RECLAMATION *Managing Water in the West*

Predicting the Outflow Hydrograph from a Potential Power Canal Breach

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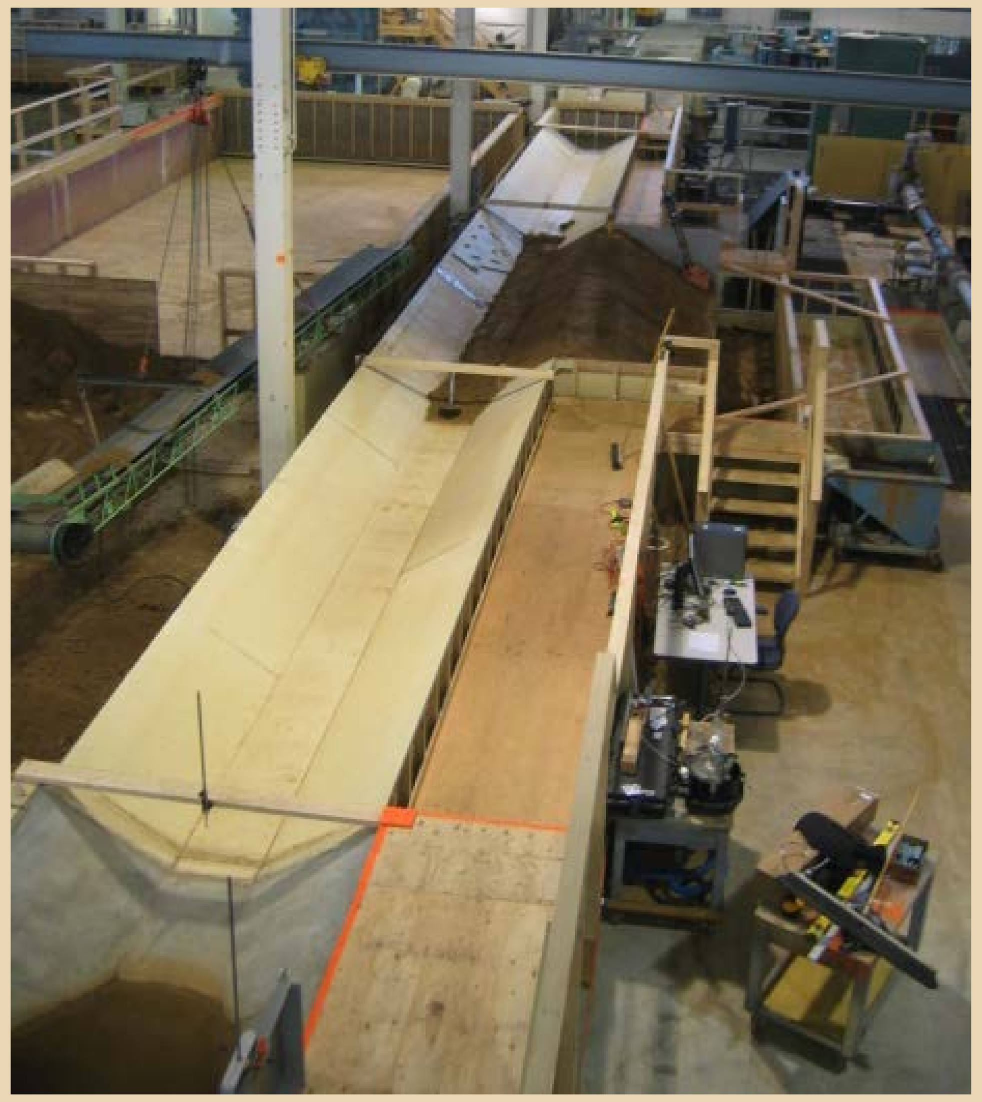
Background

Tools are needed to help identify canal reaches that pose serious flooding threats in the event of a canal embankment failure.

The Bureau of Reclamation (Reclamation) is responsible for more than 8,000 miles of canals in the western U.S., most conveying irrigation water and a few associated with hydropower and pumped-storage developments. Failures of irrigation canal embankments have occurred periodically throughout Reclamation's operating history. Canals originally constructed in rural areas are now in urban settings where potential damages from a canal breach are much greater.

Numerical modeling of breach outflows and downstream flooding can be used to evaluate potential consequences of a canal breach, but there have been questions about appropriate parameters to describe a canal breach. To resolve these issues, Reclamation undertook a program of physical hydraulic modeling of erosion and breach processes and numerical modeling of transient canal behavior during a hypothetical breach event. Results have been used to develop procedures for estimating breach initiation and breach enlargement rates and associated canal breach outflows.



Canal Breach Test Facility – Denver, Colorado

Water can be provided into both ends of a non-erodible canal with an erodible test section in the middle.

Physical Modeling

Physical model tests were performed to study erosion processes and the mechanics of breach development

The test facility simulates canal flow conditions during a breach. Each test starts with normal canal flow past the test embankment, allowing reverse flow to develop in the downstream canal leg as the breach enlarges. This maintains boundary conditions at the breach that represent a fast-developing breach in a long canal reach (i.e., a relatively steady canal water surface). The model simulates the worst-case condition of a breach that develops so quickly that intervention cannot take place (e.g., shutting down the canal).

Physical Model Results

Erosion processes were similar to those seen in traditional dam breaches.

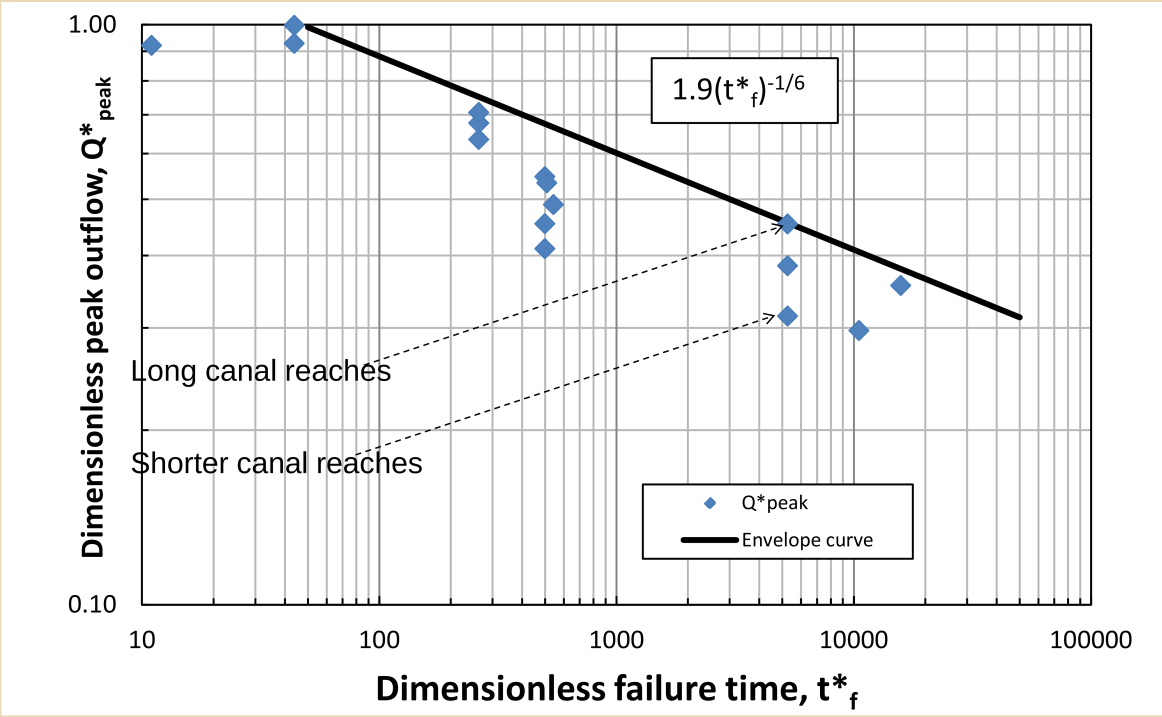
Relationships between applied stresses, measured soil erodibility parameters, and observed erosion rates (headcut advance and breach widening) were similar to those seen in tests of traditional dam breach.

The significant differences between a canal breach and a dam breach are related to the boundary condition–an upstream canal with small storage volume and limited conveyance capacity vs. an upstream reservoir with large storage and practically no limits on conveyance capacity to the breach site.

Numerical Modeling

HEC-RAS unsteady models were used to study the combined effects of breaching time and canal dynamics on breach outflow hydrographs

HEC-RAS simulations of several hypothetical canals studied the differences in breach outflow for fast vs. slow breaches and long vs. short canal reach lengths. Breach outflows were characterized in non-dimensional terms, as fractions of the theoretical maximum outflow that could occur if a canal embankment failed instantaneously and the outflow was the result of instant critical-depth flow conditions developing in each canal leg.



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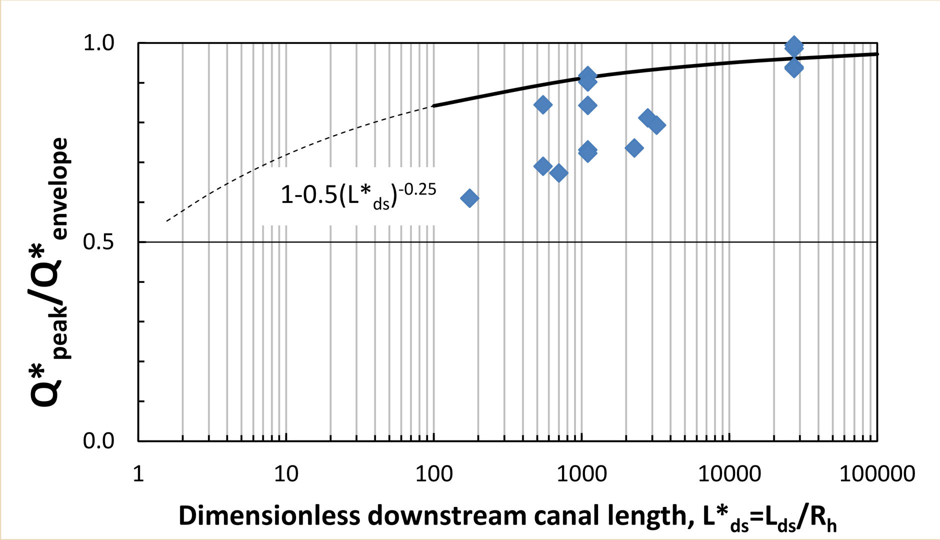
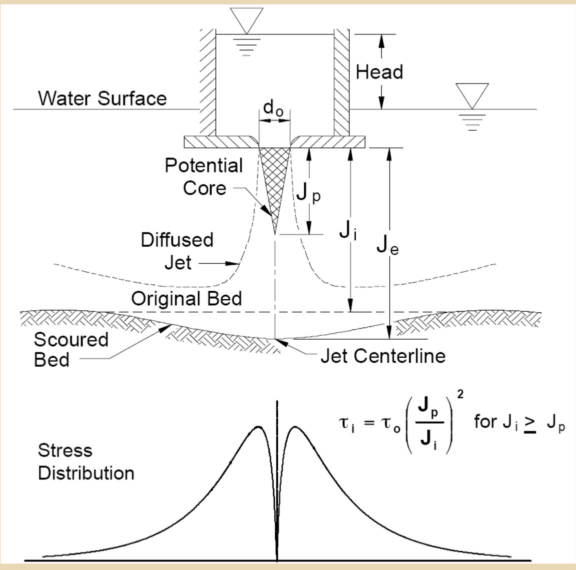


Breach Hydrograph Prediction Procedure

Soil erodibility parameters are the key. Erodibility is very sensitive to soil type and water content at time of compaction.

Soil erodibility will determine the rate at which erosion takes place, which in turn determines breach initiation time (time for headcut to advance through the embankment and reach the canal), and breach formation time (time needed for breach to enlarge from zero to full size). Erodibility was measured in physical models with the submerged jet erosion test developed by Greg Hanson at ARS hydraulics lab (Stillwater, Oklahoma). Erodibility can be measured in field using *in situ* jet tests, or can be estimated as a function of soil type and compaction conditions (% clay, % water content, and applied compaction energy).



Breach initiation time is estimated for either overtopping or piping flows that cause headcutting through the embankment.

A spreadsheet provides calculators that can estimate the time needed for headcut advance through an embankment, assuming either overtopping of the canal bank by a specified amount, or piping flow through an initial defect in the embankment with a specified diameter and elevation.

Breach widening rate is estimated and used to compute total breach widening time.

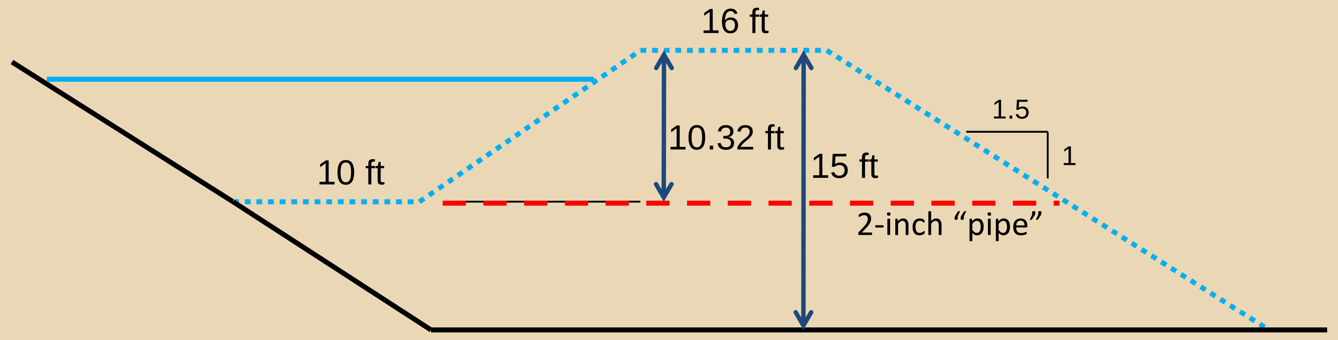
Breach widening rate is related to the hydraulic stress applied to the sides of the breach and the erodibility parameters for the soil. The breach formation time is the time needed for the breach to widen sufficiently to capture the maximum theoretical flow (at critical depth) of both canal legs (assuming critical flow through the breach).

Breach Hydrograph

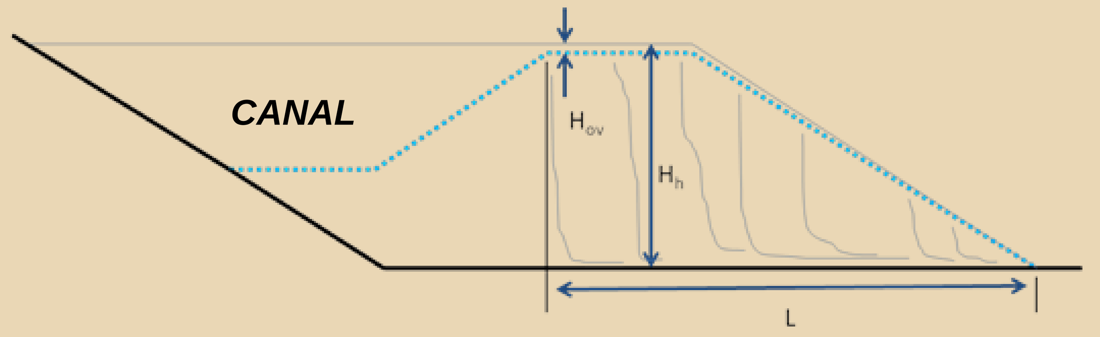
Knowing the breach formation time, the breach outflow hydrograph can be estimated using the relations developed from the numerical modeling work.

Example Application

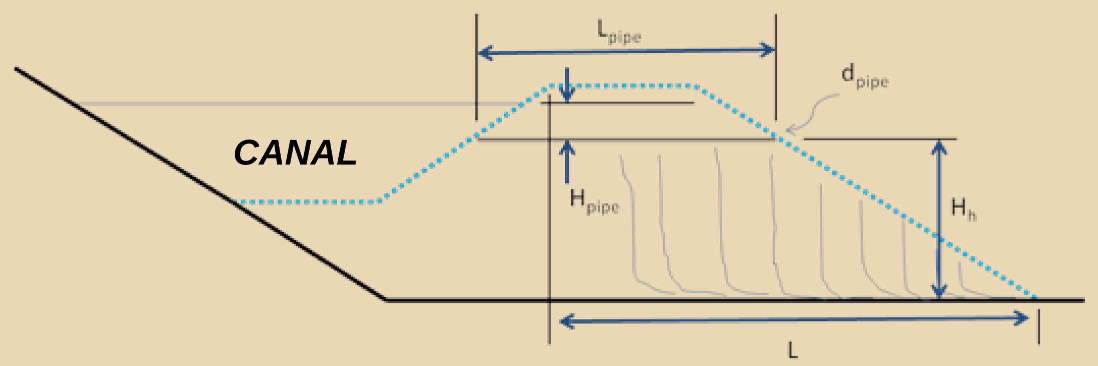
Piping Through a Power Canal Embankment



Peak Breach Outflow



Overtopping *– Flow over embankment causes headcutting of external slope*



Piping *– Flow through pipe causes headcutting*

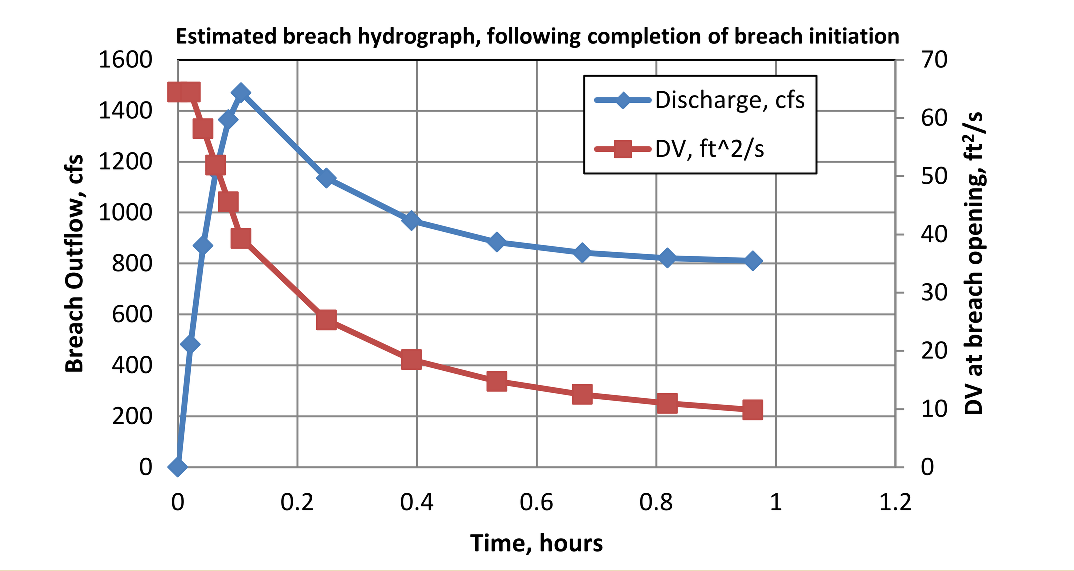
Alternatives for Breach Initiation

Example

- 3-mile long, 800 cfs power canal
- 10-ft base width, 1.25:1 side slopes, S_{bed}=2 ft/mile, *n* = 0.016, normal depth 8.32 ft
- Sandy lean clay, CL, 6% clay fines, standard compaction at optimum water content

Results

- Breach initiation, 61 min; breach formation time, 25 min
- Peak outflow is 1167 cfs if breach occurs 2 miles from downstream end of canal, 654 cfs if breach occurs at downstream end.
- If erodibility is changed to reflect compaction in a dry-of-optimum condition, breach initiation reduces to 15 min, breach formation takes 6 min, and the peak breach outflow at the upstream site increases to 1471 cfs.



Example canal breach outflow hydrograph

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