The Power of Long-Term Hourly Data:
Validating URBS 64 bit Continuous Simulation using Flood Frequency Analysis

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ABSTRACT

Continuous simulation modelling (CSM) is a valuable tool for managing water systems and assessing flood risk, but the availability of long-term, high-resolution rainfall data often limits its accuracy. Daily timestep datasets fail to capture the crucial sub-daily rainfall variability that drives many hydrological and geomorphic processes. This paper presents a robust method for validating continuous streamflow simulations generated by the URBS hydrological model using extended, sub-daily rainfall records. Leveraging a 136-year hourly rainfall dataset developed from daily records and reanalysis products, it can be demonstrated how URBS, configured with the Recovering Initial Loss Model (RILM) in 64-bit mode, can, with a set of parameters, accurately simulate long-duration streamflow. Model calibration and validation were performed by comparing simulated outputs against gauged records using event hydrographs, Flood Frequency Analysis (FFA), and flow duration curves. The results show good agreement with gauged data and align well with the Monte Carlo Total Probability Theorem (TPT) estimates, particularly for more frequent events. This validation approach provides increased confidence in using long-duration CSM for reliable predictions in water management, mine closure planning, and infrastructure economic appraisal.

INTRODUCTION

Continuous simulation modelling (CSM) plays a crucial role in predicting the behaviour of complex water management systems, including those on mine sites, and in assessing infrastructure vulnerability to flooding. However, the effectiveness of these models is often constrained by the availability of representative long-term rainfall datasets, particularly the lack of high-resolution, sub-daily data. While daily timestep models provide valuable insights, sub-daily rainfall variability fundamentally drives many hydrological and geomorphic processes. Previous studies, such as Vitale (2017), have highlighted the benefits of CSM for applications like assessing flood closures but also underscored the limitations imposed by short pluviograph records.

This paper addresses this critical data gap and presents a novel method for validating continuous simulation results generated using the URBS hydrological model, leveraging significantly extended hourly rainfall datasets. Building on the approach detailed in Millard et al (2025) for generating 136 years of hourly data from available daily and reanalysis records, we demonstrate how long-duration hourly streamflow can be reliably simulated using existing URBS models. By applying rigorous Flood Frequency Analysis techniques and flow duration curves, we validate these simulated flows against gauged records. This validation process provides essential confidence for making robust predictions in vital areas such as water resource management, mine closure planning, and the economic appraisal of waterway crossings under various flood scenarios.

Overview

Daily timestep continuous simulation (CSM) numerical models are widely used to simulate the behaviour of water management systems, dams, landform evolution and flood closure economics. However, some applications require sub-daily inputs to represent physical processes appropriately. For example, releases or overflows from water storage systems may be too short-lived to be adequately represented by daily runoff models.

This paper presents a method for validating continuous simulation results generated using URBS. Millard et al (2025) presented an approach for generating 136 years of hourly datasets from available daily records and gridded reanalysis datasets. That approach was based on sub-daily rainfall patterns extracted from surrounding ‘donor’ rain gauges to enhance the rainfall record and overcome data limitations using the regionalised method of fragments (Westra, 2012). That approach also used Woldemeskel (2016) “IFD conditioning” approach to ensure the rainfall record remained consistent with the expected intensity-frequency-duration (IFD) characteristics.

This paper documents how long-duration hourly streamflow can be simulated using existing URBS models. The generated streamflow can be compared to the gauged record using Flood Frequency Analysis techniques and flow duration curves. This additional analysis provides confidence in making reliable predictions about water management, mine closure challenges, or the economics of waterway crossings.

Many open-source access datasets, such as BoM’s BARRA-R2 or ERA5 reanalysis global climate data (Copernicus, 2023), are now freely available. These gridded rainfall sources provide rainfall and evapotranspiration at various grid resolutions and time steps (hours or days) over many decades. A further advantage of the open-source gridded rainfall datasets is that they can be easily adapted to work with evolving sub-catchment delineation between model configurations.

Defining the Problem

Sub-daily rainfall enhances continuous simulation modelling. Finer temporal resolution of rainfall allows the model to represent the response to the intensity and frequency of storm events, which are the key determinants of gully erosion extent, sediment transport, and final landform. Studies by Hancock (2017), Coulthard (2016), and Skinner (2020) have demonstrated that, when using historical and stochastically generated rainfall sequences, sub-daily rainfall variability significantly affects landscape evolution.

Vitale (2017) documented how continuous simulation of stream flows and closure status on the Gore Highway informed economic appraisal by reducing road user costs for the link. CSM provided a basis for prioritising crossing upgrades. The continuous hydrologic, hydraulic and road closure simulation was primarily performed within a GoldSim simulation environment. The continuous hydrologic simulation was resolved at 30-minute interval from available pluviographs. The rainfall records spanned 1973 to 2011 (39 years) to determine the behaviour of crossings with low flood immunity. Vitale (2017) documented the advantages of the CSM method for evaluating flood closures and how it could reveal the characteristics of road closures for both individual waterway crossings and the full length of the highway link.

METHODOLOGY

Conceptual Overview

The timing and arrival of a flood wave through the river systems can be modelled using the URBS hydrologic software. URBS is widely used for flood forecasting and design flood studies throughout Australia. Hydrologic models are necessary to assess large river systems, particularly where a highway network could be subject to flooding at numerous locations throughout the same catchment. Vitale (2017) outlined why flood travel time is vital for the economic assessment of a network link flood study.

Malone (2023) documented URBS software’s extensive application for flood forecasting and design flood studies. Malone catalogued and summarised the parameters from the calibration of 310 models throughout Australia. One key learning from Malone’s 2023 paper was the promise shown by the

Recovering Initial Loss Model (RILM) over the Initial and Continuing Loss (IL/CL) model. Malone concluded that RILM produced superior calibration, particularly in analysing long-duration multipeak events. RILM is an extension of the IL/CL model and allows for recovery of the initial loss when rainfall rates on pervious areas are less than the continuing loss rate.

While URBS has had RILM and CSM functionality, the previous releases were compiled for a 32-bit memory address, which limited the size of array calculations. This limitation was overcome by the 2024 release of URBS to a 64-bit version, allowing the model runs to experience a step change in temporal resolution and run duration.

It is now possible to generate and run models at subdaily timesteps with representative climate records for over 100 years duration. Rainfall records are available throughout Australia from nearby weather stations or gridded products (the Bureau of Meteorology's (BoM) or Queensland Government (SILO, Jeffrey et al (2001)) service).

Software

The URBS hydrological model (Carroll, 2021) is a runoff-routing computer program that uses a network of conceptual storages to represent the routing of rainfall excess through a catchment. The URBS model was used in the 'split mode,' which enables the separate simulation of catchment and channel routing. Rainfall losses are subtracted from the total rainfall hyetograph to obtain rainfall excess. The rainfall excess is then routed through conceptual catchment storage to determine the local runoff hydrograph for each sub-catchment of the model before being added to the creek or river channel. Routing through the creek or river system uses the non-linear Muskingum method, whose lag time is assumed to be proportional to the stream length. Full details of the URBS model and its features are given in the URBS User Manual (Carroll, 2021).

One of the significant benefits of adopting URBS is the vast collection of calibrated models of the river basins in Australia. In addition to calibrating an URBS model against gauge records, URBS can be validated with the design event approach or verified with design flow quantiles undertaken using the URBS Monte Carlo TPT module. URBS models key hydrological processes relating to rainfall, potential evapotranspiration (PET), and streamflow run-off.

Example Application: Adapting URBS to CSM

The starting point for this is a calibrated URBS model. Typically, an URBS model is calibrated to historic flood events using the IL/CL approach. Running URBS CSM requires additional parameters to describe how soil moisture stores vary. The URBS continuous simulation loss module also requires a subarea rainfall (.r) files, and a single evaporation (.pet) file described in the rainfall definition file (.rdf). Each URBS model subarea is assigned a 136-year hourly rainfall sequence. The initial release of URBS 64-bit only requires one evapotranspiration sequence per model vector. While evapotranspiration does not vary as significantly as rainfall, future URBS development will allow individual evapotranspiration sequences to be assigned at each subarea. The following CSM variables then parameterise the URBS model:

- Initial loss (IL) [model initialisation state only].
- Continuing loss (CL).
- Maximum Initial loss (IL_{max})
- Initial loss recovery factor (RF)
- Maximum infiltration capacity (IF); and
- Infiltration recovery (K_d).

A graphical representation of the URBS CSM's recovering initial loss model is shown in Figure 1.

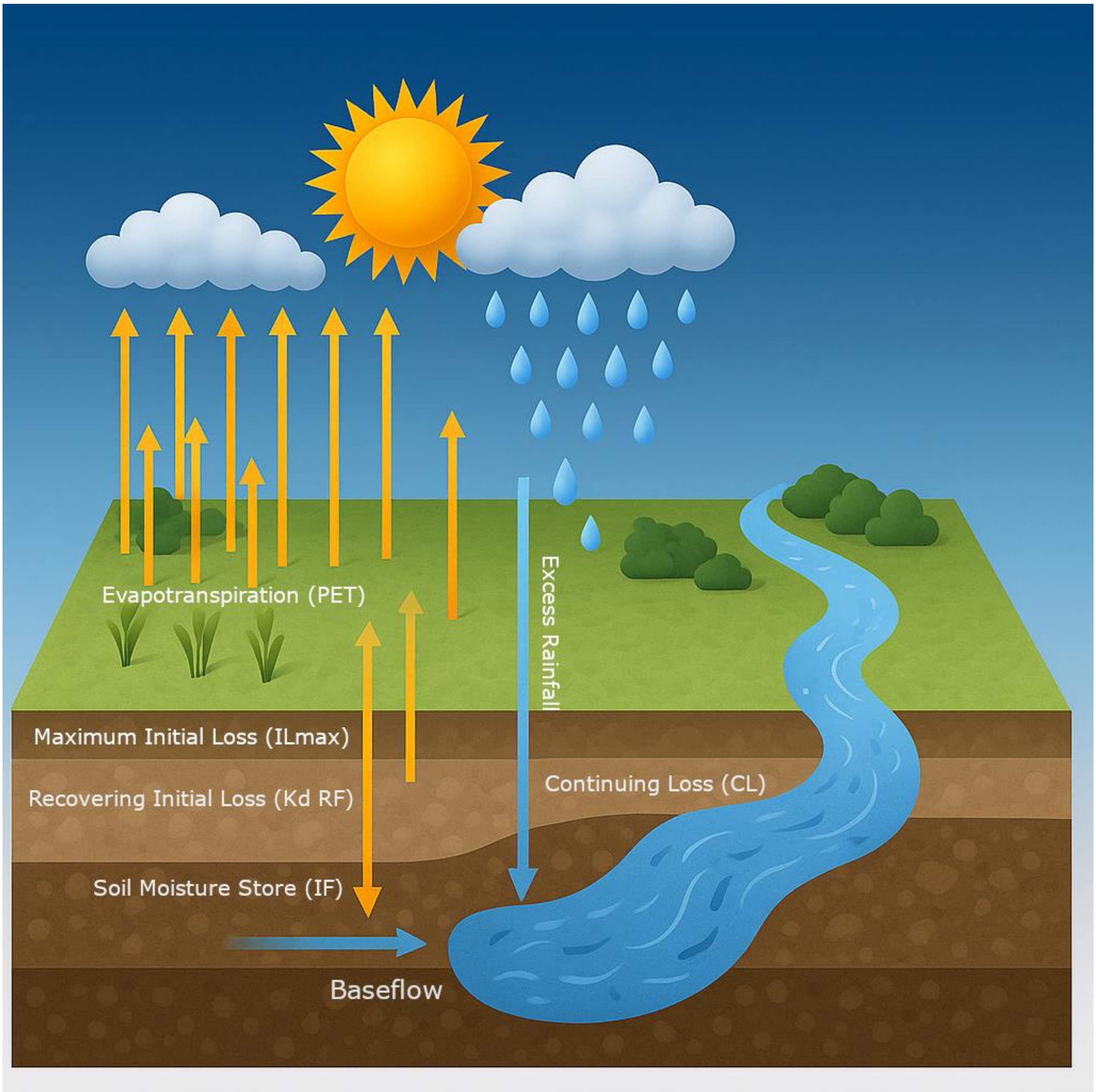

Figure 1 – URBS RILM Schematisation

The CSM parameters were calibrated by analysing the full flow series against the gauge's rated discharge hydrographs, flow duration curves and Flood Frequency Analysis (FFA). The FFA was undertaken using FLIKE for the period of record available at the gauge, not the full generated flow series.

Step 1: Calibrating CSM to events

The calibration of CSM parameters are first compared to the rated gauge discharge hydrographs, is shown by zooming into each calibration event, as shown in Figure 2. The calibration step is undertaken by adjusting the maximum initial loss (IL_{max}) and the continuing loss (CL).

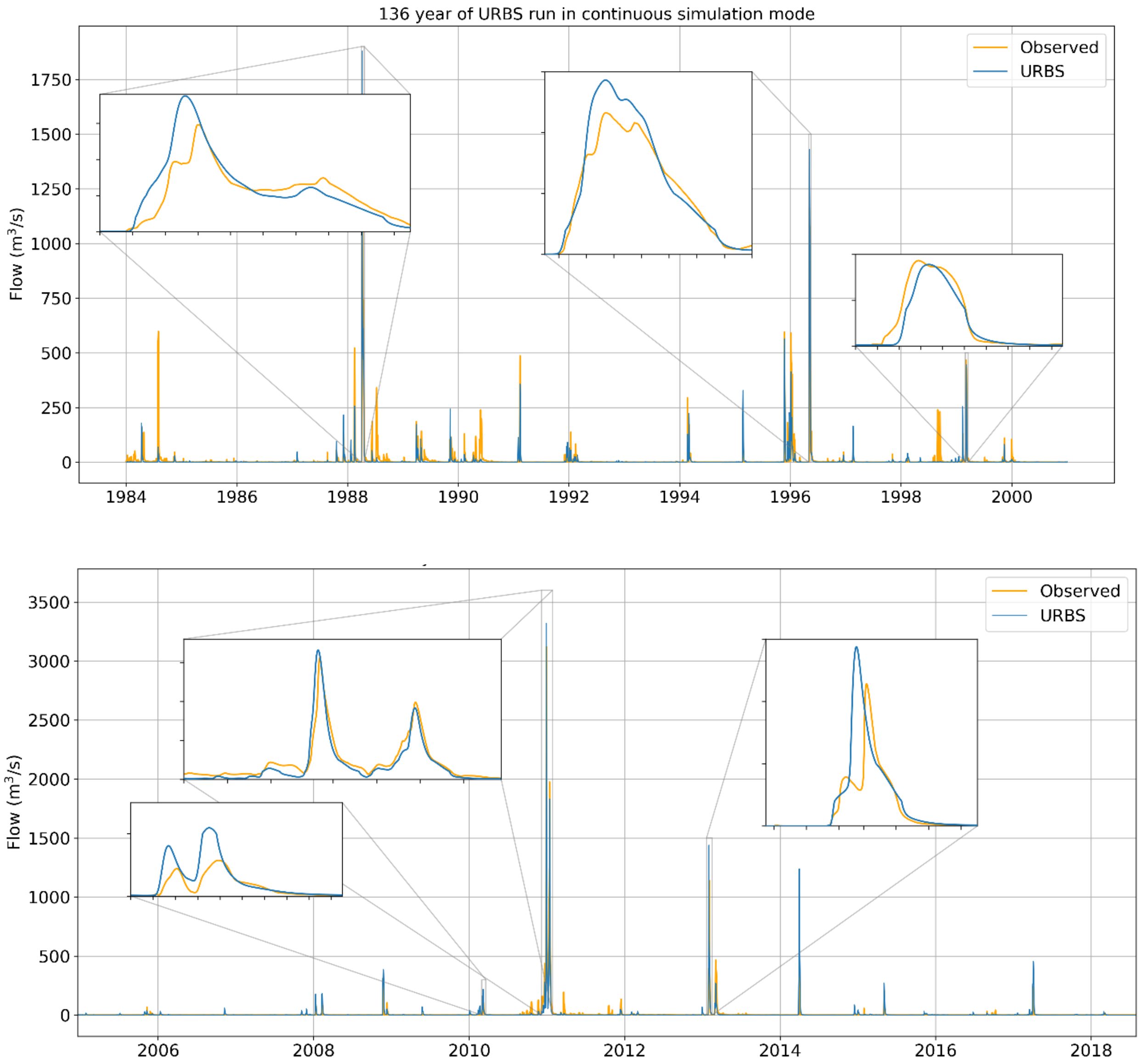

Figure 2 – Hourly timeseries from URBS CSM

Step 2: Flood Frequency Analysis and Flow Duration

Once the hydrograph calibration was deemed acceptable for events of interest, it could then be used to analyse the full record using the statistics. The modelled flow series could be processed into an annual maxima series and compared with the available gauged flow series. Adjustments to the RF, CL, and ILmax were made to improve the FFA match between the gauge record and model output without compromising the hydrograph's calibration. FFAs were undertaken in both FLIKE and RMC-BestFit using the Log Pearson III fitting method.

Another global check is the generation of the flow duration curves from both flow series. Calibration of flow duration curves focused on flow rates above a nominal 20% AEP flow rate. By comparing the model-predicted flow duration curves to the gauge records, calibration could be undertaken by primarily adjusting the RF parameter. Adjustment of RF did not compromise the FFA or event hydrograph calibration. Minor IL_{max} and CL adjustments were also made as part of the calibration of the flow duration curve.

Figure 3 is a comparison of the at site FLIKE Flood Frequency Analysis undertaken using the gauge and corresponding URBS flow series.

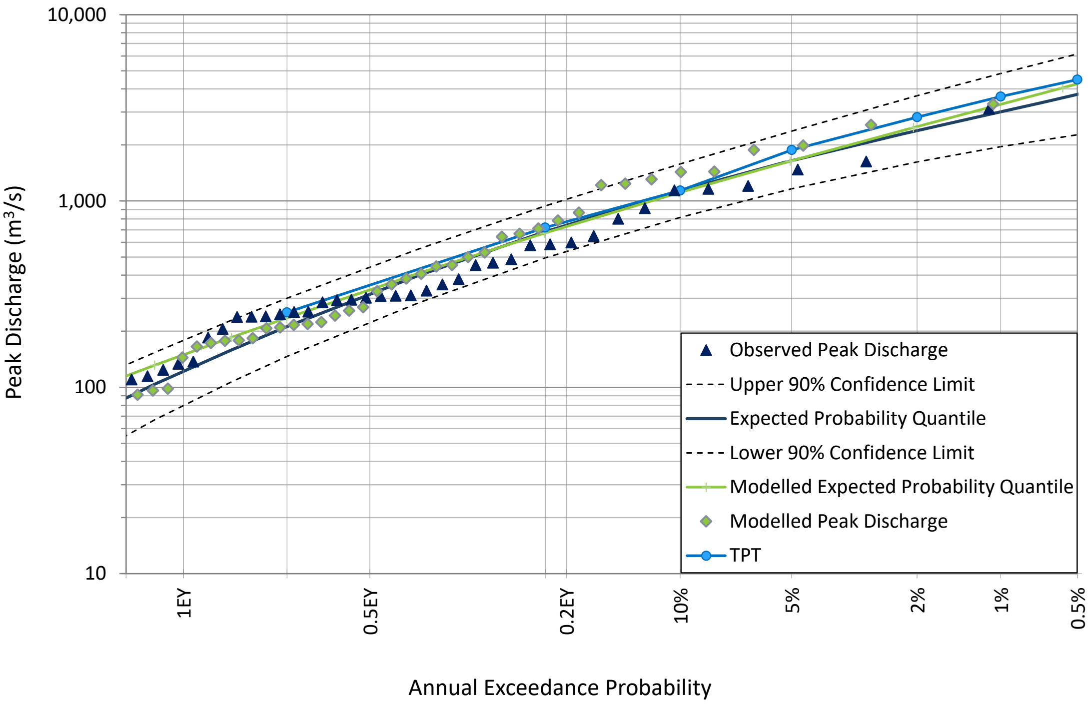

Figure 3 - Flood Frequency Analysis and comparison with TPT.

Discussion

This paper has demonstrated that it is possible to parameterise and calibrate a long-duration URBS model using RILM and CSM. Calibration can be achieved by comparing to available gauge records and using the event hydrographs, FFA and flow duration curve assessments. The model's accuracy in reliably representing the catchment response to flooding is subject to the length of the record and the spatial coverage of rainfall and streamflow data in the catchments.

A further comparison is possible within URBS by using the Monte Carlo Total Probability Theorem (TPT). TPT is often used with Design Event modelling as a method to reconcile a model against a gauge's FFA. Figure 4 shows the quantile estimates derived from model-predicted flow series against those obtained through a Monte Carlo TPT analysis. Also shown is the at site FFA from the gauge. Monte Carlo TPT design discharge estimates are in good agreement with CSM across all AEPs. This agreement could also be confirmed using traditional ensemble design event analysis as described in ARR 2019 (Ball, et al.,2019).

The at-site FFA expected probability quantile shows agreement with the CSM for more frequent events. However, it does not align with 1 in 200 AEP predicted by the MC TPT and CSM approach. Monte Carlo TPT design discharges may not, initially, perfectly align with the model-predicted CSM quantiles. This may indicate a need to fully investigate Monte Carlo initial loss distribution parameters or modelled storm event durations.

The flood quantiles generated from the model-predicted flow series can be regarded as robust estimates. This robustness suggests that they offer a reliable representation of the probable flood events that could occur.

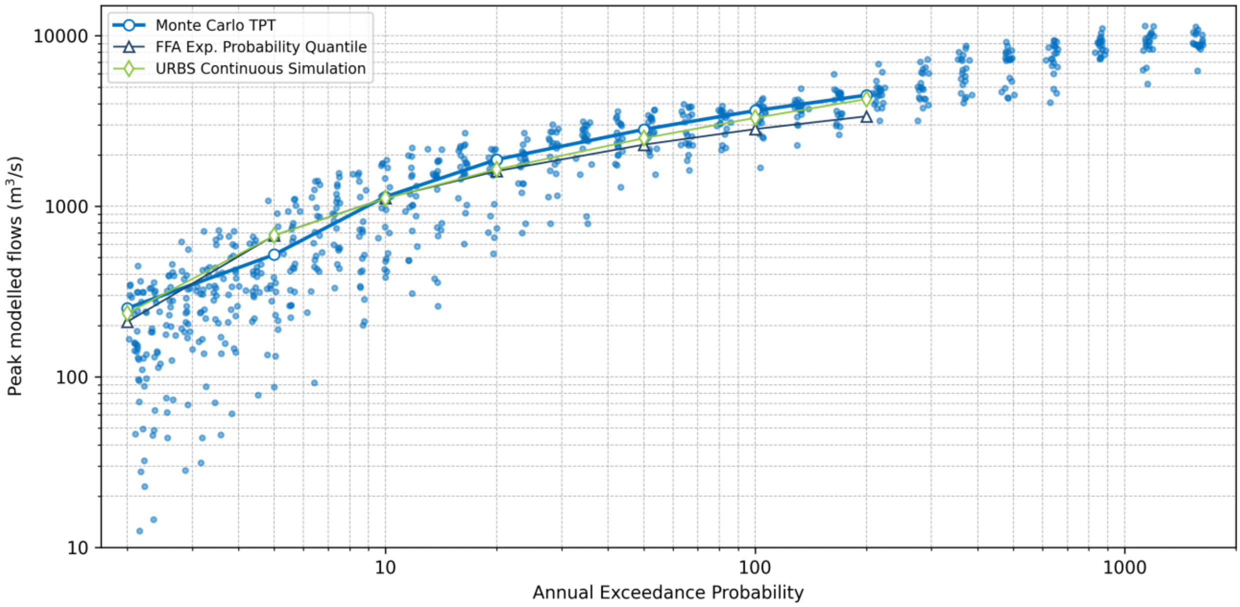

Figure 4 - Monte Carlo TPT realisations and URBS CSM

CONCLUSION

This paper successfully demonstrated a method for parameterising and calibrating a long-duration URBS model using the RILM and CSM approaches. By comparing modelled results to available gauge records through event hydrographs, Flood Frequency Analysis, and flow duration curve assessments, we have shown that this method provides a robust approach for validating continuous simulation outputs. The strong agreement observed between the CSM results and those from Monte Carlo TPT further increases confidence in the reliability of the generated flood quantiles. This enhanced reliability has significant implications for making informed predictions regarding water management, mine closure planning, and economic assessments of infrastructure like waterway crossings.

ACKNOWLEDGEMENTS

Code and data availability. The code described in this study was Python 3.11. The data presented in this paper can be made available on request from the corresponding author. The dataset of the Australian rainfalls and flows can be obtained from the Australian Bureau of Meteorology.

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The author acknowledges the work and effort undertaken by Terry Malone and Don Carroll in developing the Australian URBS models and datasets. Terry Malone has had an extensive career in flood forecasting, dam operations, and flood hydrology design at the Bureau of Meteorology, SunWater, Seqwater, and overseas. Since retirement, this interest has continued, and he collated and standardised a database of over 300 URBS models applied to over two thousand events. Don Carroll is the author of the URBS model and has a lengthy career in Australia and overseas. Over this time, he has been continually developing the URBS model to ensure it is sufficiently flexible and efficient to meet the industry's needs.

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