2D Morphodynamic Modeling of a Stream Simulation Culvert | Mason Lacy EIT, MS, CFM

INTRODUCTION

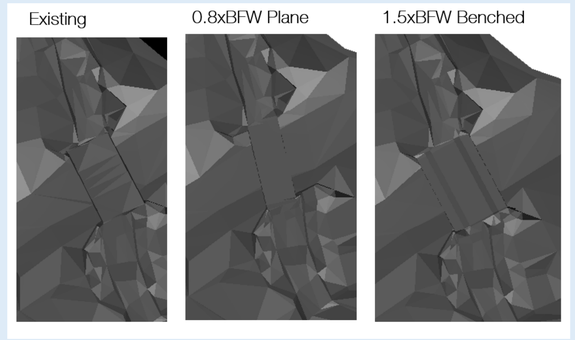
The Chehalis Basin has 2,700 culverts documented as being barriers to fish passage. Hydraulic and geomorphic theories suggest that, if discharges and sediment loads increase, in-stream velocities rise and the channel responds by increasing its BankFull Width (BFW). Hence, if (as expected), stream discharges and catchment sediment yields in the Chehalis Basin increase due to changes in land use and climate, the possibility exists that culverts which currently meet fish passage requirements may also cease to do so within their service lives.

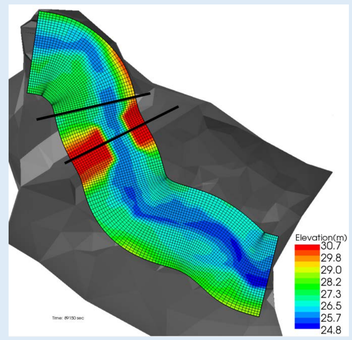
These considerations have led Washington Department of Fish & Wildlife (WDFW) to investigate how existing culvert designs might be adapted to allow for the possibility that they will in the future need to safely convey higher stream flows and sediment loads in wider channels, while continuing to meet requirements for fish passage.

Purpose

During the process of developing culvert performance metrics, the ability to quantify sediment transport, resulting scour and bathymetric change, and bed material composition was identified as crucial to the performance of a stream simulation culvert and also lacking from a purely hydraulic analysis. A two-dimensional sediment transport and bed morphology model (also referred to as a "morphodynamic model") was developed for an existing stream simulation culvert on Comfort Creek in the Chehalis Basin of Washington State.

METHODOLOGY

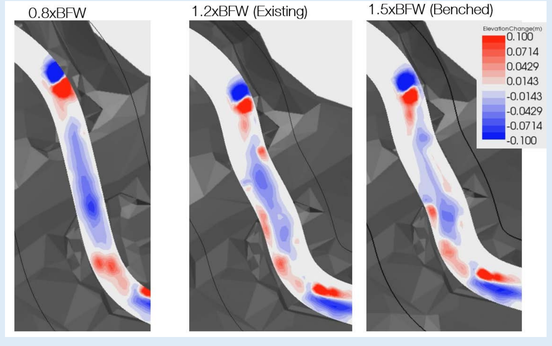


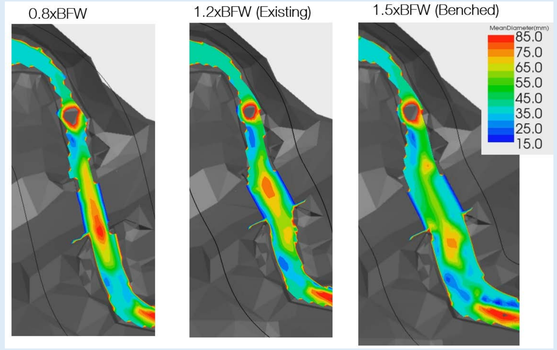


At left are the three culvert configurations modeled with Nays2DH at Comfort Creek. The existing conditions and 1.5xBFW culverts are slightly skewed to the thalweg of the natural channel, while the 0.8xBFW culvert is in line. At right is the computational mesh and cross-section locations for outputs.

Morphodynamic Model

The analysis was performed using the Nays2DH solver within the public-domain International River Interface Cooperative (iRIC) software. The focus of the study was to investigate bed response and stream simulation culvert performance during the ten-year, high-flow event (Q10) with a variety of different culvert geometries, including varying widths and the presence or absence of floodplain benches within the culvert. The 24-hour Q10 hydrograph was routed through each culvert geometry, with the model computing fully unsteady hydraulics, sediment transport, and bed deformation with non-uniform bed material. In addition to the Q10 model runs, other runs included a future flow hydrograph based on the expected increase in peak discharge due to climate change, and back-to-back Q10 hydrographs to investigate how an already deformed and sorted bed would respond to a high-flow event. The results were analyzed and data output for use in the stream simulation culvert performance metrics tool.



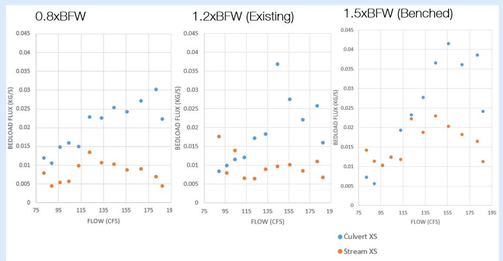


At left is elevation change at the end of the hydrograph for the three Q10 hydrograph runs. Blue represents areas of negative elevation change (scour), and red represents positive elevation change (deposition). At right is mean diameter of the bed. The display is cropped above a mean diameter of 85mm, resulting in the hole located at the location of the LWD upstream of the culvert. The color scale was set to display the range of values in the vicinity of the culvert.

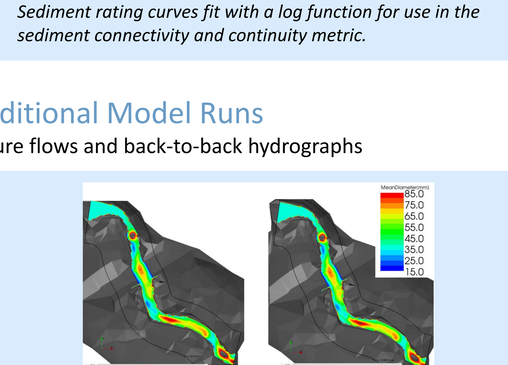
CONCLUSIONS

Performance Metrics Outputs

Output metrics for the stream simulation performance evaluation tool were obtained using a cross-sectional approach. The majority of the data for the culvert metrics are relatively straightforward to compute such as average velocity, and bed and water surface elevations. The two stream simulation metrics that are more complicated to determine are bed mobility, and sediment connectivity and continuity.



Bedload flux (kg/s) vs. discharge (cfs) across the culvert and stream cross-sections. The culvert data points are shown in blue, and the stream points are orange.



Sediment rating curves fit with a log function for use in the sediment connectivity and continuity metric.

Additional Model Runs

Future flows and back-to-back hydrographs

More on This Project

POSTER: "Futureproofing Stream Simulation – Exploratory Hydraulic Modeling to Investigate the Influence of Stream Simulation Culverts on Stream Process and Sediment Transport Now and In the Future," Steve Winter, Natural Systems Design

POSTER: "Stream Simulation Culvert Performance Evaluation Tool," Elizabeth Gutierrez, ESA

PRESENTATION: "Quantifying Performance of Stream Simulation Culverts in the Chehalis Basin," Joe Richards, ESA | Jane Atha, WDFW | Steve Winter, Natural Systems Design | Colin Thorne, ESA

Project Data

Project Name: Chehalis Basin Sediment Transport
Client: Washington Department of Fish & Wildlife
Location: Thurston County, WA