FishPAC Fact Sheet
Interagency Engineering Work Group

HYDRAULIC MODELING for FISH PASSAGE

Engineers use hydraulic modeling to analyze how rivers and floodplains interact with, and are affected by, culvert and bridge facilities. Hydraulic models consider flowing water, channel bed and overbanks, vegetation, and sediment to evaluate and develop bridge design solutions that incorporate natural watershed processes and ensure that salmon and Steelhead Trout are able to access habitat above and below development, to include transportation facilities.

One-Dimensional (1D) and Two-Dimensional (2D) Hydraulic Modeling

Hydraulic analyses consider flow depth, flow velocity, and forces from flowing water. Based on the site, the appropriate analysis is required to ensure fish are able to pass through structures based on the target species swimming and jumping capabilities.

Hydraulic models predict and illustrate the flow depth and velocity of water through space and time in one dimension (1D) or two dimensions (2D). A typical 2D model can provide more accurate information and findings than the capabilities of a 1D model. The 2D complexities include determining velocities of flow around an object, such as bridge foundations in flat and wide floodplain areas, where flow passes abrupt bends, in areas with alluvial fans, in highly braided streams, and in places where the flow path of water is not completely known. 1D models are best suited for in-channel flows and when floodplain flows and lateral velocities are minor because 1D models have numerous assumptions, and velocity can only be calculated in a downstream direction in one-dimension (Figure 1).

Table 1. Comparison of 1D and 2D modeling hydraulic variables.

Hydraulic Variables	One-Dimensional Modeling	Two-Dimensional Modeling
Flow direction	Assumed by user	Computed
Flow paths	Assumed by user	Computed
Channel roughness	Assumed constant between cross sections	Computed at every element
Ineffective (blocked) flow areas	Assumed by user	Computed
Flow contraction and expansion through bridges	Assumed by user	Computed
Flow velocity	Averaged at each cross section; Assumed in one direction	Magnitude and direction computed at each element
Flow distribution	Assumed based on conveyance	Computed based on continuity
Water surface elevation	Assumed constant across cross sections	Computed at each element

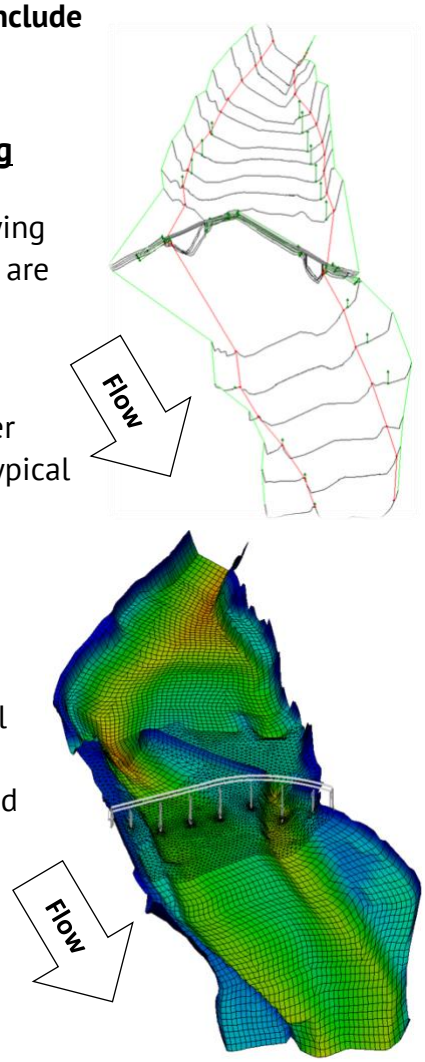
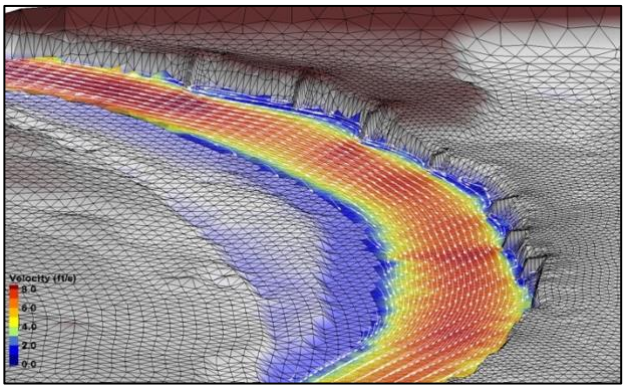


Figure 1. (Top graphic) 1D model output - The channel geometry is represented by, and the hydraulic computations occur at, each cross section. (Bottom graphic)—2D model output—The channel geometry is represented by thousands of elements, and hydraulic computations occur at each element. Source: Rick Macala, CDFW.

2D Hydraulic Modeling software

- US Army Corps of Engineer's HEC-RAS 2D Model
  - This model performs 2D hydrodynamic routing, detailed 2D channel and floodplain modeling, combined 1D channel flow with 2D floodplain flow areas, directly connects 1D reaches into and out of 2D flow areas, and produces detailed flood mapping and flood animations.
- Surface-Water Modeling System (SMS) with the Sedimentation and River Hydraulics – 2 Dimensional (SRH-2D) Model
  - A graphical user interface and analysis tool that facilitates the establishment and operation of numerical 2D models such as SRH-2D. SRH-2D models can analyze steady and unsteady flow simulations, to include bridges, weirs, and complex fishways. Free community version.



SMS's SRH-2D model is appropriate for most transportation and fish passage hydraulic applications because it incorporates 2D hydrodynamic routing; steady and unsteady detailed 2D channel and floodplain modeling; while also modeling local flow velocities, eddy patterns, flow recirculation, lateral velocity variation, and flow spills over banks and levees; and illustrating flood mapping and flood animations (such as velocity vector tracing).

1D Hydraulic Modeling software

- USACE's Hydrologic Engineering Center-River Analysis System (HEC-RAS) is the industry standard in 1D hydraulic modeling/analysis. This tool can assess steady and unsteady flow computations, unsteady flow sediment transport/mobile bed modeling, analyze a single river reach, a multi-branched river system, or a network of channels, and is able to model inline structures, such as weirs, fishways, culverts, and bridges.
- Federal Highway Administration's (FHWA) HY-8 Culvert Hydraulic Analysis Program automates culvert 1D hydraulic computations, and is used to determine the upstream headwater depth and culvert barrel flow profile for numerous culvert configurations.
- United States Forest Service (USFS) FishXing – Fish Passage Analysis Through Culverts models culvert 1D hydraulics compared to the swimming capabilities and performance of target fish species and life stages across a range of discharges.

The software in this sidebar is used to perform hydrologic analysis

Flow Analysis with Stream Gage Data

- Flood Frequency Analysis Software (USGS PeakFQ, USACE HEC-SSP)
- Percent Exceedance Flow Analysis Software (Flow Duration Curve Analysis (Appendix IX-C for fish passage flow calculations)
- Online sites providing peak flow discharges and average daily stream flows at stream gages (USGS Surface-Water Data for California; CDWR Data Exchange Center)

Flow Analysis without Stream Gage Data

- Regional Regression Analysis Software (USGS StreamStats)

Precipitation-Runoff Hydrological Models

- Precipitation-Runoff Modeling Software (USACE HEC-HMS; NRCS WinTR-55 Small Water Hydrology)
- Meteorological Data – NOAA Atlas 14, Volume 6 for Point Precipitation Frequency Estimates for California)

WMS – The Watershed Modeling System

- FHWA free "pro" version; Free "community" version that does not include advanced analysis and graphic features.