HDR

Above: Screenshots from IPAST

Information Processing and Synthesis Tool (IPAST)

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Abstract

The California Department of Water Resources (DWR) and the US Army Corps of Engineers, Sacramento District (Corps), conducted a multi-year study—the Central Valley Hydrology Study (CVHS)—to update flood hazard assessment of the Central Valley. The study included developing flow-frequency and stage-frequency curves at over 200 locations (analysis or index points) in the Sacramento and San Joaquin river basins (shown in Figure 1). The study applied computer programs HEC-HMS, HEC-ResSim, HEC-RAS, HEC-DSSVue, and PeakFQ. In early phases of the CVHS, the study team used Excel spreadsheets to review model results, extract volumes and maximums from time series data, and complete simple arithmetic. The study's monumental amount of data and information necessitated a more efficient method for processing model results. Ford Engineers, under contract to the Corps, designed and developed a software tool called the Information Processing and Synthesis Tool (IPAST). This technical note provides an overview of the design, development, and use of IPAST.
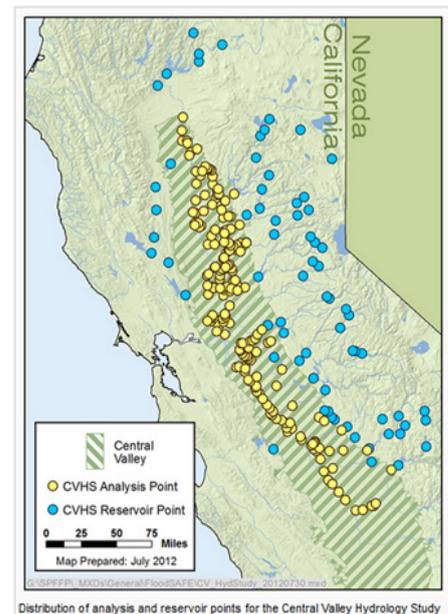
Distribution of analysis and reservoir points for the Central Valley Hydrology Study

Figure 1. Distribution of analysis and reservoir points for the Central Valley Hydrology Study (Figure courtesy of DWR)

Keywords: IPAST; Central Valley Hydrology Study; data processing; unregulated flow-frequency curves; unregulated-to-regulated transforms

Project context: the CVHS required massive amounts of data processing

OVERVIEW OF THE CVHS

As principal contractor for the Corps, Ford Engineers managed hydrologic analyses to support floodplain delineation behind all the federal-state levees in the Sacramento and San Joaquin river basins. This project, known as the Central Valley Hydrology Study (CVHS), included flow-frequency analysis of large watersheds, simulation of reservoir operations for regulated curve development, and estimation of flows for ungaged watersheds.

Specific tasks included development of study procedures; analysis of ungaged watersheds; development of unregulated and regulated flow series through system model simulations; and predicting the effects of climate variability on the results of the CVHS flow-frequency analysis.

The major tasks that comprised the CVHS are represented in Figure 2. The study relied on the application of computer programs such as HEC-HMS, HEC-ResSim, HEC-RAS, HEC-DSSVue, and PeakFQ.

The main products of the CVHS were unregulated and regulated flow-frequency curves to describe flood risk, associated hydrographs for floodplain delineation, and systemwide historical hydrographs.
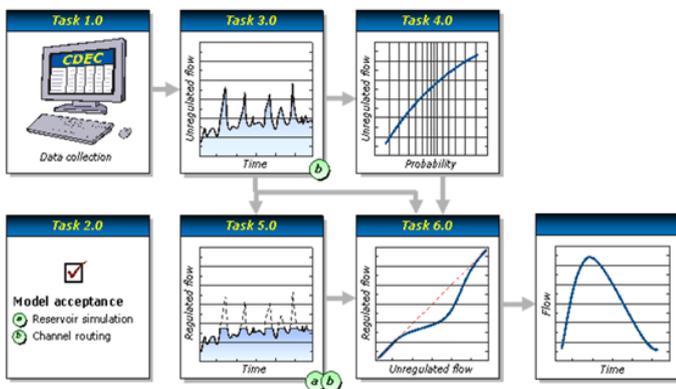

Figure 2. This flowchart depicts the major tasks that comprised the Central Valley Hydrology Study; they are described in the documents posted at cvhydrology.org. This flowchart became a key tool in communicating study procedures and tools to stakeholders.

The CVHS was completed in an open, collaborative fashion with DWR and study stakeholders. To facilitate the communication necessary for the project's success, we worked with the CVHS team to develop and implement a study Web forum: www.cvhydrology.org. On this site, we posted documents and presentations given by the Corps, Ford Engineers, and DWR staff at conferences and workshops. Documents about IPAST, as well as other aspects of the CVHS, can be found at *www.cvhydrology.org*.

MOTIVATION FOR IPAST: DATA PROCESSING REQUIREMENTS FOR THE CVHS

The CVHS included developing flow-frequency and stage-frequency curves at over 200 locations in the Sacramento and San Joaquin river basins. Thus, the study required thousands of simulations of system models. In addition, model outputs needed to be reviewed and synthesized to produce the required study products. In early phases of the CVHS, the study team used Excel spreadsheets to review model results, extract volumes and maximums from time series data, and complete simple arithmetic. It soon became clear that the team was faced with a monumental amount of information to store and process, and that much of that effort consisted of repetitive, relatively simple mathematical operations. It was apparent that a more efficient method was needed.

Our task: design and development of IPAST

Ford Engineers designed, developed, and applied IPAST to automate much of the data processing and facilitate the application of judgment by the CVHS team to finalize study products. IPAST is a stand-alone software application that takes model results, such as from HEC-RAS and HEC-ResSim, extracts relevant values, and processes those values to create hydrologic outputs. The tool itself, a screenshot of which is shown in Figure 3, became a study product along with the watershed, reservoir, and channel models that the team built.

IPAST COMPONENTS

IPAST has these major components:
- Relational database, which stores the results of various processes and provides input for other processes.
- Processes (scripts), which are a combination of computations, queries, and syntheses using values stored in the relational database.
- Configuration files that group HEC-DSS records, based on computer model simulations, necessary for analysis of an index point.
- Configuration files that specify parameters of various arithmetic computations.
- Output reports, which display the results of a process in the GUI and document completion of a task.
- A simple graphical user interface that allows users to define and configure operations, specify HEC-DSS records, execute operations, and review/modify results.
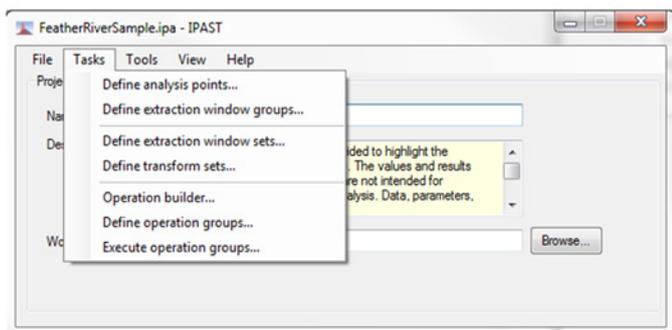
Figure 3. IPAST became a key tool to manage, organize, and synthesize model information to produce the required study products. The modular design of the application allowed for additional capabilities (operations) to be added as needed throughout the study.

IPAST OPERATIONS

IPAST carries out the same procedures that the CVHS study team completed in the early phases of the study using spreadsheets, only more efficiently: it takes model results from Corps-certified tools such as HEC-RAS and HEC-ResSim, extracts the relevant values, and synthesizes those values to create the required hydrologic outputs (unregulated flow-frequency curves and unregulated-to-regulated flow transforms).

Specifically, IPAST completes the following operations:

- Extract for frequency analysis: returns extraction window event maximums for flow-frequency analysis.
- Fit unregulated flow-frequency curve: returns analytical flow frequency curve parameters.
- Extract for event analysis: returns extraction window event maximums for multiple time series for event analysis.
- Correlation analysis: completes a correlation analysis on a set of paired data.
- Fit transforms: returns a best fit line through a set of paired data.
- Compute regulated frequency curve: follows CVHS procedure to transform unregulated curves to regulated curves.
- Combine curves: returns a single curve resulting from the combining of multiple curves.
- Query event data set: returns specific events based on specified selection criteria.
- Build synthetic hydrographs: returns a synthetic hydrograph that is defined based on user-defined flow-duration values.

A companion tool developed to process IPAST results is the Advanced Query Tool. This tool, which is a stand-alone program, allows users to compare model results, event data, and flow- and stage-frequency curves from various IPAST projects in a single location.

INPUTS INTO IPAST

The basic inputs to IPAST, unregulated and regulated flow time series, are read from HEC-DSS files. Through the graphical user interface (GUI), the user specifies the appropriate time series for each analysis point. IPAST extracts the relevant information and

stores it in a relational database. There, through the GUI, the user specifies the required criteria for completing the tasks noted above.

TYPICAL IPAST WORKFLOW

1. Define analysis points—name and time series.
2. Define extraction window groups—windows of time for extracting/processing data.
3. Define individual operations (in logical order) by analysis point in the operation builder.
4. Define operation groups (a listing of operations).
5. Execute operation groups.
6. View/inspect database results in GUI and modify operations as needed.

OUTPUTS FROM IPAST

The results of the analysis are stored back in the relational database or extracted as text files and HEC-DSS records. While IPAST facilitates the completion of the tasks above, it is important to note that user judgment is still required to review and accept the candidate outputs.

How IPAST has been used in projects

IPAST has proven helpful in several projects to date. For example:

- **Central Valley Hydrology Study.** As noted above, in this large, complex analysis of the Sacramento and San Joaquin river basins, we determined flow frequency at approximately 200 locations, routed and scaled historical events through HEC-ResSim and HEC-RAS models, and extracted and synthesized modeling results. IPAST helped the project team extract peaks and volumes; organize and visualize values; modify values and keep a record of those modifications; format the results; and compare results across locations.
- **Channel capacity atlas for Central Valley.** DWR is preparing a channel capacity atlas for the Central Valley. The atlas is a compilation of maximum computed water surface profiles based on unsteady flow simulations. These profiles, composed of the maximum computed water surface elevation at each cross section for a specified event, were creating using the Central Valley Floodplain Evaluation and Delineation (CVFED) Program HEC-RAS system routing model. To create the water surface profiles, the upper end of the regulated flow-frequency curves were updated based on modified reservoir system routings, namely modification of the Folsom Reservoir operating rules to reflect the Joint Federal Project for the p=0.01 and p=0.005 flows. This includes scaled versions of the 1956, 1965, 1986, and 1997 events' inflows. We completed the system routing simulations of these events and used IPAST to extract maximum peaks and volumes at key locations from the simulations. IPAST was also used to develop the upper end of the regulated flow-frequency curves at the analysis points. We selected the scaled version of each historical pattern that has peak regulated flows that match the specified flow quantile at each analysis point location. The initial results of this effort are tables listing the peak regulated p=0.01 and p=0.005 flows for each analysis point, and the scaled version of the simulated historical 1956, 1965, 1986, and 1997 events that

match those flows at the analysis points. In addition, through the development of that information, corresponding HEC-RAS maximum water surface profiles resulting from the unsteady flow simulations were also developed. For each historical pattern, we selected the scaled event whose simulated peak regulated flow most closely represents the peak p=0.01 and p=0.005 flows.

REFERENCES

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Central Valley Hydrology Study web forum, http://www.cvhydrology.org, accessed 12/9/2015.

IPAST Glossary

IPAST term (1)	Definition (2)
Analysis point	Point location in the Central Valley where we process study outputs including hydrographs, transforms, and frequency curves.
Build synthetic hydrographs	Operation to build a balanced hydrograph, a time series that has user-specified flow-duration properties and hydrograph pattern.
Combine curves	Operation to combine outputs from previous processes, specifically frequency curves and transforms.
Correlation analysis	Operation to identify critical duration at an analysis point.
Extract for event analysis	Operation to extract significant event values to support transform development, critical duration calculations, and event selection.
Extract for frequency analysis	Operation to extract annual maximum values to support unregulated flow-frequency analysis.
Fit transform	Operation to find a "best fit" line through a given dataset using the robust locally weighted scatterplot smoothing (LOWESS) algorithm.
Fit unregulated flow-frequency curve	Operation to fit an analytical flow-frequency curve to an annual maximum series in a manner consistent with Bulletin 17B and EM 1110-2-1415.
Operation	1 of 8 key subroutines that together fulfill the computational and functional requirements of IPAST.
Operation ID	Unique identification for each combination of analysis point and operation.
Query event data	Operation to identify historical and/or scaled historical events that meet specific sets of criteria.
Scale group	Group ID for input time series for variables that were scaled using historical data.
Time window groups	Group of start and end dates of the periods for extracting.