

HYDROLOGIC MODELING OF AN EXTREME FLOOD IN THE GUADALUPE RIVER IN TEXAS

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Abstract Many of the storms creating the greatest rainfall depths in Texas, measured over durations ranging from one minute to 48 hours, have occurred in the Texas Hill Country area. The upstream portion of the Guadalupe River Basin, located in the Texas Hill Country, is susceptible to flooding and rapid runoff due to thin soils, exposed bedrock, and sparse vegetation, in addition to the Balcones Escarpment uplift contributing to precipitation enhancement. In November 2004, a moist air mass from the Gulf of Mexico combined with moist air from the Pacific Ocean resulted in the wettest November in Texas since 1895. While the peak discharges were not the highest on record, the U.S. Geological Survey (USGS) stream gauge on the Guadalupe River at Gonzales, Texas reported a daily mean discharge of 2,304 m³/s on November 23, 2004 (average discharge is 53 m³/s). In this study, we examine the meteorological conditions that led to this event and apply two hydrologic models: a semi-distributed conceptual model and a two-dimensional, physically based, distributed-parameter hydrologic model to simulate the response of a portion of the basin during this event. The simulations highlight the distinct differences in the modeling process and results for the two models. While the conceptual model needed significant calibration and parameter optimization, results of physically based model were superior. Moreover, the study results clearly demonstrate the ability of a physically based, distributed model, driven by operational radar products, to adequately model the cumulative effect of the two events and route inflows from three upstream watersheds without the need for significant calibration.

The main objective of this study is to assess the flood event that took place over the middle Guadalupe River in November 2004. We first present an overview of the meteorological conditions that led to this event. Then we use two hydrologic models, a semi-distributed conceptual model and a two-dimensional, physically based, distributed-parameter hydrologic model to simulate the response of a portion of the basin. Details of the modeling process over this 1,630 km² largely rural catchment are provided. The models were driven by Multi-sensor Precipitation Estimator radar products and observations from a dense rain gauge network. Results of the distributed model are compared to those of a conceptual semi-distributed model to highlight the benefit of distributed hydrologic modeling.

The study area is located in the middle of the Guadalupe River watershed upstream of Gonzalez gauge (USGA gauge 08173900) and downstream of three USGS gauging stations: number 08168500 on the Guadalupe River at New Braunfels (drains an area of 3930 km²), number 08173000 on Plum Creek near Luling (drains an area of 800 km²), and number 08172000 on the San Marcos River at Luling (drains an area of 2170 km²). The study sub-basin has an area of 1,630 km². The month of November 2004 is on record (since 1895) as the wettest November in the Texas history, with a statewide average of 154.4 mm (NWS 2009). Several locations in Texas accumulated November rainfall totals that ranged from three to ten times the 30-year, (1971-2000) climate normals (NWS 2009). Rain occurred over the upper Guadalupe River in mid-November, some of which was likely routed through Canyon Dam and into the study area. However, this longwave trough brought 50 to 305 mm of rain to a large portion of Central Texas and the Texas Coastal Plains, with the study area in Caldwell and Guadalupe Counties receiving between three and six inches of rain.

As a major flooding event took place in the lower Guadalupe River Basin in November 2004 resulting of heavy amounts of precipitation around the 17th and the 22nd. The flood was the second significant flood in three years to result from precipitation that persists over several days. These occurrences highlight the need for new approaches for developing intensity-duration-frequency curves that take into account longer

storm durations. The region would also benefit from the use of sound hydrologic modeling to predict water response to these devastating storms.

Results of simulation by the distributed model demonstrate the advantage of using quality controlled radar-products, which typically better characterize the spatial and temporal distribution of rainfall than rain gauges although the resolution of the MPE product used here is much coarser than the native resolution of the weather radar. There were distinct differences between the results and modeling processes of the two models. HEC-HMS needed significant calibration and parameter optimization. Moreover, the optimization process could not identify a set of parameters that would result in acceptable estimates of the two observed peaks. Consequently, the simulations had to be performed on two separate events each centered on each of the two discharge peaks. This is a major shortcoming of HEC-HMS implying that the model may not perform well if used for flood forecasting. The physically-based model results would likely be further improved if precipitation products of higher spatial and temporal resolutions are available. The coarse resolution of the model grid, 150 m, seems to be adequate for the size of catchment and duration of the event. The study results clearly demonstrate that physically based, distributed-parameter modeling and operational radar products such as the MPE that are typically available in near real time have great potential in flood forecasting in South-Central Texas for flood events similar to the one described in this study. In addition to predicting the peak discharge, a model like GSSHA can produce invaluable information related to predictions of spatially-distributed flow and inundation depths that can be used by various authorities during such flood events.

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