HEC-WAT: A Planning Tool for Watersheds

Adams, Lea, Chief – Water Resource Systems Division, USACE – Hydrologic Engineering Center, Davis, CA, lea.g.adams@usace.army.mil
Lehman, William, Senior Economist, USACE – Hydrologic Engineering Center, Davis, CA, william.p.lehman@usace.army.mil

Introduction

The USACE Hydrologic Engineering Center (HEC) released Hydrologic Engineering Center-Watershed Analysis Tool (HEC-WAT) Version 1.0 in September 2017. HEC-WAT is a flexible software application designed to support the field of water resources engineering. Because of its flexibility, the mission statement for HEC-WAT is necessarily broad: A water resources tool that integrates engineering and consequence software to support a wide range of USACE applications, including watershed and systems-based risk analysis.

HEC-WAT was developed in response to a series of USACE policy documents stretching back to 2000 that established study guidelines requiring that the planning process "address the Nation's water resources needs in a systems context" (Engineer Regulation 1105-2-100), and apply risk assessment methods (Engineer Regulation 1105-2-101). In short, these and other policy documents required USACE to evaluate projects more comprehensively and with consideration of risk and uncertainty.

Beyond supporting USACE requirements, it's readily apparent that study teams in the field of water resources should take a broad perspective when solving problems. With climate change, population growth and demographic shifts, the demands on our infrastructure to reduce our risk from extreme conditions of drought and flood are increasing. And to meet these demands, we have to more fully embrace integrated water resource management. HEC-WAT is a useful tool for evaluating projects from a more cohesive, watershed-scale perspective.

This discussion focuses on using HEC-WAT as a planning tool at the watershed scale. The three key topics are: 1) integration of software that evaluates various aspects of water resources within a watershed; 2) spatial representation of watershed processes; and 3) incorporation of risk and uncertainty study methods. In addition, results are reviewed and several example project applications are described to illustrate different watershed planning use cases for HEC-WAT.

Integration of Water Resources Software

Currently, HEC-WAT integrates four primary pieces of HEC water resources software: HEC-HMS, HEC-ResSim, HEC-RAS and HEC-FIA. Each of these programs allows users to evaluate a specific aspect of water resources management within a watershed: HEC-HMS (Hydrologic Modeling System) models the rainfall-runoff transformation, HEC-ResSim (Reservoir System Simulation) models reservoir operations, HEC-RAS (River Analysis System) models river hydraulics and HEC-FIA (Flood Impact Analysis) models damage and life loss due to flooding. HEC-WAT integrates these software packages by facilitating the flow of information from one model to the next, eliminating the need for manual handoffs by a modeler. When a study team is evaluating a large number of planning alternatives (especially large-scale or complex

alternatives), creating the data communication pathways inside HEC-WAT can save a tremendous amount of time, as linking models only needs to be done once. Connecting models inside HEC-WAT can also eliminate errors that accidentally occur when users manually transfer data from one model to the next. HEC-WAT allows import of existing HEC models (e.g. HEC-HMS, HEC-RAS, etc.) to efficiently re-use available data, or users can build new individual HEC models within the HEC-WAT framework.

Spatial Representation of Watershed Processes

The spatial component of a watershed-scale water resources study is often key to accomplishing the purpose of the study. One example that illustrates this concept is the application of HEC-WAT to evaluate potential modifications to reservoir operations within the Russian River, California, watershed (Figure 1). In this case, the study team analyzed the changes in flood frequency in the downstream communities of Healdsburg and Guerneville in response to various operational alternatives at Lake Mendocino in the upper watershed. The reservoir is located 50 to 80 miles upstream of the communities of concern, with a number of tributaries joining the Russian River along the way. In this case, the impact locations of concern were spatially distant from the project location within the watershed. The analysis also crossed modeling platforms, using stage-frequency results from HEC-RAS to evaluate flood risk impacts in response to reservoir operation changes modeled in HEC-ResSim. In this way, HEC-WAT supports both the spatial and cross-platform modeling components of watershed evaluations, providing a comprehensive analysis approach.

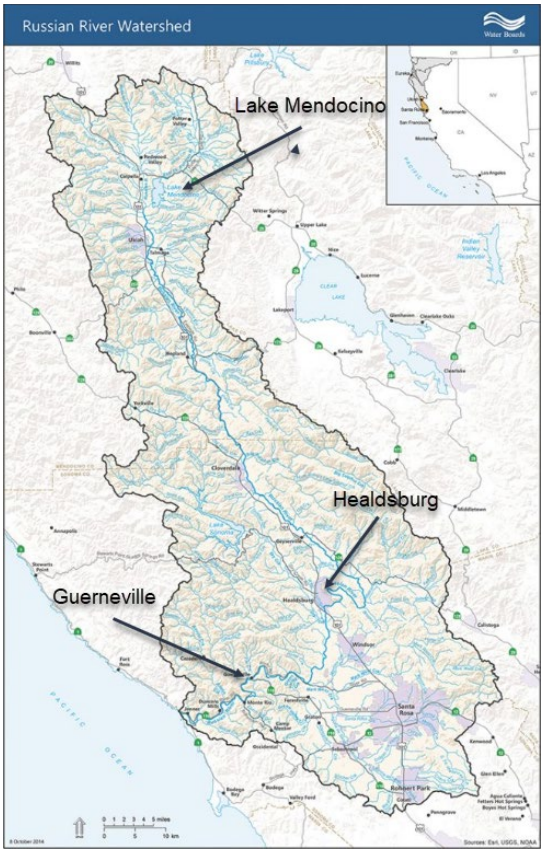

Figure 1. Russian River Watershed

Risk and Uncertainty Methods

The HEC-WAT Flood Risk Analysis (FRA) compute type utilizes a Monte Carlo-style compute to support risk analysis. Hydrologic boundary conditions (precipitation and flow) are typically generated within a tool called the Hydrologic Sampler within HEC-WAT. Uncertainty in initial conditions and parameter values are sampled from uncertainty distributions specified by users within the individual HEC software programs. For example, starting reservoir pool elevations can be sampled within HEC-ResSim, initial loss rates within HEC-HMS, and uncertainty in structure first floor elevations within HEC-FIA. Within a standard FRA compute, hundreds or thousands of events are generated. Each flood event is hydrologically independent, and multiple flood events are organized into groups of events termed 'realizations' (consisting of a minimum of 500 events). Two types of uncertainty are sampled separately within HEC-WAT: knowledge uncertainty and natural variability. Knowledge uncertainty parameters are sampled once per realization, while natural variability parameters are sampled for each flood event within a realization.

Project Results and Example Studies

HEC-WAT users can access standard results from the individual HEC software applications, as well as results specific to an HEC-WAT compute. Results for variables of interest generated during an HEC-WAT FRA compute can be viewed by individual event, or viewed collectively via histograms and frequency curves with uncertainty bounds. Depending on the variable, results can also be displayed spatially.

HEC-WAT has been used on a number of watershed studies to date, including: a climate change evaluation of the Red River basin (North Dakota and Minnesota); a forecast-informed reservoir operations study in the Russian River watershed (California); and a reservoir operations and risk evaluation in support of the Columbia River Treaty (Pacific Northwest and Canada).

Summary

HEC-WAT supports watershed-scale planning studies through: 1) integration of software that evaluates various aspects of water resources within a watershed; 2) spatial representation of watershed processes; and 3) incorporation of risk and uncertainty study methods. It generates standard results from the individual HEC software applications as well as risk analysis results from FRA computes, including spatially distributed results. HEC-WAT has been used to successfully evaluate a range of watershed planning studies, ranging from the effects of climate change to alternative reservoir operations.

References

Engineer Regulation 1105-2-100. 2000. Planning Guidance Notebook. U.S. Army Corps of Engineers.

Engineer Regulation 1105-2-101. 2017. Risk Assessment for Flood Risk Management Studies. U.S. Army Corps of Engineers.