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THE INTERACTIVE NWS RIVER FORECAST PROGRAM

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1. INTRODUCTION

Recent increases in the capability of scientific workstations in computing power and graphical display have opened up new ways to approach the use of large computer models. By taking advantage of the ability of the scientific workstation to run several tasks and show several views at one time, it is now practical to allow model users to graphically display model input and output and to interactively make modifications.

The National Weather Service (NWS) Office of Hydrology is developing just such a program for use in their River Forecast Centers (RFCs) as part of the NWS modernization effort and the PROTEUS (Prototype RFC Operational Testing, Evaluation, and User Simulation) project. This program, the Interactive Forecast Program (IFP), allows river forecasters to run the National Weather Service River Forecast System (NWSRFS) models (Anderson, 1986), view model results in a graphical mode, and easily make modifications to data and parameters to produce more timely, accurate forecasts of river flows.

The IFP runs on a scientific workstation with a UNIX operating system and the X Window System. The program is written in C, using the X Window System interclient communications, links to existing FORTRAN code to model the hydrologic processes, and a commercially available graphics package. The IFP depends on the use of a mouse driven cursor to point to and select from options that appear on the screen in popup windows. Some of these windows also accept keyboard input. The windows are designed to present the user with an easy to use, consistent graphical interface to the NWSRFS. The design concepts of the windows are outlined in Adams (1991).

2. NWSRFS INTERACTIVE FORECAST PROGRAM

The display windows available in the IFP fall into three groups based on the information they contain. One type presents information for setting up and displaying the progress of the NWSRFS simulation run. Another displays input and output time series and allows the forecaster to make modifications to them. The third type allows other run-time modifications to be made to the specific NWSRFS model inputs. Wiele and Smith (1991) discuss the structure of the NWSRFS, the purpose of making run-time modifications, and the advantages of making modifications in an interactive environment.

2.1 Setup and Display NWSRFS Run Windows

To start an IFP session, the initial display allows the user to choose which forecast group to run (Fig. 1). A forecast group is a previously defined set of forecast points, ordered from upstream to downstream along a river. The forecast group is chosen by pointing to and selecting the name with the mouse. When selected, the name becomes highlighted by reversing the foreground and background colors (reverse video). Only one forecast group may be highlighted at a time, so selecting another forecast group name causes the first to return to normal and the second to be highlighted. The forecast group that is highlighted when the **Begin** button is selected is the one that will be run.

The IFP needs to know the dates to use for the run. Three dates need to be set; the starting date for the run, the end of the observed data period, and the end of the simulation period. The forecaster may change the default run dates by selecting the **Set_Dates** option from the main NWSRFS menu. A window is displayed that shows the default dates and allows the user to change them (Fig. 2). Components of the dates are month, day, year, hour, and time zone code. Each of these is in a box that, when selected, is highlighted in reverse video. When a component is highlighted, the arrow icons can be used to change the value that is displayed. When all three dates are correct the user selects the **Set** button and stores the dates for use by NWSRFS to get the appropriate data for the run.

After a forecast group is selected, the IFP reads the appropriate files to determine how the forecast points in the group are connected and creates a schematic display of the forecast point connectivity (Fig 3). This display, a Forecast Group Map or FG_Map, appears on the screen in a scrollable window. Forecast points are oriented from upstream on the left to downstream on the right.

Associated with this display is a three button FG_Map menu that allows the user to choose whether or not the map and/or the associated list of forecast points are to be displayed (Fig. 3). This allows the user to have rapid access to the map and list but not take up space on the workstation screen when other displays are shown.

In the FG_Map display, forecast point names are color coded based on the river condition at the time of the run. Names are displayed in green, yellow, or red to indicate whether the river is in normal, alert, or flood condition, respectively. Selecting the name of a forecast point with the right mouse button outlines the name and brings up a second window that has additional information about that point (Fig. 3). Any number of forecast point information windows can be brought up at one time. When the user is finished looking at the information, the **Done** button can be selected. This removes the additional display and the outline of the forecast point name on the FG_Map display. Selecting the forecast point name with the left mouse button causes that point to be selected and the name displayed in reverse video. Selecting again will unselect the point and the name will be displayed normally. Selection of a forecast point is important for two of the options for controlling how the points of the forecast group are run.

There are three options in the main menu for running the model for the forecast points (Fig. 4). The **Run_All** option will begin

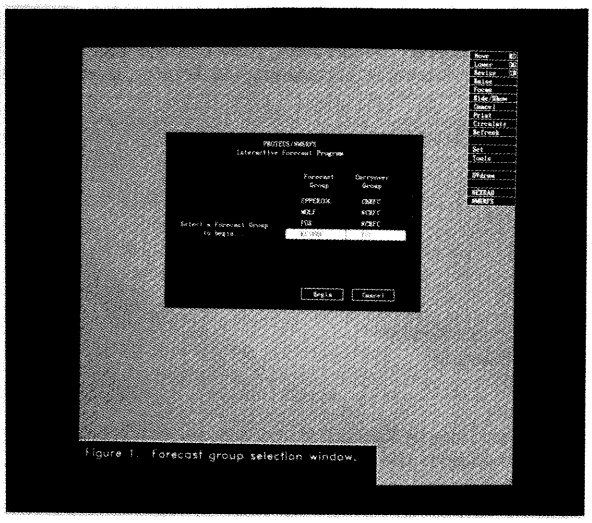

Figure 1. Forecast group selection window.

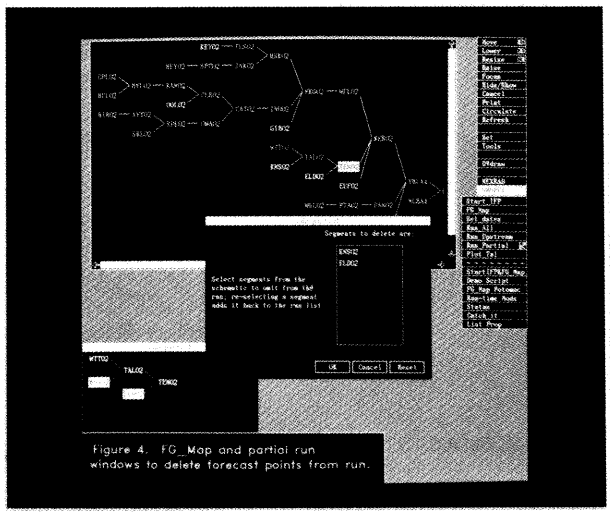

Figure 4. FG_Map and partial run windows to delete forecast points from run.

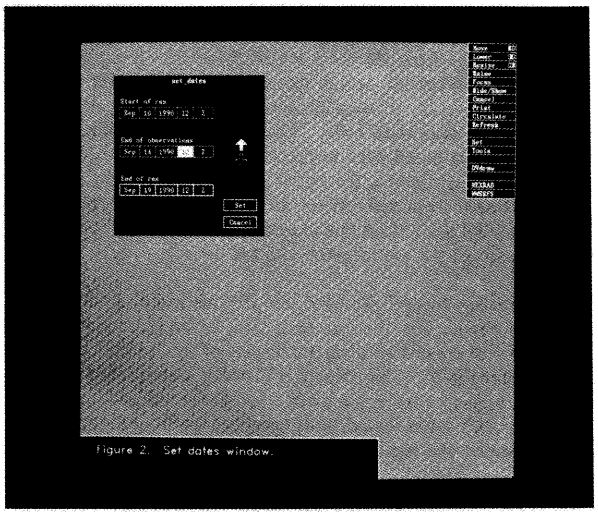

Figure 2. Set dates window.

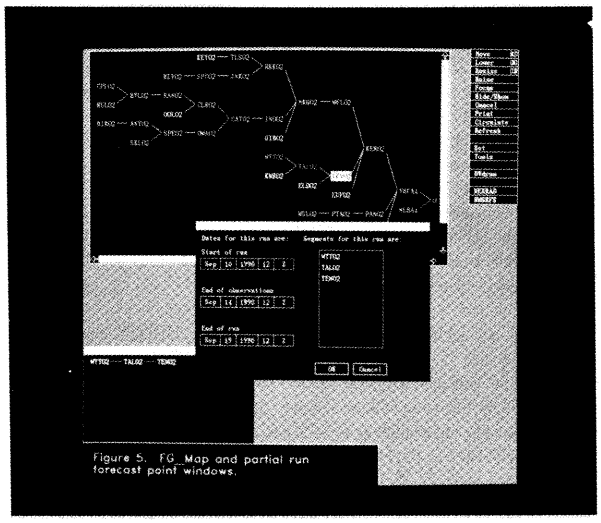

Figure 5. FG_Map and partial run forecast point windows.

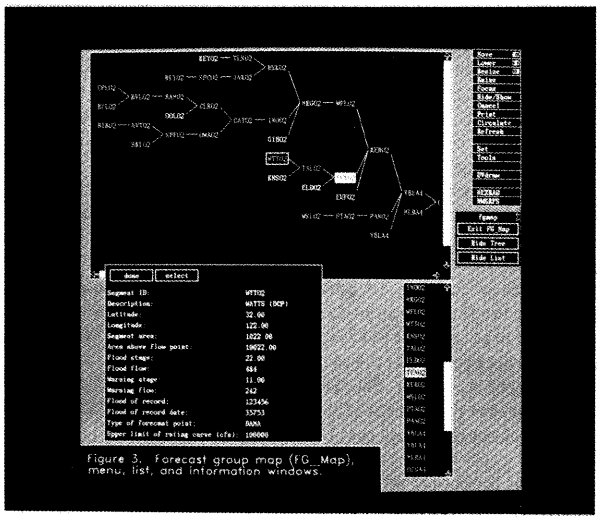

Figure 3. Forecast group map (FG_Map), menu, list, and information windows.

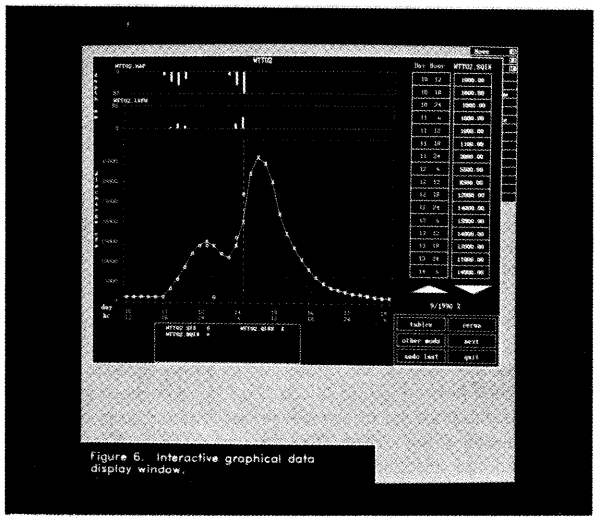

Figure 6. Interactive graphical data display window.

execution of the hydrology portion of NWSRFS for each forecast point in the forecast group starting at the furthest upstream point and cycling through all points going downstream. The other two options allow the user to choose a subset of the forecast group by first selecting a forecast point, as discussed above, then choosing either the **Run_Upstream** or **Run_Partial** options. **Run_Upstream** cycles through all forecast points that are upstream from the selected one starting with the most upstream and working downstream. **Run_Partial** is a special case of **Run_Upstream** that allows the user to remove individual forecast points from the selected subset of points.

For each run option, two additional windows are displayed. One shows a schematic of the forecast points that are going to be run. The second contains a list of forecast point names in their computational order and the dates that are set for the current run. If the user is satisfied with the proposed run, the **Begin** button is selected and the hydrologic simulation begins. For the **Run_Partial** option, before the final windows appear, a schematic of all points upstream from the selected point is shown with the option for the user to select forecast point names to delete from the run (Fig. 4). These points are then listed for further review. When the user is finished removing forecast points for the current run, **OK** is selected and the schematic is redrawn with the points deleted and a final list of forecast points is displayed showing the proposed run (Fig. 5).

During the run, the schematic presents the flow conditions as each forecast point is processed by showing the color coded names for points that have been run and highlighting the current point. Forecast points that have not been run are displayed in white.

The color coded FG_Map schematic allows the user to immediately see the current condition of the river. If all of the points are in normal flow condition the user may decide to select the **Run_All** option from the main menu. If there are areas that are in alert or flood condition, the forecaster may decide to concentrate on making forecasts for those points first using the **Run_Upstream** or **Run_Partial** options.

2.2 Time Series Data Display and Modification Windows

When the run begins, the parametric, time series, and current condition data for the first forecast point are read and the NWSRFS models that have been defined for that point are run. These include some of the snow, rainfall-runoff, and routing procedures described in Wiele and Smith (1991). When the models have been run for the forecast point, the second major type of display appears on the screen (Fig. 6). These windows are graphical data display windows that contain the various time series that are model input and output, displayed in graphical plots and/or in tables. The values in these time series can be adjusted by the user and the new values used in subsequent model runs.

The initial data display contains the forecast point name, graphs, tabular data, information lines, and buttons that, when selected, trigger other tasks. There are two types of graphs displayed. Near the top of the screen, under the forecast point name, are two bar graphs that display the mean areal precipitation (MAP) and runoff or stream inflow (INFW) time series for the forecast point (Fig. 6). The values displayed are for the observed accumulation over the last time interval (6 hours, in this case). If any precipitation has been forecast for the time period beyond the observed precipitation, it is displayed on the MAP bar graph in a different color.

The other type of graph is a hydrograph showing the various time series data used or generated by the NWSRFS models (Fig. 6). They are plotted in a color coded scheme according to time series type. Time series type is determined by type of data that time series represents. The letters that follow the period in the time series name (i.e. QIN or MAP) indicate the code used by NWSRFS to distinguish the various data types used by the models. If there are more than one time series of the same type, they are distinguished by the symbols used to plot the points. A legend appears at the bottom of the window that has the color coded time series name and the symbol used for plotting. All time series points are connected by lines except the observed data time series which is plotted with just the symbol. Figure 6 shows one observed (WTTO2.QIN) and two output time series (WTTO2.SQIN and WTTO2.QINE) plotted. The values for the two output time series are the same so the two separate plots are not obvious.

In addition to the time series lines, other lines appear on the hydrograph. There is a vertical blue dashed line that indicates the end of the observed data period. Depending on the scale of the data, color coded horizontal lines for alert, flood, and maximum flood of record could also appear. The alert and flood lines are color coded in yellow and red, respectively, as that they are in the FG_Map display.

There are two columns of data displayed on the right side of the window. They contain the data (time and values) for one of the time series. If more data appears on the hydrograph plot than in the tables, the arrows at the bottom of the columns allow the user to scroll through the data set.

As previously mentioned, the forecaster can use this display to interactively make changes in the time series data for the model. This may be necessary if, for example, the forecaster receives a corrected value from an observation point. There are two ways to do this, either by drawing in points on the graph or by entering new values into the table. To enter points on the graph, the name of the time series in the legend is selected. The graph is redrawn with the selected time series displayed in white and a series of vertical lines drawn on the graph (Fig. 7). New values are then chosen by selecting on the graph where the new values should be. An open circle is drawn at the selected point. After entering all new values, the name of the time series is selected again and the graph is redrawn with the new values shown in the graph (Fig. 8) and in the table.

In order to change a time series value in the table, the value to be changed is selected and a highlighted box appears in the table for the user to type a new value. When the **Enter** key is pressed the window is redrawn with the new value displayed in the table and in the graph.

Other actions that can be taken from this window result from selecting the buttons that are in the lower right corner. The **tables** button brings up another window that may contain up to nine time series for the forecaster to view (Fig. 9). To get another time series displayed in the original time series window, the name of that time series in the tables window is selected and the time series is copied into the first window.

The **other mods** button brings up windows that allow for model specific run-time modifications. These windows are described below. The **undo last** button allows the user to return the most recently changed time series to its previous state. The **quit** button allows the user to terminate the run completely.

The **rerun** and **next** buttons control the cycling of the IFP through the forecast points. When the user is finished making modifications, **rerun** is selected and the NWSRFS hydrologic models for the forecast point are rerun using the modifications. When this is completed, a new time series window is drawn (Fig. 10). The forecaster may make several iterations of this run-time modification process until the results are judged satisfactory.

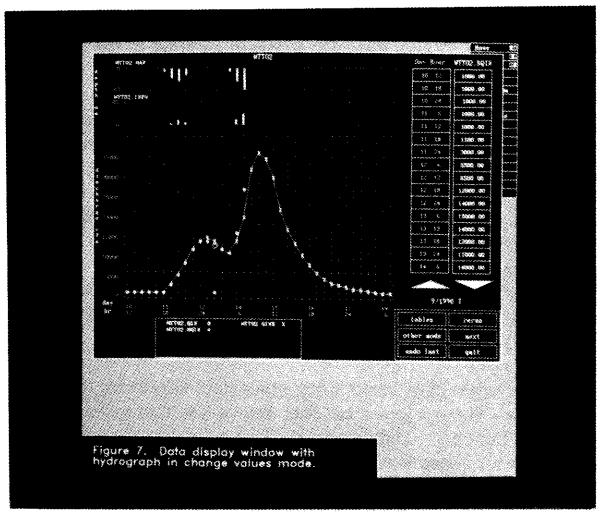

Figure 7. Data display window with hydrograph in change values mode.

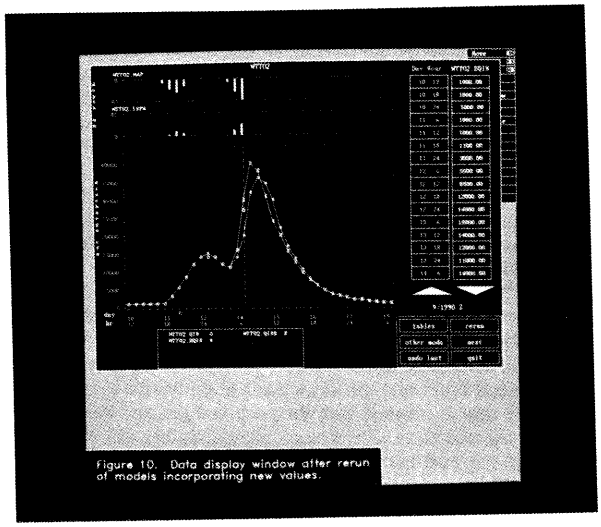

Figure 10. Data display window after rerun of models incorporating new values.

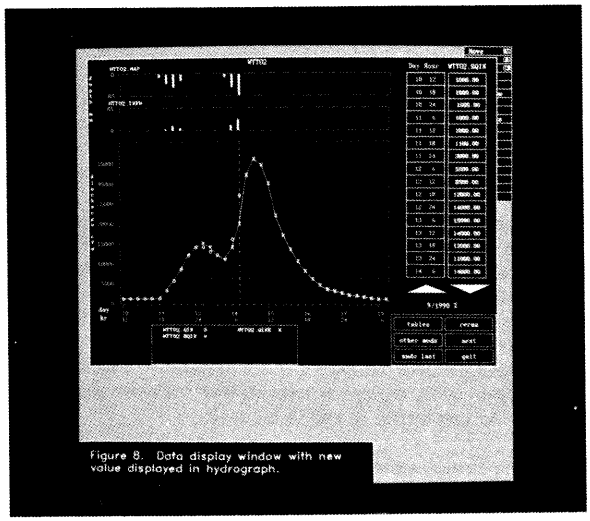

Figure 8. Data display window with new value displayed in hydrograph.

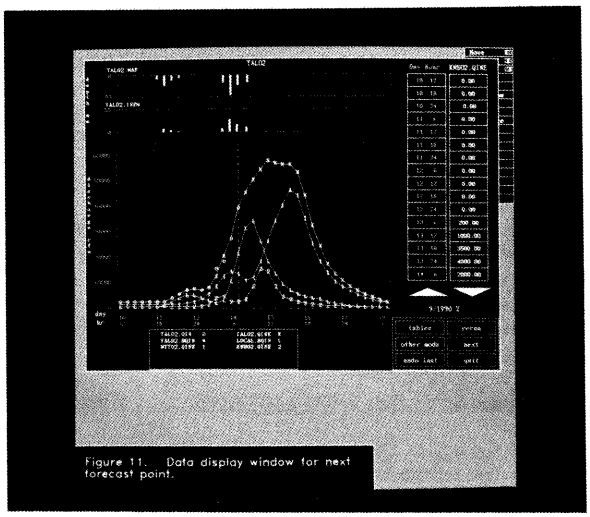

Figure 11. Data display window for next forecast point.

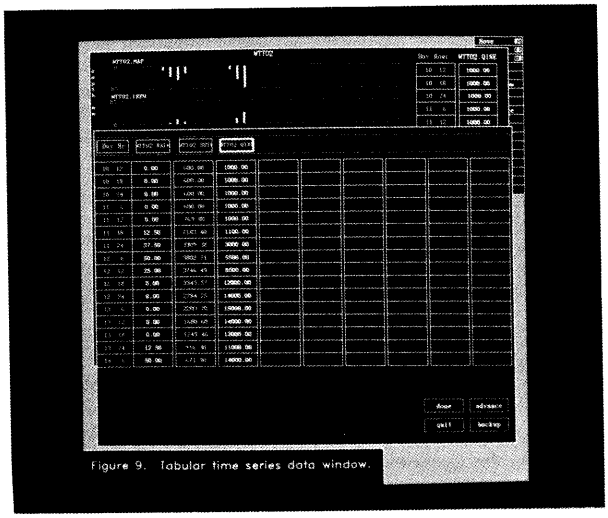

Figure 9. Tabular time series data window.

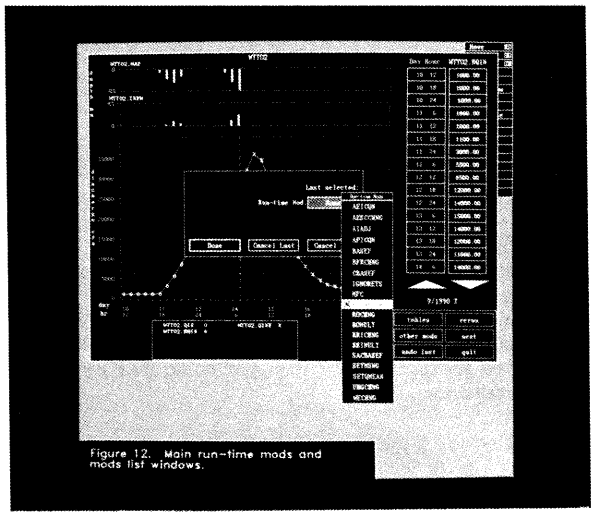

Figure 12. Main run-time mods and mods list windows.

When the forecaster is satisfied with the results of a run, the **next** button is selected, causing the hydrology to be run for the next forecast point downstream and displaying a new time series window (Fig. 11). It is in this cycle of running a forecast point, making modifications, and moving to the next forecast point, that the IFP moves through a forecast group.

2.3 Other Run-Time Modification Windows

The button labeled **other mods** brings up the third major type of windows in the IFP. They are important for letting the forecaster make modifications (mods) to other model inputs that may not be time series. When selected, the main mods window is displayed that shows the name of the last run-time mod (Fig. 12). Pressing the left mouse button while the cursor is on this name brings up another window with a list of the available modifications. As the cursor is dragged through this list, the names of mods that would be appropriate to use with the current NWSRFS run become highlighted. To select one, the mouse button is released while the name is highlighted.

After the selection, another window comes up that has information and choices about that particular modification (Fig. 13). Although each mod has slightly different information displayed, depending on its requirements, all have the name of the mod and a list of the operations defined for the NWSRFS run that it can be applied to. Initially, all operations in the list are highlighted but by selecting the names of operations, the user can unselect (unhighlight) ones the mod will not be applied to. In general, the dates the mod will be applied to will also be displayed. In some cases, they may be changed (in the same manner as in the **Set_Dates** window described earlier). In others, they are displayed for information only.

There are many variations in the information needed for the different mods but they can be grouped into three broad categories. The first is modifications that require a single input value, such as the snow model's (Anderson, 1978) melt factor correction (**MFC**) option (Fig. 14). For these modifications, the value is entered from the keyboard in the appropriate box. As it is entered it is checked to make sure it is within acceptable limits. If it is not, a warning or error message window appears with information about the range allowed for the parameter. Other information about the modification such as the dates and the operations it applies to may also be displayed and in some cases altered.

The second category contains mods to change values of time series not displayed in the hydrograph portion of the time series window. These allow the user to make changes to a time series either on the graph plot or in the data table, the same ways as in the original hydrograph plot. Figures 15-18 demonstrate this with the unit hydrograph change mod (**UHGCHNG**).

When the user selects the Plot option (Fig. 15), a new window displaying the unit hydrograph and the parametric data for it appears (Fig. 16). The name of the unit hydrograph is selected and the graph is redrawn in the mode that allows changes (Fig. 17). The points for the new values are selected and open circles drawn. When all the new points are entered, the unit hydrograph name is selected again and the graph is redrawn with the new values plotted and displayed in the data table (Fig. 18).

Another example of this type of mod is shown in Figures 19-21. When the rainfall change (**RRICHNG**) option is chosen (Fig. 19) a window opens that displays the same precipitation data that is plotted in the top bar graph on the original time series window. This view allows for changes to the precipitation data in the same ways discussed above. Figure 20 shows a new value being entered from the table (a value of 50 mm at day 14 hour 18). A new bar is added to the graph when the screen is redrawn (Fig. 21).

The third category of mods contains those that allow the user to change how values for a time period are used. Figure 22 shows the mod to tell NWSRFS to treat certain values for a time series as missing data (**SETMSNG**). This would be used if there were incorrect observed data. The user selects the dates that the values are to be set to missing for the selected time series. The list of time series is equivalent to the list of operations for other mods and individual time series can be selected.

When a mod is completed, **OK** is selected in its mod window and it disappears. The information for the modification is written to a file in the proper format for NWSRFS. When the forecaster is finished making all other mods changes, the **done** button is selected in the main mods window and control returns to the time series window.

3. IFP RUN SEQUENCE

The typical IFP run is a five step sequence outlined below:

1. Select a forecast group.
2. Set the dates for the NWSRFS run.
3. Choose the set of forecast points to run.
4. For each forecast point:
   a. Look at model results
   b. Make necessary modifications
   c. Rerun the NWSRFS hydrology
   d. Repeat steps 4a-4c until the forecaster is satisfied with the results graphically displayed
   e. Run the next forecast point
5. Store modifications made to forecast points for future NWSRFS simulation runs.

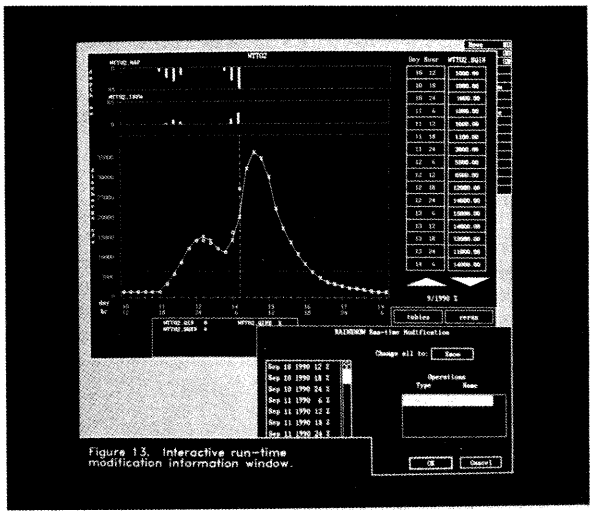

Figure 13. Interactive run-time modification information window.

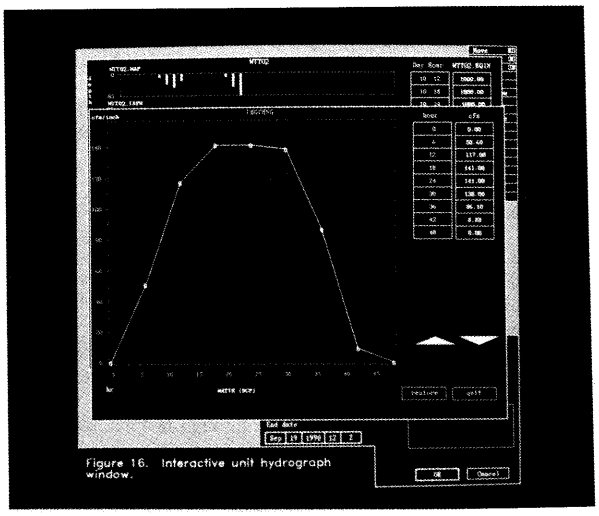

Figure 16. Interactive unit hydrograph window.

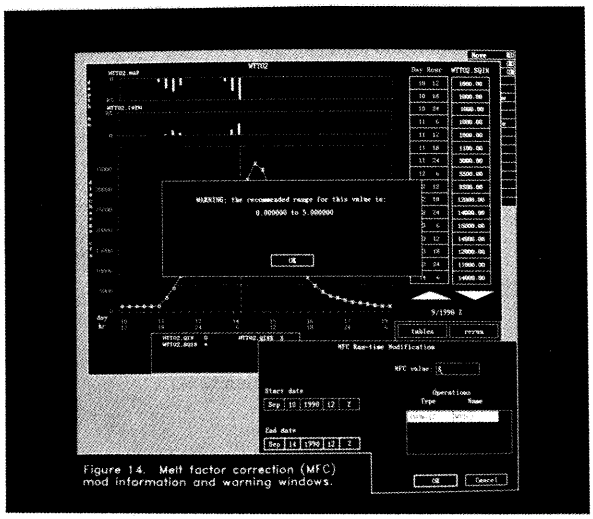

Figure 14. Melt factor correction (MFC) mod information and warning windows.

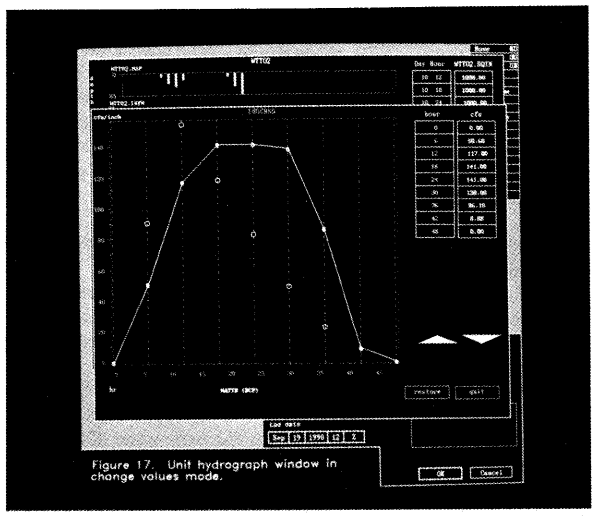

Figure 17. Unit hydrograph window in change values mode.

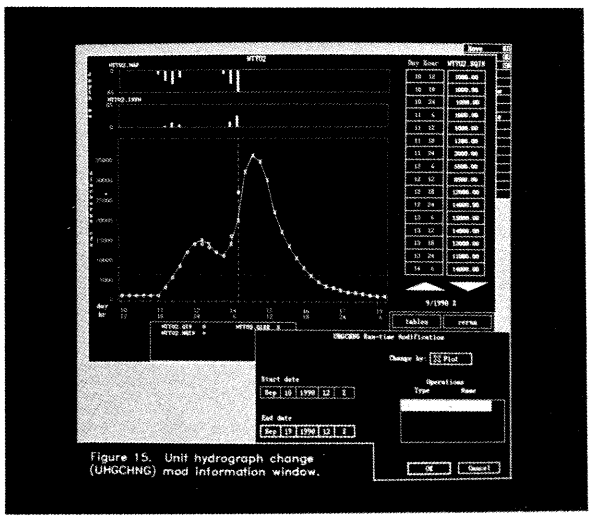

Figure 15. Unit hydrograph change (UHGCHNG) mod information window.

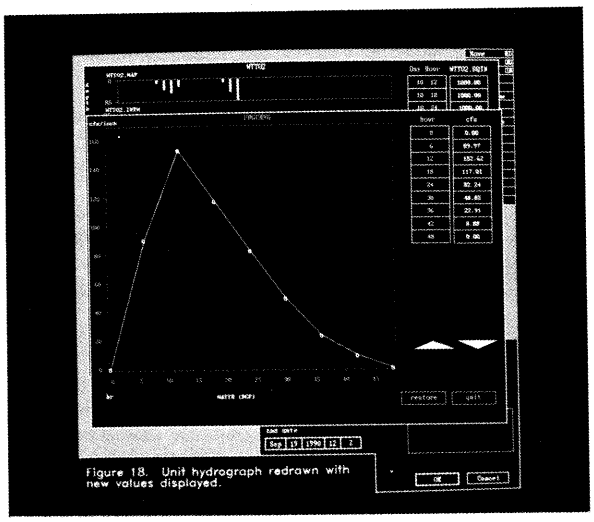

Figure 18. Unit hydrograph redrawn with new values displayed.

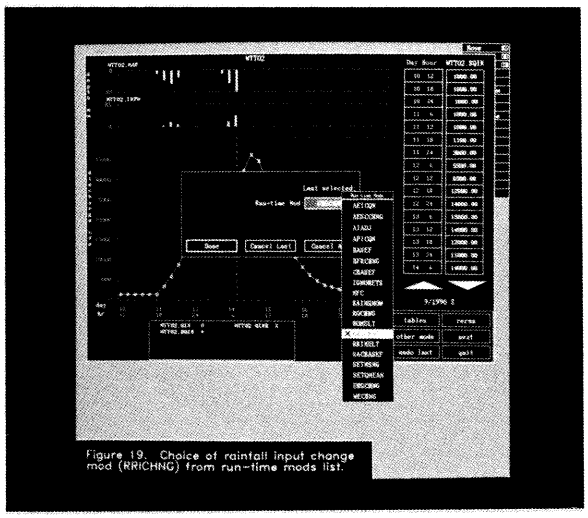

Figure 19. Choice of rainfall input change mod (RRICHNG) from run-time mods list.

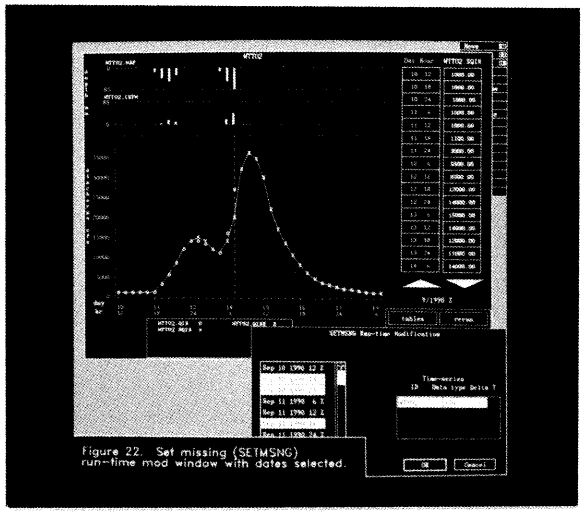

Figure 22. Set missing (SETMSNG) run-time mod window with dates selected.

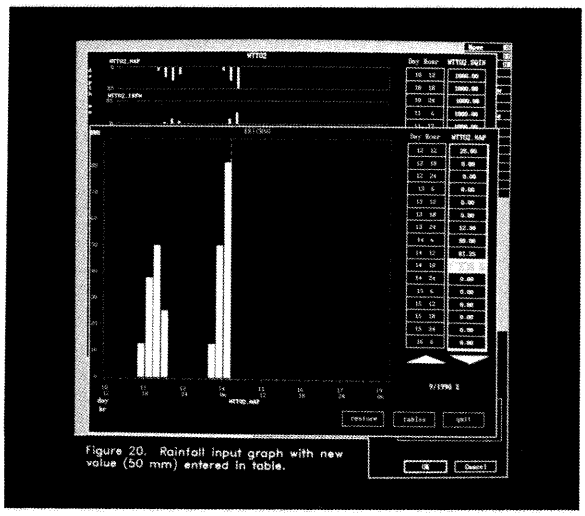

Figure 20. Rainfall input graph with new value (50 mm) entered in table.

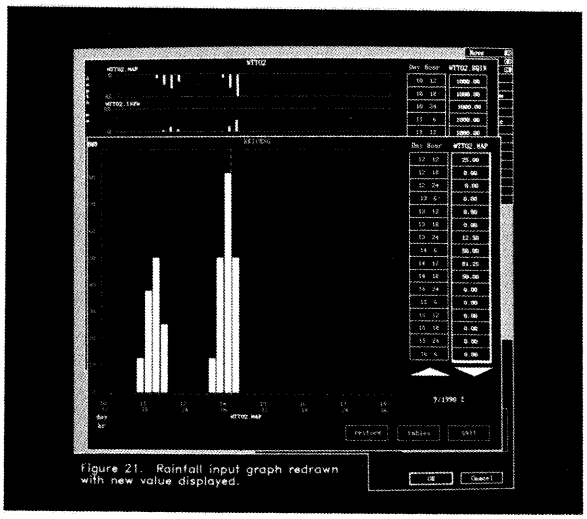

Figure 21. Rainfall input graph redrawn with new value displayed.

4. SUMMARY

The Interactive Forecast Program (IFP) is a graphical user interface to the National Weather Service River Forecast System (NWSRFS) models. It consists of a series of interactive windows that allow forecasters to easily set up an NWSRFS run, make modifications to the model input, and quickly see the results in graphical displays. The IFP, developed as part of the NWS modernization effort, makes more information available to forecasters in a timely, efficient manner, allowing them to better use their hydrologic training and skills to improve river forecasts.

5. ACKNOWLEDGEMENTS

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6. REFERENCES

Adams, T. E., 1991: Graphical user interface concepts for hydrologic forecasting in the modernized Weather Service. *Proc. Seventh International Conference on Interactive Information and Processing Systems for Meteorology, Oceanography, and Hydrology*, New Orleans, Amer. Meteor. Soc., January 13-18, 1991.

Anderson, E. A., 1986: The National Weather Service River Forecast System and Its Application to Cold Regions. *Proc. of the Sixth Northern Research Basins Symposium/Workshop*, Houghton, Michigan, January 29, 1986.

Anderson, E. A., 1978: Snow Accumulation and Ablation Model. *National Weather Service River Forecast System Users Manual*, Hydrologic Research Laboratory, National Weather Service, NOAA, U. S. Department of Commerce, Silver Spring, MD, Part II Ch. 2.

Wiele, S. M., G. F. Smith, 1991: Improved hydrologic forecasting with the interactive NWS river forecast program. *Proc. Seventh International Conference on Interactive Information and Processing Systems for Meteorology, Oceanography, and Hydrology*, New Orleans, Amer. Meteor. Soc., January 13-18, 1991.