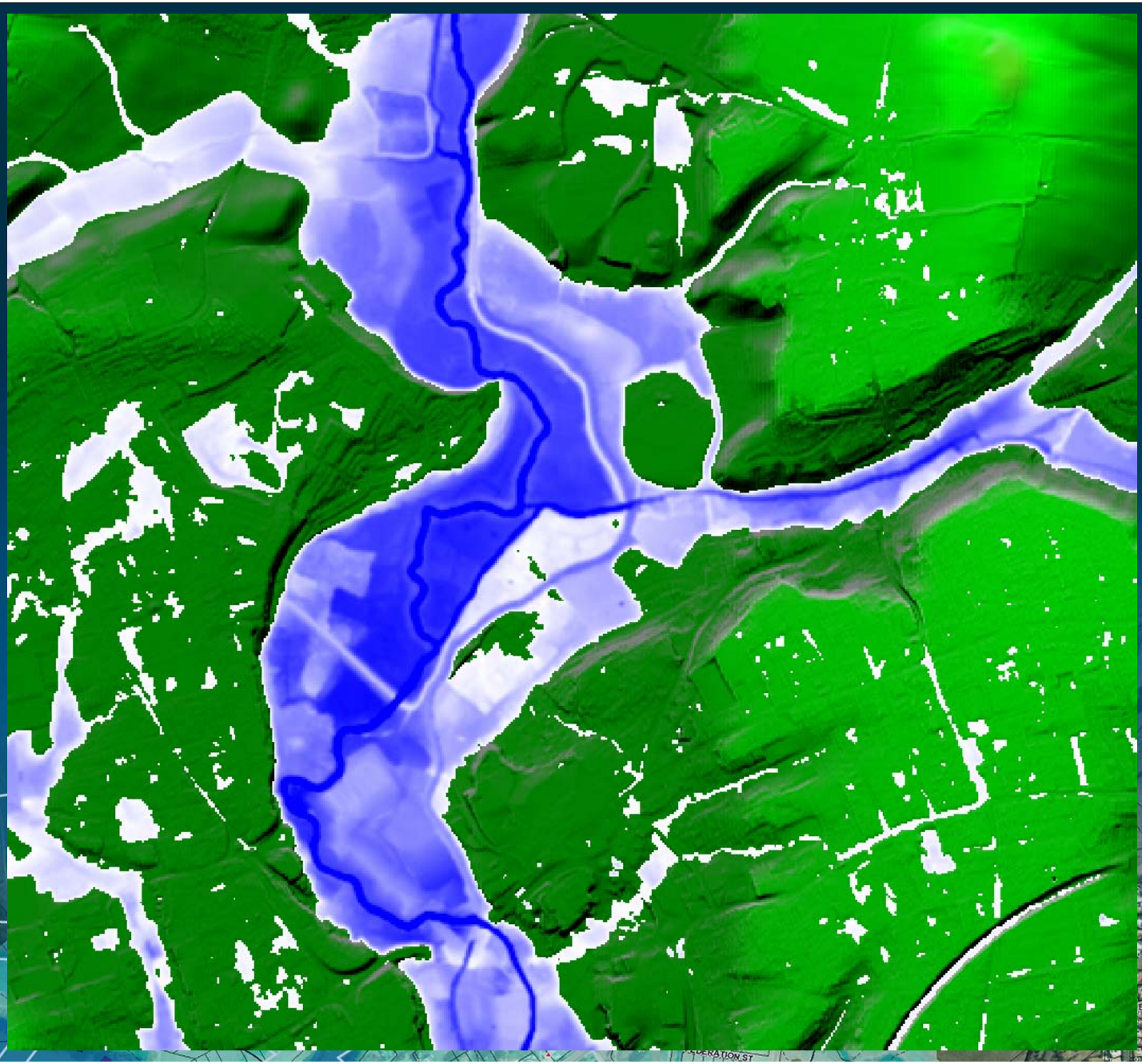


River Stour, UK

- ~10 million 2D cells
- 5m grid
- Direct rainfall

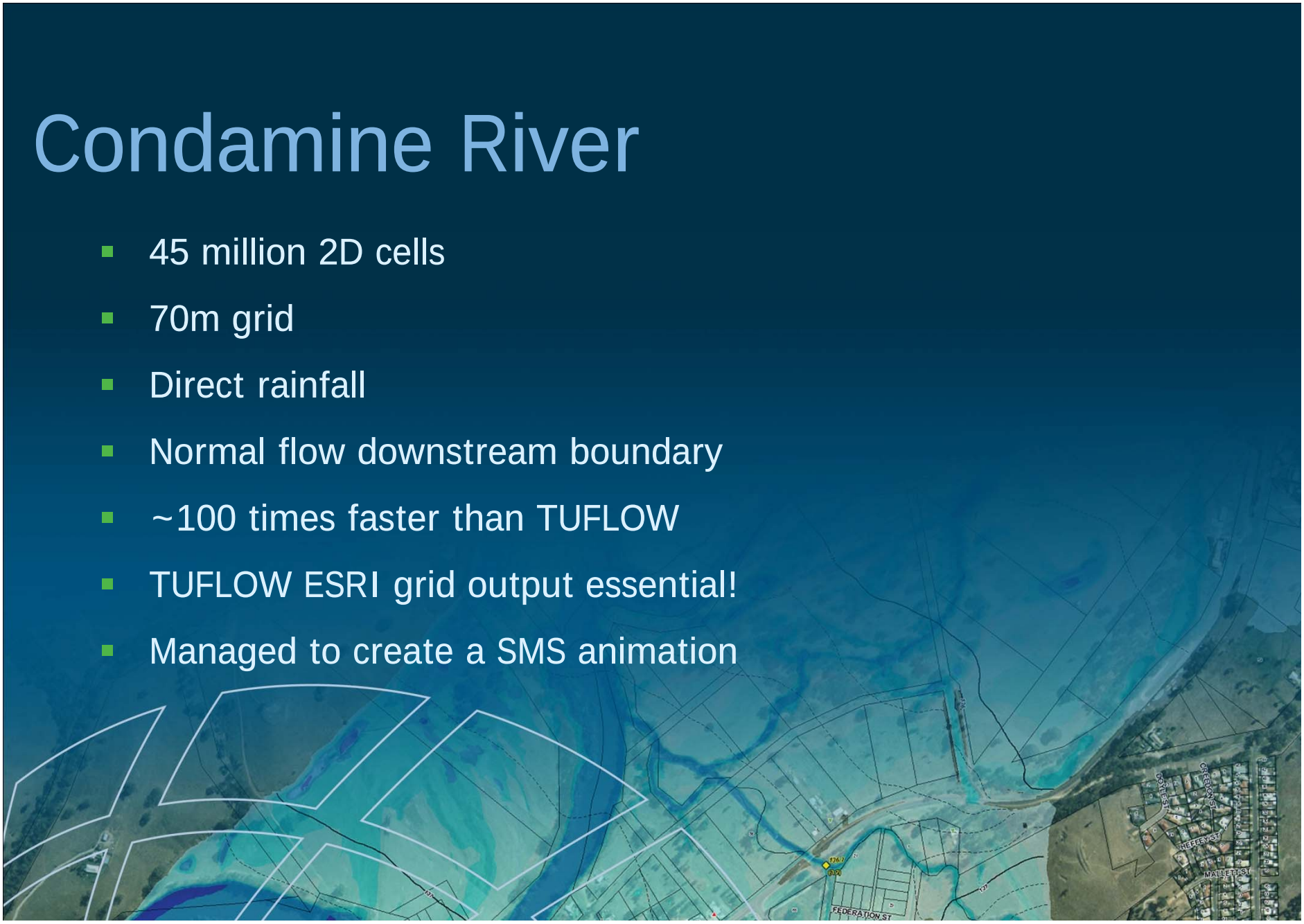


River Stour

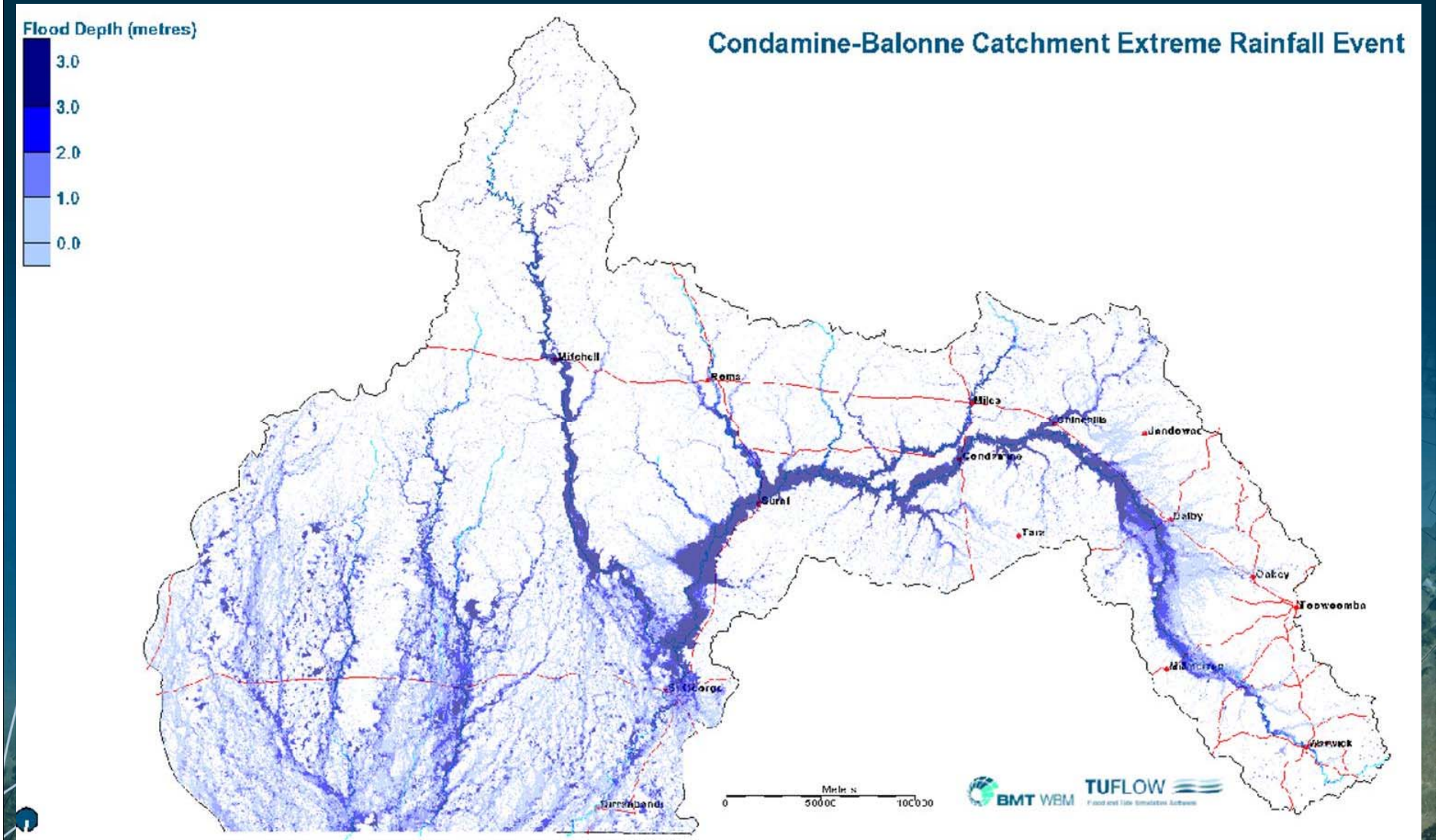


Condamine River

- 45 million 2D cells
- 70m grid
- Direct rainfall
- Normal flow downstream boundary
- ~100 times faster than TUFLOW
- TUFLOW ESRI grid output essential!
- Managed to create a SMS animation



Condamine River



thank you