TEXAS TECH UNIVERSITY
Multidisciplinary Research in Transportation

PROJECT SUMMARY

Texas Department of Transportation

0-6654: Empirical Flow Parameters—A Tool for Hydraulic Model Validity Assessment

Background

Hydraulic modeling assembles models based on generalizations of parameter values from textbooks, professional literature, computer program documentation, and engineering experience. Actual measurements adjacent to the model location are seldom available for use in refining model parameters.

This situation often leads to good-faith estimation of velocities (needed for assessing forces on bridge piers, and assessing erosion and scour potential) that are unusually large. This research developed independent ways to assess computed velocities based on prior, authoritative, and observational experience as an independent tool to assess hydrologic and hydraulic model validity.

What the Researchers Did

The researchers used existing data in Texas from the U.S. Geological Survey physical stream flow and channel property measurements for gaging stations in Texas to construct relations between observed stream flow, topographic slope, mean section velocity, and several other hydraulic factors, and produced three methods to assess if model results are off.

The data were analyzed using a generalized additive modeling technique to develop two equations, QGAM and VGAM, that estimate discharge and velocity at a location in Texas from a cross-sectional flow area, topwidth, location (latitude and longitude), and mean annual precipitation.

The data were also analyzed to develop conditional distributions of hydraulic parameters based on location-related values. For example, the database can be used to produce an empirical distribution of velocity in Texas for topwidth values less than a prescribed limit and for contributing drainage areas of some prescribed range.

Lastly, the data, and ancillary properties developed in the research, were used to develop dimensionless bankfull depth discharge and similar charts as a way to evaluate anticipated behavior in streams in Texas.

What They Found

The QGAM model provides a supplemental approach to discharge estimation to support hydrologic methods currently used. The model estimates discharges based on properties of the stream itself under the conjecture that the hydraulic shape of the stream "records" hydrologic information by virtue of its topwidth, cross-section flow area at that particular topwidth, and location in the state.

Equation 1 is the QGAM model; A is the cross-sectional flow area, B is the topwidth, P is the mean annual precipitation, Ω is a spatial parameter, and f_5 and f_6 are functions that modify the estimate based on the position in Texas and the value of P. The entire model needs only the geometric properties on A and B to estimate a discharge at a location. The values of f_5 and f_6 are derived from plots in the final report.

$$\log(Q) = -0.2896 + 1.269\log(A) - 0.2247\log(B) + 0.2865\Omega + f_5(\text{longitude, latitude}) + f_6(P) \quad \textbf{Eq. 1}$$

Equation 2 is the VGAM model, a similar tool that provides rapid estimation of mean section velocity, V, at a location. In the VGAM equation, B is the topwidth, P is the mean annual precipitation, Ω is a spatial parameter, and f_9 and f_{10} are functions that modify the estimate based on the position in Texas and the value of P. The values of f_9 and f_{10} are derived from plots in the final report.

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$$V^{1/5} = 0.9758 + 0.1588\log(Q) - 0.1820\log(B) + 0.0854\Omega + f_9(\text{longitude, latitude}) + f_{10}(P) \qquad \textbf{Eq. 2}$$

Figure 1 is a plot of the mean section velocity as a function of topwidth. The upper and lower envelope lines (red and blue) approximate the observed upper and lower anticipated velocity values in a Texas stream for a particular topwidth. The conditioned empirical distribution is essentially a vertical slice of the data cloud in Figure 1, and in addition to upper and lower bound information, the engineer can obtain an estimate of the relative rarity of a particular value. If a hydraulic model produces an estimate outside the range represented by the envelope, then the modeler would be concerned that there may be an error—perhaps data entry or even conceptual. The empirical distributions are an extension to the QGAM and VGAM models and have the potential to return estimated quantiles as well as estimate values of A and B that could be expected at a location conditioned on contributing drainage area or other similar criterion in the database.

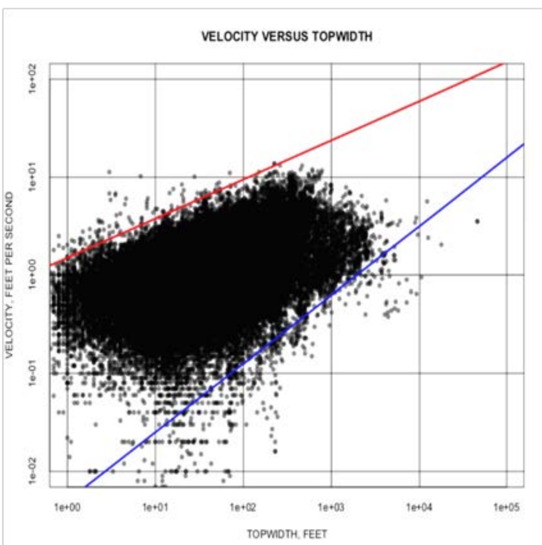

Figure 1. Velocity-Topwidth Relation for Texas.

Figure 2 is a plot of dimensionless bankfull discharge versus topwidth. This figure is representative of the third way to assess model validity—valid models should plot somewhere close to the groups of observations that are classified by bed material type. That is, sand rivers should behave like other sand rivers, or there is possibly a conceptual modeling error.

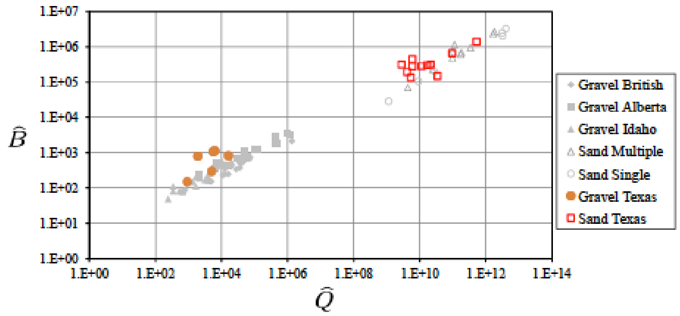

Figure 2. Dimensionless Discharge and Topwidth for Texas Streams.

What This Means

The QGAM and VGAM equations provide a tool to independently validate hydrologic response and hydraulic response from a reduced set of input parameters that are a function of location in the state, and elementary hydraulic properties such as the topwidth and cross-sectional flow area.

The empirical distributions, such as that displayed in Figure 1, provide an additional tool to accomplish a similar task, with the added benefit of being able to make some estimate about the likelihood of a particular value. Furthermore, the empirical distributions provide a way to estimate the values of A and B that would populate the QGAM/VGAM models based on contributing drainage area or other sorting value in the database.

The dimensionless bankfull charts provide a third way to assess hydraulic model validity. All three tools combined provide an ability to judge a model's applicability and suggest revisions based on observed data.

For More Information

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