



**US Army Corps
of Engineers®**

Hydrologic Engineering Center

Hydrologic Modeling System HEC-HMS

Release Notes

Version 2.2.0
August 2002

Introduction

Version 2.1.3 of the Hydrologic Modeling System (HEC-HMS) was completed in October 2001 and released for general use shortly thereafter. A number of program errors have been found since that release and mainly occur in portions of the program used infrequently. Some problems have also been found that only affected the Windows 2000 operating system. This new release [repairs defects](#) and adds new capabilities to the [reservoir](#) element. Unfortunately, a small number of [known defects](#) remain in the program at the time of release. This release is available for computers running the Microsoft Windows 2000/NT/98/95 operating systems or the Sun Microsystems Solaris operating system.

Development of the software is ongoing. The entire program is currently being converted from the C++ programming language to the Java language. New snowmelt simulation capabilities will be added to the meteorologic model in the future. Further details may be found in the [Future Plans](#) section.

The Technical Reference Manual for Version 2.0 continues to accurately describe the mathematical models included in the program. The User's Manual labeled Version 2.1 continues to accurately describe the use and application of the program. Supplemental description of the new reservoir features is included in this document.

The installation program and all documentation are available on the HEC website at <http://www.hec.usace.army.mil/>.

Installation

The installation package is designed to be easy to use. If you have never installed the HEC-HMS program before, the installation package will take you through the steps of selecting a directory for the program files, a directory for the sample project files, and making other settings. If you have installed the HEC-HMS program before, the installation package will automatically detect the previous version and upgrade to the new release. Use the following steps to install or upgrade the program:

1. Download the installation package from the HEC website to a temporary folder on the computer. Alternately, insert the provided CD-ROM or other media in the appropriate drive.
2. Run the installation program. In Windows Explorer, double-click the icon for the installation program.
3. Follow the on-screen prompts to install or upgrade the program. Be sure to reboot the computer before using the HEC-HMS program if this is the first installation of the program.

New Users

The program has been designed to be easy to use. However, an understanding of how the program works is critical to producing accurate results. It is suggested that a new user read Chapter 3 of the User's Manual and Chapters 2 and 3 in the Technical Reference Manual before attempting to start and use the program. Subsequently, start the program and construct the example application

contained in Chapter 10 of the User's Manual. These chapters provide the fundamental instruction necessary to effectively use the program.

Experienced Users

The User's Manual contains information about using each of the computational methods included in the program. A Technical Reference Manual is also available to describe the theoretical basis for the methods included in the program. It is recommended that experienced users read the topics, both in the User's Manual and Technical Reference Manual, for methods used frequently.

Closed Defects

A total of 41 defects have been repaired since the release of Version 2.1.2. A brief description of each repaired defect follows:

Project, Runs, Optimization

1. The program would crash during a compute if the gridded soil moisture accounting loss method was used and one or more of the soil moisture units specified in the grid cell file did not exist in the soil moisture unit manager. The compute is now aborted with appropriate error messages.
2. The program would crash during a compute if the gridded SCS curve number loss method was used and one or more curve numbers was missing from the grid cell file. The compute is now aborted with appropriate error messages.
3. The missing-flow data check performed during optimization was performed for the entire time window. It is now performed only for the time window over which the objective function is evaluated.
4. The program would crash during a compute if a subbasin editor was open and the constant monthly baseflow method was not in use. A compute now finishes successfully if a subbasin editor is open.
5. The program would crash when attempting to access optimization results using the basin model button in the toolbar of the optimization manager screen. The results are now correctly displayed.
6. No initial values for the gridded SCS curve number loss method were shown in the optimization manager screen. Default initial values are now copied from the basin model used in the optimization run.
7. The program would crash after deleting the last optimization run. It now closes all of the optimization screens without crashing.
8. The Nelder & Mean optimization search method always failed to converge and the objective function value did not decrease as the number of iterations increased. The problem has been repaired, but "stagnation" problems inherent in the algorithm still cause the search to fail to converge in some situations. However, the objective function value does decrease as the number of iterations increases even if the convergence criteria is not met. When stagnation occurs, the estimated parameters may not be optimum.

9. The program would crash during a compute if the basin model used the user-specified s-graph transform method and the selected s-graph did not have "0" as the first time ordinate. The compute is now aborted with appropriate error messages.

Gage Manager, Paired-Data Manager, Soil Moisture Units

1. The program would crash when closing the "DSS Pathname Select" screen with the title bar "X" button if the operating system was Microsoft Windows 2000. The screen can now be closed this way without causing the program to crash.
2. The user-specified unit hydrograph editor did not add new rows when the available rows had been used. New rows are now added correctly.
3. The time interval and units for a new user-specified unit hydrograph were not grayed-out when the hydrograph would be retrieved from an external DSS file. They are now correctly grayed-out.
4. The evapotranspiration portion of the soil moisture unit manager did not draw correctly when many units were defined. It now draws correctly regardless of the number of soil moisture units.

Basin Model

1. Pressing the "OK" button in the constant monthly baseflow global editor after making no changes to the data caused the program to crash. The editor can now be closed and the data will be saved successfully without causing the program to crash.
2. The program would crash under some conditions when performing a compute with a basin model using the kinematic wave transform method. It would only occur if the basin model was a copy that had not yet been saved and at least one subbasin used two kinematic wave planes. The compute is now finished successfully without causing the program to crash.
3. Opening and closing several basin model screens in rapid succession could occasionally cause the program to crash. This did not occur when opening and closing basin models at a normal pace. The problem has been fixed no matter what speed basin models are opened and closed.
4. The reservoir storage graph did not always show the correct data. It now shows appropriate data for the storage-outflow, elevation-storage-outflow, and elevation-area-outflow input options.
5. The flow ratio for a source element was not saved with the rest of the source element data. The data is now correctly saved.
6. The bounded recession baseflow method did not correctly check parameter values during a compute. It tried to check data that did not exist and was not necessary to perform the compute. It now checks the appropriate parameter data.
7. The soil moisture accounting loss method did not correctly set the data units for canopy excess precipitation when the metric unit system was used. The units are now set correctly.

8. Changes to the stage-discharge curve for an element were not recognized unless the basin model was closed and reopened. Changes are now recognized immediately.
9. The s-graph table name was not copied when a subbasin using the s-graph transform method was copied. This applied to copies made using the Duplicate command on the Edit menu of the Basin Model screen, or when copying the entire basin model. The s-graph names is now copied correctly.
10. The constant monthly baseflow rates were missing after copying a subbasin using the constant monthly baseflow method. This applied to copies made using the Duplicate command on the Edit menu of the Basin Model screen, or when copying the entire basin model. Copies are now performed correctly.
11. The subbasin list screen in the meteorologic model did not always work correctly when only one basin model existed in the project. It now correctly adds subbasins to the meteorologic model no matter how many basin models exist.
12. The recovery rates for the deficit and constant loss method were lost if no rate was entered for January. All rates are now saved correctly.
13. Opening the soil moisture accounting loss method global editor when no soil moisture units existed caused the program to crash. The editor is now opened without crashing.
14. Switching from the soil moisture accounting loss method to the initial and constant loss method caused the program to crash. The switch is now performed correctly without crashing.
15. The program would crash after using the element list to change the loss method for one or more subbasins. The switch is now correctly performed without crashing.
16. The bounded recession global editor did not correctly save data when only the initial flow or recession factors were changed. All data is now correctly saved.
17. The program would crash when closing the subbasin editor after changing from the soil moisture accounting loss method to any other method. The change is now made correctly.
18. The user-specified unit hydrograph method did not check the hydrograph data to make sure it was valid before attempting to use it; this could lead to a program crash during a compute under some conditions. A check is now performed and prevents a crash.
19. The hydrograph selection list for the user-specified unit hydrograph method did not show the proper selections after switching transform methods. The list is now shown correctly.
20. The recession baseflow global editor did not save data if the only change was the method of specifying the initial condition or the method of specifying the recession threshold. All data is now correctly saved.

21. The diversion element could compute negative outflow if the diverted flow was very close to the inflow. Negative outflows are now prevented through an improved algorithm for computing outflow for diversion flows very close to the total inflow.
22. The outflow from the linear reservoir baseflow method was incorrect when more than one routing step was used. The outflow is now computed correctly for any number of routing steps.
23. The straddle-stagger routing data was not copied when a reach element or entire basin model was copied. All data is now correctly copied.
24. The straddle-stagger routing method was not available in the element list. It is now a routing option for reaches.
25. The straddle-stagger routing method editor incorrectly translated parameter data specified in hours to minutes and caused incorrect results. The time translation is now done correctly and computed results are correct.

Meteorologic Model

1. Cumulative precipitation was not correctly converted to incremental precipitation during a compute. The data was incorrectly interpreted as period cumulative instead of the instantaneous cumulative. The data is now processed correctly.
2. Changing a gage in the inverse distance precipitation method from recording to non-recording would cause the gage to disappear from the screen until the meteorologic model was closed and reopened. The same thing happened when the gage was changed from non-recording to recording. The user can now switch a gage without it disappearing.
3. Deleting a gage from the gage manager when it was used in a user-specified gage weights precipitation method could cause the program to crash. The gage is now deleted, the precipitation method updated, and no crash occurs.

Open Defects

A total of 6 major and minor defects are currently open and undergoing investigation and repair. Future versions of the program should solve most of these issues. The following defects are open:

1. The program can only print using a PostScript language print driver. Attempts to use other print driver languages, for example Printer Control Language (PCL), will result in many pages of output containing seemingly random text characters. PostScript print drivers are available for almost all laser printers. Contact the printer manufacturer for the latest PostScript print driver, or download it from their website.
2. The program may crash under some conditions when attempting to graph element results. The crash may occur before the graph has finished drawing, while moving or resizing the graph, or when closing a graph. The crash occurs whenever diversion flow from a diversion element is connected downstream to another element in the basin

model. The crash does not occur if the diversion flow *is not* connected downstream. The exact cause of the problem is unknown at this time.

3. Optimization results will be lost if any of the hydrologic elements used in an optimization trial are renamed in the supporting basin model. Additional problems will occur if the loss, transform, or baseflow method is changed in a subbasin after it has been added to an optimization trial. Generally speaking, the basin model used in an optimization run and trials should not have elements added, renamed, or removed, and the methods selected for the elements should not be changed. The exact cause of the problem is unknown at this time.
4. The program will crash if the parameters in an optimization trial are reordered after a new trial is created and before it is computed for the first time. The exact cause of the problem is unknown at this time.
5. The program may become unresponsive or crash under some conditions when using the mouse to very quickly open and close screens other than the basin model screen. The instability becomes more intense if selections are made or parameters entered on the screen when quickly opening and closing the screens. The problems disappear when the program is used at a normal pace.
6. Subbasin results for soil moisture accounting may not appear exactly as anticipated. The soil moisture accounting time-series table always shows results for the "first" subbasin regardless of the subbasin selected when the results were requested. The selection list in the upper right corner of the time-series table can be used to switch to any subbasin using the soil moisture accounting loss method.

New Features

Reservoir Element

Previous versions of the reservoir element calculation required either a storage-outflow, elevation-storage-outflow, or elevation-area-outflow curve. This required the user to synthesize a curve external to the program that accounted for all outlet structures, spillways, and other methods of releasing water from the reservoir. The reservoir element now includes the capability to calculate outflows from structures including outlets, spillways, dam overflows, and dam breaks. The reservoir element continues to operate exactly as before when using any of the original three input options. The new outflow calculation requires an elevation-storage or elevation-area curve and the hydraulic characteristics of the structures.

Previous versions of the program performed reservoir calculations using the modified Puls method with one routing step. This version of the program continues to use the same method of simulation when the storage-outflow, elevation-storage-outflow, or elevation-area-outflow options are used. A different solution technique is used when simulating reservoir routing with structures. In this later case, the continuity equation:

$$\frac{dS}{dt} - Q_{IN} + Q_{OUT} = 0$$

is solved, where S is reservoir storage, t is time, Q_{IN} is inflow, and Q_{OUT} is outflow. Inflow is taken as the sum of all inflows to the reservoir element. Outflow is computed using the physical properties of the outlet, spillway, overflow, and dam break. Brent's method is used to find the root of the equation, which then gives the change in storage and the outflow for the time step (Press *et al.*, 1988). Brent's method is repeated for each time step of a simulation.

The only low-level outlet option currently available is an orifice outlet. It is assumed that the water surface elevation inside the reservoir is at least 1.2 times the diameter of the outlet above the bottom invert of the outlet so that pressure flow prevails in the outlet structure. Outflow is computed as:

$$Q_{OUT} = C_D A \sqrt{2gh}$$

where Q_{OUT} is the outflow, C_D is the discharge coefficient, A is the cross-sectional area of the outlet, g is the gravitational acceleration of 9.80665 m s^{-2} , and h is the smaller of the quantities: head difference between the reservoir interior water surface elevation and the tail water surface elevation, or head difference between the reservoir interior water surface elevation and the outlet elevation. It is always assumed that the water within the reservoir has zero velocity and consequently the energy head can be approximated with the water surface. The outlet discharge coefficient includes the inlet loss, friction loss in the outlet pipe, and expansion loss. Each loss component is typically specified with the coefficient K . The discharge coefficient entered in the interface can be computed as:

$$C_D = \sqrt{\frac{1}{\sum K_i}}$$

For inlets, K ranges from 0.03 for smooth transitions to 0.5 for no transition (Roberson and Crowe, 1993). For expansions, K ranges from 0.2 for a gentle transition to open channel flow, up to 1.0 for a very abrupt transition. For pipe friction losses, K depends on the properties of the individual pipe. Consult a fluid mechanics textbook for more information on computing the friction loss in a pipe (for example White, 1994 or Roberson and Crowe, 1993).

Two options are included for specifying spillways: broad-crested and ogee. Outflow from the broad-crested spillway is computed as:

$$Q_{OUT} = C_D L h^{1.5}$$

where Q_{OUT} is the outflow, C_D is the discharge coefficient, L is the length of the spillway, and h is the head difference between the reservoir interior water surface elevation and the spillway invert elevation. It is always assumed that the water within the reservoir has zero velocity and consequently the energy head can be approximated with the water surface. The discharge coefficient represents total losses including contraction losses entering the spillway and friction losses through the spillway structure. It generally ranges from 1.39 to 1.72 in metric units, and from 2.5 to 3.1 in U.S. customary units (Roberson and Crowe, 1993). The upper limit of the discharge represents the theoretical zero-loss condition where friction is negligible while smaller values include approach, friction, or other losses over the spillway structure.

The outflow from the ogee spillway is computed using empirical data described by Bureau of Reclamation (1977). In this case, the discharge coefficient is

automatically computed based on the ratio of the current reservoir water surface elevation to the design head.

Two options are included for specifying overflow of the dam: level and non-level crest. Level overflow is computed by assuming broad-crested spillway flow. The same equation is used and the specification of the discharge coefficient is the same. Non-level overflow is computed using seven separate level spillway segments to represent the 8-point cross section. The broad-crested spillway assumption is made for each of the seven segments.

One dam-break option is included for simulating an over-topping failure. The breach that opens during the failure grows from a point to the maximum size in linear steps once the interior reservoir water surface elevation reaches the trigger elevation. Maximum size is determined by the breach top elevation (often the top of the dam), the breach bottom invert elevation, the breach bottom width, and the breach side slope. Outflow through the breach is computed as:

$$Q_{OUT} = 1.7 W_B h^{1.5} + 1.35 S h^{2.5}$$

where Q_{OUT} is the outflow, W_B is the width of the breach, S is the side slope of the breach, and h is the smaller of the quantities: head difference between the reservoir interior water surface elevation and the tail water surface elevation, or head difference between the reservoir interior water surface elevation and the breach bottom invert elevation. It is always assumed that the water within the reservoir has zero velocity and consequently the energy head can be approximated with the water surface.

Dam failure capability of the program is limited to simulating the opening of a breach in an earthen dam, routing the water from reservoir storage through the breach, and using reach elements to route the reservoir outflow hydrograph downstream. The physical process of breach initiation and development is not simulated in the program. Many sources are available for predicting the final bottom width of the breach, invert elevation of the bottom of the breach, and the side slope of the breach. Sources are also available for predicting the amount of time required for the breach to develop to the final, maximum size. Notable sources of parameter data were summarized by Wahl (1998). Principal among the sources are: simulation of the breach development with the BREACH model (Fread, 1988) and regression equations developed from case studies (MacDonald and Langridge-Monopolis, 1984; Froehlich, 1995).

Tail water surface elevation is determined using the stage-discharge rating curve specified for the reservoir element. This curve is separate from the storage curve specified with one of five options mentioned above. The stage-discharge curve is accessed from the right-mouse menu for the reservoir in the basin model screen. Discharge from the outlet, spillway, dam overflow, and dam break is automatically adjusted for submergence affects using the stage-discharge curve. If the curve is not present, then downstream stage is assumed to have no affect on discharge from the reservoir.

Miscellaneous

Previous versions of the program have not included support for the "clipboard" that allows data to be copied from one program to another. This useful feature was not provided because the HEC-HMS program operates on multiple operating systems and only some operating systems include a clipboard. Customized programming has been added to support the clipboard, but only when the

program is running in Windows operating systems. The cut, copy, and paste features associated with the clipboard are not available from the menu system. However, the shortcut keys can be used; ctrl+X for cut, ctrl+C for copy, and ctrl+V for paste. Support is provided for copying data out of HEC-HMS into other programs, and for copying data into HEC-HMS.

Previous versions of the program placed a limitation on the computation time step that could be used with the standard project storm precipitation method. The limitation has been relaxed to allow a time step down to 1 minute. Previous versions required the time step to be greater than 5 minutes.

Previous versions of the program did not always handle HEC-1 imports well if the optimization option was used. The HEC-1 program used a negative parameter value to indicate that optimization should be used to estimate the actual parameter value for simulation. The absolute value of the parameter became the initial value for the optimization. Optimization is a separate process in HEC-HMS and generally cannot be inferred from the HEC-1 input file. Negative parameter values from the HEC-1 input file carried over to HEC-HMS would result in errors during a run. All negative parameter data encountered during an import is now converted to positive values. This virtually guarantees that an imported HEC-1 input file will compute successfully in HEC-HMS without modification.

A percent impervious area was added to the soil moisture accounting loss method. It is now consistent with all other loss methods which already have a percent impervious area. This dramatically increases the ease of calibrating the loss method to small precipitation events within the longer record.

The source element no longer automatically replaces missing data with the value "0.0" when reading the data from a discharge gage. The exact behavior with respect to missing data is controlled by an optional setting in the basin model attributes. The option specifies that missing data will be set to zero. When the option is not set, missing data causes the run to abort with an error message.

The straddle-stagger routing method has been added to the program. It now appears as an option in the reach element.

Future Plans

In terms of look and feel, the current version of the program has changed little from the original Version 1.0 release in March 1998. The design of the interface was implemented by using the C++ programming language and the Galaxy development library. The library allowed nearly identical versions of the program to run on both Microsoft Windows and Sun Solaris operating systems even though they use conflicting methods for rendering images on the computer display. At the time, the library represented state-of-the-art development techniques for deploying software to multiple operating systems.

The software development industry has changed radically since the HEC-HMS project began in 1992. At that time it was very difficult to create software designed to operate on multiple operating systems if a graphical user interface was required. The intervening years between then and now have brought about the Java programming language. Contrary to earlier languages or development systems, the Java language is specifically designed to look and operate the same on a wide variety of operating systems without any additional work by software developers. The advantages of the Java language are so great that in

2000 the decision was made to adopt Java for future development work in replacement of C++ and the Galaxy library.

Version 2.2.0 will be the terminal release using the C++ programming language and the Galaxy library. All future releases, beginning with Version 3.0, will be developed using the Java language. A significant amount of work has already been completed to convert the existing computation engine to Java. Instead of replacing the existing interface with one written in Java using a similar look and feel, the development team has taken this opportunity to critically examine the interface and redesign it as necessary. The final design is complete and compares nicely with other engineering and scientific software programs from commercial companies. Work is under way to implement the new design for the interface and an approximate date for the beta release of Version 3.0 is fall 2003.

Version 3.0 will contain all of the capability present in Version 2.2.0 and will also add snowmelt simulation to the meteorologic model. Algorithms originally developed for the Distributed Snow Process Model (DSPM) are being adapted for use in HEC-HMS. DSPM is a temperature index method that has already been successfully applied in a number of projects (Daly *et al.*, 1999). The algorithms represent a reasonable advancement over snow melt algorithms included in HEC-1 and will support both lumped subbasins using unit hydrograph or kinematic wave methods, and gridded subbasins using the ModClark method. Unfortunately, the advancements in algorithm design will preclude importing HEC-1 files set up for snow melt simulation.

As time allows, features in addition to snowmelt simulation will also be added to Version 3.0 before its first release. These features may include customizable reports for basin model, meteorologic model data, and run results, or automatic depth-area reduction analysis. The first priority is to release Version 3.0 in a timely manner with the temperature index snowmelt simulation. Extensive beta testing will be undertaken prior to release of the new interface system.

Additional features are being planned for inclusion after the Version 3.0 is released. These may include: additional reservoir capabilities for modeling interior flood zones, energy budget snowmelt simulation, user scripting to automate simple tasks, frequency curve generation, animated graphs of gridded precipitation and runoff results, additional optimization features, and user extensions for adding new methods such as reach routing.

A comprehensive program validation guide is currently under development and will be published when complete. The guide gives detailed information about the tests used to determine the accuracy of the mathematical models included in the program, for example, the SCS curve number loss method. The section for precipitation methods is currently complete in draft form. Sections for junctions, sinks, diversions, reservoirs, and some reach routing and loss rate methods are also complete in draft form. It was found that HEC-HMS accurately implements all features in the tested methods.

Documentation

The *Hydrologic Modeling System HEC-HMS: User's Manual* contains extensive information on installing and using the program. An example application is included to illustrate the steps necessary to produce results.

The *Hydrologic Modeling System HEC-HMS: Technical Reference Manual* contains information on how to use the various methods included in the program.

The scientific origin and equation derivations are presented for each method. Specific solution algorithms for a method are discussed when necessary for a complete understanding. Application and parameter estimation for each method is also included.

The *Hydrologic Modeling System HEC-HMS: Applications Guide* is currently under development and will be released soon. The guide will provide detailed information on the application of the program to a wide variety of studies. Study types to be addressed include urban flooding, flood frequency, flood-loss reduction, flood warning system planning, reservoir spillway adequacy, and environmental restoration. Details for each study type will include typical objectives, required hydrologic information, modeling options and selection criteria, model configuration, design criteria where appropriate, and results presentation. A case study will illustrate each study application.

The online help system within the program contains topics describing each screen of the graphical user interface.

Support Policy

Technical support for program users within the Corps of Engineers is provided through an annual subscription service. Subscribing offices can expect full support from HEC staff in the routine application of the program. Users are strongly urged to consult with HEC staff on the technical feasibility of using the program before beginning a project with unique requirements such as grid-cell hydrology, snow melt, or continuous simulation. Extended support for large or complex projects can be arranged under a separate reimbursable project agreement.

Support can not be provided to users outside the Corps of Engineers. Domestic and foreign vendors are available that provide fee-for-service support similar to the support provided to subscribing Corps offices. Such service agreements are between the user and the vendor and do not include HEC staff. Vendors do contact HEC on behalf of their users when unusual problems or errors are encountered. A list of vendors can be found at <http://www.hec.usace.army.mil/>.

Reporting of suspected program errors is unrestricted. We are continuously working to improve the program and possible bugs should always be reported. Reports should include a written description of the steps that lead to the problem and the effects that result from it. We will reply to all correspondence concerning program errors.

Request support or report program errors through the following channels:

- Call +1-530-756-1104, 7:30 am to 4:30 pm PT Monday through Friday.
- Fax +1-530-756-8250 any time.
- Write to U.S. Army Corps of Engineers, Institute for Water Resources, Hydrologic Engineering Center, 609 Second Street, Davis, CA 95616-4687 USA.
- Send email to hms@usace.army.mil on the internet.
- Visit our web site at <http://www.hec.usace.army.mil>.

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