Development of Stage-Discharge Relations for Ungaged Bridge Waterways in Western Iowa

Tech transfer summary

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RESEARCH PROJECT TITLE
Development of Stage-Discharge Relations for Ungaged Bridge Waterways in Western Iowa

SPONSORS
Iowa Highway Research Board
(IHRB Project TR-567)

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IIHR's historic C. Maxwell Stanley Hydraulics Laboratory was dedicated as a National Historic Civil Engineering Landmark in 2005, placing it among the major structures of national importance to the engineering profession. The mission of the IIHR is to conduct research in water resources and environmental engineering.

Continuous stage measurements, Large Scale Particle Image Velocimetry, and a hydrologic model were used to develop flow rating curves for ungaged streams in western Iowa.

OBJECTIVES

The primary goal of this project was to develop a stage-discharge relationship for 11 ungaged-streams in the Hungry Canyons Alliance (HCA) region of western Iowa.

This project included three major activities: (1) in-situ flow discharge measurements using Large Scale Particle Image Velocimetry (LSPIV); (2) monitoring of stage (i.e. flow depth in terms of a reference point) using semi-automated in-stream pressure transducer sensors; and (3) compilation and processing of flow discharge measurements with corresponding stage data on 11 ungaged streams in the HCA region.

PROBLEM STATEMENT

Continuous but accurate stream discharge data are critical for analyzing many hydrologic, geomorphologic, and ecological processes in streams. However, direct measurements are laborious, costly, and impractical especially during high flows.

Discharge records can be obtained from surrogate variables such as stage, or water depth, which is more easily and more accurately measured. Stage and discharge are often related through regression techniques, like fitting a power law curve through the data. This stage – discharge relationship is known as a *flow rating curve* and it is standard practice for agencies like the U.S. Geological Survey for stream discharge predictions.

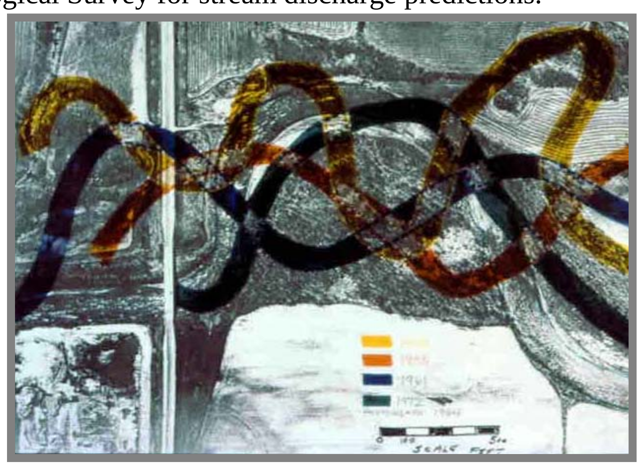

Figure 1. The response of the East Nishnabotna River alignment to different flow discharges during the last fifty years. It is a challenge for engineers to predict the channel response to natural events without knowledge of the discharge.

RESEARCH DESCRIPTION

A flow rating curve was developed for eleven (11) ungaged streams in the HCA region of western Iowa. Continuous, semi-automated measurements of stage were obtained during the study period by installing pressure transducers with attached dataloggers in these streams. Stream flow velocity measurements were conducted at each site using Large Scale Particle Image Velocimetry (LSPIV).

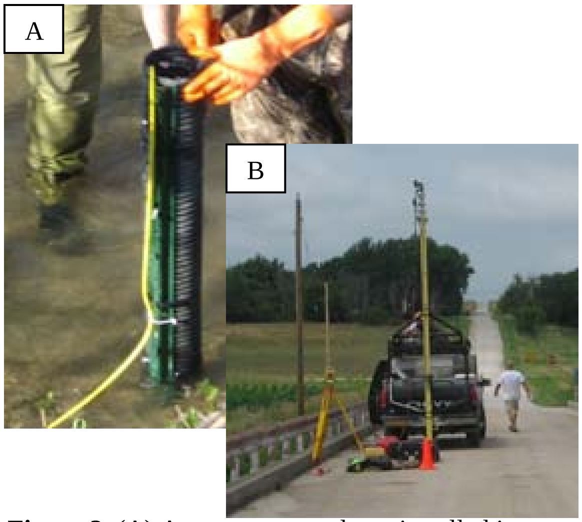

Figure 2. (A) A pressure transducer installed in a stilling well at a test site. (B) The LSPIV truck is ready to make a velocity measurement

These data were used to educate and calibrate a hydrologic model, which was used to develop the flow rating curve for the sites under different hydrologic conditions.

The model predictions were compared with the collected data and additional USGS data from nearby gaging stations in order to perform statistical error analysis.

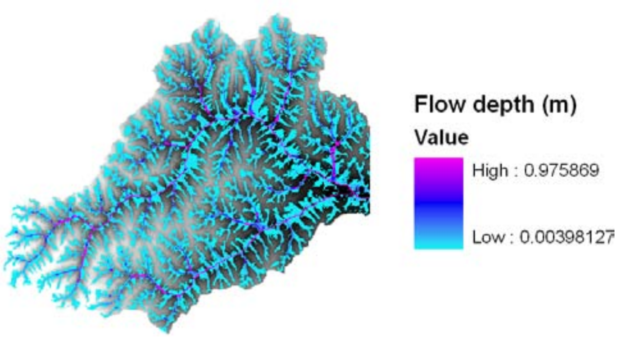

Figure 3. Example of the simulated flow depth in Picayune Creek (Harrison County) using the hydrologic model.

OUTCOMES

- This study provided the first orchestrated monitoring effort in western Iowa and provided stage-discharge ratings of statistical importance.
- We were able to test the performance of the rating curve not only for a *wide range of flow conditions* but also for *different scale resolutions*.

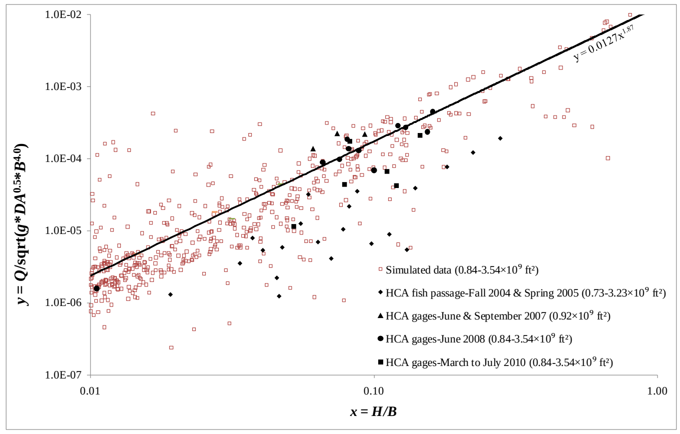

Figure 4. Comparison between the simulated stage-discharge data with measured data from the current study and previous field measurements in the HCA area.

KEY FINDINGS

- Comparisons of the study findings regarding stage-discharge predictions with other studies in the HCA region show striking agreement.
- The dimensionless representation of the data makes the proposed flow rating curve attractive to use at sites with similar hydro-geomorphology.

$$\frac{Q}{\sqrt{gDA^{0.5}B^{4.0}}} = 0.0127 * \left(\frac{H}{B}\right)^{1.87}$$

Equation 1. The flow rating curve for the HCA region. *Q* is the flow discharge (in cfs), *g* is the acceleration due to gravity (in ft/s^2), *DA* is the drainage area of the site (in ft^2), *B* is the width of the channel (in ft), and *H* is the flow depth (in ft).

RECOMMENDATIONS

A gaging network should be designed simply but with future expandability in mind. Equipment costs, licensing fees, steepness of learning curve, and maintenance load are all points of failure. Training for network engineers and field technicians on operation and maintenance of the sensor network is also a key factor that should not be underestimated.