Project Completion Report

Project 8442: — Physical Hydraulic Modeling of Canal Breaches

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Project Summary

Reclamation is responsible for more than 8,000 miles of irrigation canals in the western United States. Most of these canals were originally constructed in rural areas, but many are now surrounded by urban development and have the potential to cause property damage or loss of life if they fail. The objective of this project was to develop tools that would support the modeling of potential canal failures, with degrees of sophistication ranging from appraisal-level estimation of breach outflows using simple empirical equations and readily available input data to site-specific investigations utilizing on-site erodibility testing and computational embankment-failure modeling.

A test facility was constructed in the hydraulics laboratory in Denver, Colorado, and four physical model tests were conducted, three between December 2010 and February 2011, and a fourth in August 2013. The test facility consisted of a 90-ft-long trapezoidal canal constructed primarily from plywood, with a 20-ft-long central test section in which a 2-ft-high erodible embankment was constructed on one side of the canal. Data were collected that allowed the observed erosion rates and breaching behavior to be related to the hydraulic driving forces (pressure head, shear stress, etc.) and the erosion resistance characteristics of the embankment soils. Piping failure modes were used for all four tests, with the elevation of the initial pipe varying from deep in the canal to just below the normal canal water surface. One test was also converted to an overtopping failure mode midway through the test by cutting a pilot channel through the crest of the embankment. Soils used in the tests were silty sands (SM) with low plasticities (PI = 5 to 6). The water content and compaction effort were varied among the four tested embankments so that erodibility rates of the soils varied over about three orders of magnitude (i.e., 1000:1 ratio). Thus, although similar soils were used for all four tests, they effectively represented a very wide range of soils that could typically be encountered in real canal embankments. The test results affirmed this, as failure times varied from less than 7 minutes to over 21 hours.

Analysis of data collected during the tests confirmed that existing relations between hydraulic stress, erodibility, and observed erosion rates developed by other investigators for embankment dams (with upstream storage reservoirs) were also applicable to canal embankments. Such relations can be used to estimate the rate of breach widening, which would be an essential input

to a site-specific computational canal-breach modeling study. This would be analogous to the breach parameter inputs (breach width and time of failure) needed for a dam-failure study. The tests also illustrated that the canal conveyance capacity is an important limiting factor for canal breach outflow. This is in contrast to dam failure events in which there is a much greater potential for a large peak outflow, since the entire upstream reservoir volume is located immediately adjacent to the breach.

Reclamation's responsibility for a large inventory of canals makes it important to develop tools that could be used to make appraisal-level estimates of canal-breach flooding conditions. The objective here was to develop relatively simple equations that could be used to estimate peak breach outflows for a given canal, using available information on canal hydraulic characteristics, embankment geometry, and embankment soil properties. To develop such equations it was assumed that breach development rates could be estimated based on embankment geometry and soil properties, using the results of the physical testing. Next, a series of unsteady-flow HEC-RAS models was used to relate peak breach outflows to breach widening rates and canal hydraulic properties. The numerical modeling made it possible to incorporate the effects of dynamic flow conditions in the canal reach that could not be fully represented in the physical models. Equations were developed to relate dimensionless peak breach outflow to a dimensionless failure time parameter. The secondary effect of the breach location within the canal pool (distance from nearby canal check structures) was also quantified. Finally, breach hydrograph recession times were also related to the dimensionless failure time parameter so that a complete outflow hydrograph could be estimated. This set of equations was developed into an interactive spreadsheet that can be used to estimate the outflow hydrograph from a canal breach. The methodology is intentionally conservative, as it assumes that the topography surrounding the canal is low enough that tailwater effects do not limit the breach outflow.

Applications

The products of this research were applied in 2013 for the 'A Canal' Breach Inundation Study. This canal is located in a very urbanized area in Klamath Falls, OR. Breach size and widening rates were estimated based on embankment geometry and known soil properties. Bruce Feinberg (86-68250) modeled potential failures at three different locations using the one-dimensional MIKE11 and two-dimensional MIKE21 models, linked by MIKEFlood. MIKE11 was used to simulate the upstream and downstream canal reaches, while MIKE21 was used to model the flow through the breach and outside of the canal prism over the surrounding landscape and urban infrastructure. The modeling showed that tailwater effects significantly reduced the peak breach outflow rates, and as expected, peak breach outflows were smaller than those predicted by the appraisal-level spreadsheet.

Continuing Research

The fourth canal breach test in August 2013 was instrumented by Justin Rittgers (Seismotectonics and Geophysics Group, 86-68330, and Colorado School of Mines) with an array of passive seismic sensors as part of a separate study of the use of geophysical instrumentation for monitoring of seepage and piping processes associated with dams, levees, and canal embankments. Promising results were obtained and a new research project was funded in 2014 by the Dam Safety Office. This project will construct a new dam breach test facility in the hydraulics laboratory where we will conduct breach testing of embankments with associated geophysics monitoring.

End Products

The primary end product of the research is research report HL-2011-09, listed below. The spreadsheet tool for making appraisal-level estimates of canal-breach outflow hydrographs is also available from the principal investigator. The principal investigator also intends to submit an article to a peer-reviewed journal in the near future.

Research Report:

Wahl, Tony L., and Dale J. Lentz, 2011. *Physical hydraulic modeling of canal breaches*. Hydraulic Laboratory Report HL-2011-09, U.S. Dept. of the Interior, Bureau of Reclamation, Denver, Colorado, 56 pp. [online paper]

Conference Papers:

Wahl, Tony L., Dale J. Lentz, and Bruce D. Feinberg, 2011. Physical hydraulic modeling of canal breaches. In: *Dam Safety 2011*, Annual Meeting of the Association of State Dam Safety Officials (ASDSO), Sept. 26-29, 2011, Washington, DC. [online paper]

Wahl, Tony L., 2012. Numerical modeling to predict canal breach outflow hydrographs. 2012 World Environmental and Water Resources Congress, Environmental and Water Resources Institute of the American Society of Civil Engineers, Albuquerque, NM, May 20-24, 2012. [online paper]

Wahl, Tony L., and Dale J. Lentz, 2012. Experimental methods for studying canal breach processes. 2012 Specialty Conference on Hydraulic Measurements and Experimental Methods, Environmental and Water Resources Institute of the American Society of Civil Engineers, Snowbird, UT, August 12-15, 2012. [online paper]

Wahl, Tony L., Dale J. Lentz, and Bruce D. Feinberg, 2012. Appraisal-level prediction of canal breach outflow hydrographs. In: *Dam Safety 2012* , Annual Meeting of the Association of State Dam Safety Officials (ASDSO), Sept. 16-20, 2012, Denver, CO. [online paper]

Wahl, Tony L., 2013. What happens if the canal breaks? Tools for estimating canal-breach flood hydrographs. USCID Water Management Conference, April 15-19, 2013. Scottsdale, AZ. [online paper]

Wahl, Tony L., 2013. Predicting the outflow hydrograph from a potential power canal breach. *HydroVision International 2013*, July 23-26, 2013, Denver, CO. [online paper] [poster]