Published in the November 2016
Floodplain Management Association Newsletter
www.floodplain.org

Flood Modeling: How Accurate is Your Model?

Chris Huxley, TUFLOW (chris.huxley@tuflow.com)
Phillip Ryan, TUFLOW (phillip.ryan@tuflow.com)

Flood modeling is a cost-effective tool for informing all aspects of floodplain management. Flood mitigation assessments, land use planning controls, infrastructure design and even flood insurance classifications are all directly impacted by the precision and accuracy of the flood modeling on which they are based. With this in mind, it is prudent that our flood estimates are accurate, if for no other reason than to avoid costly overdesign, or worse, unexpected and potentially dangerous under-design.

There are numerous factors that contribute to inaccuracy in flood model results; technical guidelines, software certification, engineer certification/sign off all aim to minimize error in modeling activities. Unfortunately these safeguards provide no tangible measure for determining whether model results are correct. Models can be built to guideline specification, though still produce inaccurate results due to reasons such as; over simplifying assumptions within the chosen hydraulic modeling software, input data quality issues and/or model schematization errors. The most effective method to measure a flood model's performance is through calibration to past historic events. For this reason, all flood engineers should place significant emphasis on model calibration.

Many agencies recognize this need and require model calibration to varying degrees. This article briefly discusses some related topics worthy of consideration by agency officials, floodplain managers and consulting engineers.

Calibration Flood Event Selection

Appropriate historic event section is critical. Ideally, model calibration should be completed using multiple historic events of varying magnitude.

1. Calibration to small in-bank flood events is useful for testing whether the dominant conveyance zones are represented adequately within the flood model. Past experience has found model refinement to achieve calibration for an in-bank event is recommended prior to out-of-bank calibration. This staged calibration approach allows for focused refinement of the in-bank model features before consideration of broader floodplain features.
2. Calibration to larger events with significant out-of-bank floodplain inundation tests three critical elements of a flood model: the interchange of flow between the river and floodplain, floodplain storage and flow resistance across the floodplain due to spatial variation in vegetation density.

In addition to magnitude, event selection should also consider data availability, events of historic significance and event recency. Community recollection of these events is typically greatest. If a flood model can reproduce known flood behavior it builds community "trust" in the model's performance. Furthermore, calibration to recent events demonstrates that the model adequately represents the current catchment conditions. This is particularly relevant for models that will be used for design flood estimations following calibration.

Hydraulic modeling software that is founded on the equations of fluid flow and successfully benchmarked should readily replicate the historic flood behavior for the full range of flood events without requiring adjustment of model parameters unless the parameter is event specific. Examples of event specific parameters are the hydrologic inputs (rainfall intensity, duration, spatial distribution, antecedent conditions) and significant physical changes within the catchment that require back dating in the model (land use changes or major topographic updates such has road upgrades). All other model inputs and parameters should be consistent across all historic calibration events. It is

symptomatic of either; software inadequacies, data quality issues and/or model schematization errors if calibration to varying magnitude events cannot be achieved using this approach. For example, unless physically justifiable due to changes in vegetation, in-bank Manning's n value would not be expected to change between events.

Model calibration can be one of the most challenging of all hydraulic modeling tasks. It requires an in-depth understanding of hydraulic principles and also knowledge of the chosen software's limiting assumptions. Engineers new to model calibration should approach the process with a critical mind. If your model doesn't calibrate well, confirm the model inflows are correct, double check the accuracy of topographic datasets (particularly hydraulic controls such as raised road embankments), review/sensitivity test your model parameterization, and seek advice from experienced modelers and/or your software provider. Also consider the vertical, spatial and temporal accuracy of your calibration dataset.

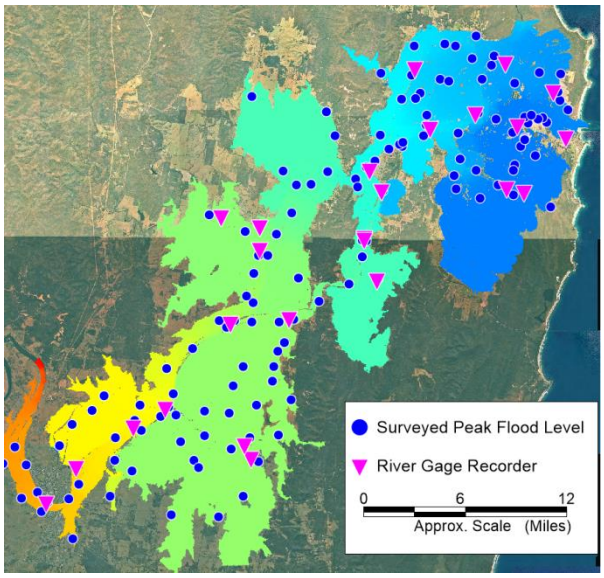
Calibration can be very satisfying when all the pieces align. Be wary of, and avoid, immediately explaining poor calibration by creative reasoning focused on why recorded datasets are inaccurate. You will miss the learning opportunities that come with model calibration, and worse yet create a model that doesn't reflect true flood behavior!

Calibration Methods

Calibration Approach	***Comment***
Neighboring catchment outflow or regression equation flow comparisons	This type of comparison is not a reliable form of model calibration. It does not provide a measure of a models flood level prediction performance. There is, however, still value in the comparison approach as a basic form of anecdotal quality assurance check.
River gage water level time series comparison	This is an excellent measure of a models performance in the main channel. The calibration should focus on replicating the rising limb, falling limb, and flood peak. Note, good calibration in the river channel does not automatically translate to good calibration in the floodplain (see below). Calibration to multiple gages is essential to demonstrate the model correctly reproduces the travel time and flood wave attenuation down the river. Achieving a satisfactory match at gages is reliant on the hydrologic inflows also being calibrated or correct. Preferably calibration of the hydrologic modeling is carried out jointly with the hydraulic model calibration as the accuracy of the hydrologic modeling will directly affect the accuracy of the hydraulic modeling.
Floodplain peak water level /debris mark comparison	Peak water level calibration to debris marks in the floodplain should supplement gauge water level time series calibration. Properties in the floodplain represent the sensitive receptors in most flood modeling assessments. As such, flood level result accuracy is paramount in the floodplain. Inundation in the floodplain can often be offset from levels in the river channel. Perched river embankments or levees regulate the volume of flow entering the floodplain. Floodplain storage and variations in vegetation density determines the flood behavior within the floodplain. Calibration to surveyed peak water level and debris marks are the best available method to confirm whether these features are correctly defined in the flood model and the models results are accurate.
Anecdotal observation verification	Anecdotal observations are useful. This could include information such as the timing of backflow up tributaries or when flooding overtopped or breached a significant river embankment or levee.
Flood frequency analysis comparison	Design event hydrology is a potential source of predictive uncertainty. Design flood model result comparison against a gage flood frequency analysis is a useful method to reduce this uncertainty.

Calibration Data

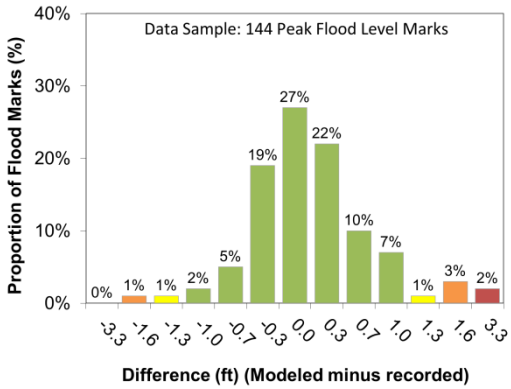
Flood model calibration requires accurate historic flood records. Experience has shown that calibration data is sparse and in some cases unreliable in some locations. Agencies responsible for flood planning within the USA should be aware of the potential implications of this data shortage.

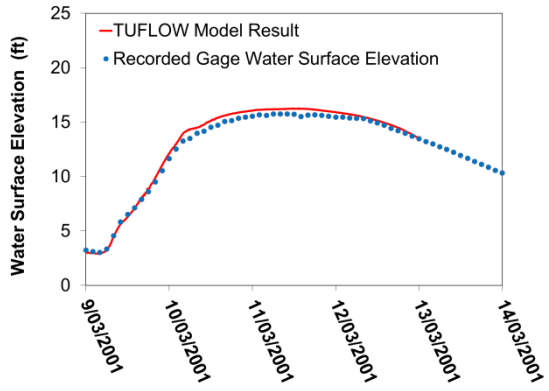


Post flood event datasets requiring collection and archiving include; rainfall pluviograph and river gage water level and /or flow time series data, surveyed floodplain peak water level /debris mark information and anecdotal observations. Metadata should be associated with each dataset to provide some comment of its reliability / accuracy. The metadata information is particularly useful during flood model calibration years after an event has occurred.

The regional nature of floods often mean their impact extend well beyond county and city boundaries. For this reason, joint agency collaboration following an event is often the most appropriate and cost effective approach to data collection efforts. In NSW, Australia, the State department funds and manages post event data collection efforts. Local agencies work with the state, and are responsible for collecting on-ground data (such as surveyed peak water level and debris marks). This joint State / Local agency approach is multi-beneficial:

- Data collection immediately following an event increases the data accuracy. Particularly for floodplain peak water level / debris mark survey. It also identifies significantly more flood marks compared to community surveys undertaken years after an event. Some catchments within Australia have over 1,000 surveyed peak flood level recordings from a single event. This data coverage is invaluable!
- The State managed process ensures data quality and format consistency.
- Recent social psychology research suggests the personal interactions between the affected community and local agency officials responsible for the on-ground data collection have positive psychological benefits. It helps with their recovery, from what in many cases is a traumatic experience. (Lisa Gibbs, Floodplain Management Australia Conference Keynote address, Nowra 2016)





Conclusion

The accuracy of our flood models is of utmost importance for financial planning and also public safety. Model calibration is the most effective approach to verify the predictive accuracy of a flood model. All professionals associated with the floodplain management industry; including agency officials, floodplain managers and consulting engineers should give model calibration a high priority.

2D modeling guidelines have been a topic of discussion for some time in the USA. We hope any guidelines that are created give due emphasis to model calibration and all agencies in the industry recognize the benefits associated with data collection efforts needed to support model calibration.