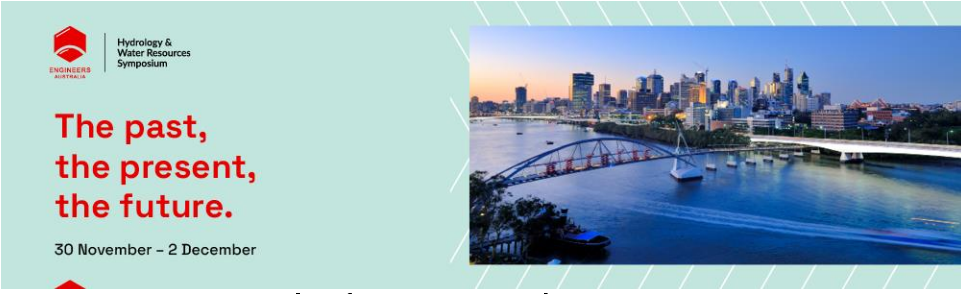

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Direct Rainfall Hydraulic Model Validation

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ABSTRACT

Hydrologic modelling has traditionally been undertaken using simplified lumped runoff routing models. Recent computer hardware and two-dimensional shallow water equation solution scheme advancements are now expanding our available options for hydrologic assessments. Catchment wide hydrology can now be simulated using two-dimensional hydraulic models that solve the equations of motion on the surface and also in the subsurface domains. These models use direct rainfall (rain-on-grid) methods to drive runoff calculations on spatial scales of sub-metre to hundreds of metres, and temporal scales of seconds.

Whilst hydrologic models remain substantially faster, improvements to 2D solvers and GPU acceleration continue to make direct rainfall hydraulic modelling an increasingly viable option for simulating catchment wide rainfall-runoff hydrologic processes. Benefits of the 2D solver include faster model setup times, broader result options and superior visual presentation of outputs for stakeholders. However, due to direct rainfall hydraulic modelling being a comparatively newer analysis approach compared to lumped or semi-distributed hydrology modelling, there is a smaller body of industry research currently published validating the alternative approach.

This research focuses on the validation of direct rainfall hydraulic modelling. It discusses new computational features of TUFLOW HPC that improve direct rainfall hydraulic modelling predictive accuracy, namely sub-grid sampling and sub-surface (interflow) flow. Sub-surface flow has transformed TUFLOW's traditional 2D surface flow model into a quasi-3D above and below ground simulation tool. The new below-ground feature supports multiple subsurface layers, each with varying user defined hydraulic properties vertically and horizontally.

This paper presents the effects of varying Manning's n values, cell size, infiltration and, subsurface flows during direct rainfall hydraulic modelling. Model calibration is undertaken using both short term (event based) and long term simulations for a range of catchment types, including urban, rural and mixed catchments.

INTRODUCTION

Flood modelling has traditionally been carried out in two stages – hydrologic modelling and hydraulic modelling. Hydrologic modelling typically uses semi-distributed hydrologic models (Caddis *et al.*, 2008). Simplified routing is used to propagate the runoff from the upper sections of the catchment down to the upstream hydraulic model extent. Flows generated from hydrologic models are then applied as inflows to hydraulic models to simulate the flood behaviour.

Recent computational hardware and two-dimensional shallow water equation solution scheme advancements are now expanding our available options for hydrologic assessments. Direct rainfall modelling has been applied in this field for over 10 years, refer Caddis *et al.* (2008), Johnson (2013) and Boyte (2014), however, it is becoming more prevalent. This paper presents the effects of varying Manning's *n* values, cell size, infiltration and subsurface flows during direct rainfall hydraulic modelling. Model calibration is undertaken using both short term (event based) and longer-term simulations for a range of catchment types, including urban, rural and mixed catchments.

BACKGROUND

There are numerous approaches for modelling the hydrologic processes that generate flood flows. Typically for flood flows, these are quickflow mechanisms that rapidly convert rainfall to streamflow and so generate a flood hydrograph. Slower processes (such as baseflow) are contributed by release of stored water over time (Ball *et al.*, 2019).

Australian Rainfall and Runoff (ARR) Book 4 (Ball *et al.*, 2019) describes models based on the spatial resolution as lumped, semi-distributed or distributed, refer Figure 1 below (reproduced from ARR book 4, Ball *et al.*, 2019). A commonly used approach for flood modelling is linking a semi-distributed hydrology model with a hydraulic model. Direct rainfall modelling (also referred to as rain-on-grid modelling) is a distributed model where the runoff processes are simulated by applying rainfall to each cell in the 2D grid or mesh and the 2D hydraulic solver is used to route the water down the catchment.

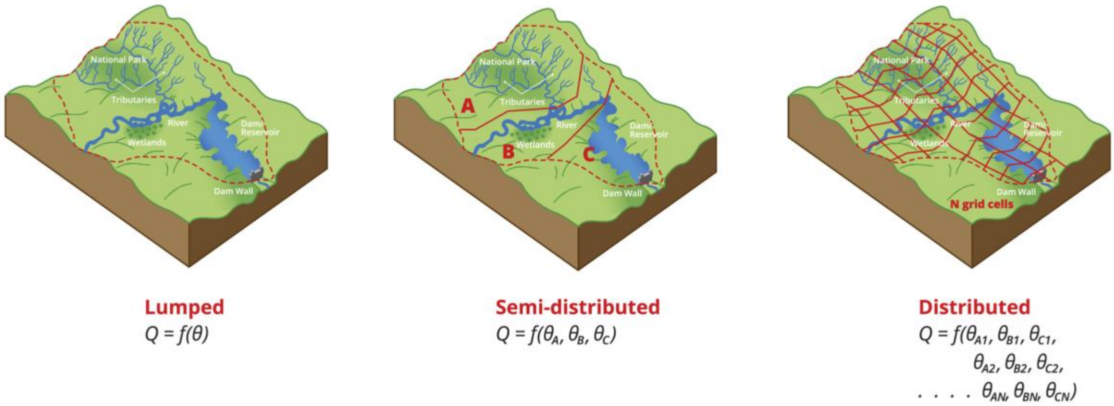

Figure 1. Catchment Hydrology Approaches (ARR 2019, Book 4 Figure 4.2.5)

Among the potential advantages of direct rainfall modelling are:

- No subcatchment delineation is required, which can be difficult in flat areas due to cross-subcatchment flows.
- Higher resolution representation of hydrologic processes.
- Consistency between land use types in the hydrologic and hydraulic models.
- Simplified modelling process with 1 model rather than 2 separate models.

Potential disadvantages for direct rainfall modelling include:

- Requires elevation data (e.g. Digital Elevation Models (DEMs)) of sufficient quality.
- Slower runtimes compared to lumped or semi-distributed hydrology models.
- Industry acceptance.
- Need to filter shallow depths from hydraulic model outputs.

CASE STUDY ASSESSMENTS

This paper introduces three case studies. For each study, predictions of 2-Dimensional (2D) hydraulic model results using direct rainfall are compared to recorded data and the semi-distributed hydrology models used for the study.

Case Study 1: Throsby Creek

The *Throsby, Cottage and CBD Flood Study* (BMT WBM Pty Ltd) was completed for Newcastle City Council (Council) in 2008. The 2008 model has been updated for this research as follows:

1. The hydraulic model was converted from TUFLOW Classic (Software Version 2007-07) to TUFLOW HPC (Software Version 2020-10-AD).
2. The hydraulic model extent was extended to the catchment boundary to allow for all inflows to be accounted for using direct rainfall.
3. The 2008 flood study encompassed both Throsby and Cottage Creek catchments, for this research the larger Throsby Creek catchment is used as this had the majority of the recorded data.

Beyond these changes, the model inputs from the 2008 study remain unchanged. For a full description of the flood model and overview of the 2008 assessment, refer to the 2008 study report hosted online by Council: Report-Throsby-Cottage-CBD-Flood-Study.pdf (BMT WBM 2008).

The Throsby, Cottage and CBD Flood Study area represents an excellent urban case study location suitable for real-world benchmarking.

- The catchment is heavily urbanised, including the central business district of Newcastle, New South Wales's second most populated city.
- The catchment topography, landuse and stormwater drainage data are considered of high quality (BMT WBM 2008).
- Pluviograph coverage within and surrounding the catchment is reasonable. Six rainfall gauges are located within the catchment. There are a further six additional rainfall gauges in neighbouring catchments to the north, west and south close to the catchment boundary.
- Water level gauge recordings at five sites along the main channels, three within Throsby Ck.
- Council have proactively collected historic flood data following notable events.
- Heavily engineered drainage system, with extensive concrete open channels and culverts (refer Figure 2) with evidence of very high flood velocities.

The research focuses on comparing direct rainfall and hydrology model results to recorded data from the 1990 flood event. The 1990 event saw several intense rainfall bursts over a 48-hour period on the 2nd and 3rd of February 1990. Rainfall across the catchment was relatively uniform, varying from around 350 mm in the west to 450 mm in the east (BMT WBM 2008).

Following the 1990 event, Council collected 70 surveyed peak flood marks, and water level timeseries data from stream height gauge recorders installed by Hunter Water Corp were recovered from 5¼" floppy drives. The peak flood marks were classified in terms of reliability, from Grade 1 being the most reliable (e.g. high water mark in building) to Grade 4 (rough observation). Results reported below focus on two stream gauge recorders, namely Jellicoe Pde and Litchfield Pk and the 27 Grade 1 peak flood levels in the Throsby catchment. The Jellicoe Gauge is on the main trunk drainage line for the catchment. It is located within a 20 m wide concrete lined man-made trapezoidal channel. The Litchfield Gauge is on a tributary drain of the main trunk drainage line. It is also a concrete lined man-made trapezoidal channel construction, although is only approximately 12 m wide. A third gauge (Bates St) is within the catchment but significantly under-recorded the flood levels based on nearby flood marks but whilst it was still useful for the flood timing it is not included in the results below.

The hydraulic model uses a 10 m cell size with open channels and structures (bridges, pipe and culverts) modelled as embedded 1D elements. The layout of the hydraulic model is shown in Figure 2 with the location of gauges and flood marks shown in the left panel and land-uses in the right panel.

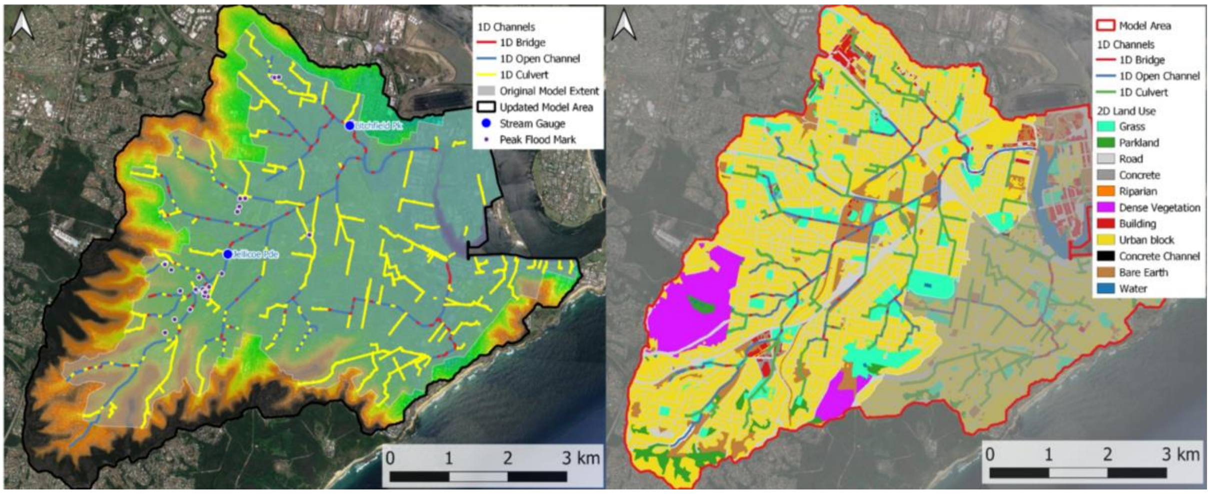

Figure 2. Throsby Creek TUFLOW model layout and land uses

For the 2008 flood study, a detailed hydrology model using the Watershed Bounded Network Model (WBNM) software was created and calibrated. This model consists of 198 sub-catchments containing their area, percentage impervious, and pervious/impervious lag parameters. The hydrology model has 135 channel routes connecting the sub-catchments, each having a defined lag parameter. The cumulative rainfalls from the pluviographs and the WBNM model layout are presented in Figure 3.

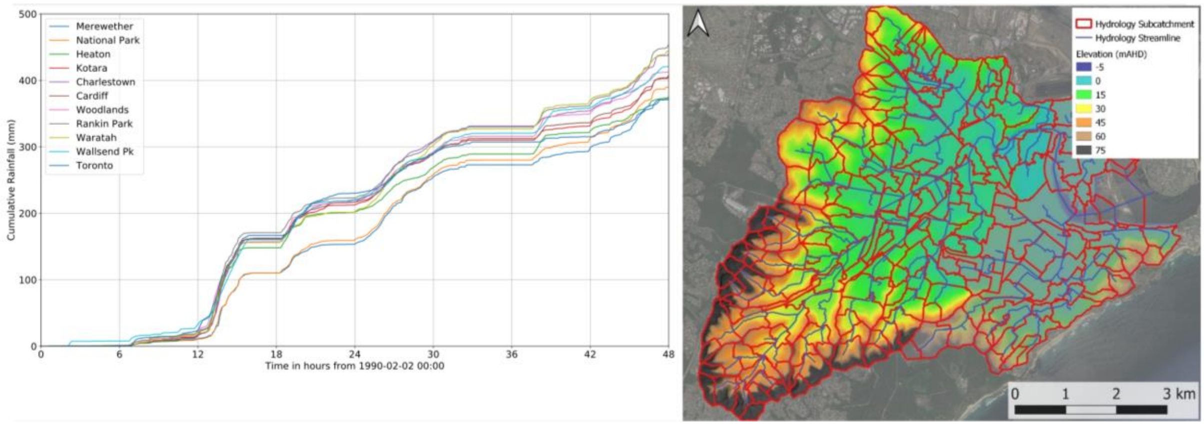

Figure 3. Cumulative Rainfalls and Throsby Creek WBNM Sub Catchment Layout

The hydraulic model was configured to run with both the original hydrology model inputs as well as direct rainfall, all other inputs remaining consistent. For the direct rainfall model, spatial interpolation of rainfall depths used an inverse distance weighting approach between pluviograph locations. The timeseries results at the two gauges are shown in Figure 4. A histogram of the differences between model and recorded peak flood levels for the Grade 1 flood marks are presented in Figure 5. Statistics for the median, mean and root mean squared error (RMSE) are included.

For this urbanised catchment the calibrated hydraulic model using direct rainfall achieved a similar quality calibration as the hydraulic model using semi-distributed hydrology model. The consistency between the hydrology and direct rainfall with no recalibration of the hydraulic model required (e.g. modifying Manning's *n* for direct rainfall runoff) is encouraging.

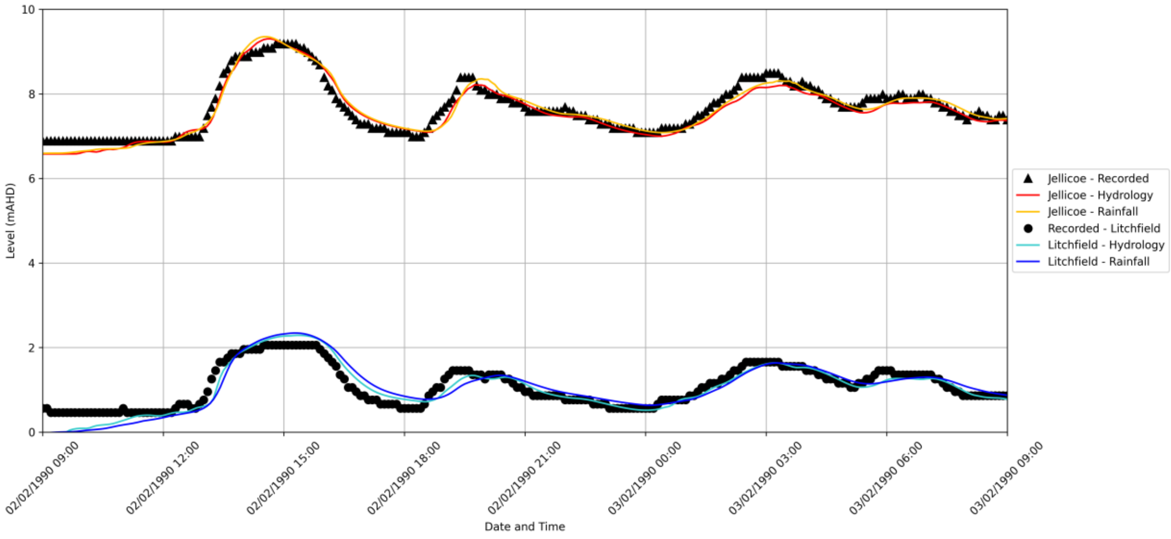

Figure 4. Throsby Creek Hydrology Inflows and Direct Rainfall

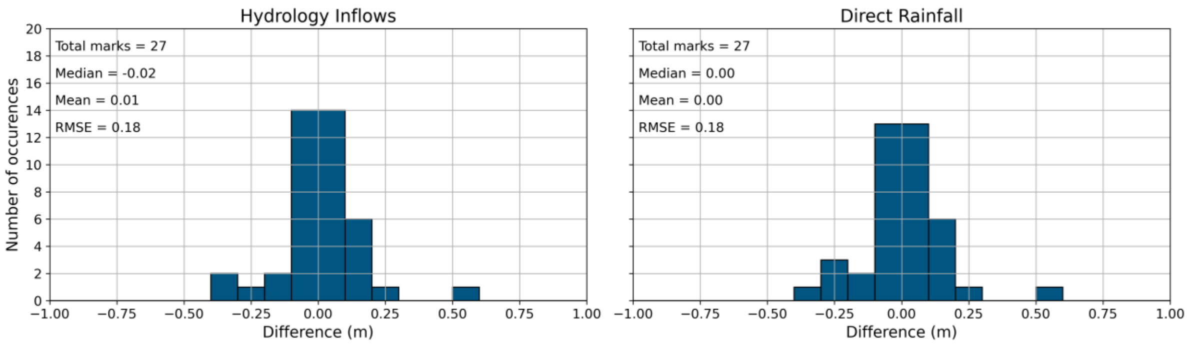

Figure 5. Throsby Creek Histogram of Modelled and Recorded Peak water levels

Case Study 2: Plynlimon

The second case study presented is from a small well gauged catchment in Wales (UK). The catchment area is 11.6 km^2 and the predominant landuse is grassland. Whilst not located in Australia, this dataset represents an excellent case study for testing direct rainfall due to the quality of the data set. This catchment is a research catchment for the UK Natural Environment Research Council (UK NERC, refer Plynlimon Research Catchments) and has a long record of data collection. Relevant to direct rainfall research is that there is a rainfall pluviograph located within the catchment and three water level recording locations at control structures producing accurate flow estimates.

Rainfall and flow data were used in conjunction with the Flood Estimation Handbook (FEH13) catchment descriptors to calibrate a Revitalised Flood Estimation Handbook 2 within the ReFH2 software (RefH2 is the UK standard for estimating runoff hydrographs). The Plynlimon observed rainfall and flow data were provided by the Centre of Ecology and Hydrology, Bangor. Results comparisons have been made to timeseries of flow at the Cefn Brwn gauge, which is the downstream gauging station. The elevation, aerial imagery, and gauge locations for the Plynlimon catchment are presented in Figure 6.

Results comparisons have been made primarily for a 24hr event in November 2015 that includes a double peak in the observed flow. A secondary 1-month period in January and February 2018 that includes a number of discrete rain events was also modelled.

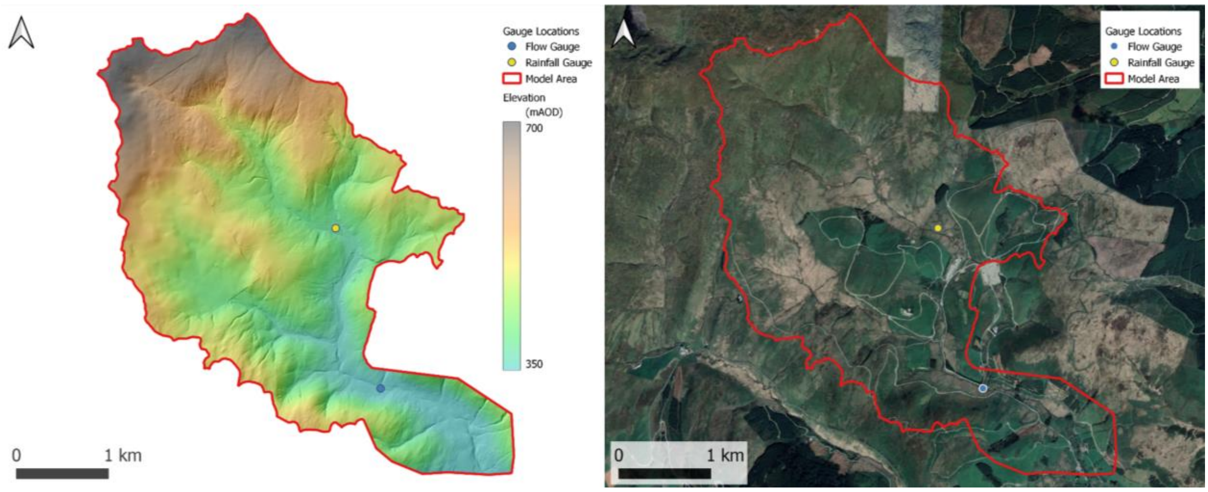

Figure 6. Plynlimon Elevation, gauge locations and aerial imagery

Cell size and topography sampling

Solution convergence to cell size refers to the tendency for model simulation results to trend towards a common answer as cell size decreases (Kitts, 2020). A cell size convergence test was carried out on the Plynlimon model using the traditional approach of sampling single elevations at the cell centres and cell mid-sides. This was repeated using the Sub Grid Sampling (SGS) approach, which extracts elevations at sub-grid resolution to develop a non-linear relationship between the water surface elevation and the cell's volume to describe the cell's storage capacity (Huxley, 2021). SGS also generates a non-linear relationship between the water surface elevation and the cell face area and cell width (or wetted perimeter) to improve the representation of the fluxes across the cell faces as flow is conveyed through the model. Figure 7 presents the results for the traditional topography sampling approach and Figure 8 presents those for SGS topography sampling.

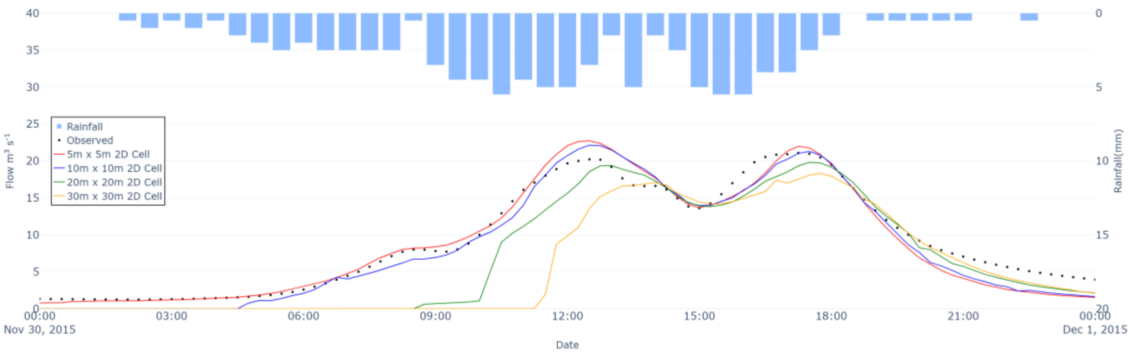

Figure 7 Plynlimon 2015 Model Results – Traditional Topography Sampling

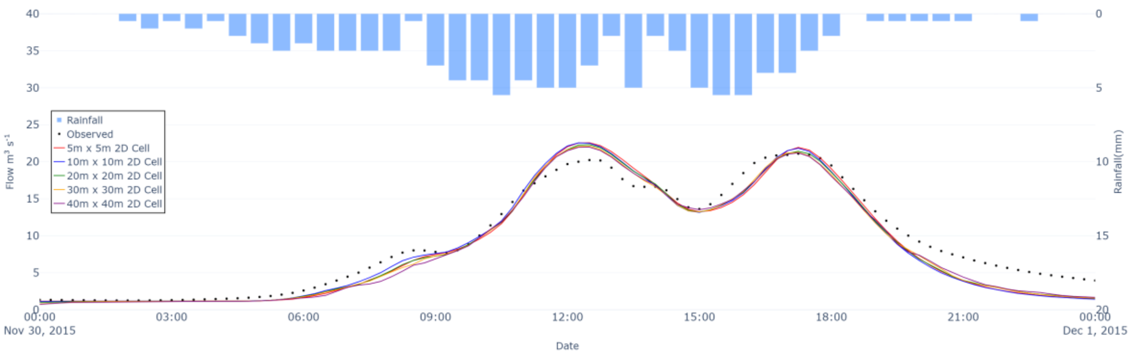

Figure 8 Plynlimon 2015 Model Results – SGS Topography Sampling

For traditional topography sampling a finer resolution cell size is required than SGS topography sampling to achieve a converged solution. For direct rainfall modelling, a large portion of the model has shallow flows and the ability of the model to represent physical terrain and hydraulic complexity may require a small cell size or SGS topography sampling to ensure accurate runoff response.

Manning's roughness

Preliminary simulations were based on a Manning's n values for grasslands of 0.06, this was found to produce hydrographs with a faster response than observed. A depth varying Manning's n was tested which had an $n = 0.30$ at shallow depths below 0.2 m to $n = 0.06$ above 0.5 m. This was still found to produce hydrographs that were faster than observed. A better fit for timing of peaks and attenuation of the hydrograph was obtained with $n = 0.3$ for all depths, however, the authors were uncomfortable with this value as it is well outside the industry range for grassland.

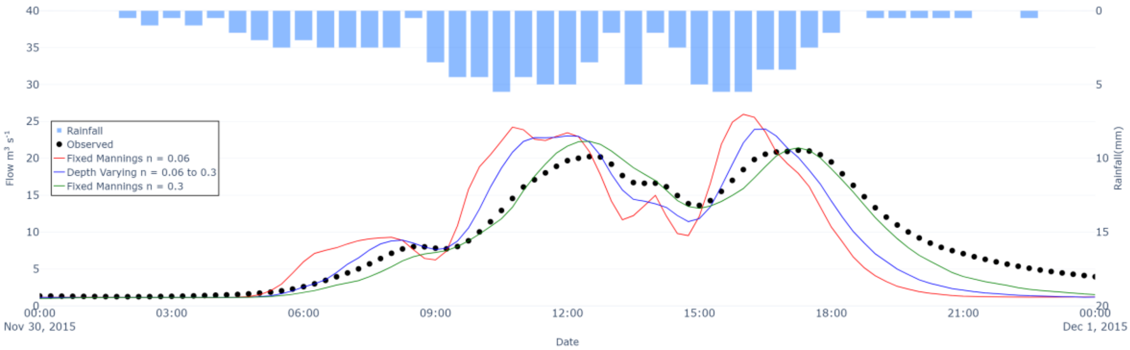

Figure 9 Plynlimon 2015 Results Manning's *n*

Infiltration and Subsurface Flows

As the rainfall intensity is relatively low, the model results are sensitive to infiltration rate. With best fit grassland Manning's n value of 0.3, results for no infiltration into the soil and with 2 mm/hr continuing loss are shown in Figure 10.

The inability of the direct rainfall model to replicate the flows using standard range Manning's n values indicates that there is a potential flow mechanism missing in the model. To explore this further the TUFLOW 2022 version that supports multiple layer subsurface flow was applied. The sub-surface flow approach is based on a 2D implementation of Darcy's law, as described by the equations below.

$\boldsymbol{Q^z} = -\boldsymbol{k}A$	*1) vertical flow*	*k is vertical hydraulic conductivity (mm/hr)*
$\boldsymbol{Q^x} = -\boldsymbol{k_{hor}A_x}\,\frac{\boldsymbol{dh}}{\boldsymbol{dx}}$	*2) x-direction flow*	*k_{hor} is horizontal conductivity (mm/hr)*
$\boldsymbol{Q^y} = -\boldsymbol{k_{hor}A_y}\,\frac{\boldsymbol{dh}}{\boldsymbol{dy}}$	*3) y-direction flow*	*A is flow area (mm2)*

The hydraulic model was simulated with a typical grassland Manning's n value of 0.06 and with a subsurface flow assuming a maximum subsurface flow depth layer of 0.15 m. The results are presented in Figure 10 and show calibration can be achieved with Manning's n values that are within normal ranges, by including subsurface flow mechanism.

Comparison with ReFH2 hydrology

ReFH (Kjeldsen, *et al*., 2005) is a runoff generation method that estimates flows and routing for observed event and design events. Flows for the direct rainfall model and the ReFH2 approach are presented in Figure 11. The results show that direct rainfall is providing improved calibration compared to the ReFH approach in terms of peak flows and timing of peaks.

To investigate this outcome further, a longer duration simulation with multiple rainfall events was simulated with both direct rainfall and ReFH2 with the results presented in Figure 12. The results highlight that for the longer simulation a comparable quality of calibration to the ReFH2 approach occurs.

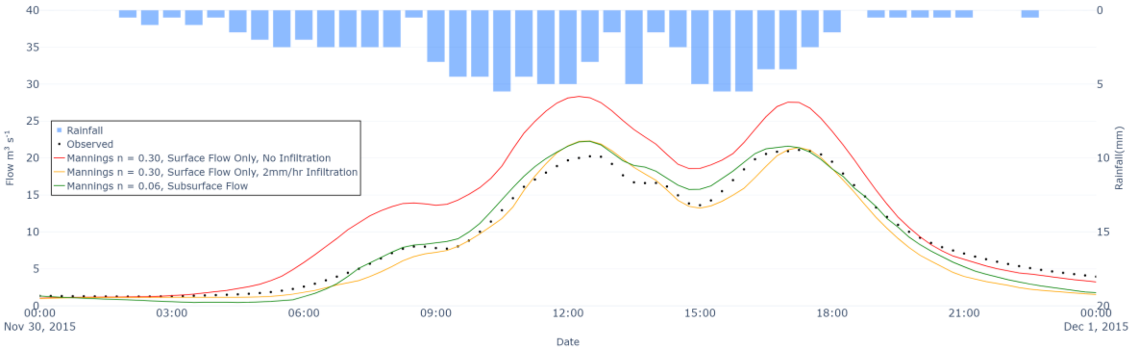

Figure 10. Plynlimon 2015 Results Subsurface Flows

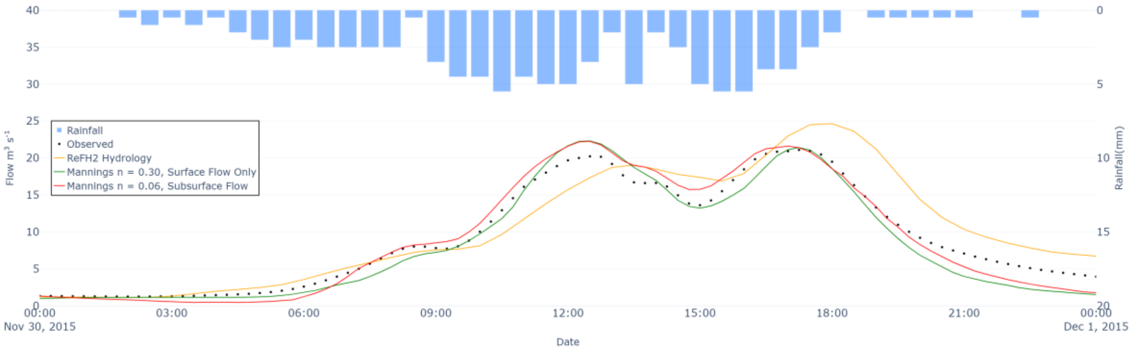

Figure 11. Plynlimon 2015 Results comparison to ReFH2 Model

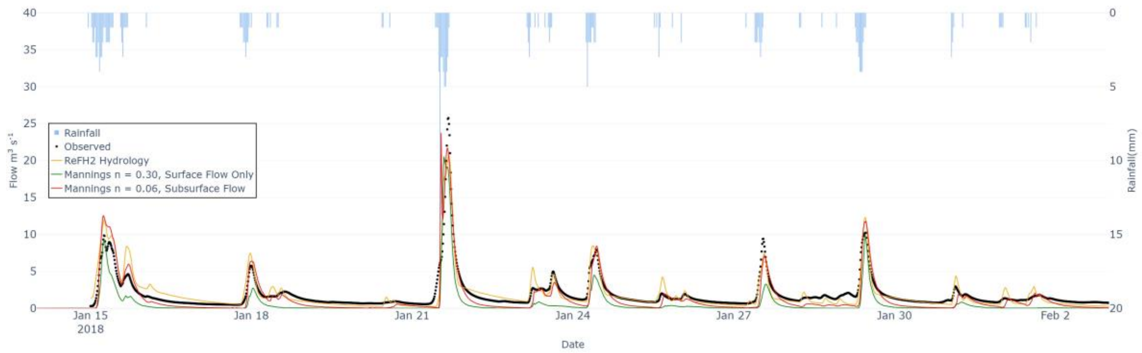

Figure 12. Plynlimon 2018 Result comparison to ReFH2 Model

The above calibration was achieved manually in the usual manner of trial and error. For the 2015 calibration model with a 20 m cell size and SGS topography, the model takes <1 min to run (45 secs including model initialisation on a Titan XP GPU). This makes automated optimisation of model parameters feasible in terms of computational effort, for example with 10 horizontal hydraulic conductivities, 5 infiltration loss rates, 5 Manning's *n* values, 4 soil porosities, and 4 soil depths a total of 4,000 simulations are required to be simulated, which is feasible for a less than one minute run time. Figure 13 shows the bulk simulation results and the best fit as determined using a Nash–Sutcliffe model efficiency coefficient (NSE).

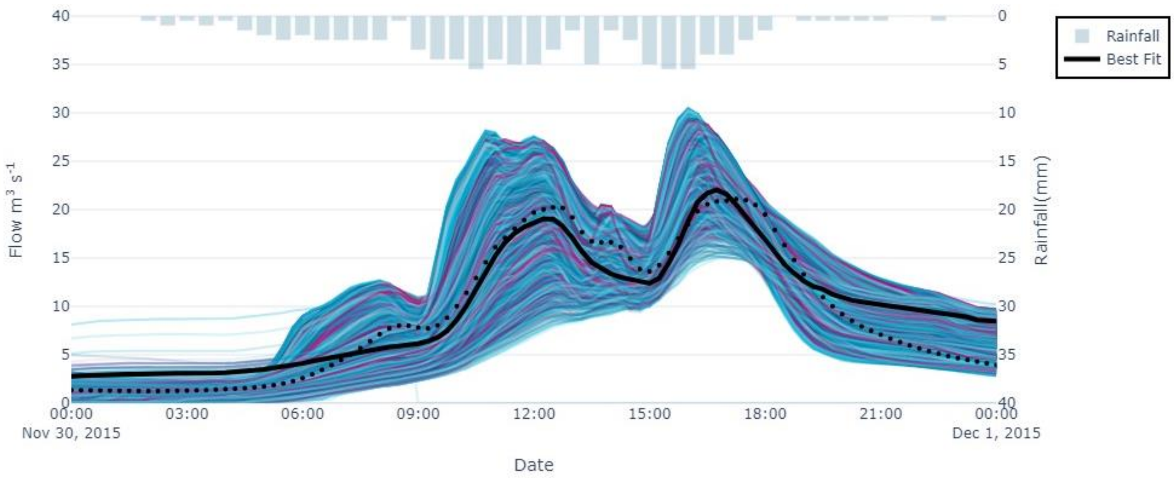

Figure 13. Plylimon 2015 Bracketed Calibration

Case Study 3: Johnstone River Catchment

The Johnstone River Catchment in far north Queensland is a large predominately rural catchment covering an area of 1,645 km^2. Grazing pasture dominate the upper catchment tablelands and sugar cane field covers much of the lower catchment's floodplains. The central region of the catchment is a National Park area covered in dense rainforest. Elevations range from sea level (0mAHD) to over 1,200 mAHD over a distance of approximately 70 km. The region is one of the wettest areas in Australia with very high rainfall events.

The catchment was the subject of a direct rainfall analysis presented at the HRWS 2016 conference (Huxley and Syme 2016) and was revisited for this paper to assess the effects of recent developments in direct rainfall modelling. For background information on the model site, development and outcomes refer to the original 2016 paper.

The modelling focuses on comparing modelled flows to recorded data from the February 2009 flood event. The event was a multi-peak flood that occurred over a 12-day period with the highest peak comparable to a 20% Annual Exceedance Probability (AEP) flood.

The Johnstone River catchment has high quality LiDAR digital elevation data for the lower portion of the catchment. However, the upper catchment is limited to Shuttle Radar Topography Mission (SRTM) DEM data at coarser spatial resolution and lower vertical accuracy (**Error! Reference source not found.**). For the original work, which was based on modelling in 2010 for the Cassowary Coast Regional Council Flood Study (BMT WBM 2014), the 3-sec (~90 m) SRTM data set was used. Use of newer SRTM data at 1-sec (~30 m) resolution in unmodified and hydrologically enforced (DEM-H) formats available from the Geosciences Australia (GA) ELVIS portal was also investigated.

Four SRTM DEM scenarios were modelled:

- 3-sec DEM – 3-sec SRTM data with no hydrologic enforcing as used for the 2016 paper
- 3-sec DEM-H – 3-sec SRTM data with hydrologic enforcing as used for the 2016 paper
- 1-sec DEM – 1-sec SRTM data with no hydrologic enforcing available from GA
- 1-sec DEM-H – 1-sec SRTM data with hydrologic enforcing available from GA

To minimise run times so that the full 12-day event could be simulated, cell size results convergence testing was carried out using the original model which used the 3-sec DEM-H SRTM data set. Poor convergence was apparent without SGS (**Error! Reference source not found.**) whilst reasonable convergence occurred with SGS (**Error! Reference source not found.**). The 100 m resolution 2D model with SGS was considered to provide the best balance between fast run times (20 mins to simulate 12 days) and consistent results compared with finer cell sizes when comparing flows at the Central Mill gauge (Figure 14).

For the longer 12-day event modelling, a reducing rainfall loss approach using the Horton model applied as a soil infiltration loss (rather than a rainfall excess loss) was found to provide a better match to runoff volume for the 2D direct rainfall simulations. An initial loss rate of 5 mm/hr declining at 0.1 mm/hr was used. As the loss was applied as a soil infiltration, the 0.1 mm/hr decline only applies whilst the 2D cell is wet. By comparison, the original 2016 direct rainfall modelling used a constant 2 mm/hr continuing loss and the URBS hydrologic modelling used a constant 5 mm/hr. For comparison, the original hydrologic modelling using URBS (BMT WBM 2014) is presented on the charts.

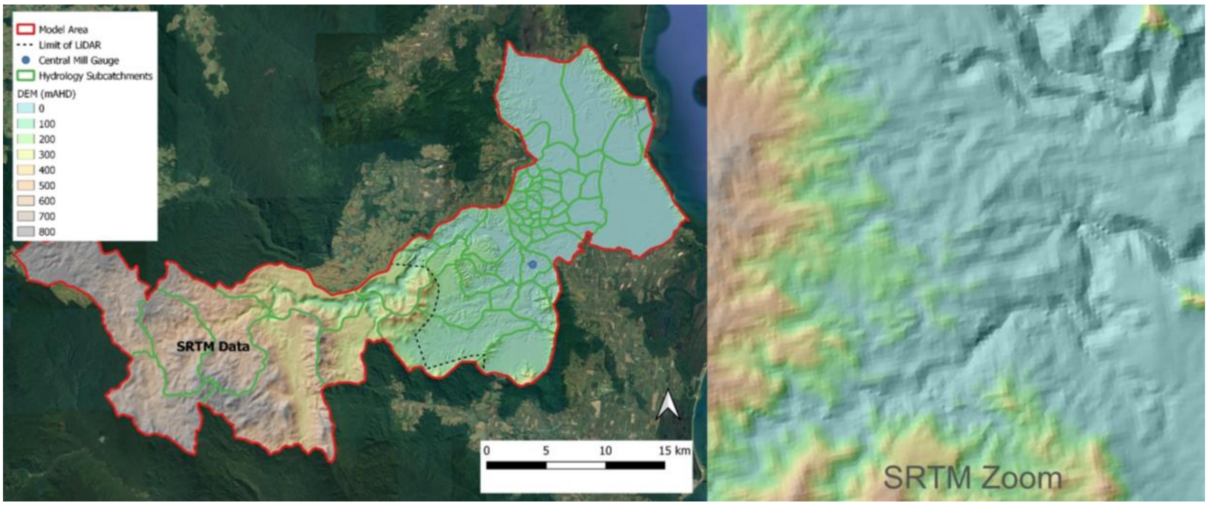

Figure 14 Johnstone Catchment Elevations and Central Mill Gauge Location

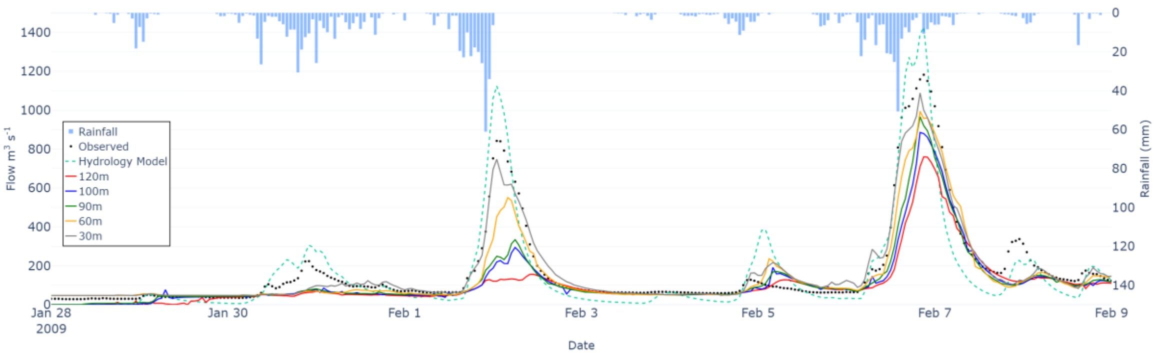

Figure 15 Johnstone River Cell Size Convergence Results - Traditional Topography Sampling

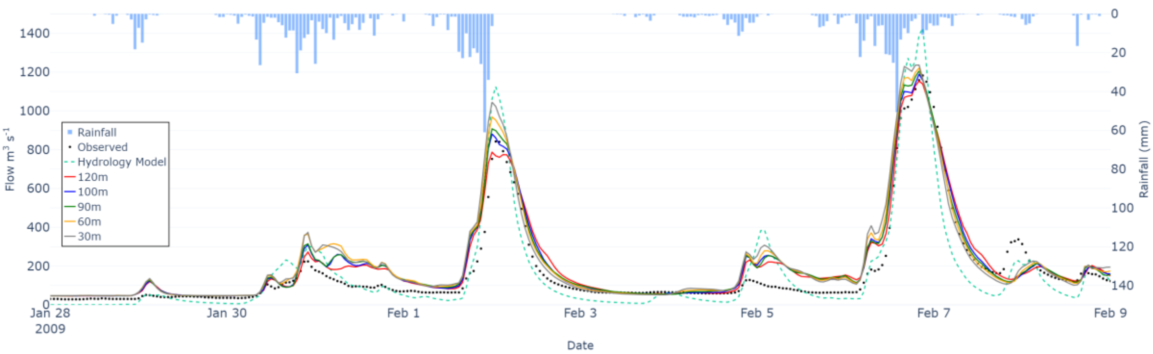

Figure 16 Johnstone River Cell Size Convergence Results – With SGS Topography Sampling

The effects of hydrologic enforcing, with and without SGS, are presented in Figure 17 and Figure 18 using the 1-sec and 3-sec SRTM DEMs. The charts show that without SGS there is a very poor reproduction of the estimated gauge flows using a 100 m 2D cell size. With SGS, a much better representation is achieved, with seemingly better results with hydrological enforcing.

For high-quality DEMs that have a good representation of in-bank flowpaths, the general recommendation is that there should be no need for hydrologic forcing using gully lines if using SGS. Without SGS, however, gully lines are needed to modify the DEM so that a continuously smooth low flow path along streamlines occurs in the 2D model. However, for low-quality data sets like SRTM, there seems to be a benefit for using hydrologic enforcing if using SGS. The results also show that if not using SGS, considerable care needs to be adopted if using low-quality data sets like SRTM. Regardless, confirmation that an appropriate 2D cell size is being used needs to be demonstrated through carrying out cell size results convergence testing.

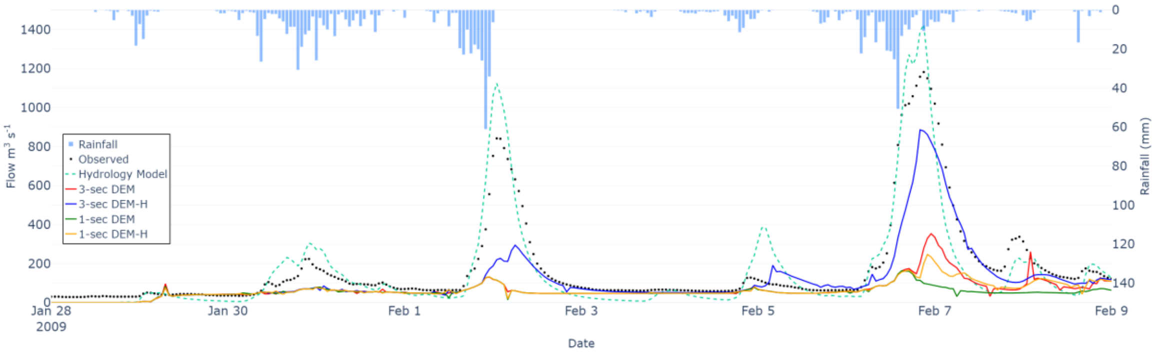

Figure 17. Johnstone River Results – With and Without Hydrologic Enforcing (No SGS)

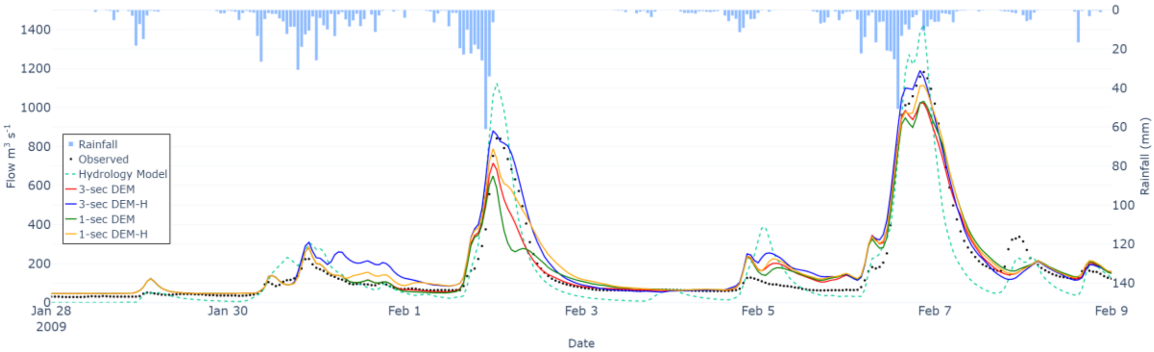

Figure 18. Johnstone River Results – With and Without Hydrologic Enforcing (With SGS)

CONCLUSION

This study aimed to compare direct rainfall and hydrologic modelling to recorded data for a range of catchments. The three case studies represent significantly different catchments in both catchment scale and landuse. The Throsby model is representative of highly urbanised area with complex rainfall/runoff characteristics, flowing overland into an engineered network of open channel and urban stormwater drainage network. The Plynlimon catchment is a smaller rural catchment with lower rainfall intensities and sub-surface flows. The Johnstone River is a very large rural catchment with lower quality elevation data in the upper catchment area.

Cell size results convergence testing appears to be strongly recommended for direct rainfall models as the hydrological response can vary substantially with 2D cell size. Sub-Grid Sampling (SGS), a technique to sample DEM elevations at resolutions finer than the 2D cell size helps ensure low flows are represented for flowpaths narrower than the 2D cell size. SGS significantly improves direct rainfall modelling by low flow transmission of water with minimal retention or blocking of flows thereby producing superior reproduction of the rise and fall of gauged hydrographs. SGS also demonstrated excellent cell size results convergence allowing the use of much larger 2D cell sizes and faster run times.

Direct rainfall is more sensitive to topographic data quality compared to lumped or semi-distributed hydrological methods. In addition to standard hydrology processes (infiltration, imperviousness, roughness, etc), the DEM is preferably of high-quality to be suited for direct rainfall modelling. If using SGS, there is negligible or minor benefit in hydrologically enforcing high-quality DEMs. However, evidence from the Johnstone River modelling suggests hydrologic enforcement of low-quality DEMs maybe beneficial.

Sub-surface flows can be important for catchments with conductive soils or for longer term simulations where sub-surface conditions play an important role in the runoff process. Direct rainfall applications with sub-surface flows and stores represented in the hydraulic model is an emerging area that warrants on-going research and benchmarking.

The real-world model applications presented demonstrates that direct rainfall can be a valid alternative to traditional hydrological modelling approaches whilst offering additional benefits.

REFERENCES

Ball J., Babister M., Nathan R., Weeks W., Weinmann E., Retallick M., Testoni I., (Editors) *Australian Rainfall and Runoff: A Guide to Flood Estimation*, Commonwealth of Australia (Geoscience Australia), 2019.

BMT WBM, “Throsby, Cottage and CBD Flood Study”, Technical Report Prepared Newcastle City Council, BMT WBM Pty Ltd, 2008.

BMT WBM, “Cassowary Coast Regional Council Flood Study – Part 1”, Technical Report Prepared Cassowary Coast Regional Council, 2014.

Caddis, B.M., Jempson, M.A., Ball, J.E. & Syme, W.J., “Incorporating Hydrology into 2D Hydraulic Models – The Direct Rainfall Approach”, 9th National Conference on Hydraulics in Water Engineering, September 23-26 2008.

Huxley, C. and Syme, W,. “TUFLOW GPU – Best Practice Advice for Hydrologic and Hydraulic Model Simulations”, Hydrology and Water Resource Symposium, 2016.

Kitts, D. and Syme, W,. “Mesh orientation and cell size sensitivity in 2D SWE solvers”, IAHR River Flow Conference, 2020.

Kjeldsen, T.R., Stewart, E.J., Packman, J.C., Folwell, S.S., & Bayliss, A.C. “Revitalisation of the FSR/FEH rainfall-runoff method”. Defra R&D Technical Report FD1913/TR, 2005.

BIOGRAPHY

Phil Ryan is software development lead for the TUFLOW Classic and HPC hydraulic modelling software products. Phil been actively involved in a range of consultancy projects over 15+ years. These include flood studies, floodplain management studies, flood impact assessments, storm tide studies, Monte Carlo analysis, wave modelling, coastal hydrodynamic and advection-dispersion modelling.

Bill Syme has 38 years’ experience primarily in the flood hydraulics field. During this time, he successfully managed and led a wide range of studies in Australia and overseas. The widely used TUFLOW hydrodynamic modelling software was first developed by Bill starting in 1989. Today, Bill is BMT’s Software Business Lead, managing TUFLOW’s global operations, and continues to provide specialist hydraulic modelling and flood risk management advice. He was the Project Manager for the award-winning Brisbane River Flood Study Hydraulic Assessment, and in 2022, Bill was the recipient of the FMA Allan Ezzy Flood Risk Manager of the Year Award.

Shuang Gao graduated from Tokyo Institute of Technology with a PhD degree in Environmental Hydraulic Engineering. He joined the TUFLOW software development team in 2017, and has been involved in varieties of R&D projects, flood and coastal modelling, technical support and training. His main interests lie in the development of cutting-edge modelling methods applied to real-world engineering problems.

Greg Collecutt is the principal GPU software developer at TUFLOW. He has degrees in mechanical engineering and a PhD in theoretical physics, and has spent most of the last twenty years working in computational fluid dynamics and flood modelling. In this role he is primarily involved with the implementation and benchmarking of new modelling features in the TUFLOW HPC 2D engine.