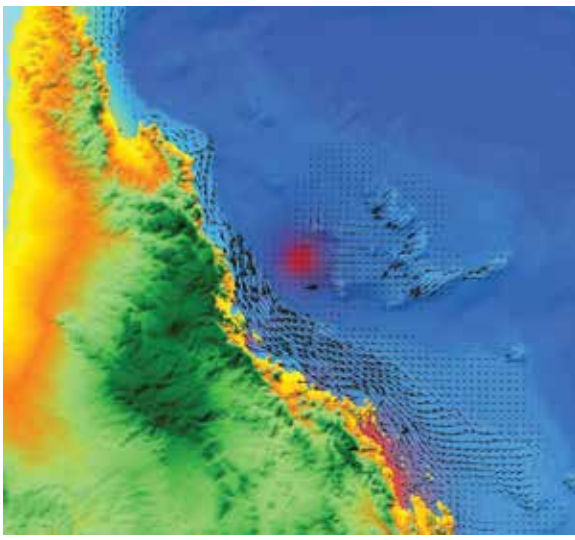
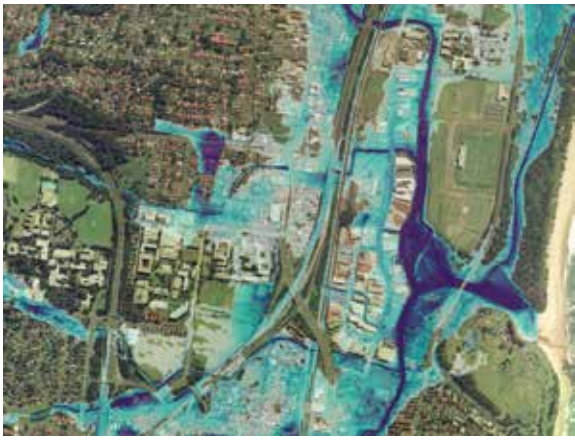
TUFLOW





Flood, Urban Stormwater & Coastal
Simulation Software

BMT

www.tuflow.com

Contents

TUFLOW Software Areas of Application

Catchments

Fast computing via GPU hardware for fine-scale distributed hydrologic applications and basin scale modelling.

Sophisticated options for landuse representation and a range of soil infiltration methods.

Urban drainage and stormwater

Superior 1D solver for simulating pipes, manholes, pits and lined channels. 1D links and operatable structures provide the solution for complex urban drainage, pipe networks and river systems.

Floodplains and rivers

TUFLOW's heritage, providing the benchmark modelling tool for floodplain management.

New alternatives and options with logic controls and advanced gate operations leading to flood warning and emergency response.

Flexible mesh and fast computing options.

Estuaries and river entrances

Where rivers and the sea meet; a complex interaction of tides, inflows and ocean currents combined with sediments and environmental issues.

Coastal and nearshore

Winds and waves, hurricanes, wave setup and current generation.

Longshore transport of sediments and morphological change.

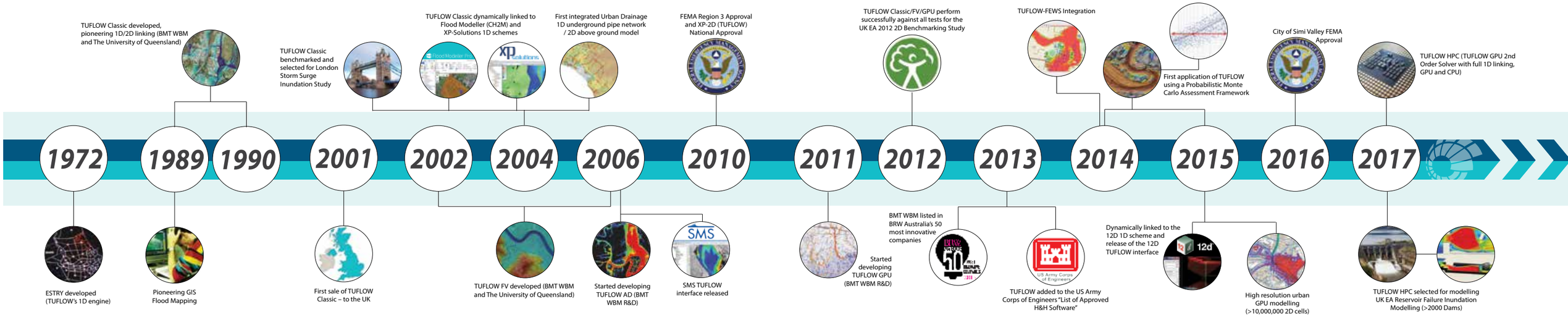
Tsunami propagation and inundation.

Offshore and metocean

Providing a link between oceanography and coastal engineering with high resolution nesting and advanced 3D boundary transfers.

Supporting the oil and gas industry; oil spill response and drill mud dispersion.

Our History



TUFLOW “Classic” and HPC

Fixed Grid Modelling

Floods, storms and coastal surges cause extensive damage, stress, loss of life-and-limb and disruption. To understand and manage these risks requires software that quickly and accurately models the inundation of rivers, urban areas and coastal floodplains.

TUFLOW is the most fully featured software for modelling:

- Flooding in major rivers
- Complex overland and piped urban flows
- Storm tide inundation of coastal plains
- Estuarine and coastal tidal hydraulics

Try TUFLOW for FREE

wiki.tuflow.com

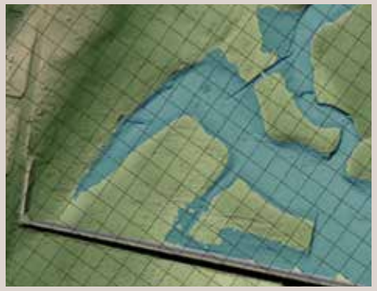
Ahead of the pack

TUFLOW is a fully featured modelling platform that has been continuously enhanced, based on users’ needs, since the 1990s. Key features are:

- Choice of 2nd order ADI (Classic) or 2nd order FV (HPC) 2D solvers
- Layered data approach - no data duplication
- Layers independent of 2D cell size, grid extent and orientation
- Modify data easily for “what-if” scenarios
- Powerful topography manipulation tools
- Hydraulic structures in 1D and 2D
- Supercritical, weir and subcritical flow switching in 1D and 2D
- The best 1D/2D linking available
- Boundaries and 1D/2D links at any orientation and location
- Ability to vary the 2D cell size and orientation using the multiple 2D domains module
- Easy and efficient management of events and scenarios
- Speed and reliability for real-world modelling
- Extensive range of outputs
- Advanced flood risk management analyses
- Extensive QA and healthy model checks
- Comprehensively detailed manual
- Seamless integration with GIS platforms and third party graphical user interfaces
- Single and double precision; regular releases
- Customisable hazards – create your own USER_DEFINED.dll
- TUFLOW Tutorial/Demo models
- Active on-line TUFLOW Forum and Wiki

Background

TUFLOW originated from a joint R&D project between WBM Pty Ltd and The University of Queensland in 1989/90 to develop a 2D modelling system with dynamic links to a 1D system, and has since gone from strength to strength as an industry leader.



Fixed grid mesh

Workflow Efficiency

The simple logical scripts, GIS data layering, powerful topographic modification functions and clever event and scenario management, make TUFLOW the modeller’s model. For those who wish to model quickly and efficiently, TUFLOW is the preferred option.

TUFLOW’s workflow efficiency and superior accuracy are the primary reasons TUFLOW has become the dominant 1D/2D flood modeling software in Australia and the UK, and is seeing a significant uptake in the USA and elsewhere. TUFLOW makes modelling easy, flexible, customisable and extremely efficient for detailed flood assessments and modelling numerous what-if scenarios.

Solution Schemes

TUFLOW’s Classic 2D solution is the leading alternating direction implicit (ADI) scheme on the market, while the new 2nd order TVD finite volume (FV) 2D solver (HPC) is taking the industry by storm. The 1D scheme is a very stable and accurate second-order, Runge-Kutta solution. TUFLOW’s engines were top performers in the 2012 UK EA Benchmark Study.

The 2D schemes automatically handle upstream controlled flow regimes (supercritical flow down steep slopes and weir flow over levees), bridge decks, box culverts, excellent wetting and drying and other features. HPC’s adaptive timestep FV approach makes it virtually 100% stable.

The 1D solution includes detailed representation of rivers, floodplains, extensive pipe network systems, pits and manholes, and a range of structure types, and highly flexible structure operational controls. Energy loss coefficients at manholes and culvert transitions are reevaluated every timestep.

TUFLOW 1D/2D Dynamic Linking

TUFLOW’s 1D/2D dynamic linking is the best in the industry.

- 1D/2D links can be at any orientation to the 2D grid, start completely dry, and wet and dry during the simulation.
- Operate as simple source/sink links (eg. connections to pipe network pits) through to momentum preservation links across major waterways, large 1D structures and along river banks.
- 1D/2D links do not force a reduction of the 2D timestep
- Apply the full 2D solution for momentum preservation
- Switch automatically to the weir equation when upstream controlled (eg. free flow over a levee)
- Do not need to be reworked if the 2D cell size or grid orientation changes.

Estry

TUFLOW's 1D Engine

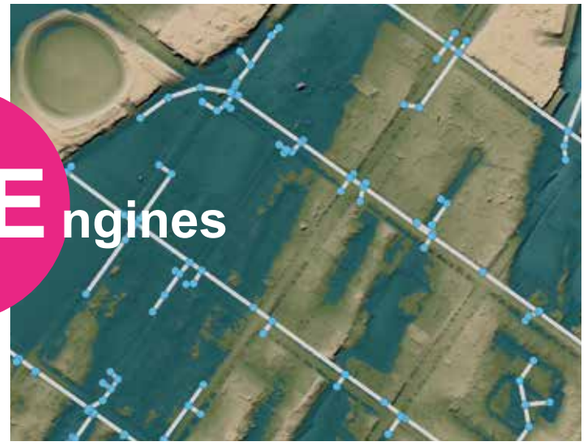
ESTRY is the primary 1D engine used by TUFLOW. It has been developed over a period of 50 years, has continued ongoing development. It is in its own right is a powerful 1D network dynamic flow software. It is suitable for modelling of open channel riverine and catchment flooding, operated control structures or urban underground pipe networks. ESTRY is dynamically linked with all TUFLOW fixed grid 2D solvers.

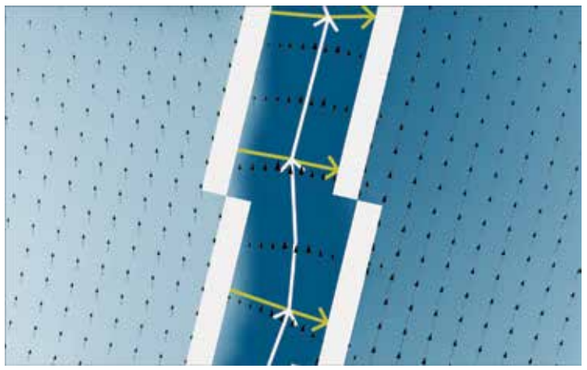
Features

- Open channel network and catchment storage areas
- Culvert equations for circular, rectangular (box) and irregular culverts
- Bridges
- Weirs, spillways, radial and sluice gates
- Dynamic structure operational controls, including gates and pumps
- Pipe networks, including pit and manhole inlets
- Advanced treatment of pipe network energy losses

History

- Development started in 1972
- Linked to TUFLOW Classic (2D) in 1989
- Linked to TUFLOW HPC (including the GPU Module) in 2017





Solution Schemes

- Open channel flow are calculated using the full one-dimensional (1D) free-surface St Venant flow equations.
- Culvert equations are built directly into TUFLOW. Twelve different flow regimes have been coded into the software. The regime for every structure is checked every timestep of a simulation.
- Bridge flow dynamics, adjustment of bridge form loss values accounting for the transition from upstream controlled flow to/from downstream controlled flow is automatically accounted for by ESTRY.
- Losses within an underground pipe network at pipe junctions account for change in pipe geometry, angle, elevation and flow expansion/contraction at manholes. They are calculated and adjusted based on the hydraulic conditions at every pipe junction every timestep of the simulation.
- Nine weir types have been coded into ESTRY. Manual coefficient specification is also an option. ESTRY automatically tests for flow submergence every timestep and adjusts the hydraulic calculations accordingly.

Fixed Grid Modules

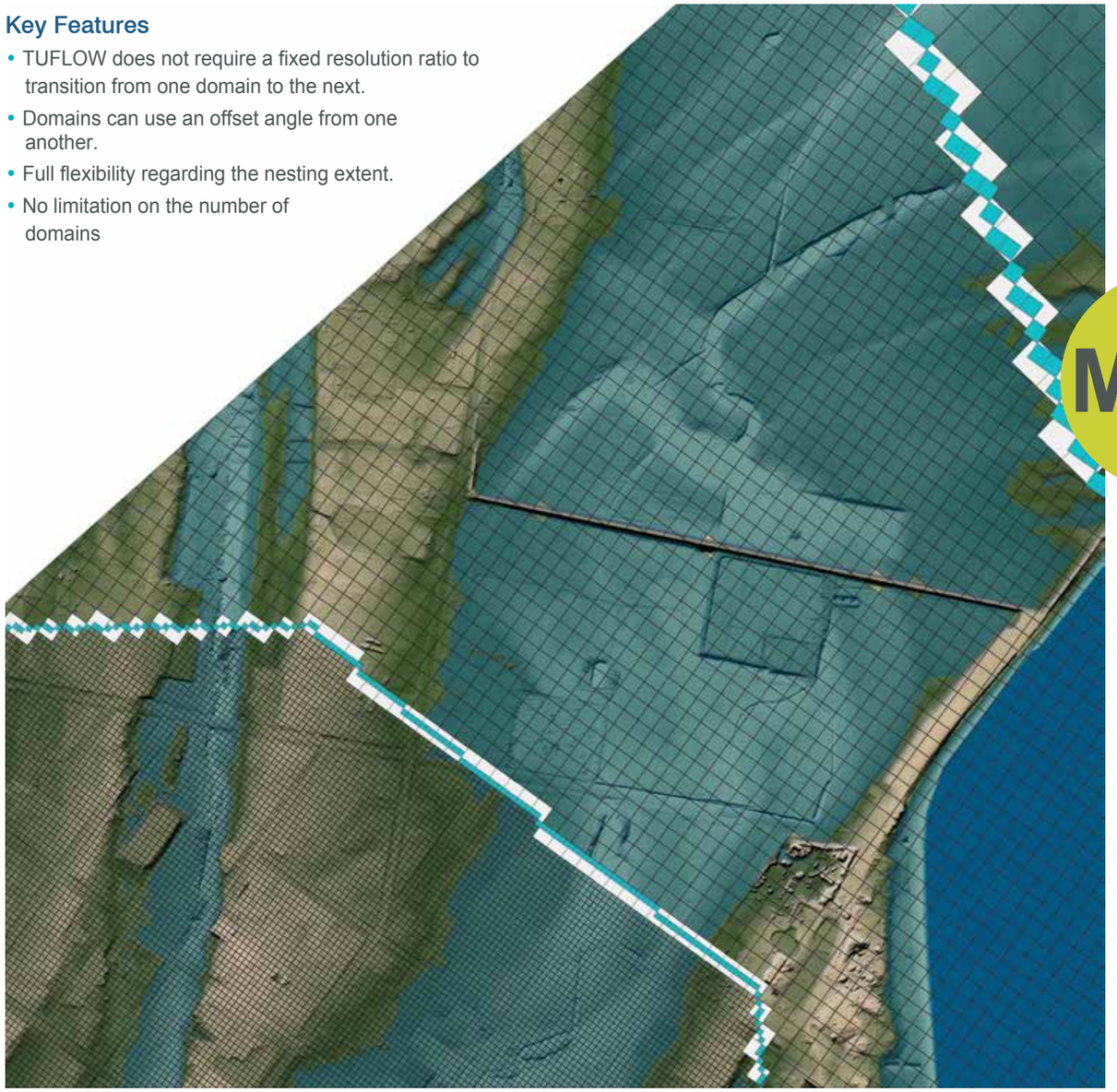
TUFLOW Classic and HPC fixed grid modules have been designed to increase simulation efficiency and speed

Multiple 2D Domain Module

TUFLOW's multiple 2D domain (M2D) module is available using TUFLOW Classic. The module provides the capability to nest areas of finer mesh resolution within a coarser resolution. This feature allows users to obtain high resolution accuracy in key areas of interest without excessively increasing the overall cell count and simulation run time for a model, as would be the case for a single domain model at high resolution.

Key Features

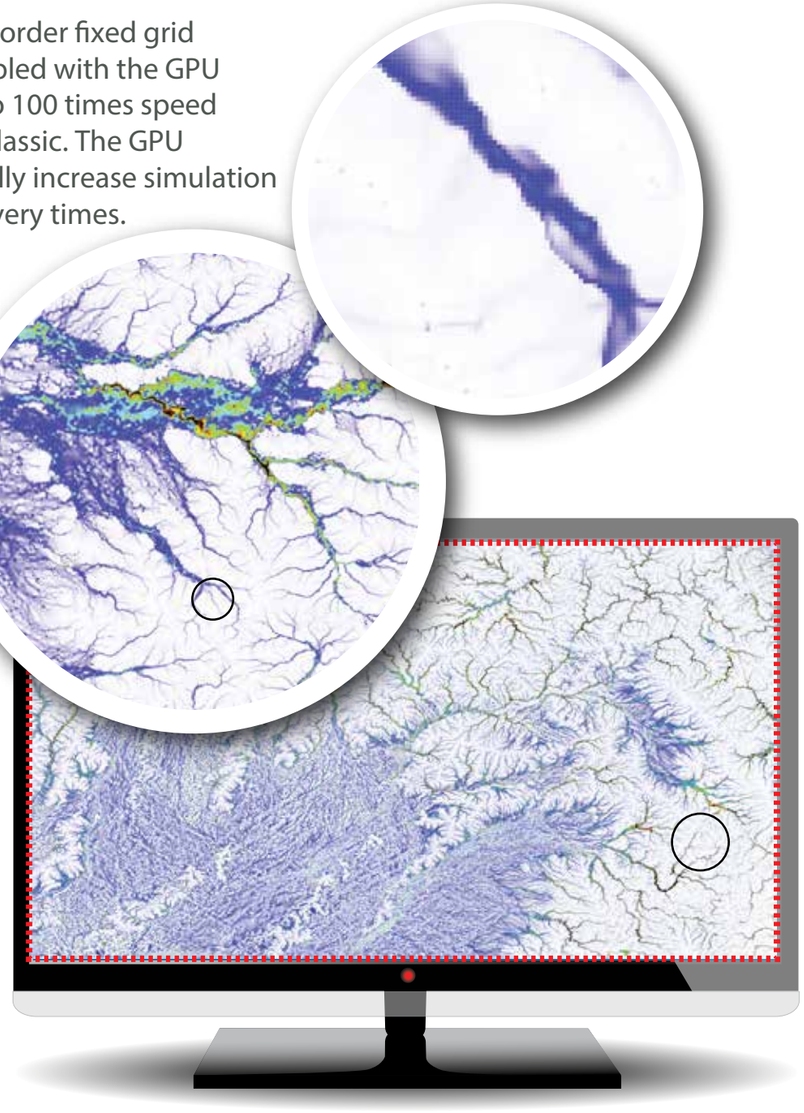
- TUFLOW does not require a fixed resolution ratio to transition from one domain to the next.
- Domains can use an offset angle from one another.
- Full flexibility regarding the nesting extent.
- No limitation on the number of domains



Fixed Grid Modules

GPU Acceleration

The HPC parallelised explicit 2nd order fixed grid hydrodynamic solver can be coupled with the GPU Hardware Module to deliver 10 to 100 times speed increase compared to TUFLOW Classic. The GPU Hardware Module can substantially increase simulation turnover and reduce project delivery times.



Basin scale modelling

Direct rainfall over the Condamine-Balonne catchment and surrounds, an area of over 400,000 km², was modelled on a 30 m resolution grid using TUFLOW HPC. A total of 486 million elements over a rectangular area of 810 km x 540 km.

The simulation, performed on a standard desktop computer plus four additional nVidia GTX 1080Ti cards, simulated a 5 day flood event over a period of 2 days.

Modules

Supercomputer performance on a desktop

100% stability make HPC the optimum tool for dam breach reservoir flooding assessments

TUFLOW HPC Integrated 1D/2D Urban Drainage modelling

- All the power and flexibility of TUFLOW's superior GIS functionality, scripting and scenario/event management is at your fingertips when using HPC's GPU Module.
- The explicit finite volume 2nd order space, 4th order time solution is 100% stable.
- Solves the full 2D free-surface equations including inertia and sub-grid turbulence (eddy viscosity) – a superior solution at all levels compared with other GPU accelerated solvers.
- Successfully benchmarked and a top performer of the 2012 UK EA 2D Benchmarking.
- Full 1D/2D dynamic linking functionality.
- High resolution integrates 1D pipe / 2D overland urban drainage modelling now a reality.
- Soil infiltration using IL/CL, Green-Ampt and Horton methods.
- Multiple water level boundaries, rainfall distributions and catchment inflows.
- Vary Manning's 'n' with depth.
- The GPU Module requires CUDA enabled NVidia cards.
- Multiple GPU cards supported.

M

TUFLOW FV

Flexible Mesh Modelling

A 1D / 2D / 3D flexible mesh finite volume numerical model that simulates hydrodynamic, sediment transport and water quality processes in oceans, coastal waters, estuaries and rivers. A powerful engine proven at all scales.

FV Solution Scheme

The finite volume numerical scheme solves the conservative integral form of the non linear shallow water equations (NLSWE).

The equations can be solved in

1D, 2D (vertically averaged) and 3D.

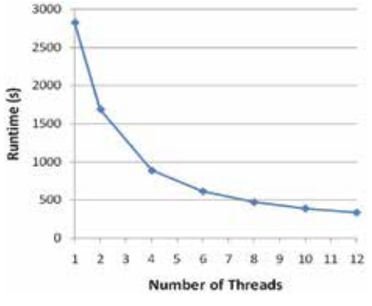
Engines

Key FV Scheme Features

- Intrinsically handles shocks
- Subcritical, supercritical and transitional flows
- Locally (and globally) conservative to numerical precision
- Robust wetting/drying
- Parallelised explicit scheme (varying Courant dependent timestep)
- 2D and 3D with 1st and 2nd order schemes

Speed

TUFLOW FV code is optimised and parallelised for multi-processor machines, using the OpenMP implementation of shared memory parallelism.



Features

Flexible controls / interfacing

TUFLOW FV inputs are controlled via a macro style text-file interface. This allows the user to flexibly and efficiently control model configuration, boundary condition specification and output requirements.

Open boundaries

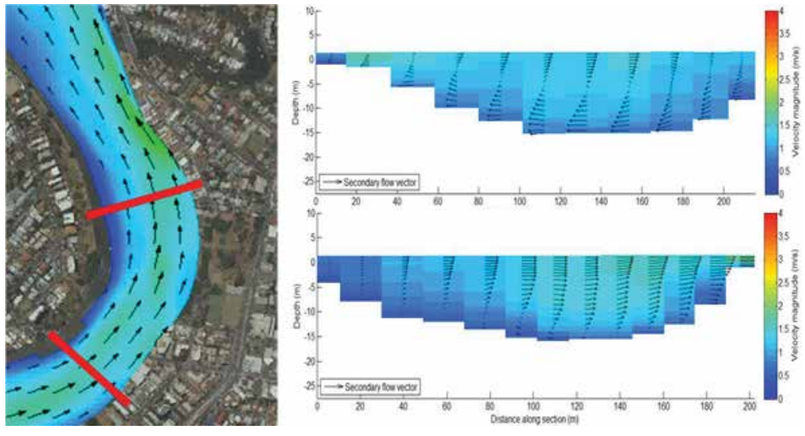
- Fully open (non-reflective)
- Specified water level
- Specified discharge
- 3D linkages to ocean circulation models

Additional forcings

- Global cell inflows and outflows (e.g. rainfall, evaporation)
- Cell inflows/outflows (e.g. pollutant source/sinks)
- Wind and wave stresses, atmospheric pressure
- Holland parametric cyclone wind and pressure model

Structures

- Weirs, culverts
- Adjustable beds, levee failure, etc
- hQh matrix specification at selected cells
- Logical controls
- Auto weir function



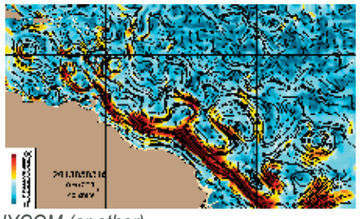
A combined 2D/3D flood model

TUFLOW FV has an option to insert 3D within a 2D model. This feature, which allows simulation of overland inundation plus complex 3D flow patterns in the main river channel, was successfully applied to the design of riverbank infrastructure.

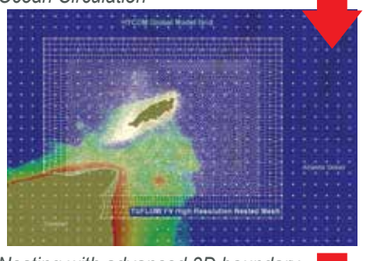
Complex problems require clever solutions

A nested modelling approach around Trinidad and Tobago to establish design parameters for infrastructure:

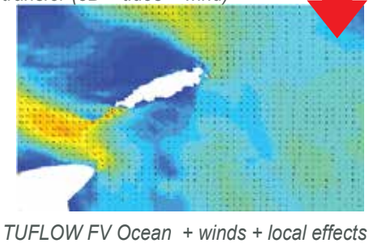
- 3D currents and vortex shedding from the HYCOM global model
- Hurricane activity, generating high currents on local and regional scales
- Rapidly shallowing bathymetry, with tidal and wind driven currents becoming influential close to the coastline



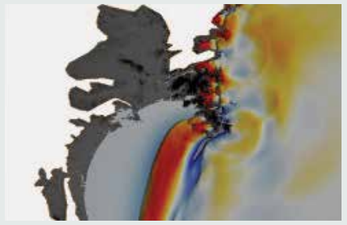
HYCOM (or other) Ocean Circulation



Nesting with advanced 3D boundary transfer (3D + tides + wind)



TUFLOW FV Ocean + winds + local effects



Tsunami

To accurately capture steep tsunami wave gradients, the higher order spatial solution scheme available for TUFLOW FV was applied to simulate the Great East Japan Earthquake in 2011.

UK EA Benchmark Testing:

TUFLOW FV performs well against all alternative products, including dambreak tests with sub-supercritical transitions

Flexible Mesh Modules

TUFLOW FV's modules are additional components providing expanded functionality and capability.

Modules

Sediment Transport and Morphology

TUFLOW FV ST has cohesive and non-cohesive sediment transport capabilities, linked to hydrodynamic response via a morphological update routine to simulate evolution of bed features.

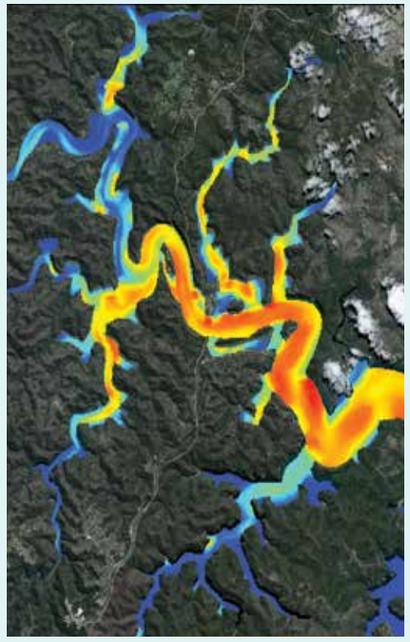
Applications

- Sediment plumes
- River, estuarine and coastal morphology
- Scouring and bank stability

AD and Heat Balance

The AD (advection dispersion) module provides capability to simulate constituent fate and transport in receiving waters. It is applicable to:

- Mixing in inland waterways
- Fate of plumes
- Flushing assessments
- Advanced atmospheric heat exchange routines simulate thermal mixing and plumes
- For 3D applications the AD scheme is coupled to salinity, temperature and sediment concentrations to simulate density driven currents
- The AD scheme is at the core of subsequent sediment and water quality capabilities



Sediment plumes using TUFLOW FV ST Module, Gladstone

The water and environment of the Port of Gladstone (Australia) has been studied using TUFLOW for two decades. Recently, TUFLOW FV played a key role in managing excess suspended sediments from dredging activities.

Water Quality

Water quality modelling is currently available in-house using TUFLOW FV in combination with AED2, developed by the University of Western Australia.

3D

The TUFLOW FV 3D Module is a fully three-dimensional model that assumes a hydrostatic pressure distribution in the water column, including baroclinic terms.

When run in 3D, TUFLOW FV has the ability to simulate temperature, salinity and density stratification in order to fully resolve baroclinic (density) driven processes. Linked with this ability is a capability to accept and respond to atmospheric forcing parameters and heat transfer processes (including air temperature, relative humidity, long and short wave radiation and wind speed and direction).

M

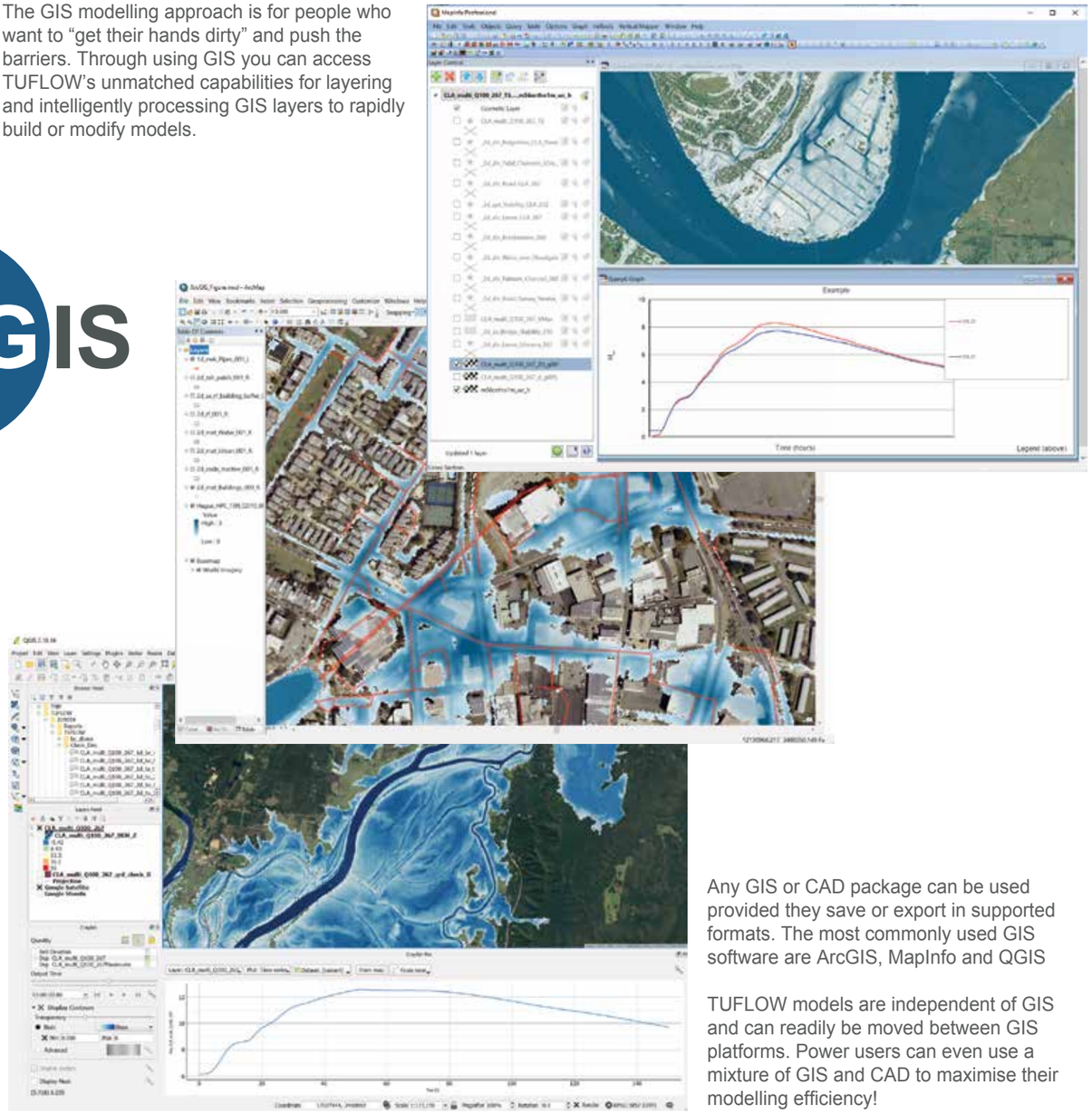
Model Development Environments

Geographic Information Systems (GIS)

Using GIS as your TUFLOW modelling environment gives you maximum flexibility and efficiency, especially for detailed, complex models or modelling investigations with numerous events and scenarios.

The GIS modelling approach is for people who want to “get their hands dirty” and push the barriers. Through using GIS you can access TUFLOW’s unmatched capabilities for layering and intelligently processing GIS layers to rapidly build or modify models.

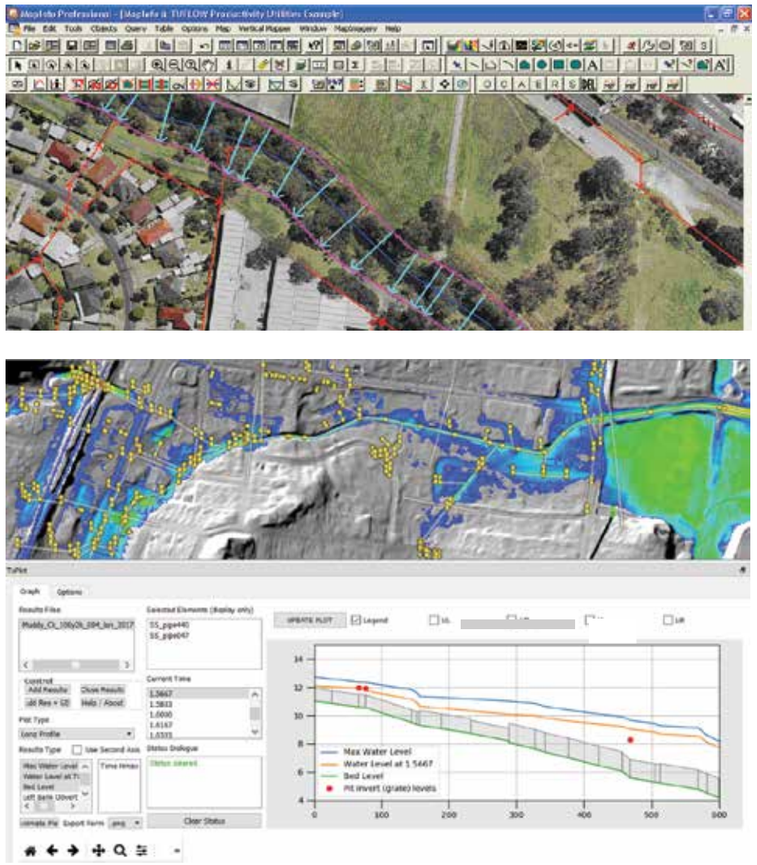
GIS

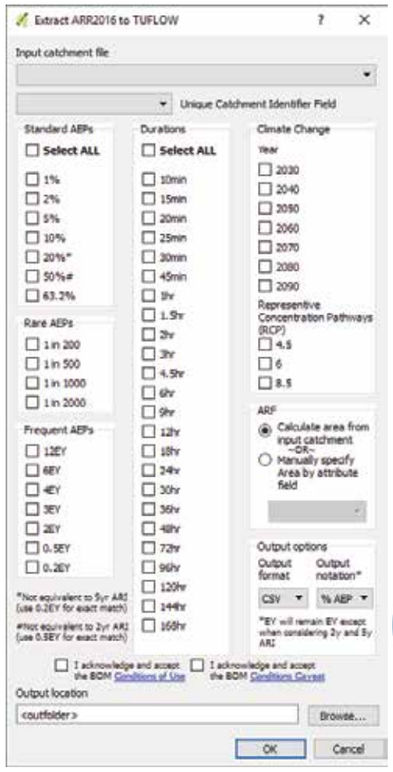


MapInfo (top right), ArcGIS (middle) and QGIS (bottom left)

Any GIS or CAD package can be used provided they save or export in supported formats. The most commonly used GIS software are ArcGIS, MapInfo and QGIS

TUFLOW models are independent of GIS and can readily be moved between GIS platforms. Power users can even use a mixture of GIS and CAD to maximise their modelling efficiency!





QGIS TUFLOW Plugins

TuPlot, its ARR2016 datahub interface and Crayfish

ArcGIS Toolbox

The ArcGIS toolbox is a free ArcGIS add-on. It includes a range of tools to improve the efficiency of building, running, and viewing results of TUFLOW models within ArcGIS.

New in 2018 is the quick access ArcTUFLOW Toolbar that allows users to initiate TUFLOW utilities with a single click, further improveing the ease of access of building models within ArcGIS.

Available tools include a 1D and 2D time series results viewer, as well as a range of new model build tools. For Australian users, the toolbox also now includes options to source hydrologic inputs from Australian Rainfall and Runoff (2016) datahub. The datahub outputs are automatically formatted into the correct format for TUFLOW modelling.

MapInfo miTools

The MapInfo and TUFLOW Productivity Utilities (miTools) is a TUFLOW Software Product that has been developed to specifically improve the efficiency of setting up and reviewing TUFLOW models, as well as improving the day to day ease of using MapInfo Professional (MI Pro).

The suite of utilities enables ‘automation’ of many of the common repetitive tasks, saving valuable time and therefore money. The utilities also enable efficient creation and visualisation of key TUFLOW model inputs/outputs within the MapInfo environment. Other tools provide data checking and quality assurance functionality, thus helping to minimise modelling errors.

QGIS Plugins

QGIS is an open source GIS package used by many to create TUFLOW models. In addition to the basic GIS package, a variety of useful free QGIS plugins are now available. TuPlot and Crayfish are two of the most popular of these.

TuPlot is a plugin used to configure a TUFLOW project, import and update template GIS files and also run simulations. The plugin includes a powerful 1D result viewer and for Australian users, an automated method to source hydrologic inputs in TUFLOW format from Australian Rainfall and Runoff (2016) datahub.

The Crayfish plugin is a 2D result viewer and analyser developed by Lutra Consulting.

Collectively, QGIS and these plugins make QGIS a complete 1D and 2D model build and result viewing platform.

Model Development Environments

3rd Party Links and Interfaces

TUFLOW has unrivalled development environment flexibility. Numerous other software use TUFLOW as the computation engine within a Graphical User Interface (GUI) environment, and/or offer dynamic links to TUFLOW's 1D and 2D schemes.

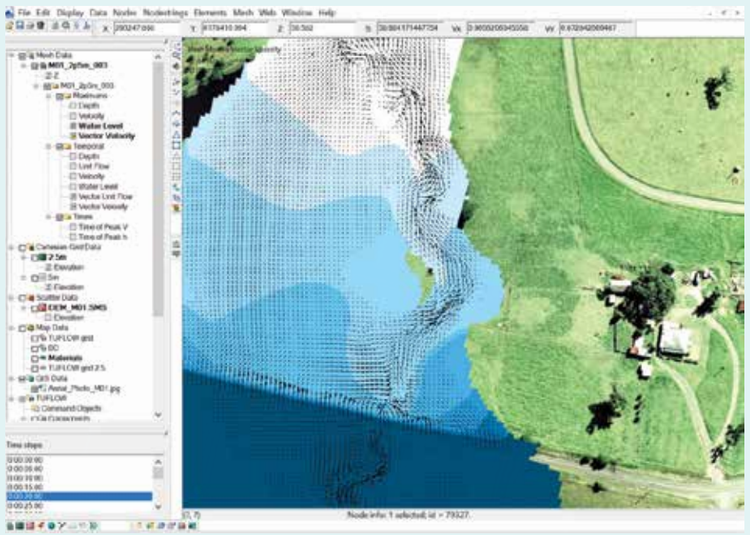
Flood Modeller

Flood Modeller (previously known as ISIS), was linked with TUFLOW's 2D scheme in 2004 and to TUFLOW's 1D scheme in 2010. TUFLOW's 2D and excellent 1D pipe network modelling capabilities have allowed Flood Modeller 1D models to be substantially value added through replacing overbank areas as 2D and inclusion of urban pipe networks linked to Flood Modeller in-bank river networks.

Interfaces

SMS

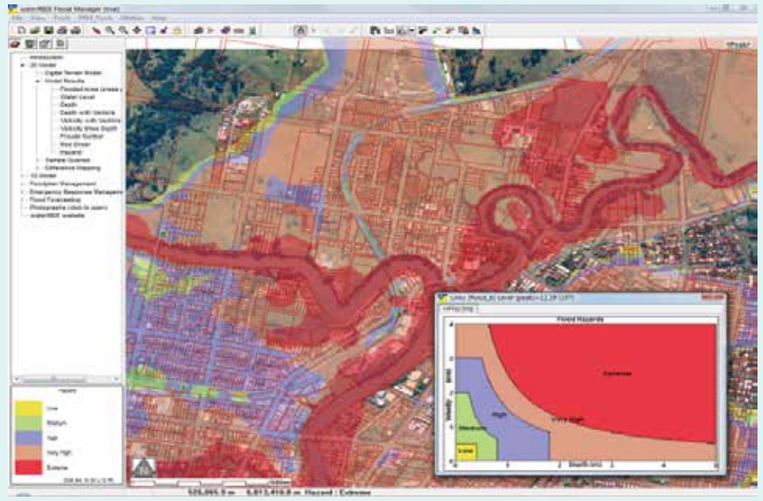
Aquaveo released a customised GUI for TUFLOW "Classic" 1D and 2D within their SMS Surfacewater Modelling System in 2006. SMS is popular with TUFLOW GIS based modellers for viewing and animating results and increasingly for developing TUFLOW models. The ability to move TUFLOW GIS layers between SMS and GIS provides the modeller with even more functionality. SMS's powerful flexible mesh capabilities and generic interface is popular with TUFLOW FV users.



> We focus on highly accurate, work flow efficient, numerical engines and choose interfaces that best suit our modelling requirements

XP-2D

XP-Solutions 1D scheme was dynamically linked to TUFLOW's 2D solution in 2004, and in 2006 they released the XP-2D GUI. Today, XP-Solutions (now Innovyze) has an extensive 1D/2D modelling user base throughout the world. XP-SWMM 1D users can easily add 2D domains to their 1D models within an intuitive and easy to use GUI to more accurately model urban and river flooding. XP-2D (TUFLOW) was granted National FEMA approval in 2010.

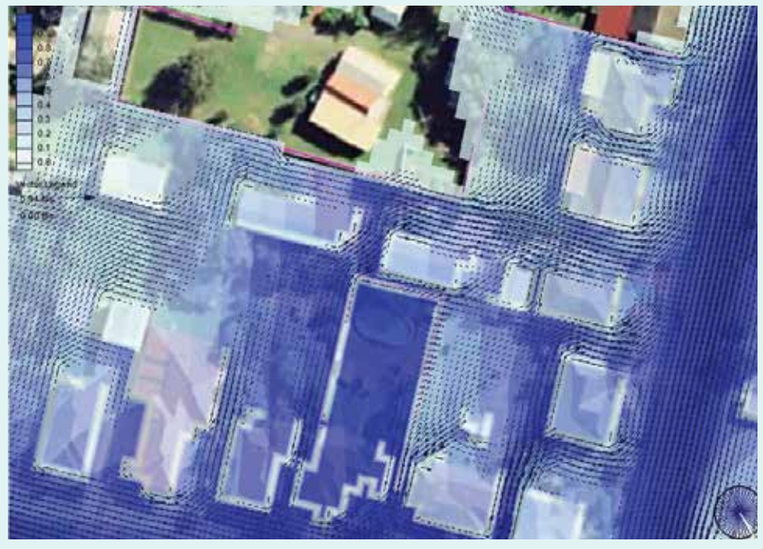


waterRIDE

waterRIDE FLOOD Manager provides a unique, highly visual environment to integrate time-varying 1D and 2D model results with GIS capabilities. It is a dedicated floodplain management tool that allows you to review and integrate your TUFLOW and TUFLOW FV results and communicate "what the flooding means". TUFLOW offers direct output in waterRIDE format.

12D

12D Solutions Dynamic Drainage Analysis (DDA) 1D solver has been dynamically linked with TUFLOW's 2D scheme, and the 12D GUI adapted for 1D/2D modelling. The TUFLOW integration allows modellers to easily interchange with GIS and offers an intuitive interface for working with TUFLOW's powerful scripting capabilities.



> Our priority is to make the TUFLOW modelling experience an enjoyable one

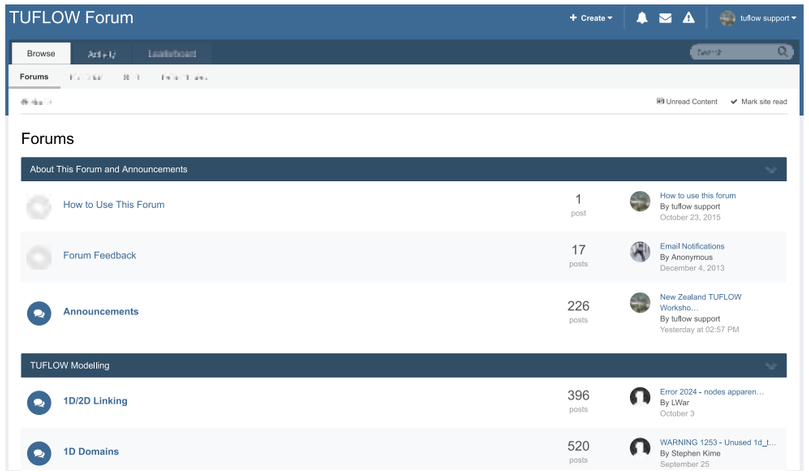
Join the TUFLOW User Community

There is a large and enthusiastic community of TUFLOW users. The TUFLOW forum has over 2500 members and is a great source of knowledge, support and advice. The TUFLOW Wiki and LinkedIn User groups also provide excellent online support.

Sign up today:

www.tuflow.com/forum
wiki.tuflow.com
https://www.linkedin.com/groups/1908583

User feedback is taken seriously at TUFLOW. Our products develop year on year almost entirely on user's needs and recommendations.



Training and Support

Training

We run annual release workshops and training in Australia, China, New Zealand, the United Kingdom and United States of America. There is also a TUFLOW User conference in the United Kingdom every second year.

In addition to these regular scheduled events, we also offer customised project based training. See the TUFLOW website or email *training@tuflow.com* for event and/or customised training details.

> The Support team are amazing! They're always quick to respond, friendly and have outstanding knowledge of TUFLOW and hydraulics. Their guidance has helped me become a better modeller.

Support

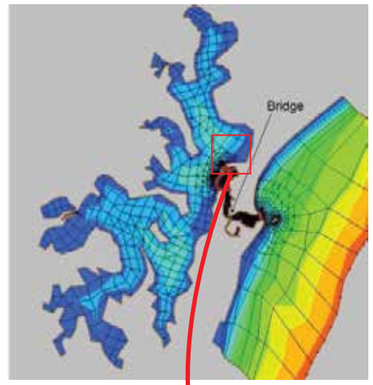
Support is provided by the experts that develop and use the software.

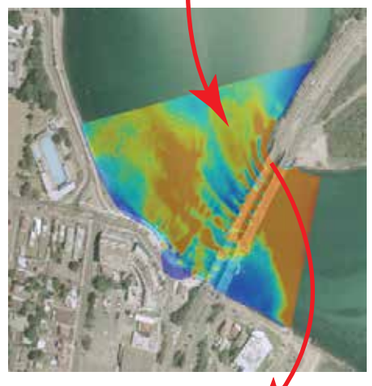
There is a strong support network through our company and our 3rd party partners.

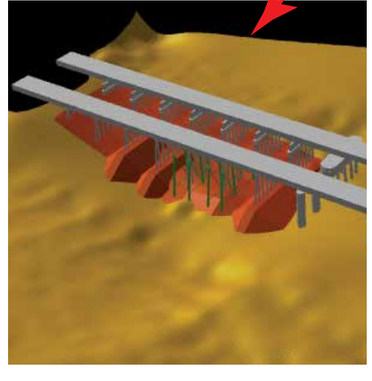
Contact *support@tuflow.com*.

Model Reviews

Model reviews are an excellent way to ensure that you are using the best and latest features, modelling efficiently and producing quality models. Reviews include constructive feedback so that the modeller benefits from the review process.







Customised TUFLOW

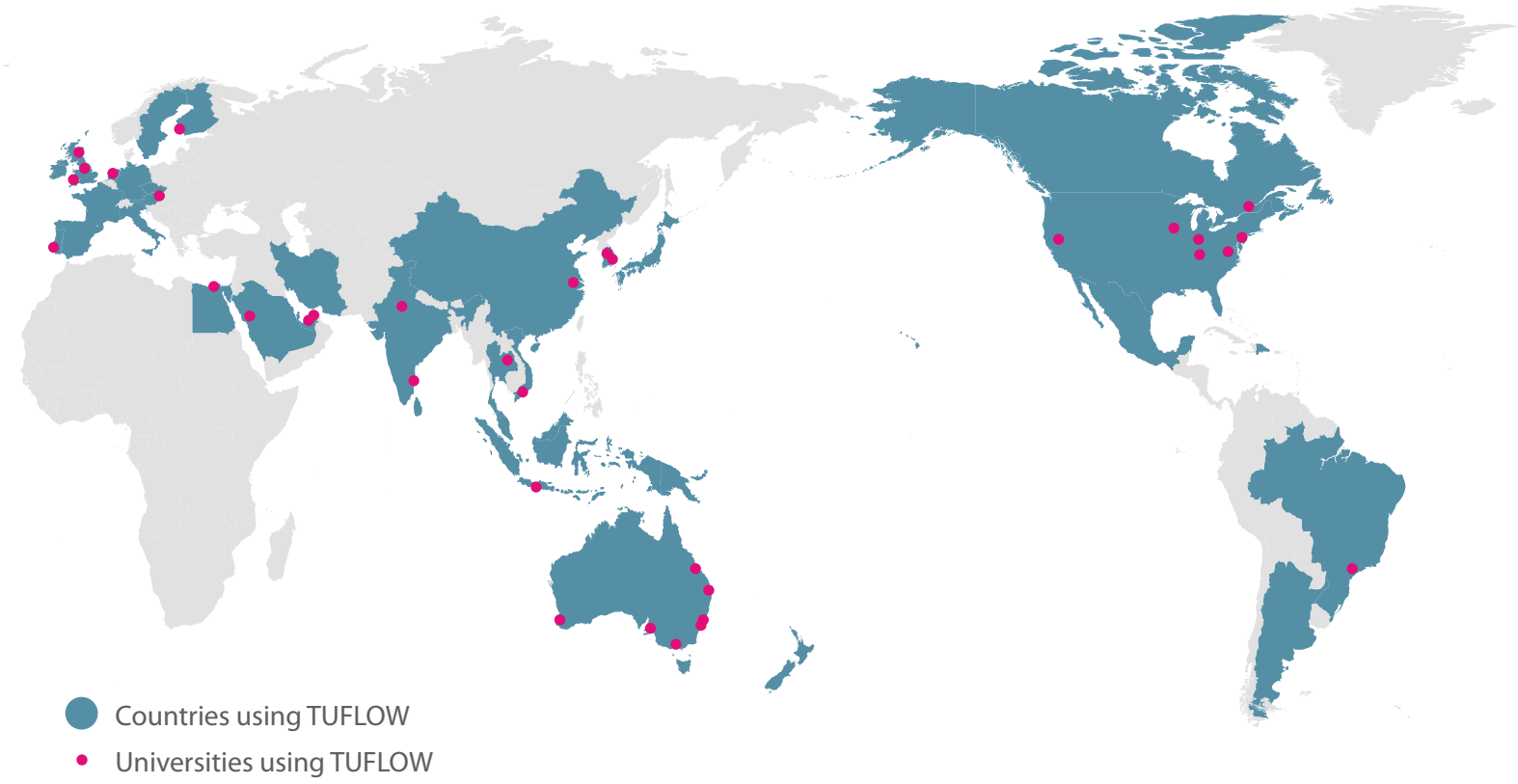
We are constantly developing products to satisfy demands from modellers; this is the key to TUFLOW's success.

If your organisation has specific requirements, we can work with you to deliver these features. Please contact us at *support@tuflow.com*.

Customised modelling application

CFD was applied to establish complex hydrodynamics around bridge piers, driven by boundary conditions provided by a TUFLOW FV simulation.

TUFLOW is developed by BMT. We offer more than just TUFLOW; we are a global organisation with a heritage and reputation for innovation and technical excellence. See www.bmt.org.



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