Urban Drainage Modeling: Tools for Improving Urban Planning and Design Decision Making

Chris Huxley, TUFLOW
Anthony Kuch, XP Solutions

Short duration high intensity storms can quickly exceed the capacity of the local urban drainage network. As inlet capacity and small overland flow paths become overwhelmed the overland flows in an urban area easily travel to unintended locations. Intersections can become impassable and all too frequent surface flows reach commercial and residential property. The long-term damage cost of more frequent localized flooding associated with the urban drainage network can be equally as significant to homeowners as catchment scale flood events. This is primarily due to the potential regularity of minor flood inundation damage resulting from localized urban drainage events. In comparison the occurrence of catchment scale flood events has traditionally been reduced by regional scale flood protection efforts such as levees or floodways. Many cities and towns are now recognizing the cost of localized urban drainage events and are using advanced 1D pipe/2D overland flow modeling tools to inform their infrastructure planning, design and upgrade decisions. Commonly used software include TUFLOW, Infoworks, FLO-2D, MIKE URBAN and XPSWMM.

This article discusses some of the concepts that are unique to 1D/2D urban drainage modeling.

Coupled 1D/2D Modeling: Coupled 1D /2D models use 1D elements to represent the underground pipe network and the 2D cells for the overland flow and flood storage areas. The 1D/2D model design currently represents the most accurate approach available for defining the interactions between overland flow and the pipe network. Compared to 1D only models, the inclusion of a 2D overland component removes the necessity for sub-catchment delineation and reduces the possibility of errors. In addition, the definition of overland flow between sub-catchment when the underground pipe network is exceeded becomes an integrated part of the model description. As such, the 1D/2D approach provides the best available estimate of the above ground inundation extent and depth estimates.

Grid Size: Urban drainage models require smaller cell sizes compared to catchment scale event flood models. Cell sizes typically range from 3ft to 15ft. Small cell sizes are required to adequately define the preferential flow paths between buildings, along roads (gutter flow) and within drainage channels. Cell size assumptions are typically influenced by a balance between the level of detail (result accuracy) and model usability (simulation run-time).

Direct Rainfall Inflows: Direct rainfall inflows (also known as 'rainfall on grid' or 'distributed hydrology') apply rainfall to every 2D cell within the model. In some of the modeling packages these flows in the cells can be subject to infiltration losses. Flow is then routed within the model based on the cell elevation topography characteristics. As such, the direct rainfall approach relies on accurate topography data inputs. High quality LiDAR data is now making this possible. This relatively new inflow approach is an alternative to the more traditional lumped sub-catchment inflows derived from separate rainfall-runoff hydrological modeling. It removes the possibility for errors in sub-catchment delineation affecting the accuracy of the model results.

Inlet Characteristics: Inlet information is used to define the physical characteristics of inlets to the underground pipe network (width, length, height etc.). This data is required to determine the interaction of flow between the 2D overland areas and 1D underground pipe network. During high intensity short duration events these inlets can become inundated and the bypassing overland flows can spread into intersections, parking lots etc. and then beyond and find new pathways following the terrain. Including this inlet data within the model framework enables the drainage network capacity to be influenced by either the dimensions and slope of the underground pipes, or the inlet information.

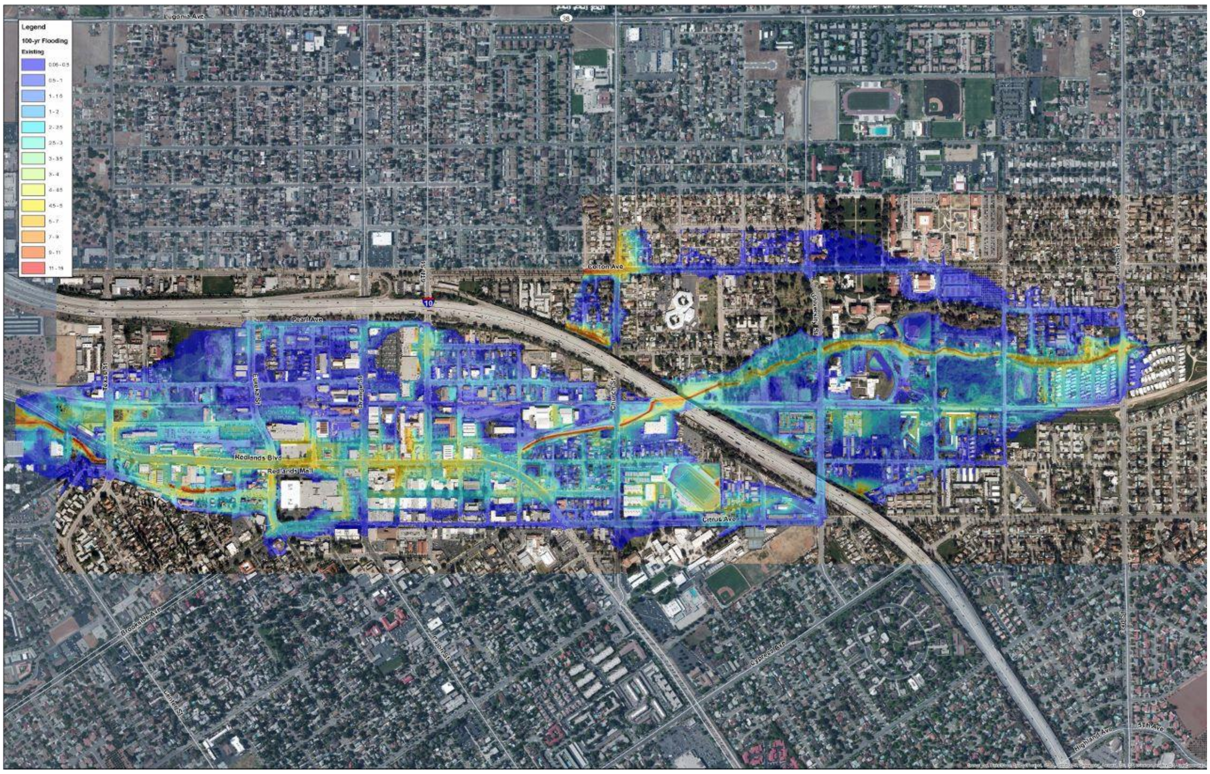

Figure 1: XPSWMM Urban Drainage 1D/2D Model – 100 Year Flood Inundation Depth

__Calibration / Verification:__ Model calibration is recommended for all types of flood modeling. Recorded peak flood level data availability is however typically scarce for localized urban drainage events. Inundation extent verification against city property damage database information, or alternatively, resident survey data has proved to be a valuable model validation approach.

__Sensitivity Tests:__ Sensitivity testing of model parameters, such as the blockage of features within the drainage network is also recommended in addition to the model verification exercise. This type of analysis can be used to define the minimum and maximum variation in above ground inundation extent. This is particularly relevant for defining the possible worst case flooding that can occur in the Fall when intense storms can coincide with trees shedding their leaves and blocking inlet structures.

__Conclusion:__ 1D/2D urban drainage modeling is one of the most useful advances in flood modeling to have occurred in the past 5 years. Improvements in LiDAR topography data collection/processing, software developments and hardware computing power has made this possible. Floodplain managers and practitioners alike should be aware of this type of modeling and consider the locations where it would be best applied to reduce the impact of regular nuisance flooding caused by urban drainage design problems. This integrated approach is the next generation in the evolution of flood modeling, as it builds on the more basic overland flooding technology. Fortunately for practitioners, learning how to develop an urban drainage model is relatively easy, particularly if prior knowledge of the flood modeling software is known for overland flooding purposes.