CENTER FOR TRANSPORTATION RESEARCH

PROJECT SUMMARY

Texas Department of Transportation

5-9054-01: Streamflow Measurement at TxDOT Bridges

Background

The National Weather Service has developed a National Water Model that continually forecasts flow throughout the river and stream network of the United States. Water has become like weather—forecast everywhere, at local scale, all the time. In Texas, forecast information is provided on about 190,000 miles of streams and rivers divided into about 100,000 forecast reaches. However, the streamflow measurement data available to correct and validate the National Water Model are sparse. At present, the National Water Model uses data from about 550 US Geological Survey stream gaging sites in Texas. Texas has 27,000 bridges located on stream reaches forecast by the National Water Model. This project establishes a transect of radar streamflow measurement sites on Interstate Highway 10 (I-10) bridges as a pilot implementation to examine the feasibility of a broader streamflow measurement program on TxDOT bridges.

What the Researchers Did

Each of the 20 sites is instrumented with an RQ-30 indirect measurement system, which uses radar to measure both the water elevation and velocity without the instruments touching the water. Water velocity data are useful in the coastal zone, such as on I-10 in the Beaumont District, where all the gage sites have a stream bed elevation below sea level. Each gage site is powered by a battery recharged from a solar panel. Water level and velocity data are communicated every 15 minutes through a cellphone connection. Each bridge and radar site is documented using 360° photography and a virtual staff gage is superimposed on the bridge at the gage site so as to allow better visualization of the water height. The stream cross-section is measured by using lidar data and GPS surveying, supplemented for sites with permanent water using Acoustic Doppler Current Profiler measurements, which provide velocity profiles and estimates of flow for comparison with the radar gages.

The data are received and processed in a cloud data system maintained by the Kisters firm, in which water level and velocity are converted to streamflow discharge. The Kisters Big Data system also ingests the National Water Model flow forecasts for all of Texas and converts these to an estimate of water level in each stream reach. The water levels measured at the TxDOT radar gages and the USGS gages are compared with the levels estimated from the National Water Model.

A statistical methodology for using the errors between observed and forecast water levels and flows was developed and applied to a test case in the Navidad river basin. This methodology shows promise for improving the flow forecasts for about 15 miles upstream and 30 miles downstream of a gage. A geostatistical variogram was constructed

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for peak flows simulated by the National Water Model on streams crossing I-10 during Tropical Storm Imelda, which showed that there is some correlation out to about 50 miles during this event. The gages on the I-10 transect are separated on average by 20 miles west of Houston and 10 miles east of Houston. These spacings are adequate to ensure that storm flows are adequately sampled along the transect. A plan for installing gages on additional highway transects north of I-10 is presented. In September 2019, Tropical Storm Imelda occurred in Southeast Texas, and the report concludes with a preliminary assessment of the lessons learned during this large flood event.

What They Found

The gages are portable and relatively easy to install on the bridge berm. Communication of the data through the cell phone system is reliable and was even sustained throughout TS Imelda. Under normal conditions, the gages function autonomously and have not required maintenance visits. Some equipment was lost by theft at two sites, and three sites were inundated by flooding during TS Imelda. A maintenance program to replace gaging equipment that is lost or damaged will be needed; ideally the gages should be mounted above the bridge berm level so that they will not be inundated during bridge overflows. The Kisters Big Data system absorbed and processed a very large volume of data apparently effortlessly. No data were lost, and access to the web and data services interfaces was reliable.

Bridges on I-10 east of Houston have stream beds that are below sea level, which means that the flows are affected by backwater effects and permanently high groundwater levels. The radar sensor measures both water level and velocity so this sensor can cope with tidal effects but 2D or 3D modeling of the flow characteristics around the bridges and the gage would improve the quality of the discharge measurements.

What This Means

This research is a first for the United States: a transect of radar streamflow measurement sensors mounted along an interstate highway. However, the project is more than just putting sensors on bridge. Underlying this is a statewide data system implementing real-time flow forecasts from the National Water Model, which creates a basis for wide area flood planning to improve flood response on and near the highway, and road closure management during flood events. Combining the National Water Model for flow simulation, the accurate lidar terrain data now covering Texas, and detailed hydrodynamic modeling creates a foundation for regional flood risk assessment of the highway system to identify weak points with increased likelihood of road closures during flood events.

For More Information

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