

UTILIZING ENSEMBLE STREAMFLOW PREDICTIONS TO INCORPORATE UNCERTAINTY IN REAL-TIME RESERVOIR OPERATIONS.

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Abstract: The US Army Corps of Engineers (USACE) is one of a team of federal, state, local, and private agencies that operate our Nation's reservoirs to meet flood reduction, water supply, environmental support, hydropower, recreation, and navigation needs. The USACE Hydrologic Engineering Center (HEC) has developed a reservoir simulation modeling tool that is now being used by reservoir modelers world-wide. Designed to simulate reservoir operations for flood management as well as flow augmentation, HEC-ResSim represents a significant decision support tool for the water manager.

HEC continues to improve HEC-ResSim through a variety of funding sources and for a variety of purposes. In collaboration with California Department of Water Resources, the National Weather Service, Yuba County Water Agency, and the USACE Sacramento District, HEC is expanding the capability of HEC-ResSim to iterate through an ensemble of inflow forecasts for the reservoirs and associate stream network, produce an ensemble of regulated flow hydrographs throughout the network, and prepare statistical analysis of those hydrographs. This statistical analysis is expected to assist reservoir operators to incorporate principals of "acceptable risk" in their operational decisions.

The specific features involved in adding Ensemble Management to HEC-ResSim include:

- Add features to build, edit, and plot *collection* to HEC-DSSVue. *Collections* are a grouping concept for HEC-DSS time-series records and will be implemented through a DSS pathname naming convention. Ensembles of inflow traces for a given location will be stored in HEC-DSS as a *collection*.
- Add a new *Ensemble* alternative type to HEC-ResSim and modify the Alternative Editor to allow specification of an Ensemble alternative. Currently, to study the results for an ensemble of inflows on a fixed set of physical and operational data, the modeler would have to create a separate HEC-ResSim alternative for each trace set in the ensemble. The new Ensemble alternative will allow the modeler to create only one alternative to process a full ensemble set of inflows for a specified set of physical and operational data. HEC-ResSim will iterate through each trace set in the ensemble of inflows and produce an associated ensemble of results. Figure 1 illustrates the primary change that will be added to identify an *ensemble* alternative. Figure 2 shows the how the time-series mapping of inflows will be modified to indicate where an ensemble of inflows are to be used in place of a single inflow time-series.
- Add Ensemble graphics and reports. Since studying the results from more than 5-7 runs is very challenging, studying the individual per-trace results from an ensemble run is not expected. Rather, some basic statistical functions (e.g., quantiles) will be added to HEC-DSSVue to make analysis of ensemble results more manageable. The results of these statistical analyses will be stored back ot DSS and available in plotted or tabular form.
- Add Output Control. HEC-ResSim produces a very large volume of output to DSS; for example, a period of record simulation for a relatively small but complex watershed with

a just handful of alternatives can produce DSS files that over 2 gigabytes in size, making them too large to work with effectively. Because ensemble alternatives are expected to represent a great deal more than 5 runs, the ability to limit the HEC-ResSim output becomes extremely important. An output selector will enable the modeler to identify only the output he believes will be necessary for analysis. Figure 3 shows a mockup of the output control feature.

- Investigation and implementation of compute-time efficiencies. The more complexity that has been added to HEC-ResSim’s release decision logic, the longer a simulation takes to compute. This new development effort has provided the impetus to revisit the compute logic to find and implement efficiencies to improve performance.

Initial implementation of the new Ensemble Management features in HEC-ResSim is expected to be completed Fall 2010, at which point testing, debugging, and integration into the Yuba-Feather real-time forecasting system will begin. A general release of HEC-ResSim that will include these features is planned for Summer 2011.

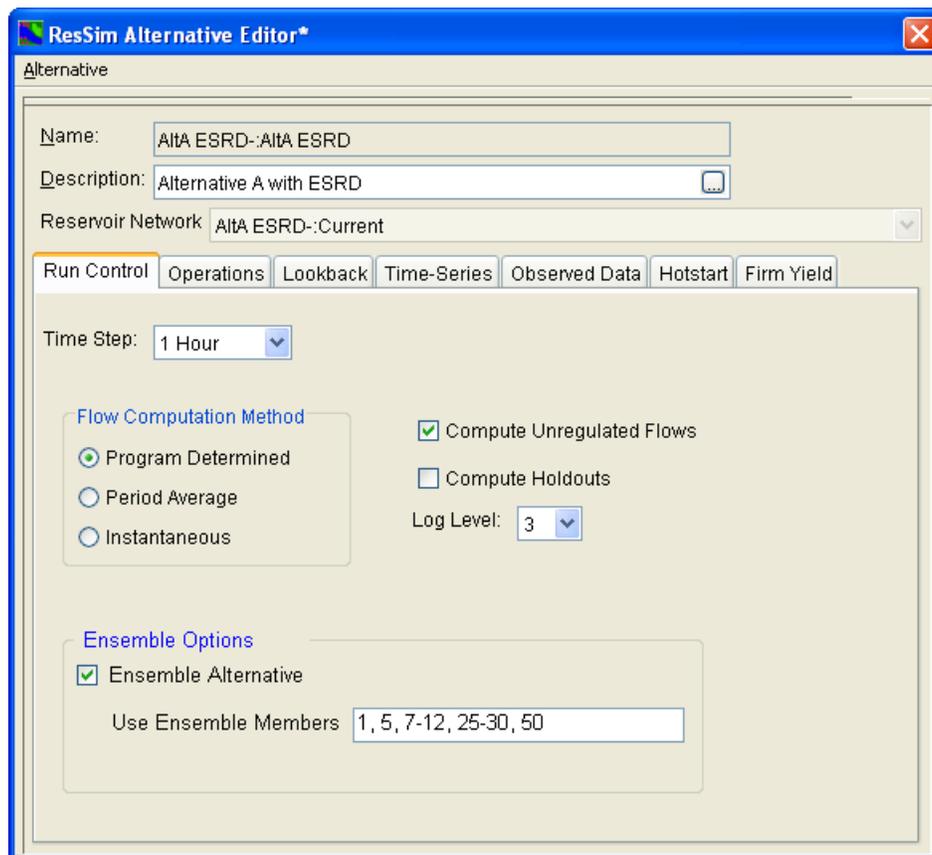


Figure 1 HEC-ResSim Alternative Editor – Ensemble Alternative Definition

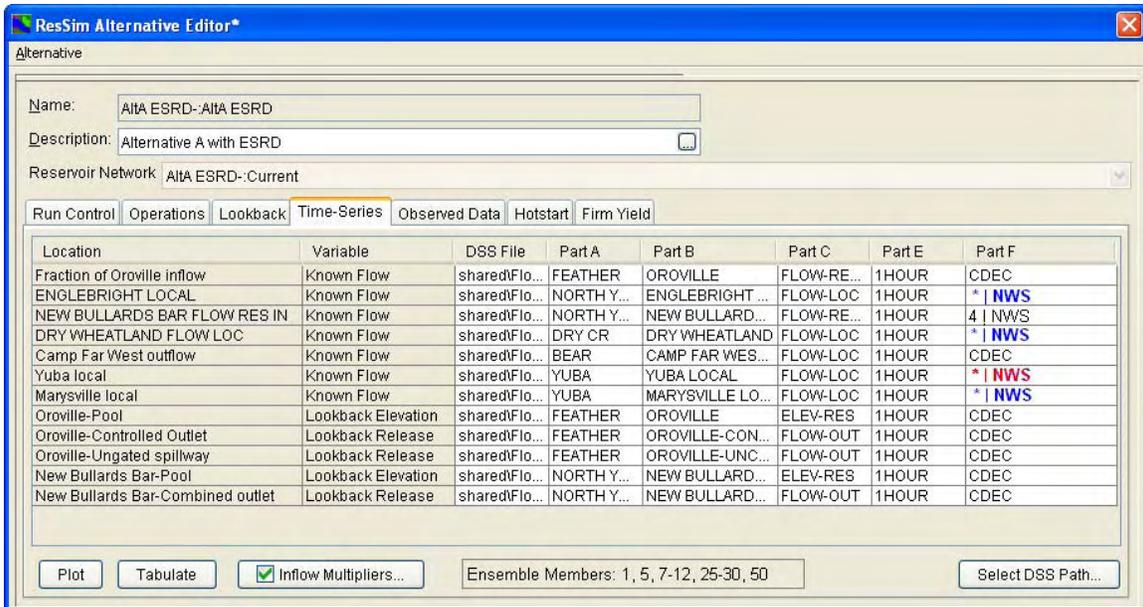


Figure 2 HEC-ResSim Alternative Editor – Time Series tab showing the mapping of ensembles of inflows and selected locations.

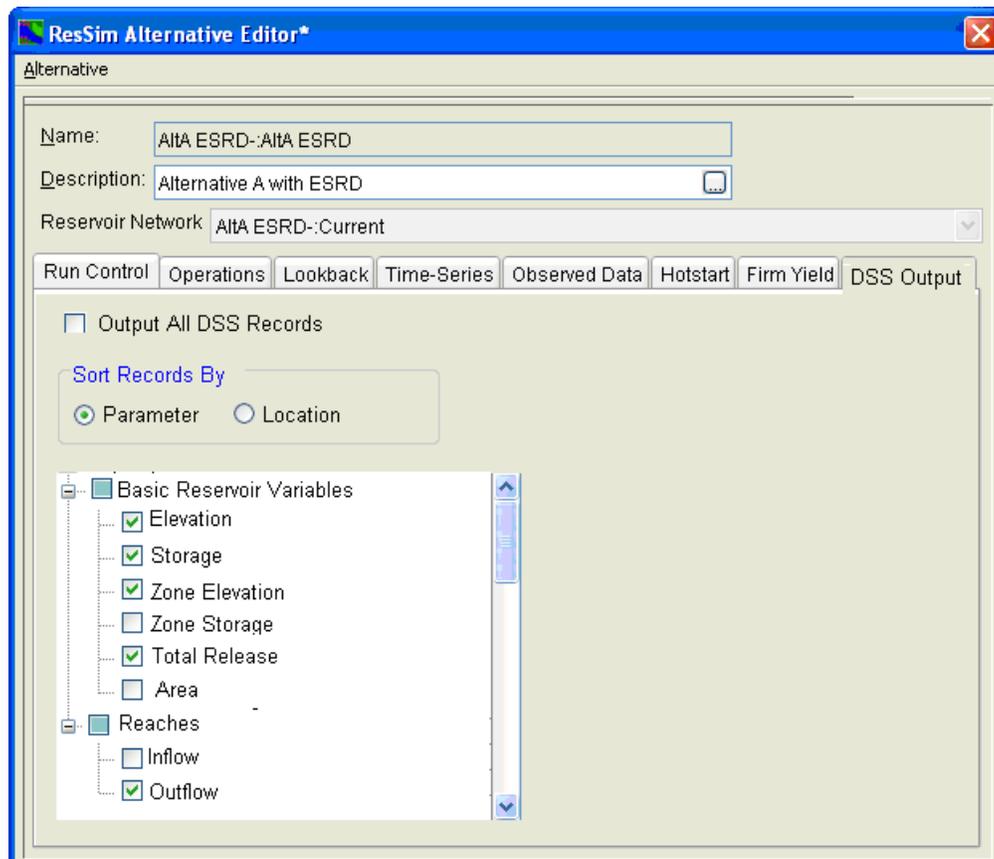


Figure 3 HEC-ResSim Alternative Editor – Output Control Feature