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Mississippi Basin Modeling System Operations Guide

April 1999

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14. ABSTRACT

This document is intended to be a desktop guide for the use of the Mississippi Basin Modeling System (MBMS). It describes the processes and operations the graphical user interface (GUI) performs, the simulation capabilities, and, the files that are created, used and/or changed. The creation, contents, and use of MBMS output displays are summarized. Also, the document provides information describing the mechanics of changing various modeling parameters, advice on selecting values for those parameter, and, advice regarding modeling strategies.

15. SUBJECT TERMS

Mississippi Basin Modeling System, MBMS, graphical user interface, GUI, simulation, forecast operations, parameters, rivers, geometry input, boundary condition, time window, DSPLAY, HEC-DSS, levee parameters, UNET, COED, null internal boundary condition, NIBC, DSSMATH, lock and dam operations

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Foreword

This document is intended to be a desktop guide for the use of the Mississippi Basin Modeling System (MBMS). It describes the processes and operations that the Graphical User Interface (GUI) performs, the simulation capabilities that the user can invoke via the GUI; and the files that are created, used and/or changed by the GUI. The creation, contents, and use of MBMS output displays are summarized. Information given herein regarding implementation of some functions (such as the Null Internal Boundary Condition) using the GUI is more detailed than that found elsewhere.

This document provides information describing the mechanics of changing various modeling parameters via the GUI. Advice on selecting values for those parameters (such as Manning's *n*, levee breach characteristics, etc.) is given in the referenced material. Advice regarding modeling strategies may also be found in that material. Descriptions of the files, data and parameters used internally by the UNET system are not given here; that information can be found in the documentation that is referenced for each GUI function. Also included as a separable appendix to this document are the MBMS installation instructions and file naming conventions that will be helpful for use of the MBMS at your WCDS site.

Organization of this document. The descriptions herein are sequenced based on the items shown on the MBMS GUI Function Selection Screen from top to bottom (See Fig. 3). Then, there are higher level, composite functions which are called "applications" herein (such as operation of the Null Internal Boundary Condition) that the GUI provides. These are described in Chapter 2. A key item in this category is "Prepare Forecast", which summarizes the GUI steps necessary to perform a routine forecast.

This document does **not** describe the development or calibration of UNET data (including levee breaching parameters), customization of the GUI, operation of DSS/DSPLAY and related Water Control software, preparation of forecast flows (including hydrologic modeling), data storage, forecast dissemination, forecast accuracy analysis, and system configuration and management.

Chapter 1 - GUI FUNCTIONS

The MBMS GUI introductory screen is shown below as Figure 1:

Figure 1 MBMS Introductory Window

To begin the forecast, select Model, then UNET-->1D (see Figure 2).

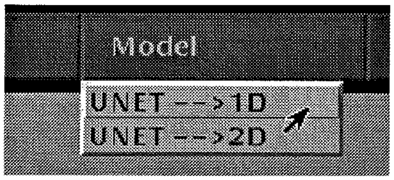
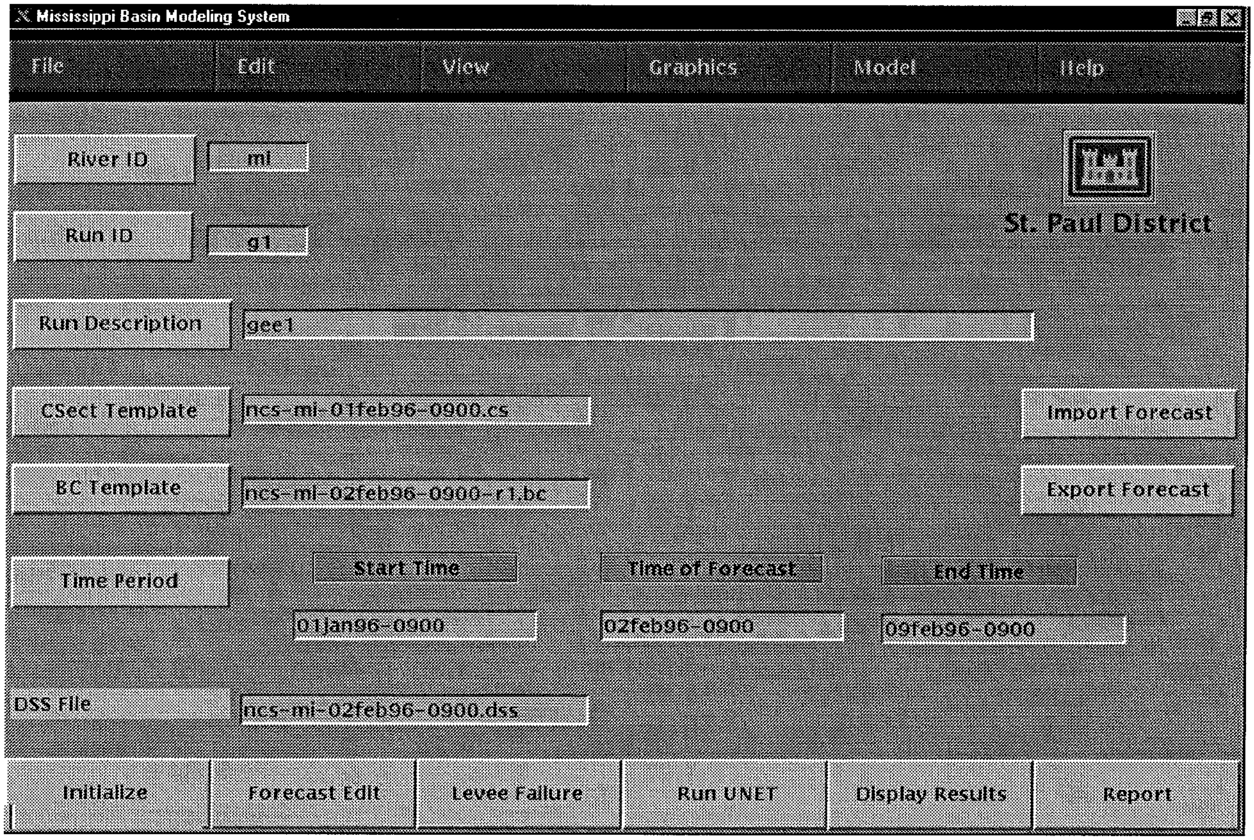


Figure 2 Model Menu Bar

The MBMS Main Window (Figure 3) is then displayed:



River ID: mi
Run ID: g1
Run Description: gee1
CSect Template: ncs-mi-01feb96-0900.cs
BC Template: ncs-mi-02feb96-0900-r1.bc
Start Time: 01jan96-0900
Time of Forecast: 02feb96-0900
End Time: 09feb96-0900
DSS File: ncs-mi-02feb96-0900.dss

Figure 3 MBMS Main Window

The MBMS GUI Main Window is arranged with the Main Menu Bar (Figure 4) at the top, the file and forecast identification parameters in the middle, and the Simulation Options at the bottom.

1.1 The Main Menu

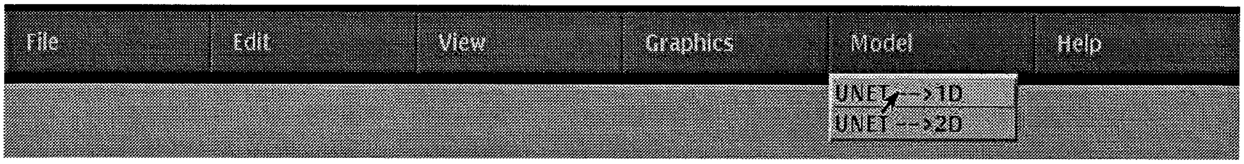


Figure 4 MBMS Main Menu Bar

The menus available from the Main Menu Bar are **File**, **Edit**, **View**, **Graphics**, **Model**, and **Help**. The options available from each menu are detailed below.

File

File Browser (Figure 5)
This loads a standard file chooser that allows you to select, view and edit files.

Exit
To exit or close the MBMS GUI program.

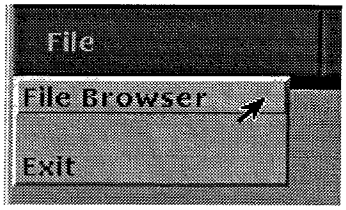


Figure 5 File Menu Bar

Edit

Text Edit (Figure 6)
The jedit text editor will be launched from this menu option. Online help is available from within the editor.

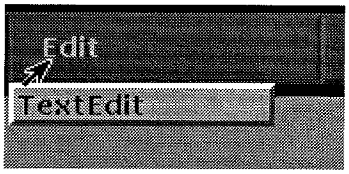


Figure 6 Edit Menu Bar

View

CORPSVIEW (Figure 7)
The CORPSVIEW program for display and modifcation of geographically scaled images will be executed.

<u>NOTE</u>: CORPSVIEW may or may not be available, depending upon your installation.

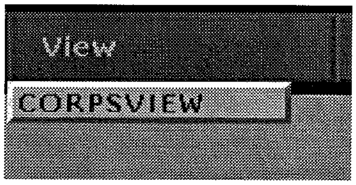


Figure 7 View Menu Bar

Graphics

District Maps (Figure 8)
Select your region from the list. This option will display GIS mapping of Office territory showing streams, communities, and gage locations.

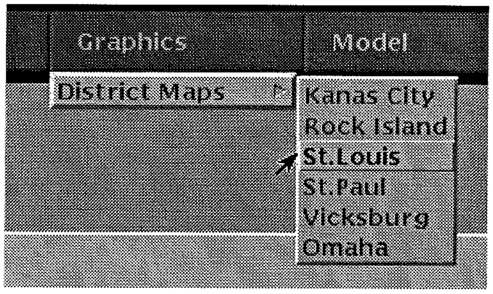


Figure 8 Graphics Menu Bar

Model

Select a modeling approach; **UNET->1D** or **UNET->2D**. This selection should only be performed from the Introductory Window when the MBMS is first started. See Figure 4.

<u>NOTE</u>: At this time, only UNET->1D is available.

Help

About (Figure 9)
Displays program name, version, date, and authors.

NOTE: On-line help is not available at this time.

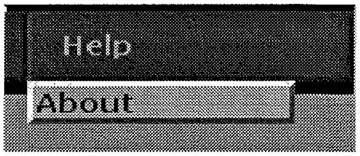


Figure 9 Help Menu Bar

1.2 File Selection and Forecast Parameters

River ID (Figure 10)
Purpose: To select the river system for forecast operations. The selection list includes all rivers being modeled by the entire MBMS group offices. Only those river system setup files relevant to your office will be available so not all options in the list will be operational. A default River ID is currently coded directly into the GUI setup file when customization is performed for your office, so only use this option if you have more than one river system for which you must prepare a forecast.

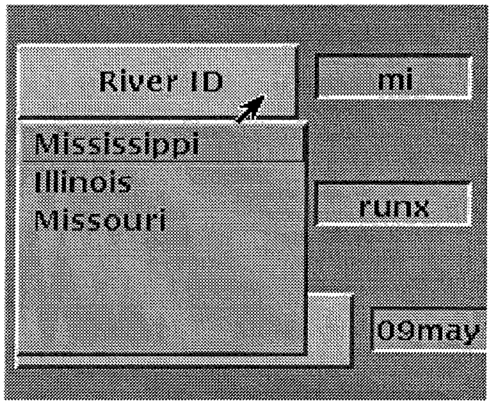
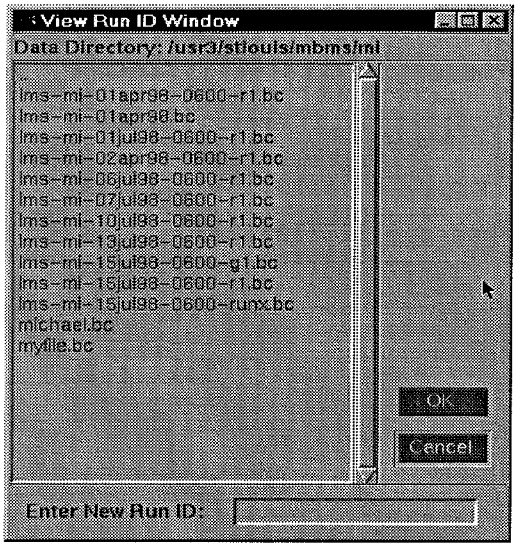


Figure 10 River ID Menu Bar

Run ID (Figure 11)
Purpose: To select an identifier that distinguishes this run from the template. This identifier becomes the last part of the name of the bc file and part of the F part of the dss pathname for the computed results. The F part of the pathname will be *Office ID-Run ID*. The Run ID is also put onto the third title record of the bc file to be used for UNET execution.

Action: When selected, another window will appear listing the names of all the bc files available for this river system. Place your cursor in the area labeled **Enter New Run ID** and type in your new run ID. This ID may be up to 4 characters long; for example *runx*. When done, select ok. This new RunID will appear to the right of the **Run ID** button and on the DSPLAY hydrographs to identify the information computed from this run.



Data Directory: /usr3/stlouis/mbms/mi

```
lms-mi-01apr98-0600-r1.bc
lms-mi-01apr98.bc
lms-mi-01jul98-0600-r1.bc
lms-mi-02apr98-0600-r1.bc
lms-mi-06jul98-0600-r1.bc
lms-mi-07jul98-0600-r1.bc
lms-mi-10jul98-0600-r1.bc
lms-mi-13jul98-0600-r1.bc
lms-mi-15jul98-0600-g1.bc
lms-mi-15jul98-0600-r1.bc
lms-mi-15jul98-0600-runx.bc
michael.bc
myfile.bc
```

Figure 11 View RUN ID Window

Advice: See **bc Template** and **DSS File** below.

Run Description

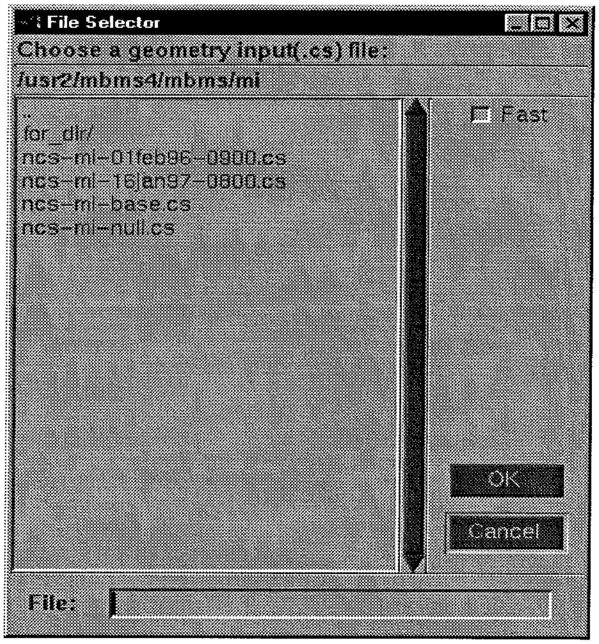
Purpose: To specify a text description for this run. This text is placed on the fourth title record of the bc file associated with this run.

CSect Template (Figure 12)

Purpose: To select a geometry input (cs) file to be used and execute CSECT if necessary. Unless you require a new cs file, the file will not usually have to be changed for each forcast.

NOTE: the cs file cannot be created/edited from here - use the EDIT button.

Action: First select a geometry file from the File Selector window which will appear when the **CSect Template** button is pressed.



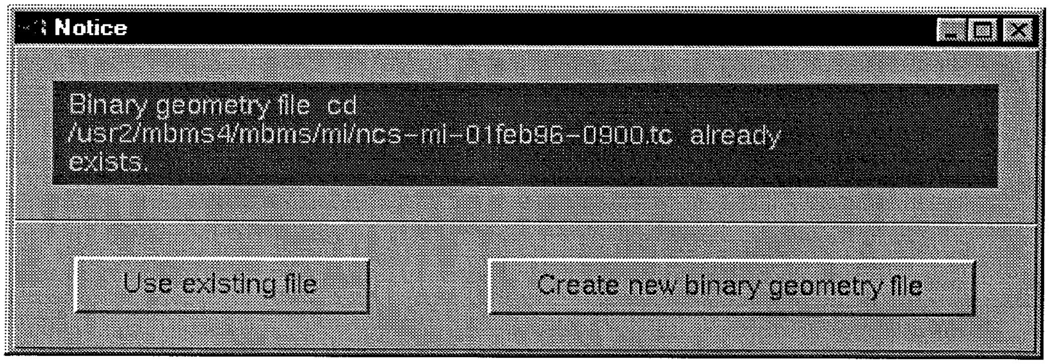
Choose a geometry input(.cs) file:
/usr2/mbms4/mbms/mi

```
..
for_dir/
ncs-mi-01feb96-0900.cs
ncs-mi-16jan97-0800.cs
ncs-mi-base.cs
ncs-mi-null.cs
```

File:

Figure 12 Geometry File Selector Window

A notice window (Figure 13) is then opened. If your cs file is new or has changed, select "Create new binary geometry file" to execute CSECT and create a tc file.



Binary geometry file cd /usr2/mbms4/mbms/mi/ncs-mi-01feb96-0900.tc already exists.

Figure 13 Existing Geometry File Notice Window

Data Modification: A CSECT file can be modified through the Edit ➛ Text Editor ➛ File selection sequence. This launches the jedit editor.

Graphics: No capability to plot cross sections through the GUI exists at this time.

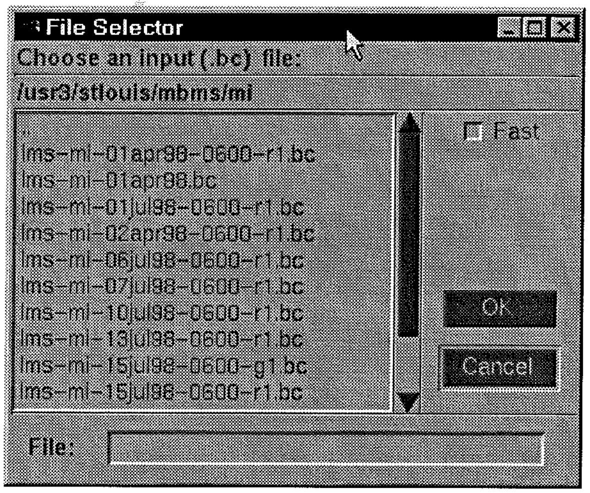
Advice: You may always exit the MBMS GUI and use COED (or any other editor) to modify text files. Of course, the same situation exists regarding DSS files. See Appendix A for file naming conventions.

Reference Docs: UNET User's Manual, Appendix B

bc Template (Figure 14)

Purpose: To select a boundary condition (bc) file that is used as a template for the creation of a bc file to be used for this forecast.

Action: Change the bc template file to be used if needed. Usually, the bc file will not require changes beyond those performed by the GUI. If you do want to change the bc template file, select the new file from those listed in the File Selector box.



Choose an input (.bc) file:

/usr3/stlouis/mbms/mi

```
..
lms-mi-01apr98-0600-r1.bc
lms-mi-01apr98.bc
lms-mi-01jul98-0600-r1.bc
lms-mi-02apr98-0600-r1.bc
lms-mi-06jul98-0600-r1.bc
lms-mi-07jul98-0600-r1.bc
lms-mi-10jul98-0600-r1.bc
lms-mi-13jul98-0600-r1.bc
lms-mi-15jul98-0600-g1.bc
lms-mi-15jul98-0600-r1.bc
```

Figure 14 Input File Selector Window

Data Modification: The bc file can be changed through the Edit ➛ Text Editor ➛ File selection sequence. The jedit editor is then launched.

Advice: The actual bc file used in the run begins as a copy of the bc template file and is then modified to specify the output DSS file with the "WRITE HYDROGRAPHS TO DSS" command (**DSS File**) and place the Run ID (see **Run ID** above) on the third title record to become the F part of the pathname. Other modifications include changes to the time window specification to reflect the current forecast **Time Period**.

The name of the bc file that is created and used in the execution of UNET is :

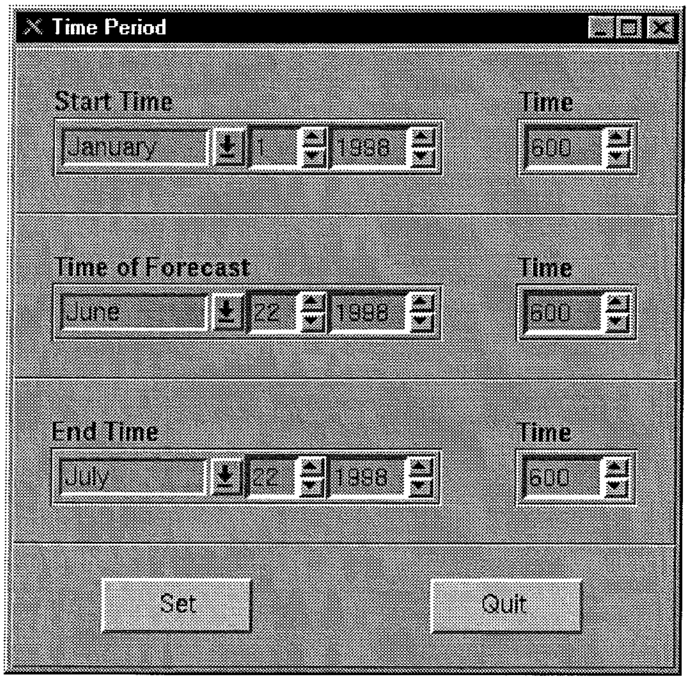
office ID-River ID-Time of Forecast-Run ID.bc

Reference Docs: UNET User's Manual, Appendix C.

Time Period (Figure 15)

Purpose: To specify the time window for the current run.

Action: When the **Time Period** button is pressed, the Time Period definition window (Figure 15) will appear. Using the arrow buttons for each field, specify the Start Date and Time, Date and Time of Forcast, and the End Date and Time.



Start Time: January 1 1998 Time: 600

Time of Forecast: June 22 1998 Time: 600

End Time: July 22 1998 Time: 600

Figure 15 Time Period Window

Data Modification: The time window must be reset for each forecast. At this time, only the dates can be changed. The starting time of 0600 cannot be changed.

The Start Time, Time of Forecast and End Time boxes on the MBMS Main Window echo this information defined here and are not active.

Advice Each time the Time Period is changed, the functions **Initialize** and **Import Forecast** should be invoked. NOTE: The UNET hotstart capability is not currently available from the GUI. Therefore, a period of time prior to the time of forecast needs to be re-run every time a forecast run is made to warm up the system and integrate the recently updated data that have changed from being “forecast” to being “observed”.

Reference Docs: HEC TP#145 “Application of Rainfall-Runoff Simulation for Flood Forecasting”, June 1993.

DSS File

Purpose: This is the file that will be used for output from this run; it may contain input data as well. This field cannot be edited directly; the dss file name is formed by the GUI from the **Office ID**, **River ID** and **Time of Forecast**.

Advice: The DSS files for each forecast tend to accumulate as the Time of Forecast progresses. Archiving of input and output files for a set of forecasts should be performed periodically. Also, you may wish to keep a record of each dss file name and its associated run parameters. See Function: **bc Template**.

Import Forecast

Purpose: To access data from other offices and agencies that have been provided in previously arranged files and communications protocols.

Data Modification: Data are obtained from the dss file *offid-rivid-date-time.dss* that is placed in the directory "datain" by the **File Delivery System** (FDS) or a similar process. (In this case, *offid* is the office originating the data.) A subsequent dss file (see **DSS File**) is created based upon the simulation time period. From this file, information is obtained for editing (Forecast Edit) and forecast executions.

Advice: Details of this process are defined upon MBMS setup. Those details are dependent upon local communications protocols and master database management policies.

Export Forecast

Purpose: To provide computed forecast data to clients.

Data Modification: Data are placed in the directory "dataout" to be transferred to recipients by FDS or a similar process. See **DSS File**.

Advice: Details of this process are defined upon MBMS setup. Those details are dependent upon local communications protocols and master database management policies.

1.3 Simulation Options

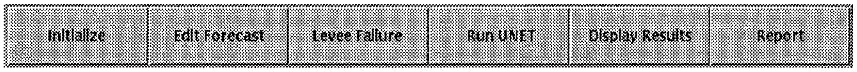
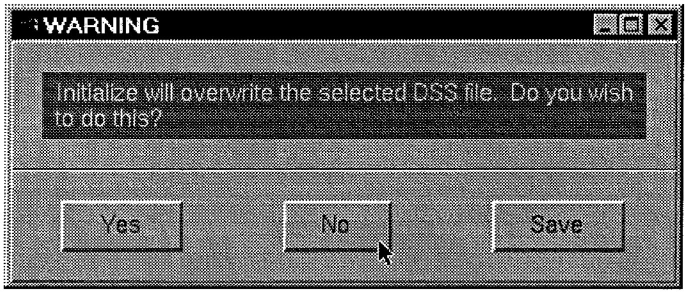


Figure 16 MBMS Simulation Options Buttons

Initialize (Figure 16)

Purpose: To move all current observed data into the current working data base and move the most recent forecast data into the working data base.



Initialize will overwrite the selected DSS file. Do you wish to do this?

Figure 17 File Overwrite Warning

Action: When selected, a notice window (Figure 17) will appear to ask if you want to overwrite the selected DSS file. This answer will be yes most of the time.

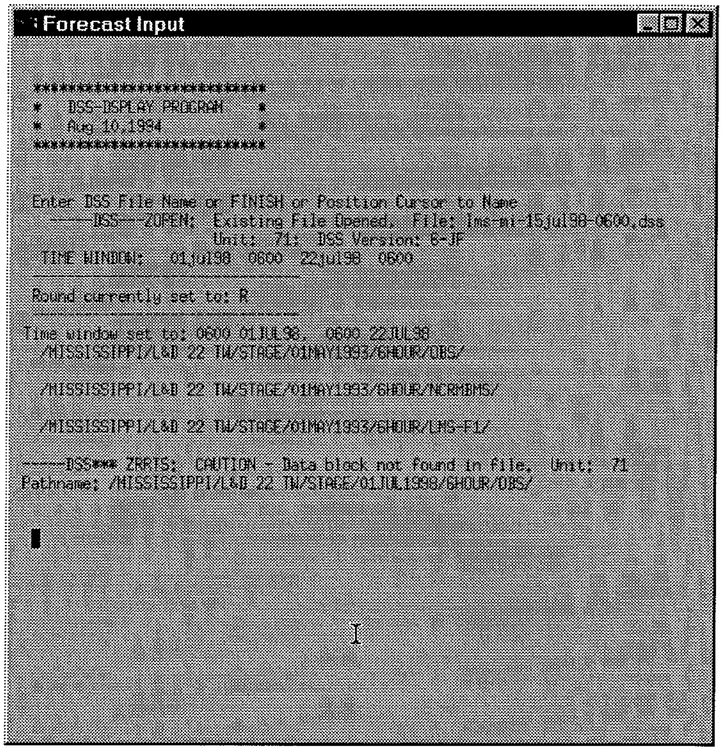
Advice: This function must be performed upon initiation of each forecast activity.

Edit Forecast (Figure 18)

Purpose: To extend the forecast data to the end time.

Action: Selecting this button will activate the DSPLAY editor. Two windows will appear. As illustrated at right, one is a text window displaying DSS-DSPLAY status information.

The other window (Figure 19) is a DSPLAY plot showing the incoming forecast.



```
 **************************
 *   DSS-DSPLAY PROGRAM   *
 *   Aug 10,1994          *
 **************************


 Enter DSS File Name or FINISH or Position Cursor to Name
   -----DSS---ZOPEN;  Existing File Opened.  File: lms-mi-15jul98-0600.dss
                     Unit:  71;  DSS Version: 6-JF
  TIME WINDOW;   01jul98  0600  22jul98  0600

 Round currently set to: R

Time window set to: 0600 01JUL98,  0600 22JUL98
  /MISSISSIPPI/L&D 22 TW/STAGE/01MAY1993/6HOUR/OBS/

  /MISSISSIPPI/L&D 22 TW/STAGE/01MAY1993/6HOUR/NCRMBMS/

  /MISSISSIPPI/L&D 22 TW/STAGE/01MAY1993/6HOUR/LMS-F1/

-----DSS*** ZRRTS:  CAUTION - Data block not found in file.  Unit:  71
Pathname: /MISSISSIPPI/L&D 22 TW/STAGE/01JUL1998/6HOUR/OBS/
```

Figure 18 Forecast Input Window

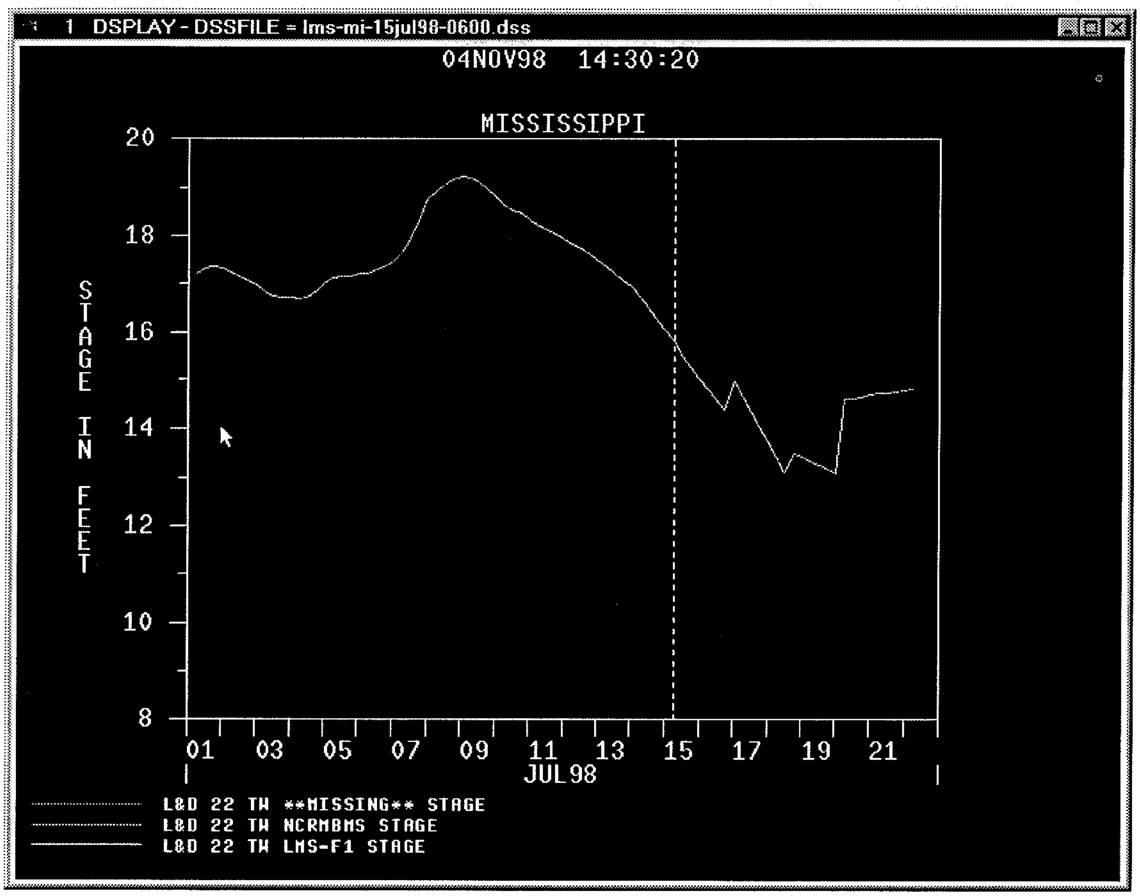
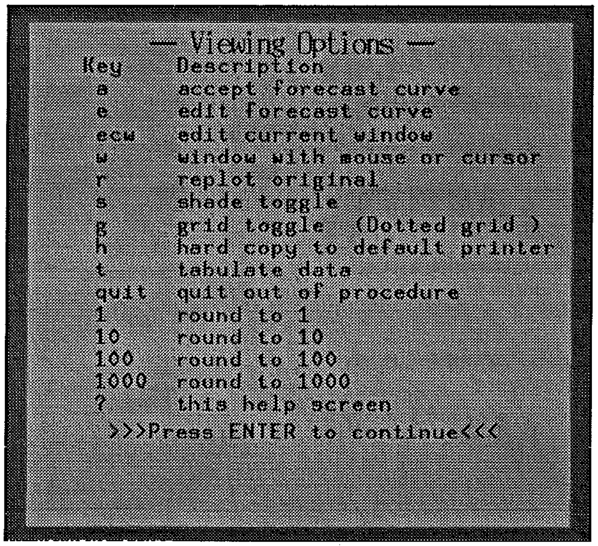


Figure 19 Incoming Forecast Plot

From these windows you can edit the DSS data for each of the locations (sequentially) at which the forecast needs to be extended.

Entering a question mark “?” brings up the window below (Figure 20):



```
      — Viewing Options —
Key   Description
 a    accept forecast curve
 e    edit forecast curve
 ecw  edit current window
 w    window with mouse or cursor
 r    replot original
 s    shade toggle
 g    grid toggle  (Dotted grid )
 h    hard copy to default printer
 t    tabulate data
 quit quit out of procedure
 1    round to 1
 10   round to 10
 100  round to 100
 1000 round to 1000
 ?    this help screen
  >>>Press ENTER to continue<<<
```

Figure 20 Viewing Options Window

<u>How-To Example</u>: Enter **ecw** to edit the curve. Position the cursor at the location where the data is going to be changed and click the **left** mouse button. Move the cursor to the next point and click the **left** mouse button again. Continue in this manner until the forecast extends to the margin of the plot, then move the cursor off the plot and double click the **right** mouse button. The new plot should change to yellow. Enter **a** if you are satisfied with the new forecast. When you are done, enter **quit** to exit this routine.

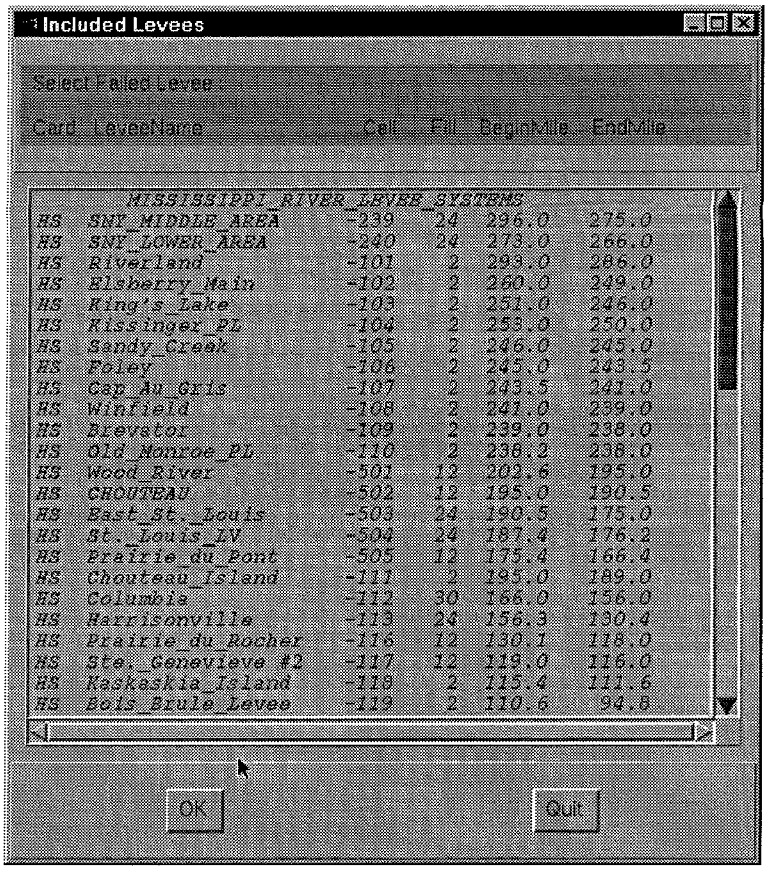
<u>How-To Example, Using Insert Mode</u>: Type in **ecw** to edit the curve. Move your cursor to the time on the plot that you want to enter the data. Type **I**. You will then be prompted for a number. Type in the number. Move to the next time period and type **I** again and enter the next number. Repeat this process until you are complete. Move the cursor off the plot and double click the right mouse button. A new display will appear. When you are done type **quit** to exit this routine. When you are done modifying the forecast data, the windows will disappear.

<u>Reference Docs</u>: Stephens, Dennis, “User’s Manual-Mississippi Basin Model System”, St. Louis District, July 1997.

HEC, “HEC-DSS Guide and Utility Manuals, User’s Manual” CPD-45, March 1995.

Levee Failure

Purpose: To allow display and modification of the levee parameters. These parameters reside in a file named "leveefile" that must be developed (customized) for your particular application. **The CSECT data and associated include files for levee failure information cannot be modified via this GUI option.** The GUI may be used to modify levee data by appending certain records to the bc file.

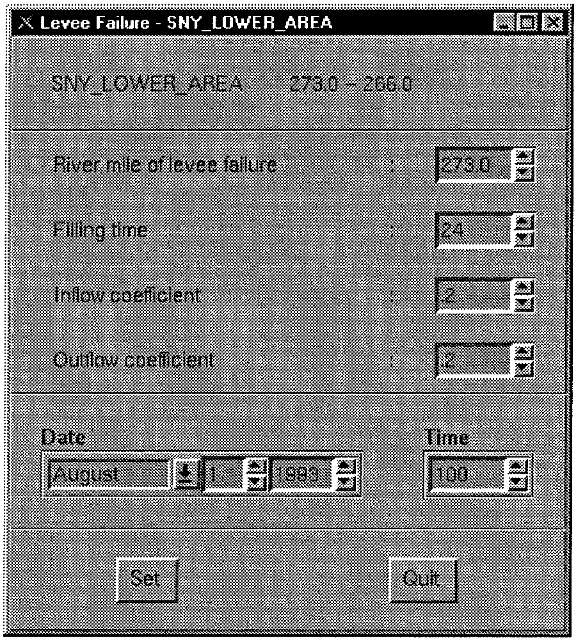


```
Card  LeveeName                 Cell   Fill  BeginMile  EndMile

      MISSISSIPPI_RIVER_LEVEE_SYSTEMS
HS    SNY_MIDDLE_AREA           -239   24    296.0      275.0
HS    SNY_LOWER_AREA            -240   24    273.0      266.0
HS    Riverland                 -101    2    293.0      286.0
HS    Elsberry_Main             -102    2    260.0      249.0
HS    King's_Lake               -103    2    251.0      246.0
HS    Kissinger_PL              -104    2    253.0      250.0
HS    Sandy_Creek               -105    2    246.0      245.0
HS    Foley                     -106    2    245.0      243.5
HS    Cap_Au_Gris               -107    2    243.5      241.0
HS    Winfield                  -108    2    241.0      239.0
HS    Brevator                  -109    2    239.0      238.0
HS    Old_Monroe_PL             -110    2    238.2      238.0
HS    Wood_River                -501   12    202.6      195.0
HS    CHOUTEAU                  -502   12    195.0      190.5
HS    East_St._Louis            -503   24    190.5      175.0
HS    St._Louis_LV              -504   24    187.4      176.2
HS    Prairie_du_Pont           -505   12    175.4      166.4
HS    Chouteau_Island           -111    2    195.0      189.0
HS    Columbia                  -112   30    166.0      156.0
HS    Harrisonville             -113   24    156.3      130.4
HS    Prairie_du_Rocher         -116   12    130.1      118.0
HS    Ste._Genevieve #2         -117   12    119.0      116.0
HS    Kaskaskia_Island          -118    2    115.4      111.6
HS    Bois_Brule_Levee          -119    2    110.6       94.8
```

Figure 21 Included Levees Window

Action: Selecting this option produces the window shown in Figure 21.



SNY_LOWER_AREA 273.0 – 266.0

River mile of levee failure : 273.0

Filling time : 24

Inflow coefficient : .2

Outflow coefficient : .2

Date: August 1 1993

Time: 100

Figure 22 Levee Failure Window

Select (with a single mouse click) one of the levees listed in this window and press **OK**.

Another window (Figure 22) will appear allowing you to modify several parameters related to the selected levee. Those parameters are:

River mile of levee failure: This value must be set to correspond to the river mile identified on the RE Record in the CSECT INCLUDE file for this levee; which should be the same as that in the "leveefile". The levee name is given on the HS Record in the INCLUDE file.

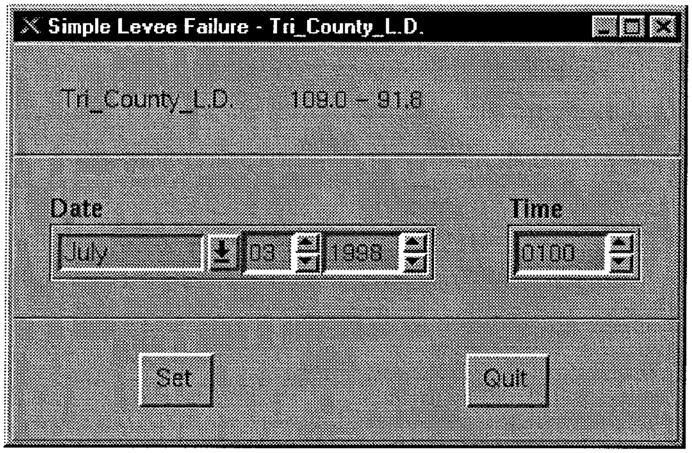
Filling time (in hours): Selectable via this window.

Inflow and Outflow coefficients: These are not changeable via this window. Any value you add in these fields will be ignored. These parameters can only be changed by editing the CSECT INCLUDE file and re-running CSECT.

Date and *Time*: Insert the beginning calendar date and time of the failure of this levee; it should be within the **Time Period** being used. The values that appear are set in the customization of the GUI and **must be reset every time the Levee Failure option is activated** to fall within the Time Period.

The edited levee failure parameters are appended to the run bc file as "LEVEE FAILURE" Records.

Kansas City Levee Algorithm (HL data) is edited via the window (Figure 23) that appears when an HL Record is selected from list. NOTE: **only the date of failure initiation is changeable via the GUI**. The other parameters, such as the upstream and downstream station numbers are defined on the LV Record in the include file (see Appendix D).



Simple Levee Failure - Tri_County_L.D.

Tri_County_L.D. 109.0 - 91.8

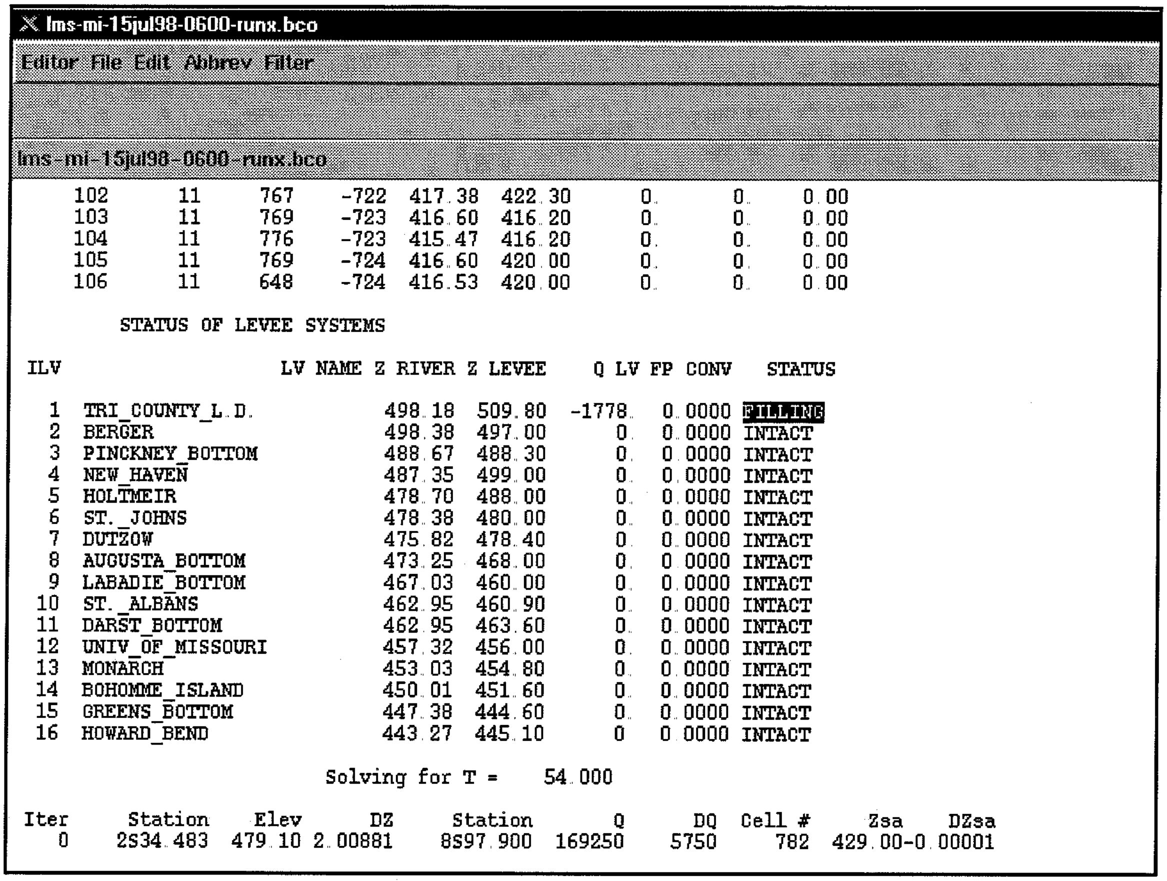
Date: July 03 1998

Time: 0100

Figure 23 Simple Levee Failure

The edited levee failure parameters for the Kansas City Levee Algorithm are appended to the run bc file as "SIMPLE LEVEE FAILURE" Records.

The UNET output file (.bco) contains a useful table such as that shown in Figure 24 to track the behavior of the Kansas City Levee Algorithm.



```
     102        11       767     -722  417.38  422.30        0.        0.      0.00
     103        11       769     -723  416.60  416.20        0.        0.      0.00
     104        11       776     -723  415.47  416.20        0.        0.      0.00
     105        11       769     -724  416.60  420.00        0.        0.      0.00
     106        11       648     -724  416.53  420.00        0.        0.      0.00

          STATUS OF LEVEE SYSTEMS

ILV                   LV NAME Z RIVER Z LEVEE    Q LV FP CONV   STATUS

  1  TRI_COUNTY_L.D.              498.18  509.80  -1778.   0.0000 FILLING
  2  BERGER                       498.38  497.00      0.   0.0000 INTACT
  3  PINCKNEY_BOTTOM              488.67  488.30      0.   0.0000 INTACT
  4  NEW_HAVEN                    487.35  499.00      0.   0.0000 INTACT
  5  HOLTMEIR                     478.70  488.00      0.   0.0000 INTACT
  6  ST._JOHNS                    478.38  480.00      0.   0.0000 INTACT
  7  DUTZOW                       475.82  478.40      0.   0.0000 INTACT
  8  AUGUSTA_BOTTOM               473.25  468.00      0.   0.0000 INTACT
  9  LABADIE_BOTTOM               467.03  460.00      0.   0.0000 INTACT
 10  ST._ALBANS                   462.95  460.90      0.   0.0000 INTACT
 11  DARST_BOTTOM                 462.95  463.60      0.   0.0000 INTACT
 12  UNIV_OF_MISSOURI             457.32  456.00      0.   0.0000 INTACT
 13  MONARCH                      453.03  454.80      0.   0.0000 INTACT
 14  BOHOMME_ISLAND               450.01  451.60      0.   0.0000 INTACT
 15  GREENS_BOTTOM                447.38  444.60      0.   0.0000 INTACT
 16  HOWARD_BEND                  443.27  445.10      0    0.0000 INTACT

                         Solving for T =    54.000

Iter     Station    Elev      DZ     Station        Q       DQ  Cell #      Zsa    DZsa
   0    2S34.483  479.10 2.00881    8S97.900   169250     5750     782  429.00-0.00001
```

Figure 24 UNET Output - Kansas City Levee Failure Algorithm

Static Data: The data that describe levee connections and potential failure/overtopping parameters are developed for the entire system and placed in the CSECT include files. The data in the "leveefile" was derived from that in the CSECT include files at the time of GUI customization/installation. Those parameters are described in the references.

Graphics: Displays of the status of the levees are obtained by selecting the **Display Results** button, typing "levee", then entering the specific levee name. Following is an example of the resulting DSPLAY plot for an HL levee; similar, though simpler, plots are available for HS type levees.

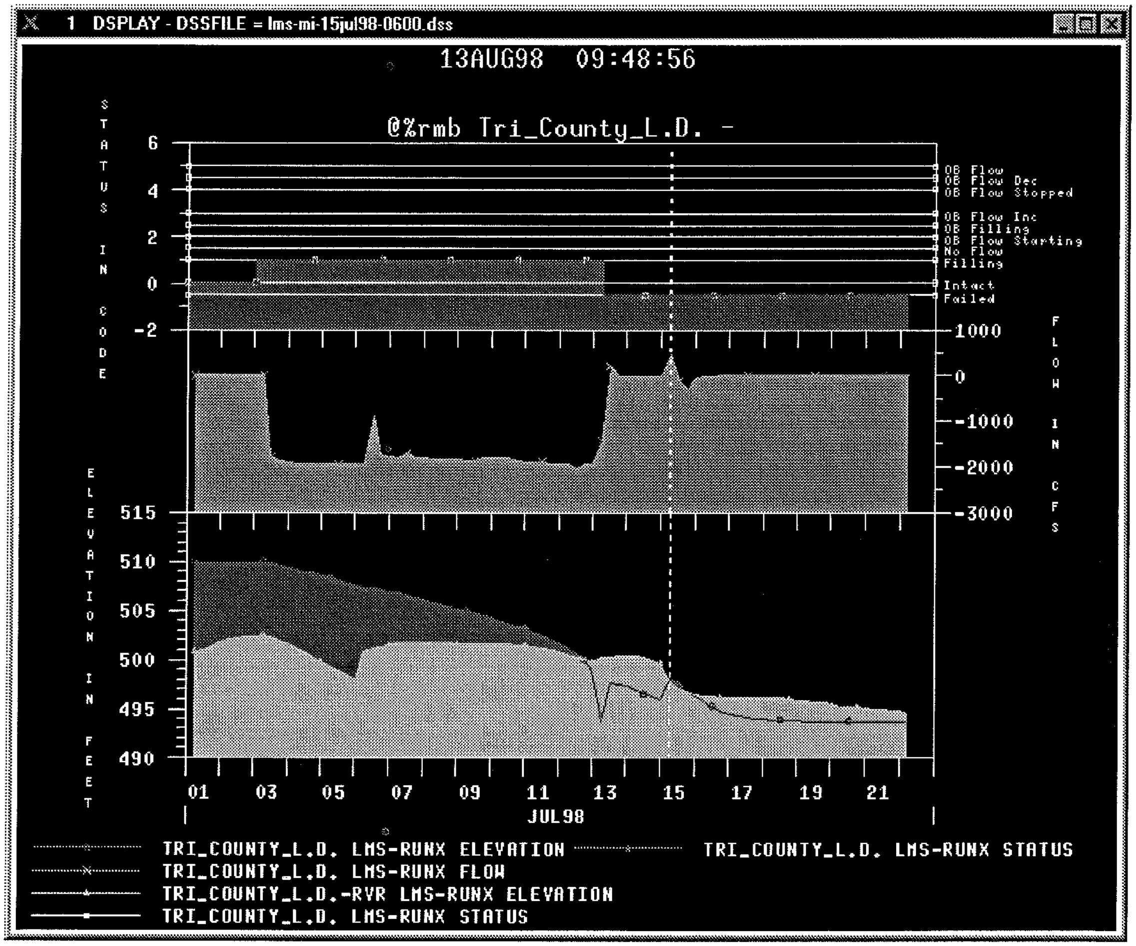


Figure 25 Levee Failure Display Example

In the data illustrated in Figure 25, the levee failure was specified to begin at 0100 hrs on 3 July 1998. This is reflected in the top graph in the above figure where the status changed from "intact" to "filling" and remained 'failed" until the end of the simulation.

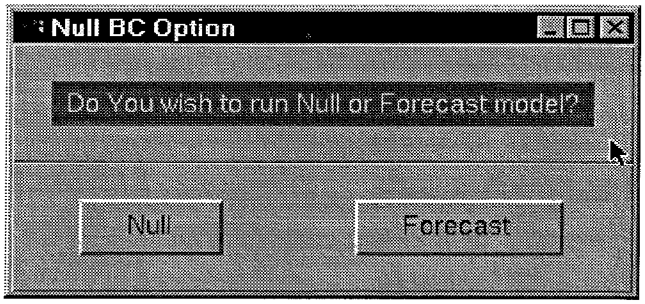
Advice: **The changes made here only persist through the next activation of "Run UNET". If you wish to keep the changes that have been made here, copy the run bc file to one with a different name; that file may then be used as the "bc Template" for future analyses.**

Reference Docs: HEC, UNET User's Manual, Appendix B - Include Files, August 1997.

"Kansas City Levee Algorithm", Appendix D of this document.

Run UNET

Purpose: To run the UNET modules (RDSS, UNET and TABLE) using the data and time window currently defined. **(Also enables the first pass thru the null internal bc (NIBC) - see Chapter 2 for instructions on use of the NIBC.)** After selecting **Run UNET**, a notice window will appear (Figure 26) asking if you wish to run a Null Internal Boundary Condition model or a standard Forecast model. Select one or the other. A text window will then appear on the left of your screen showing the progress of the computations. This window will close automatically upon successful completion of the UNET execution.



Do You wish to run Null or Forecast model?

Figure 26 Null bc Option Window

Reference Docs: HEC, UNET User's Manual, August 1997.

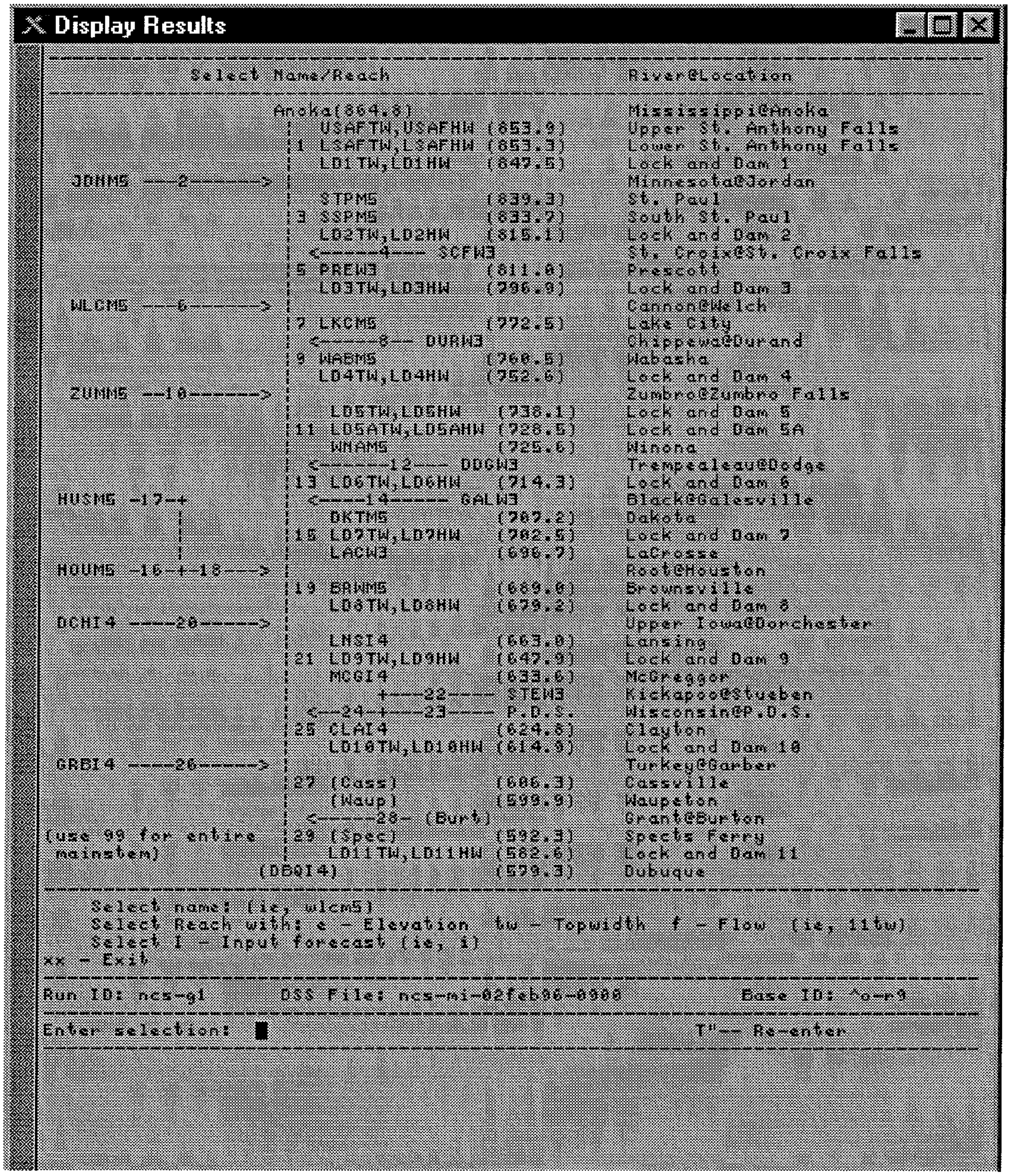
"Null Internal Boundary Condition" Appendix C of this document.

Display Results

Purpose: To invoke the DSS-DSPLAY system for graphical viewing of the output.

Action: When **Display Results** is selected, one of three windows will appear (depending on your terminal software). The three windows are: 1) a text window that will require keyboard input and displays a schematic drawn with standard text characters, 2) a graphic window displaying the schematic of the district which requires mouse input to locate gage station, and 3) a screen which displays levee districts which requires mouse input to locate the levee district. Arrange the windows for easy access. The following discussion refers to the window requiring keyboard input, illustrated in Figure 27.

Enter the name of a gage station, structure, or location, or enter a reach number as seen in the schematic (Figure 27). In this example, entering "spec" (for Spechts Ferry) produced the DSPLAY plot shown in Figure 28. **xx** can be entered to quit or exit the **Display Results** option.



```
----------------------------------------------------------------------------
               Select Name/Reach                      River@Location
----------------------------------------------------------------------------
                      Anoka(864.8)                   Mississippi@Anoka
                      |  USAFTW,USAFHW (853.9)       Upper St. Anthony Falls
                      |1 L3AFTW,L3AFHW (853.3)       Lower St. Anthony Falls
                      |  LD1TW,LD1HW   (847.5)       Lock and Dam 1
   JDHMS ---2------>  |                              Minnesota@Jordan
                      |   STPM5        (839.3)       St. Paul
                      |3 SSPM5         (833.7)       South St. Paul
                      |  LD2TW,LD2HW   (815.1)       Lock and Dam 2
                      | <-----4--- SCFW3             St. Croix@St. Croix Falls
                      |5 PREW3         (811.0)       Prescott
                      |  LD3TW,LD3HW   (796.9)       Lock and Dam 3
   WLCM5 ---6------>  |                              Cannon@Welch
                      |7 LKCM5         (772.5)       Lake City
                      | <------8-- DURW3             Chippewa@Durand
                      |9 WABM5         (760.5)       Wabasha
                      |  LD4TW,LD4HW   (752.6)       Lock and Dam 4
   ZUMM5 --10------>  |                              Zumbro@Zumbro Falls
                      |   LD5TW,LD5HW   (738.1)      Lock and Dam 5
                      |11 LD5ATW,LD5AHW (728.5)      Lock and Dam 5A
                      |   WNAM5         (725.6)      Winona
                      | <-------12--- DDGW3          Trempealeau@Dodge
                      |13 LD6TW,LD6HW   (714.3)      Lock and Dam 6
  HUSM5 -17-+         | <----14----- GALW3           Black@Galesville
            |         |   DKTM5         (707.2)      Dakota
            |         |15 LD7TW,LD7HW   (702.5)      Lock and Dam 7
            |         |   LACW3         (696.7)      LaCrosse
  HOUM5 -16-+-18--->  |                              Root@Houston
                      |19 BRWM5         (689.0)      Brownsville
                      |   LD8TW,LD8HW   (679.2)      Lock and Dam 8
  DCHI4 ----20----->  |                              Upper Iowa@Dorchester
                      |   LNSI4         (663.0)      Lansing
                      |21 LD9TW,LD9HW   (647.9)      Lock and Dam 9
                      |   MCGI4         (633.6)      McGreggor
                      |       +---22---- STEW3       Kickapoo@Steuben
                      | <--24-+---23---- P.D.S.      Wisconsin@P.D.S.
                      |25 CLAI4         (624.8)      Clayton
                      |   LD10TW,LD10HW (614.9)      Lock and Dam 10
  GRBI4 ----26----->  |                              Turkey@Garber
                      |27 (Cass)        (606.3)      Cassville
                      |   (Waup)        (599.9)      Waupeton
                      | <-----28- (Burt)             Grant@Burton
(use 99 for entire    |29 (Spec)        (592.3)      Spects Ferry
 mainstem)            |   LD11TW,LD11HW (582.6)      Lock and Dam 11
                    (DBQI4)             (579.3)      Dubuque
----------------------------------------------------------------------------
    Select name: (ie, wlcm5)
    Select Reach with: e - Elevation  tw - Topwidth  f - Flow  (ie, 11tw)
    Select I - Input forecast (ie, i)
xx - Exit
----------------------------------------------------------------------------
Run ID: ncs-g1       DSS File: ncs-mi-02feb96-0900          Base ID: ^o-r9
----------------------------------------------------------------------------
Enter selection: █                                  T"-- Re-enter
----------------------------------------------------------------------------
```

Figure 27 Results Display Locator

Type xx to exit this routine.

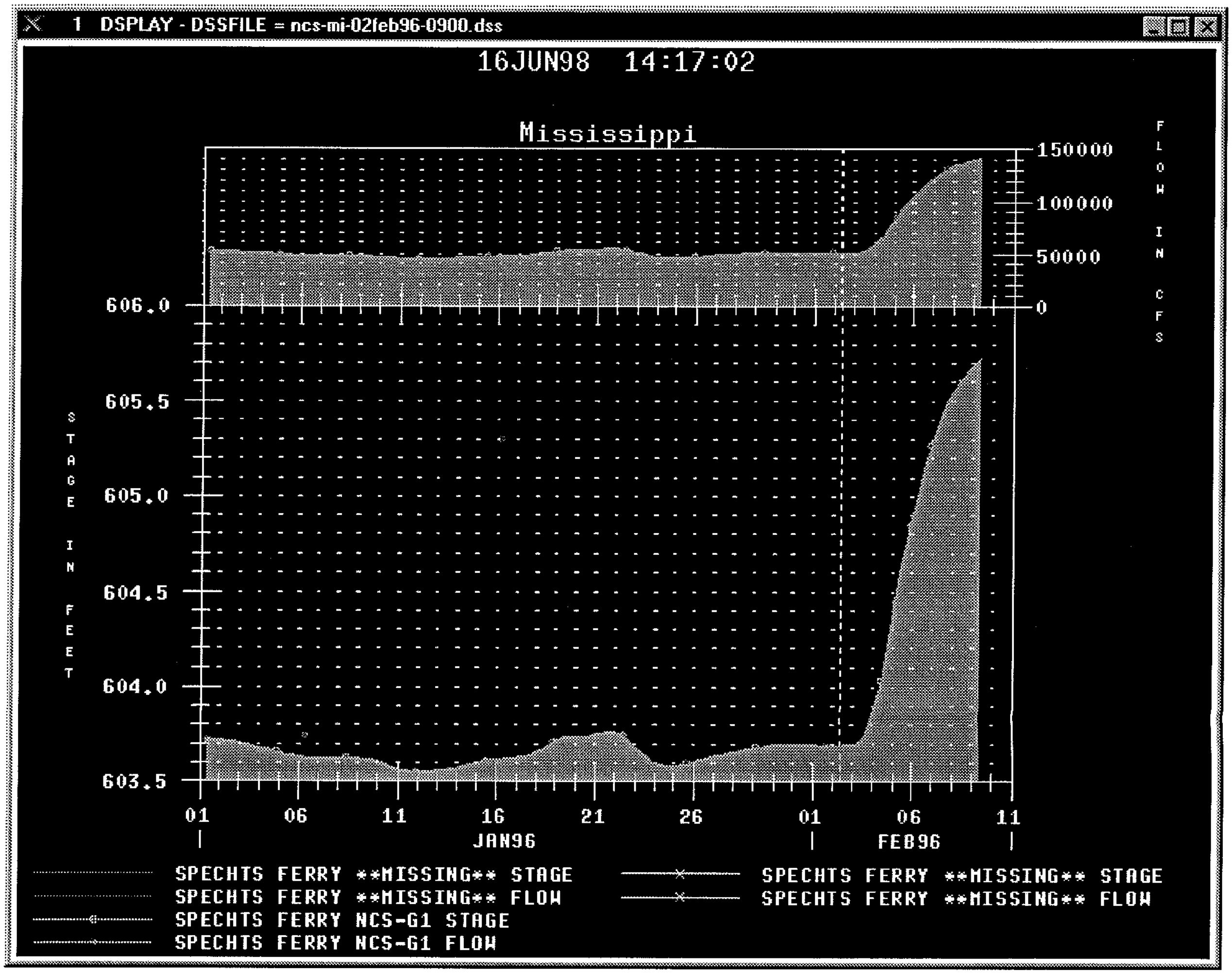


Figure 28 Results Display Example

After entering the station, one or more of the command keys in Table 1 can be used to interact with the DSPLAY plot:

Table 1
Command Keys

Key	Description
w	window (zoom) with mouse or cursor
r	replot original
s	shade toggle (dotted grid)
h	hard copy to default printer
t	tabulate data--Give hard copy or cancel when done
x	return to schematic window
?	this help screen

Static Data: The files named "PLOT.SCN" and "PLOT.MAC" contain the data that describe the system schematic (from which a specific location is selected) and pre-define the DSPLAY screens. These files use PREAD to build DSPLAY macros. They must be customized for your MBMS installation.

Advice: As the graphics presented (see Figure 28) are created by DSPLAY, the default plot design parameters may be changed by using standard DSPLAY commands.

Reference Docs: HEC, "HEC-DSS Guide and Utility Manuals, User's Manual", DSPLAY and PREAD, HEC CPD-45, March 1995.

Stephens, Dennis, "User's Manual - Mississippi Basin Model System", St. Louis District, July 1997.

Chapter 2 - APPLICATIONS

2.1 Prepare Forecast

The following is a description of the (minimum) steps necessary to prepare a forecast. The sequence described here may not apply in all details to the implementation of the MBMS customized for your site.

1) Update, using COED, data in the “datain” file to extend it to the forecast time.

2) Launch the MBMS GUI, then;
    Launch UNET- - > 1D
    (Import Forecast)
    Check the Run ID and change if necessary
    Check Run Description
    Check CSect Template - Note CSECT can only be executed via this button.
    Check bc Template - usually will be OK
    Change (update) the Time Period
    Initialize
    Perform Forecast Edit
    Run UNET
    Display Results
    Export Forecast
    Report

3) Exit MBMS.

Advice: Any other function such as **Navigation Dam Operation** will need to be inserted into the above sequence as appropriate.

Reference Docs: Stephens, Dennis “User’s Manual Mississippi Basin Model System”, St. Louis District, July 1997.

2.2 View output files

Purpose: View the traditional “print” files from the UNET system for diagnostic information.

Action: To view the printed output files from CSECT, RDSS, etc., use the Edit ➛ Text Edit ➛ File ➛ Load sequence to select a file. This puts you into the jedit text editor for X Windows. There is an "about" file and a "help" file for jedit available there. The CSECT output file is given the extension .cso and the UNET output file the extension .bco. The leading part of the file name is that shown in the associated template window.

Graphics: The "Display Results" button activates DSS-DSPLAY for hydrograph plots.

Advice: As these output files will be overwritten unless the template name is changed, renaming them may be prudent at times.

2.3 Null Internal Boundary Condition

Purpose: The "Null Internal Boundary Condition" (NIBC) is a modification to the UNET system created by Dr. Barkau to estimate residual (incremental) flows. These may be thought of as ungaged lateral inflows or outflows. The NIBC may be used at gage locations within a reach where the stage records are accurate and a stable rating curve exists. The NIBC is inserted between two identical cross sections that overlay each other. It assumes that the flow and stage hydrographs at those two cross sections should be identical. This procedure uses two executions of UNET. The first assumes stage continuity at gages, with each gage location being an internal boundary condition. This execution yields computed flow hydrographs both upstream and downstream of the NIBC gage; they will most likely differ. DSSMATH (an HEC-DSS utility) is then used to compute the residual flow (difference) for each reach between NIBC gages needed to obtain flow continuity at each of them. These residual flows are then distributed throughout the reach upstream of each NIBC gage and lagged in time as deemed appropriate. The distribution is usually assumed to be uniform. The second execution of UNET uses these flows as (uniform) lateral inflow hydrographs and removes the internal boundary conditions, resulting in an open river condition at the gages. The computed stage hydrograph at the gage location should acceptably match the observed if the model is well calibrated.

Action: Define the "null" cs and bc templates. Select "null" from the Run UNET button. The following sequence of computations is then performed (steps 1 & 2 are done automatically by the GUI):

1) UNET is executed and the computed flows upstream and downstream of the NIBC locations (defined in the cs file) are stored as directed in the bc file.

2) DSSMATH is launched to compute the residual flows. The DSSMATH macro shown in Table 2 was developed prior to this action. DSSMATH computes and stores the residual lateral inflow hydrographs.

3) Extend the computed residual inflow hydrographs through the forecast period similarly to the other inflow hydrographs - see **Edit Forecast** under Section 1.2.

Table 2
Example Macro File to Obtain Lateral Inflows using HEC-DSSMATH

```
BOOTSTRAP
!Run Begin

--------------------------------------------------------------------
This file is used to develop the lateral inflow from the results
of the null boundary condition run of UNET. Only the names in
quotes below would have to be edited.
--------------------------------------------------------------------

Macro Begin
!teach 1 $OFF_ID
!teach 2 $RIV_ID
OPEN ^1-^2-null.dss
!teach 3 $START_DATE
!teach 4 $START_TIME
!teach 5 $FORECAST_DATE
!teach 6 $FORECAST_TIME
TI ^3 ^4 ^5 ^6
!teach 7 $COMP_INTERVAL
!teach 8 $WORK_DSS
!teach 9 $FORECAST_ID
!Run Lat-flow "STPM5"  "ANKM5 TO STPM5"
!Run Lat-flow "WNAM5"  "STPM5 TO WNAM5"
!Run Lat-flow "MCGI4"  "WNAM5 TO MCGI4"
finish
EndMacro
------------------------------------------------------------------------------------------------------------
Macro Lat-flow   %in  %out
**
GET QUS=^1-^2-null:/MISSISSIPPI/%inU/FLOW//^7HOUR/^1-n0/
GET QDS=^1-^2-null:/MISSISSIPPI/%inD/FLOW//^7HOUR/^1-n0/
COM QDIFF=QDS-QUS
COM QLAT=TSHIFT(QDIFF,-1D)
SD QLAT Type=INST-VAL  Units=CFS
comp q1=gentsr(6h,0h,-901.0,M)
comp q2=mrg(QLAT,q1,M)
comp lastv=last(QDIFF)
smissing -9999.0
com if ( q2 eq -901.0 ) q2 = lastv
com if ( q2 eq -902.0 ) q2 = lastv
smissing -901.0 -902.0
PUT.R Q2=^1-^2-null:/MISSISSIPPI/%out/FLOW//^7HOUR/^1-n0/
PUT.R Q2=^1-^2-fc:/MISSISSIPPI/%out/FLOW//^7HOUR/fc/
PUT.R Q2=^8:/MISSISSIPPI/%out/FLOW//^7HOUR/^9/
* TA QUS QDS QDIFF QLAT
CLEAR ALL
$Continue
EndMacro
-------------------------------------------------------------------------------------------
```

4) Return to the GUI and select the bc file in the bc Template that references the computed and extended lateral inflow hydrographs and perform your forecast.

First Pass: In this case the cs file for the first pass is named ncs-mi-null.cs. A Null Internal Boundary Condition is located in that file with the NI Record as shown in Table 3:

Table 3
Location of NI Records Within a cs File

```
GR 677.6 10725.4  680.12 10759.4  678.82 10765.8  678.82   10766  678.12   10791
GR 680.7 10816.9  680.62 10831.7  681.42   10859  681.42 10859.2  681.62 10863.2
GR 682.5 10883.3  682.52 10889.9  686.05   10897  9999.9   10897  9999.9 10929.3
GR9999.9 10934.6  9999.9 10952.8  9999.9 10956.3  9999.9 10968.5  9999.9 10981.6
GR9999.9 11008.6  9999.9 11015.6

X1839.34      97   10000 10929.3       1       1       1
HY STPM5U
X3    10
GR9999.9  9820.6  9999.9  9840.1  9999.9  9847.2  9999.9  9870.3  9999.9  9882.5
GR9999.9  9893.2  9999.9  9900.3  9999.9  9903.5  9999.9    9922  9999.9    9948
GR9999.9  9981.1  9999.9   10000  694.92   10000  678.42 10051.1  672.92 10057.5
GR 666.8 10085.8  665.82 10099.5  666.02 10104.3  670.22 10125.5  670.22 10129.1
GR 671.6 10142.2  670.32 10169.8  669.92 10183.4  670.02 10186.8  669.72 10198.6
GR 669.7 10199.8  670.02 10208.5  678.42 10220.8  678.82 10230.7  673.32 10255.2
GR 669.7 10258.9  669.82 10261.5  669.92 10264.6  666.92 10277.3  666.92   10284
GR   667 10286.6  666.62 10290.7  666.62 10292.4  666.02 10307.9  666.82 10323.7
GR 666.8 10325.6  666.82 10327.2  666.92   10330  669.32 10338.1  671.92 10350.7
GR 671.9 10355.3  672.72 10364.4  672.72 10367.3  673.52 10382.8  673.52 10388.4
GR 673.4 10391.2  699.72 10430.5  699.82 10440.1  702.72   10446  702.62 10454.1
GR 724.4 10454.2   724.4 10521.1  702.62 10521.2  702.62   10535  703.42   10540
GR 701.9 10544.1  699.22 10548.9  696.82 10605.6  694.62 10613.4  695.12 10615.5
GR   685 10634.3  685.52 10644.2  680.02 10661.6  677.82 10698.3  678.72 10707.8
GR 678.8 10709.7  678.92 10710.2  677.52 10717.3  677.52 10719.2  677.62 10721.1
GR 677.6 10725.4  680.12 10759.4  678.82 10765.8  678.82   10766  678.12   10791
GR 680.7 10816.9  680.62 10831.7  681.42   10859  681.42 10859.2  681.62 10863.2
GR 682.5 10883.3  682.52 10889.9  686.05   10897  9999.9   10897  9999.9 10929.3
GR9999.9 10934.6  9999.9 10952.8  9999.9 10956.3  9999.9 10968.5  9999.9 10981.6
GR9999.9 11008.6  9999.9 11015.6

NI STPM5

X1839.34      97   10000 10929.3      60      60      60
HY STPM5D
X3    10
GR9999.9  9820.6  9999.9  9840.1  9999.9  9847.2  9999.9  9870.3  9999.9  9882.5
GR9999.9  9893.2  9999.9  9900.3  9999.9  9903.5  9999.9    9922  9999.9    9948
GR9999.9  9981.1  9999.9   10000  694.92   10000  678.42 10051.1  672.92 10057.5
GR 666.8 10085.8  665.82 10099.5  666.02 10104.3  670.22 10125.5  670.22 10129.1
GR 671.6 10142.2  670.32 10169.8  669.92 10183.4  670.02 10186.8  669.72 10198.6
GR 669.7 10199.8  670.02 10208.5  678.42 10220.8  678.82 10230.7  673.32 10255.2
GR 669.7 10258.9  669.82 10261.5  669.92 10264.6  666.92 10277.3  666.92   10284
GR   667 10286.6  666.62 10290.7  666.62 10292.4  666.02 10307.9  666.82 10323.7
GR 666.8 10325.6  666.82 10327.2  666.92   10330  669.32 10338.1  671.92 10350.7
GR 671.9 10355.3  672.72 10364.4  672.72 10367.3  673.52 10382.8  673.52 10388.4
GR 673.4 10391.2  699.72 10430.5  699.82 10440.1  702.72   10446  702.62 10454.1
GR 724.4 10454.2   724.4 10521.1  702.62 10521.2  702.62   10535  703.42   10540
GR 701.9 10544.1  699.22 10548.9  696.82 10605.6  694.62 10613.4  695.12 10615.5
GR   685 10634.3  685.52 10644.2  680.02 10661.6  677.82 10698.3  678.72 10707.8
GR 678.8 10709.7  678.92 10710.2  677.52 10717.3  677.52 10719.2  677.62 10721.1
GR 677.6 10725.4  680.12 10759.4  678.82 10765.8  678.82   10766  678.12   10791
GR 680.7 10816.9  680.62 10831.7  681.42   10859  681.42 10859.2  681.62 10863.2
GR 682.5 10883.3  682.52 10889.9  686.05   10897  9999.9   10897  9999.9 10929.3
GR9999.9 10934.6  9999.9 10952.8  9999.9 10956.3  9999.9 10968.5  9999.9 10981.6
GR9999.9 11008.6  9999.9 11015.6
```

(NOTE: a tc file needs to be created by a prior execution of CSECT with this cs file; see function **CSect Template.**)

For the first pass, observed stages are accessed and used via the OBSERVED INTERNAL BOUNDARY CONDITION Record in the bc file as shown in Table 4:

Table 4
Reference to Observed Stages in the bc File.

```
ZERO=-.5
OBSERVED INTERNAL BOUNDARY CONDITION AT ST. PAUL
STPM5
/MISSISSIPPI/STPM5/ELEV/01AUG1995/6HOUR/ncs-f1/

ZERO=-.5
OBSERVED INTERNAL BOUNDARY CONDITION AT L&D 2
L&D2
/MISSISSIPPI/DAM2-POOL/ELEV/01JAN1995/6HOUR/ncs-f1/
ZERO=0.
```

Note that the location given on the NI Record of the cs file corresponds to the B part of the pathname of the observed stage data.

On the first pass through UNET, the computed hydrographs upstream (STPM5U) and downstream (STPM5D) of the NIBC are written to dss as directed by the HY Records highlighted above. The DSSMATH macro shown in Table 2 then subtracts these hydrographs and lags them by one day with the following commands:

```
....
COM QDIFF=QDS-QUS
COM QLAT=TSHIFT(QDIFF,-1D)
....
```

The resulting hydrograph's B part is “ANKM5 TO STPM5". These hydrographs are shown in Figure 29.

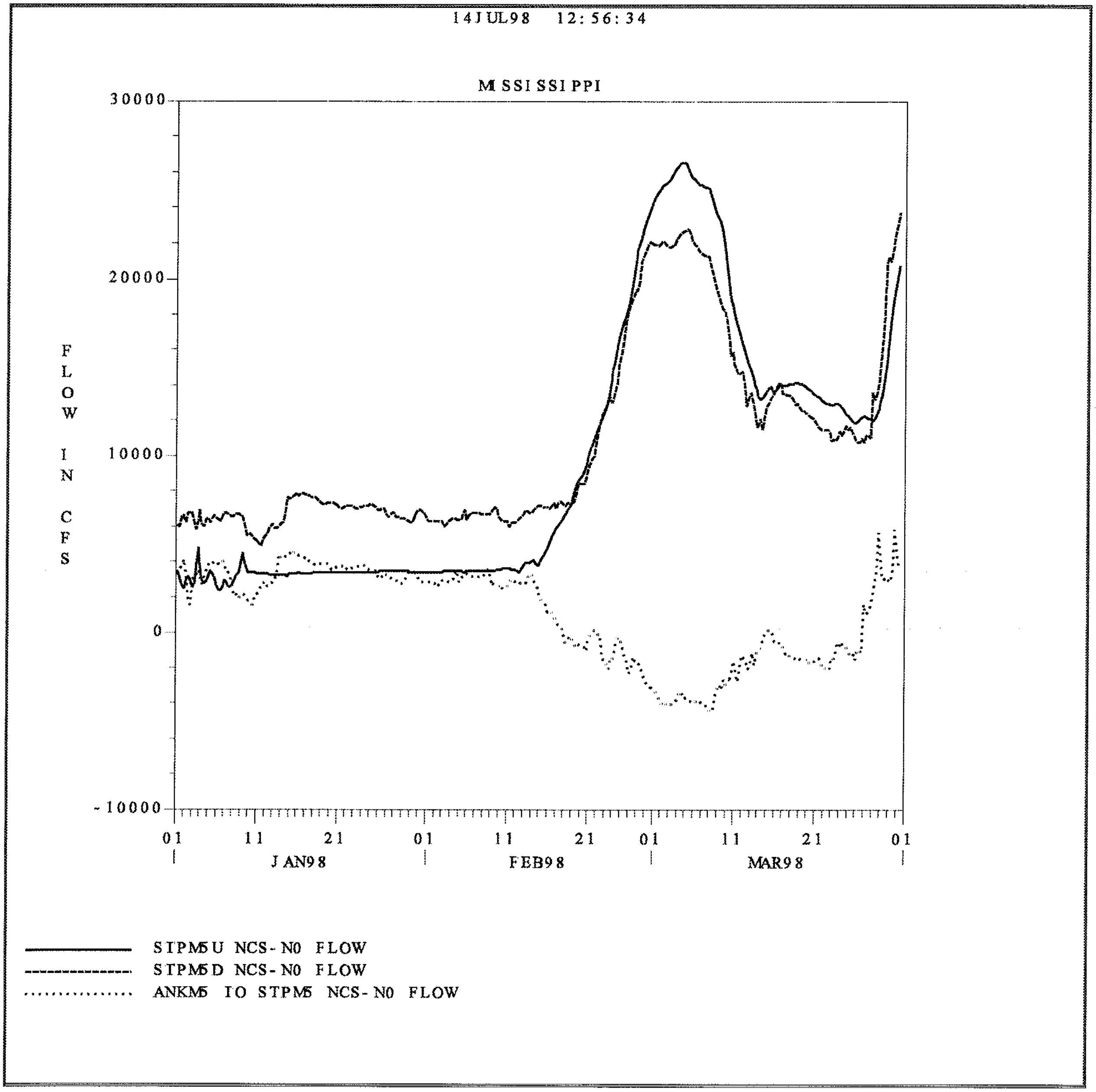


Figure 29 NIBC Hydrographs - First Pass

The dashed line (STPM5D) is the computed hydrograph downstream of the NIBC, the solid line (STPM5U) is the computed hydrograph upstream of the NIBC and the dotted line (ANKM5 TO STPM5) is the difference (QDS-QUS), lagged one day. This difference hydrograph is then used as a UNIFORM LATERAL INFLOW HYDROGRAPH during the second pass.

Second Pass: A different geometry file is created that removes references to the Null Internal Boundary Condition (NI Records). The portion of that file corresponding to Table 3 is shown in Table 5:

Table 5
cs File without NI References (Compare with Table 3).

```
GR 666.8 10325.6  666.82 10327.2  666.92   10330  669.32 10338.1  671.92 10350.7
GR 671.9 10355.3  672.72 10364.4  672.72 10367.3  673.52 10382.8  673.52 10388.4
GR 673.4 10391.2  699.72 10430.5  699.82 10440.1  702.72   10446  702.62 10454.1
GR 724.4 10454.2   724.4 10521.1  702.62 10521.2  702.62   10535  703.42   10540
GR 701.9 10544.1  699.22 10548.9  696.82 10605.6  694.62 10613.4  695.12 10615.5
GR   685 10634.3  685.52 10644.2  680.02 10661.6  677.82 10698.3  678.72 10707.8
GR 678.8 10709.7  678.92 10710.2  677.52 10717.3  677.52 10719.2  677.62 10721.1
GR 677.6 10725.4  680.12 10759.4  678.82 10765.8  678.82   10766  678.12   10791
GR 680.7 10816.9  680.62 10831.7  681.42   10859  681.42 10859.2  681.62 10863.2
GR 682.5 10883.3  682.52 10889.9  686.05   10897  9999.9   10897  9999.9 10929.3
GR9999.9 10934.6  9999.9 10952.8  9999.9 10956.3  9999.9 10968.5  9999.9 10981.6
GR9999.9 11008.6  9999.9 11015.6

X1839.34      97   10000 10929.3      60      60      60
HY STPM5D
X3    10
GR9999.9  9820.6  9999.9  9840.1  9999.9  9847.2  9999.9  9870.3  9999.9  9882.5
GR9999.9  9893.2  9999.9  9900.3  9999.9  9903.5  9999.9    9922  9999.9    9948
GR9999.9  9981.1  9999.9   10000  694.92   10000  678.42 10051.1  672.92 10057.5
GR 666.8 10085.8  665.82 10099.5  666.02 10104.3  670.22 10125.5  670.22 10129.1
GR 671.6 10142.2  670.32 10169.8  669.92 10183.4  670.02 10186.8  669.72 10198.6
GR 669.7 10199.8  670.02 10208.5  678.42 10220.8  678.82 10230.7  673.32 10255.2
```

A second bc file (in this case ncs-mi-22jun98-0600-p2.bc) must also be prepared that removes the references to OBESERVED INTERNAL BOUNDARY CONDITION and replaces them with the UNIFORM LATERAL INFLOW HYDROGRAPH's computed with the DSSMATH macro that was shown in Table 2. A portion of that bc file is shown as Table 6:

Table 6
bc File using Inflows from the NIBC Computations.

```
************************************************************************
*
* Ungaged inflow between Anoka and the Minnesota River

REACH=1
QMULT=0.812
UNIFORM LATERAL INFLOW BETWEEN ANOKA AND THE MINNESOTA RIVER
 864.80 844.01
 ncs-mi-null:/MISSISSIPPI/ANKM5 TO STPM5/FLOW/01DEC1997/6HOUR/NCS-N0/
* CLOSE DSS FILE

OPEN DSS FILE
  ncs-mi-22jun98-0600  01jan98  0600  22jun98  0600  6HOUR

QMULT=1.0

QBASE=1000.
ZERO=0.
RATING CURVE FOR THE MINNESOTA RIVER NEAR JORDAN
/MINNESOTA/JORDAN MN/STAGE-FLOW//06SEP94/JDNM5/
```

Shown in Figure 30 are four of the computed hydrographs resulting from this application of the NIBC. Looking at the peak flow period around 1 March 1998 they are (in descending flow magnitude):

1) Pass 1 computed upstream - solid “STPM5U NCS-N0 FLOW”
2) Pass 2 computed (same upstream and downstream) - dotted “STPM5U NCS-P2 FLOW”
3) Pass 1 computed downstream - dashed “STPM5U NCS-P2 FLOW”
4) Pass 1 computed residual [i.e. (3)-(1)] - solid “ANKM5 TO STPM5 NCS-N0 FLOW”

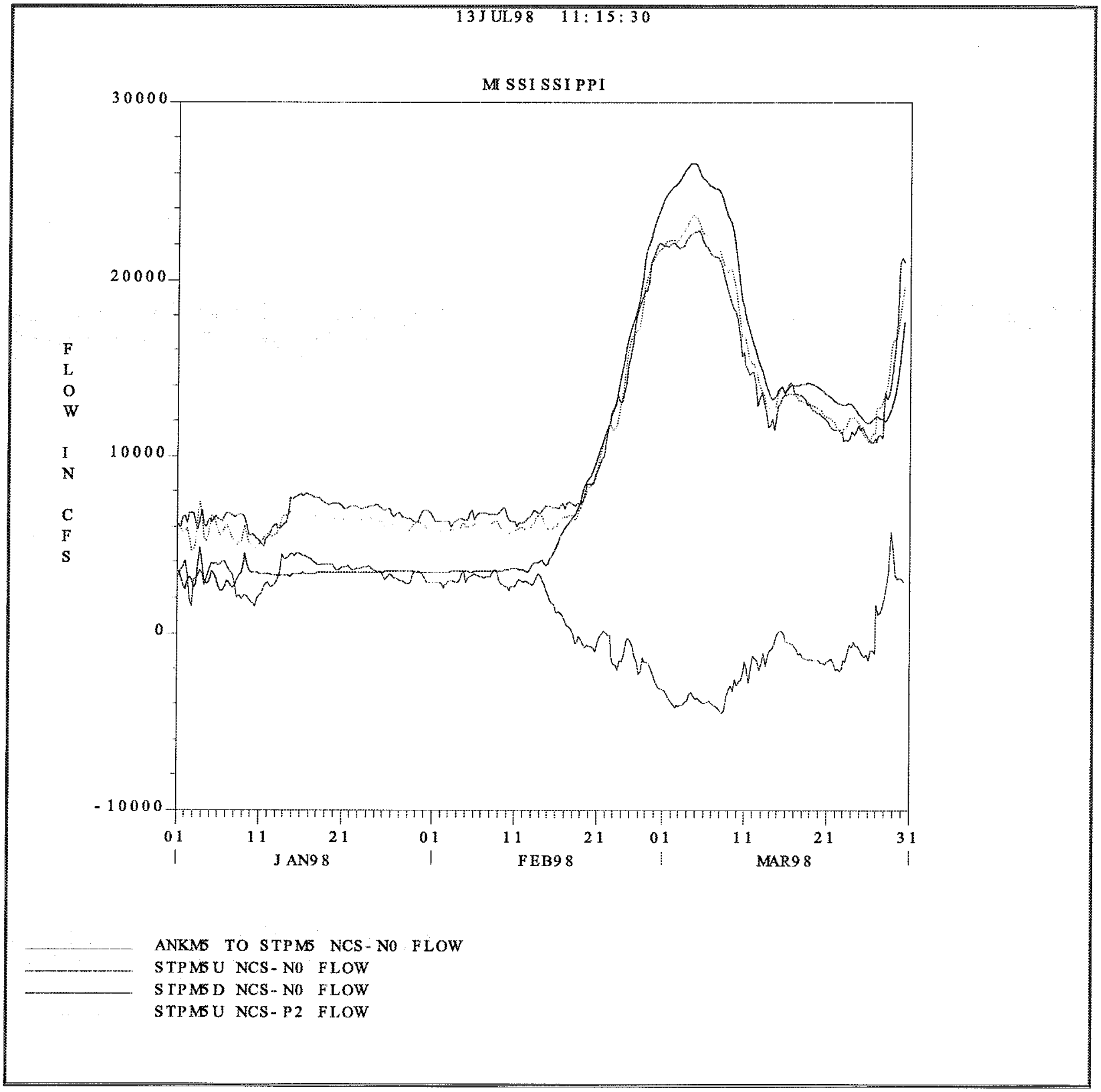


Figure 30 NIBC Hydrographs - First and Second Passes

Curves "STPM5D NCS-N0" and "STPM5U NCS-P2" reflect the target (with internal stage bc) and resulting (open river) flows at the location of the NIBC respectively.

Advice: The NIBC can be usefully applied at locations where:

a) Stage records are accurate.
b) Backwater effects from tributaries do not influence the results.
c) Backwater effects from regulated structures do not influence the results.
d) The elevation-discharge rating does not shift in time sufficiently to influence the results.
e) The rating curve is nearly single-valued. Note that the NIBC assumes that stage is accurate; therefore, any spread in the relation between stage and flow at the location of interest will be included in the computed residual flows.

The computed residual flows, as shown in this case, may at times be negative. This may indeed be the situation; as, for example, ungaged diversions. The process used by the NIBC of mechanically adjusting flows to achieve stage continuity at a gage throws all of the errors at that location (including those that might be later recovered in the calibration process) into the flow adjustment. Given that flow is typically less accurately measured than stage, this process is defensible. The resulting residual hydrograph should be examined, however, and explanations for any unexpected results sought in the physical characteristics of the basin and possible measurement errors. In the case shown, a positive flow residual existed until early February 1998; then, the computed upstream flows were larger than the downstream flows for a few weeks, requiring negative inflows. No physical explanation for this result is offered here as this is not considered to be a complete, calibrated, data set and is being used only for the purpose of illustration of the implementation of the NIBC. The next step in this process would be to compare the stage imposed during pass 1 with that computed in pass 2. If further adjustments to the data model are then deemed to be necessary, calibration of UNET will be necessary.

Reference Docs: Barkau, R. L., 1995, "The Estimation of Ungaged Inflow Using the Null Internal Boundary Condition", August 1995.

Dobberpuhl, Stu, "Mississippi River Real-Time Forecast UNET Model", St. Paul District, July 1997.

HEC, "HEC-DSS Guide and Utility Manuals, User's Manual", DSSMATH, HEC CPD-45, March 1995.

2.4 Navigation Dam Operation

Purpose: A major effort was undertaken to provide the MBMS with the ability to simulate lock and dam operations. The capability to use operating rule curves at navigation dams as internal boundary conditions was developed and implemented (Barkau, 1996). Preparation of the input data necessary to describe these rule curves must be done outside of the GUI. As of this writing, the GUI is being modified by CECRL for the St. Louis District to reflect the needs of real-time L&D operation simulation.

Reference Docs: HEC, "Mississippi Basin Modeling System Development and Application", HEC PR-36, April 1998.

Barkau, R. L., 1996, "Navigation Dam Algorithm", a report submitted to the Hydrologic Engineering Center, December 1996 (Appendix J of HEC FY96 MBMS Status Report).

Appendix A

Download/Installation Instructions for the GUI

Table of Contents

Section Title **Page**

TABLES

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A.1 Mississippi Basin Modeling System (MBMS) Download Instructions

1. FTP to ftp.crrel.usace.army.mil
2. Login as "anonymous" using the password "guest".
3. cd to rsgisc/software/tickle/SUNSol.
4. Then set your ftp tool to binary mode - type "bin" with Unix ftp.
5. Now type "mget *" - You'll need to say "yes" to all files.
6. Once you have all the files. Follow the instructions in the README file for uncompressing and untar-ing the directories.

A.2 MBMS GUI Files and Directories

A.2.1 GUI Files

mbms - Startup script for GUI.

mbmsex - TCL/TK (Tickle) source for starting GUI.

setup - Global GUI file for environment variables. Contents of this file are listed in Table 1.

Table 1
File Containing Environment Variables Controlling the Execution of MBMS Components.

```
# This file contains environment variables that control the
# execution of MBMS components.  The first settings are fixed
# for a specific office and river system.  The second settings
# are set by the GUI based on user actions.
#=======Begin setting system variables===============================

setenv MBMS_HOME /home/bjp/mbmsgui
setenv MBMS_DATA /home/bjp/mbms
setenv MBMS_OFFICE "lms"

setenv PS_PRINTER laser4_1
setenv PS_PRINTER- COLOR color

setenv DATA_IN $MBMS_DATA/datain
setenv DATA_OUT $MBMS_DATA/dataout

setenv MBM_BIN $MBMS_HOME/bin
setenv MBM_MAC $MBMS_HOME/macros

setenv OFF_ID ncr
setenv OFF_NAME "Rock Island"
setenv RIV_ID mi
setenv RIV1_NAME "Mississippi"
setenv RIVI_NAMEABV "mi"
setenv RIV2_NAME "Illinois"
setenv RIV2_NAMEABV "il"
setenv RIV3_NAME " "
setenv RIV3_NAMEABV ""
setenv RIV4_NAME ""
setenv RIV4_NAMEABV ""
setenv RIV5_NAME ""
setenv RIV5_NAMEABV ""
setenv RIV6_NAME ""
setenv RIV6_NAMEABV ""
#========Begin Fixed MODEL level setting area
================================

setenv COMP_INTERVAL 6
setenv MBM_BAS $MBMS_DATA
setenv MASTDB $MBM_BAS/masterdb

setenv O_R $OFF_ID-$RIV_ID

# ====== Begin GUI setting area=============================

setenv CORPSVIEW /usr/local/bin
setenv RUN_SEQUENCE r3
```

A.2.2 GUI Directories

/bin directory - All binary files such as UNET, dsplay_edit, (see MBMS Data Directories and Files, Table 3.)

/macros directory - All UNET macros are in this directory. (see MBMS Data Directories and Files.)

/lib directory - All the TCK/TK lib files and the MBMS GUI source code files are in this directory. These files should not be touched or modified.

A.2.3 README - Instructions for setting up GUI.

See Table 2.

Table 2
Instructions for Setting up GUI

1. Uncompress files v2mbms.tar.Z - "uncompress v2mbms.tar.Z"

2. Untar mbms.tar - "tar xvf v2mbms.tar"

3. Place directories in your system's locations.
Example: "/usr/local/pkg/mbmsgui" for GUI and "/data2/mbms" for DATA. !!!
Beware Data will grow.

4. Edit .cshrc (A .cshrc file is located in this directory)
Change the homes for GUI and DATA directories.
Example: setenv MBMS_HOME /???/???/mbmsgui <----- Change Path

```
############################################
# GUI VARIABLES
############################################
setenv MBMS_HOME/data2/mbmsgui    <---- Change Path
setenv MBMS_DATA/data2/mbms    <---- Change Path
setenv TCL_LIBRARY $MBMS_HOME/lib/tcl
setenv TK_LIBRARY $MBMS_HOME/lib/tk
set path = ($MBMS_HOME $MBMS_HOME/bin $path)
setenv LD_LIBRARY_PATH
$MBMS_HOME/lib:/opt/SUNWspro/lib:/opt/SUNWmotif/lib:/usr/openwin/lib
############################################
```

5. Edit "setup" file in HOME directory.

```
# This file contains global environment variables that control the
# execution of the global MBMS components.  The first settings are fixed
# for a specific office and river system.
#
# ====== Begin Fixed SYSTEM level setting area
===================================
#
setenv MBMS_HOME /data2/mbmsgui     <---- Change Path
setenv MBMS_DATA /data2/mbms    <---- Change Path
```

6. Create MBMS_DATA directories, one for each river.
(example: mi for Mississippi) You also need to create river setup files.
(example: misetup) Use the MBMS_DATA tar file for samples.

7. Edit "mbmsex" file in GUI home directory and the j??? files in GUI bin directory.
Change the first line of each file to read:

```
#!/data2/mbmsgui/bin/wish -f    <----- Current Path
#!/???/???/mbmsgui/bin/wish -f    <---- Change Path
```

8. Setup Data directory filesystems.

9. Run MODEL with "mbms".

A.3 MBMS Setup File to Data Directory

Table 3
MBMS Setup File to Data Directory

```
# ====== Begin GUI setting area=================================

setenv FORECAST_DATE 09sep96
setenv FORECAST_TIME 0600

setenv START_DATE 02aug96
setenv START_TIME 0600

setenv END_DATE 04sep96
setenv END_TIME 0600

setenv RUN_SEQUENCE r4
setenv RUN_DES 123_Fortecast

setenv FORECAST_ID ncr-f1
setenv NCS_TRANSFER_ID ncs-rx
setenv LMS_TRANSFER_ID lms-rx
setenv NCS_TRANSFER_FILE ncr-transfer
setenv LMS_TRANSFER_FILE ncr-transfer

setenv BASE_BC_FILE ncr-i1-10jun96-0600-r1.bc
setenv BASE_CS_FILE ncr-mi-13sep96

setenv INC_FILE ncr-mi-v1.inc

# ====== Begin derived setting area================================

setenv RUN_ID $OFF_ID-$RUN_SEQUENCE
setenv SDATEHR $START_DATE-$START_TIME
setenv FDATEHR $FORECAST_DATE-$FORECAST_TIME
setenv EDATEHR $END_DATE-$END_TIME
setenv WORK_DSS $O_R-$FORECAST_DATE-$FORECAST_TIME
setenv TRANSFER_FILE $OFF_ID-$FORECAST_DATE-
$FORECAST_TIME
```

A.4 MBMS Naming Conventions

A.4.1 Standard Naming Convention for Real Time Applications

1) The new GUI design permits the use of the UNET model in a real time mode. To provide a product that will be robust over time, understandable by changing staff, easily documented, teachable in class and workshop environments, and supportable by staff a consistent naming convention is required.

2) This file organization and naming convention will support the simultaneous use of the MBMS system by multiple users running on a single computer system.

3) All date and times are input and displayed in military style. All times are expressed in **central time**.

4) While data in local **master data bases** should be named as the **individual office** decides, data that is copied into model runs should be placed into files of consistent names, and in DSS files, the pathnames must follow these system wide standards. Defining a reasonable convention for naming files and paths is essential when teaching, debugging, and providing on-going support for a system. Tabulating data, plots and other functions are greatly simplified. A specific naming convention for files is given in Section A.4.2, and for pathnames in Section A.4.3.

5) The user is able to select from alternative forecast inputs. Alternative inputs may represent low, medium, and high estimates, particular reservoir releases, or other contingencies.

6) The user is able to select from alternative inputs transferred from another office. The transfer data may represent several possible conditions: all levees up, certain levees failed, high, medium, or low input, etc.

7) The user must be able to associate a run number with a text description of the alternate being executed. A table of runID and description will be used when comparing the results from alternative forecasts. All input, and output associated with the execution must be named with the runID.

8) The plotting capability must be enhanced to include comparison with other alternatives, other locations, and previous forecasts.

9) When creating names of locations, particularly levees, be sure that the name does not exceed **18 characters**. Names for stations should be unique across all MBMS sites.

10) A .bc file with the runID of r_ should be created as the original base .bc file. Other runs are then created from this original base file, or other existing .bc files. See Section A.4.2 for the file naming convention.

11) A .cs file named according to Section A.4.2 should be created. The OH recors are ignored as the PLTCON file is not used. The plot.mac and plot.scr files control all graphics.

A.4.2 MBMS File Naming Convention

This file naming convention applies ONLY to those files generated or directly used by the MBMS. The local files containing master data base values are NOT covered by this convention. Naming of master data base files is at the discretion of the local office.

Unless specifically indicated otherwise, ALL characters used in file names and environment variables will be LOWERCASE.

A.4.2.1 FILE NAME PARTS

Office Identifier (offID):

The three character Corps office symbol. Examples: ncr, lmv, mrk[1].

River Identifier (rivID):

A two character identifier from the following table:

mi	Mississippi River
mo	Missouri River
i1	Illinois River
oh	Ohio River

Run Identifier (runID):

Office and nine sequence number. An associated table provides text description of run.

Form:	off1D-r*	where * is a sequence number.
Example:	ncr-r4	

Forecast Date (fcDate):

7 character military style date.

Form:	ddmmmyy
Example:	03dec96

Forecast Time (fcTime):

4 character 24 hour time[2].

Form:	hhmm
Example:	0600

A.4.2.2 FILES

CSECT Files:

Input files containing cross-section geometry data.

Form:	off1D-rivID-date.cs
Example	ncr-mi-sep95.cs

---

[1] Original installation files include old office symbols - It is up to the discretion of each office to update appropriately.

[2] Currently - the fcTime is fixed at 0600. It cannot be reset.

BC Files:

Boundary condition information for run.

Form:	offID-rivID-fcDate-fcTime-runID.bc
Example:	lms-mi-03dec96-0600-r3.bc

Unet DSS File:

File containing all time series data for a given forecast time for a specific segment of a river. Any number of runs may be included within this file. This is the main DSS file containing all information for a specific river forecast time.

Form:	offID-rivID-fcDate-fcTime.dss
Example:	mrk-mo-03dec96-0600.dss

Text description of run identifier:

File containing a description of the unique difference in each run, along with references to corresponding alternatives used for input and transfer data. This file documents each run made by the user.

Form:	offID-rivID-fcDate-fcTime.txt
Example:	mrk-mo-03dec96-0600.txt

Transfer File:

DSS file containing all records to be transferred outside an office. The file must contain both upstream and downstream transfer locations and any input within the transfer overlap area that the transferring office is responsible for providing. Multiple runs may be included to provide alternatives for downstream impact evaluation. Each run is distinguished by its runID in the F part of the pathname.

Form:	offID-fcDate-fcTime.dss
Example:	mrk-03dec95-0600.dss

Levee Include Files:

Files containing levee information.

Form:	offID-rivID-v*.inc
Example:	ncr-il-v2.inc

Rating Curves:

File containing current and historical rating curves.

Form:	offID-rivID-ratings.dss
Example:	lms-mi-ratings.dss

Profile Curves:

File containing river profile information.

Form:	offID-rivID-profiles.dss
Example:	lms-mi-profiles.dss

A.4.3 HEC-DSS Pathname Convention

The naming of HEC-DSS paths by this convention applies ONLY to those files directly associated with the MBMS. The master data base may use any existing naming convention desired by the implementer. The purpose of this naming convention is to facilitate: (1) the orderly exchange of data; (2) the comparison of results across different runs; (3) the comparison of results at different locations; (4) and the comparison of forecasts made from one time to another.

General notes:

Keep names short, descriptive, and recognizable. Do not have multiple embedded blanks in any pathname parts. That is use **REACH^1**, not REACH^^1, (where ^ is used here to show a blank).

Where the name of a river is used, do not include the word river as part of the name. That is, use **MISSOURI**, not MISSOURI RIVER, or **LITTLE BLACK**, not LITTLE BLACK RIVER.

A.4.3.1 Observed Time Series:

This information is extracted from a local office's master database and stored in the unet DSS file for each new forecast time.

Form: /river/location/parameter/01JAN1995/1HOUR/OBS/

where:

location - defined by the local office, but MUST be unique throughout the MBMS study area.
parameter - from the list: STAGE, FLOW, ELEV.

Example: /MISSOURI/RULO/STAGE/01JAN1995/OBS/

A.4.3.2 Computed Time Series:

For run #4 made by Kansas City District.

Form: /river/location/parameter/01JAN1995/01HOUR/runID/

Example: /MISSOURI/RULO/STAGE/01JAN1995/MRK-R4/

A.4.3.3 Forecast Input:

For forecast alternative #2 made by Rock Island District. The local office may generate any number of alternative forecast inputs for analysis by the model. Each forecast would be identified by a forecastID. The text description of each forecast, keyed to the forecast identification number, is defined in the file in item 9 of Section A.4.2.

Form:	/river/location/parameter/01JAN1995/1HOUR/forecastID/
Example:	/MYRIVER/MYLOCATION/FLOW/01JAN1995/NCR-F2/

A.5 MBMS Glossary of files

In the following description, program names are shown in uppercase. This is done only to distinguish them from other text. The actual name for a program on UNIX systems will always be in lowercase.

A.5.1 Global files in $MBMS_DATA directory for each office and river.

masterdb.dsc

Catalog file for a Master DSS database, for a specific office.

masterdb.dss

Master DSS file containing incoming data for all locations within the local office. Data is extracted from this file to create a working DSS file for each forecast session. The name and location of this file or any number of such files is arbitrary. The masterdb files are set by the local office to their own naming convention.

[riverID]setup - (e.g. ilsetup, misetup, ohsetup)

Procedure to execute setenv commands to pre-set environment river variables that control execution of procedures. This file will be updated by the GUI as the user makes changes to model configuration parameters.

A.5.2 Files in $MBMS_DATA/$RIVER_ID data directory that are defined for a given river.

Each of the files in this section must be edited to configure a specific office and river. These files contain specific names and other information needed to define model operations and control.

edit-fc.mac

Macro file used by DSPLAY in run-edit-fc to allow the forecaster to review all input data and to edit the forecast inputs, if necessary.

export-fc.mac

Stations to be written to this site's export file. List should contain all stations, both those that are on the upstream and downstream boundaries of the office. All inflow information that is within the overlap area belonging to this office must be included.

extrct-2

Procedure file to extract initial forecast values into the forecast DSS file. This procedure would be used only once and never again. The forecast DSS file would be updated at the end of a forecast session, so thereafter would always contain the latest forecast the start of the next forecast session.

extrct-2.lst

List of original stations to put into forecast DSS file.

import-fc.mac

Directives to import data from upstream and downstream boundary offices.

init-dss-copyfc.mac

Macro file used by DSSUTL to copy records from fc DSS file to working DSS file. The records are then modified to include the specified F part name. The fc DSS file would always contain the latest forecast values saved from the most recent model run.

init-dss.lst

List of data to be extracted from master database(s) to create working file of observed conditions. Data may be taken from any number of master database files. The names of the master database files are up to the local office. The pathnames in the master database files are up to the local office. Within the working DSS file and associated DSS files, the names should conform to the MBMS naming standards. This is to facilitate the use of macros and GUIs, for reporting results, and to permit consistent transfer of information between offices.

mrk-mo-0laug93-0600-r0.bc

Boundary condition file for Kansas City District, Missouri River, run with forecast time of 0lAug1993 at 0600 with a run sequence id of r0.

mrk-mo-0lmay93.cs

CSECT input file to be used for runs after 0lmay93.

mrk-mo-fc.dss

Forecast DSS file containing the latest forecast of all inputs. This file is updated at the end of a forecast session to be the starting values for the next session.

mrk-mo-null.bc

UNET null boundary condition input file. Used in run-null-bc.

mrk-mo-null.cs
CSECT input file for the null boundary condition.

mrk-mo-profiles.dss
DSS file holding profile data.

mrk-mo-ratings.dss
DSS file holding rating information.

null-bc-math.mac
Macro file used by DSSMATH to derive local uniform inflows from the UNET null boundary condition run.

plot.mac
Macro file used by DSPLAY in run-plot to view results.

plot.scn
Screen file used by DSPLAY in run-plot to view results. Eventually, a real GUI interface will replace this file.

post-unet-coed.mac
Edit instructions to combine series of REACH profiles in DSSUTL edit format into a complete river profile.

post-unet-write.mac
Update catalog file. Write out all REACH profiles for sub-reaches in text form.

A.5.3 Files in $MBMS_DATA/$RIVER_ID directory that are generated during execution.

PLTCON
Standard file created by TABLE to make plots based on OH records in .cs file. This file is NOT used in the MBMS system.

coedfun
PREAD function file used by COEDP.

coedmac
PREAD macro file used by COEDP. The name is hardwired so desired macros must be copied to this file before execution of COEDP. COEDP is a special version of COED that contains PREAD capabilities. This allows COEDP to execute macros, use function characters, and otherwise interact with other application products. At this time COEDP is not a generally distributed program. A key feature is the ability to access environment variables and edit them into text files. Most of this need could also be accomplished with awk or other unix utilities.

extrct-2.out

Output from extrct-2

genfun

PREAD function file shared by most steps in MBMS system. See genfun.lst for the definitions of each function character.

init-dss.out

Output file from run-init-dss.

nirk-mo-01aug93-0600.dss

Working DSS file for Kansas City District, Missouri River, run with forecast time of 0lAug1993 at 0600. This file will contain all input forecast information and computed results for all runs that are made with the specified forecast time. Each run will have its own runID in the F part of the pathname.

mrk-mo-0laug93-0600.runs

Summary of all runIDs.

mrk-mo-01aug93-0600-r0.bco

Output file

mrk-mo-0lmay93.cso

CSECT output file.

mrk-mo-0lmay93.tc

CSECT transfer file.

mrk-mo-null.bco

UNET output file for null boundary condition execution.

mrk-mo-null.cso

CSECT output file for null boundary condition execution.

mrk-mo-null.dss

Working DSS file to hold results of null boundary condition run.

mrk-mo-null.tc

CSECT transfer file for null boundary condition execution.

post-unet.out

Output file from post UNET processing.

pre-unet.out

Output file from pre UNET processing.

A.5.4 Files in $MBMS_HOME/macros directory shared by all applications.

acadfile
File used by DSPLAY to provide user defined graphics on a plot. Currently used to provide help message to the plot screen.

init-dss-dc.mac
Macro file used by DSSUTL to set data compression and tag generation conditions for the working DSS file.

null-bc-edit.mac
Macro file used by COEDP in run-null-bc to edit the null boundary condition .bc file to contain the current time window.

post-unet-cat.mac
Update DSS file catalog.

post-unet-read.mac
Read in edited complete river profiles from text back into a single DSS paired-data record.

pre-unet-edit.mac
Macro file used by COEDP in run-pre-unet to edit the .bc file to contain the current runId, time window, and input/output DSS file names.

A.5.5 Files in MBMS Directory Bin Area Shared by All Applications

run-csect
Procedure to execute CSECT.

run-edit-fc
Procedure to execute edit of forecast input data.

run-export-fc
Procedure to execute export of current runID results to transfer file to other offices.

run-import-fc
Procedure to execute import of other office forecast results for use in current working DSS file.

run-init-dss
Procedure to execute initiation of new working DSS file. NOTE: Any prexisting DSS file for the same forecast time will be deleted.

run-null-bc
Procedure to execute null boundary condition run. Results will be placed in working DSS file for use as input.

run-plot

Procedure to execute plots of input, intermediate and final results.

run-unet

Procedure to execute UNET model.

A.6 PRead Function Character Usage

These PRead function characters have been Pre-Set from within the GUI macros and setup files. Note the usage for each function character.

Table 4

PRead Function Characters

Function Char.	Max Length	Example	Usage
9	8	abcdefgh	---> Any temporary use (0-9)
A	20	351.8 Allen 11 723.7	---> Parameter string for plot macro
B	10	!screen ^s	---> Line to be executed upon completion of HOLD
F	6	mrk-f1	---> Forecast input runID
G	6	DOTTED	---> Grid style
H	1	x	---> Last keyboard response
L	4	rulo	---> Alternative compare location
N	8	Missouri	---> Mainstem river name
R	4	1000	---> Data edit round precision
S	3	OFF	---> Shading control
U	5	mrk-r0	---> Alternative compare runID
X	7	08aug93	---> End Date
Y	4	0600	---> End Time
Z	19	mrk-mo-0laug93-0900	---> Alternative DSS filename base
a	2	Lv	---> Name of mostly recently executed plot macro
b	12	!Run Show_it	---> Line executed at end of each plot macro
d	7	0laug93	---> Forecast Date
e	0		---> Plot command optional E for multi plots
i	1	6	---> Computational time interval, in hours
m	3	one	---> One or More plot flag
o	3	mrk	---> Office ID
p	2	sx	---> Printer name
r	2	mo	---> River ID
s	4	Main	---> Next screen name
t	4	0600	---> Forecast Time
u	6	mrk-ro	---> Run ID
x	7	15may93	---> Start Date
y	4	0600	---> Start Time
z	19	mrk-mo-0laug93-0900	---> DSS filename base

Appendix B

Navigation Dam Algorithm

Submitted to

Hydrologic Engineering Center
Corps of Engineers

by

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December 11, 1996

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B.1 Introduction

This report presents a new algorithm for the simulation of navigation dams in the UNET program. The algorithm simulates two types of navigation dams - dams with the control point at the dam and dams with the control point within the pool, also called hinge pool operation. The UNET program has also been modified to include features which first exactly reproduce recorded pool stages and secondly allow a regulator to control the operation of the navigation pool during forecasting with the UNET program.

B.2 Types of Navigation Dams

Two types of navigation dams will be simulated by this algorithm:

B.2.1 Control point at the dam

This is the simplest regulation procedure for a navigation dam. The navigation pool is maintained at a target elevation at the dam. When the tailwater elevation plus the head loss through the structure exceed the target elevation, the pool is no longer controlled by the dam and the dam is in open river conditions. The target elevation can change with the seasons. For example, in the Rock Island District, the winter pool elevation is .5 foot lower than the summer pool elevation. Also, the target pool cannot be precisely maintained; therefore, a tolerance exists about the target pool elevation. In the Rock Island District, the tolerance range is +0.1 feet and -0.4 feet.

B.2.2 Control point within the navigation pool

The navigation pool is operated to maintain a constant elevation at a control point in the navigation pool. This procedure is also called hinge pool operation because the pool conceptually tilts about the control point. Hinge pool was devised to minimize the amount of flooded land that had to be purchased by the government in the upper reaches of the pool. The operation of a hinge pool is given by a operating curve (essentially a rating curve) at the dam which was derived from experience. Figure 1 shows the rating curve for Lock and Dam No. 9 in the St. Paul District. The control point is Lansing, Iowa which is maintained at an elevation of 620.5' NGVD (620.0' 1912 G. A. MSL +.5' correction factor to NGVD). The stage is maintained at Lansing of 620.5' until a flow of 32,000 ft^3/s when the maximum allowable drawdown of the pool, 619.5' NGVD, is attained. The maximum drawdown is maintained until the tailwater elevation plus the head loss of the structure exceeds the pool elevation and the dam is at open river. Hinge pool operation is also used for the dams in the St. Louis District, although, the operating curves have a different appearance. The operating curves are a set of curves which relate control point elevation to pool elevation at constant flow.

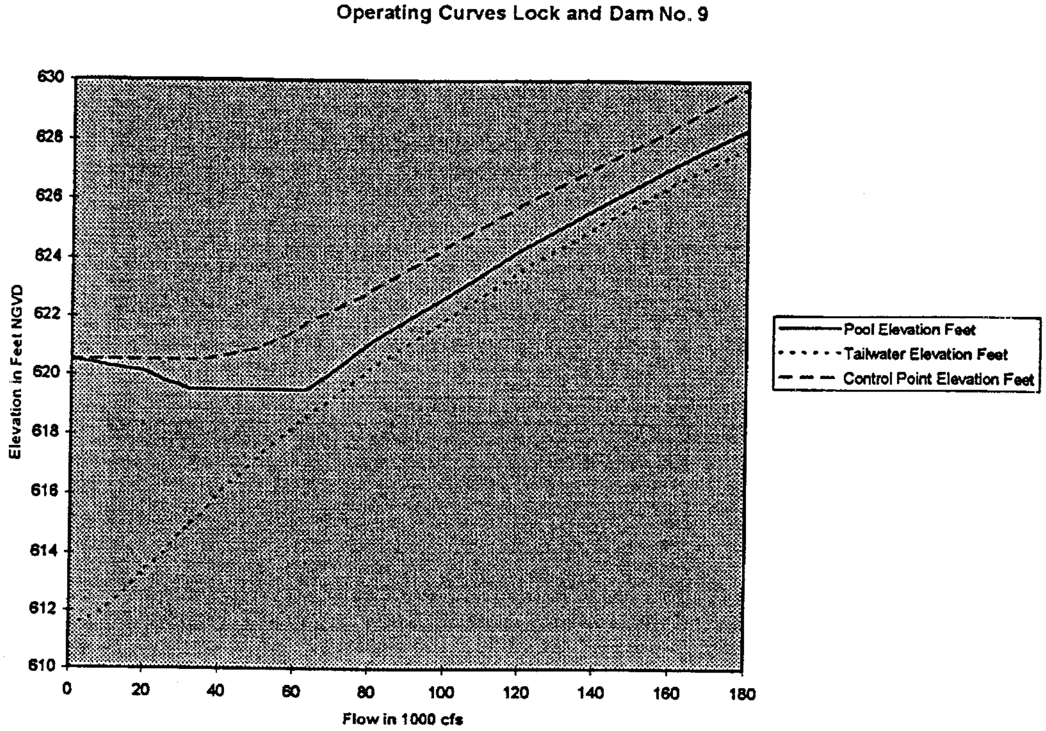

Figure 1 **Operating Rule for Lock and Dam No. 9 Pool.**

B.3 Types of Operation

The navigation dam algorithm will function under two modes of operation-simulated operation and forecast operation.

B.3.1 Simulated operation

Under simulated operation, the navigation dam algorithm will operate the dam exactly as specified in the regulation manual. Each time step, the UNET program (within the limits of calibration and computational accuracy) will exactly reproduce the target pool stage at the control point, whether the control point is at the dam or the control point is within the pool.

B.3.2 Forecast operation

Under forecast operation, the navigation dam algorithm will exactly reproduce pool stages at the dam until the forecast time. After the forecast time, the program will either:

1. Simulate the target elevations as specified by the regulation manual.
2. Simulate target pool elevations as specified by the regulator.
3. Simulate a specified outflow hydrograph as specified by the regulator.

B.4 Navigation Dam Algorithm for Simulated Operation

The navigation dam algorithm under simulated operation will exactly reproduce the operation specified in the regulation manual. The navigation dam is treated as an internal boundary condition. During low flow, a pool stage is specified that produces the specified elevation at the control point. During higher flow, when the dam is open to the river, the head loss induced by the dam is added as an added force into the momentum equation.

B.4.1 Controlled Operation

The pool stage required to achieve an elevation at a control point is given by a family of operating curves. The operating curves for a control point within the pool are shown in Figure 2. Each operating curve corresponds to a elevation of the control point. When the control point is at the dam, the rating curves are horizontal lines. The algorithm requires that the target elevation at the control point be specified; therefore, summer and winter control point elevations must be specified as well as the transition periods.

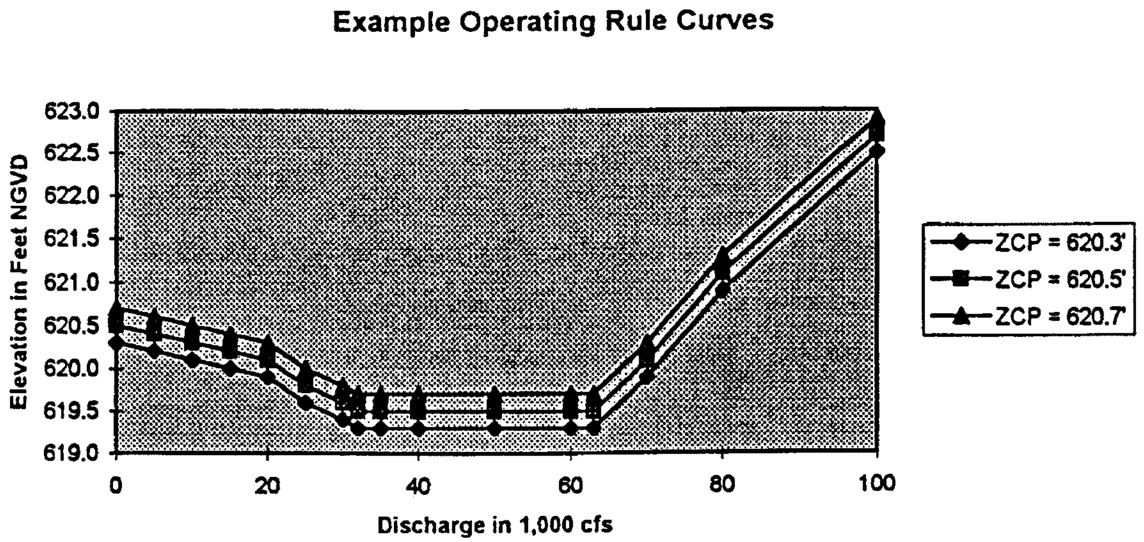

Figure 2 **Example of the operating rules for navigation dam. The three curves correspond to control point elevations of 620.3', 620.5', and 620.7'.**

During low flow, the navigation dam is treated as in internal boundary condition where the continuity and momentum equations are replaced. If cross-sections j and j+1 bound the navigation dam, the exact continuity equation is:

$$Q_j^{n+1} = Q_{j+1}^{n+1} \tag{1}$$

in which time step n+1 is at the unknown time line.

The momentum equation is replaced by:

$$z_j^{n+1} = Z_p\left(z_{target}, Q_j^n\right) \tag{2}$$

where z_j^{n+1} = the pool stage at the unknown time step, n+l.
Z_p = the pool elevation corresponding to the target elevation, z_{target}, and the flow, Q_j^n, at the known time step. The pool elevation is interpolated from the family of operation curves.

Equation 2 is missing a derivative of pool stage with respect to discharge. The derivative when multiplied by the change in flow, estimates the change in the target pool over the time step. Including this change term resulted in oscillation because of the negative slope and the discontinuities in the operating rule.

B.4.2 Head Loss from the Dam

During uncontrolled operation, the constriction of the structure induces a head loss upstream. If the structure is not influenced by backwater from a downstream tributary, the most accurate estimate of the head loss is from observed records. Otherwise the head loss must be estimated from an empirical equation.

The d'Aubuisson formula (Chow, 1956) for flow through a contraction is:

where:

$$Q^n_{j+1} = K_A b_c \left(z^n_{j+1} - z_{sp}\right)\sqrt{2g\Delta h^n + V_j^{n^2}} \tag{3}$$

Q_j^n = flow
K_A = d'Aubuisson coefficient, commonly from 0.7 to 0.9
b_c = width of the constriction
z_{sp} = elevation of the spillway crest
g = gravitational constant
Δh^n = $z_j - z_{j+1}$, head loss
V_j = upstream velocity

For the navigation dam problem, the flow, Q_j and the tailwater stage, z_{j+1} is known at time n. Equation 3 is iteratively, solved for the head loss, Δh^n. The upstream stage at time n is $z_j^n = z_{j+1}^n + \Delta h$. For the unknown time step n+1, the head loss is given by:

$$\Delta h^{n+1} = \Delta h^n + \left[\frac{\partial(\Delta h)}{\partial Q}\right]^2 \Delta Q_j + \left[\frac{\partial(\Delta h)}{\partial z_{j+1}}\right]^n \Delta z_{j+1} \tag{4}$$

where:

$\left[\frac{\partial(\Delta h)}{\partial Q}\right]^n$ = the partial derivative of head loss with respect to flow.

$\left[\frac{\partial(\Delta h)}{\partial z_{j+1}}\right]^n$ = the partial derivative of head loss with respect to tailwater stage.

The momentum equation is:

$$\frac{\partial Q}{\partial t}+\frac{\partial QV}{\partial x}+gA\left[\frac{\partial z}{\partial x}+S_f+S_h\right]=qV_1 \tag{5}$$

The head loss is inserted into the momentum equation as an added slope, in which:

$$S_h=\frac{\Delta h}{\Delta x} \tag{6}$$

Δx = distance between upstream and downstream cross-sections.

B.4.3 Uncontrolled Flow (Open River Conditions)

Open river conditions occur when the pool elevation for controlled flow is less than the tailwater elevation plus the head loss, i.e.:

$$Z_p < Z_{j+1}+\Delta h \tag{7}$$

For open river conditions, the only impact of the dam is the head loss and the momentum equation is augmented by Equation 6.

B.5 Forecast Operation

In real life the pool is not operated according to the regulation plan. Errors in estimating inflow, errors in gate rating curves, and errors in the operation of the gates all contribute to a difference between the target pool stage and the actual pool stage. The model must exactly reproduce the observed pool stages prior to the forecast time for the forecast to be valid. After the forecast time, the program simulates the navigation pool in three ways: according to the regulation manual, returning the pool to the target stages; according to pool stages entered by the regulator; or according to outflows entered by the regulator.

B.5.1 Reproduce Observed Pool Stages

The navigation dam is an observed internal boundary condition between cross-section j and j+1. The observed pool stages are entered as a boundary condition at cross-section j:

$$Z_j^{n+1} = Z_{observed} \qquad \textbf{(8)}$$

The exact continuity equation transfers the flow downstream:

$$Q_j^{n+1} = Q_{j+1}^{n+1} \qquad \textbf{(9)}$$

Equation 8 is a downstream boundary condition for the reach up to cross-section j.

The outflow from this reach is computed from the inflow and the backwater induced by the observed stage. Equation 9 transfers the outflow from the upstream reach downstream. The stage at j+1 is computed from the hydraulics of the downstream channel. Potentially, a problem can occur if the model is poorly calibrated and the downstream stage is higher than the upstream observed flow.

B.5.2 Simulation of Target Stages

Observed stages are exhausted, when the HEC-DSS missing value of -901.0 is encountered in the time series, at the forecast time. At this point, the program automatically switches over to simulating the navigation dam according to the regulation plan, as described in Section B.4. The algorithm will attempt to return the pool to the stages specified by the regulation policy. The change in pool stage, although limited by a maximum change per day, may not be the value desired by the regulator.

B.5.3 Entered Pool Stages

The observed pool stages can be extended beyond the forecast time. The time series is extended by adding a second pathname with the parameter (C-Part) of STAGE or ELEVATION. The extended values are added at the start of the missing data (DSS missing value of -901.0).

B.5.4 Entered Flow Values

The time series can be extended with entered flow values. The observed internal boundary condition switches from stage to flow at the start of the missing data. Stage data takes precedence over flow. When the stage runs out, the program switches to flow. The extended flow data can be entered by appending a second pathname with the parameter (C-Part) of FLOW, in the OBSERVED INTERNAL BOUNDARY CONDITION Record.

B.6 New Input Records

The new algorithm for navigation dams requires several new input records and records for the UNET program. In the cross-section file, new records are defined (Section B.6.1). In the boundary condition file, new records were added (Section B.6.2).

B.6.1 New Input Records in the Geometry File for Navigation Dams:

ND Record - the maximum change in daily pool stage was added to the Record.
NR Record - the operating rule for a given control point elevation.
NZ Record - seasonal variation in control point elevations.

B.6.1.1 ND Record - Navigation Dam - (Optional Record)

The ND Record defines a navigation dam. The ND Record is inserted between the cross-sections bounding the navigation dam. The record defines the geometry of the spillway, the elevation and the width of the spillway crest. If an overflow weir exists, the geometry is defined on the WD Record. If the control point elevation is constant throughout the year, the control point is defined on the ND Record; otherwise, a seasonal control point elevations can be defined on the NS Record. Finally the name of the navigation dam is defined in the tenth field. The name is used to connect the navigation dam to the OBSERVED INTERNAL BOUNDARY CONDITION Record in the BC file. The format of the ND Record is compatible with earlier versions of the UNET program.

Field	Variable	Value	Description
0	ID	ND	Record identification.
1			Not used.[1]
2			Not used.
3	ZCP	+	Target elevation of the control point.
4			Not used. [1]
5	WSP	+	Width of the spillway in feet.
6	ZSP	+	Elevation of the spillway crest in feet.
7	SH	+	Known head loss for the dam in feet. The head loss is assumed constant for the structure for both positive and negative flow.
8	CE	+	d'Aubuissons's contraction coefficient. The typical range is from 0.6 to 0.9. A value of 0.8 is frequently used for design purposes (Chow 1959, page 502).

---

[1] Field was retained for compatibility with earlier versions of the program.

Field	Variable	Value	Description
		-	Known head loss for the dam in feet. The head loss is assumed constant for the structure for both positive and negative flow. [1]
9	DZPMAX	+	Maximum allowable change in the pool elevation per day in feet. The change in pool elevation is less than DZPMAX unless the pool is approaching open river conditions.
10	SPNAM	A8	Name of the navigation dam. The name associates the dam with the observed stages or flow in an OBSERVED INTERNAL BOUNDARY CONDITION Record in the BC file.

B.6.1.2 NR Record - 0perating Rule Curve for the Navigation Dam

The NR Record defines the operating rule for navigation pool for a given control point elevation. Up to 8 of these operating curves can be defined for each structure. The operating rules are entered by control point elevation from the lowest to the highest. The curves are entered in succession. The pool elevation required to achieve the desired control point elevation is interpolated from the family of operating curves. If the operating rule is not entered, the control point is assumed to be at the dam and the navigation dam maintains the control point elevation from the ND Record at the dam. The ND Record applies to the last navigation dam entered on a ND Record.

Field	Variable	Value	Description
0	ID	NR	Record identification.
1	ZCPR(ICP)	+	Control point elevation in feet.
2	NOR(ICP)	+	Number of points in the operating rule (maximum of 10).
3	QPR(1,ICP)	+	Flow in ft^3/s.
4	ZPR(I, ICP)	+	Pool elevation in feet.
5, 7, 9	QPR(I,ICP)	+	Flow in ft^3/s
6, 8,10	ZPR(I,ICP)	+	Pool elevation in feet.

NR Records are repeated until NOR points are input.

B.6.1.3 NZ Record - Seasonal Target Elevation at the Control Point - (Optional Record)

The NZ Record defines the seasonal variation of the control point elevation at a navigation dam. A maximum of 20 points can be defined. The time ordinate is given by a military day and three character month abbreviation in capital letters; for example the April 10th is 10APR. If the NZ Record is not entered, the control point elevation defined on the ND Record is assumed constant throughout the time series. The NZ Record applies to the last navigation dam entered on a ND Record.

Field	Variable	Value	Description
0	ID	NZ	Record identification.
1,3,...	SDATE(I)	+	Military day and month (for example 10APR).
2,4,...	ZCP(I)	+	Control point elevation in feet.

B.6.2 New Input Records in the Boundary Condition file for Navigation Dams:

OBSERVED STAGE INTERNAL BOUNDARY CONDITION Record - a second pathname was added to extend the observed stage Record with stages input by a regulator.

TARGET CONTROL POINT ELEVATION Record - change the seasonal variation in control point elevations at run time.

B.6.2.1 Observed Stage Internal Boundary Condition

This data set specifies an observed time series of navigation pool water surface elevations upstream of unregulated navigation dams. The stage hydrograph can be entered using either the standard or DSS syntaxes. In a forecasting model, the observed pool elevations are used as an internal boundary condition up to the time of forecast. At this point, the ND, NR, and NZ Records in the CSECT input file provide the model with the information necessary to control the operation of the navigation dam.

The program has the ability to merge the data from two pathnames into a single time series. This capability allows the program to merge observed data with a time series of pool stages prescribed by a regulator through the forecast period. The second pathname is optional and the merging process is identified by the second pathname following the first.

Command Line: OBSERVED STAGE INTERNAL BOUNDARY

Variables:

Standard syntax:
IBC, NIBCI, (TIBCI(I), ZIBCI(I), I=I,NIBCI)

DSS syntax:
IBC (1st line)
PN (2nd line) ← Observed stage data.
PN (3rd line) ← Entered stage data (optional).

Variable	Value	Description
IBC	+	Internal boundary condition number. This number is obtained from the CSECT output file in the listing of “Navigation Dams and Spillways”. It is a counter based on the order that various internal boundary conditions are entered in the CSECT input file.
NICI	+	Number of points in the hydrograph.
TIBCI	+	Time values (hours).
ZIBCI	+	Elevation values (feet).
PN	A78	DSS pathname (left justified, must include parts A-F).

Example (Standard syntax):
OBSERVED STAGE INTERNAL BOUNDARY
2 5 24 467.2 25 467.8 26 468.5 27 467.8 28 467.2

Example of DSS syntax:
OBSERVED STAGE INTERNAL BOUNDARY
2
/OHIO/DAM26/STAGE/01 JAN1979/1HOUR/OBSERVED/

Example of DSS syntax with extended pool stages:
OBSERVED STAGE INTERNAL BOUNDARY
2
/OHIO/DAM26/POOL STAGE/01 JAN1979/1HOUR/OBS/ ← Observed
/OHIO/DAM26/POOL STAGE/01JAN1979/1HOUR/FORC/ ← Extended

B.6.2.2 Observed Stage and Flow Internal Boundary Condition

The observed stage and flow internal boundary condition is a mixed boundary condition where a stage hydrograph is inserted as the observed boundary until the stage hydrograph runs out of data; afterward a flow hydrograph is used. The end of data is identified by the HEC-DSS missing data code -901.0. The stage and flow hydrographs can either be entered in a table or can be entered from DSS. The mixed boundary condition is primarily used for forecast models where the end of stage data is the forecast time and the flow hydrograph is the flow forecast.

Command Line: OBSERVED STAGE AND FLOW INTERNAL BOUNDARY CONDITION

Variables: Standard syntax
IBC, NIBCI, (T(J), ZIBCI(J), QIBCI(J), J=1,NU)

DSS syntax
IBC (1st line)
PN (2nd line) stage
PN (3rd line) flow

Variable	Value	Description
IBC	+	Internal boundary condition number from CSECT file.
NIBCI	+	Number of hydrograph ordinates.
T(J)	+	Time values (hours).
ZIBCI(J)	+	Stage value (feet).
QIBCI(J)	+	Flow values (ft^3/s).
PN	A80	DSS pathname (left justified, must include parts A-F).

Examples (Standard syntax):

```
OBSERVED STAGE AND FLOW INTERNAL BOUNDARY CONDITION
1      4
0      451  -901
24     451   2000
48    -901   2000  ← Start using flow hydrograph
72    -901   2000
```

Example of DSS syntax:

```
OBSERVED STAGE AND FLOW INTERNAL BOUNDARY CONDITION
2
/OHIO/DAM26/POOL STAGE/01JAN1979/1HOUR/OBS/
/OHIO/DAM26/FLOW/01JAN1979/1HOUR/OBS/
```

B.6.2.3 Target Control Point Elevation

The seasonal array of target control point elevations for a navigation pool can be replaced in the boundary condition file. A maximum of 20 points can be defined. The time ordinate is given by a military day and three character month abbreviation in capital letters; for example the April 10th is 10APR.

Command Line: TARGET CONTROL POINT ELEVATION

Variables: Standard syntax
SPNAM, NIBCI, (T(J), ZIBCI(J), QIBCI(J), J=1,NU)

DSS syntax
SPNAM (1st line)
PN (2nd line) stage
PN (3rd line) flow

Variable	Value	Description
SPNAM	+	Name of the navigation dam on the ND Record.
SDATE(I)	+	Military day and month (for example 10APR).
ZCP(I)	+	Control point elevation in feet.

Example

```
TARGET CONTROL POINT ELEVATION
L&D26
01JAN   418.9
01APR   419.0
15APR   419.1
15NOV   419.0
01DEC   418.9
31DEC   418.9
```

B.7 Examples

The navigation dam algorithm was applied to the Mississippi River Navigation Dams in the St. Paul, Rock Island, and St. Louis Districts.

The definition of the Dam No. 10 and its operating rule is shown in Table 1. Pool 10 is operated as a hinge pool. From the historic record, it was observed that the pool was drawn down during the winter to an average elevation of 609.8; so the winter operating rule is entered on the first set of NR Records. The warm season operating rule, is entered on the second set of NR Records. Remember, the operating rule is entered from the lowest control point elevation to the highest. The seasonal variation of the operating rule is entered on the NZ Record. Figure 3 shows the reproduction of water years 1991 and 1992.

The operating rules will probably need to be adjusted to match the historic record, since the regulators seldom often depart from the regulation manual. Therefore, if the computed pool stage differs from the observed record, adjust the operating rule accordingly.

The definition of Dam 11, in the Rock Island District, is shown in Table 2. Dam 11 has its control point at the dam; therefore, an operating rule (NR Record) is not required.

The target pool elevation is 603.0' during the warm season and 602.5' during the winter season. The seasonal variation is defined on the NZ Record. Figure 4 shows the reproduction of calendar year 1986.

Figure 5 shows the simulation of Lock and Dam 14 pool for calendar year 1986. Pool 14 operated as a hinge pool. The dam was coded in a manner similar to Dam 10. Figure 6 shows the simulation of Lock and Dam 24 pool for calendar year 1986. The operating rule for Dam 24 was calibrated by trial and error to reproduce the pool stage hydrograph.

Table 1
Definition of Dam 10 and its operating rule.

```
X1615.20      36      .0  1210.0   520.0   520.0   520.0     .00    0.00       0
Z0   -.5
OH HISTMISS://DAM10-POOL/ELEV/01JAN1989/1DAY//
HY LD10HW
KR \SPMISS\RC\HSPMS:/MISSISSIPPI RIVER/DAM10_POOL/STAGE-FLOW/65 & 90 TO 94//OBS/
GR629.50      .0  591.00      .0  590.80    10.0  580.80    60.0  583.00   150.0
GR581.30   235.0  579.30   270.0  578.60   355.0  583.50   435.0  582.50   475.0
GR587.20   555.0  588.20   710.0  586.50   750.0  588.00   830.0  585.80   900.0
GR585.20   970.0  595.00  1125.0  590.10  1170.0  600.50  1210.0  602.30  1350.0
GR603.10  1505.0  599.50  1660.0  600.10  1720.0  603.50  1820.0  599.50  1855.0
GR599.50  2250.0  604.50  2280.0  604.50  2510.0  599.50  2550.0  599.50  2750.0
GR604.50  2780.0  604.50  4980.0  604.50  5680.0  599.50  5690.0  599.50  6700.0
GR629.50  6820.0     .00      .0     .00      .0     .00      .0     .00      .0
KR OFF

* L&D 10; POOL STAGE = 610.5
* R.M. 615.1
ND         610.5                                                     -.2   L&D10
* Operating rule for winter
NR       2   609.8       0   609.8   89000   609.8
* Operating rule for summer
NR       8   610.5       0   610.5   40000   610.5   43000   610.5   45000  610.35
NR 50000     610   52500   609.5   78000   609.5   89000   610.5
* Seasonal variation of the operating rule
NZ 28MAR   609.8   01APR   610.5   28NOV   610.5   01DEC   609.8

*
* POOL 11 POL ELEVATION 603.00
*
*  STARTING ELEV IN PROP TABLE = ELSTRT - RISE = 598
*          RISE  ELSTRT
XK           50     648            2.25
X1     1

NC 0.150   0.080   0.028
X1 614.9      40 10000.0 11050.0  1000.0  1000.0  1000.0    0.00    0.00       0
Z0   -.5
OH HISTMISS://DAM10-TAIL/ELEV/01JAN1989/1DAY//
HY L&D 10 TW
KR \SPMISS\RC\HSPMS:/MISSISSIPPI RIVER/DAM10_TW/STAGE-FLOW/65 & 90 TO 94//OBS/
GR650.00  4200.0  630.00  4250.0  620.00  4400.0  615.00  4450.0  604.00  4500.0
GR595.00  4600.0  595.00  5500.0  604.00  5620.0  612.00  5650.0  612.00  5920.0
GR610.00  6000.0  610.00  6250.0  610.00  6470.0  610.00  6700.0  612.00  6710.0
GR612.00  7650.0  606.00  7700.0  604.00  7720.0  600.00  7850.0  604.00  7940.0
GR606.00  7950.0  606.00  8020.0  608.00  8050.0  608.00  8220.0  608.00  8610.0
GR606.00  8880.0  604.00  8900.0  600.00  9000.0  600.00  9300.0  604.00  9340.0
GR608.00  9350.0  608.00  9650.0  606.00  9950.0  604.00 10000.0  586.00 10200.0
GR586.00 10900.0  604.00  1105.0  620.00 12600.0  630.00 13400.0  650.00 13500.0
```

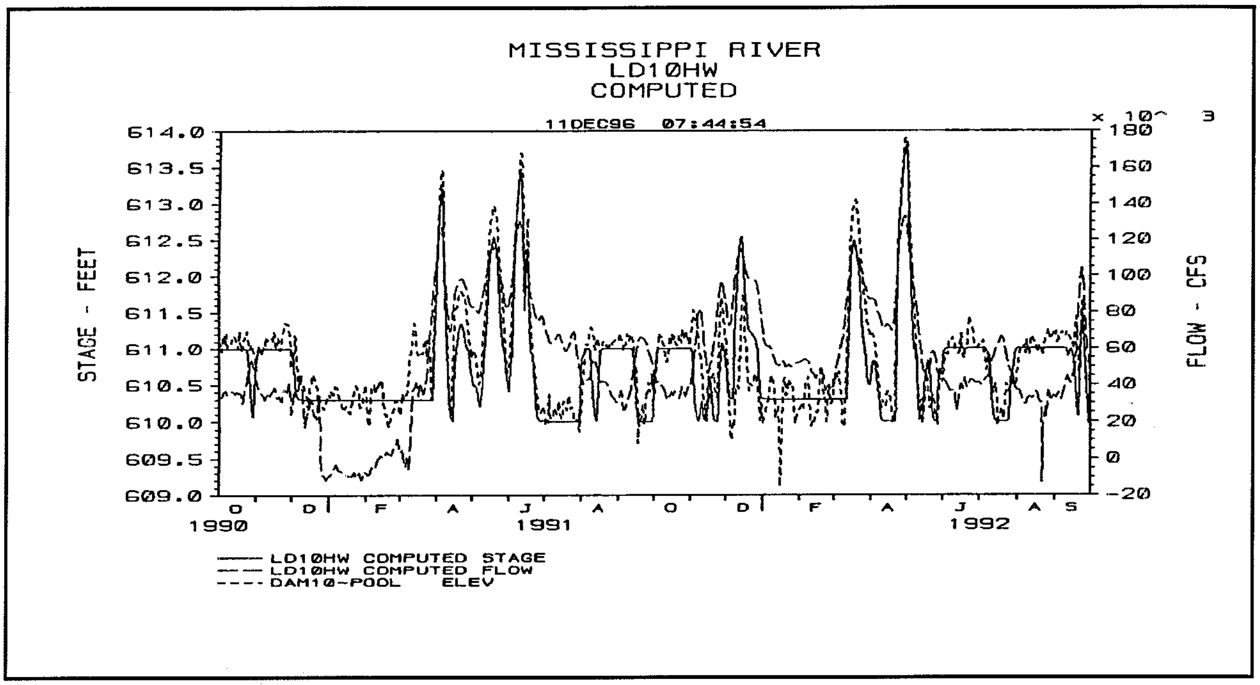

Figure 3 **Computed and observed pool stage hydrograph for Lock and Dam 10 for water years 1991 and 1992.**

Table 2
Definition of Lock and Dam 11.

The dam has its control point at the dam; therefore no operating rule is required. The seasonal variation of the control point elevation is defined on the NZ Record.

```
X1 583.0       17     1025     7000      3500     2100      2450
KR \RIMISS\MISSRC:/MISSISSIPPI RIVER/L&D 11 POOL/STAGE-FLOW/CY 93//COMPUTED/
OH \RIMISS\MISS:/MISSISSIPPI BASIN/L&D 11 POOL/ELEV//1DAY/MISSISSIPPI RIVER/
HY L&D 11 POOL - RM 583.0
GR 650.0        0    640.0       25     630.0       50    620.0      175   610.0
     975
GR 603.0     1025    594.4     5285     574.2     5825    569.1     6185   570.8
    6305
GR 560.7     6505    581.7     6665     579.0     6785    603.0     7000   610.0
    7025
GR 640.0     7100    650.0     7150        .0        0       .0        0      .0
       0
* L&D 11; POOL STAGE = 603
* R.M. 583.0
ND                603.0                1080      583.0    602.6      -0.4
* Seasonal variation of the control point
NZ  12MAR 602.5   15MAR 603.0  07DEC 603.0   10DEC 602.5

*
* POOL 12 POOL ELEVATION 592.00
*
* STARTING ELEV IN PROP TABLE = ELSTRT - RISE = 587
*          RISE   ELSTRT
XK           50      637             2.25
XI    .5

KR OFF
X1 582.6       26     4400     5575      6700     4700      6250
KR \RIMISS\MISSRC:/MISSISSIPPI RIVER/L&D 11 TAIL/STAGE-FLOW/CY 93//COMPUTED/
X3    0.        0.      .00       0.       .00    5700.  -999.00       .00     .00
OH \RIMISS\MISS:/MISSISSIPPI BASIN/L&D 11 TAIL/ELEV//1DAY/MISSISSIPPI RIVER/
HY L&D 11 TAIL - RM 582.6
```

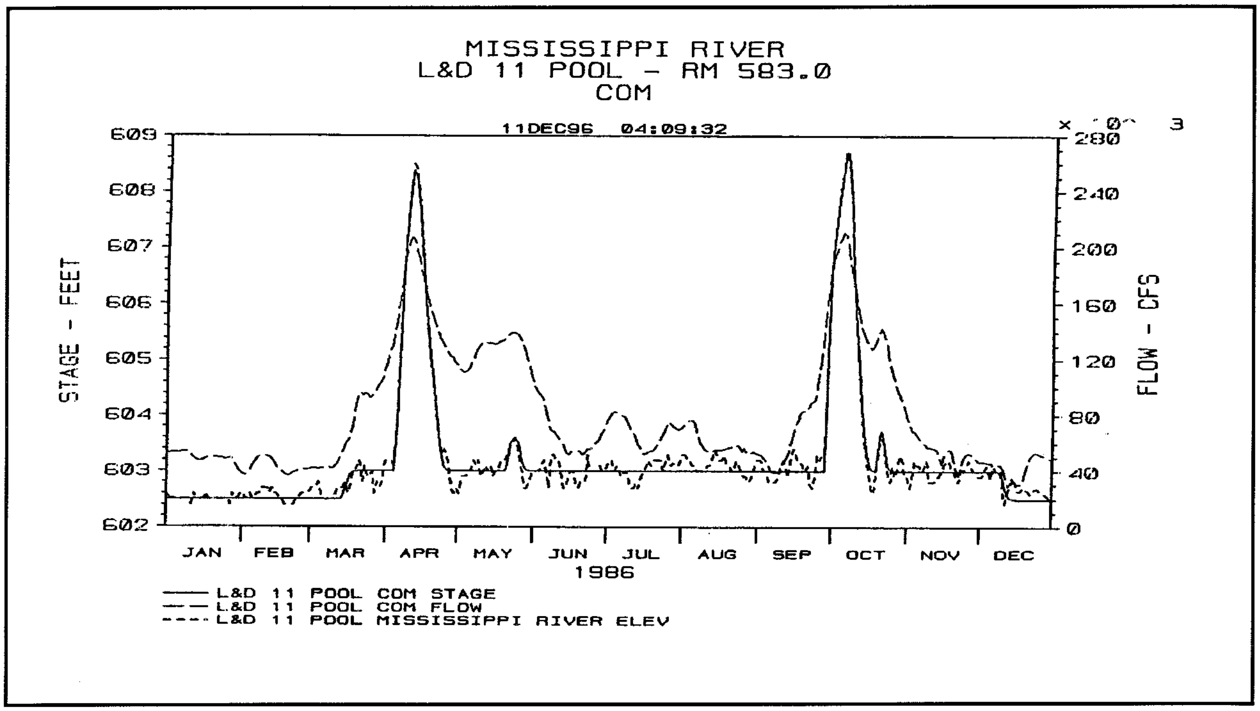

Figure 4 Computed and observed pool stage hydrograph for Lock and Dam 11 for calendar year 1986.

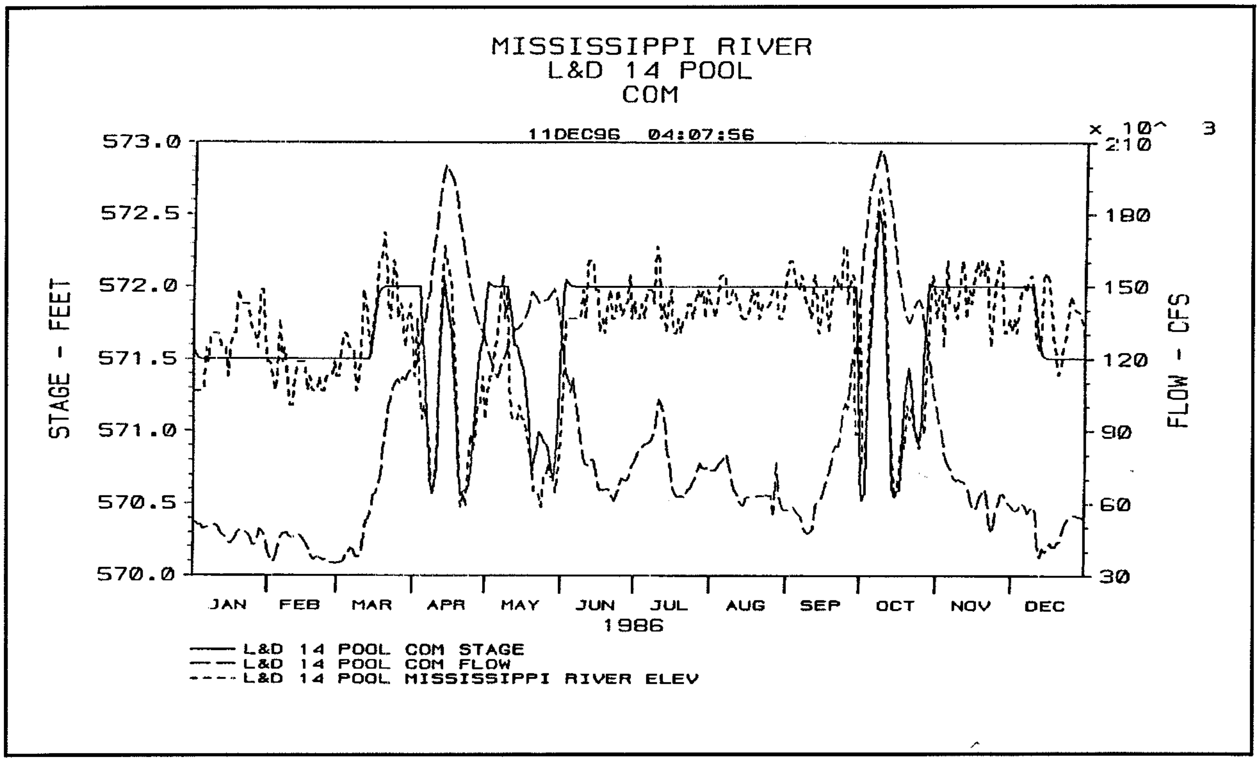

Figure 5 Computed and observed pool stage hydrograph for Lock and Dam 14 for calendar year 1986.

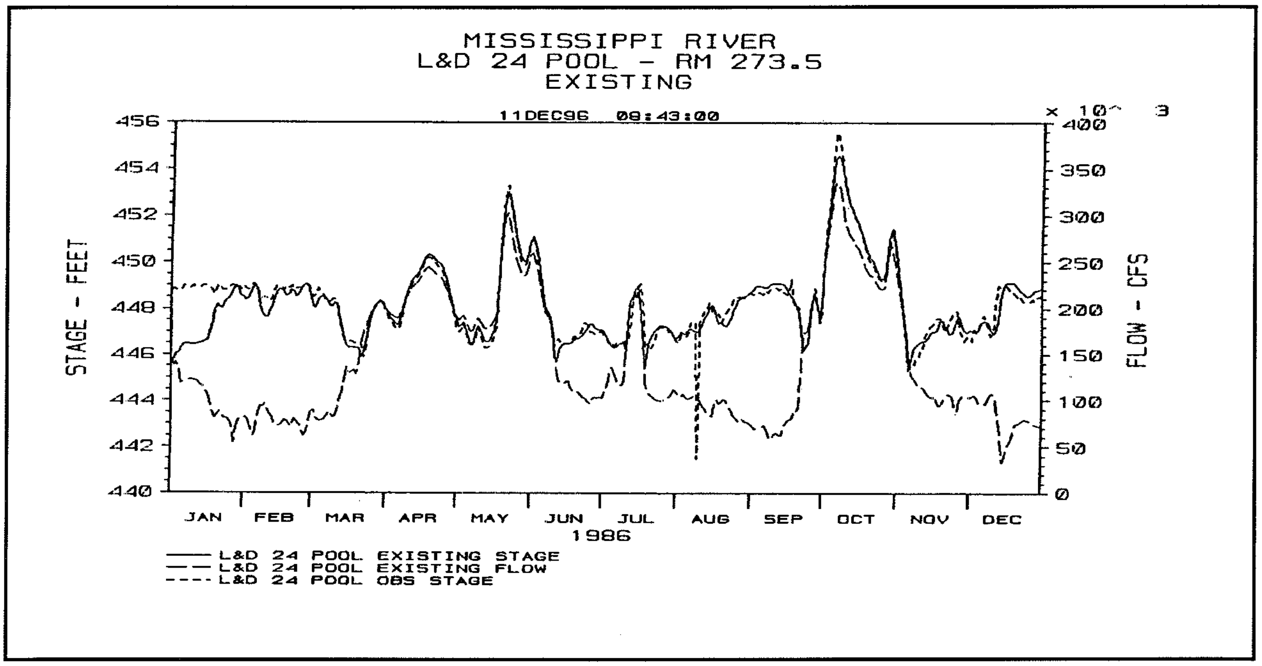

Figure 6 Computed and observed pool stage hydrograph for Lock and Dam 24 for calendar year 1986. The operating rule for Dam 24 was calibrated from observed pool data.

B.8 References

Chow, V.T., 1956. *Open Chanel Flow.* MCGraw Hill Book Company, New York.

Appendix C

Null Internal Boundary Condition

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FIGURES

TABLES

C.1 The Estimation of Ungaged Inflow Using the Null Internal Boundary Condition

The Null Internal Boundary Condition (NIBC) is a tool for estimating ungaged lateral inflow in a river system. The NIBC is inserted between two identical cross-sections that overlay one another. The NIBC assumes that the stage and flow at the two cross-sections are the same; hence, if the upstream cross-section is number j, then

$$Z_j^n = Z_{j+1}^n \quad \textbf{(1)}$$

$$Q_j^n = Q_{j+1}^n \quad \textbf{(2)}$$

in which:

Z = stage
Q = flow

If an observed stage hydrograph is specified for NIBC, the river routing reach is effectively broken into two routing reaches. The stage hydrograph is used as the downstream boundary for the upstream reach and the stage hydrograph is used as the upstream boundary for the downstream reach; cross-sections j and j+1 are downstream and upstream boundaries respectively. For the upstream reach, the flow at j is the routed flow from upstream. Since the ungaged inflow is unknown and not entered, the flow at j is missing the ungaged inflow. For the downstream reach, the flow at j+1 from a stage boundary condition is computed from the hydrodynamics and the geometry reach downstream. This flow does contain the ungaged inflow. Hence, the unaged inflow is simply the difference between the flow at j and the flow at j+1,

$$Q_U^n = Q_{j+1}^n - Q_j^n \quad \textbf{(3)}$$

in which

Q_u = ungaged inflow

This ungaged inflow is from the upstream boundary of the upstream reach to cross-section j, effectively the downstream boundary. To use the ungaged inflow in a model, the flow is lagged backward in time (usually one day) and inserted in the model as a uniform lateral inflow.

For a reach of river of any length, the NIBC is inserted at the principal gage locations where the stage records are the most accurate. Generally, these locations are the USGS gaging stations. If a reach includes k interior gages, inserting NIBC at each of the gages creates k independent routing reaches. The independence of the routing reaches is important, because, the system must be solved only once for all the ungaged inflow hydrographs. For example, Figure 1 shows the Missouri River between Rulo, Nebraska and St. Charles, Missouri. NIBC's are inserted at the USGS gages at St. Joseph, Kansas City, Waverly, Boonville, and Hermann, breaking the model into five independent routing reaches. Inflow from tributaries do not affect the calculations; although backwater from a large tributary downstream from a NIBC will affect the accuracy of the calculations.

The NIBC is inserted using the NI Record, which is described in Section C.2, between cross-section j and j+1. Cross-section j is a repeat of cross-section j+1 and the reach length between the cross-sections is zero. The only parameter on the NI Record is an eight character name which uniquely defines the name of the NIBC when attaching an observed stage hydrograph in the boundary condition file. HY Records must be inserted at cross-sections j and j+1 to define output hydrographs. Table 1 shows the definition of a NIBC at Boonville. The name on this station on the NI Record is BOON. The OH Records upstream and downstream attach the USGS hydrograph to the plot macro.

The observed stage hydrograph is entered using the OBSERVED STAGE HYDROGRAPH Record in the boundary condition file. A description of the record is shown in Section C.3. Table 2 shows the definition of OBSERVED STAGE HYDROGRAPH Record for the Boonville NIBC. The name of the station, BOON, is entered on the second line before the DSS pathname. The gage zero is entered using the ZERO=parameter.

For our example problem, Figure 2 compares the routed flow hydrograph upstream of the NIBC with the USGS observed flow hydrograph. This hydroraph does not include ungaged lateral inflow. Figure 3 compares the computed hydrograph, the USGS flow hydrograph, and the USGS flow measurements downstream of the NIBC. Since the model is well calibrated, the computed hydrograph almost exactly matches the USGS flow hydrograph and the observed flow measurements.

The ungaged inflow hydrograph is estimated by subtracting the routed hydrograph from the computed hydrograph and lagging the ungaged hydrograph backward one day. This operation is performed by the DSSMATH program. The input file for DSSMATH is shown in Table 3.

The ungaged flow is entered as a uniform lateral inflow from Waverly, the upstream boundary of the reach, and Boonville. Figure 4 shows the routed flow hydrograph, USGS observed flow hydrograph, and the observed flow measurements at Boonville. The agreement is nearly exact. Figure 5 shows the computed stage hydrograph at Boonville. The agreement in stage is also very good because of the exact reproduction of flow. The routed flow and stage hydrographs for Rulo, St. Joseph, Kansas City, Waverly, and Hermann are included in Section C.4.

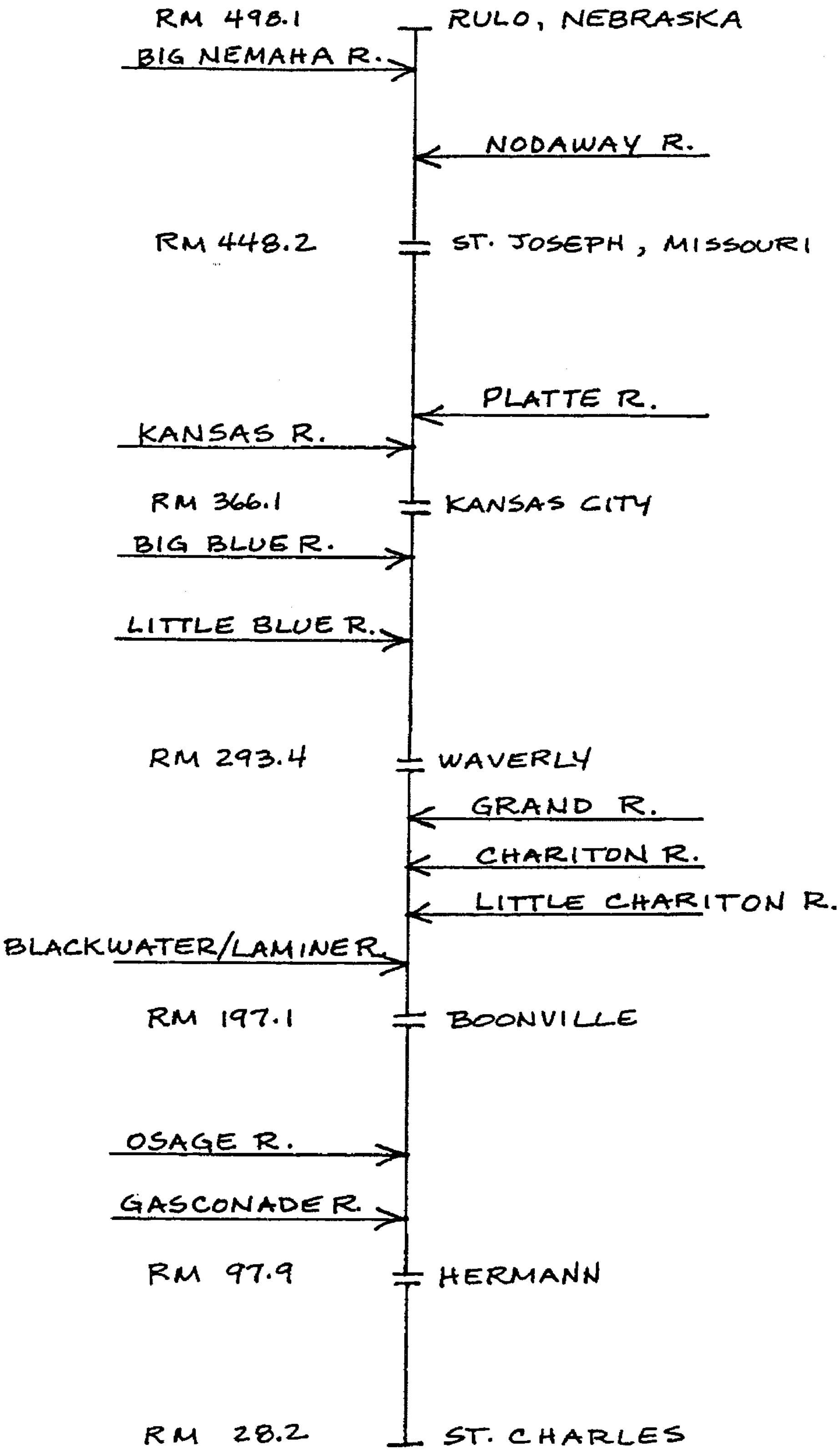

Figure 1. Missouri River between Rulo and St. Charles. NIBC's are located at St. Joseph, Kansas City, Waverly, Boonville, and Hermann, breaking the system into six routing reaches.

Table 1

Null Interior Boundary Condition at Boonville.

The cross-section at Boonville was repeated and NI Record was inserted between the cross-sections. The name of the NIBC on the NI Record was BOON.

```
NC .0500    .05000    .02100
X 1197.22       94    19520.    21060.       1         1         1
KR \KCMO\FORECAST\RC\MORRC:/MISSOURI RIVER/BOONVILLE/STAGE-FLOW//1993-PRES/EST/
OH \KCMO\MOR.DSS:/MISSOURI RIVER/BOONVILLE/STAGE/01JUN1992/6HOUR/CORP/
ZO  565.4
HY  BOONVILLE
X3    -12       0.       .00     18621.  -900.99       0.       .00        3        3
GR 640.0     8050.     620.0      8160.   612.0     8240.     605.7     8330.    593.2     8780.
GR 594.8     8950.     597.2      9130.   598.2     9320.     597.6     9550.    602.0     9700.
GR 593.5     9770.     595.3     10110.   592.0    10580.     588.0    10860.    592.0    11190.
GR 590.0    11560.     593.2     11880.   590.9    12130.     593.2    12500.    592.0    12600.
GR 590.0    13150.     588.0     13170.   588.0    13260.     590.0    13500.    585.5    13680.
GR 589.7    14280.     589.5     14800.   589.3    15270.     600.0    15500.    600.0    16000.
GR 600.0    16500.     600.0     17000.   600.0    17500.     600.0    18000.    600.0    18500.
GR 600.0    19000.     594.4     19520.   583.5    19610.     586.2    19710.    589.0    19850.
GR 581.0    19850.     546.3     19962.   548.6    19981.     555.9    20002.    558.9    20022.
GR 556.5    20042.     556.1     20061.   556.2    20082.     556.0    20102.    553.3    20123.
GR 546.8    20143.     543.4     20160.   541.7    20183.     542.6    20202.    550.2    20224.
GR 558.3    20247.     557.2     20266.   547.2    20288.     534.1    20311.    534.3    20332.
GR 532.2    20353.     538.8     20373.   545.9    20393.     550.1    20413.    551.1    20433.
GR 555.2    20454.     556.7     20474.   556.3    20494.     557.1    20514.    555.6    20534.
GR 558.3    20554.     559.1     20574.   559.5    20594.     559.3    20614.    559.7    20634.
GR 556.9    20654.     558.4     20671.   559.8    20694.     558.8    20714.    558.9    20734.
GR 557.6    20754.     558.2     20774.   558.7    20795.     560.0    20813.    559.4    20836.
GR 557.3    20857.     556.3     20877.   555.8    20899.     557.2    20919.    558.1    20938.
GR 581.0    21020.     589.0     21020.   600.0    21060.     640.0    21150.

NI  BOON

KR  OFF
X 1197.22       94    19520.    21060.    1282.     1282.     1426.
KR \KCMO\FORECAST\RC\MORRC:/MISSOURI RIVER/BOONVILLE/STAGE-FLOW//1993-PRES/EST/
OH  \KCMO\MOR.DSS:/MISSOURI RIVER/BOONVILLE/FLOW/01JUN1992/1DAY/OBS/
ZO  565.4
HY  BOONVILLE DS
X3    -12       0.       .00     18621.  -900.99       0.       .00        3        3
GR 640.0     8050.     620.0      8160.   612.0     8240.     605.7     8330.    593.2     8780.
GR 594.8     8950.     597.2      9130.   598.2     9320.     597.6     9550.    602.0     9700.
GR 593.5     9770.     595.3     10110.   592.0    10580.     588.0    10860.    592.0    11190.
```

Table 2

Insertion of an Observed Hydrograph for the NIBC at Boonville into the UNET Boundary Consition File.

The name BOON agrees with the name defined on the NI Record.

```
ZERO=565.4
OBSERVED INTERNAL BOUNDARY CONSITION AT BOONVILLE
BOON
/MISSOURI RIVER/BOONVILLE/STAGE//1DAY/CORP/
```

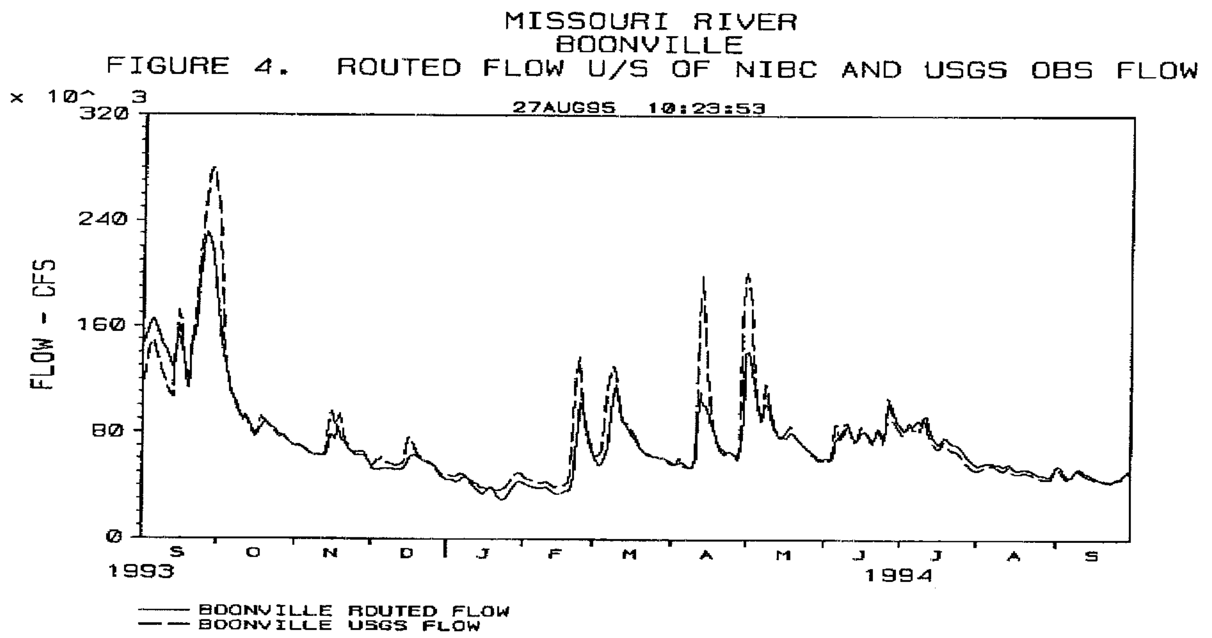

Figure 2 Routed flow upstream of the NIBC at Boonville. The routed flow is compared to the USGS observed flow hydrograph. The difference is the ungaged lateral inflow.

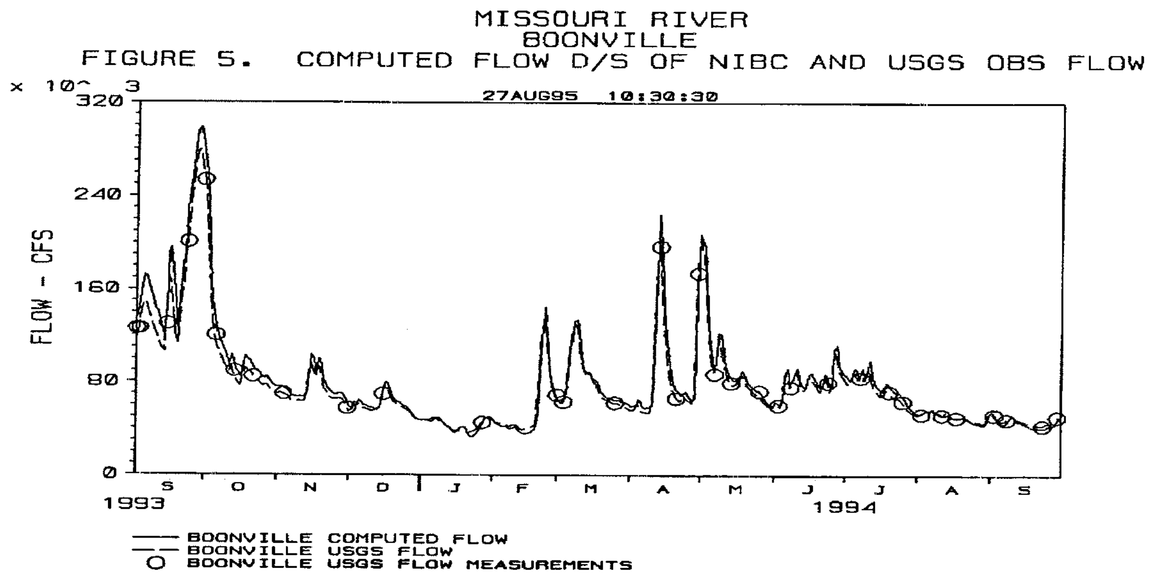

Figure 3 Computed flow downstream of the NIBC at Boonville. The computed flow is compared to the USGS observed flow and the USGS flow measurements at the gage. The computed flow is the flow required to reproduce the stages at the Boonville gage using the model with the current calibration.

Table 3
Input File for DSSMATH that Determines Ungaged Lateral Inflow at St. Joseph, Kansas City, Waverly, Boonville, and Hermann.

The program subtracts the computed flow hydrograph upstream of the NIBC from the computed flow hydrograph downstream of the NIBC and lags the result backward one day. The lagged hydrograph is an estimate of the ungaged local flow.

```
OPEN MOON
TI   01SEP1993  0700  31DEC1994  0700
**
**   RULO TO ST. JOSEPH
**
GET   QUS=MOON:/MISSOURI RIVER/ST. JOSEPH/FLOW//1DAY/COMPUTED/
GET   QDS=MOON:/MISSOURI RIVER/ST. JOSEPH DS/FLOW//1DAY/COMPUTED/
COM  QDIFF-QDS-QUS
COM  QLAT=TSHIFT (QDIFF, -1D)
PUT A QLAT=\KCMO\MOR:/MISSOURI RIVER/RULO TO STJ/UG FLOW//1DAY/EST/
TA QUS QDS QDIFF QLAT
CLEAR ALL
**
**   ST. JOSEPH TO KANSAS CITY
**
GET   QUS=MOON:/MISSOURI RIVER/KANSAS CITY/FLOW//1DAY/COMPUTED/
GET   QDS=MOON:/MISSOURI RIVER/KANSAS CITY DS/FLOW//1DAY/COMPUTED/
COM  QDIFF=QDS-QUS
COM  QLAT=TSHIFT (QDIFF, -1D)
PUT A QLAT=\KCMO\MOR:/MISSOURI RIVER/STJ TO KC/UG FLOW//1DAY/EST/
TA QUS QDS QDIFF QLAT
CLEAR ALL
**
**   KANSAS CITY TO WAVERLY
**
GET   QUS=MOON:/MISSOURI RIVER/WAVERLY/FLOW//1DAY/COMPUTED/
GET   QDS=MOON:/MISSOURI RIVER/WAVERLY DS/FLOW//1DAY/COMPUTED/
COM  QDIFF=QDS-QUS
COM  QLAT=TSHIFT (QDIFF, -1D)
PUT A QLAT=\KCMO\MOR:/MISSOURI RIVER/KC TO WAV/UG FLOW//1DAY/EST/
TA QUS QDS QDIFF QLAT
CLEAR ALL
**
**   WAVERLY TO BOONVILLE
**
GET   QUS=MOON:/MISSOURI RIVER/BOONVILLE/FLOW//1DAY/COMPUTED/
GET   QDS=MOON:/MISSOURI RIVER/BOONVILLE DS/FLOW//1DAY/COMPUTED/
COM  QDIFF=QDS-QUS
COM  QLAT=TSHIFT (QDIFF, -1D)
PUT A QLAT=\KCMO\MOR:/MISSOURI RIVER/WAV TO BOON/UG FLOW//1DAY/EST/
TA QUS QDS QDIFF QLAT
CLEAR ALL
**
**   BOONVILLE TO HERMANN
**
GET   QUS=MOON:/MISSOUR RIVER/HERMANN/FLOW//1DAY/COMPUTED/
GET   QDS=MOON:/MISSOURI RIVER/HERMANN DS/FLOW//1DAY/COMPUTED/
COM  QDIFF=QDS-QUS
COM  QLAT=TSHIFT (QDIFF, -1D)
PUT A QLAT=\KCMO\MOR:/MISSOURI RIVER/BOON TO HERM/UG FLOW//1DAY/EST/
TA QUS QDS QDIFF QLAT
CLEAR ALL
**
```

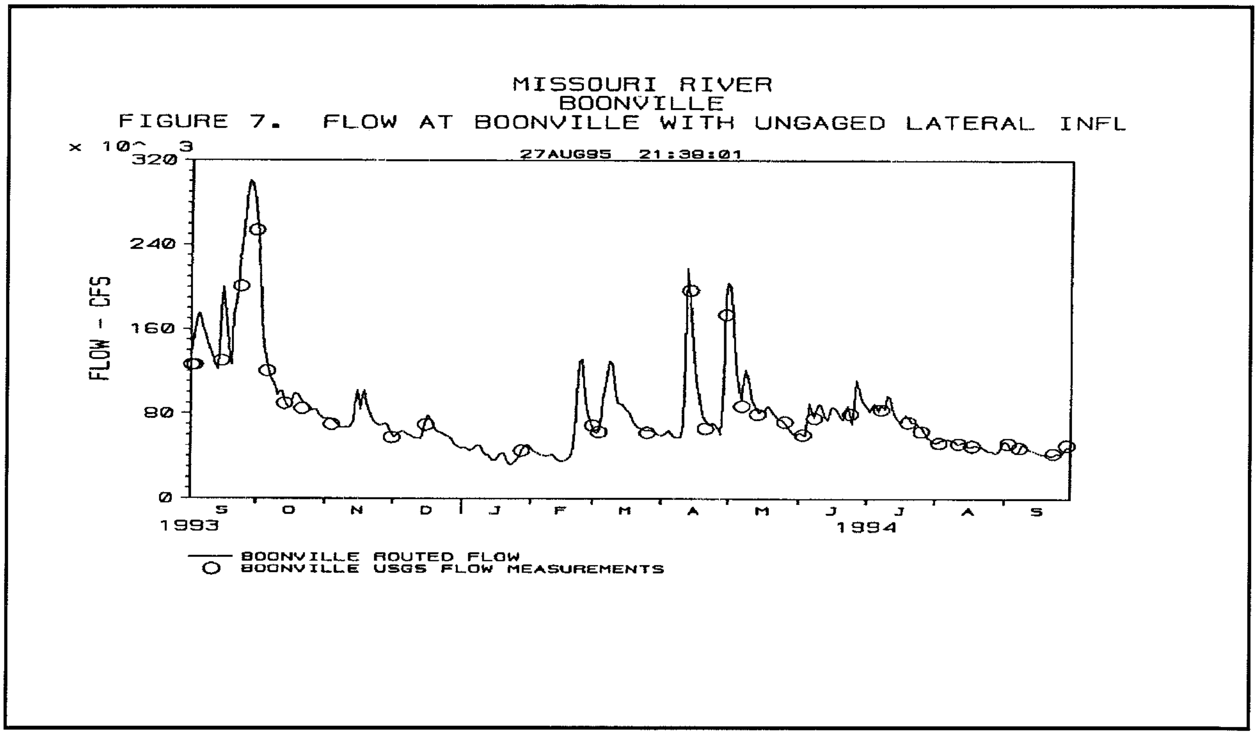

Figure 4 Computed flow at Boonville with ungaged inflow. The flow hydrograph is compared to the observed USGS discharge measurements.

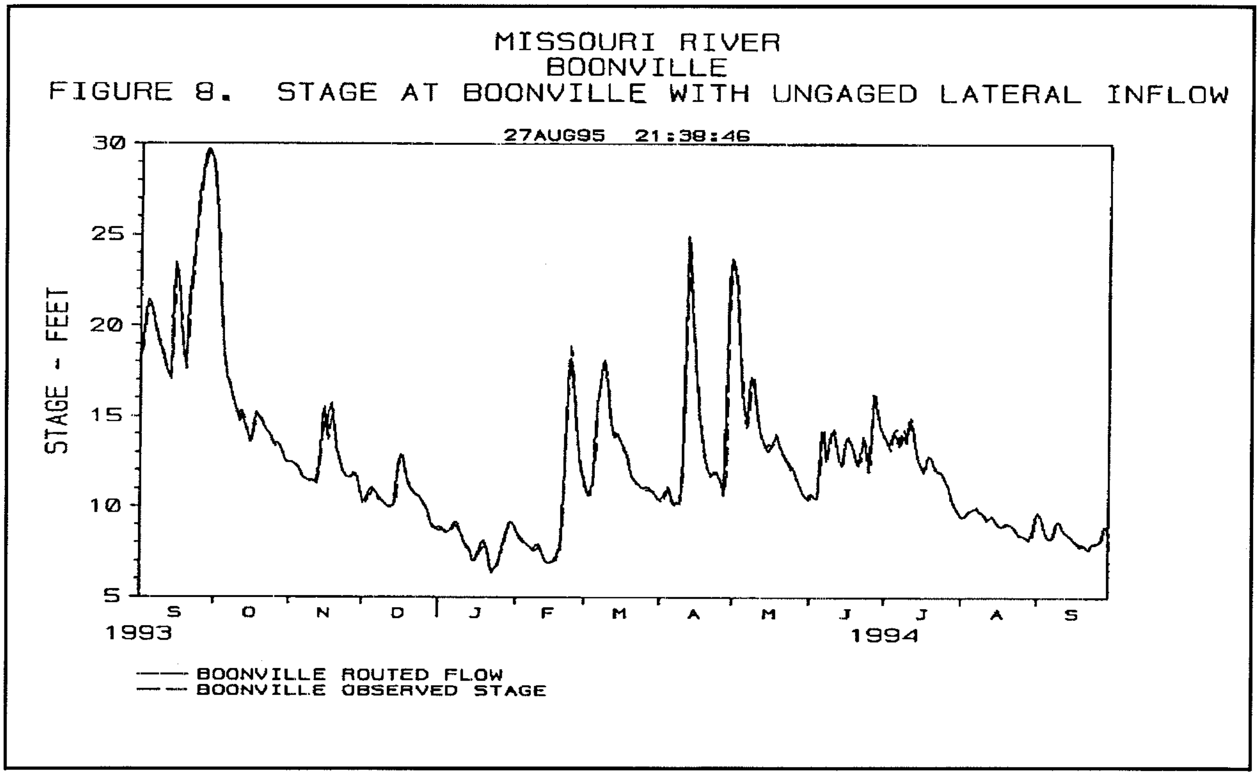

Figure 5 Computed stage at Boonville with ungaged lateral inflow. The hydrograph is compared to the observed stage hydrograph.

C.2 NI Record Null Internal Boundary Condition

The NI Record defines a null internal boundary condition (NIBC) connecting two cross-sections. The NIBC assumes that the flow and stage at the cross-sections are identical. The NIBC is used in conjunction with an OBSERVED INTERNAL BOUNDARY CONDITION Record in the boundary condition file.

Field	Variable	Value	Description
0	ID	NC	Record identification.
1	IBCNAME	alpha	Name of the NIBC

C.3 Observed Stage Internal Boundary Condition

This data set specifies an observed time series of navigation pool water surface elevations upstream of unregulated navigation dams. The stage hydrograph can be entered using either the standard or DSS syntaxes. In a forecasting model, the observed pool elevations are used as an internal boundary condition up to the time of forecast. At this point, the ND and CP Records in the CSECT input file provide the model with the information necessary to control the hinge point operation of the navigation dam.

Command Line: OBSERVED STAGE INTERNAL BOUNDARY

Variables: Standard syntax:
IBCNAME, NIBCI, (TIBCI(I), ZIBCI(I), I=1, NIBCI)

DSS syntax:
IBCNAME (1st line)
PN (2nd line)

Variable	Value	Description
IBCNAME	+	Internal boundary name. This eight character name is entered on the SP, LS, LA, ND, or NI Record in the cross-section file.
NIBCI	+	Number of points in the hydrograph.
TIBCI	+	Time values (hrs).
ZIBCI	+	Navigation pool elevation values (ft).

Variable	Value	Description
PN	A78	DSS pathname (left justified, must include parts A-F)

Example (DSS syntax):
OBSERVED STAGE INTERNAL BOUNDARY
DAM26
/OHIO/DAM26/STAGE/01JAN1979/1HOUR/OBSERVED/

C.4 Computed Flow and Stage Hydrograph at Principal Missouri River Stations

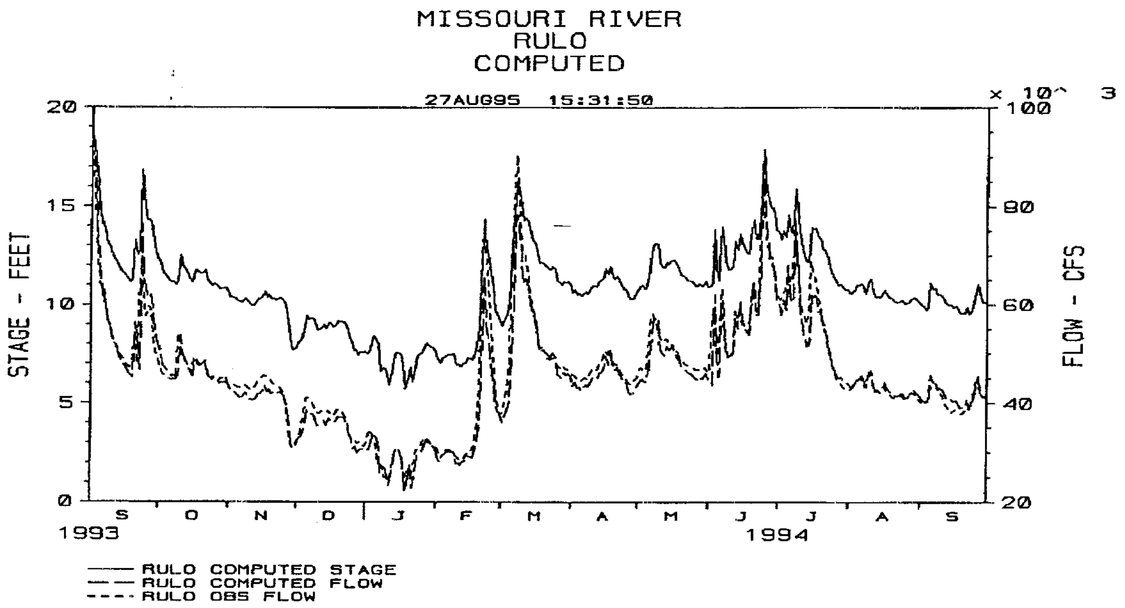

Figure 6 RULO Computed.

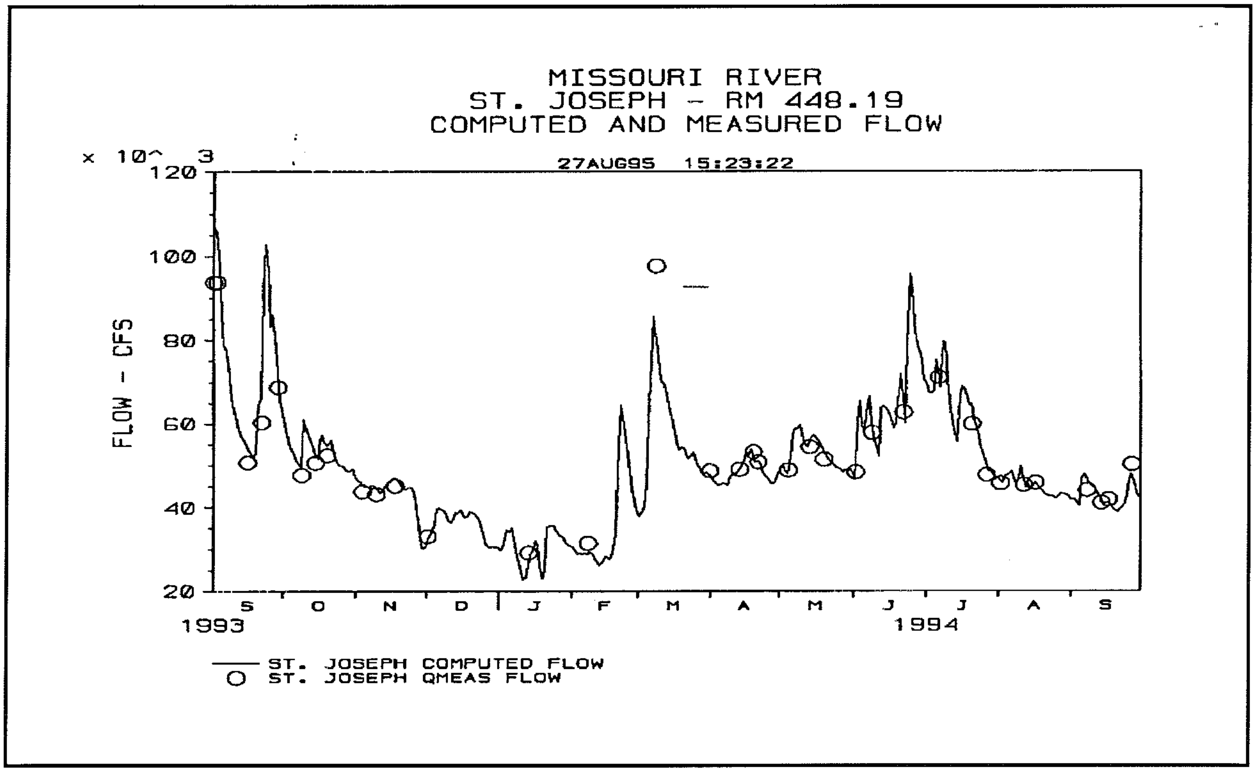

Figure 7 St. Joseph Computed and Measured Flow.

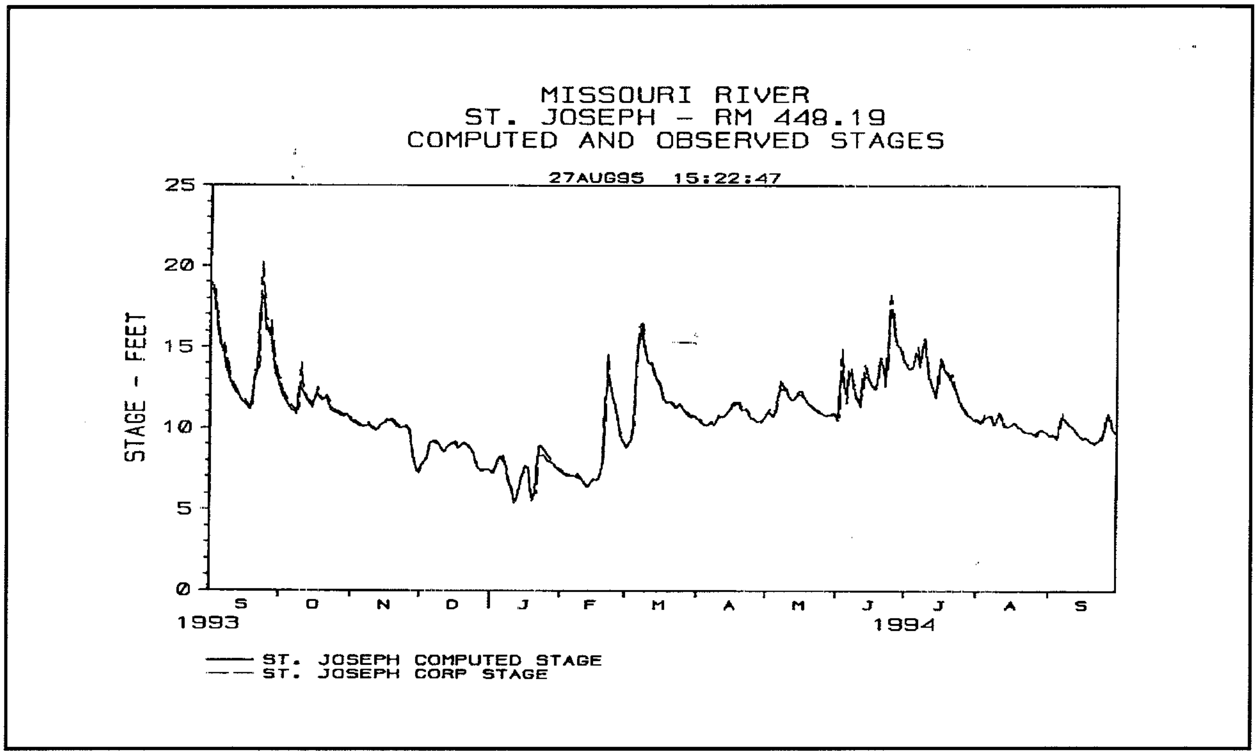

Figure 8 St. Joseph Computed and Observed Stages.

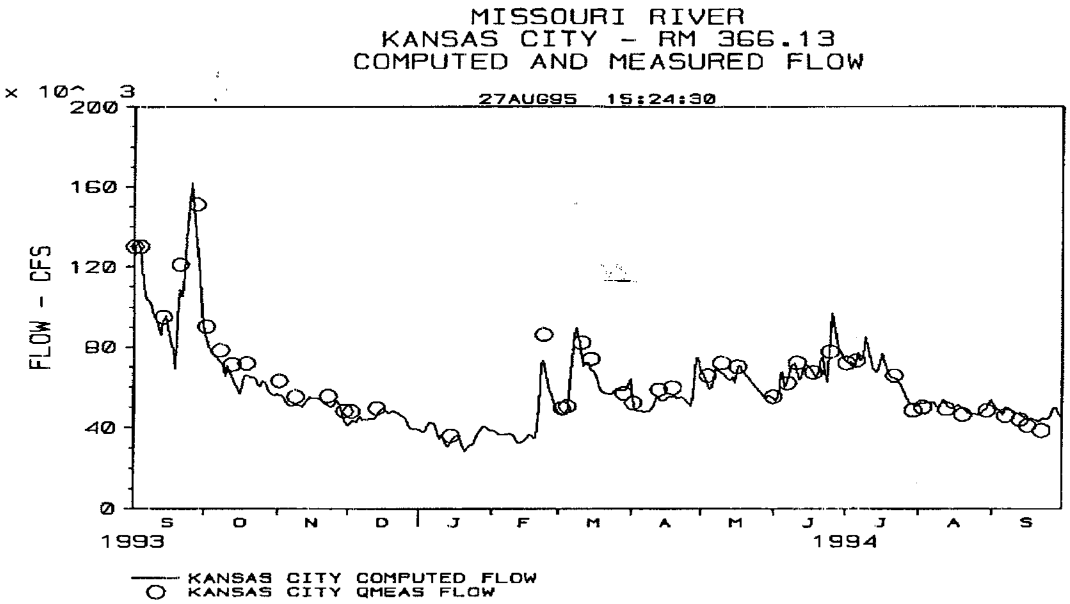

Figure 9 Kansas City Computed and Measured Flow.

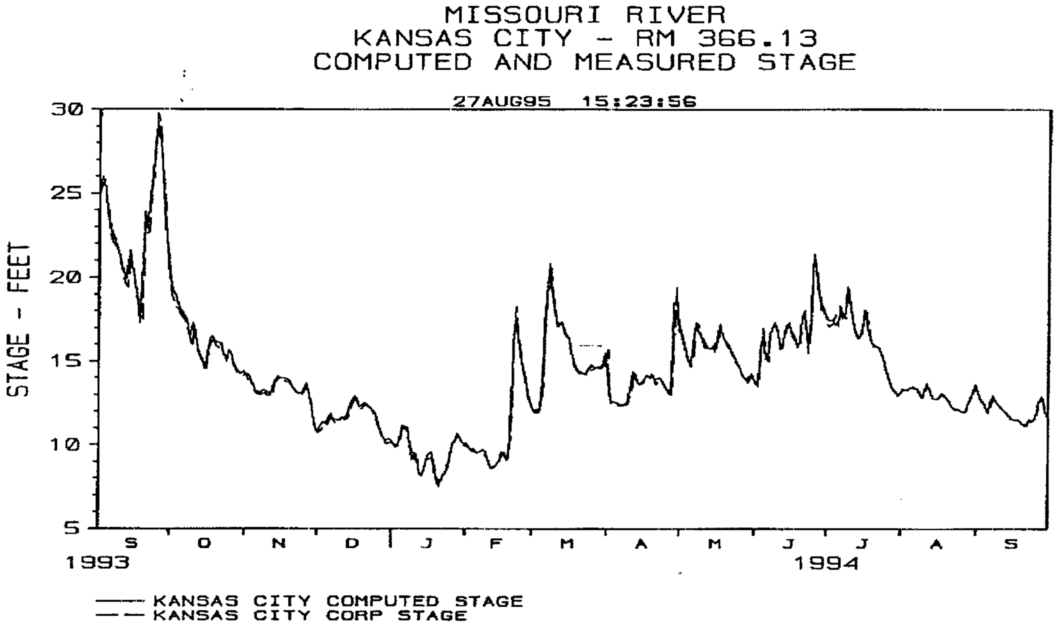

Figure 10 Kansas City Computed and Measured Stage.

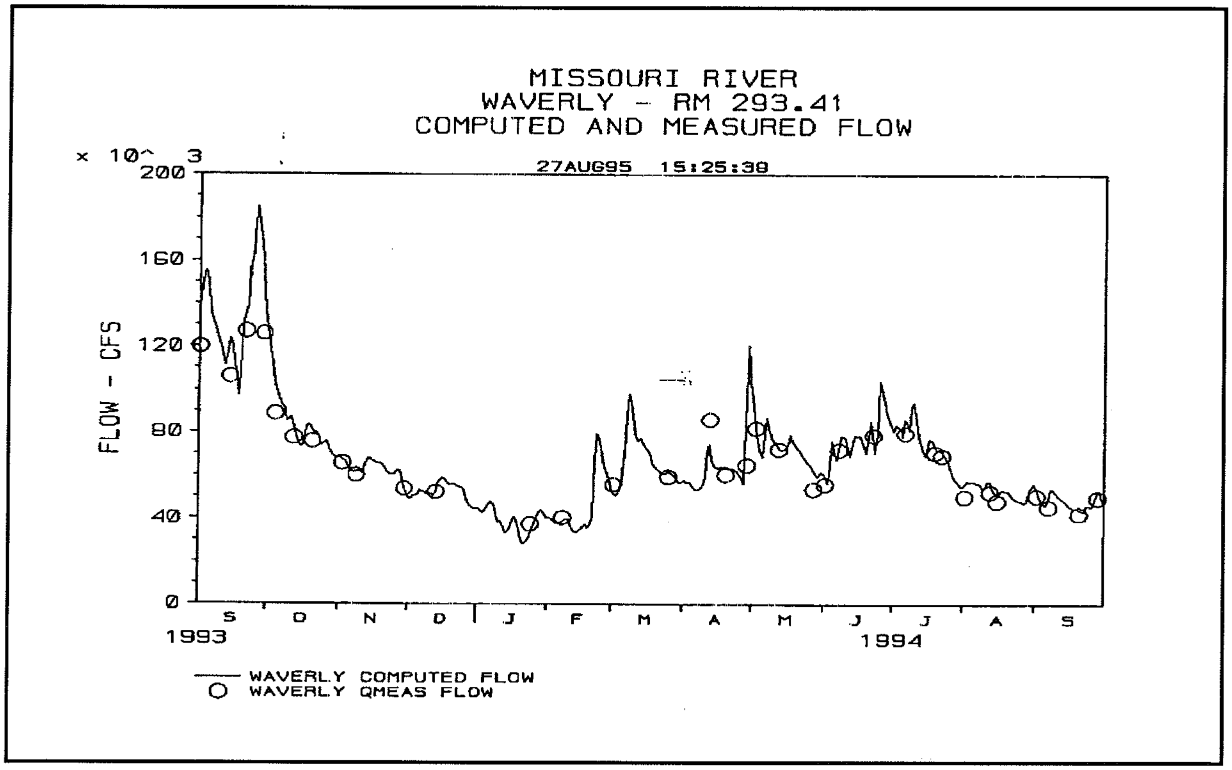

Figure 11 Waverly Computed and Measured Flow.

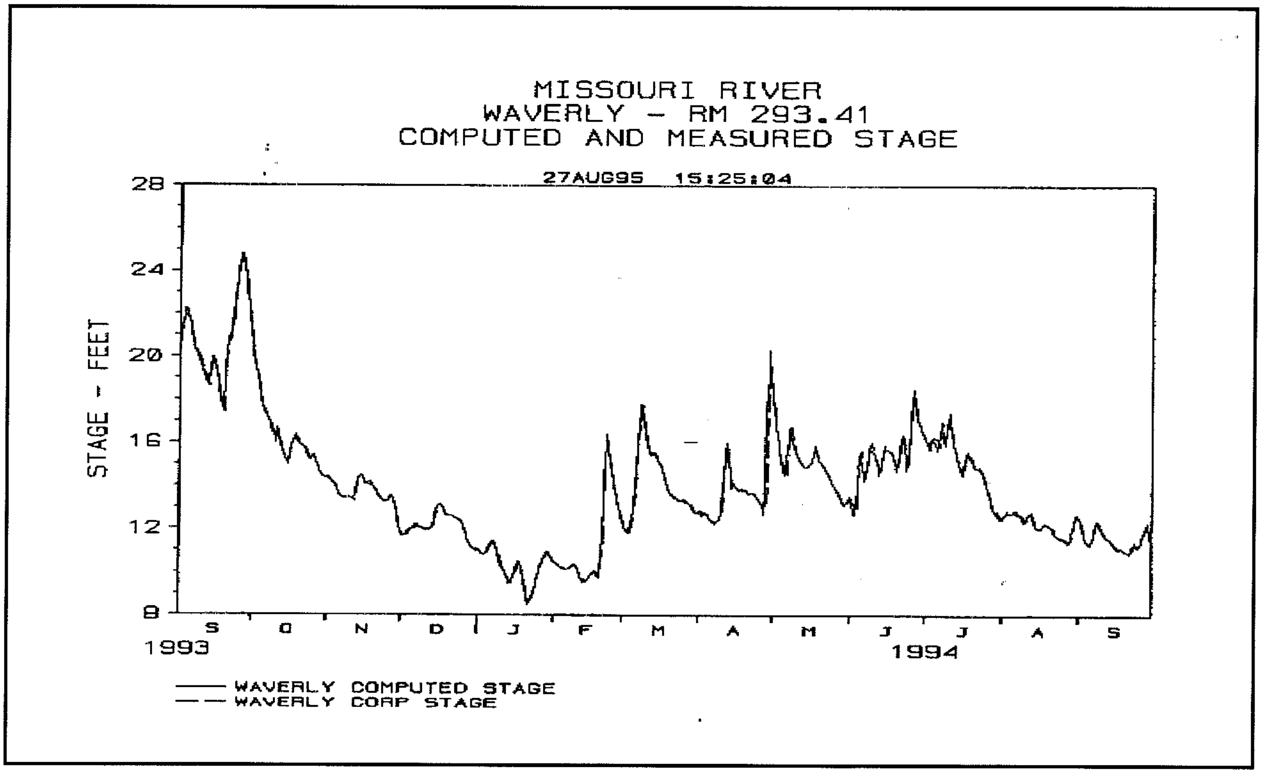

Figure 12 Waverly Computed and Measured Stage.

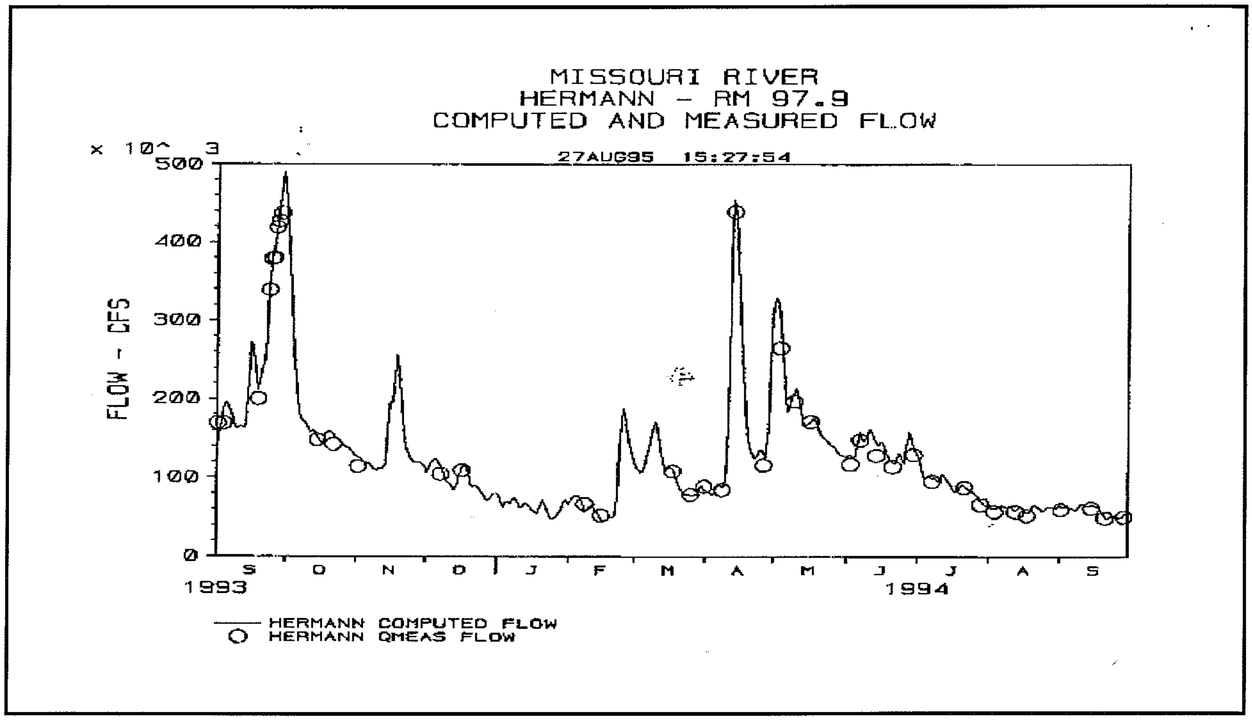

Figure 13 Hermann Computed and Measured Flow.

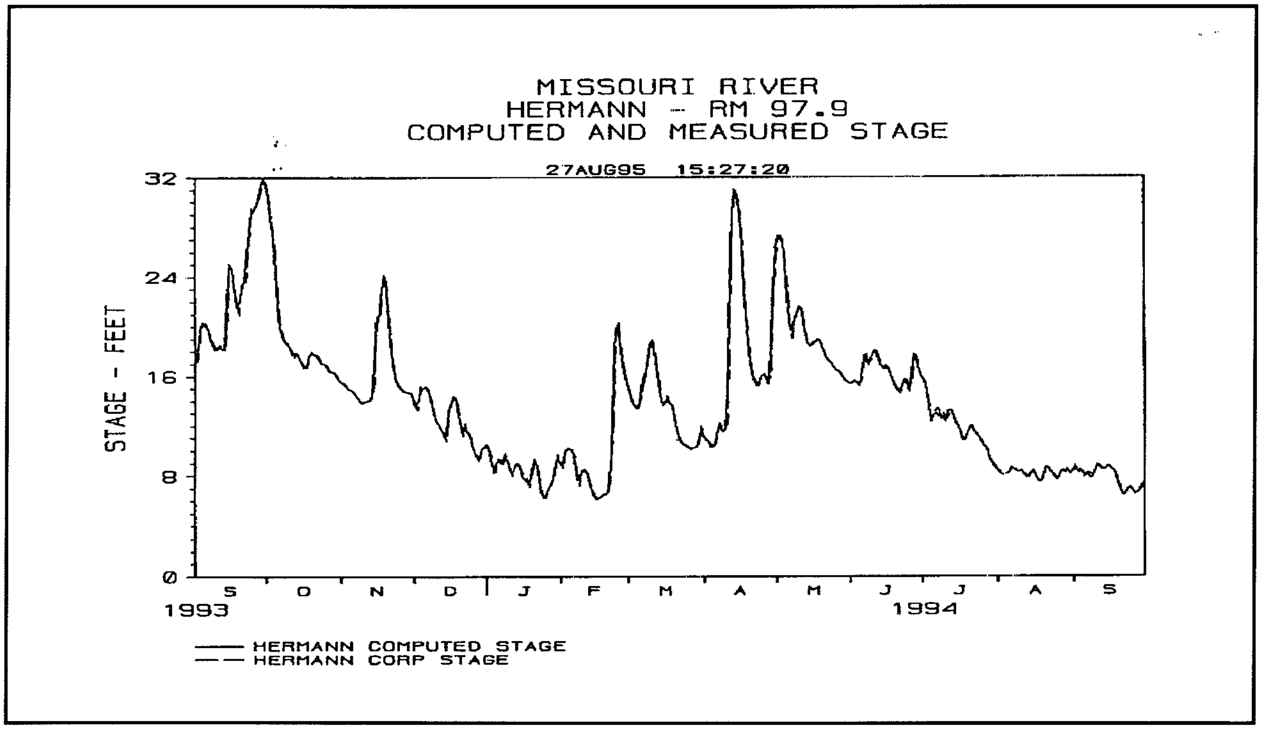

Figure 14 Hermann Computed and Measured Stage.

Appendix D

Kansas City Levee Algorithm

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FIGURES

TABLES

D.1 Introduction

During the 1993 flood a unique flow situation developed along the Missouri River. The smaller, 25 year levees, which protect the floodplain, were dwarfed by the magnitude of the 1993 flood, which was a 100 year to 500 year event. The levees were overtopped and breached. Their interiors filled during the middle of July, before the main crest arrived. In late July, during the main crest, the remaining embankments were overtopped and severely eroded by the overwhelming volume of water and the floodplain started to convey flow. The restoration of the flow in the floodplain resulted in a rating curve that exhibits an abrupt change in slope at the discharge where the floodplain starts to convey flow. Figure 1 is the rating curve for the Missouri River at Boonville, River Mile 197.1. The slope of the rating curve changes at 350,000 ft^3/s, a

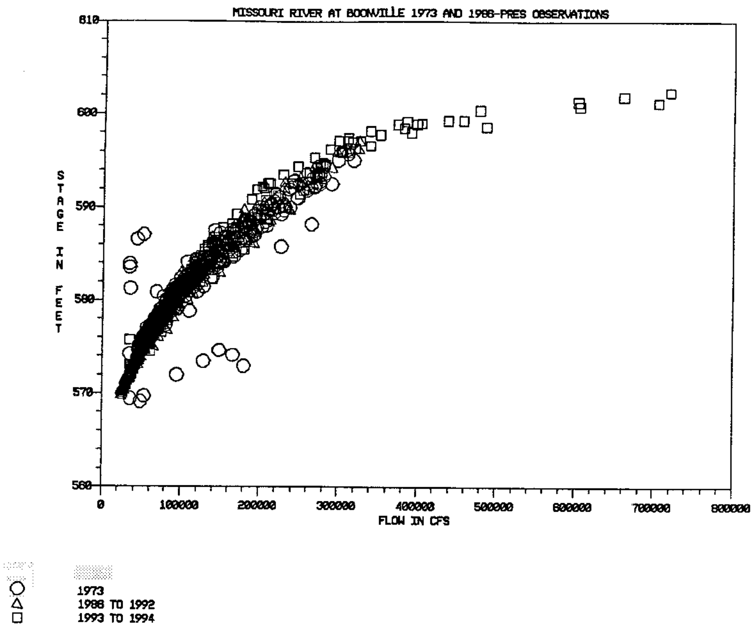

Figure 1. Observed stage versus USGS flow for the Missouri River at Boonville. The slope of the scatter changes at about 350,000 ft^3/s when the interiors of the levees begin to convey flow. The slope of the rating curve while the levees still confined the flow was about 15,000 ft^3/s per foot. The slope of the rating curve after total failure was 120,000 ft^3/s per foot.

stage of about 598 feet. Flood stage is 586 feet and the levees confine the flow for about 12 feet above flood stage. Above 350,000 ft^3/s the levees are eroded or overtopped and the flow is conveyed by the floodplain, which causes the large change in the slope of the rating curve.

The levees pose a peculiar modeling problem. Up until the transition point, the levee interior operates as a cell which communicates with the river through a breach or breaches in the embankment. This scenario can be modeled by assuming that the levee interior functions as a storage cell or lake and then the breaches can be modeled either as simple embankment failures (linear routing connections) or as complex embankment failures (hydraulics computed from the breach geometry). When the river flow exceeds the transition discharge, the area behind the levee no longer acts as a cell, instead it becomes a part of the river, conveying flow. Thus, we have two conditions that must be simulated -- a storage cell and a flowing river.

The Kansas City levee algorithm models a smaller levee by simulating it as a cell during breaching and at lower river discharges. When a transition discharge is exceeded, the area and conveyance of the cross-sections of the floodplain behind the levee are added to the river cross-sections and channel-floodplain routing starts. The channel-floodplain routing continues until the river flow drops below a cessation discharge when the levee cross-section properties are subtracted from the river cross-sections and the cell routing is restored.

The following different states of flow are defined:

1) <u>Levee failure.</u> A breach forms and the water enters the leveed area through the breach, filling the levee interior (Figure 2).

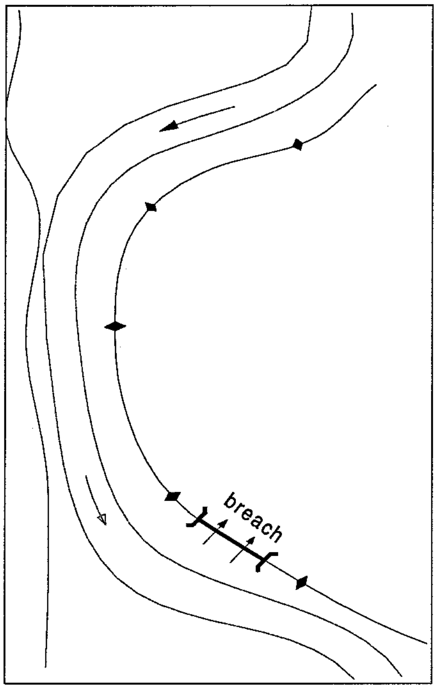

Figure 2. The levee system, functioning as a cell, is filled by flow through the breach.

2) Storage cell routing. The leveed area has filled and multiple breaches have formed along the entire length of the levee frontage. The breaches still restrict the flow to and from the leveed area and the levee interior resembles a lake (Figure 3).

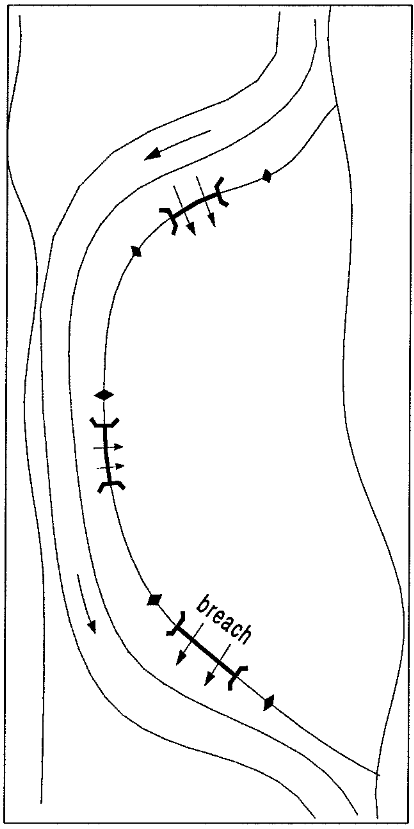

Figure 3. The filled levee, still functioning as a cell, exchanges water with the river through multiple breaches.

3) Transition from a storage cell to channel-floodplain routing. The flow in the river exceeds a critical discharge and the levees no longer control the flow. The breaches in the levee no longer restrict the flow; the water surface in the levee interior approaches the slope of the river and the floodplain conveys flow downstream.

4) Levee interior conveys flow. The slope of the water surface approaches the slope of the river and the flow is routed over the river and floodplain (Figure 4).

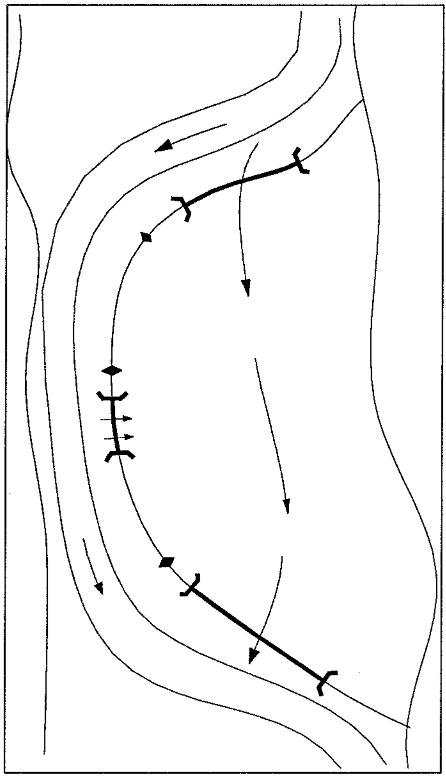

Figure 4. The levee breaches enlarge to a point where the once protected floodplain conveys flow.

5) Transition from channel-floodplain routing to storage cell routing. The river flow has dropped below the cessation discharge. The breaches along the levee frontage once again control the flow to and from the leveed area and the levee interior begins to act as a lake. The leveed area returns to storage cell routing.

6) Cessation of storage cell routing. The elevation of the water surface inside the cell falls below the minimum elevation of the cell interior. The levee is considered to be repaired.

D.2 Modeling Approach

The UNET program is a one-dimensional modeling system that can simulate a network of open channels and an interconnected network of lakes. The modeling approach for these levee systems is as follows:

1) Model the levees during failure using storage routing through a network of lakes.

2) Convert the levee interior into floodplain area and begin channel-floodplain routing.

We are therefore, modeling the levees as storage cells, converting the cells to cross-sections and modeling the flow through the levee as a channel and floodplain flow and then converting the cross-sections back to storage cells.

Because the levee interior must become a routing reach, the interior must be described by cross-sections. Therefore, to maintain the continuity of water, the volume of the storage cell must be defined by cross-sections. When the levee is breached, the water is transferred to and from the river through the breach and the storage is modeled by the cross-sections. When the leveed area has filled, numerous breaches are assumed to have formed along the entire length of the levee frontage. The water is routed into the leveed area along the entire length of the levee frontage. When the interior is conveying water, the area and conveyance properties of the cross-sections inside the levee are added to the river cross-sections; thus creating a river with a floodplain.

D.3 Levee Variables

The primary variables that describe the levees are:

RMLVU -- Upstream river mile of the levee frontage.
RMLVD -- Downstream river mile of the levee frontage.
Z0SLV -- Initial elevation inside the levee storage.
ZBRCH -- The river elevation when the levee fails.
RMBRCH -- The river mile of the breach.
ROUTLVIN -- Linear routing coefficient for inflow (hours^{-1}).
ROUTLVOUT -- Linear routing coefficient for outflow (hours^{-1}).
XNLV – Manning's *n* value behind the levee.
QFPON – River discharge when the floodplain starts to convey flow.
QFPOFF – River discharge when the floodplain stops conveying flow.

D.4 Levee Storage

The leveed area storage is described by cross-sections. River cross-sections are entered from bluff to bluff, including the area behind the levee. The levee storage is separated from the river cross-section by encroachments using the X3 Record. When the CSECT program computes the properties (area and conveyance) for the cross-sections, it also computes the elevation-area table for the storage behind the levee. The storage within the levee is computed by the average end area method; thus for elevation z_k, the storage is:

$$V_k = \sum_{j=m+1}^{n} \frac{(A(z_k)_{j-1} + A(z_k)_j) \cdot \Delta x_{j-1}}{2} \qquad (1)$$

where: j = the cross-section number.
m = the upstream cross-section.
n = the downstream cross-section.
A_j = the area function for cross-section j.
Δx_{j-1} = the distance between cross-section $j-1$ and j.

D. 5 Storage Routing to and from the Levee

Storage routing to and from the levee is governed by the hydrologic continuity equation,

$$\frac{dV}{dt} = \sum Q_i \qquad (2)$$

in which V is the volume inside the levee and Q_i is the flow to and from the levee. Positive flow is into the leveed area.

D.6 Levee Failure

A levee is assumed to fail when the river elevation at the breach location exceeds a specified failure elevation. Alternatively, the breach can begin forming at a specified time. Two modes of filling are supported; linear routing into the levee storage and constant flow during a time of filling.

Linear routing assumes that the flow is proportional to storage in the leveed area that can be filled. The available storage is defined as:

$$\Delta S = V(z_B) - V(z_L) \tag{3}$$

where:

ΔS = the available storage.
z_B = the river elevation at the breach.
$V(z_B)$ = levee storage if the water surface inside the levee is the same as the river elevation at the breach.
z_L = the water elevation inside the levee.
$V(z_L)$ = existing levee storage.

During formation of the levee breach, the linear routing coefficient cannot assumed to be constant. At failure the river elevation is high and the levee interior is nearly empty, hence the available storage is very large. Potentially, at failure, the discharge into the leveed area could be very large. To create a more realistic scenario, the linear routing coefficient is increased during a period of time which corresponds to the time of breach enlargement. The linear routing factor is given by:

$$r = \frac{t - t_{fail}}{t_{enlarge}} r_{in} \tag{4}$$

where:
r = linear routing coefficient.
t = simulation time.
t_{fail} = time of failure.
$t_{enlarge}$ = time of enlargment.
r_{in} = linear routing coefficient for inflow.

The flow into the levee by linear routing is given by:

$$Q_{in} = r \cdot \Delta S \tag{5}$$

If the time of filling is specified, then the levee is assumed to fill over that period. The flow into the levee is given by:

$$Q_{in} = \frac{\Delta S}{\left[(t_{fail} + t_{fill}) - t\right]} \tag{6}$$

in which t_{fill} is the time of filling.

D.7 Storage Routing

After the leveed area has filled, numerous breaches are assumed to have formed along the levee frontage and water passes between the river and the leveed area along the levee's entire length. The flow to and from the levee is given by the linear routing equation,

$$Q_L = r \cdot \Delta S_R \qquad \textbf{(7)}$$

where: Q_L = levee flow.
r = linear routing factor (hours^{-1}).
ΔS_R = change in storage from cross-sections and river elevation.

Because the breaches are assumed to be uniformly distributed along the frontage, the potential levee storage is assumed to have the same slope as the river; therefore, the change in storage, ΔS_R, is computed using the average end area method and the area at each levee cross-section between the river elevation and the leveed area elevation,

$$\Delta S_R = \sum_{j=m+1}^{n} \left[\frac{(A(z_{j-1})_{j-1} + A(z_j)_j) \cdot \Delta x_{j-1}}{2} - \frac{(A(z_L)_{j-1} + A(z_L)_j) \cdot \Delta x_{j-1}}{2} \right] \qquad \textbf{(8)}$$

where: z_j = river elevation at cross-section j.
z_L= leveed area elevation.
m = the upstream cross-section.
n = the downstream cross-section.
A_j = the area function for cross-section j.

The flow is distributed along the levee frontage by distance; hence,

$$Q_{Lj} = Q_L \cdot \frac{\Delta x_j}{\sum_{i=m}^{n-1} \Delta x_i} \qquad \textbf{(9)}$$

D.8 Transition to Open Channel Flow behind the Levee

When the river flow exceeds a critical value, the area inside of the levee begins to convey flow. To transition from storage cell routing to open channel flow, the following steps must be performed:

1) The water surface elevations of the levee cross-sections must equal the water surface elevations of the adjoining river cross-sections; therefore the storage inside the levee must equal the potential storage computed from the river elevations. The linear routing from equation (7) continues to be used with a routing factor of $r = 0.17$. When ΔS_R is less than 1% of the total storage, the linear routing factor is increased to 1.0 and the storage is the same over the next time step and $\Delta S_R = 0$.

2) The water surface is identical in both the river and the levee and the cross-sectional area behind the levee can be added to the river cross-sectional area.

3) The river conveyance is increased linearly over a 24 hour period, after which the floodplain inside the levee is fully conveying flow.

D.9 Transition from Floodplain Flow to Storage Routing

When the river flow falls below a critical value, the routing over the floodplain is stopped and the storage cell routing is restored. The following steps are performed.

1) The conveyance is reduced, linearly, over 24 hours from its full value to zero.

2) At zero conveyance, the levee cross-sectional area is subtracted from the river cross-sectional area.

3) Storage cell routing is restored.

D.10 Cessation of Levee Storage Routing

When the levee interior elevation falls below the minimum elevation of the levee, Z0SLV, the breach is repaired and the levee protection is restored.

D.11 Messages from the Levee Algorithm

The program produces the messages listed in Table 1, to describe the status of the levee computations. The messages are displayed in a table in the program output file.

Table 1
Levee Algorithm Messages

Status	*Description*
INTACT	Levee embankments are intact.
FILLING	Levee embankment has failed at the breach and the levee interior is filling.
FAILED	Levee interior has filled and the levee storage is exchanging water with the river through breaches along the levee frontage through storage routing.
OB FILLING	First step in the initialization of overbank flow. The levee storage is coming to equilibrium with the river by storage routing.
OB FLOW STARTING	Second step in the initialization of overbank flow. The protected area behind the levee has been added to the river cross-sections. Storage routing from the river breaches has ceased. No conveyance, but the levee storage is now directly connected to the river.
OB FLOW INCREASING	Third step in the initialization of overbank flow. Conveyance of the protected area is being added to the river cross-sections. The overbank is conveying flow.
OB Flow	The overbank is conveying flow.
OB FLOW DECREASING	The conveyance of the protected area is being subtracted from the river cross-sections. The overbank is still conveying flow but the amount is decreasing.
OB FLOW STOPPED	The conveyance and area of the levee interior has been subtracted from the cross-sections and the levee storage once again is exchanging water with the river through the breaches via storage routing.

D.11.1 Example

A simple levee can be entered in two ways; either in the cross-section file or in an include file. When the levee is entered in the cross-section file, the LV Record is positioned in the reach where the levee is located, preferably after the first cross-section along the levee frontage. Table 2 shows the Grossermeyer levee system inserted in the cross-section file. The LV Record is inserted after River Mile 234.99 which is near the start of the levee system at mile 235. The levee will breach at mile 235 when the water surface at the breach exceeds elevation 624.0 ft. The levee will fill in 72 hours; after filling, the levee will interact with the river through storage routing with a linear routing factor of 0.05 hr^{-1}. The presence of the LR Record indicates that the levee interior can convey water if the levee has been breached and the flow exceeds 290,000 ft^3/s. The storage of the levee is computed from the cross-sections between miles 235 and 231.5. The levee stops conveying water when the flow falls below 200,000 ft^3/s.

Table 3 demonstrates the entry of the Grossermeyer levee in an include file. Except for the RE Record, the entry of the levee is identical. The RE Record specifies the reach number which includes the starting river mile of the levee. The river mile field on the RE Record is not used.

Figure 5 shows the stage hydrograph of the levee interior and the flow hydrographs from the levee breaches. The stage hydrograph is an average across the levee interior. The breach flow hydrograph shows a zero flow when the levee interior is conveying water; therefore, one sees a positive flow when the leveed area is filling, zero flow while the interior is conveying water, and negative flow while the levee is emptying.

During an event like the 1993 flood, the time at which the levee system is breached may be known. The “SIMPLE LEVEE FAILURE” record in the boundary condition file can specify the time of that time. The “SIMPLE LEVEE FAILURE” record for the Grossermeyer Levee System is shown below.

```
SIMPLE LEVEE FAILURE FOR THE GROSSERMEYER LEVEE SYSTEM
 GROSSERMEYER 14JUL1993 0700
```

The name on the second line, which corresponds to the name on the HL Record with all blanks removed, identifies the levee sytem. The levee fails at 14JUL1993 at 0700 in the morning.

Table 2
Simple levee inserted in a cross-section file.

```
DI         650.  603.8  350.   5.0
X1234.99    84 29770. 31100.  1760.  1760.  4435.
X3  -12    0.   .00 28991. -999.0 31347. -999.0    3    3
GR 620.0   900.  691.0  1852.  700.0  7200.  650.0  7700.  624.7 10891.
GR 620.0 28700.  650.0 28980.  633.5 28980.  632.0 29000.  620.0 29025.
GR 618.0 29190.  616.0 29260.  616.0 29580.  620.0 29660.  622.0 29690.
GR 624.3 29770.  620.0 29790.  619.0 29800.  610.0 29800.  599.1 29937.
GR 598.6 29957.  597.9 29977.  598.0 29998.  598.4 30019.  598.1 30039.
GR 598.0 30059.  597.6 30079.  597.9 30099.  597.5 30119.  597.3 30139.
GR 596.8 30159.  596.0 30179.  595.8 30199.  596.1 30219.  596.2 30239.
GR 596.5 30259.  595.8 30280.  596.0 30299.  594.5 30320.  595.9 30340.
GR 594.4 30360.  593.7 30380.  593.5 30400.  593.2 30420.  593.9 30440.
GR 592.7 30460.  591.5 30480.  591.2 30500.  591.9 30520.  592.4 30540.
GR 592.8 30560.  592.3 30580.  591.9 30600.  591.7 30620.  592.8 30640.
GR 592.2 30659.  591.5 30680.  590.5 30698.  591.5 30720.  592.6 30741.
GR 591.4 30761.  589.8 30781.  590.4 30802.  588.5 30822.  587.7 30842.
GR 586.2 30862.  585.4 30883.  584.7 30903.  584.2 30924.  586.2 30944.
GR 591.6 30963.  612.0 31000.  612.0 31030.  620.0 31070.  623.8 31100.
GR 624.0 31310.  627.0 31350.  620.0 31380.  620.0 31450.  620.2 31480.
GR 620.0 31950.  619.8 32170.  619.6 32270.  650.0 32270.

************************
*
* Missouri River Levee Number -212 - Grossermeyer
* The levee is on the right bank
*

*  IRCH   RM
RE   17   2.35

*   ALV  TFILL  Z0SLV  RMLVU  RMLVD  ZTOPLV  RMLVB  ZBRCH  ROUTIN ROUTOUT
LV          72  621.70    235  231.5  625.3    235  624.00   .050   .050

*    n  ZFPON  ZFPOFF  BANK  QFPON  QFPOFF
LR  .640                  R  290000 200000

HL Grossermeyer
*

************************


DI         650.  603.2  350.   5.0
X1234.15   104 29890. 31650.  2472.  2472.  6230.
X3  -12    0.   .00 29046. -999.0 34226. -999.0    3    3
GR 700.0  2100.  650.0  3000.  640.0  6000.  620.0 12000.  621.0 28800.
GR 650.0 29060.  633.0 29060.  632.0 29085.  616.0 29130.  615.5 29350.
GR 616.0 29550.  616.5 29700.  620.0 29850.  624.0 29870.  625.0 29890.
GR 593.4 29920.  594.7 29945.  591.6 29965.  591.4 29985.  585.8 30005.
GR 583.1 30025.  584.1 30045.  585.0 30065.  586.5 30085.  587.1 30105.
GR 586.8 30125.  589.6 30145.  588.5 30166.  588.8 30186.  590.4 30206.
GR 590.3 30226.  589.3 30246.  589.0 30267.  589.5 30287.  590.1 30307.
GR 589.9 30327.  589.0 30347.  588.5 30367.  588.5 30387.  589.4 30407.
GR 588.3 30427.  588.7 30447.  589.6 30467.  589.7 30487.  590.0 30507.
GR 589.6 30527.  589.5 30548.  590.1 30567.  589.7 30587.  590.4 30607.
GR 591.0 30627.  592.4 30647.  592.8 30667.  592.8 30688.  592.8 30708.
GR 591.6 30729.  590.9 30750.  592.9 30770.  591.2 30790.  585.1 30811.
GR 577.8 30831.  572.4 30852.  569.8 30873.  568.0 30894.  568.8 30914.
GR 571.3 30934.  577.0 30954.  583.4 30974.  590.9 30994.  616.0 31000.
GR 620.0 31000.  620.0 31080.  620.0 31280.  624.0 31400.  625.0 31450.
GR 624.0 31540.  624.0 31600.  628.0 31640.  629.0 31650.  628.0 31660.
GR 624.0 31820.  622.0 32170.  621.0 32370.  622.0 32560.  624.0 32740.
GR 625.6 32750.  624.0 32770.  620.0 32810.  616.0 32840.  616.0 32920.
GR 624.0 32950.  624.8 32980.  624.0 33000.  622.0 33080.  620.0 33420.
GR 618.0 33600.  618.0 33640.  620.0 33650.  620.0 33760.  619.5 34010.
GR 619.5 34230.  650.0 34230.  620.0 36200.  670.0 36600.
```

Table 3
Entry of the Grossermeyer levee in an include file.

```
***********************
*
* Missouri River Levee Number -211 - Chariton R Mainstem
* The levee is on the left bank
*

*   IRCH      RM
RE    15  238.80

*    ALV   TFILL   Z0SLV   RMLVU   RMLVD  ZTOPLV   RMLVB   ZBRCH  ROUTIN ROUTOUT
LV             72  620.30   238.8   227.3      628   238.8  633.50    .050    .050

*      n   ZFPON  ZFPOFF    BANK   QFPON  QFPOFF
LR  .640  624.00  622.00       L  290000  200000

HL Chariton R Mainstem
*

***********************
*
* Missouri River Levee Number -212 - Grossermeyer
* The levee is on the right bank
*

*   IRCH      RM
RE    17    2.35

*    ALV   TFILL   Z0SLV   RMLVU   RMLVD  ZTOPLV   RMLVB   ZBRCH  ROUTIN ROUTOUT
LV             72  621.70     235   231.5    625.3     235  624.00    .050    .050

*      n   ZFPON  ZFPOFF    BANK   QFPON  QFPOFF
LR  .640  624.50  622.50       R  290000  200000

HL Grossermeyer
*

***********************
*
* Missouri River Levee Number -213 - Noth
* The levee is on the right bank
*

*   IRCH      RM
RE    17    2.31

*    ALV   TFILL   Z0SLV   RMLVU   RMLVD  ZTOPLV   RMLVB   ZBRCH  ROUTIN ROUTOUT
LV             72     608     231   217.6      621  218.01  624.00    .050    .050

*      n   ZFPON  ZFPOFF    BANK   QFPON  QFPOFF
LR  .110  623.00  621.00       R  290000  150000

HL Noth
*
```

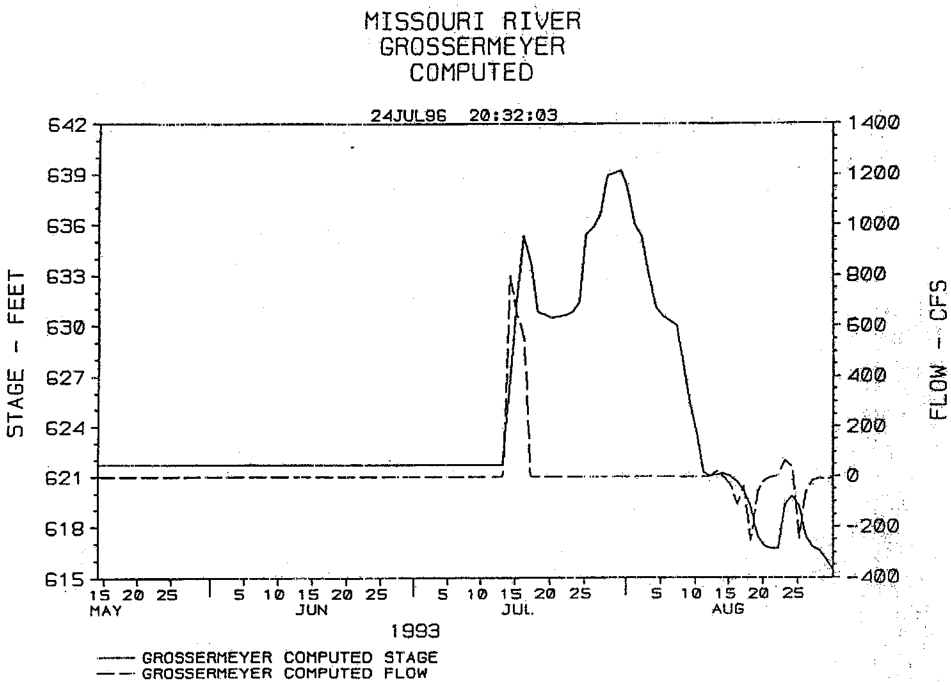

Figure 5 Levee stage and flow hydrograph for the Grossermeyer Levee system. The levee breaches on July 14th. The strong positive flow is through the breach and fills the levee system. After filling the levee interior begins to convey flow, which is indicated by a flow through the breaches of zero. On August 12th the levee once again begins acting as a cell as shown by the positive and negative flow as the levee storage interacts with the river.

D.12 LV Simple Levee System Record

The LV Record defines the location and the breach parameters for a simple levee system. If the LV Record is used by itself, the leveed area functions as a storage cell and the surface area of the levee, ALV, defines the elevation-volume relationship. Optionally, the SV Record can be used to enter an elevation-volume relationship for the levee. If the LR Record is entered following the LV Record, the levee interior can convey water (channel-floodplain routing). The HL Record defines the name of the levee and the B part of the DSS pathname.

Field	Variable	Value	Description
0	ID	LV	Record identification.
1	ALV	+	The surface area of the levee in acres.
		0	The elevation-volume relationship for the cell will be defined either by an SV Record or computed from the cross-sections as directed by a LR Record.
2	TFILL	F6.0	The time required to fill the levee, assuming a constant inflow.
3	Z0SLV	F8.0	The invert elevation of the levee for storage computations.
4	RMLVU	F8.0	Upstream river mile or station number.
5	RMLVD	F8.0	Downstream river mile or station number.
6	ZTOPLV	F8.0	Elevation of the levee crown at the midpoint of the levee, at (RMLVU + RMLVD) / 2.
7	RMLVB	F8.0	River mile or station number of the levee breach.
8	ZBLV	F8.0	River elevation when the breach in the levee initiates.
	ROUTLVIN	F8.0	Linear routing coefficient for inflow into the levee system, in hours^{-1}. Generally, $0 \le \text{ROUTLVIN} \le 1$.
9	ROUTLVOUT	F8.0	Linear routing coefficient for outflow from the levee system, in hours^{-1}. Generally, $0 \le \text{ROUTLVOUT} \le 1$.
10	LVNAM	A8	Name of the levee system. The time of failure and other levee parameters may be specified in the boundary condition file. These run-time parameters are assigned to the levee system by the name of the levee system, LVNAM.

D.13 LR Simple Levee Floodplain Routing Record

The LR Record defines the parameters that control the routing of water through the levee interior. The routing of water through the floodplain is initiated when the river exceeds elevation ZFPON at the upstream end of the levee or the flow exceeds QFPON. The flow trigger takes precedence over the elevation trigger; therefore, if the QFPON is specified the value of ZFPON is ignored. The routing of water through the floodplain is halted when the river elevation falls below ZFPOFF or when the flow falls below QFPOFF. Likewise, the flow trigger takes precedence over the elevation trigger. The roughness of the floodplain is given by the parameter XNLV. Channel-floodplain routing cannot occur without a LR Record.

Field	Variable	Value	Description
0	ID	LR	Record identification.
1	XNLV	F6.0	Manning's *n* value for the floodplain inside the levee.
2	ZFPON	F8.0	River elevation to start floodplain routing through the levee.
3	ZFPOFF	F8.0	River elevation to stop floodplain routing through the levee.
4	QFPON	F8.0	Flow to start floodplain routing through the levee.
5	QFPOFF	F8.0	Flow to stop floodplain routing through the levee.

D.14 HL Name of Simple Levee Floodplain Routing

The HL Record defines the name of the levee system. That name becomes the B part of the DSS pathname.

Field	Variable	Value	Description
0	ID	HL	Record identification.
1	LVNAM	A32	The name of the levee system.

D.15 Simple Levee Failure

The simple levee failure record specifies a time at which a simple levee system breaches. The record has three parameters; the name of the levee on the HL with all blanks removed, the breach date, and the breach time. The record can be placed anywhere in the boundary condition file.

Command Line: SIMPLE LEVEE FAILURE

Parameters: LVNAM, DATE, TIME

Parameter	***Value***	***Description***
LVNAM	Alpha.	Name of the levee system.
DATE	Alpha.	Military date (for example, 14JUL1993).
TIME	Alpha.	Military time (for example, 0730).

Example:

```
SIMPLE LEVEE FAILURE OF THE GROSSERMEYER LEVEE SYSTEM
GROSSERMEYER 14JUL1993 0730
```

Appendix E

Dike Fields

TABLE OF CONTENTS

FIGURES

TABLES

E.1 Dike Fields

The Missouri River Bank Stabilization and Navigation Project between Sioux City, Iowa, and the mouth, traverses the 498.1 river miles within the Kansas City District, plus 233.9 river miles in the Omaha District. This project entails the use of bank revetments and dikes to achieve a free-flowing navigation channel. A dike field is a system of rock embankments or timber structures that protrude from the bank. The dikes block the flow along the bank, concentrating the flow along the opposite bank, deepening the channel. The slack water areas behind the dikes eventually fill with sediment, burying the dike and forming a narrower but deeper river channel. Dikes are generally located on the point bars on the inside of a river bend. Figure 1 shows a typical dike field along the Missouri River.

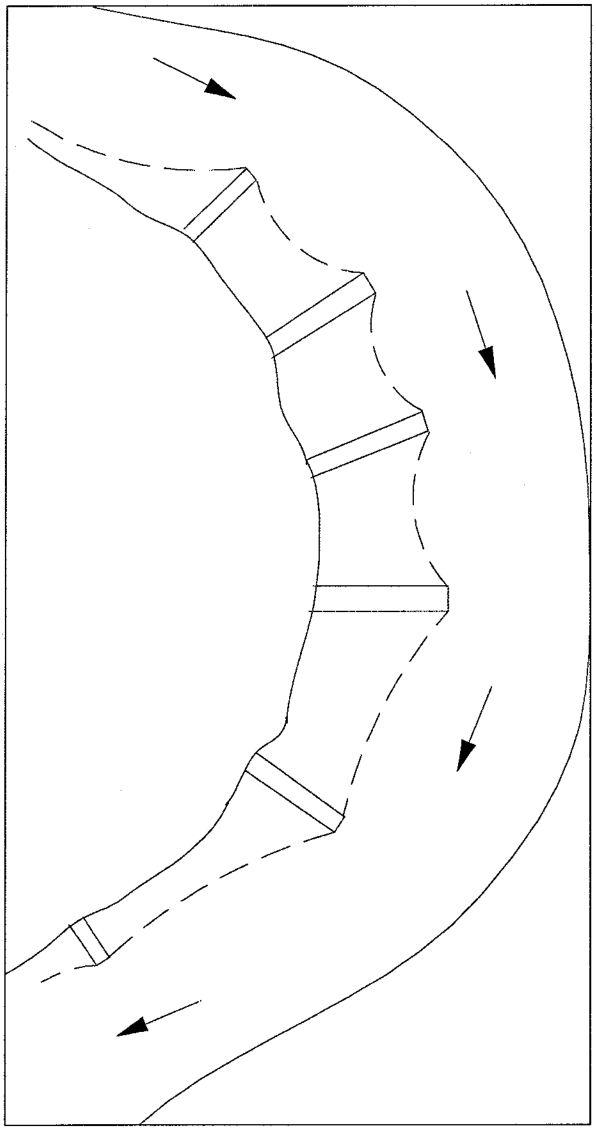

Figure 1 A dike field on the inside of the river bend. The dike field narrows the river to a design topwidth. The slack water area blocked by the dikes fills with sediment and a new bank line eventually develops.

A typical dike on the left bank of the river is shown in Figure 2. The dike field creates a channel with a design width at a low flow profile which is called the construction reference plane (CRP) on the Missouri River. The target topwidth, TWCH, extends from the opposite bank to the end of the dike. The dike can have two steps - a lower step and an upper step. The lower step has a set width with a crest elevation defined by a distance below the CRP, ZSTEP = ZCRP - DZLOW. The width of the upper step is the remaining distance from the bank. The crest elevation of the upper step is an increment, DZSTEP, above the lower step, ZDIKE = ZSTEP + DZSTEP.

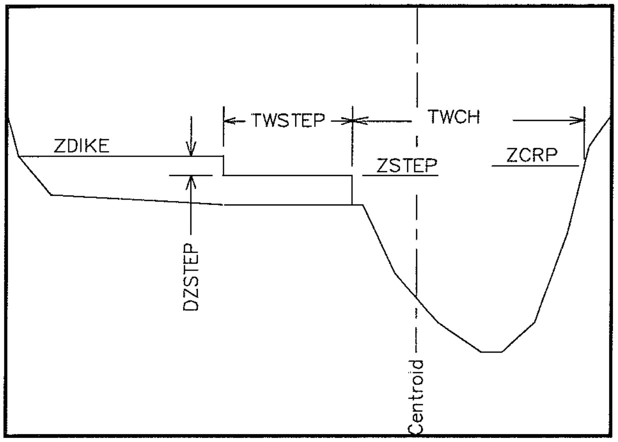

Figure 2 Dike on the left side of the channel. The dike is positioned on the left side of the channel because the centroid is within the right 40% of the channel.

The following parameters define a dike field in the UNET program:

ZCRP = the elevation of the CRP at a cross-section.

TWCH = the design topwidth of the contracted channel cross-section.

TWSTEP = the topwidth of the lower step.

DZLOW = distance between the CRP and the lower step.

ZSTEP = ZCRP - DZLOW = elevation of the lower step.

DZSTEP = elevation difference between the lower step and the upper step.

ZDIKE = ZSTEP + DZSTEP = elevation of the upper step.

E.2 Simulation of a Dike Field

A dike field is defined as a system of structures that contract the low flow cross-section to the design width of the channel. The model is one-dimensional; therefore, the effect of each individual dike cannot be simulated. Rather the cross-sections are contracted to simulate the contraction of the dike field. The area blocked by the dike field can be modeled as storage area or as a dead area which is deducted from the cross-section. The storage area simulates the condition where the area behind the dike has not as yet filled with sediment and the area stores water. When the water exceeds the top of the dike, the storage area is assumed to return to active flow area, since the submerged dike field has little impact on the conveyance of high flow. The added form roughness of the dike is part of the calibration of the model. The dead area simulates the condition when the area behind the dike has been filled with sediment and the area has been lost for all river stages.

The dike field may be positioned either on the left or the right bank. The modeler can specify the bank or the modeler can allow the program to choose the appropriate bank. The program always attempts to place the dike field on the point bar opposite the channel. The program uses the centroid of the area about the left bank station to locate the dike. The following rules apply:

1. If the centroid is located within the right 40% of the cross section topwidth, the dike field is located on the left bank (Figure 2).
2. If the centroid is located within the left 40% of the cross section topwidth, the dike is located on the right bank (Figure 3).
3. If the centroid is located within the middle 20% of the topwidth, then the dike field is located on the side opposite the minimum elevation (Figure 4).

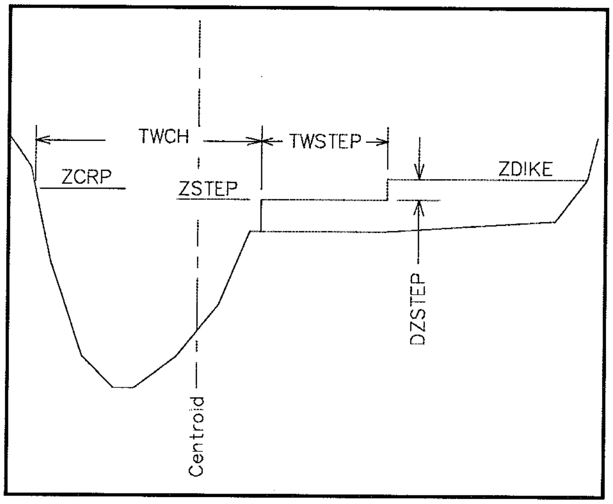

Figure 3 Dike on the right side of the channel. The dike is positioned on the right side because the centroid of the channel is within the left 40% of the channel.

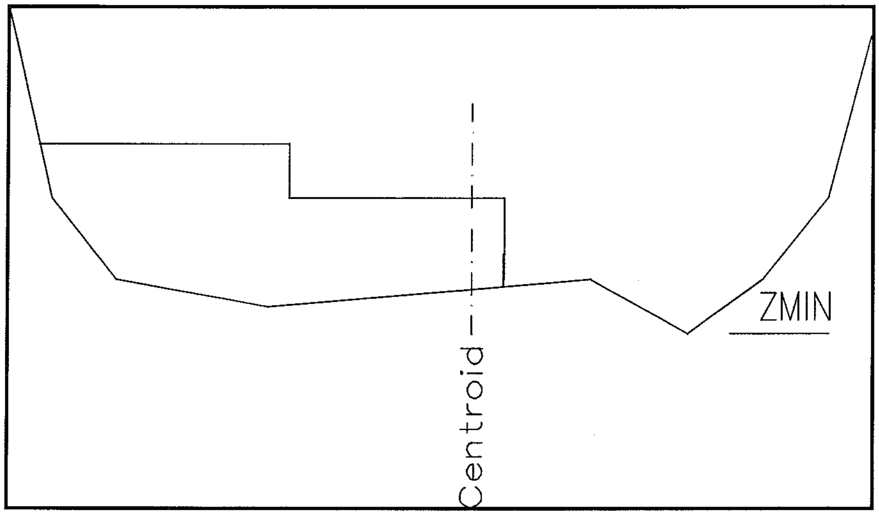

Figure 4 At this crossing cross-section, the dike is located on the left side because the centroid is in the middle 20% of the topwidth and the minimum elevation is on the right side.

Rules 1 and 2 apply to a pool cross-section where a point bar is on the left and the right sides respectively. The 40% limit is based on the UNET program developer's judgment. Rule 3 applies to a crossing cross-section, where the area is uniformly distributed, and assumes that the appropriate location of the dike field is on the side opposite the invert.

The effect of the dike field can be modeled by entering five points into a cross-section (Figure 5).

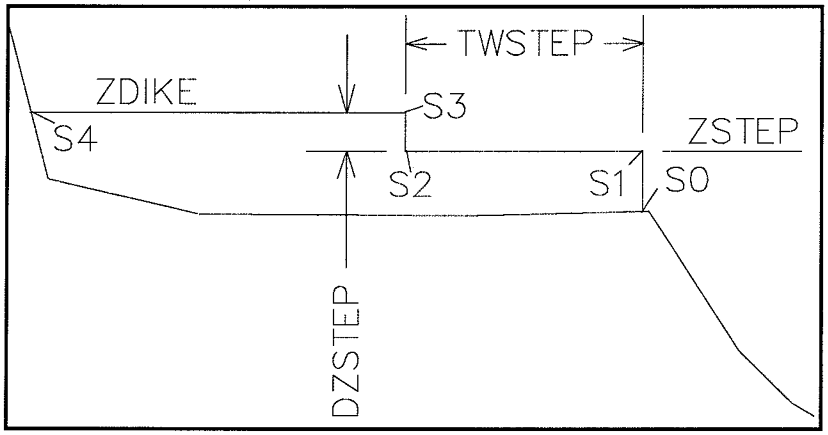

Figure 5 The dike is defined by 5 points, S0 through S4.

The five points are as follows:

1) Point S0 is at the end of the dike at the intersection of the ground and the dike.

2) Point S1 is at the end of the dike at the bottom of the lower step.

3) Point S2 is at the inner limit of the lower step.

4) Point S3 is at the inner limit of the upper step.

5) Point S4 is at the intersection of the upper step with the bank line.

To insert the effect of the dike field into a cross-section, points S1 through S4 are entered into the dike cross-section and all cross-section points between S1 and S4 are brought up to the appropriate elevations, either ZDIKE or ZSTEP. The minimum width of the dike field is the width of the lower step. If the width of the channel is insufficient to insert the lower step, the dike field is not inserted. A dike field is added to the geometry file on the DK Record which is described in Section E.4. The DK Record is inserted before the GR Records of a cross-section.

Table 1
DK Record Inserts a Dike for Cross-Section 220.05.
The value of 0 entered for DFSTOR directs that the area blocked by the dike will be used for storage.

```
*                   TWCH    ZCRP  TWSTEP  DZSTEP   DZLOW  DFSTOR
DK                  650.   591.6    350.     5.0      2.       0
*
X1220.05     100   9750.  11090.   4165.   4165.   5808.
X3     -12      0.     .00   9236.  -999.0  11721.  -999.0       3       3
GR 700.0   8150.   612.0   8330.   610.8   8670.   610.4   9060.   608.9   9580.
GR 608.0   9750.   579.9   9846.   579.0   9870.   579.7   9893.   578.0   9914.
GR 578.0   9937.   578.8   9959.   578.0   9981.   578.5  10001.   578.2  10022.
GR 577.0  10043.   577.3  10064.   576.5  10085.   576.8  10108.   576.5  10129.
GR 576.2  10149.   576.3  10170.   575.8  10190.   575.7  10210.   575.9  10233.
GR 576.4  10251.   576.3  10271.   575.7  10292.   577.4  10312.   576.7  10332.
GR 577.1  10352.   578.3  10373.   578.0  10393.   574.7  10413.   576.4  10433.
GR 575.0  10453.   575.1  10474.   575.7  10494.   575.1  10514.   575.7  10534.
GR 575.4  10555.   575.4  10576.   575.1  10596.   575.8  10617.   570.5  10639.
GR 565.7  10659.   565.0  10679.   566.3  10700.   570.9  10721.   577.1  10741.
GR 583.5  10761.   586.3  10781.   587.7  10802.   586.6  10822.   587.2  10843.
GR 587.5  10862.   587.1  10882.   587.2  10904.   588.1  10924.   604.0  11000.
GR 609.4  11090.   602.9  11500.   618.5  11720.   601.1  11800.   609.7  12080.
GR 605.3  12430.   609.0  12650.   607.4  13030.   609.5  13060.   607.9  13270.
GR 610.8  13510.   607.5  13640.   605.9  13830.   608.8  14010.   607.5  14170.
GR 610.4  14410.   606.8  14740.   609.5  14950.   606.8  15170.   609.6  15700.
GR 613.7  15960.   607.5  16080.   610.3  16160.   607.8  16270.   611.5  16590.
GR 612.3  16720.   607.6  16950.   610.6  17090.   606.8  17330.   604.5  17570.
GR 603.1  17860.   618.8  17950.   604.0  18050.   604.7  18280.   608.4  18520.
GR 610.0  18610.   608.0  19000.   640.0  19170.   680.0  19820.   700.0  19920.
```

E.3 Example of Cross-Sections in a Dike Field

Table 1 shows the insertion of a dike into a cross-section at RM 220.05 of the Missouri River. The DK Record is inserted before the X1 Record for the cross-section. For this example, the area behind the dike is to be used as storage, which is specified by a value of 0 for the DFSTOR parameter on the DK Record. Figure 6 shows the inserted dike and Table 2 shows the property table for this cross-section. Note that the area behind the dike is now used as storage. Figure 7 compares the active channel area properties with and without the dike. The cross-section area properties are identical when the upper elevation of the dike is exceeded.

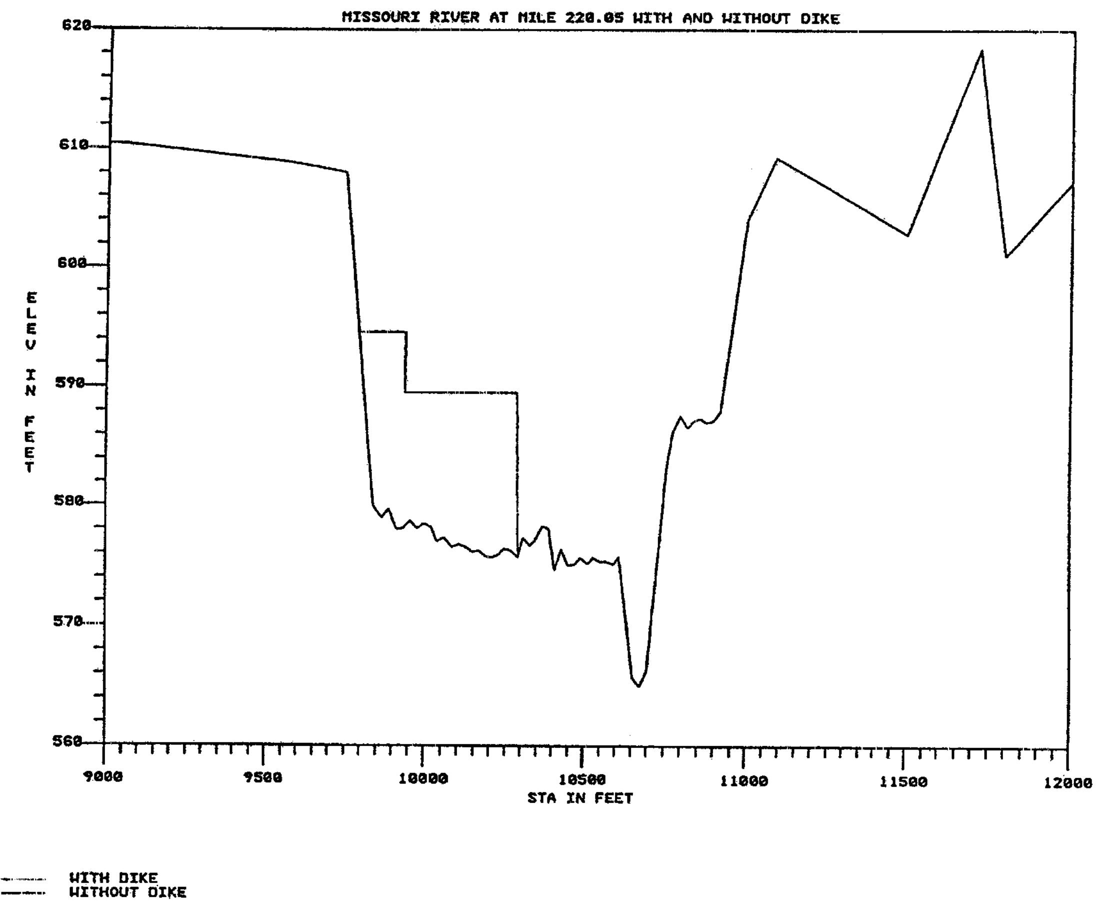

Figure 6 The cross-section at RM 220.05 on the Missouri River with and without the dike.

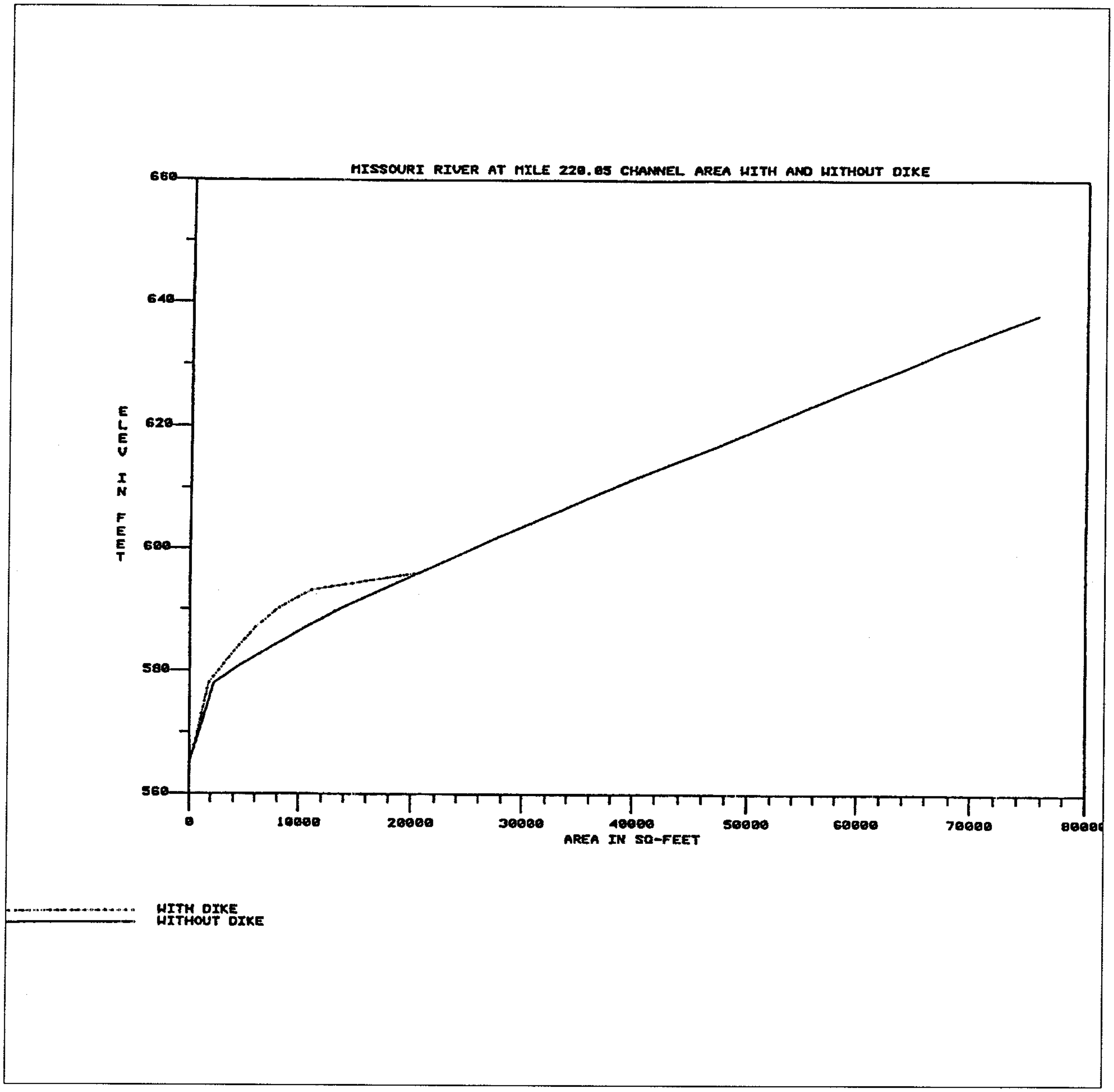

Figure 7. Channel area with and without dike for the Missouri River at RM 220.05.

Table 2
The property table for RM 220.05 when the area blocked by the dike is used as storage.

```
ICS# 516, CROSS SECTION PROPERTIES AT R.M. 220.050

ELEV      ALOB     ACH   AR08    AREA    CLOB     CCH   CROB    CONV BAREA     TW  SLOB  SROB    S      AOL      AOR

(FT)   <---------(FT^2)-------------> <--------X1000 CFS--------> (FT^2)(FT)  <----(FT^2)----> <----(FT^2)---

->

578.21        0.   1823.     0.   1823.      0.    275.     0.    275.    0.   445.    0.   0. 483.       0.       0.
581.21        0.   3195.     0.   3195.      0.    680.     0.    680.    0.   462.    0.   0.1739.       0.       0.
584.21        0.   4598.     0.   4598.      0.   1221.     0.   1221.    0.   475.    0.   0.3104.       0.       0.
587.21        0.   6069.     0.   6069.      0.   1729.     0.   1729.    0.   563.    0.   0.4498.       0.       0.
590.21        0.   8173.     0.   8173.      0.   1956.     0.   1956.    0.   993.    0.   0.5711.       0.       0.
593.21        0.  11174.     0.  11174.      0.   3257.     0.   3257.    0.  1008.    0.   0.6117.       0.       0.
596.21        0.  20771.     0.  20771.      0.   8353.     0.   8353.    0.  1172.    0.   0.   0.       0.       0.
599.21        0.  24326.     0.  24326.      0.  10716.     0.  10716.    0.  1197.    0.   0.   0.        0.      0.
602.21        0.  27954.     0.  27954.      0.  13324.     0.  13324.    0.  1222.    0.   0.   0.       0.      23.
605.21        0.  31664.     0.  31664.      0.  16057.     0.  16057.    0.  1261.    0.   0.   0.       0.      969
608.21        0.  35536.     0.  35536.      0.  18872.     0.  18872.    0.  1320.    0.   0.   0.       0.     5979
611.21     1091.  39544.     0.  40635.     33.  22329.     0.  22362.    0.  1854.    0.   0.   0.     446.    22815
614.21     2633.  43564.  4204.  50400.    145.  26238.   296.  26680.    0.  2423.    0.   0.   0.    3079.   44041.
617.21     4175.  47584.  5975.  57734.    313.  30397.   507.  31217.    0.  2466.    0.   0.   0.    5820.    65849
620.21     5717.  51604.  7855.  65176.    529.  34796.   783.  36109.    0.  2485.    0.   0.   0.    8579.    87838
623.21     7259.  55624.  9748.  72631.    788.  39430.  1122.  41340.    0.  2485.    0.   0.   0.   11356.   109893
626.21     8801.  59644. 11641.  80086.   1086.  44293.  1509.   46888    0.  2485.    0.   0.   0.   14152.   131997
629.21    10343.  63664. 13534.  87541.   1421.  49380.  1940.  52741.    0.  2485.    0.   0.   0.   16967.   154148
632.21    11885.  67684. 15427.  94996.   1792.  54685.  2412.  58889.    0.  2485.    0.   0.   0.   19800.   176346
```

E.4 Syntax of the DK Record

DK Dike Field. A dike field is entered on the DK Record. The dike field modifies the cross-section specifying that a portion of the low flow channel which is blocked by the dike is either storage or dead area. The DK Record applies to the set of GR Records following where it is entered. The dike field modifications to the cross sections continue until another DK is encountered. A blank DK turns off the modifications. Fields 1 and 2 define an old dike routine. Fields 3 through 8 define the newer dike routine that was used for the Missouri River.

Field	Variable	Value	Description
0	ID	DK	Record identification.
1	ZDIKE	+	Elevation of the crest of the dike.
		0	
2	AFDIKE	+	Fraction of the channel area below ZDIKE that is blocked by the dike field.
3	TWCH	+	Design topwidth of the channel.
4	ZCRP	+	Elevation of minimum low water at the cross-section. The crest elevations of the dike are based on this design low water elevation.
5	TWSTEP	+	Width of the lower step.

Field	Variable	Value	Description
6	DZSTEP	+	Elevation difference between the lower step and the upper step.
		0	Halt dike computations.
7	DZLOW	+	Elevation difference between ZCRP and the lower step.
8	DZSTOR	0	The area blocked by the dike field is used as storage.
		+	The area blocked by the dike field is not used (dead area.)
9	DFSIDE	L	Dike on the left side.
		R	Dike on the right side.
		Blank	Dike automatically positioned.