Development of a Real Time Flood Forecasting System - Toronto, Canada

Rob James[1], Karen Finney[1], Mark Randall[1*] and Michael Heralall[2]

1. Computational Hydraulics International, Guelph, Ontario, Canada (www.chiwater.com), * mark@chiwater.com
2. Toronto and Region Conservation Authority, Toronto, Ontario, Canada (www.trca.on.ca)

Introduction

Flooding in urban areas can cause major property damage and injury to humans. Development of reliable hydrological modeling tools for the forecasting of extreme events is an essential component of effective flood prevention and risk management. The ability to incorporate remote sensing radar data into rainfall-runoff models has inspired a new generation of flood forecasting systems. Radar reflectivity provides high resolution temporal and spatial data for computing precipitation (Wang *et al.,* 2009; Chintalapudi *et al.*, 2012). Integrating computed radar rainfall can improve flood warning systems, mitigating negative impacts to flood-prone areas (Xie, *et al.*, 2011; Arnaud *et al.*, 2002).

To improve the accuracy and lead time of flood forecasting for the Don River Catchment, Computational Hydraulics International and the Toronto and Region Conservation Authority have developed a high resolution, deterministic, real-time flood forecasting and web-based decision support system. Key features of the flood forecasting system include: real-time radar rainfall acquisition, processing and forecasting, real-time flow and rain gauging, continuous hydrologic modelling, flood vulnerable asset analysis and predictive weather modelling. This paper briefly outlines the Real-time system's hydrologic model development and selection of bias correction method for radar-rainfall input data.

Methods

All hydrologic and hydraulic calculations in the PCSWMM Real-time system are performed using the United States Environmental Protection Agency's (USEPA) Storm Water Management Model (SWMM5), a dynamic rainfall-runoff simulation model used for single-event and long-term simulation of surface and subsurface hydrology.

A hydrologic model of the 360,000 ha Don River watershed was developed in PCSWMM, a GIS-based spatial decision support software for the USEPA's SWMM5. Hydraulic components were imported into a single SWMM5 model from 42 existing HEC-RAS models representing 225km of natural channels using PCSWMM import routines (James *et al*., 2012). Hydrology components of the model were based on a GIS layer containing 70 subcatchments derived from a digital elevation model (DEM). Subcatchment attribute values were calculated from soils and land-use layers using area-weighting operations.

Next Generation Radar (NEXRAD) level III data available from the National Oceanic and Atmospheric Administration's (NOAA) National Weather Service (NWS) were used for the real-time radar rainfall data acquisition, processing and forecasting, component of the PCSWMM Real-time system.

The Don River SWMM5 model was calibrated to observed flow data for ten large precipitation events by varying subcatchment parameters within realistic ranges. The calibration process was repeated eight separate times, each using an alternative method for rain-gage radar rainfall bias correction. The rainfall scenarios used were:

1. base reflectivity radar rainfall
2. Digital hybrid scan reflectivity (DHSR) radar rainfall
3. base reflectivity raingage rainfall
4. DHSR raingage rainfall
5. base reflectivity watershed raingage rainfall
6. DHSR watershed raingage rainfall
7. Digital Precipitation Array, ignoring negative values
8. rain gauge only (no radar)

Results of the calibrations were evaluated to determine which bias correction method produced the closest agreement with the observed flow data of calibration events.

Results

Through the comparison of the eight different radar-rainfall calibration scenarios, it was found that the scenario using the DHSR rain gage - rainfall bias correction method produced the best agreement between computed and observed maximum flows. All ten of the calibration events for this scenario had computed peak flows within 20% of the observed peak flows, and eight of the events were within 10% of the observed peak flows (see the highlighted data points in Figure 1). The DHSR rain gage rainfall scenario also had the best agreement between computed and observed peak rainfall, total rainfall, and total flow (James *et al.* 2013).

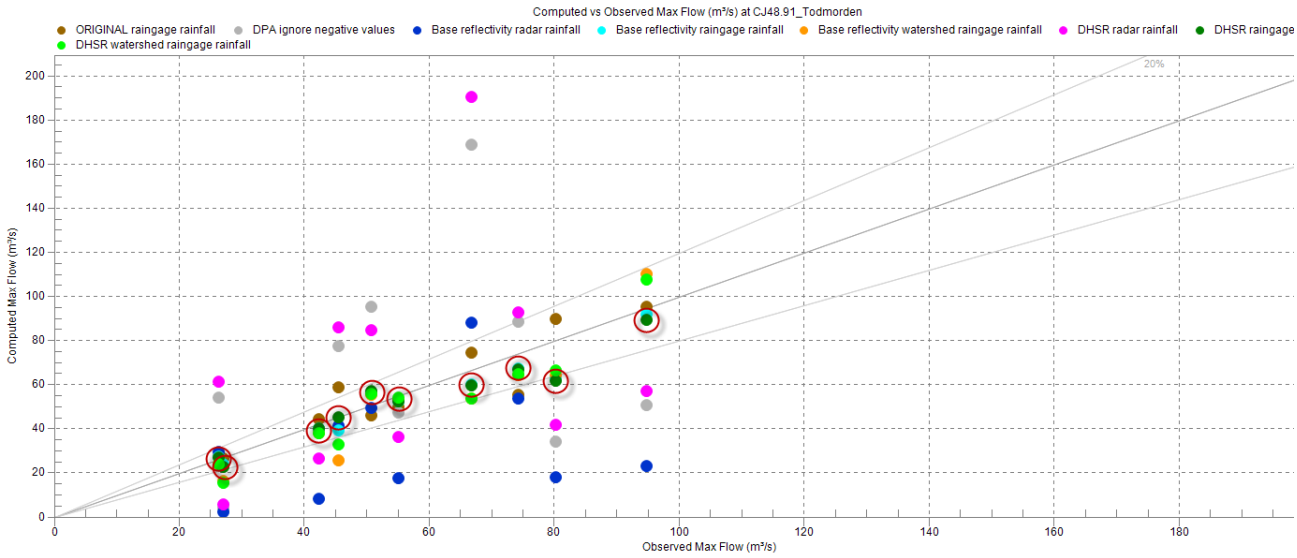

Figure 1. Computed vs. observed maximum flows for eight rainfall-radar scenarios.

Conclusions

For flood duty officers to make informed decisions prior to a storm arrival, improved warning systems are critical. This paper outlined a real-time radar based system for use in the Don River Catchment in Canada. A SWMM5 model was developed then calibrated using eight radar-rainfall scenarios based on alternative bias correction methods. Of the eight scenarios evaluated, DHSR rain gage rainfall bias correction was found to generate the best rainfall and flow response and was chosen as the input for the real-time flood forecasting system. The PCSWMM Real-time flood forecasting system outlined in this paper is currently in operation and serving as a decision support tool for Toronto and Region Conservation Authority staff. Ongoing improvement of the Don River SWMM5 model involves further discretizing subcatchments, modelling individual stormwater ponds in detail and recalibrating subcatchment parameters using precipitation data from several recent, large precipitation events.

References

1. Arnaud P, Bouvier C, Cisneros L, Dominguez R. 2002. Influence of rainfall spatial variability on flood prediction. Journal of Hydrology 260: 216–230.
2. Chintalapudi, S., Sharif, H.O., Yeggina, S. and Elhassan, A. 2012. Physically Based, Hydrologic Model Results Based on Three Precipitation Products. Journal of the American Water Resources Association, 48: 1191 – 1203.
3. James, R.W., Finney, K. and James, W. 2012. Auto-Integrating Multiple HEC-RAS Flood-lie Models into Catchment-wide SWMM Flood Forecasting Models. AWRA Hydrology & Watershed Management Technical Committee, 7: 1–15.
4. James, R.W., Finney, K., James, W., and Heralall, M. (2013). Real time flood forecasting with PCSWMM, NEXRAD and SWMM5. CSCE 21st Canadian Hydrotechnical Conference, May 14-17, 2013.
5. Wang, Y. and Chandrasekar, V. Quantitative Precipitation Estimation in the CASA X-band Dual-Polarization Radar Network. 2010. Journal of Atmospheric and Oceanic Technology, 27: 1665-1676.
6. Xie, H., Zhang, X., Yu, B. and Sharif, H. Performance evaluation of interpolation methods for incorporating rain gage measurements into NEXRAD precipitation data: a case study in the Upper Guadalupe River Basin. 2011. Hydrological processes, 25: 3711-3720.