

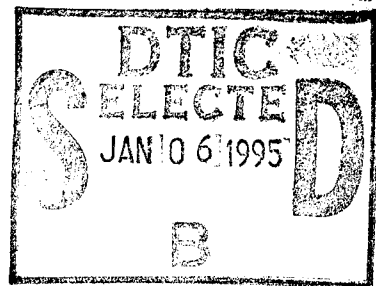
12



**US Army Corps
of Engineers**

Hydrologic Engineering Center

HEC River Analysis System (HEC-RAS)



Technical Paper No. 147

August 1994

DTIC QUALITY INSPECTED 5

Approved for Public Release. Distribution Unlimited.

19950104 112

Papers in this series have resulted from technical activities of the Hydrologic Engineering Center. Versions of some of these have been published in technical journals or in conference proceedings. The purpose of this series is to make the information available for use in the Center's training program and for distribution within the Corps of Engineers

The findings in this report are not to be construed as an official Department of the Army position unless so designated by other authorized documents.

The contents of this report are not to be used for advertising, publication, or promotional purposes. Citation of trade names does not constitute an official endorsement or approval of the use of such commercial products.

Accession For	
NTIS GRA&I	<input checked="checked" type="checkbox"/>
DTIC TAB	<input type="checkbox"/>
Unannounced	<input type="checkbox"/>
Justification	
By	
Distribution	
Availability Codes	
Dist.	Small and/or Special
A-1	

HEC River Analysis System (HEC-RAS)

Gary Brunner¹ and Vernon Bonner²

Abstract

The Hydrologic Engineering Center (HEC) is developing next generation software for one-dimensional river hydraulics. The *HEC-RAS River Analysis System* (HEC, 1994) is intended to be the successor to the current steady-flow *HEC-2 Water Surface Profiles* Program (HEC, 1990a) as well as provide unsteady flow, sediment transport, and hydraulic design capabilities. A common data representation of a river network is used by all modeling methods, thus allowing the user to more easily migrate from steady-flow to other one-dimensional flow calculations. The concept also provides a consistent usage of data among the modeling methods. The HEC-RAS program provides a steady-flow model with several significant advances over HEC-2. An overview of the program package and some of the improved hydraulic features are presented. The Version 1.0 steady-flow model is targeted to be released early in 1995, and unsteady-flow capability is planned for the following year.

Introduction

HEC has initiated the development of the Next Generation (NexGen) of hydrologic engineering software (Davis, 1993). While the existing software will continue to be maintained, the NexGen project is an acknowledgement that some HEC software packages have evolved as far as they should. New software is being developed for the engineering desk-top computer. Presently, a new *Hydrologic Modeling System (HEC-HMS)* is under development to be the successor to the *HEC-1 Flood Hydrograph Package* (HEC, 1990b). HEC-HMS is being developed for the Unix Workstation using a Graphical User Interface (GUI) based on OSF/Motif standard. The *HEC-RAS* has been developed for the high-end personal computer operating in a Windows™ environment. Both modeling systems will eventually be implemented on PC and Unix computers. Successor programs are planned for other hydrologic and planning analysis software.

Acknowledgement

This paper is a combination of two, developed and presented by the authors. Co-authors included Mark Jensen, Co-Op Student, who was responsible for the HEC-RAS GUI and graphics, and Steven Piper, Hydraulic Engineer, who developed major portions of the new program code. Model testing, reported herein, was performed by Ken Yokoyama, student intern from UC Davis. Mr. Gary Brunner is team leader for this project.

¹Senior Engineer and ²Chief, Training Division, Hydrologic Engineering Center, 609 Second Street, Davis, CA 95616.

Presented at the ASCE 1994 National Conference on Hydraulic Engineering, August 1-5, 1994, Buffalo, NY.

HEC-RAS Overview

The HEC-RAS is an integrated package, designed for interactive use in a multi-tasking environment. The system uses a Graphical User Interface (GUI) for file management, data entry and editing, program execution, and output display. The system is designed to provide one-dimensional river modeling using steady-flow, unsteady-flow and sediment-transport computations based on a single geometric representation of the river network. The first release will provide steady-flow, sub-critical, supercritical, and mixed-flow regime profile calculations for a river network.

The program has been developed based on a single definition of the river geometric data for all modeling methods. The five steps for developing a hydraulic model are: 1. Create a project file, 2. Develop the river network and enter geometric data, 3. Define flow and boundary conditions, 4. Perform hydraulic analysis, 5. Review results and produce reports.

A **Project File** is a set of data files associated with a particular river system. Within a project, **Plans** can be developed from combinations of geometric and flow data, plus boundary conditions and run specifications. All input and output data for a plan are linked and assembled by the file manager.

River Networks are defined by drawing, with a mouse, a schematic of the river reaches from upstream to downstream, as shown in the Geometric Data Window in Figure 1. Each **River Reach** is identified by a name. As reaches are connected together, **Junctions** are automatically formed. Junctions are also identified by name. After the network is defined, reach and junction input data can be entered. The data editors can be called by pressing the appropriate buttons on the right of the Geometric Data Window. Or, reach data can be imported from existing HEC-2 data sets.

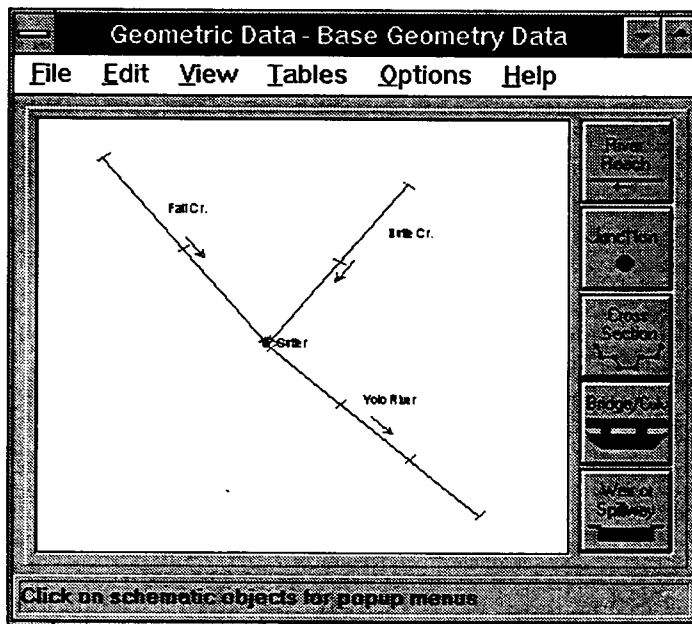


Figure 1. Geometric Data Window.

Junctions are created in the network when reaches combine or divide. The junction is treated as a separate model element; either energy or momentum-based calculations can be performed at the junctions. Energy calculations are based on a reach length between the reaches, the momentum calculation also requires the angle of approach for the reach.

Cross sections are located by the reach name and river station. Pressing the cross-section icon provides the data entry editor. Data are defined by station-elevation

coordinates, up to 500 coordinates are allowed. There is no maximum number of cross sections. The section data are stored in a downstream order based on their river-station number. Cross sections can be easily added or modified in any order. Cut, paste, and copy features are provided, along with separate expansion or contraction of the cross-section elements of overbanks and channel. Cross section interpolation will be provided using cross section coordinates or hydraulic tables.

Steady-flow data are defined for the reach at any cross-section location. Multiple-profile calculations are supported. The boundary conditions are defined at downstream, and/or upstream ends of reaches depending on flow regime. Internal boundary conditions are defined by the junctions. The HEC-2 options for starting profile calculations are all supported.

Profile calculations are performed using the standard-step procedure. Overbank conveyance is computed incrementally at coordinate points (HEC-2 style) or at breaks in roughness (HEC-RAS default). Subcritical, supercritical, and mixed-flow profile calculations can be performed. The critical-depth routine searches the entire range of depths and locates multiple minima. The transition between supercritical and subcritical flow is determined based on momentum calculations. Detailed hydraulic jump location and losses are not computed; however, the jump location is defined between two cross sections.

Tabular output is available using pre-defined and user-defined tables. Cross-section tables provide detailed hydraulic information at a single location, for a profile. Up and down arrow buttons allow the user to page through the output or select specific cross sections. Profile tables provide summary information for all cross sections and profiles. Several pre-defined summary tables are available for the cross section, bridge, and culvert computations. User-defined tables can be developed from a menu of 120 output variables. Selected variables can be stored and recalled like pre-defined tables.

Graphical displays are available for cross sections, profiles, and rating curves. The geometric data can be displayed from the **View** option, provided in most of the data-input editors. Computed results are available as cross section, profiles and rating curves from the **View** menu on the HEC-RAS Main Window. User control is provided for variables to plot, line color, width and type, plus axis labels and scales. The user can also zoom-in on selected portions of the display, and zoom-out to the original size. All graphics are in vector form using calls to the Window's™ Graphics Device Interface. Graphics can be sent to output devices through the Window's™ print manager, or they can be written to a meta file or sent to the Window's™ clip board.

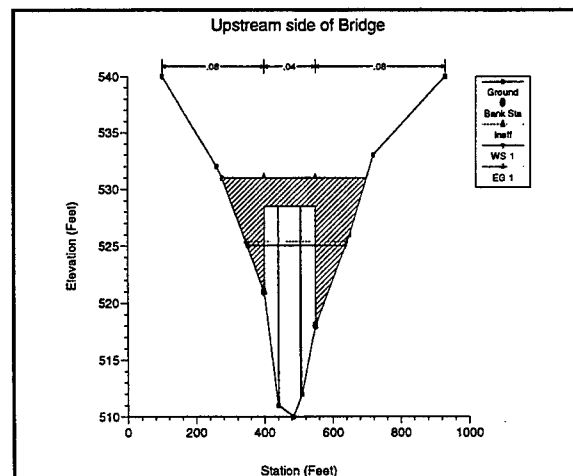


Figure 2. Cross Section Bridge Plot.

Documentation includes a User's Manual (HEC, 1994), plus a Technical, Engineering and Application Reference documents are planned. The user's manual provides the basics for loading and using the software. The reference manuals are intended to provide the hydraulic equations, engineering assumptions, and technical details on menu options, error messages, and basic trouble-shooting.

Alternative Channel Subdivision for Conveyance Calculations

Both HEC-RAS and HEC-2 utilize the Standard Step method for balancing the energy equation to compute a water surface at a cross section. A key element in the solution of the energy equation is the calculation of conveyance. The conveyance is used to determine friction losses between cross sections, the flow distribution at a cross section, and the velocity weighing coefficient alpha. The approach used in HEC-2 is to calculate conveyance between every coordinate point in the cross section overbanks (Figure 3). The conveyance is then summed to get the total left overbank and right overbank values. HEC-2 does not subdivide the main channel for conveyance calculations. The HEC-RAS program supports this method for calculating conveyance, but the default method is to make conveyance calculations only at n-value break points (Figure 4).

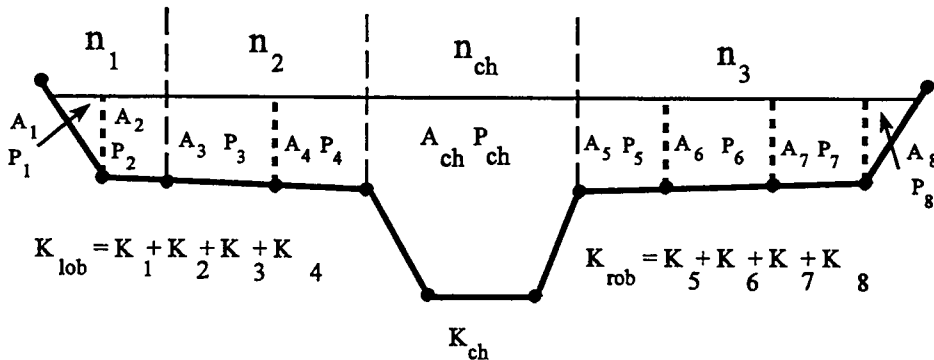


Figure 3. HEC-2 Conveyance Subdivision

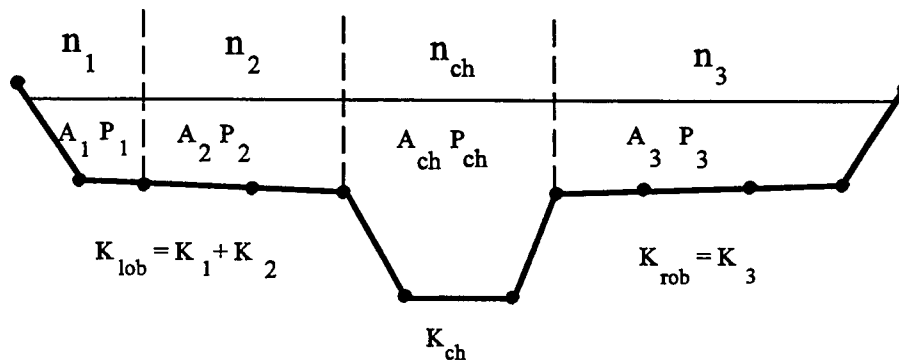


Figure 4. HEC-RAS Conveyance Subdivision

Testing Using HEC-2 Approach. Comparisons of HEC-RAS results with those from HEC-2 were performed using 97 data sets from the HEC profile accuracy study (HEC, 1986). Water surface profiles were computed for 10% and 1% chance floods using HEC-2 and HEC-RAS, both programs using the HEC-2 approach for computing overbank conveyance. Table 1 shows the percentage, of approximately 2000 cross sections, within ± 6 mm (± 0.02 feet). For the 10% chance flood, 53 cross sections had difference greater than ± 6 mm. For those sections, 62.2% were caused by differences in computation of critical depth and 34% resulted from propagation of the difference upstream. For the 1% chance flood, 88 sections had elevation differences over ± 6 mm, of which 60.2% resulted from critical depth and 36.4% from the upstream propagation. HEC-RAS uses 3 mm (0.01 feet) for the critical depth error criterion, while HEC-2 uses 1% of the flow.

Table 1. Computed Water Surface Elevation Difference (HEC-RAS - HEC-2)

Difference (mm)	-6	-3	0.0	3	6	Total
10% Chance Flood	0.8%	11.2%	73.1%	11.2%	0.6%	96.9%
1% Chance Flood	2.0%	11.6%	70.1%	10.8%	1.3%	95.8%

Testing Using RAS and HEC-2 Approach. The two methods for computing conveyance will produce different answers whenever portions of the overbanks have ground sections with significant vertical slopes. In general, the HEC-RAS default approach will provide a lower total conveyance for the same elevation and, therefore, a higher computed water surface elevation. In order to test the significance of the two ways of computing conveyance, comparisons were performed using the same 97 data sets. Water surface profiles were computed for the 1% chance event using the two methods for computing conveyance in HEC-RAS. The results confirmed that the HEC-RAS default approach will generally produce a higher computed water surface elevation. Out of the 2048 cross section locations, 47.5% had computed water surface elevations within 30.5 mm (0.10 ft.), 71% within 61 mm (0.20 ft.), 94.4% within 122 mm (0.4 ft.), 99.4% within 305 mm (1.0 ft.), and one cross section had a difference of 0.84 m (2.75 ft.). Because the differences tend to be in the same direction, some effects can be attributed to propagation.

The results from these comparisons do not show which method is more accurate, they only show differences. In general, it is felt that the HEC-RAS default method is more commensurate with the Manning equation and the concept of separate flow elements. Further research, with observed water surface profiles, will be needed to make any conclusions about the accuracy of the two methods.

Mixed Flow Regime Calculations The HEC-RAS software has the ability to perform subcritical, supercritical, or mixed flow regime calculations (without requiring the user to re-order the cross section data). Mixed flow regime calculations are accomplished in two stages. First, a subcritical water surface profile is computed starting from a known downstream boundary condition. During the subcritical calculations, all locations where the program defaults to critical depth are flagged for further analysis. The next step is to perform supercritical profile calculations. The program starts at the upstream boundary and begins checking for locations that defaulted to critical depth in the subcritical run.

When a critical depth is located, the program uses it as a boundary condition to begin a supercritical profile calculation. The program calculates a supercritical profile in the downstream direction until it reaches a cross section that has both a subcritical and a supercritical answer. When this occurs, the program calculates the momentum of both computed water surface elevations. Whichever answer has the greater momentum is considered to be the correct solution. If the supercritical answer has a greater momentum, the program continues making supercritical calculations in the downstream direction and comparing the momentum of the two solutions. When the program reaches a cross section whose subcritical answer has a greater momentum, the program assumes that a hydraulic jump occurred between that section and the previous cross section. The program then goes to the next downstream location that has a critical depth answer and continues the process. An example mixed flow profile from HEC-RAS is shown in Figure 5, adapted from a problem in Chow's "Open Channel Hydraulics" (Chow, 1959).

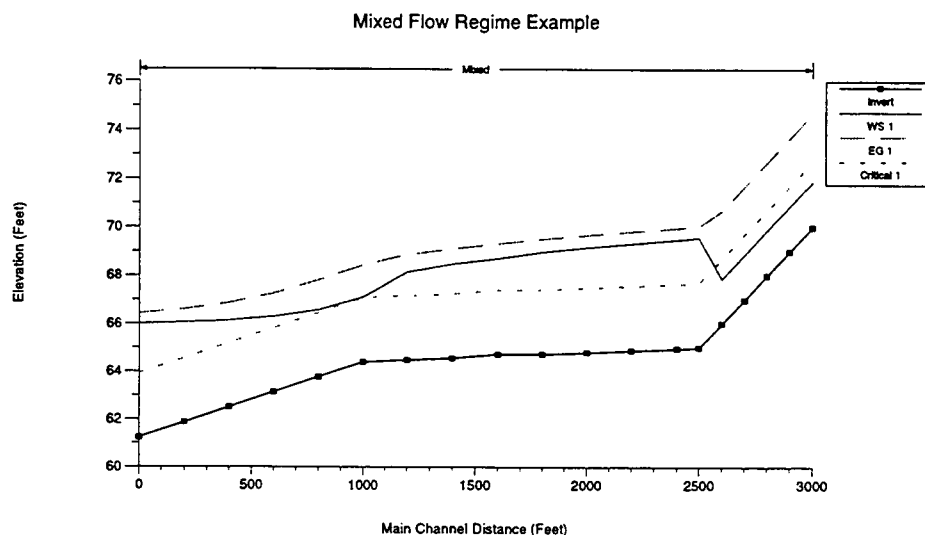


Figure 5. Example Mixed Flow Profile From HEC-RAS

Modeling Full Stream Networks and Junctions

The HEC-RAS system has the ability to model dendritic river systems, as well as a full network of streams. The program can handle an unlimited number of river reaches. Junctions (locations where reaches either combine or split) are limited to five reaches either combining or splitting. The water surface profile through a junction can be modeled in two different ways. The default method is to use the energy equation. An energy balance is performed across the junction on a reach by reach basis. The user has the option of selecting an alternative method that utilizes the momentum equation. The momentum equation allows the user to enter an angle for each reach that is not parallel to the normal direction of flow. The program then performs a momentum balance across the junction to obtain the water surface profiles.

New Bridge and Culvert Routines

The **Bridge Routines** in HEC-RAS allow the modeler to analyze a bridge by several different methods without changing the bridge geometry. The model utilizes four user defined cross sections in the computations of energy losses due to the structure. Cross sections are formulated inside the bridge on an as need basis by combining the bridge geometry with the two cross sections that bound the structure.

For **Low Flow Computations** the program first uses the momentum equation to define the class of flow. For Class A low flow (completely subcritical), the modeler can select any or all of the following four methods: standard step energy; momentum; Yarnell equation; or USGS Contracted Opening method. If more than one method is selected, the user must choose a single method as the final solution, or tell the program to select the method that produces the highest energy loss through the structure. For Class B low flow (passes through critical depth) the program uses the momentum equation. Class C low flow (completely supercritical) can be modeled with either the standard step energy method or the momentum equation. The program does not require the user to enter a trapezoidal approximation for the bridge opening. Also, for the momentum method, the user can instruct the program to incorporate weight and/or friction components in addition to the pier impact losses.

Pressure Flow occurs when the flow comes into contact with the low cord of the bridge. The program begins checking for the possibility of pressure flow when the energy grade line goes above the maximum low chord. The user has the option of telling the program to use the water surface instead of energy. The program will handle two cases of pressure flow. The first is when only the upstream side of the bridge is in contact with the flow (sluice gate). In the second case, both the upstream and downstream side of the bridge are in contact with the flow (orifice equation).

Weir Flow occurs when water flows over the bridge and/or roadway. Weir flow is calculated using a standard weir equation. For high tailwater conditions, the amount of weir flow is reduced to account for the effects of submergence. If the weir becomes highly submerged, the program will switch to calculating energy losses by the standard step energy method. The criteria for when the program switches to energy based calculations is user controllable. When combinations of low flow or pressure flow occur with weir flow, an iterative procedure is used to determine the amount of each type of flow.

The **Culvert** hydraulic computations in HEC-RAS are similar to the bridge routines, in that the cross section layout, the use of ineffective areas, the selection of contraction and expansion coefficients, and other aspects are the same. The culvert routines have the ability to model the following shapes: box; circular; arch; pipe arch; and elliptical. The program uses the Federal Highway Administrations (FHWA, 1985) standard culvert equations to model inlet control. Outlet control is analyzed by either standard step backwater calculations or full flow friction losses. Entrance and exit losses are incorporated in both options.

Program Testing

Initial testing has consisted of comparing results to the current HEC-2 program. Additional testing is now underway using all the observed data we can locate. The bridge routines are being extensively tested using 21 USGS data sets from the Bay St. Louis

After all the testing has been completed, and final corrections and additions have been made, HEC will release the first official version.

Distribution

After extensive internal and volunteer testing have been completed, and the necessary program corrections and additions are finished, HEC will release the Version 1 steady-flow model for general use. Work will continue to add additional features to the steady-flow capability and to add unsteady flow modeling. Major program releases are expected approximately annually during the development of the program package. The addition of hydraulic design, scour, and sediment transport capability is planned for future development.

References

- Chow, V.T., (1959). "Open-Channel Hydraulics," McGraw-Hill Book Co., New York.
- Davis, D.W. (1993). "The HEC NexGen Software Development Project," Technical Paper No. 138, Hydrologic Engineering Center, Davis, CA.
- FHWA, (1985). "Hydraulic Design of Highway Culverts," Hydraulic Design Series No. 5, US Department of Transportation, Washington, DC.
- HEC, (1986). "Accuracy of Computed Water Surface Profiles," Research Document No. 26, Hydrologic Engineering Center, Davis, CA.
- HEC, (1990a). "HEC-2 Water Surface Profiles," User's Manual, Hydrologic Engineering Center, Davis, CA.
- HEC, (1990b). "HEC-1 Flood Hydrograph Package," User's Manual, Hydrologic Engineering Center, Davis, CA.
- HEC, (1994). "HEC-RAS River Analysis System," Draft User's Manual, Hydrologic Engineering Center, Davis, CA.
- FHWA, (1985). "Hydraulic Design of Highway Culverts," Hydraulic Design Series No. 5, US Dept. of Transportation, Washington DC.
- Ming, C.O., Colson, B.E. and G.J. Arcement, (1978). "Backwater at Bridges and Densely Wooded Flood Plains," Hydrologic Investigation Atlas Series, U.S. Geological Survey.

TECHNICAL PAPER SERIES

- | | | | |
|-------|--|-------|---|
| TP-1 | Use of Interrelated Records to Simulate Streamflow | TP-38 | Water Quality Evaluation of Aquatic Systems |
| TP-2 | Optimization Techniques for Hydrologic Engineering | TP-39 | A Method for Analyzing Effects of Dam Failures in Design Studies |
| TP-3 | Methods of Determination of Safe Yield and Compensation Water from Storage Reservoirs | TP-40 | Storm Drainage and Urban Region Flood Control Planning |
| TP-4 | Functional Evaluation of a Water Resources System | TP-41 | HEC-5C, A Simulation Model for System Formulation and Evaluation |
| TP-5 | Streamflow Synthesis for Ungaged Rivers | TP-42 | Optimal Sizing of Urban Flood Control Systems |
| TP-6 | Simulation of Daily Streamflow | TP-43 | Hydrologic and Economic Simulation of Flood Control Aspects of Water Resources Systems |
| TP-7 | Pilot Study for Storage Requirements for Low Flow Augmentation | TP-44 | Sizing Flood Control Reservoir Systems by Systems Analysis |
| TP-8 | Worth of Streamflow Data for Project Design - A Pilot Study | TP-45 | Techniques for Real-Time Operation of Flood Control Reservoirs in the Merrimack River Basin |
| TP-9 | Economic Evaluation of Reservoir System Accomplishments | TP-46 | Spatial Data Analysis of Nonstructural Measures |
| TP-10 | Hydrologic Simulation in Water-Yield Analysis | TP-47 | Comprehensive Flood Plain Studies Using Spatial Data Management Techniques |
| TP-11 | Survey of Programs for Water Surface Profiles | TP-48 | Direct Runoff Hydrograph Parameters Versus Urbanization |
| TP-12 | Hypothetical Flood Computation for a Stream System | TP-49 | Experience of HEC in Disseminating Information on Hydrological Models |
| TP-13 | Maximum Utilization of Scarce Data in Hydrologic Design | TP-50 | Effects of Dam Removal: An Approach to Sedimentation |
| TP-14 | Techniques for Evaluating Long-Term Reservoir Yields | TP-51 | Design of Flood Control Improvements by Systems Analysis: A Case Study |
| TP-15 | Hydrostatistics - Principles of Application | TP-52 | Potential Use of Digital Computer Ground Water Models |
| TP-16 | A Hydrologic Water Resource System Modeling Techniques | TP-53 | Development of Generalized Free Surface Flow Models Using Finite Element Techniques |
| TP-17 | Hydrologic Engineering Techniques for Regional Water Resources Planning | TP-54 | Adjustment of Peak Discharge Rates for Urbanization |
| TP-18 | Estimating Monthly Streamflows Within a Region | TP-55 | The Development and Servicing of Spatial Data Management Techniques in the Corps of Engineers |
| TP-19 | Suspended Sediment Discharge in Streams | TP-56 | Experiences of the Hydrologic Engineering Center in Maintaining Widely Used Hydrologic and Water Resource Computer Models |
| TP-20 | Computer Determination of Flow Through Bridges | TP-57 | Flood Damage Assessments Using Spatial Data Management Techniques |
| TP-21 | An Approach to Reservoir Temperature Analysis | TP-58 | A Model for Evaluating Runoff-Quality in Metropolitan Master Planning |
| TP-22 | A Finite Difference Method for Analyzing Liquid Flow in Variably Saturated Porous Media | TP-59 | Testing of Several Runoff Models on an Urban Watershed |
| TP-23 | Uses of Simulation in River Basin Planning | TP-60 | Operational Simulation of a Reservoir System with Pumped Storage |
| TP-24 | Hydroelectric Power Analysis in Reservoir Systems | TP-61 | Technical Factors in Small Hydropower Planning |
| TP-25 | Status of Water Resource Systems Analysis | TP-62 | Flood Hydrograph and Peak Flow Frequency Analysis |
| TP-26 | System Relationships for Panama Canal Water Supply | TP-63 | HEC Contribution to Reservoir System Operation |
| TP-27 | System Analysis of the Panama Canal Water Supply | TP-64 | Determining Peak-Discharge Frequencies in an Urbanizing Watershed: A Case Study |
| TP-28 | Digital Simulation of an Existing Water Resources System | TP-65 | Feasibility Analysis in Small Hydropower Planning |
| TP-29 | Computer Applications in Continuing Education | TP-66 | Reservoir Storage Determination by Computer Simulation of Flood Control and Conservation Systems |
| TP-30 | Drought Severity and Water Supply Dependability | TP-67 | Hydrologic Land Use Classification Using LANDSAT |
| TP-31 | Development of System Operation Rules for an Existing System by Simulation | TP-68 | Interactive Nonstructural Flood-Control Planning |
| TP-32 | Alternative Approaches to Water Resource System Simulation | TP-69 | Critical Water Surface by Minimum Specific Energy Using the Parabolic Method |
| TP-33 | System Simulation for Integrated Use of Hydroelectric and Thermal Power Generation | TP-70 | Corps of Engineers Experience with Automatic Calibration of a Precipitation-Runoff Model |
| TP-34 | Optimizing Flood Control Allocation for a Multipurpose Reservoir | TP-71 | Determination of Land Use from Satellite Imagery for Input to Hydrologic Models |
| TP-35 | Computer Models for Rainfall-Runoff and River Hydraulic Analysis | TP-72 | Application of the Finite Element Method to Vertically Stratified Hydrodynamic Flow and Water Quality |
| TP-36 | Evaluation of Drought Effects at Lake Atitlan | | |
| TP-37 | Downstream Effects of the Levee Overtopping at Wilkes-Barre, PA, During Tropical Storm Agnes | | |

- TP-73 Flood Mitigation Planning Using HEC-SAM
- TP-74 Hydrographs by Single Linear Reservoir Model
- TP-75 HEC Activities in Reservoir Analysis
- TP-76 Institutional Support of Water Resource Models
- TP-77 Investigation of Soil Conservation Service Urban Hydrology Techniques
- TP-78 Potential for Increasing the Output of Existing Hydroelectric Plants
- TP-79 Potential Energy and Capacity Gains from Flood Control Storage Reallocation at Existing U. S. Hydropower Reservoirs
- TP-80 Use of Non-Sequential Techniques in the Analysis of Power Potential at Storage Projects
- TP-81 Data Management Systems for Water Resources Planning
- TP-82 The New HEC-1 Flood Hydrograph Package
- TP-83 River and Reservoir Systems Water Quality Modeling Capability
- TP-84 Generalized Real-Time Flood Control System Model
- TP-85 Operation Policy Analysis: Sam Rayburn Reservoir
- TP-86 Training the Practitioner: The Hydrologic Engineering Center Program
- TP-87 Documentation Needs for Water Resources Models
- TP-88 Reservoir System Regulation for Water Quality Control
- TP-89 A Software System to Aid in Making Real-Time Water Control Decisions
- TP-90 Calibration, Verification and Application of a Two-Dimensional Flow Model
- TP-91 HEC Software Development and Support
- TP-92 Hydrologic Engineering Center Planning Models
- TP-93 Flood Routing Through a Flat, Complex Flood Plain Using a One-Dimensional Unsteady Flow Computer Program
- TP-94 Dredged-Material Disposal Management Model
- TP-95 Infiltration and Soil Moisture Redistribution in HEC-1
- TP-96 The Hydrologic Engineering Center Experience in Nonstructural Planning
- TP-97 Prediction of the Effects of a Flood Control Project on a Meandering Stream
- TP-98 Evolution in Computer Programs Causes Evolution in Training Needs: The Hydrologic Engineering Center Experience
- TP-99 Reservoir System Analysis for Water Quality
- TP-100 Probable Maximum Flood Estimation - Eastern United States
- TP-101 Use of Computer Program HEC-5 for Water Supply Analysis
- TP-102 Role of Calibration in the Application of HEC-6
- TP-103 Engineering and Economic Considerations in Formulating
- TP-104 Modeling Water Resources Systems for Water Quality
- TP-105 Use of a Two-Dimensional Flow Model to Quantify Aquatic Habitat
- TP-106 Flood-Runoff Forecasting with HEC-1F
- TP-107 Dredged-Material Disposal System Capacity Expansion
- TP-108 Role of Small Computers in Two-Dimensional Flow Modeling
- TP-109 One-Dimensional Model For Mud Flows
- TP-110 Subdivision Froude Number
- TP-111 HEC-5Q: System Water Quality Modeling
- TP-112 New Developments in HEC Programs for Flood Control
- TP-113 Modeling and Managing Water Resource Systems for Water Quality
- TP-114 Accuracy of Computed Water Surface Profiles - Executive Summary
- TP-115 Application of Spatial-Data Management Techniques in Corps Planning
- TP-116 The HEC's Activities in Watershed Modeling
- TP-117 HEC-1 and HEC-2 Applications on the MicroComputer
- TP-118 Real-Time Snow Simulation Model for the Monongahela River Basin
- TP-119 Multi-Purpose, Multi-Reservoir Simulation on a PC
- TP-120 Technology Transfer of Corps' Hydrologic Models
- TP-121 Development, Calibration and Application of Runoff Forecasting Models for the Allegheny River Basin
- TP-122 The Estimation of Rainfall for Flood Forecasting Using Radar and Rain Gage Data
- TP-123 Developing and Managing a Comprehensive Reservoir Analysis Model
- TP-124 Review of the U.S. Army Corps of Engineering Involvement With Alluvial Fan Flooding Problems
- TP-125 An Integrated Software Package for Flood Damage Analysis
- TP-126 The Value and Depreciation of Existing Facilities: The Case of Reservoirs
- TP-127 Floodplain-Management Plan Enumeration
- TP-128 Two-Dimensional Floodplain Modeling
- TP-129 Status and New Capabilities of Computer Program HEC-6: "Scour and Deposition in Rivers and Reservoirs"
- TP-130 Estimating Sediment Delivery and Yield on Alluvial Fans
- TP-131 Hydrologic Aspects of Flood Warning - Preparedness Programs
- TP-132 Twenty-five Years of Developing, Distributing, and Supporting Hydrologic Engineering Computer Programs
- TP-133 Predicting Deposition Patterns in Small Basins
- TP-134 Annual Extreme Lake Elevations by Total Probability Theorem
- TP-135 A Muskingum-Cunge Channel Flow Routing Method for Drainage Networks
- TP-136 Prescriptive Reservoir System Analysis Model - Missouri River System Application
- TP-137 A Generalized Simulation Model for Reservoir System Analysis
- TP-138 The HEC NexGen Software Development Project
- TP-139 Issues for Applications Developers
- TP-140 HEC-2 Water Surface Profiles Program
- TP-141 HEC Models for Urban Hydrologic Analysis
- TP-142 Systems Analysis Applications at the Hydrologic Engineering Center
- TP-143 Runoff Prediction Uncertainty for Ungauged Agricultural Watersheds
- TP-144 Review of GIS Applications in Hydrologic Modeling
- TP-145 Application of Rainfall-Runoff Simulation for Flood Forecasting
- TP-146 Application of the HEC Prescriptive Reservoir Model in the Columbia River System
- TP-147 HEC River Analysis System (HEC-RAS)

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED			1b. RESTRICTIVE MARKINGS		
2a. SECURITY CLASSIFICATION AUTHORITY			3. DISTRIBUTION / AVAILABILITY OF REPORT		
2b. DECLASSIFICATION / DOWNGRADING SCHEDULE					
4. PERFORMING ORGANIZATION REPORT NUMBER(S) TECHNICAL PAPER NO. 147			5. MONITORING ORGANIZATION REPORT NUMBER(S)		
6a. NAME OF PERFORMING ORGANIZATION HYDROLOGIC ENGINEERING CENTER		6b. OFFICE SYMBOL (If applicable) CEWRC-HEC-T	7a. NAME OF MONITORING ORGANIZATION WATER RESOURCES SUPPORT CENTER		
6c. ADDRESS (City, State, and ZIP Code) 609 Second Street Davis, California 95616			7b. ADDRESS (City, State, and ZIP Code) 7701 Telegraph Road Alexandria VA 22310-3868		
8a. NAME OF FUNDING / SPONSORING ORGANIZATION		8b. OFFICE SYMBOL (If applicable)	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER		
8c. ADDRESS (City, State, and ZIP Code)			10. SOURCE OF FUNDING NUMBERS		
			PROGRAM ELEMENT NO.	PROJECT NO.	TASK NO.
			WORK UNIT ACCESSION NO.		
11. TITLE (Include Security Classification) HEC RIVER ANALYSIS SYSTEM (HEC-RAS)					
12. PERSONAL AUTHOR(S) Gary Brunner and Vernon Bonner					
13a. TYPE OF REPORT Technical Paper		13b. TIME COVERED FROM _____ TO _____		14. DATE OF REPORT (Year, Month, Day) August 1994	
15. PAGE COUNT 8					
16. SUPPLEMENTARY NOTATION Presented at the ASCE National Conference on Hydraulic Engineering, 1-5 August 1994, Buffalo, NY.					
17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)		
FIELD	GROUP	SUB-GROUP	Water surface profiles, HEC-RAS computer program, microcomputer		
19. ABSTRACT (Continue on reverse if necessary and identify by block number) The Hydrologic Engineering Center (HEC) is developing next generation software for one-dimensional river hydraulics. The HEC-RAS River Analysis System is intended to be the successor to the current steady-flow HEC-2 Water Surface Profiles Program as well as provide unsteady flow, sediment transport, and hydraulic design capabilities in the future. A common data representation of a river network is used by all modeling methods, thus allowing the user to more easily migrate from steady-flow model with several significant advances over HEC-2. An overview of the Version 1 program package and some of the improved hydraulic features are presented.					
20. DISTRIBUTION / AVAILABILITY OF ABSTRACT <input checked="" type="checkbox"/> UNCLASSIFIED/UNLIMITED <input type="checkbox"/> SAME AS RPT. <input type="checkbox"/> DTIC USERS			21. ABSTRACT SECURITY CLASSIFICATION		
22a. NAME OF RESPONSIBLE INDIVIDUAL VERNON R. BONNER, Chief, Training Division			22b. TELEPHONE (Include Area Code) (916) 756-1104		22c. OFFICE SYMBOL CEWRC-HEC-T