USDA United States Department of Agriculture

NRCS
Natural Resources Conservation Service

Conservation Engineering Division

Small Watershed Hydrology

WinTR–55 User Guide

Issued January 2009

Preface

The WinTR–55 Small Watershed Hydrology Computer Program Version 1.00 has been developed to operate within the Windows® operating system. This guide assists the new or occasional user prepare input and run the program.

This version of WinTR–55 is improved over the 1992 version with the following features:

- inclusion of Windows® interface
- use of WinTR–20 for calculations

The program and supporting materials may be downloaded from the Web site *http://www.wsi.nrcs.usda.gov/products/W2Q/H&H/Tools_Models/ WinTR55.html.* The materials available include a Frequently Asked Questions file, a tutorial, and other training material.

Acknowledgments

WinTR–55 User Guide, January 2009

Small Watershed Hydrology

Contents

Tables

Figures

Windows

Small Watershed Hydrology

Introduction

Historical background

Technical Release 55 (TR–55) Urban Hydrology for Small Watersheds was first issued by the Soil Conservation Service (SCS) in January 1975 as a simplified procedure for calculating storm runoff volume, peak rate of discharge, and storage volumes for storm water management structures. TR–55 was applicable only for the SCS Type II rainfall distribution and required the user to perform manual calculations.

In September 1986, SCS released a major revision to TR–55. This version included three additional rainfall distributions (Type I, IA, and III) and defined the velocity method of computing time of concentration by splitting the time of concentration flow path into three distinct flow segments for sheet flow, shallow concentrated flow, and channel flow. A computer program was also released that automated the computations. The wide acceptance and use of TR–55 by public and private users generated a great deal of feedback used by SCS to identify where improvements could be made in the procedures and the computer program.

A WinTR–55 work group was formed in the spring of 1998 to modernize and revise the technical release and the computer software. The following changes were made to the program:

- The source code was upgraded to Microsoft® Visual Basic® 6.0.

- Data input philosophy was changed and the program revised to use a hydrograph computational routine instead of generalized tables and graphs.

- A Windows® interface and output post-processor were developed.

As a result, the hydrograph generation capability of the software was greatly enhanced as the user can now flood route hydrographs through stream reaches and reservoirs.

The availability and technical capabilities of the personal computer have significantly changed the philosophy of problem solving for the engineer. Computer availability eliminated the need for the TR–55 manual methods, thus the graphs and tables in the older documents have been eliminated.

This user guide covers the procedures used in and the operation of the WinTR–55 computer program. Part 630 of the Natural Resources Conservation Service (NRCS) National Engineering Handbook (NEH) provides detailed information on NRCS hydrology and is the technical reference for this document. Appendix C, which lists all the references, contains a list of the NEH Part 630 chapters and their subjects. Users who are not familiar with NRCS hydrologic procedures should refer to the appropriate chapters for background information and the details of procedural techniques.

Program description

WinTR–55 is a single-event rainfall-runoff, small watershed hydrologic model. The model generates hydrographs from both urban and agricultural areas and at selected points along the stream system. Hydrographs are routed downstream through channels and/or reservoirs. Multiple sub-areas can be modeled within the watershed.

Model overview

A watershed consists of sub-areas (land areas) and reaches (major flow paths in the watershed). For each sub-area, a hydrograph is generated based on land and climate characteristics. Reaches are designated as either channel reaches, through which hydrographs are routed based on physical stream characteristics, or as storage reaches, through which hydrographs are routed based on reservoir storage and outlet characteristics. Sub-area and reach hydrographs are combined as needed to represent the accumulation of flow as water moves from the upland areas down through the watershed reach network. The watershed outlet represents the location at which all runoff from the watershed is accumulated.

WinTR–55 uses the WinTR–20 (Version 1.11) computational routine for generating, routing, and adding hydrographs. The WinTR–55 system is illustrated in figure 1. This figure shows the relationship between WinTR–55 and WinTR–20, as well as the file associations within the modeling system.

Figure 1 WinTR–55 system schematic

WinTR-55 System
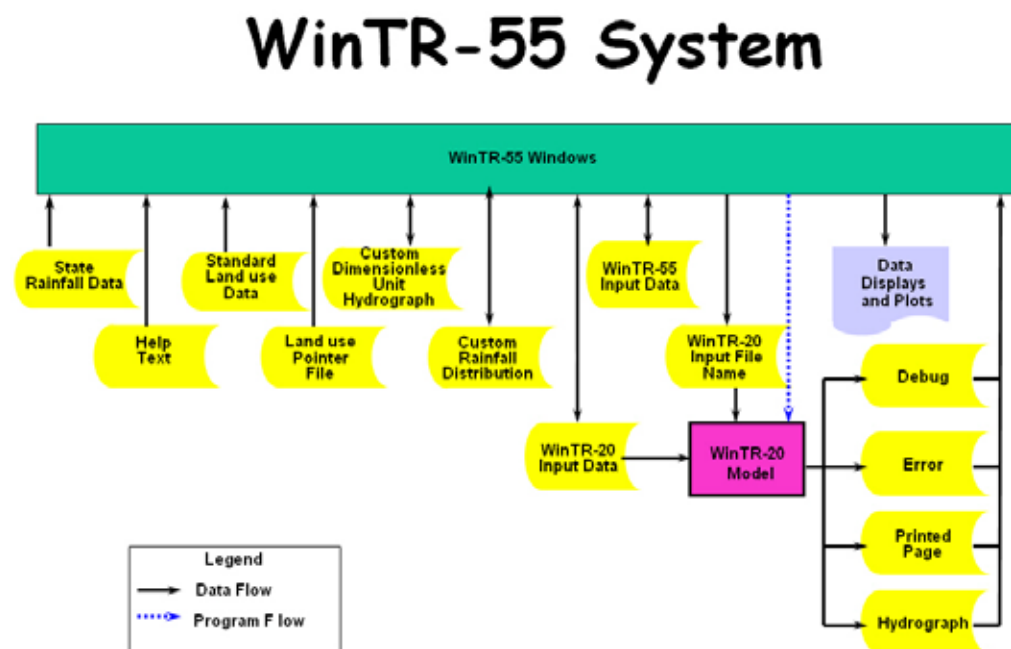
Capabilities and limitations

WinTR–55 hydrology has the capacity to analyze watersheds that meet the criteria listed in table 1.

Table 1 WinTR–55 capabilities and limitations

Variable	Limits
Minimum area	Minimum area is 0.01 acre. Carefully examine results from sub-areas less than 1 acre
Maximum area	25 square miles (6,500 ha)
Number of subwatersheds	1 to 10
Time of concentration for any sub-area	0.1 hour ≤ Tc ≤ 10 hours
Number of reaches	0 to 10
Types of reaches	Channel or structure
Reach routing	Muskingum-Cunge
Structure routing	Storage-Indication
Structure types	Pipe or weir
Structure trial sizes	1 to 3
Rainfall depth	Default or user-defined 0 to 50 inches (0 to 1,270 mm)
Rainfall distributions	NRCS Type I, IA, II, III, NM60, NM65, NM70, NM75, or user-defined (See appendix A, example 4)
Rainfall duration	24-hour
Dimensionless unit hydrograph	Standard peak rate factor 484, or user-defined (e.g., Delmarva—see appendix A, example 3)
Antecedent runoff condition	2 (average)

Model input

The user enters data into WinTR–55 through a series of windows. Figure 2 illustrates a sample watershed schematic. Figure 3 shows various features of the input windows. Data entry is required only on windows applicable to the watershed being evaluated.

Minimum data requirements

While WinTR–55 can be used for watersheds with up to 10 sub-areas and up to 10 reaches, the simplest run involves only a single sub-area. Data required can be directly entered on the **WinTR–55 Main Window**. These data include:

- Project Identification Data
  — User
  — State
  — County
  — Project
  — Subtitle
- Dimensionless Unit Hydrograph
- Storm Data Source
- Rainfall Distribution Identifier
- Sub-area Entry and Summary
  — Sub-area Name
  — Sub-area Description
  — Sub-area Flows to Reach/Outlet
  — Area (ac. or sq. mi.)
  — Weighted curve number (CN)
  — Time of concentration (Tc)

The user should note that sub-area entry and summary data can be entered directly into the table on the main window, or computed elsewhere within WinTR–55. If detailed information is developed through the other windows, the computational results are displayed here.

User responsibility

Model results can be sensitive to input data. The user must ensure that all input data (whether entered directly or implied through default values for blank data fields) are appropriate for the watershed and conditions being analyzed.

Watershed sub-areas and reaches

Modeling watersheds properly using WinTR–55 requires understanding the relationship between watershed sub-areas and reaches within the computer program. Figure 2 and table 2 show a typical watershed with multiple sub-areas and reaches.

Reaches define flow paths through the watershed to its outlet. Each sub-area and reach contribute flow to the upstream end of a receiving reach or to the outlet.

Figure 2   Sample watershed schematic
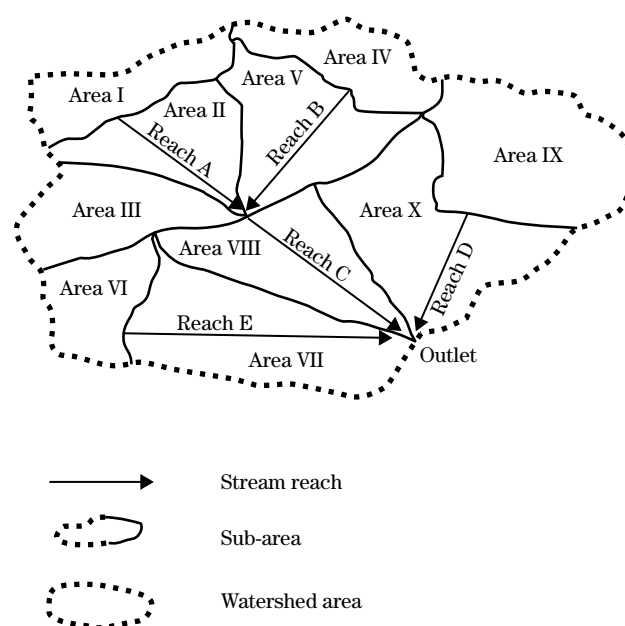
Table 2   Sample watershed flows

Sub-area	Flows into upstream end	Reach	Flows into upstream end
Area I	Reach A	Reach A	Reach C
Area II	Reach C	Reach B	Reach C
Area III	Reach C	Reach C	Outlet
Area IV	Reach B	Reach D	Outlet
Area V	Reach C	Reach E	Outlet
Area VI	Reach E		
Area VII	Outlet		
Area VIII	Outlet		
Area IX	Reach D		
Area X	Outlet		

Accumulated runoff from all sub-areas routed through the watershed reach system, by definition, is flow at the watershed outlet.

Figures 3 and 4 show some of the features available in the window entry, with the features labeled.

Figure 3 Window entry features
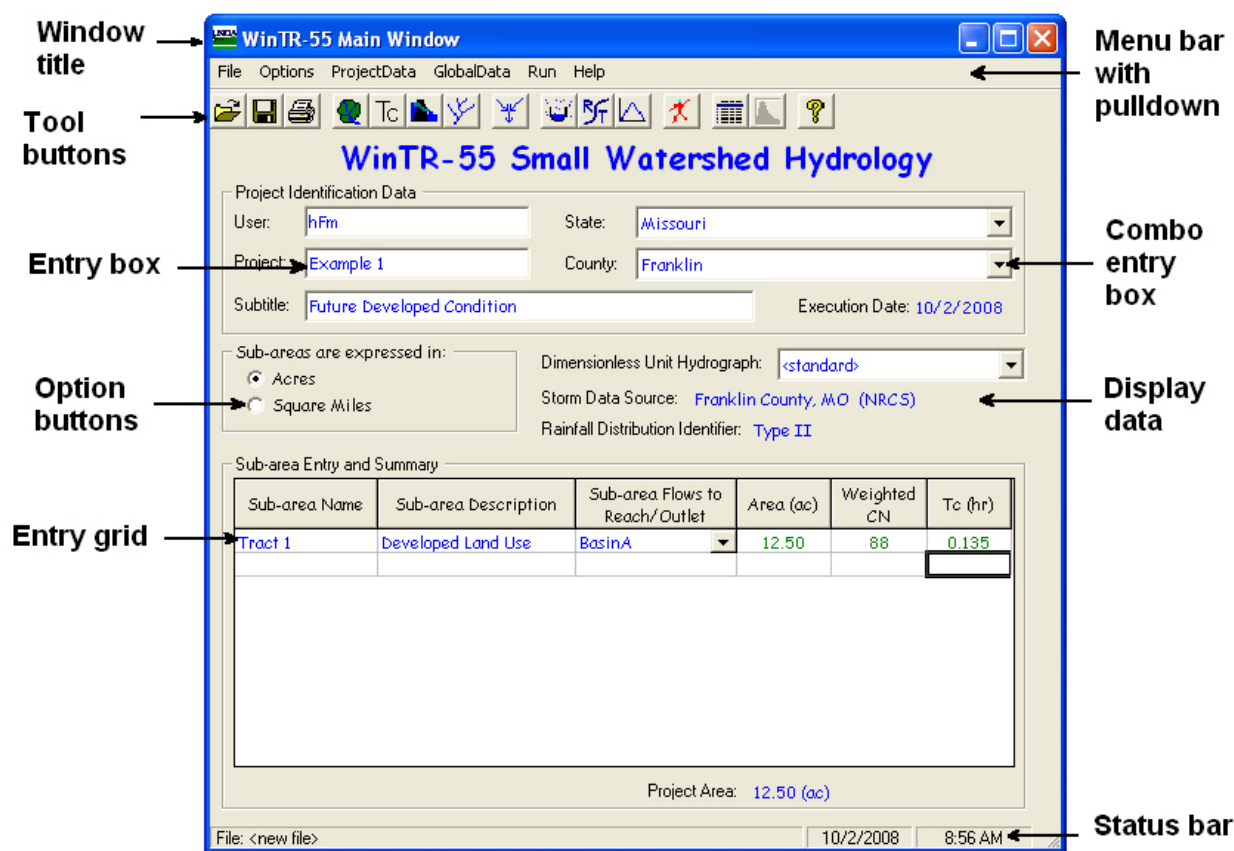
Feature	Function
Window title	Displays title of the window
Tool buttons	Quick access to functions or windows
Entry box	Enter data into box
Option buttons	Select one option of several
Entry grid	Enter data into cells
Menu bar with pulldown	Select menu options with further sub-options
Combo entry box	Select an entry or type in new data
Display data	Display only, cannot enter data into a display area
Status bar	Displays status information: filename, date, time

Figure 4   Additional window entry features
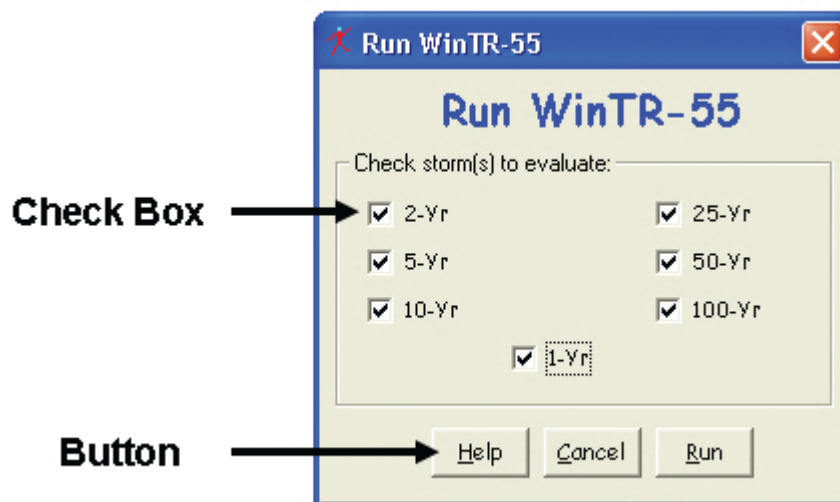
Feature	Function
Check box	Click on box to turn an option on or off
Button	Click to access named function

Welcome to WinTR–55 window

Purpose
The **Welcome to WinTR–55** window (window 1) displays introductory information. To skip this window in the future, check the box in the lower left hand corner. Additional help can be obtained by clicking on the **New User?** button which opens the help for **Welcome to WinTR–55** window (window 2).

Buttons
Exit program
Click **Exit program** to exit program.

New User?
Click **New User?** to display introductory help text.

Start
Click **Start** to begin using WinTR–55 software.

Window 1   Welcome to WinTR–55 window
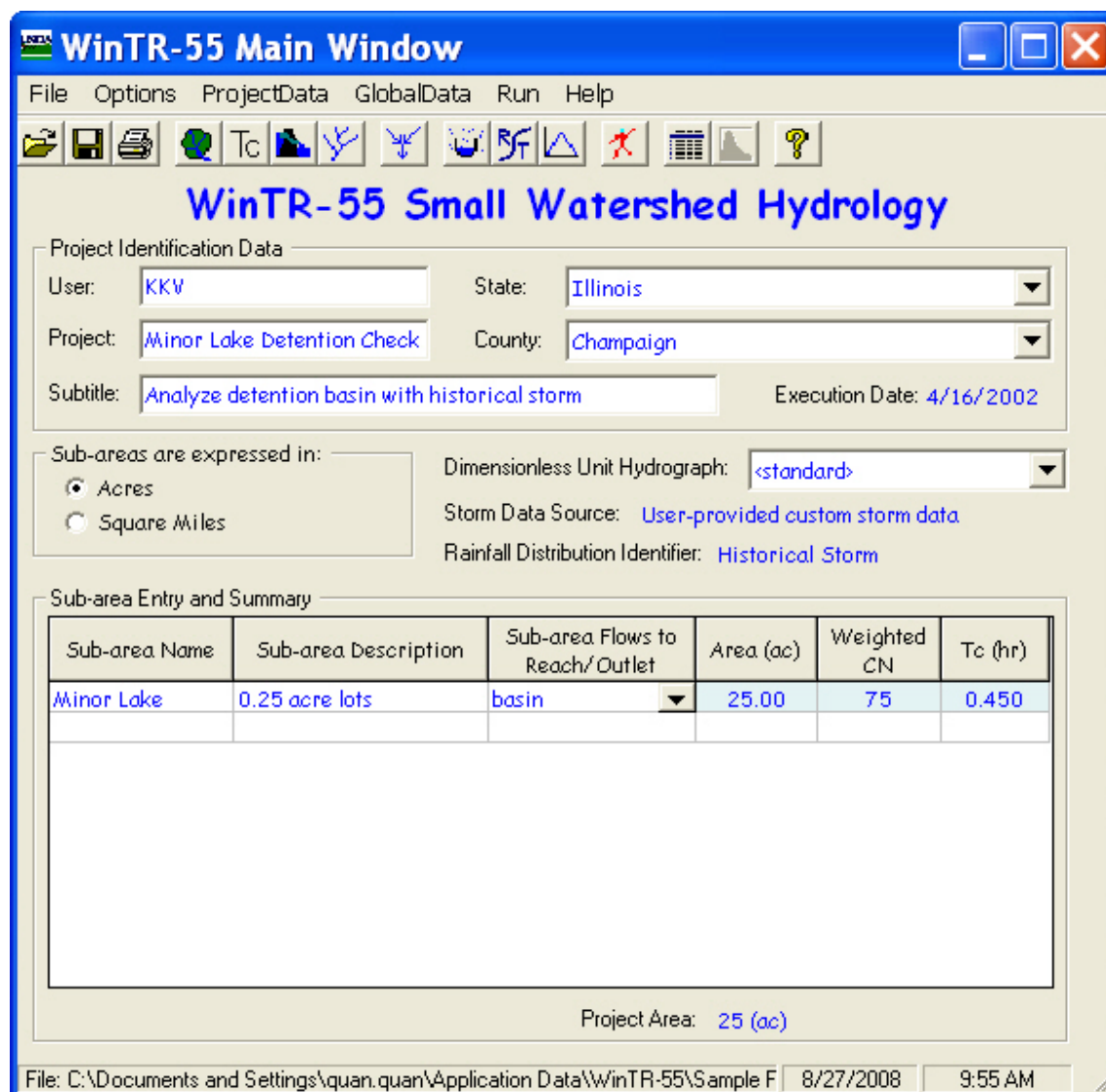
Window 2   Help for Welcome to WinTR–55 window

Help for Welcome to WinTR-55

File   Fonts   Help for...

Help for a New User

Program Description

WinTR-55 is a single-event rainfall-runoff small watershed hydrologic model. The model generates hydrographs from both urban and agricultural areas and at selected points along the stream system. Hydrographs are routed downstream through channels and/or reservoirs. Multiple sub-areas can be modeled within the watershed.

Model Overview

A watershed is composed of sub-areas (land areas) and reaches (major flow paths in the watershed). Each sub-area has a hydrograph generated from the land area based on the land and climate characteristics provided. Reaches can be designated as either channel reaches (where hydrographs are routed based on physical reach characteristics) or as storage reaches (where hydrographs are routed through an embankment based on temporary storage and outlet characteristics). Hydrographs from sub-areas and reaches are combined as needed to accumulate flow as water moves from the upland areas down through the watershed reach network. The accumulation of all runoff from the watershed is represented at the watershed Outlet. Up to ten sub-areas and ten reaches may be included in the watershed.

WinTR-55 uses the WinTR-20 model for all of the hydrograph procedures (generation, channel routing, storage routing, and addition).

Three different types of Help are available for software users.

  1). Generalized Help is available from the Help pull-down on the Main window menu bar.

  2). Window Help is available via the "Help" button on each entry window and most output windows.

  3). Variable help, shown in a box at the bottom of each window, is available via the "?" button.

WinTR–55 Main Window

Purpose
The user enters basic watershed data on the
WinTR–55 Main Window (window 3). Other win-
dows, data, and settings are accessed through the
menus, buttons, and boxes on the main window (illus-
trated in windows 4–9). As other data input windows
are closed, the program returns to the **WinTR–55
Main Window**.

Window 3   WinTR–55 Main Window

Window 4   WinTR–55 Main Window File menu

Menu
The menu bar is located at the top of the **WinTR–55 Main Window**, just below the dark blue window title.

Menu item	Pulldown choice	Explanation
File	New	Create a new input file
	Open	Open an existing input file
	Save	Save current input data using current filename
	SaveAs	Save current input data with different filename
	Page Setup	Setup printer for page output
	Exit	Exit software
		List of recently accessed files that provides a shortcut to any of them

Window 5   WinTR–55 Main Window Options menu
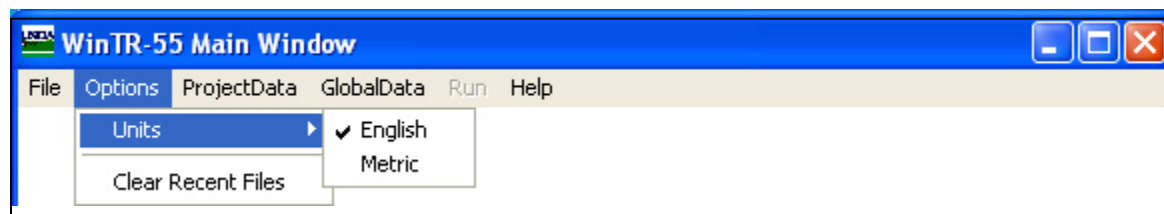
Menu item	Pulldown choice	Explanation
Options	Units	Allows user to declare measurement system: English or Metric.
	Clear Recent Files	Clear the list of recently opened files at the bottom of the File menu

Window 6   WinTR–55 Main Window ProjectData menu
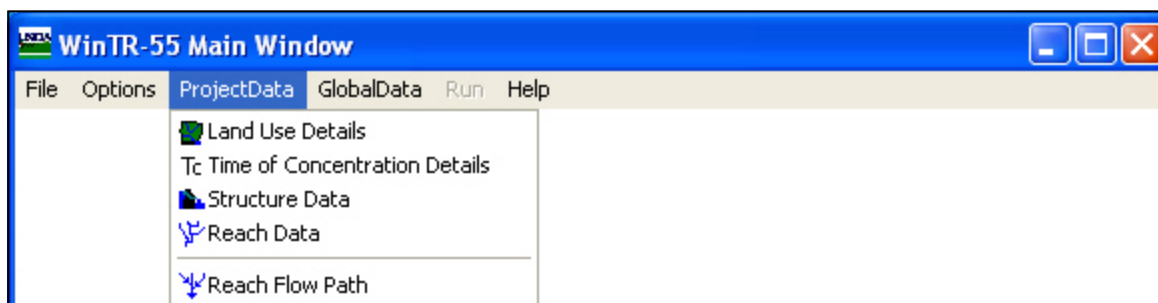
Menu item	Pulldown choice	Explanation
ProjectData	Land Use Details	Open **Land Use Details** window
	Time of Concentration Details	Open **Time of Concentration Details** window
	Structure Data	Open **Structure Data** window
	Reach Data	Open **Reach Data** window
	Reach Flow Path	Display **Reach Flow Path** schematic window

Window 7   WinTR–55 Main Window GlobalData menu
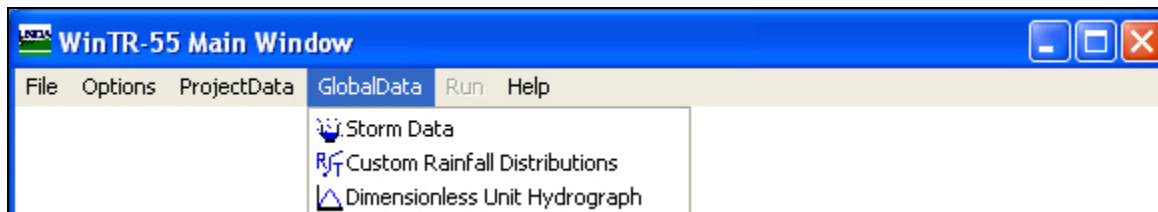
Menu item	Pulldown choice	Explanation
GlobalData	Storm Data	Open **Storm Data** window
	Custom Rainfall Distributions	Open **Custom Rainfall Distributions** window
	Dimensionless Unit Hydrograph	Open **Dimensionless Unit Hydrograph** window

Window 8   WinTR–55 Main Window Run menu
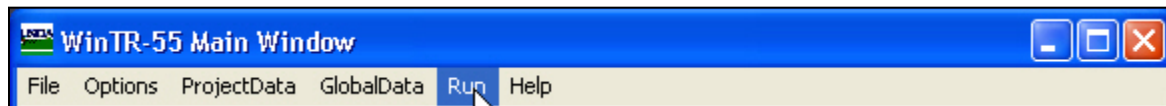
Menu item	Pulldown choice	Explanation
Run		Analyze watershed using currently entered data

Window 9   WinTR–55 Main Window Help menu
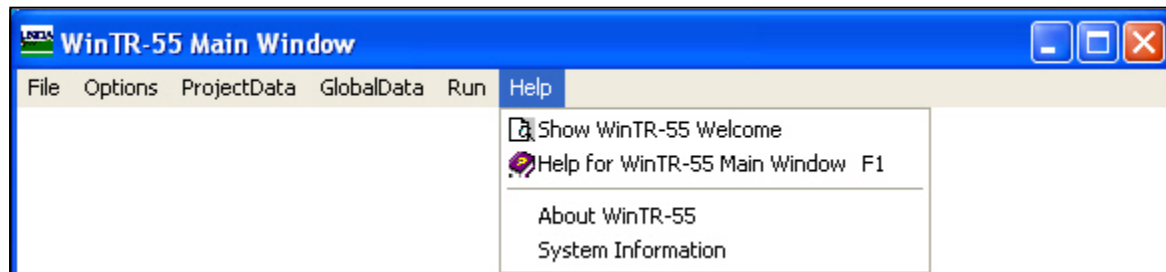
Menu item	Pulldown choice	Explanation
Help	Show WinTR–55 Welcome	Display WinTR–55 Welcome window
	Help for WinTR–55 Main Window F1	Display help
	About WinTR–55	Display program version number and date
	System Information	Display system information, such as operating system

Buttons

The button bar near the top of the **WinTR–55 Main Window** provides a graphical shortcut for some common functions described in the preceding menu section.

Open

Opens a previously created and saved WinTR–55 input data file.

Save

Saves the current data in the file named on the status bar (bottom left corner of window). This button is not available until some data have been entered. If the current data do not have a filename, a box allowing entry of a filename is displayed when **Save** is clicked.

Input Data Printout

Prints a brief report of data on the **WinTR–55 Main Window**.

Land Use Details

Displays **Land Use Details** window to enter or edit land use data by hydrologic soil group for any sub-area.

Time of Concentration Details

Displays **Time of Concentration Details** window to enter or edit flow path information used to compute time of concentration for any sub-area.

Structure Data

Displays **Structure Data** window to enter or edit data for storage ponds with either a pipe or weir outlet.

Reach Data

Displays **Reach Data** window to enter or edit reach data for all reaches in the watershed.

Reach Flow Path

Displays **Reach Flow Path** schematic.

Storm Data

Displays **Storm Data** window to view or edit rainfall depths and frequency. The associated rainfall distribution may be changed.

Custom Rainfall Distribution

Displays **Custom Rainfall Distribution** window to enter or edit custom rainfall distributions.

Dimensionless Unit Hydrograph

Displays **Dimensionless Unit Hydrograph** window to enter or edit custom dimensionless unit hydrographs.
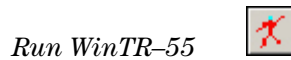
Run WinTR–55

Uses currently entered WinTR–55 data reformatted into WinTR–20 input to run the WinTR–20 model. Results from WinTR–20 are then available to the WinTR–55 program for output displays and/or reports. **Run WinTR–55** is not available until a minimum amount of data has been entered.

Output Definition

Gives the reports that are available for printing or viewing. **Output Definition** window is not available until data have been entered and a run has been completed.

Output Hydrographs

Views output hydrographs at various locations in the watershed. **Output Hydrographs** window is not available until a run has been completed.

Quick Help - Context Sensitive

Quick help provides context-sensitive help for most of the WinTR–55 user interface. Click the large yellow question mark (?) button to turn on the quick help. Clicking on any part of the window will display help information at the bottom of the window. While in help mode, a large question mark (?) is displayed next to the cursor. No data entry is allowed while in Help mode. Clicking **?** a second time returns to the standard cursor.

Some help windows will not display completely with a 600×800 screen resolution. For better viewing, change the monitor's screen resolution to a higher setting such as 1024×768.

Project identification data

The user enters the following information on the Project Identification Data portion of the **WinTR–55 Main Window**. Data to be entered are user name, project name, subtitle, and location of project by state and county. State and county names may be selected from pulldown menus. WinTR–55 can be used for locations outside of the United States by entering a name for the new location that is not on the pulldown state names list. This will cause the state and county labels to change to region and locale (window 24). State and county names supplied with the program cannot be edited. User-entered names can be edited. Entering a single letter jumps to the first match in the list.

Execution date

The execution date shown on the main window is the current date, or for a saved file, it is the date on which the file was saved.

Sub–areas are expressed in

Here, the user specifies which units are used for expressing drainage areas. If English units are used, the options are acres or square miles. If metric (SI) units are used, the options are hectares or square kilometers. The user specifies which system (English or Metric) is used to express drainage area sizes using the Options–Units menu items.

Dimensionless unit hydrograph

The default dimensionless unit hydrograph is the NRCS standard dimensionless unit hydrograph with a peak rate factor of 484 (NEH630.16). A different dimensionless unit hydrograph may be specified by selecting from the pulldown menu or by creating a new one through the **Dimensionless Unit Hydrograph** window.

Storm data source

Upon opening WinTR–55, storm data used for the previous run is listed here. The storm data source listed on the **WinTR–55 Main Window** is not automatically changed when new state and county information are entered. It is very important that the storm data source displayed is the desired data.

WinTR–55 includes a database of 24-hour rainfall values for most of the United States. This data can be viewed or edited through the **Storm Data** window (window 22). Data for locations not found in the database are entered on the **Storm Data** window. User-entered values or modifications to the database values are indicated by a note User-provided custom storm data. Use of database values with no modifications is indicated by the appropriate state and county names being displayed as the **Storm Data** source.

Rainfall distribution identifier

Rainfall distribution is included as part of the rainfall database. However, a different rainfall distribution may be specified on the **Storm Data** window (window 22), or by defining a custom rainfall distribution and entering it on the **Custom Rainfall Distribution** window (window 26).

Sub-area entry and selection

Sub-area information is entered or edited on the sub-area entry and summary table. Sub-area names are up to 10 characters long with at least one alphabetical character. A sub-area description (up to 25 characters) may also be included. The Sub-area Flows to Reach/Outlet is used to describe the upper end of the reach into which the runoff from each sub-area flows on its way to the watershed outlet. The user enters the appropriate reach name (up to 10 alphanumeric characters) here, or selects from a pulldown menu if reaches are defined on the **Reach Data** window.

The reach name Outlet is reserved for the most downstream point of the watershed being evaluated and is always the final reach for every WinTR–55 run. Sub-area drainage area (Area), weighted curve number (Weighted CN), and time of concentration (Tc) may be entered directly into this table or computed using more detailed information on the **Land Use Details** window and **Time of Concentration Details** window. Data entered directly into the table will be displayed in blue, while data computed within WinTR–55 will be displayed in green.

Double-clicking on a column entry within the Sub-area Entry and Summary table opens the appropriate data input window, **Land Use Details**, **Time of Concentration Details**, or **Reach Data**, for additional data entry or editing.

Total watershed area (Project Area) is displayed in the lower right hand corner of this table.

Status bar

The path and filename of the current data are displayed on the left side of the status bar at the bottom of the window. If no file name has been assigned to the current data, <new file> appears in this location. The remainder of the status bar contains the current date and time. The same status bar appears on all other large size data entry windows.

Land Use Details window

Purpose
The **Land Use Details** window (window 10) is used to edit and view the land use description for sub-areas with detailed land use data.

Data entry and selection
The vertical scroll bar on the right side of the window allows the user to locate and view any part of the land use list by dragging the scroll bar up or down to change the part of the cover description list that is displayed.

Scrolling from top to bottom may be time consuming since the table is long. Resizing the window to a larger window displays more lines of land cover.

Clicking any Land Use Categories option button causes the displayed portion of the Cover Description list to jump directly to the beginning of that category's cover descriptions. The complete list of the Cover Descriptions for the Land Use category may be too long to display at one time. If that is the case, use the vertical scroll bar to scroll down and view additional cover descriptions.

Once the desired cover description is in view in the table, enter the areas in the appropriate Hydrologic Soil Group columns (A, B, C, or D). Multiple hydrologic soil group entries can be made for a single cover description.

Window 10   Land Use Details window

Click on the **Sub-area Name** combo box in the upper left corner to select a previously named sub-area and display its data. To enter a new sub-area, click in the combo box and type in a new name.

Summary information
The total watershed area accumulated from the sub-area information is displayed near the bottom left of the window. This total includes all sub-areas whether the data for each were entered in the detailed land use description or as sub-areas on the **WinTR–55 Main Window**.

The Summary Screen buttons provide a toggle for display of the **Land Use Summary for Sub-area** window (window 11). Click **On** to display the summary window, and click **Off** to close the summary window. Information on the summary window is given after this current window description ends.

The accumulated area and associated weighted CN for the current sub-area are displayed in the two boxes at the bottom center of the window. As additional areas are entered or deleted, the summary values change. If both boxes are blank, no detailed land use description data have been entered.

Buttons
Rename
Rename allows the user to rename the sub-area.

Clear
Clear clears all the currently displayed sub-area land use details.

Help
Opens a new help-text window with an overview of window purpose and general data entry instructions.

Quick Help (?)
Click **?** to provide context-sensitive help for any data that are clicked on next. To replace the help question mark cursor with the standard cursor, click **?** again. Help is displayed at the bottom of the window.

Window 11   Land use summary for sub-area window

Land use for area 1	Area	HSG
Paved parking lots, roofs, driveways	2.100	B
Open space; grass cover < 50% (poor	12.000	C
Commercial & business	5.000	B

Cancel
Click **Cancel** to lose all data entered or edited since this window was opened. The window is closed and the **WinTR–55 Main Window** redisplayed.

Accept
Click **Accept** to retain all data entered on the window, close the window, and to redisplay the **WinTR–55 Main Window**. The data are retained only in the computer memory and can be lost if the program is terminated prior to saving the data to a user file. To save data, use either the Save or SaveAs choices from the File menu, or click the diskette icon on the **WinTR–55 Main Window**.

Land Use Summary for Sub-area window

Purpose
The **Land Use Summary** window (window 11) is for display only and shows the detailed land uses and associated areas by hydrologic soil group for a sub-area. The displayed sub-area is the selected sub-area on the **Land Use Details** window. The window is activated or closed from the **Land Use Details** window. To move the **Land Use Summary** window around, right click on the window and drag.

Custom Curve Number window

Purpose
The average percent impervious areas shown for the Urban and Residential Districts are those used to develop the given composite curve numbers (CN). Other assumptions made for urban and residential districts are:

- Impervious areas are directly connected to the drainage system.

- Impervious areas have a CN=98.

- Pervious area CN is equivalent to pasture in good hydrologic condition.

Of these assumptions, the only constant is that impervious areas have a CN=98.

If the table CN values do not fit a particular project, the **Custom Curve Number** window can be used to make appropriate adjustments and compute a revised value.

The **Custom Curve Number** window (window 12) allows entry and editing of data to develop a composite urban curve number when the standard Cover Description assumptions on the **Land Use Details** window do not apply. The user can enter appropriate

numbers into the **Custom Curve Number** window to create a Composite CN to fit a specific land cover. The pervious land use assumption of pasture in good hydrologic condition may not apply, so the user may change the pervious CN. The percent of impervious area in a sub-area may also be changed.

Data entry and selection

To develop a custom curve number, scroll to the user-defined urban line of the Cover Description (in the **Land Use Details** window) and click on the Custom CN button located at the bottom of the Urban Area land use section and just above the Developing Urban land use section.

Land use for setting custom curve numbers is divided into pervious and impervious areas. Impervious area is further identified as connected or unconnected.

An impervious area is a connected impervious area if runoff flows directly into the drainage system or runoff flows as shallow concentrated flow over a pervious area and then into a drainage system. Shallow concentrated flow velocity is fast enough to allow little or no infiltration into the pervious area. An example of a connected impervious area is a residential rooftop where runoff flows from a roof downspout, across a paved driveway, into a street gutter, and finally into a storm sewer drainage system.

An impervious area is unconnected if runoff from it flows as sheet flow over a pervious area before entering the drainage system. Sheet flow is slow enough to presume that some infiltration will occur in the pervious area. If the water from a roof downspout flows across a lawn as sheet flow, with an opportunity for

some of the water to infiltrate the lawn, the rooftop is unconnected impervious area. Unconnected impervious area is only available if impervious area is less than or equal to 30 percent of the total area.

Enter data for Pervious Curve Number, % Impervious Area, and % Impervious that is unconnected in the appropriate entry boxes. A composite curve number will be calculated using equations in appendix B and displayed in the Resulting Curve Number box. The Hydrologic Soil Group entry indicates which CN column (Hydrologic Soil Group A, B, C or D) of the user defined urban cover description line (**Land Use Details** window) the computed curve number will be placed in if the entered data are kept.

Buttons

Help

Opens a new help-text window with an overview of window purpose and general data entry instructions.

Quick Help (?)

Click **?** to provide context-sensitive help for any data that is clicked on next. To replace the help question mark cursor with the standard cursor, click **?** again. Help is displayed at the bottom of the window.

Accept

Click **Accept** to close the **Custom Curve Number** window and redisplay the **Land Use Details** window with the newly defined composite curve numbers. Window 13 shows how the resultant text and custom curve number value of 67 are displayed in the **Land Use Details** window for an example with following conditions:

- 20 acres condos
- Hydrologic Soil Group B
- 20% of the area is impervious
- 50% of the impervious area is unconnected
- CN for the pervious area is 61

Cancel

Click **Cancel** to close the **Custom Curve Number** window and redisplay the **Land Use Details** window, without incorporating the recently defined composite curve number data.

Window 12   Custom Curve Number window

Window 13   Land Use Details window with Custom Curve Number

Land Use Details

Sub-area Name

Condos   [Rename] [Clear]

Land Use Categories

- (•) Urban Area
- ( ) Developing Urban
- ( ) Cultivated Agriculture
- ( ) Other Agriculture
- ( ) Arid Rangeland

Area (Acres) for Hydrologic Soil Groups

Cover Description	Condition	A	CN	B	CN	C	CN	D	CN
1/2 acre	25		54		70		80		85
1 acre	20		51		68		79		84
2 acre	12		46		65		77		82
Western Desert Urban Areas									
Natural desert (pervious areas only)			63		77		85		88
Artifical desert landscaping			96		96		96		96
User defined urban (Click button to define) [Custom CN]				20.00	67		74		
% Impervious Area:					20				
% Unconnected Impervious Area:					50				
Pervious Curve Number:					61		74		
DEVELOPING URBAN AREA (No Vegetation)									
Newly graded area (pervious only)			77		86		91		94

Project Area(ac)   20.00

Summary Screen   (•) Off   ( ) On

Sub-Area   Area (ac) 20   Weighted CN: 67

[Help] [Cancel] [Accept]

File: <new file>   3/7/2008   10:04 AM

Time of Concentration Details window

Purpose
The **Time of Concentration Details** window (window 14) allows entry, editing, and/or viewing of sub-area flow path segment data and the resulting segment travel times and time of concentration for sub-areas in the watersheds that have detailed time of concentration data. The computed sub-area time of concentration is displayed in the Tc column of the Sub-area Entry and Summary portion on the **WinTR–55 Main Window**. The sub-area time of concentration can also be entered directly on the **WinTR–55 Main Window**. Data computed from the **Time of Concentration Details** window will override any prior time of concentration entries on the **WinTR–55 Main Window**. Blue boxes on the **Time of Concentration Details** window contain computed data, while white boxes contain user-entered data.

Data entry and selection
Time of concentration is computed by the method in TR–55 (USDA SCS 1986), chapter 3.

After opening the **Time of Concentration Details** window, select the sub-area in the Sub-area Name combo box. The current 2-year, 24-hour rainfall depth is displayed. To change the 2-year, 24-hour rainfall depth, go to the **Storm Data** window.

Up to five flow segments may be entered: one for sheet, two for shallow concentrated, and two for channel flow. For sheet and shallow concentrated flow, enter the length, slope, and surface type. For channel flow, either enter length, slope, Manning's n, flow area, and wetted perimeter, or enter length and velocity directly.

The equations used for computing each segment's travel time are in appendix B.

Sheet flow length
Sheet flow length in the DOS version of TR–55 was limited to 300 feet (90 m). Sheet flow for 300 feet is very unusual because the surface and the corresponding flow would need to be extremely uniform. Generally, beyond 100 feet the flow becomes concentrated flow. Therefore, sheet flow length is limited to 100 feet (30 m) in this version of WinTR–55. For additional

Window 14   Time of Concentration Details window

information, see Sheet Flow references (References on time of concentration with respect to sheet flow length, Merkel 2001) at *http://www.wsi.nrcs.usda.gov/products/W2Q/H&H/Tools_Models/WinTR55.html.*

Buttons

Rename
Rename allows the user to rename the sub-area.

Clear
Clear clears all the currently displayed time of concentration details.

Help
Opens a new help-text window with an overview of window purpose and general data entry instructions.

Quick Help (?)
Click **?** to provide context-sensitive help for any data that is clicked on next. To replace the help question mark cursor with the standard cursor, click **?** again. Help is displayed at the bottom of the window.

Cancel
Click **Cancel** to lose all data entry or revisions since this window was opened and redisplay the **WinTR–55 Main Window**.

Accept
Click **Accept** to retain all data entered or edited on the window, close the window, and redisplay the **WinTR–55 Main Window**. To save the data file, go to the **WinTR–55 Main Window**, and click the **diskette icon** or **Save** or **SaveAs** on the **File** menu.

Reach Data window

Purpose
The **Reach Data** window (window 15) allows editing and viewing of the stream network, shows whether each reach is a channel reach or a storage (structure) reach, and provides information on creating a channel rating if the reach is a channel reach. No data is required in this window if all sub-areas flow directly to the watershed Outlet. Again, WinTR–55 will only run if all the flow is directed to the outlet.

If the watershed exceeds 10 reaches or the channel or structural hydraulics require a complex rating relationship (for example, a principal spillway and an auxiliary spillway), another program should be used, such as WinTR–20 (Version 1.11) or SITES (Version 2005.02).

Reach-routing element concept
Reaches can be conceptualized as routing elements that exist in two types. The first type of routing element is a channel routing element, which is a stream reach. Data for a stream reach are entered on the **Reach Data** window.

The second type of routing element is a storage routing element, which is a reservoir or structure. If the routing element is a structure, the structure name is entered on the **Reach Data** window. The corresponding data for a structure, however, is entered on the **Structure Data** window.

Data entry and selection
Each reach must have a unique reach name and a receiving reach. Reach names are 1 to 10 characters in length and may be entered here or previously entered as Sub-area Flows to Reach/Outlet on the **WinTR–55 Main Window**.

Window 15 Reach Data window

Reach Name	Receiving Reach	Reach Length (ft)	Manning n	Friction Slope (ft/ft)	Bottom Width (ft)	Average Side Slopes	Structure Name
R3	R4	1625	0.065	0.0240	15.00	30 :1	
R4	R5	5980	0.065	0.0060	20.00	29 :1	
R5	R6	2050	0.070	0.0170	20.00	21 :1	
R6	R7	3285	0.070	0.0070	10.00	20 :1	
R7							

Channel Rating – R6

Stage (f)	Flow (cfs)	End Area (f²)	Top Width (f)	Velocity (f/s)
0.0	0.000	0.00	10.00	0.000
0.5	8.534	10.00	30.00	0.853
1.0	37.879	30.00	50.00	1.263
2.0	190.394	100.00	90.00	1.904
5.0	1854.601	550.00	210.00	3.372
10.0	11073.716	2100.00	410.00	5.273
20.0	68099.804	8200.00	810.00	8.305

File: C:\Documents and Settings\quan.quan\Application Data\WinTR-55\Sample Files\Ex 3-residue.w   9/16/2008   11:49 AM

A downstream receiving reach is required for each reach. A pulldown choice list provides previously entered reach names to chose from along with the watershed outlet. If a new name is entered into the receiving reach box, it will also be added to the reach name list as long as the current number of reaches is less than 10. If the current number of reaches is 10, then no new names are accepted in the receiving reach box.

When data are entered on the reach line for one type of routing, the box(es) for the other routing type will be grayed out. Data may still be entered in a gray box but will cause previously entered data on the line of the other routing type to be lost. Data for only one type of routing per line is retained.

To channel route, enter data for reach length, Manning's n, friction slope, bottom width, and side slope. The reach length will be either the stream channel length or the flood plain length for the reach. Which length is used depends on whether expected flows are within bank or out of bank. The other parameters define a representative cross section for the reach. Based on the channel cross section information entered, a channel rating relationship for the reach is computed and displayed below the grid. The equations used in development of the channel rating are in appendix B.

To storage route, enter a structure name, or select from the choice list (if the structure has been previously described). To edit or view structure data, double click the **Structure Name** to display the **Structure Data** window.

Selecting a representative cross section
A WinTR–55 reach cross section is either a rectangular, triangular, or trapezoidal channel. The rating is based on the channel bottom width, side slope, Manning's n, and friction slope data. The cross section rating includes Manning's equation discharges for fixed depths at the cross section (0.5, 1.0, 2.0, 5.0, 10.0, and 20.0 feet).

The Muskingum-Cunge flood routing method estimates how the hydrograph changes as it flows through the reach utilizing this rating information (Chow, Maidment, and Mays 1988; Maidment 1993; or Ponce 1989). Typically, reach storage reduces and delays the peak discharge. In addition, the hydrograph peak becomes more rounded.

During a WinTR–55 run, all selected storms use one cross section rating for a reach. For this reason, selecting a representative cross section for the reach is extremely important. Generally, the channel has a

capacity of a 5-year discharge or less (if the channel has a large capacity, the following information may not apply). If the peak discharge stays in the channel banks and the channel dimensions and roughness are entered, then the routing is reasonable. If the peak discharge flow overtops the channel banks, the reach routing is still based on the channel shape extending the side slopes up to 20 feet, which will not give a good representative stage-discharge relationship.

Using channel cross-sectional data to represent the flood plain cross section will generally raise the peak discharge at the downstream end of the reach and translate it downstream sooner than if the flood plain and its storage are considered. The impact varies with the flood plain width and its associated roughness.

The user must judge what is a reasonable approximation of the shape of the cross section above the channel banks. For example, the 2-year channel could be a 10-foot bottom width stream with 2:1 side slopes and 0.04 Manning's n. However, the 100-year flow area might be represented by a 100-foot bottom width flood plain with 10:1 side slopes and 0.07 Manning's n. However, WinTR–55 only accepts one set of data to represent the channel reach for all storms.

If the channel-only (no flood plain) approximation is unreasonable, one alternative is to enter a reach cross section representative of the flood plain (width, side slope, and Manning's n). This alternative neglects the effect of the channel on the total cross section rating.

A second alternative is to use a hydraulic model, such as U.S. Army Corps of Engineers HEC–RAS, to develop the total cross section rating to include both the channel and flood plain. Then use the NRCS WinTR–20 hydrologic model to develop and route the storm hydrographs.

Buttons
Help
Opens a new help-text window with an overview of window purpose and general data entry instructions. Close the help-text window to return to data entry.

Quick Help (**?**)
Click **?** to provide context-sensitive help for any data that is clicked on next. To replace the help question mark cursor with the standard cursor, click **?** again. Help is displayed at the bottom of the window.

Plot
Click **Plot** to produce a graphical representation of the channel rating (window 16) and end area ratings from the data entered.

Cancel
Click **Cancel** to lose all data entry or revisions since this window was opened and redisplay the **WinTR–55 Main Window**.
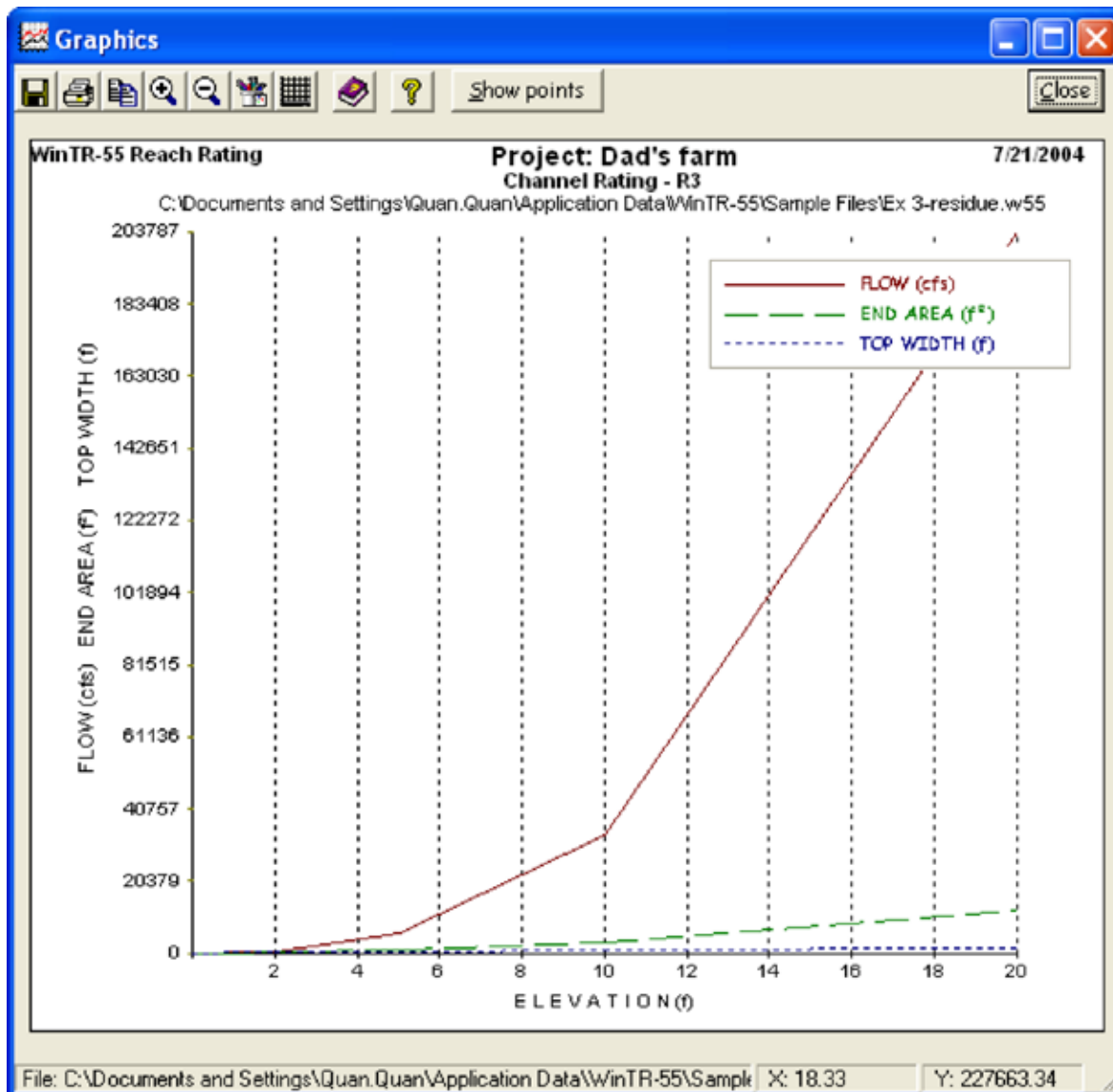
Accept
This button saves all data, closes the window, and returns to the **WinTR–55 Main Window**. To save the data file, go to the **WinTR–55 Main Window**, and click on the **Save** icon, or select **File Save** or **SaveAs** from the menu.

Reach Flow Path
Click **Reach Flow Path** to display the **Reach Flow Path** window (window 17).

Window 16   Channel Rating plot

Reach Flow Path window

Purpose

The **Reach Flow Path** window (window 17) displays a reach schematic of the currently entered reach, sub-area, and structure information. If the user clicks on Outlet in the Reach Flow Path Diagram, the total drainage area of the project appears below the Blue - Reaches label in the window.

Buttons

Detail

This button toggles between displaying detailed information with labels as shown in window 17 or displaying labels only in the schematic.

Help

Opens a new help-text window with an overview of window purpose and general data entry instructions. Close the help-text window to return to data entry.

Quick Help (**?**)

Click **?** to provide context-sensitive help for any data that is clicked on next. To replace the help question mark cursor with the standard cursor, click **?** again. Help is displayed at the bottom of the window.

Close

This button closes the **Reach Flow Path** window and returns to the previously displayed window.

Window 17   Reach Flow Path window

Structure Data window

Purpose
The **Structure Data** window (window 18) allows data entry and editing for the pond's surface area, structure outlet type and dimensions, and structure rating relationship for a structure. Three different outlet sizes (trials) may be defined for each structure. No data is required for this window if there are no structures in the watershed.

If the temporary ponding storage or structure hydraulics require a complex rating relationship, another routing method should be used, such as WinTR–20 (Version 1.11) or SITES (Version 2005.02).

Alternate outlet sizes for multiple structures
Three outlet sizes may be entered for any structure. If the watershed has multiple structures and multiple outlet sizes, WinTR–55 will only compute up to three trials. Alternative one will combine the Trial #1 outlet sizes of each structure, alternative 2 will combine the Trial #2 outlet sizes of each structure, and alternative 3 the Trial #3 outlet sizes. Otherwise, the statistically possible number of alternatives with 10 structures and 3 outlet sizes is 3^{10} (greater than 59,000). Since WinTR–55 only computes three trials, computation time is much faster and there are only three alternatives to review and evaluate.

Window 18   Structure Data (pipe outlet) window

Data entry and selection

Enter the structure name (1 to 10 characters) or select from the choice list in the combo box. If data have been previously entered for the structure name, it will be displayed in the combo boxes in the window. If no data have been previously entered, all other entries will be blank. The first eight characters in structure names must be unique in each file. For example, Structure1 and Structure2 are invalid names because the first eight characters of the name are not unique. However, Struct1 and Struct2 are valid structure names.

Enter the pond surface area at the spillway crest elevation and, optionally, a height above the spillway crest and the pond surface area at that height. The pond area and height data are used to calculate temporary storage volumes for the ponded area. If surface area at the spillway crest elevation is entered without an optional second surface area, the pond is assumed to have vertical sides, and volume is based upon a constant surface area. If a second area at some elevation above the principal spillway crest elevation is given, it is assumed the pond cross section is trapezoidal and incremental storage volume is computed based upon a variable surface area.

Select the Spillway Type (Pipe or Weir). The default is pipe.

Pipe outlet

If pipe is selected, one to three pipe diameters may be specified along with the height from the outlet invert to the spillway inlet crest for each diameter. WinTR–55 will compute pipe head from the entered data. The minimum pipe diameter is 6 inches (152.4 mm). To satisfy the short-tube flow assumptions as described in the next section, the minimum height (outlet to spillway) should be at least twice the largest pipe diameter being evaluated. The discharge equations used in the structure rating are in appendix B. Once the first pipe diameter and height are entered, a pipe rating table is generated using the pipe discharge equations in appendix B and displayed below the Outlet Description on the **Structure Data** window. The table is updated as additional information is entered or is revised.

Short-tube flow assumptions

At any given stage, WinTR–55 assumes short-tube flow for the computed pipe head based on pipe diameter. This is a reasonable assumption for the riser and pipe configuration (fig. 5 bottom schematic). However, this assumption may be unreasonable for large, straight pipes (fig. 5 top schematic).

The short-tube approximation uses an assumption of orifice flow at the pipe outlet. Therefore, this assump-

tion is best based on full-pipe flow occurring. Full-pipe flow may or may not occur, but the condition is never checked in the program. A coefficient of 0.6 is reasonable for normal conditions. It is assumed that the pipe outlet is not submerged.

For example, if the structure outlet is a 36-inch (0.91 m) diameter pipe culvert and the maximum computed stage is 1.5 feet (0.46 m), then the pipe has never been more than half-full (fig. 6). In this case, the short-tube flow assumption has not been satisfied, and WinTR–55 should not be used for structural analysis. Other routing software, such as SITES (Version 2005.02), is necessary to analyze these cases.

Weir outlet

If weir is selected, one to three weir lengths may be specified. The entry of a zero weir length indicates a V-notch weir while all other lengths are for rectangular broad-crested weirs. Once the first weir length is entered, a weir rating table is generated using the weir discharge equation in appendix B, and displayed below the Outlet Description on the **Structure Data** window. Figure 7 shows the weir diagram.

The table on the **Structure Data** window is updated as additional information is entered or is revised. Window 19 shows weir outlet data entry.

Additional items to note about entry on the **Structure Data** window are:

- Toggling between the two different outlet types clears the outlet dimension values.

- Minimum data for a valid run is surface area at the spillway crest, outlet type, and one outlet size. If the outlet is a pipe, height must also be entered.

Buttons

Clear
Clears all data for existing structure.

Delete
Deletes current structure data and name.

Rename
Renames current structure.

Accept
Accepts current data, closes the window, and returns to **WinTR–55 Main Window**.

Plot
Click **Plot** to produce a graphical representation of the structure rating as shown in windows 20 and 21.
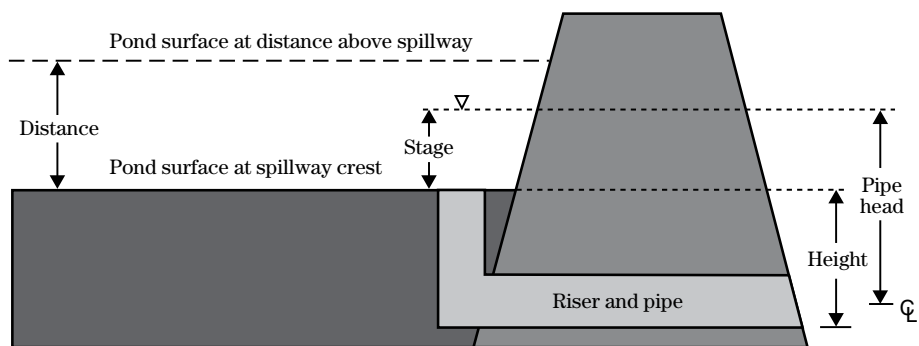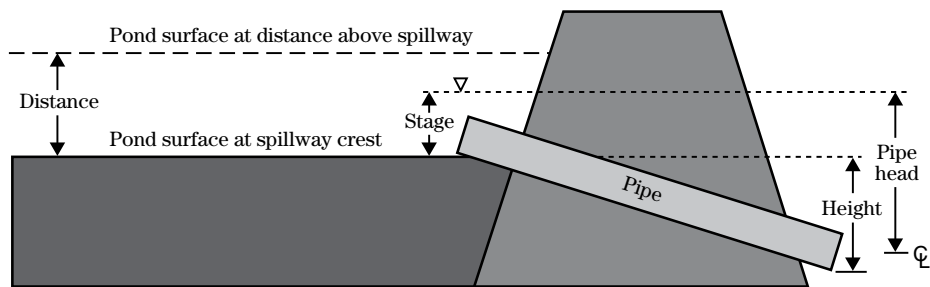
Figure 5   Pipe outlet schematics

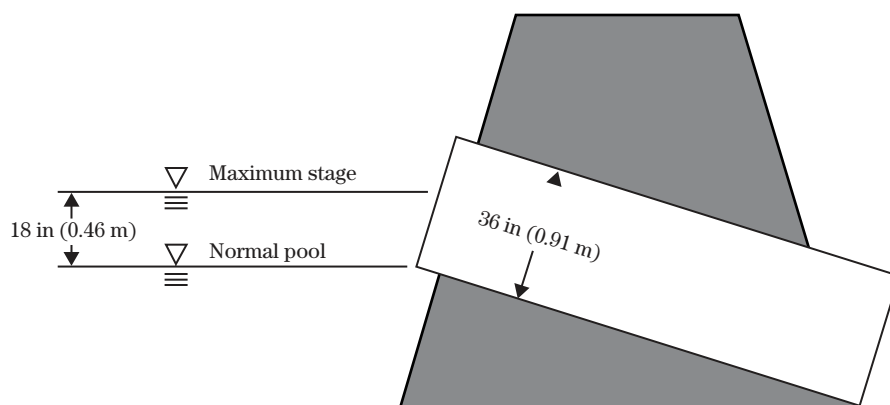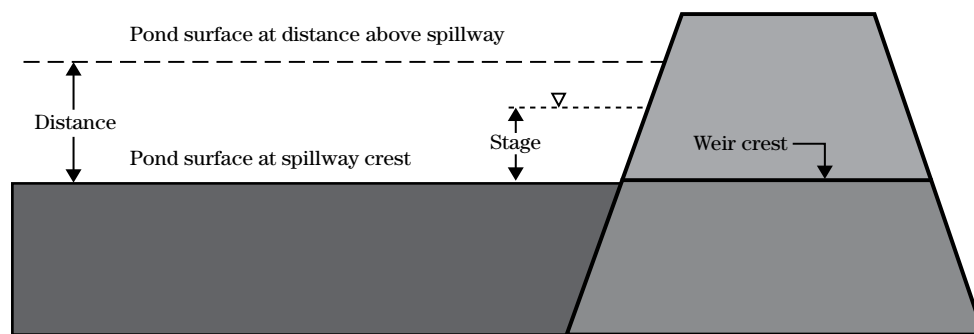**Figure 6**   Short-tube flow assumption not valid

Figure 7   Weir outlet schematic

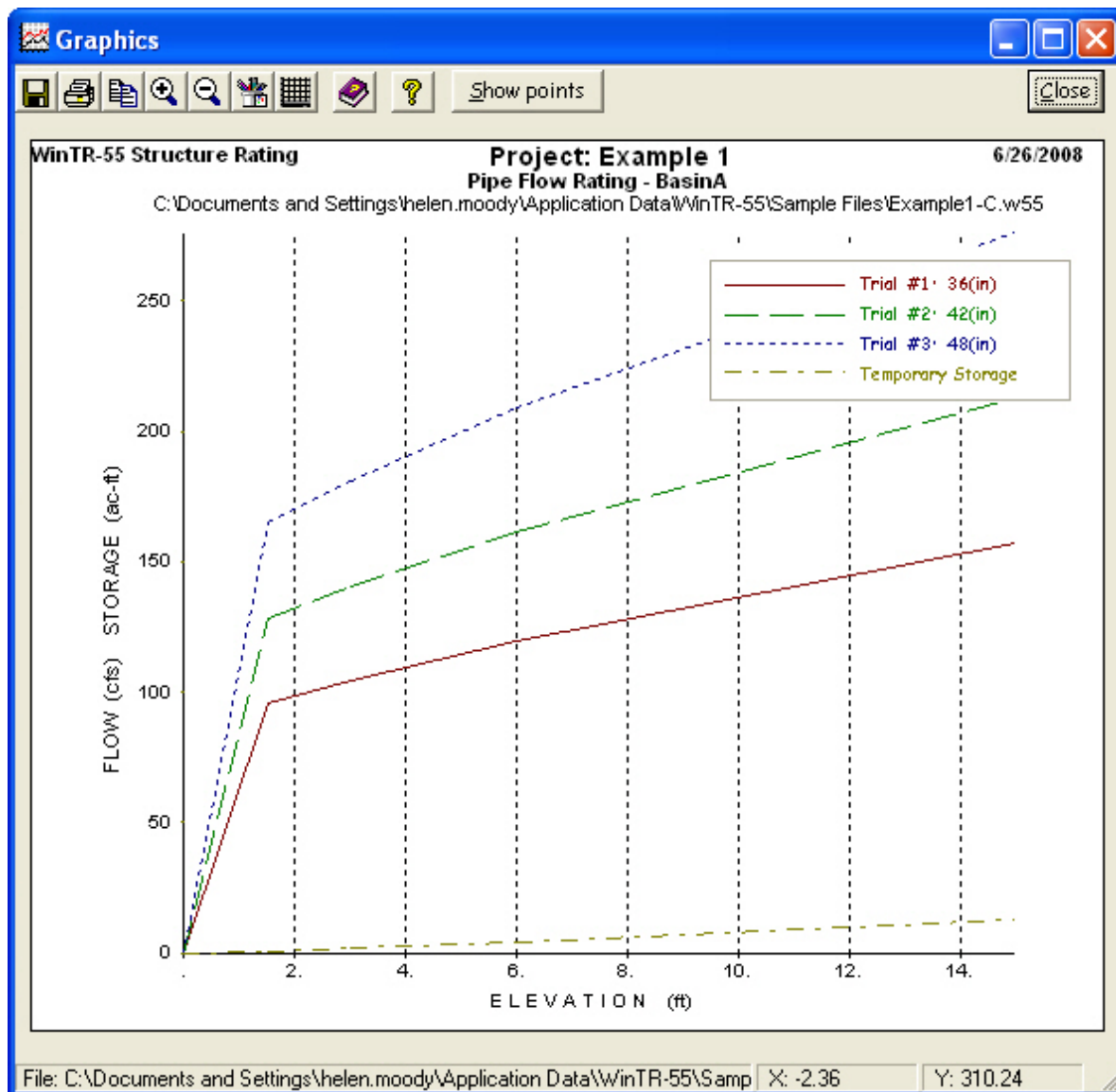**Window 19**   Structure Data (weir outlet) window

Cancel
Click **Cancel** to lose all data entry or revisions since this window was opened and redisplay the **WinTR–55 Main Window**.

Help
Opens a new help-text window with an overview of window purpose and general data entry instructions. Close the help-text window to return to data entry.

Quick Help (?)
Click **?** to provide context-sensitive help for any data that is clicked on next. To replace the help question mark cursor with the standard cursor, click **?** again. Help is displayed at the bottom of the window.

Window 20   Structure Rating plot (pipe outlet)

Window 21   Structure Rating plot (weir outlet)
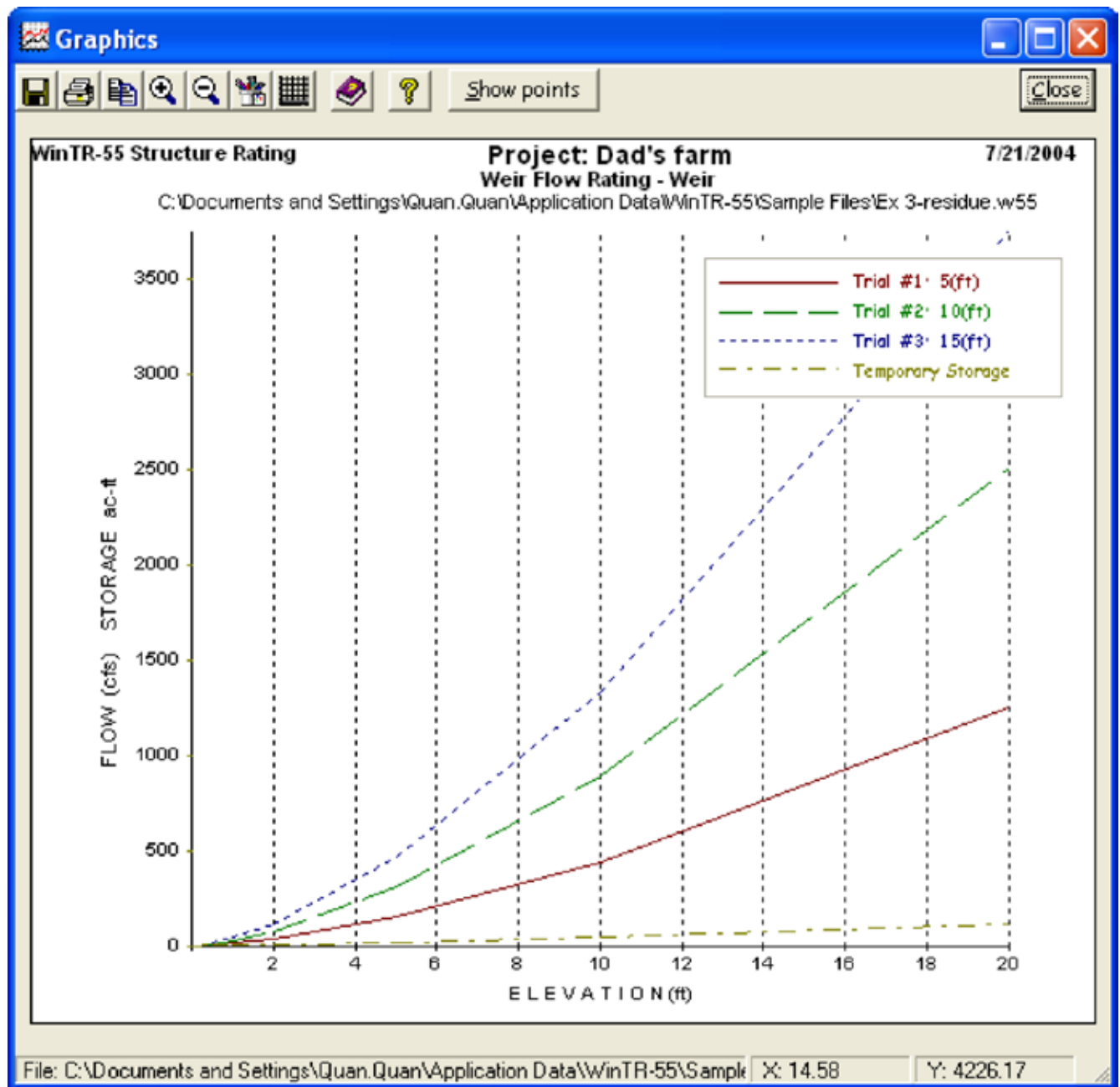
Storm Data window

Purpose
The **Storm Data** window (window 22) is used to specify rainfall data for the desired location. Storm data consists of at least one 24-hour rainfall amount, its return period, and associated rainfall distribution.

A rainfall database containing the 24-hour rainfall amounts by return period and associated rainfall distributions for many counties in the United States is included with WinTR–55.

Sometimes it is desirable to modify the database values with different amounts or rainfall distributions. Users are prevented from making changes to the database itself, but the data can be revised for individual WinTR–55 runs. Such modifications can be made on the **Storm Data** window. Revisions are saved only with the specific project data and not saved to the database.

Some states chose not to submit data for the database. It is the user's responsibility to ensure that WinTR–55 is using the proper rainfall data set for database values and provide appropriate 24-hour rainfall amounts, return periods, and distributions for values not included in the database.

Since local design requirements may supersede NRCS provided information, it is the user's responsibility to verify the appropriateness of all rainfall data inputs, including database values.

Data entry and selection
Watersheds inside United States—When the **Storm Data** window opens, the data displayed is for the previous WinTR–55 run. This may not be the correct data for the desired location of the current project. To update the data from displayed values to the desired location values from the WinTR–55 rainfall database, click on the **NRCS Storm Data** button. If no data are available for the current state and county information entered on the main window, this button is temporarily disabled, and the rainfall volumes, return periods, and distributions must be user specified.

Watersheds outside United States—No rainfall data are provided for areas outside the United States (window 23). For example, for a watershed in Durango, Mexico, the **WinTR–55 Main Window** combo box entry labels change from State and County to Region and Locale, as shown in window 24. Since the program retains previously used rainfall data until the user changes it, all watersheds outside of the United States require the user to work through the **Storm Data** window to enter the appropriate 24-hour rainfall volumes, return intervals, and distributions.

Window 22   Storm Data window

Window 23   Storm data for areas outside the United States

Window 24   Watersheds outside of the United States

The user must enter all the rainfall return period data and 24-hour rainfall amounts because the **NRCS Storm Data** button on the **Storm Data** window is disabled (window 23). The user must also select a rainfall distribution from the Rainfall Distribution Type combo entry box or develop a custom rainfall distribution.

Rainfall distribution—To change the associated rainfall distribution type displayed on this window, click on the pulldown menu to select any previously entered distribution. To enter a new rainfall distribution, click **Cancel** to return to the **WinTR–55 Main Window**, and select **Custom Rainfall Distributions** from the Global Data pulldown menu.

When **File-New** is selected from the **WinTR–55 Main Window**, all the project data (Land Use, Tc, Structure, and Reach) are cleared. However, the global data (Storm Data, Rainfall Distribution, and Dimensionless Unit Hydrograph) are not changed. Furthermore, the global data are not changed even if the state and county are changed on the **WinTR–55 Main Window**.

Window 25 shows that the Project Identification Data are for Maui, Hawaii. However, the storm data source lists Franklin County, Missouri. Obviously, the Missouri data are not appropriate for Hawaii. The user must verify that the storm data for each project are accurate and appropriate.

Window 25   Differing state/county and storm data source example

Template files for storm data—Some users may use the same storm data set or sets repeatedly. If these data sets are not NRCS storm data sets, it would become tedious to re-enter the same rainfall data for each project. To create a template file, click **File-New** on the **WinTR–55 Main Window** to clear all the project data. Then enter the desired custom storm data. All the project data (Land Use, Tc, Structure, and Reach) have been cleared in the file. Save this file with a filename descriptive of the storm data.

To use this storm data for future projects, open this template file with the storm data first. Then proceed by entering project data (Land Use, Tc, Structure, and Reach). Make sure to save the project file with a different name so the template file is not overwritten.

Buttons
NRCS Storm Data
This button retrieves NRCS rainfall data if available. If the button is not available, the rainfall is not available in the database. Therefore, the user must supply all the rainfall data.

Help
Opens a new help-text window with an overview of window purpose and general data entry instructions. Close the help-text window to return to data entry.

Quick Help (**?**)
Click **?** to provide context-sensitive help for any data that is clicked on next. To replace the help question mark cursor with the standard cursor, click **?** again. Help is displayed at the bottom of the window.

Cancel
Click **Cancel** to lose all data entry or revisions since this window was opened and redisplay the **WinTR–55 Main Window**.

Accept
Accept applies all new data, closes the window, and returns to the **WinTR–55 Main Window**. To save the data file, go to the **WinTR–55 Main Window**, and click **Save** or select **File Save** from the menu.

Custom Rainfall Distribution window

Purpose
The **Custom Rainfall Distribution** window (window 26) allows the user to input and revise nonstandard 24-hour rainfall distributions. The standard rainfall distributions in WinTR–55 may not be edited or deleted.

The first point of each distribution is 0.00000, and the last point should be 1.00000. No blank points are allowed. Each successive point must be equal to or larger than the previous one. Data are read left to right, starting at the top line and continuing to the bottom line. A maximum of 500 data points is allowed.

Data entry and selection
To enter a new distribution, type the name into the Local Distribution(s) entry box. To delete a distribution, select the distribution name from the pulldown menu, and then click **De̲lete**.

As rainfall distribution data are entered, WinTR–55 automatically displays the number of points entered and adjusts the time increment in hours for that number of points.

To view the Edit menu, right-click the mouse when the cursor is on a data point. The Edit menu allows the user to create and revise data points for the current rainfall distribution. **Insert Point** inserts a blank data point before the current point. **Delete Point** removes the current data point and moves successive points up. Click within a cell to edit the data in that cell.
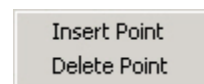
Buttons
R̲ename
Rename is used to rename the currently displayed rainfall distribution.

De̲lete
This button deletes the current distribution.

Plot
Clicking on **Plot** produces a graphical representation of the current rainfall distribution (window 27). Only one distribution may be displayed at a time.

D̲one
Done on the **Custom Rainfall Distribution** window prompts WinTR–55 to save the distribution and return to the **WinTR–55 Main Window**. Note that this process is different than saving project-specific data, such as Land Use Details, which only updates data in memory.

Window 26   Custom Rainfall Distribution window

Window 27   Custom Rainfall Distribution plot

Dimensionless Unit Hydrograph window

Purpose
The **Dimensionless Unit Hydrograph** window (window 28) is used to input and revise nonstandard dimensionless unit hydrographs. The standard dimensionless unit hydrograph (peak rate factor = 484) in WinTR–55 may not be edited or deleted.

No blank points are allowed in the dimensionless unit hydrograph data table. Each point must increase from 0.00000 to 1.00000, then decrease to 0.00000. Data are read left to right, starting at the top line and continuing to the bottom. A maximum of 500 data points is allowed. For further information on dimensionless unit hydrographs, see NRCS NEH 630.16.

The user-defined dimensionless unit hydrographs can be entered and revised. To access this feature, right click in the Dimensionless Hydrograph Points area of the **Dimensionless Unit Hydrograph** window. **Insert Point** inserts a blank data point before the current point. **Delete Point** removes the current data point and moves successive points up. Click within an individual cell to edit data in that cell.

Window 28   Dimensionless unit hydrograph window

Data entry and selection
To enter a new dimensionless unit hydrograph, type the name into the Local Hydrograph(s) entry box.

As dimensionless unit hydrograph data are entered, WinTR–55 automatically displays the number of points entered. To delete a local dimensionless unit hydrograph, select the dimensionless unit hydrograph name from the pulldown list, and click the **Delete** button.

Buttons
Rename
Rename is used to rename the currently displayed dimensionless unit hydrograph.

Delete
This button deletes the current dimensionless unit hydrograph.

Plot
Click **Plot** to produce a graphical representation of the dimensionless unit hydrograph (window 29).

Done
Clicking **Done** prompts WinTR–55 to save the dimensionless unit hydrograph and return to the **WinTR–55 Main Window**. Note that this process is different from saving watershed-specific data, such as Land Use Details, which only update data in memory.

Help
Opens a new help-text window with an overview of window purpose and general data entry instructions. Close the help-text window to return to data entry.

Quick Help (**?**)
Click **?** to provide context-sensitive help for any data that is clicked on next. To replace the help question mark cursor with the standard cursor, click **?** again. Help is displayed at the bottom of the window.

Graphics windows

Purpose and description
The **Graphics** windows for various functions (dimensionless unit hydrograph, rainfall distribution, reach rating, an output hydrograph) show graphically how two or more variables relate to one another. For example, the plot in window 30 shows how discharge or stream flow, end area, and top width vary with elevation for a channel reach section.

Window 29   Dimensionless unit hydrograph plot

Window 30   Typical Graphics window plot

Buttons

SaveAs

Saves the current plot to a bitmap file.

Print

Prints the current plot to a selected printer.

Copy to Clipboard

Copies the plot to the system clipboard for later insertion into other software, such as word processors.

Zoom In

Using the Zoom In feature allows the user to zoom into a selected area of a plot by selecting a portion of the plot that includes two or more data points. Zoom In neither plots data points, nor does it extrapolate outside the data set.

Zoom Out

Restores the view of the full plot.

Line Attributes

Through Line Attributes, the user can change the plotted graphic by selecting various line widths, colors, and types.

Grid Lines

Toggles between no grid lines, horizontal grid lines only, vertical grid lines only, and both horizontal and vertical grid lines.

Help - Context Sensitive

The help data window is displayed below the data grid at the bottom of the window.

Quick Help (**?**)

Click **?** to provide context-sensitive help for any data that is clicked on next. To replace the help question mark cursor with the standard cursor, click **?** again. Help is displayed at the bottom of the window.

Show Points

Clicking on **Show Points** causes the individual points to be plotted on the hydrograph line.

Close

Closes the **Graphics** window and returns to the previous window.

Running WinTR–55

To run the WinTR–55 model, click Run on the menu bar, or click the Run WinTR–55 button. When the **Run WinTR–55** window opens, choose which storm frequencies to run by checking the appropriate boxes, and click the Run button. A WinTR–20 input data file is prepared, and the WinTR–20 model is run producing hydrographs for all of the sub-areas and reaches (upstream and downstream), as well as for the watershed outlet. If the run is successful, the Hydrograph Peak/Peak Time table is displayed in the **File Display** window. If the run is unsuccessful, the Error file from WinTR–20 is displayed in the **File Display** window. Any data errors need to be corrected before another run is attempted.

Disclaimer
*Although WinTR–55 has been tested by its developers, **NO** warranty, expressed or implied, is made as to the accuracy and functioning of the program and related program material nor shall the fact of distribution constitute any such warranty, and **NO** responsibility is assumed by the developers in connection therewith.*

WinTR–55 processes

WinTR–55 preprocesses data during data entry for WinTR–20 hydrograph computations. The preprocessing computations are time of concentration, land use parameters, channel rating table, and structure rating table.

Time of concentration (Tc)
Sub-area Tc may be entered directly on the Sub-area Entry and Summary portion of the **WinTR–55 Main Window,** or it may be computed from the detailed flow path data entered on the **WinTR–55 Time of Concentration Details** window. Data entry and computations are subdivided into three types of flow (sheet, shallow concentrated, and channel flow). While data for only one sheet flow segment can be entered, one or two segments of data can be entered for both the shallow concentrated and channel flows. The total computed travel times for each flow path segment are indicated on the entry window as is the Tc (sum of the travel times). The equations used to compute the various travel times for each segment type are in appendix B. Tc values in the Sub-area Entry and Summary portion of the **WinTR–55 Main Window** are coded in either green or blue text. Green text indicates a value computed on the **WinTR–55 Time of Concentration Details** window, while the blue text indicates a value that was entered directly.

Land use parameters
A sub-area drainage area and weighted runoff curve number may be entered directly on the Sub-area Entry and Summary portion of the **WinTR–55 Main Window** or computed from land use data entered on the **Land Use Details** window. For each hydrologic soil group land cover complex, the area covered is entered on the **Land Use Details** window by individual sub-areas in the watershed. The land use areas entered are summed to determine the sub-area drainage area. They are also used to weigh the applicable runoff curve numbers for the land use hydrologic soil group combination to produce a sub-area weighted curve number. The equation used in the curve number weighting is in appendix B. Curve number values in the Sub-area Entry and Summary portion of the **WinTR–55 Main Window** are coded in either green or blue text. Green text indicates a value computed on the **Land Use Details** window, while blue text indicates a value that was entered directly.

The optional Custom CN button on the land use details table allows the user to compute a weighted curve number for a cover description that is not covered by the standard cover description assumptions on the **Land Use Details** window. Custom curve numbers are computed based upon a given pervious area curve number (from one of the standard table values), the percentage of the impervious area in the sub-area (CN=98), and the percentage of the impervious areas that are not directly connected to the flow path.

Channel rating table
A channel rating table is generated for each reach with channel information entered. The rating table consists of discharge, cross section end area, top width, and velocity for depths from 0 to 20 feet (0–6.1 meters). This range should cover all WinTR–55 applications. The rating table data are displayed below the entry portion of the **Reach Data** window when sufficient data are entered to perform the calculations. The equations used for each of the rating parameters are in appendix B.

Structure rating table
For each reach that has structure information entered, a structure rating table is generated. The information in the rating table depends on the structure outlet type (pipe or weir). The pipe outlet rating table consists of stage, pipe head, pipe flow, and temporary storage. The weir table consists of stage, weir flow, and temporary storage. One to three pipe diameters or weir lengths can be entered. A set of seven stages, based on multiples of the smallest pipe diameter, is computed for pipes, and similarly, a set of seven stages from 0 to 20 feet (0–6.1 meters), is computed for weirs. The

rating table data are displayed below the entry portion of the **Structure Data** window when sufficient data are entered to perform the calculations. The equations used for each of the rating parameters are in appendix B.

WinTR–20 processes

WinTR–55 relies on the WinTR–20 model for all hydrograph processes. These include hydrograph generation, combining hydrographs, channel routing, and structure routing. A brief description of each of these processes follows.

Hydrograph generation

Hydrographs are generated from sub-areas using the appropriate rainfall depth (for a specific frequency), rainfall distribution, sub-area drainage area, time of concentration (Tc), and curve number using the NRCS hydrograph generation technique. The sub-area Tc is used to establish the time interval for the spacing of points in the dimensionless unit hydrograph. This time interval defines the generated hydrograph time increment. The rainfall distribution is linearly interpolated to develop mass rainfall values to use at the time increment needed.

Combining hydrographs

Two hydrographs are combined using the first hydrograph time increment and linearly interpolating the second hydrograph. Next, the two hydrographs are combined again using the time increment from the second and linearly interpolating the first. The combined hydrograph with the highest peak is the one retained along with the appropriate time increment.

Channel routing

The program uses a Muskingum-Cunge method of channel routing (Chow, Maidment, and Mays 1988; Maidment 1993; or Ponce 1989). The rating table generated by WinTR–55 for each reach is used to represent flow in that reach. The unique feature of the Muskingum-Cunge routing is the calculation of the length of a routing reach step based on inflow peak discharge and cross section information. If the routing reach step length is shorter than the reach length, the reach is sub-stepped. For example, if there are two steps, the routing is accomplished by solving the routing equation twice: the outflow hydrograph for the upper half of the reach becomes the inflow hydrograph for the lower half of the reach. If there are less than 10 points from the beginning of the hydrograph to the peak of the inflow hydrograph, the inflow hydrograph is interpolated at a time interval to allow 10 points, the routing computed, and the outflow hydrograph interpolated to return it to the original time increment.

Structure routing

The storage-indication method (NEH630.17) is used to route structure hydrographs. While the routed hydrograph time increment (downstream end of reach) is the same as the increment at the upstream end, the actual routing may sub-step the increment during the routing. The routing time step is based on the smallest time to empty the reservoir at each of the structure rating points. The time to empty the reservoir is computed as the structure rating storage volume divided by the average outflow (rating outflow/2). The hydrograph time increment is compared to a percentage (currently 50%) of the smallest emptying time to determine the number of time steps to use between hydrograph points.

# Viewing Output

File Display window

The **File Display** window (window 31), also referred to as the Report Viewer, displays various WinTR–55 reports. This window opens after a WinTR–55 run. If there are any errors in the WinTR–55 run, this window opens with the Error File displayed. Carefully examine the error messages, and/or modify the input data to correct the errors.

If no errors are discovered in the data set, the WinTR–55 run is executed, and the **File Display** window opens with the Hydrograph Peak/Peak Time Table. Additional reports may be selected from the WinTR–20 reports and/or the WinTR–55 reports listed in the **File Display** menu or from the **Output Definition** window (window 32).

Scroll through the reports using the viewer, or select individual reports on the **File Display** window menu. A brief description of the **File Display** window menu items are in table 3.

Window 31   File Display window
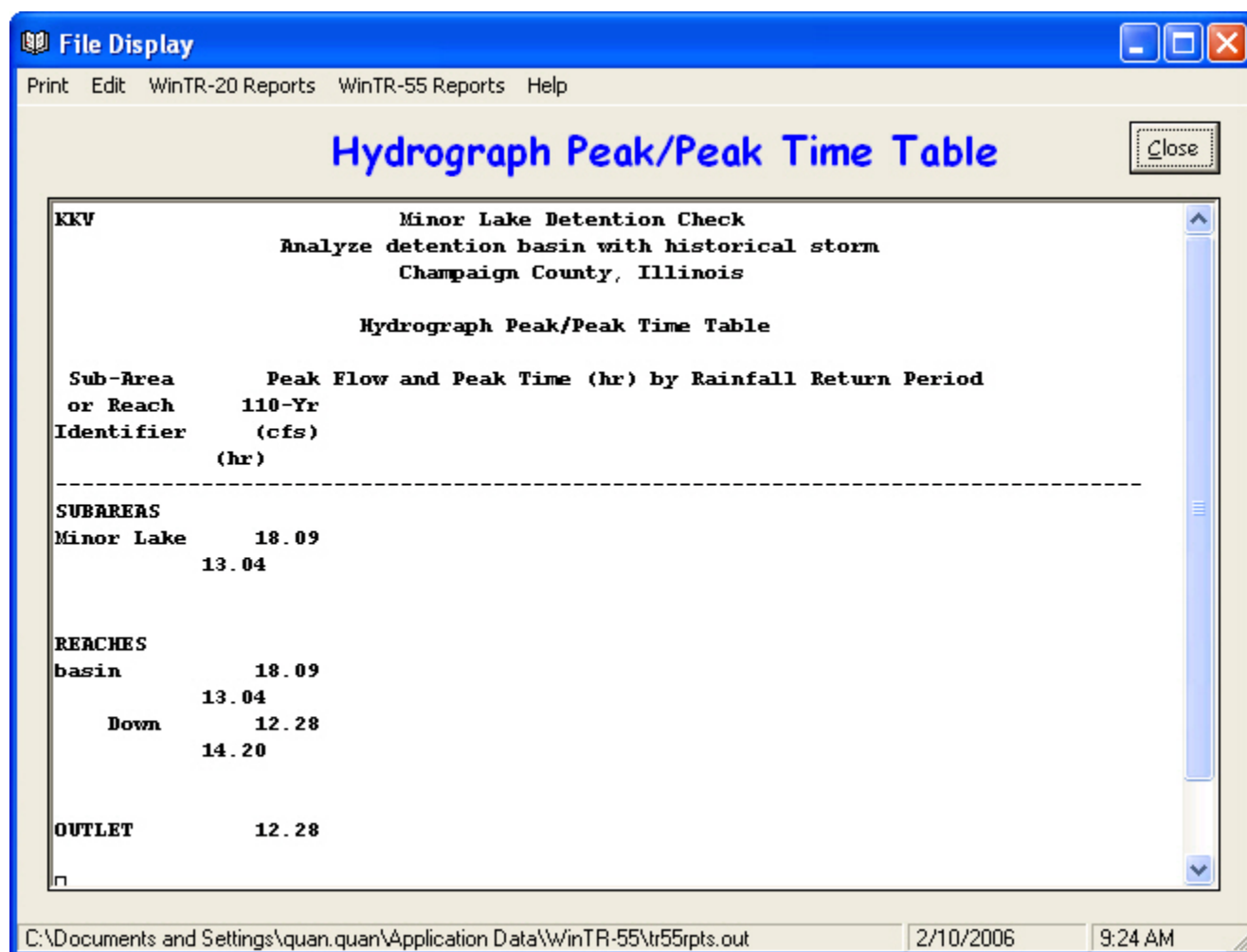
Window 32   Output Definition window
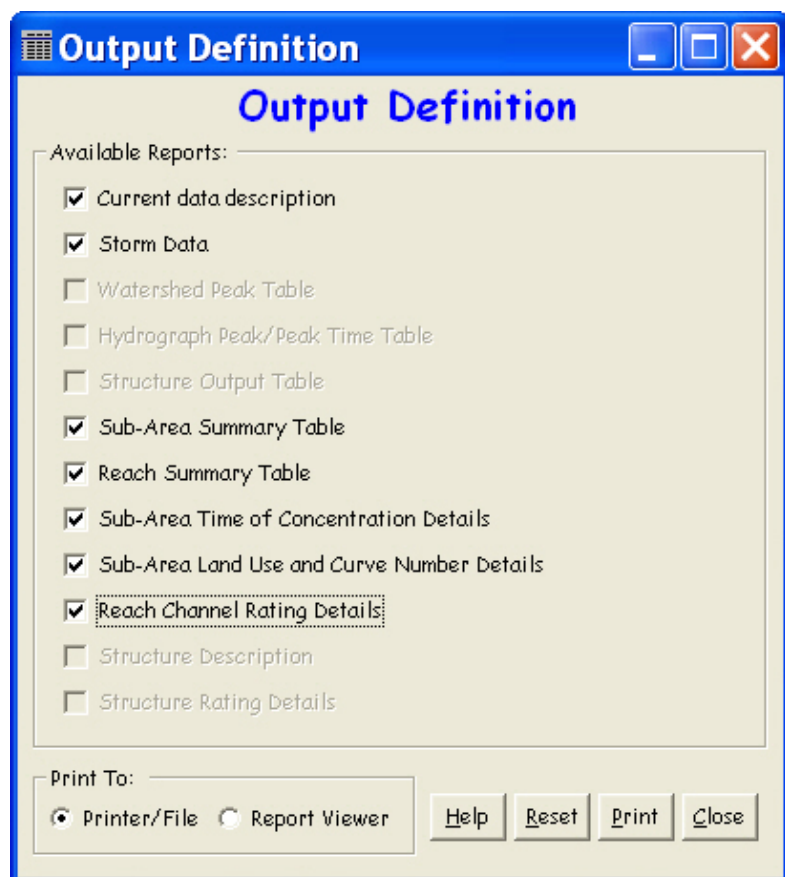
Table 3   WinTR–55 file display

Menu

Menu Item	Pulldown Choice	Explanation
Print	Print	Prints the displayed report(s).
	Page setup	Define target printer, page size, and orientation.
Edit	Copy to clipboard	Copies the displayed report(s) to the Windows® system clipboard.
	Find	Find a specific text or number. Helpful for navigating large output reports.
	Find next	Repeats a previously defined search.
WinTR–20 reports	Input file	View the WinTR–20 input file created from WinTR–55 input data.
	Printed page file	View the WinTR–20 output file.
	Error file	View WinTR–20 error file. The error messages are found in the WinTR–20 user's guide.
	Debug file	View WinTR–20 debug file. This contains any messages or warnings generated by the run.
WinTR–55 reports		See table 4 for available reports.
Help	None	Displays File Display window help text.

Buttons

Close

Click **Close** to close the **File Display** window. If you were using the report viewer, you will be returned to the **Output Definition** window. Otherwise you will be returned to the **WinTR–55 Main Window**.

Output Definition window

Once rainfall data are entered, the Output Definition button on the **WinTR–55 Main Window** is enabled. Prior to executing a WinTR–55 run, it is possible to select reports for viewing. However, some report options may be grayed out, indicating that reports are not available for viewing until an error-free WinTR–55 run is executed.

Click the Output Definition icon to open the **Output Definition** window (window 32). Specify output by clicking the box to the left of the desired report. Output may be sent to a file or to the report viewer, depending on which option is selected.

Available reports

Available reports shown in the **Output Definition** window are summarized in table 4.

Buttons

Help

Opens a new help-text window with an overview of window purpose and general data entry instructions. Close the help-text window to return to data entry.

All/Reset

If no report boxes are checked, the button label is All. Click Al̲l to check all the reports that are available. If all the report boxes are checked, the label toggles to Reset, which will clear all the check boxes.

View/Print

This button label toggles between View and Print, depending on which option button is selected, either Printer/File or Report Viewer.

Close

Click C̲lose to close the **Output Definition** window and return to the **WinTR–55 Main Window**.

Table 4   WinTR–55 reports

Report Name	Description
Current data description	Lists the current user input data
Storm Data	Lists the rainfall depth by rainfall return period information. Also shows Storm Data source, Rainfall Distribution, and the Dimensionless Unit Hydrograph
Watershed Peak Table	Not available until an error-free WinTR–55 run is executed. Upon completion of an error-free WinTR–55 run, this option will give a listing of peak discharges, by reach, for each storm evaluated
Hydrograph Peak/Peak Time Table	Not available until an error-free WinTR–55 run is executed. Upon completion of an error-free WinTR–55 run, this option gives a listing of peak discharge and time by sub-area or reach identifier, for each storm evaluated
Structure Output Table	Not available until an error-free WinTR–55 run is executed. Upon completion of an error-free WinTR–55 run, this option gives a listing of peak flow (PF), storage volume (SV), and maximum stage (STG) for structures included in the WinTR–55 run. If there are no structures in the run, this table option is grayed out
Sub-Area Summary Table	A listing by sub-area of drainage area, time of concentration, runoff curve number, receiving reach, and sub-area description
Reach Summary Table	Identifies, by reach, the receiving reach, reach length, and routing method used
Sub-Area Time of Concentration Details	A listing, by sub-area, of flow length, slope, Manning's n value, end area, wetted perimeter, velocity and travel time for time of concentration flow path segments along with the total time of concentration
Sub-Area Land Use and Curve Number Details	A listing, by sub-area, of land use, hydrologic soil group, and area for each particular land use in a sub-area. Also lists the total area and weighted curve number for each sub-area
Reach Channel Rating Details	Identifies, by reach, the reach length, Manning's n value used for that reach, friction slope, bottom width, and side slope. Also includes the computed channel rating for each reach. Channel ratings are in the WinTR–55 input data format: Stage – Flow – End Area. Rating tables also include top width and friction slope
Structure Description	Provides a summary of the entered structure data by reach. If there are no structures in the run, this table option is grayed out
Structure Rating Tables	Provides a summary of the computed structure ratings: stage, storage, and flow. If there are no structures in the run, this table option is grayed out

Plotting and viewing hydrographs

Output Graphics window
Click the Hydrographs icon to open the **Output Graphics** window (window 33), and specify hydro-graphs to plot or view. Select either sub-areas or reaches, and then check the box next to the name of the sub-area or reach for the desired hydrographs. For reach hydrographs, the hydrograph may be viewed at the upstream or downstream or both ends of the reach. Select storm event hydrographs by checking the appropriate box.

It is possible to plot all the hydrographs for all the sub-areas or reaches for all of the available storm events on one plot. However, be aware that selecting several hydrographs to view at once makes the hydrographs that much more difficult to read.

Window 33   Output Graphics window

Buttons

Plot

Once the desired hydrographs have been specified, click <u>P</u>lot and a **Graphics** window opens showing the desired plot (window 34).

Close

Click <u>C</u>lose to close this window and redisplay the main window.

Help

Opens a new help-text window with an overview of window purpose and general data entry instructions. Close the help-text window to return to data entry.

Quick Help (?)

Click **?** to provide context-sensitive help for any data that is clicked on next. To replace the help question mark cursor with the standard cursor, click **?** again. Help is displayed at the bottom of the window.

Output Graphics window

Click <u>P</u>lot on the **Output Graphics** window to plot selected hydrographs. Use the zoom button to enlarge portions of the plot as shown in window 35. Either save the plot to a file or print directly to a printer.

Click the <u>C</u>lose button to close this window.

Window 34   Graphics window output plot
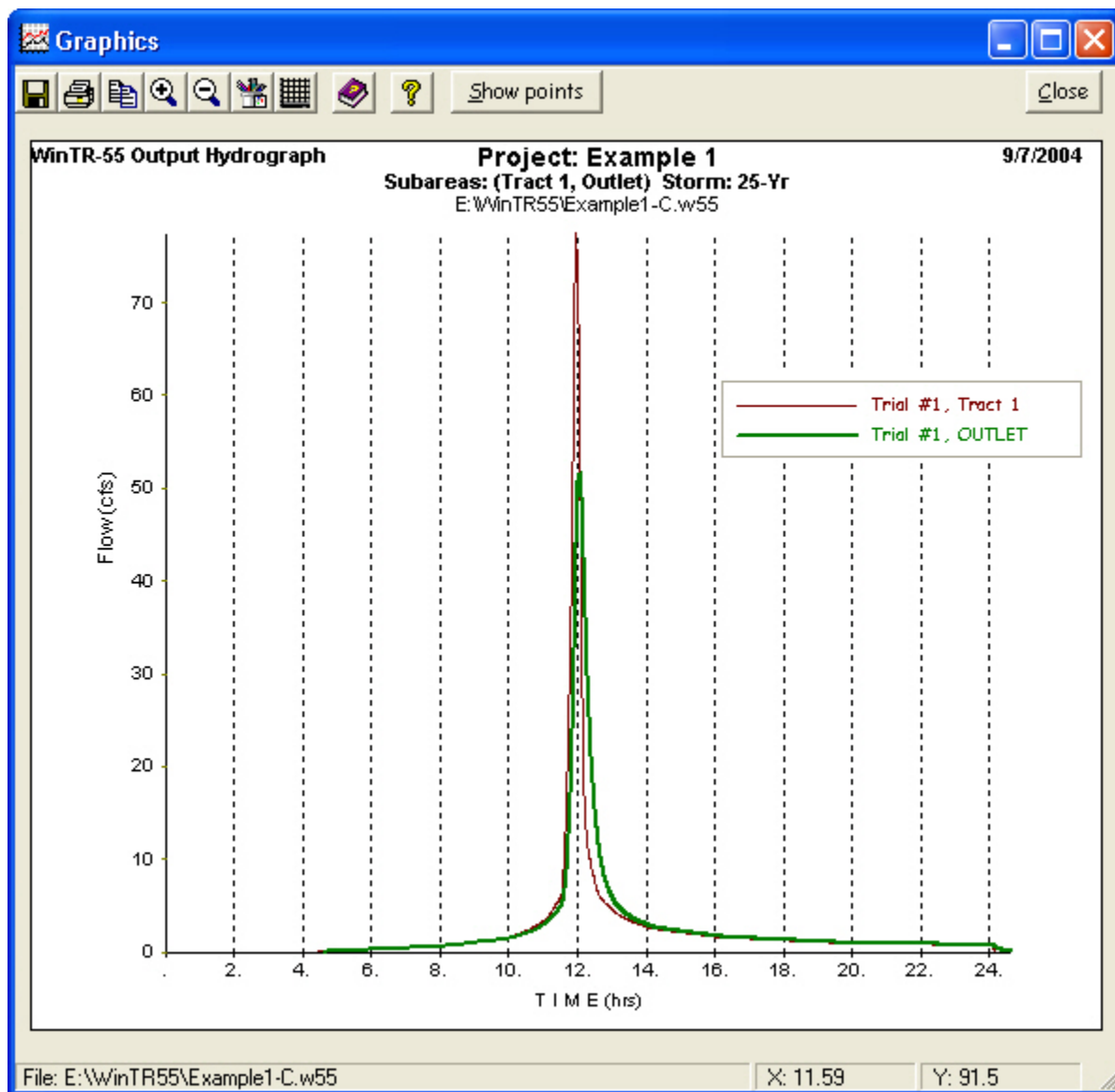
Window 35   Output plot zoom feature
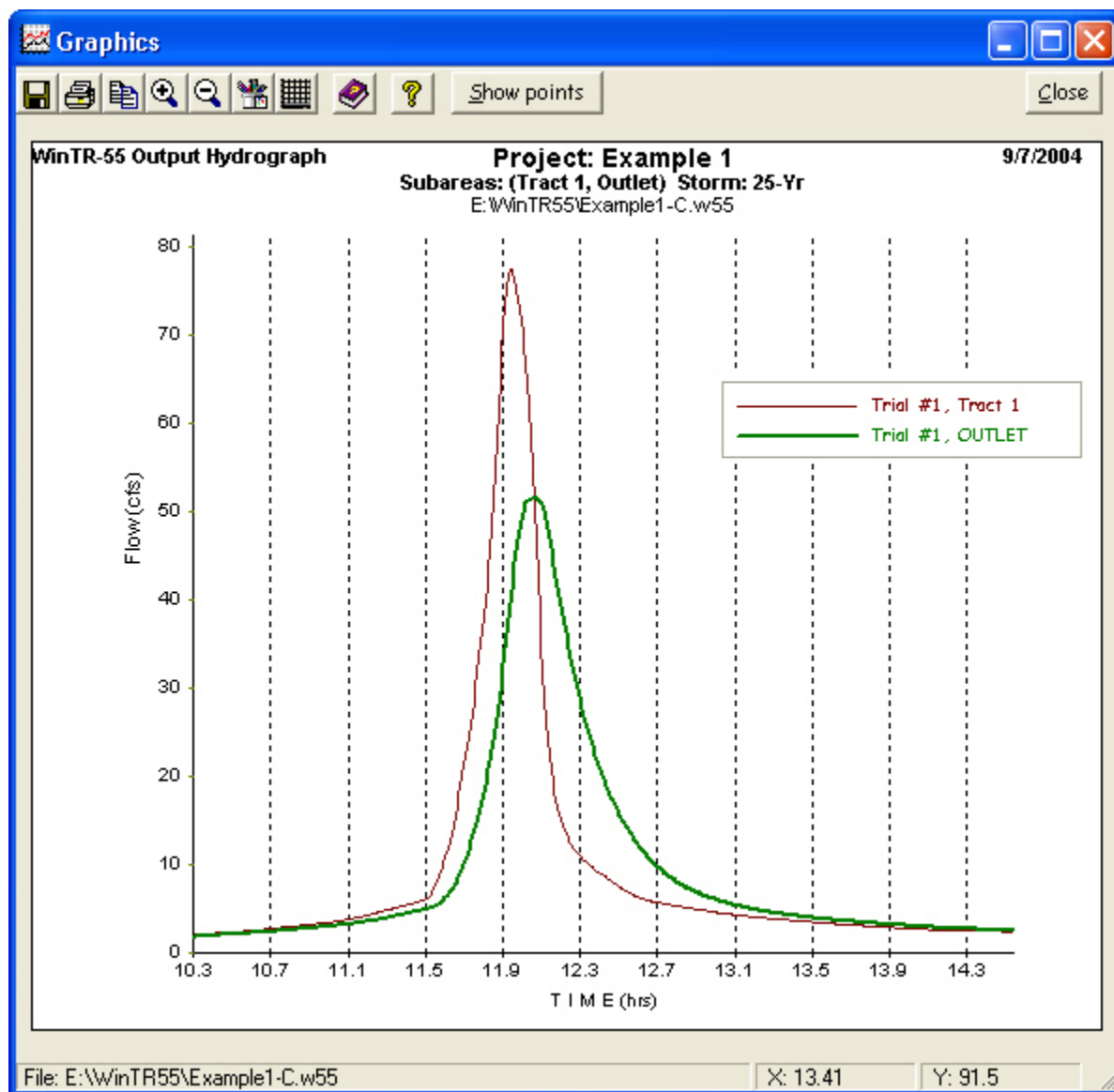
Appendices

Appendix A   Examples

Example 1   Determining Runoff From a Single Sub-area for the Existing and Developed Conditions and Sizing a Detention Basin

Background

An industrial development is planned on a 12.5-acre site in Franklin County, Missouri. The land is presently being used for corn production and is planted in straight rows. There are no special conservation practices being used, and the vegetative cover is typically in good condition. The soils on this property are hydrologic soil group B.

There is no defined channel running through the property, but there is evidence of sheet flows and shallow concentrated flows. The sheet flow path has been determined to be 25 feet long at a slope of 0.8 percent. The shallow concentrated flow path has been determined to be 825 feet long at a slope of 0.8 percent.

It is desirable to limit peak discharge from a 25-year storm for the developed condition so that it does not exceed the peak discharge from a 50-year storm for the undeveloped condition. Therefore, it is necessary to design some type of stormwater detention structure to control the runoff.

Solution

The design of the stormwater detention structure will be handled in three parts. Part A will be to determine the peak discharge and runoff volume for the existing condition. Part B will be to determine the peak discharge and runoff volume for the developed condition. Part C will focus on sizing the stormwater detention structure and analyzing its effects.

Part A   Determine existing condition peak discharge and runoff volume

Step 1:   Start the WinTR–55 program and enter User ID, Project name, Subtitle, State, and County. Specify Sub-area units (default is acres). Use the Storm Data Source default values based on the state and county specified. To make certain the correct Storm Data Source and Rainfall Distribution Identifier are selected, the user MUST complete step 2.

Step 2:   From the **WinTR–55 Main Window** menu, select **GlobalData**. From that drop-down menu, select **Storm Data**. On the **Storm Data** window, click the <u>**NRCS Storm Data**</u> button if the user decides to use the default database values for the county-state combination being modeled. Clicking the <u>**Accept**</u> button accepts the data and returns the user to the **WinTR–55 Main Window**.

Step 3:   Enter Sub-area Name, Sub-area Description, and where the water leaving this sub-area flows in the Sub-area Flows to Reach/Outlet box.

Step 4:   Click **Land Use Details** button to open the **Land Use Details** window. In this window, enter the area of the sub-area in the appropriate location. Click the **<u>Accept</u>** button to accept the data and return to the **WinTR–55 Main Window**.

The sub-area area and runoff curve number now appear in the Sub-area Entry and Summary portion of the **WinTR–55 Main Window**.

Step 5: Click **Time of Concentration Details** button to open the **Time of Concentration Details** window. In this window, enter the appropriate information to compute the sub-area time of concentration. Click the **Accept** button to accept the data and return to the **WinTR–55 Main Window**.

Flow Type	Length (ft)	Slope (ft/ft)	Surface (Manning's n)	n	Area (ft²)	WP (ft)	Velocity (f/s)	Time (hr)
Sheet	25	0.0080	Cultivated <= 20% residue (0.06) ▼					0.036
Shallow Concentrated	825	0.0080	Unpaved ▼					0.159
Shallow Concentrated			▼					
Channel								
Channel								
Total	850						1.2108	0.195

Sub-area Name: Tract 1 — Rename — Clear

2-Year Rainfall (in): 3.5

Time of Concentration Details

Help — Cancel — Accept

File: <new file>   3/28/2006   11:06 AM

The sub-area time of concentration now appears in the Sub-area Entry and Summary portion of the **WinTR–55 Main Window**.

Step 6:   Click the **Run** button to open the **Run WinTR–55** window. Select the 50–year storm event for this ex-
              ample. Once the storm events have been selected, click the **<u>R</u>un** button to execute the run.

Step 7:   When the run is complete, the **File Display** window opens showing the **Hydrograph Peak/Peak Time
              Table**. To review other output, click **Win TR–20 Reports** or **WinTR–55 Reports**, and select the reports
              to view. When complete, click the **<u>C</u>lose** button to close the **File Display** window and return to the
              WinTR–55 Main Window.
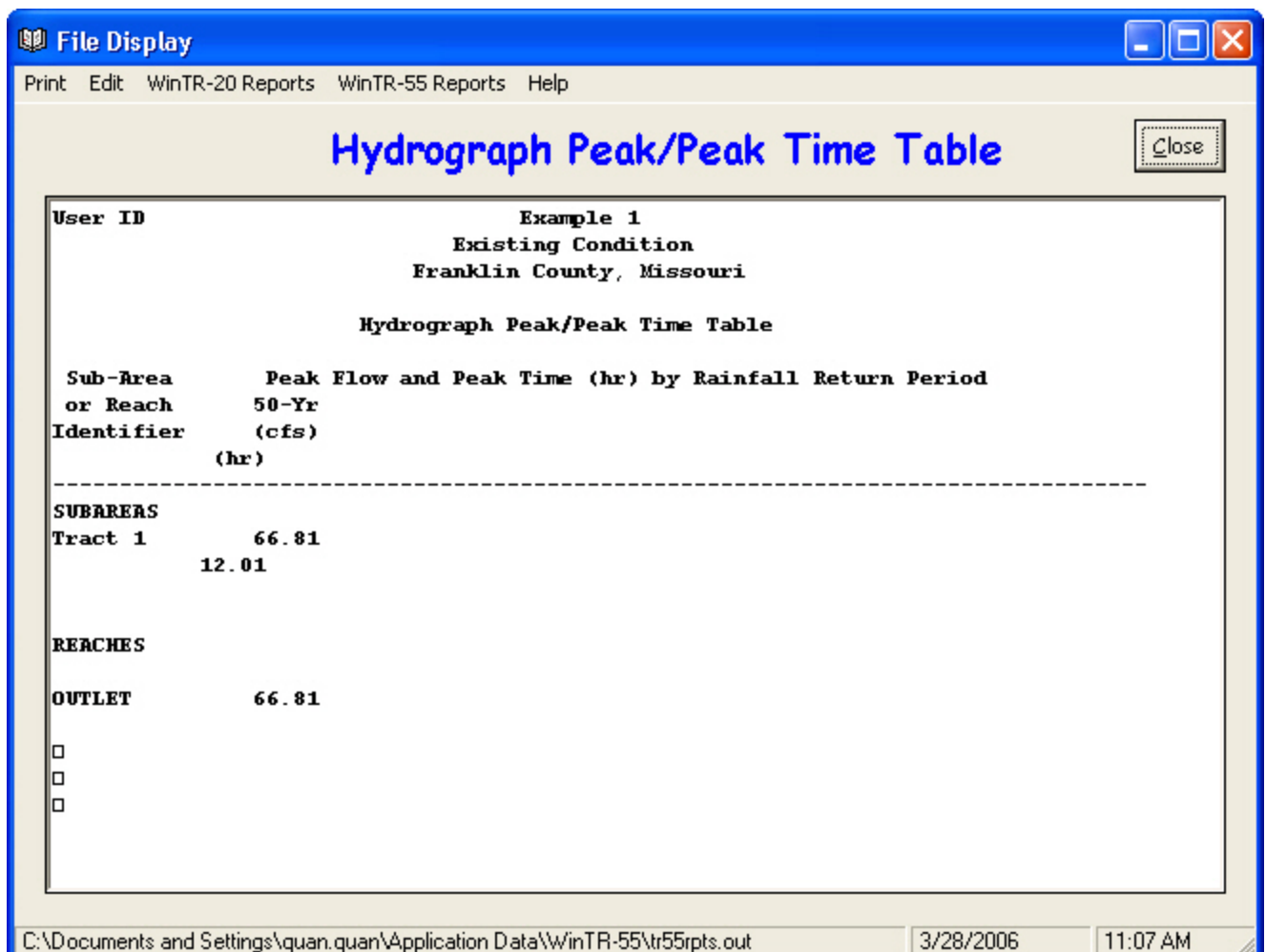
Step 8:   To save the data, click **File** and **SaveAs**. In the **Save a WinTR–55 data file as …** popup window, specify a location and file name, and click Save. The data are now saved, the popup window closes, and **WinTR–55 Main Window** is redisplayed.
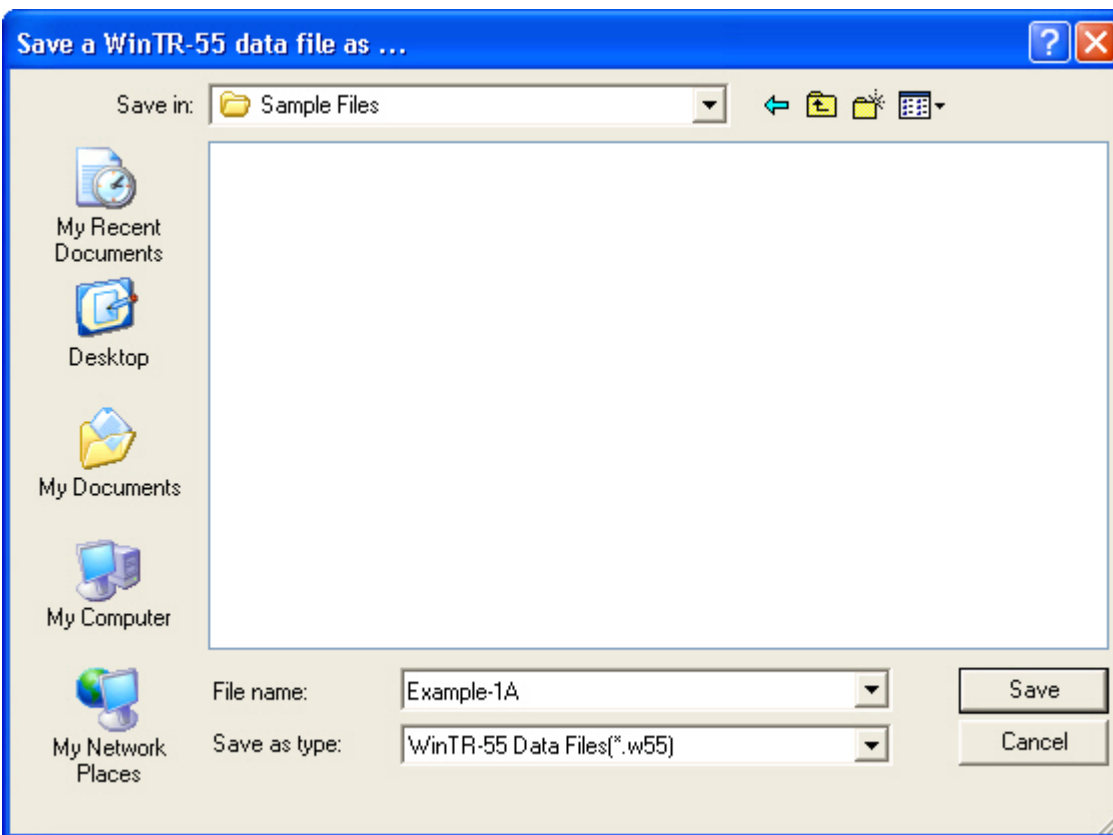
Part A Results

50-year Pre-Development Discharge = 66.8 ft^3/s

50-year Pre-Development Runoff Volume = 4.023 in (watershed-inches) = 4.19 acre-ft

$$\left(\frac{4.023}{12} \text{ ft}\right)(12.50 \text{ ac}) = 4.19 \text{ ac-ft}$$

The runoff volume can be accessed on the **File Display** window by selecting the **WinTR–20 Printed Page File**.

File Display

Print   Edit   WinTR-20 Reports   WinTR-55 Reports   Help

WinTR-20 Printed Page File   Close

```
                            Example 1
                        Existing Condition

                  Name of printed page file:
                        TR20.out

                            STORM 50-Yr

Area or      Drainage   Rain Gage     Runoff    ------------ Peak Flow ------------
  Reach        Area      ID or        Amount   Elevation    Time      Rate       Rate
Identifier   (sq mi)    Location       (in)       (ft)      (hr)      (cfs)      (csm)

Tract 1       0.020                   4.023                 12.01     66.81     3421.06

    Line
Start Time   ------------ Flow Values @ time increment of   0.012 hr ------------
     (hr)      (cfs)      (cfs)       (cfs)      (cfs)      (cfs)      (cfs)      (cfs)

     6.887     0.05       0.05        0.05       0.06       0.06       0.06       0.06
     6.973     0.06       0.06        0.07       0.07       0.07       0.07       0.07
     7.059     0.07       0.08        0.08       0.08       0.08       0.08       0.09
     7.145     0.09       0.09        0.09       0.09       0.09       0.10       0.10
     7.231     0.10       0.10        0.10       0.11       0.11       0.11       0.11
     7.318     0.11       0.12        0.12       0.12       0.12       0.12       0.12
     7.404     0.13       0.13        0.13       0.13       0.13       0.14       0.14
     7.490     0.14       0.14        0.14       0.15       0.15       0.15       0.15
```
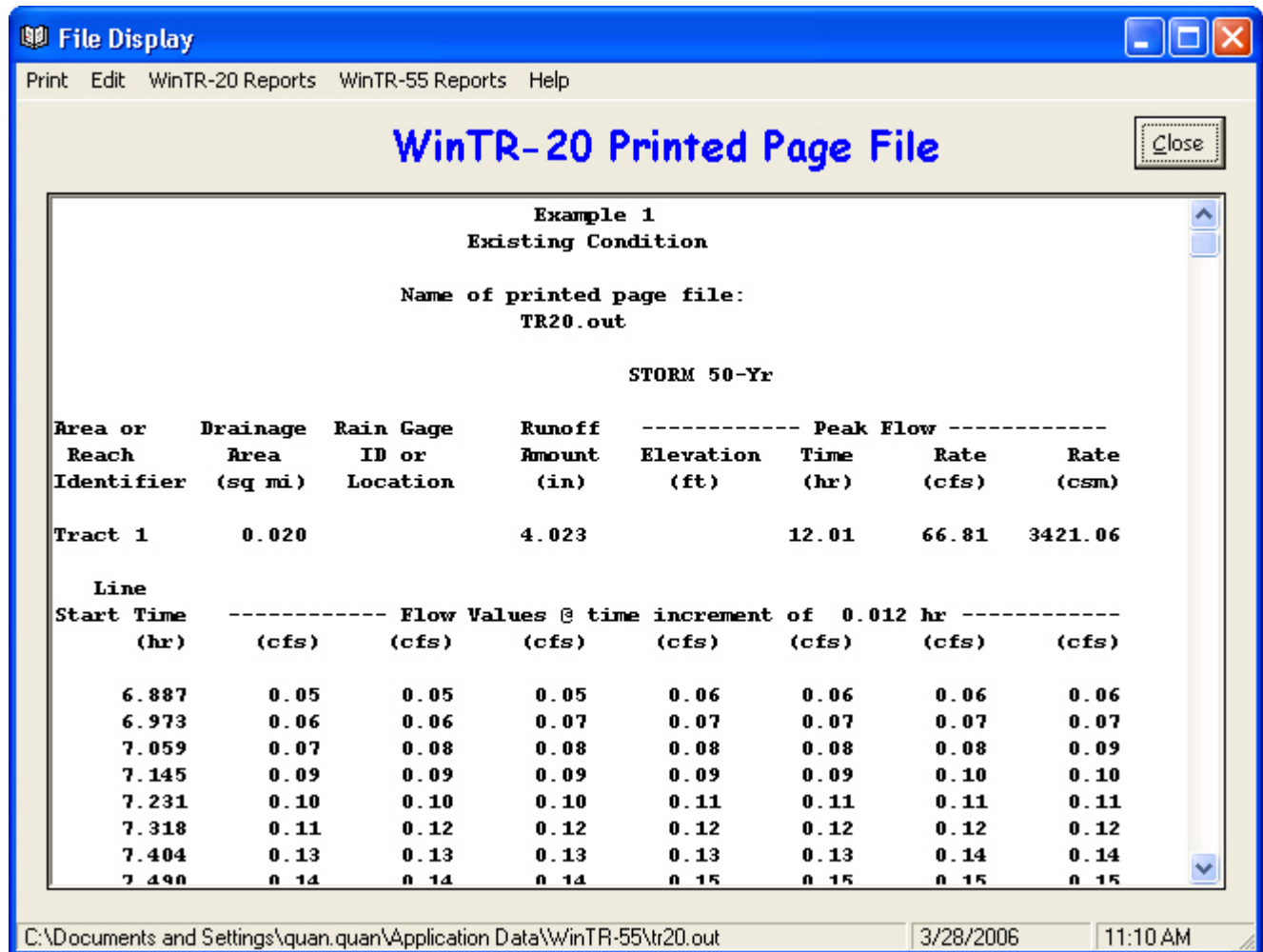
C:\Documents and Settings\quan.quan\Application Data\WinTR-55\tr20.out   3/28/2006   11:10 AM

Part B Determine developed condition peak discharge and runoff volume

Rather than beginning with a new file to determine the peak discharge and runoff volume for the developed condition, it is possible to edit the existing condition file previously created.

Step 1:   Start the WinTR–55 Program, and open the **Existing Conditions** file by selecting **Open** from the File menu and locating the file using the **Open a WinTR–55 data file** window.
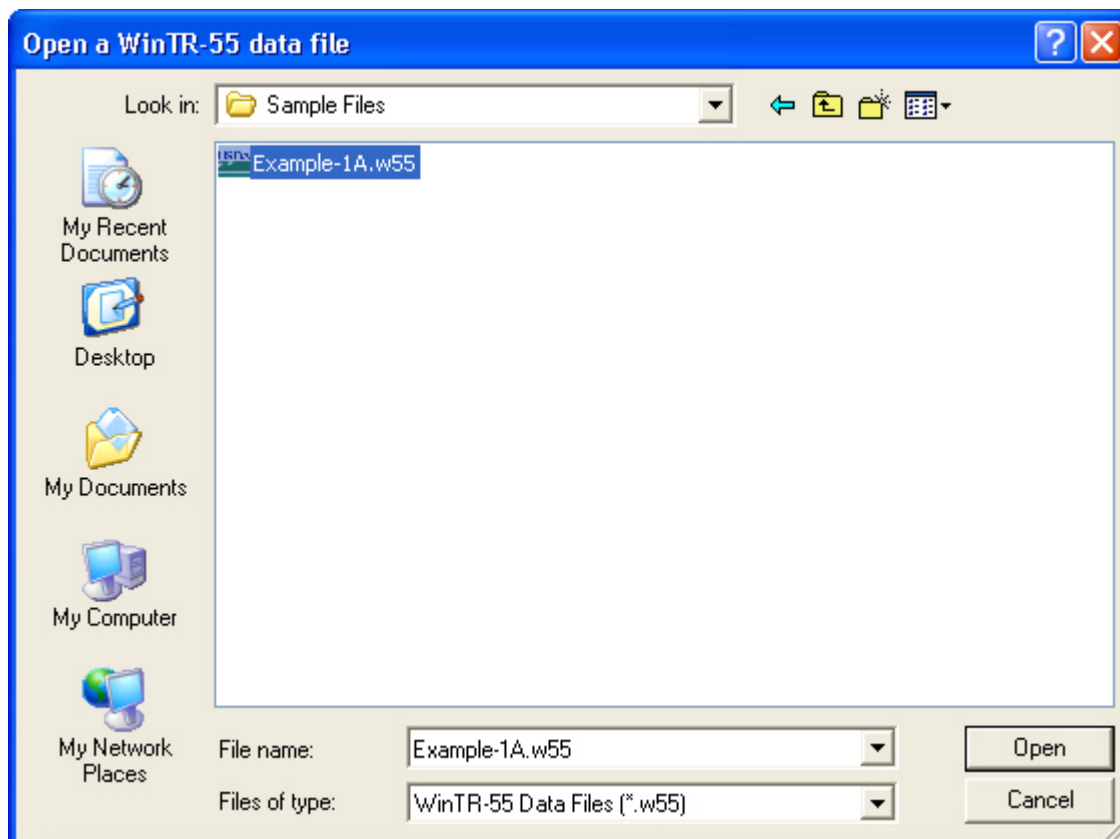
Step 2:   Edit the User I.D., Project Name, and Subtitle, as appropriate. Edit Sub-area Name, Sub-area Description, and where the water leaving this sub-area flows in the Sub-area Flows to Reach/Outlet box, as appropriate. Since this example uses the same county-state combination established previously, there is no need to work through the Global Data selection process to change the Dimensionless Unit Hydrograph, Storm Data Source, and Rainfall Distribution Identifier information.

Step 3:   Click **Land Use Details** button to open the **Land Use Details** window. In the **Land Use Details** window, edit the land use, as appropriate, and click **Accept** to accept the changes and return to **WinTR–55 Main Window**.

The sub-area and runoff curve number now appear in the Sub-area Entry and Summary portion of the **WinTR–55 Main Window**.

Step 4:   Click **Time of Concentration Details** button to open the **Time of Concentration Details** window. In the **Time of Concentration Details** window, edit the appropriate information to compute the developed condition sub-area time of concentration. The path of the flow for the Time of Concentration Details will be the same and have the same slope, but the surface itself will be paved and smooth. Click **<u>A</u>ccept** to accept the changes and return to the **WinTR–55 Main Window**.

Flow Type	Length (ft)	Slope (ft/ft)	Surface (Manning's n)	n	Area (ft²)	WP (ft)	Velocity (f/s)	Time (hr)
Sheet	25	0.0080	Smooth Surface (0.011)					0.009
Shallow Concentrated	825	0.0080	Paved					0.126
Shallow Concentrated								
Channel								
Channel								
Total	850						1.7490	0.135

Sub-area Name: Tract 1
2-Year Rainfall (in): 3.5

Time of Concentration Details

File: C:\WinTR-55\Sample Files\Example-1A.w55   3/28/2006   11:14 AM

The sub-area time of concentration now appears in the Sub-area Entry and Summary portion of the **WinTR–55 Main Window**.

Step 5:   Click on the Run icon to open the **Run WinTR–55** window. Select the 25–year storm event for this ex-
            ample. Once the storm event has been selected, click the **Run** button to execute the run.

Step 6:   When the run is complete, the **File Display** window opens showing the **Hydrograph Peak/Peak Time
            Table**. To review other output, click **WinTR–20 Reports** or **WinTR–55 Reports**, and select the reports
            to view. Click the **Close** button to close the **File Display** window and return to the **WinTR–55 Main
            Window**.
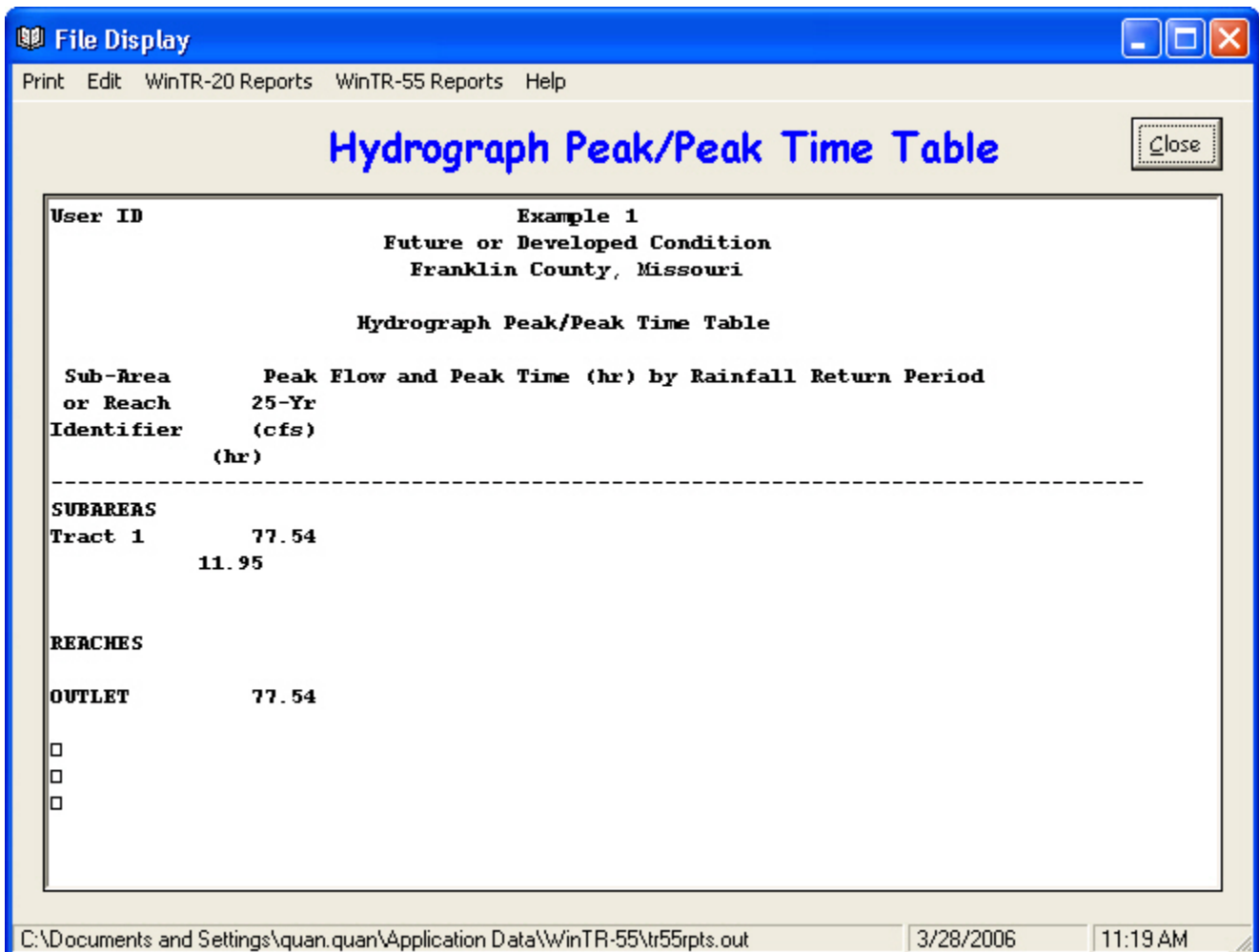
Step 7:   To save the data, click **File** and **SaveAs**. In the **Save a WinTR55 data file as …** popup window, specify
a location and a NEW FILE NAME, and click **Save**. The data is now saved, the popup window closes, and
the **WinTR–55 Main Window** is redisplayed.
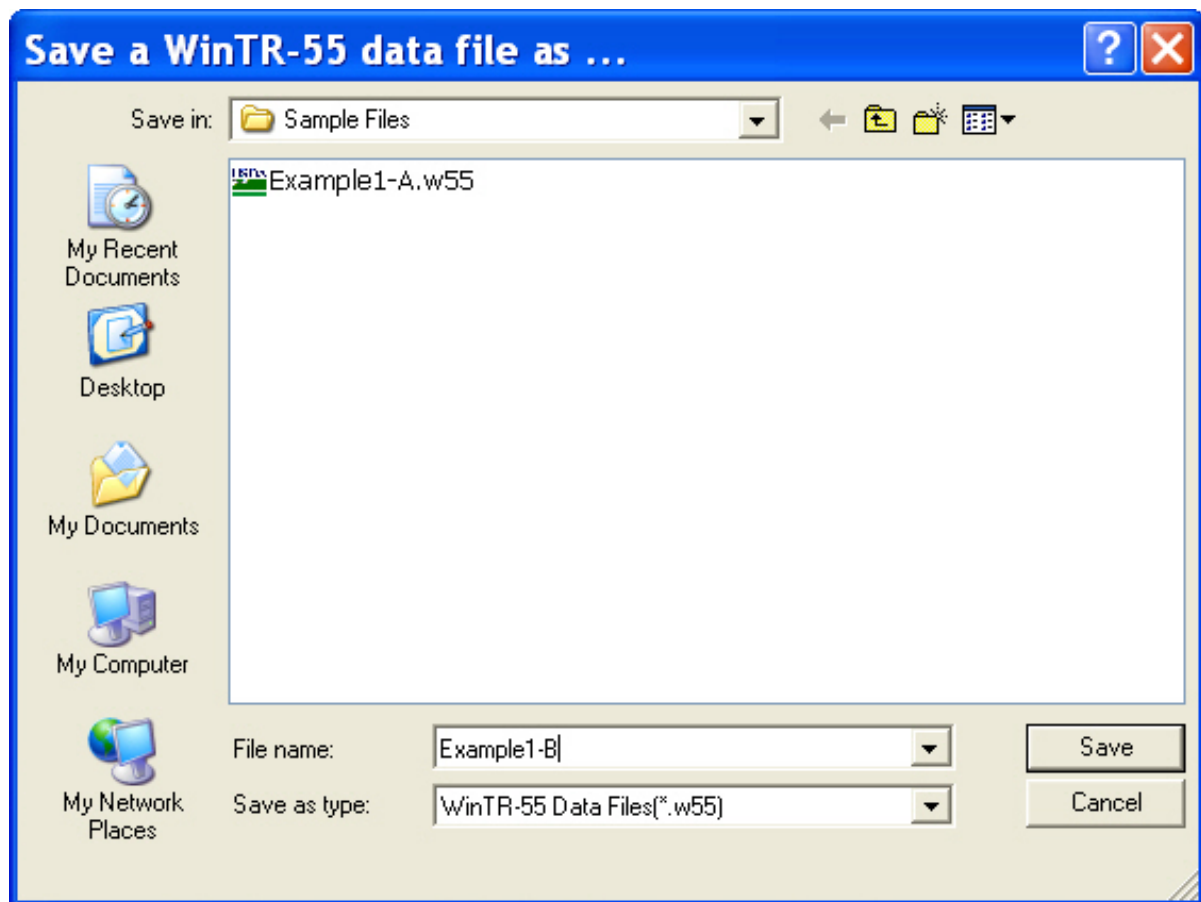
Part B Results

25-year Post-Development Discharge = 77.5 ft^3/s

25-year Post-Development Runoff Volume = 4.432 in (watershed-in) = 4.62 acre-ft

$$\left(\frac{4.432}{12}\ \text{ft}\right)(12.50\ \text{ac}) = 4.62\ \text{ac-ft}$$

The Runoff Volume can be accessed on the **File Display** window by selecting the **WinTR–20 Printed Page File**.


```
File Display

Print   Edit   WinTR-20 Reports   WinTR-55 Reports   Help

                    WinTR-20 Printed Page File            [Close]

                              Example 1
                       Future or Developed Condition

                       Name of printed page file:
                              TR20.out

                              STORM 25-Yr

Area or      Drainage   Rain Gage      Runoff     ------------ Peak Flow ------------
  Reach        Area       ID or        Amount    Elevation    Time      Rate        Rate
Identifier   (sq mi)    Location        (in)       (ft)       (hr)      (cfs)       (csm)

Tract 1       0.020                    4.432                 11.95      77.54      3970.46

    Line
Start Time   ------------ Flow Values @ time increment of   0.009 hr ------------
     (hr)     (cfs)      (cfs)        (cfs)       (cfs)      (cfs)      (cfs)       (cfs)

    4.441     0.05       0.05         0.05        0.05       0.06       0.06        0.06
    4.501     0.06       0.06         0.06        0.06       0.06       0.06        0.07
    4.561     0.07       0.07         0.07        0.07       0.07       0.07        0.07
    4.620     0.07       0.08         0.08        0.08       0.08       0.08        0.08
    4.680     0.08       0.08         0.09        0.09       0.09       0.09        0.09
    4.740     0.09       0.09         0.09        0.09       0.10       0.10        0.10
    4.799     0.10       0.10         0.10        0.10       0.10       0.11        0.11
    4.859     0.11       0.11         0.11        0.11       0.11       0.11        0.12

C:\Documents and Settings\quan.quan\Application Data\WinTR-55\tr20.out    3/28/2006    11:20 AM
```

Part C Sizing the detention basin

Two approaches can be used to size the detention basin. The first approach is to maximize the storage volume while minimizing the pipe size. Using this approach, the entire runoff volume from the 25-year post-development storm would be stored and released at a slow rate over a long period of time using a small diameter pipe. The second approach is to minimize the storage volume while maximizing the pipe size. Using the second approach, water is released at the maximum rate possible (in this case, the 50-year pre-development peak discharge), thereby minimizing the volume of water that must be stored.

The following table offers a summary of some of the advantages and disadvantages of each approach.

Method	Advantages	Disadvantages
Approach 1		
1. Maximize storage volume	Smaller diameter pipe is less expensive.	Size of area required for detention basin is large.
2. Minimize pipe size	Storage benefits for more frequent storm events are realized because increased runoff for the smaller events is also stored.	Cost of constructing a large storage basin can be expensive.
Approach 2		
3. Minimize storage volume	Size of area required for detention basin is not as large.	Larger diameter pipe is more expensive than that for approach 1.
4. Maximize pipe size	Lower construction costs for smaller storage basin.	Because pipe diameter is so large, there may not be a reduction in peak discharge for more frequent storm events. Increased runoff volume from those more frequent events may pass through the basin without any portion of the increased runoff for those storms being stored.

Note that many storm water management ordinances require a combination of storage volume and reduction in peak discharge. If that is the case, both requirements must be met. However, for this example, a minimum storage volume requirement does not apply. Therefore, to size the basin, one must look only at ways of reducing the peak discharge.

There was not a large increase in peak discharge or storage volume for the developed condition. Peak discharge increased 16 percent from Q_{50pre} = 66.8 cubic feet per second to Q_{25post} = 77.5 cubic feet per second. Runoff volume increased 10.2 percent from Q_{50pre} = 4.023 inches (4.19 acre-ft) to Q_{25post} = 4.432 inches (4.62 acre-ft).

The detention basin will have a base area at the spillway crest elevation of 150 feet on a side with side slopes of 3 foot horizontal to 1 foot vertical. This results in a base area of approximately 0.517 acres at the basin bottom. At .77 foot depth in the detention basin, the surface area of the water is 154.6 feet on a side, or 0.549 acre.

> **Note**: The WinTR–55 **Structure Data** window assumes a standard riser / conduit configuration or a straight pipe configuration for evaluating detention basins with pipes. The only other option is a weir configuration. If either of these configurations is unacceptable, use another method to size the detention basin.

A standard riser configuration is chosen for the outlet device. Based upon the amount of control desired in the initial problem statement, it is necessary only to use a pipe of sufficient diameter to reduce the peak discharge from 77.5 cubic feet per second for the post-developed condition to 66.8 cubic feet per second for the pre-developed condition.

Again, rather than beginning with a new file, it is possible to edit the existing developed condition data file created in determining the future (or developed) condition discharge and volume.

Step 1:   Start the WinTR–55 Program, and open the Developed Conditions file by selecting **Open** from the file menu and locating the file using the **Open a WinTR–55 data file** window.

Step 2:   Edit the User ID, Project name, and Subtitle, as appropriate. Edit Sub-area Name, Sub-area Description, and where the water leaving this sub-area flows in the Sub-area Flows to Reach/Outlet box, as appropriate. In the situation where water flows into a detention basin, the name of the reach containing the structure is entered in the Sub-area Flows to Reach/Outlet box.

Step 3:   Click on the Structure Data button to open the **Structure Data** window. Enter the Structure Name, the surface area at the spillway crest elevation, and the surface area at an elevation above the spillway to define the storage characteristics of the basin. **Note**: If no surface area above the spillway is entered, the program assumes the basin has vertical sides. Enter the desired pipe sizes for initial evaluation of the structure ratings and the height in feet from the centerline of the outlet pipe to the spillway crest elevation. **Note**: For the standard riser configuration, this height should be approximately two times the largest pipe diameter evaluated. As pipe diameters are entered, the structure ratings are computed and shown at the bottom of the **Structure Data** window. Upon completion of this data, click **Accept** to accept the data and return to the **WinTR–55 Main Window**.

Structure Data

Structure Name: BasinA   CLear   Delete   Rename

Structure Data

Accept | Plot | Cancel | Help

Pond Surface Area

@ spillway crest   0.517   acres

(optional)   0.77   feet above spillway   0.549   acres

Discharge Description

Spillway Type: ● Pipe   ○ Weir

Diameter(in):
Trial #1: 36   Trial #2: 42   Trial #3: 48

Height (ft) Pipe invert to spillway: 8

--- Orifice flow assumed ---

Pipe Flow Rating – BasinA

Stage [ft]	Diameter1 36(in) Pipe Head [ft]	Flow cfs	Diameter2 42(in) Pipe Head [ft]	Flow cfs	Diameter3 48(in) Pipe Head [ft]	Flow cfs	Temporary Storage [ac-ft]
0.00	6.500	0.000	6.250	0.000	6.000	0.000	0.00
1.50	8.000	95.966	7.750	128.564	7.500	165.189	0.82
3.00	9.500	104.577	9.250	140.455	9.000	180.956	1.74
6.00	12.500	119.958	12.250	161.635	12.000	208.950	3.85
15.00	21.500	157.323	21.250	212.886	21.000	276.414	12.43

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Step 4: Click the Reach Data button to open the **Reach Data** window. The name of the Sub-area Flows to Reach/ Outlet name as entered on the **WinTR–55 Main Window** is shown in the Reach Name column. In this case, the sub-area was defined to flow to BasinA. Since the structure is located at the outlet of the watershed, the receiving reach is Outlet. Also, since the sub-area runoff flows through a structure, the **Structure Name** is entered instead of reach data. This tells the program that the water from the sub-area flows through the structure to the outlet. Click **Accept** to accept the data and return to the **WinTR–55 Main Window**.

Step 5:   Click the **Run** menu option from the **WinTR–55 Main Window**. On the **Run WinTR–55** window, select the storm to evaluate. Click the **Run** button to execute the run.

Step 6:   Upon successful execution of the run, the **File Display** window opens showing the **Hydrograph Peak/ Peak Time Table** report. By scrolling down through the window, results of the runs for the different pipe sizes selected can be viewed. To review other output, click **WinTR–20 Reports** or **WinTR–55 Reports**, and select the reports to view. When complete, click the **Close** button to close the **File Display** window and return to the **WinTR–55 Main Window**.
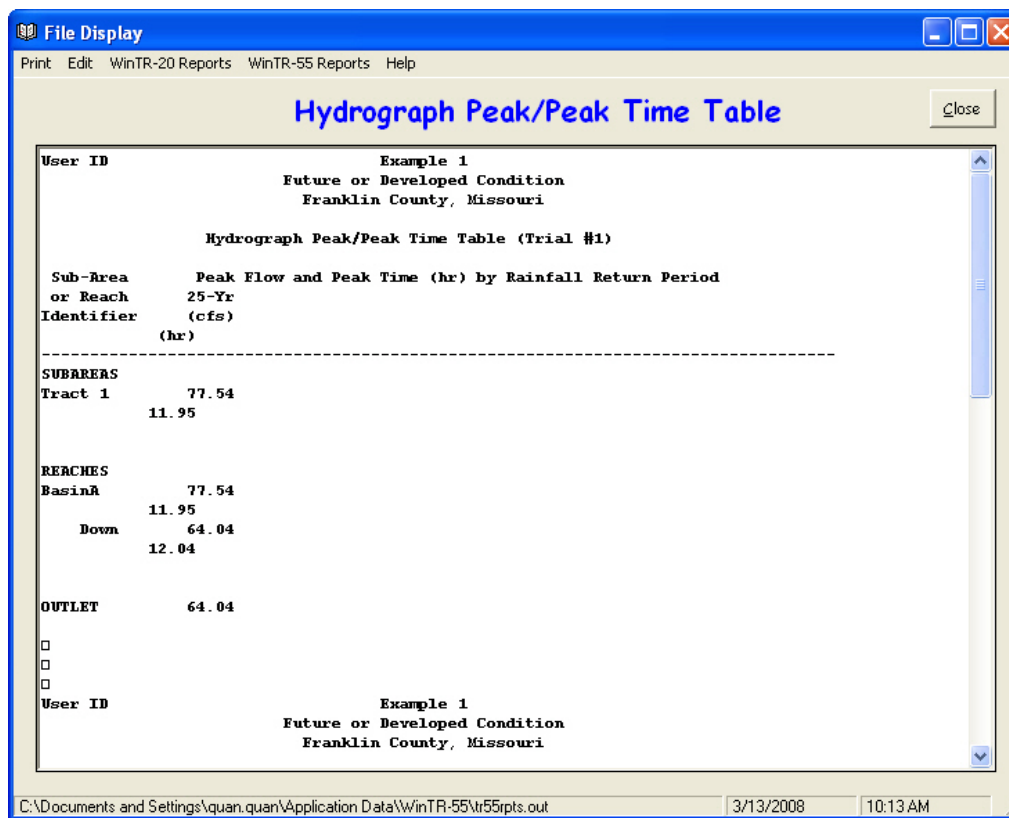
Step 7:   To save the data, click **File** and **SaveAs**. In the **Save a WinTR55 data file as …** window, specify a loca-
tion and a new file name, and click **Save**. The data are now saved and the user returns to the **WinTR–55
Main Window**.
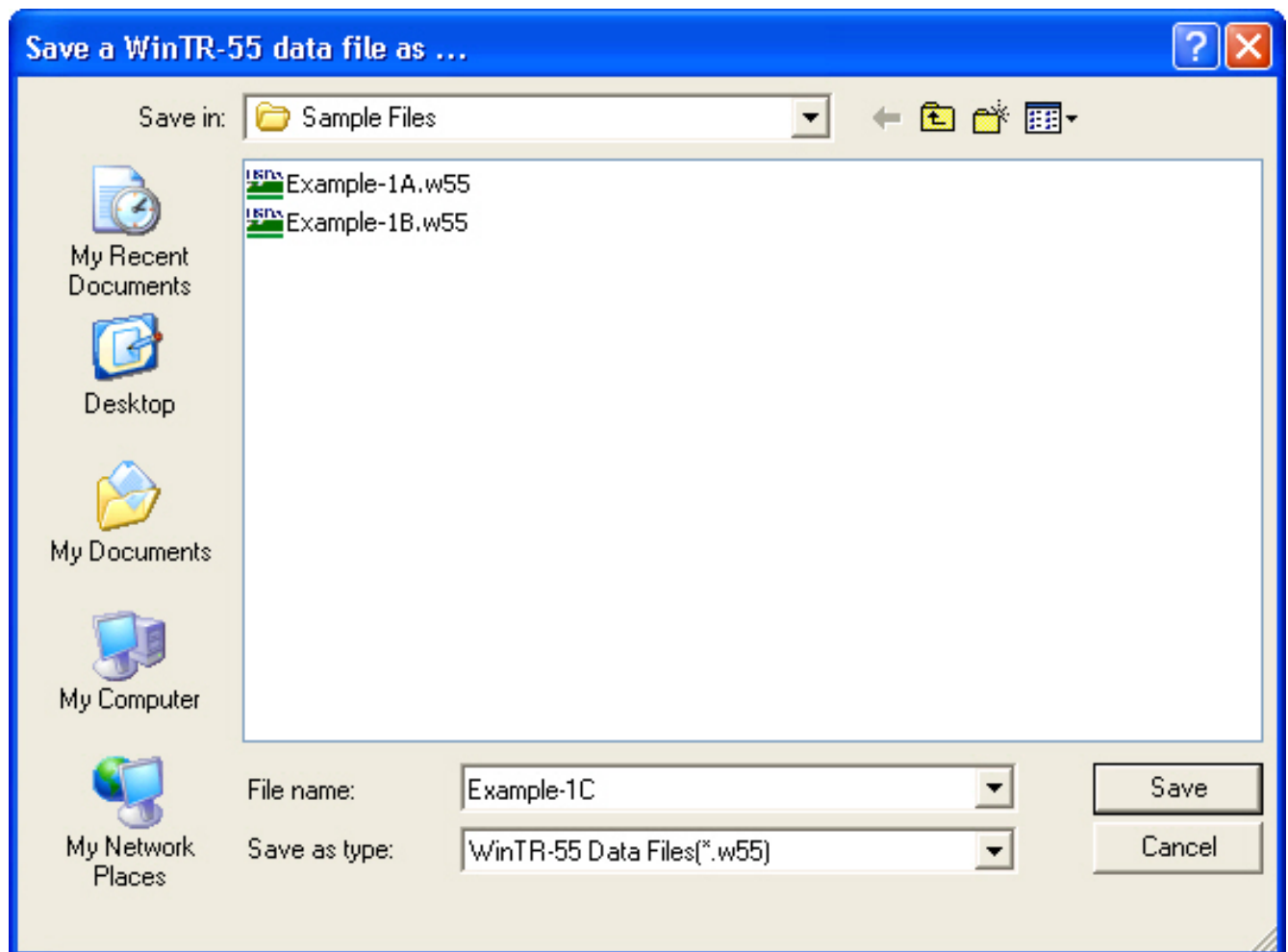
Part C Results

Peak discharges for the three pipes evaluated are as follows:

     36-inch diameter   64 ft^3/s
     42-inch diameter   67.72 ft^3/s
     48-inch diameter   70.25 ft^3/s

Since the limiting discharge value is 66.8 cubic feet per second, the 36-inch diameter pipe may be used since the pipe discharge does not exceed the limiting value.

From the **Structure Output Table** window, it can be seen that the maximum volume of water stored will be 0.55 acre-foot. This translates to a maximum depth for the 25-year storm event of 1.00 feet.


```
File Display
Print   Edit   WinTR-20 Reports   WinTR-55 Reports   Help

                        Structure Output Table                          Close

User ID                          Example 1
                      Future or Developed Condition
                        Franklin County, Missouri

                         Structure Output Table

Reach               Peak Flow (PF), Storage Volume (SV), Stage (STG)
 Identifier               by Rainfall Return Period
Structure
 Identifier      25-Yr
-------------------------------------------------------------------------
Reach: Basin A
Pipe : Basin A
 36(in)
  PF    (cfs)       64.04
  SV (ac ft)          .55
  STG    (ft)        1.00
 42(in)
  PF    (cfs)       67.72
  SV (ac ft)          .43
  STG    (ft)         .79
 48(in)
  PF    (cfs)       70.25
  SV (ac ft)          .35
  STG    (ft)         .64


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```
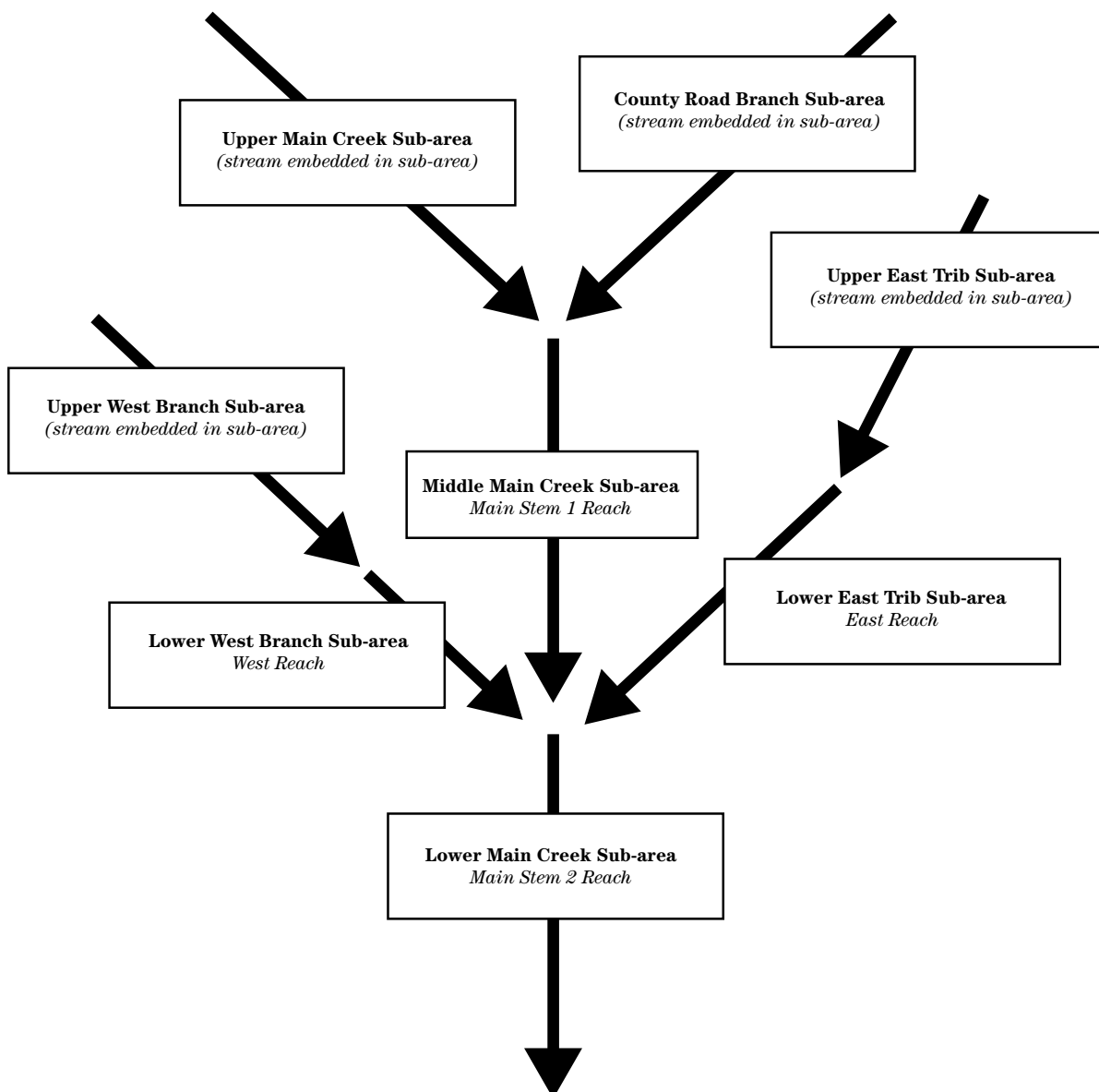
Example 2

Evaluating Larger Watersheds and User-defined Storm Data

Background

A small community in Any County, Any State, has flooded multiple times in the last several years. The community wants to reduce flood damages and has requested assistance in evaluating peak discharges in the upper reaches of the watershed. A schematic of the watershed appears below.

Note: Since there is no listing in the rainfall database for a location called Any County, Any State, the user must input custom storm data for this job.

Upper Main Creek Sub-area
(stream embedded in sub-area)

County Road Branch Sub-area
(stream embedded in sub-area)

Upper East Trib Sub-area
(stream embedded in sub-area)

Upper West Branch Sub-area
(stream embedded in sub-area)

Middle Main Creek Sub-area
Main Stem 1 Reach

Lower East Trib Sub-area
East Reach

Lower West Branch Sub-area
West Reach

Lower Main Creek Sub-area
Main Stem 2 Reach

Watershed Data

Land Use Details

Sub-area	Land Use	Area by hydrologic soil group (acres)			
		A	B	C	D
Upper Main Creek	Residential districts, 2-acre lots			40	
	Pasture, fair condition			80	
	Woods, fair condition			55	
County Road Branch	Residential districts, 2-acre lots			30	
	Meadow, cont. grass			60	
	Woods, fair condition			110	
Middle Main Creek	Farmsteads		10		
	Pasture, good condition		30	10	
	Woods-Grass, fair condition		20		
Upper East Tributary	Residential districts, 2-acre lots			60	
	Woods-Grass, fair condition			40	10
	Woods, fair condition			10	10
Lower East Tributary	Farmsteads		10		
	Pasture, fair condition		25	5	
	Woods-Grass, fair condition		45	25	
Upper West Branch	Industrial		15		
	Pasture, fair condition		10		20
	Woods, fair condition		15		5
Lower West Branch	Impervious, paved parking lots			5	
	Industrial			15	
	Residential districts, 1-acre lots			10	
	Pasture, fair condition			20	
	Woods, fair condition			25	
Lower Main Creek	Open space, lawns, fair condition		15		
	Impervious, paved parking lots		15		
	Commercial and business		15		
	Residential districts, 0.25-acre lots		85		

Where do the Land Use Details data come from?

The land use data for the watershed may be derived using GIS, if GIS coverages exist for the watershed area, developed from current aerial photographs, or be determined from a watershed site visit. The hydrologic soil group data may be obtained from the current soil survey for the county or counties in which the watershed is located.

Time of concentration details

Sub-area	Sheet Flow			Shallow concentrated flow			Open channel flow	
	length (ft)	slope (ft/ft)	surface description	length (ft)	slope (ft/ft)	surface description	length (ft)	velocity (ft/s)
Upper Main Creek	75	0.047	Dense grass	425	0.047	Unpaved	2,500	2.66
County Road Branch	75	0.067	Light woods	425	0.067	Unpaved	2,100	2.30
Middle Main Creek	65	0.052	Short grass	385	0.052	Unpaved	925	2.40
Upper East Tributary	50	0.110	Smooth surface	285	0.110	Unpaved	1,465	1.53
Lower East Tributary	100	0.051	Light woods	825	0.051	Unpaved	740	2.73
Upper West Branch	60	0.092	Smooth surface	340	0.092	Unpaved	1,705	1.50
Lower West Branch	100	0.045	Smooth surface	1,000	0.045	Unpaved	510	1.51
Lower Main Creek	100	0.036	Smooth surface	1,465	0.036	Unpaved	1,100	1.10

Where do time of concentration details data come from?

Time of concentration data should be carefully estimated for each sub-area. Length and slope for individual flow types (sheet, shallow concentrated, and open channel) can be obtained from USGS topographical maps, aerial photographs, and field observation.

Sheet flow and shallow concentrated flow lengths may be difficult to develop. The best way to estimate these values is to visit the site and determine the actual flow paths. However, these values can also be estimated from topographical maps and aerial photos.

Open channel flow paths typically appear as blue lines on USGS topographical maps or as obvious ditches or stream channels on aerial photographs and, therefore, are much easier to determine.

Surface codes for sheet flow are best determined by making a site visit. Carefully examine the land use along watershed divides. Surface codes for shallow concentrated flow are simply paved or unpaved. This is the simplest to determine.

The flow velocity must be determined for open channel flows. Either take bankfull velocity information from a previously developed water surface profile model, or entering the Manning's n value, use survey data to develop cross-sectional flow area, wetted perimeter, and slope for the stream length in question. Experienced users may simply estimate the flow velocity in the channel. Make certain that selected values are representative of the entire open channel flow length and not just one segment of the open channel flow path.

Reach data

Reach name	Receiving Reach	Reach length (ft)	Manning's n	Slope (ft/ft)	Bottom width (ft)	Side slope (Z:1)
Main Stem 1	Main Stem 2	540	0.065	0.003	20	55
East Reach	Main Stem 2	685	0.065	0.006	30	33
West Reach	Main Stem 2	810	0.065	0.011	35	40
Main Stem 2	Outlet	640	0.065	0.007	45	86

Where do reach data come from?

Reach data must be derived for each stream segment that receives water from an upstream sub-area or another reach.

Rating curves are developed for the reaches that describe the flow characteristics of the reaches. A particular cross section surveyed within the reach in question is picked to be representative of the entire reach, and the data for that cross section is used. That cross section may be located anywhere within the reach, but will represent the entire length of that reach.

Ratings for the reach are developed using the Manning's n values, slope, bottom width of the cross section, and side slopes. It is important to estimate these values for the overall valley cross section and not just the channel section. These values may differ drastically between the channel and the valley. The goal is to estimate a rating curve that represents both.

Rainfall data

The user must enter Any State and Any County in the state and county entry boxes on the Main Window, or the Main Window will not match the second Main Window on the next page.

Rainfall data for the watershed in Any County, Any State, is:

24-hour precipitation amount (in) by return period						
1-year	2-year	5-year	10-year	25-year	50-year	100-year
3.0	3.5	4.5	5.1	5.8	6.5	7.2

Entering storm data

Step 1: Select Global Data from the **WinTR–55 Main Window** menu.

Step 2: Under Global Data, select **Storm Data**.

Step 3: When the **Storm Data** window opens, enter the rainfall amount by return frequency for the desired storms, and select the appropriate rainfall distribution from the drop-down menu.

Step 4: Once the rainfall distribution type is selected (Type II rainfall distribution is applicable for this location) and the rainfall amounts have been entered, click **<u>A</u>ccept** to accept the data and return to the main window.

Note: The user should enter the state and county name on the main window BEFORE going to the **Storm Data** window to enter the custom rainfall amount.

For this example problem, the **Storm Data** window appears as follows upon completion of data entry. Note: Since Any County, Any State, is not listed in the rainfall database included with WinTR–55, and the user entered those names on the **WinTR–55 Main Window** forcing the switch to Region / Locale, the **NRCS Storm Data** button on the **Storm Data** window is disabled, and the note indicates data is not provided for regions / locales.

Click the **Accept** button to return to the **WinTR–55 Main Window**.

Upon completion of data entry, the **WinTR–55 Main Window** should appear as follows:

The 2-, 5-, 10-, 25-, 50-, and 100-year storm events were analyzed and peak discharges obtained for each sub-area and reach. The Hydrograph Peak/Peak Time Table contains a listing of peak discharges for each of the sub-areas and reaches.

WinTR–55 provides the following output data by sub-area and reach:


```
ccs                                Example 2
                                     test
                        Region: Any State       Locale: Any County

                        Hydrograph Peak/Peak Time Table

   Sub-Area         Peak Flow and Peak Time (hr) by Rainfall Return Period
   or Reach         2-Yr        5-Yr        10-Yr       25-Yr       50-Yr       100-Yr
  Identifier       (cfs)       (cfs)       (cfs)       (cfs)       (cfs)       (cfs)
                   (hr)        (hr)        (hr)        (hr)        (hr)        (hr)
  -----------------------------------------------------------------------------------
  SUBAREAS
  UpperMain       238.68      374.75      461.00      563.70      667.55      771.28
                  12.16       12.15       12.14       12.14       12.14       12.12

  CountyRoad      210.65      349.76      439.14      548.08      659.56      772.67
                  12.17       12.16       12.15       12.16       12.15       12.16

  MiddleMain       66.78      123.68      161.77      208.63      257.83      308.30
                  12.05       12.03       12.03       12.03       12.02       12.02

  UpperEast       216.21      338.62      414.28      505.19      598.04      691.70
                  12.07       12.07       12.07       12.06       12.06       12.05

  LowerEast       106.90      186.20      238.00      300.97      366.78      432.73
                  12.14       12.13       12.13       12.11       12.11       12.10

  UpperWest        99.73      156.06      191.43      233.60      276.23      319.74
                  12.10       12.10       12.10       12.10       12.10       12.08

  LowerWest       172.93      257.14      309.28      370.29      432.36      494.33
                  12.01       12.01       12.00       12.01       12.00       12.00

  LowerMain       195.22      299.62      363.91      441.53      518.96      599.27
                  12.14       12.14       12.13       12.14       12.13       12.14


  REACHES
  MainStem1       448.17      723.38      898.13     1107.93     1324.56     1541.91
                  12.16       12.15       12.14       12.14       12.14       12.15
     Down         427.46      694.49      863.71     1067.59     1277.31     1487.27
                  12.24       12.21       12.20       12.19       12.20       12.20
```

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Results

To evaluate the output results and make a judgment as to whether results are reasonable, it is beneficial to understand how WinTR–55 processes the data, and in particular, how the hydrographs are added in WinTR–55.

In the Watershed Peak Table, peak discharges are listed by sub-area and by reach. The Sub-Area Peak Discharges represent the peak discharge values obtained in determining the runoff contributed solely by a particular sub-area. So, for this example, the peak discharge for the UpperMain sub-area for the 5-year storm event is listed at 375 cubic feet per second. This peak is that obtained for the UpperMain sub-area, solely. Likewise, for the MiddleMain sub-area, the 5-year storm event peak discharge is 124 cubic feet per second. Again, this represents only the peak discharge produced by the rainfall falling on the MiddleMain sub-area. Obviously, the MiddleMain sub-area also receives water from the UpperMain and CountyBranch sub-areas; but the sub-area peak discharge, as listed in the Watershed Peak Table, is that produced by rainfall on the MiddleMain sub-area and to this point does not include water coming from outside of that sub-area. In short, the sub-area peak discharges are independent peaks and have not been routed or added to produce any composite hydrographs.

The peak discharges by reach are added and routed and represent composite hydrographs. However, it is necessary to take a close look at these peaks to understand how the WinTR–55 routing procedure works. As stated previously, the peak discharge for the UpperMain sub-area for the 5-year storm event is 375 cubic feet per second. The peak discharge for the CountyRoad sub-area for the same storm event is 350 cubic feet per second. Runoff from both of these hydrographs flow through the MiddleMain sub-area via MainStem1 reach. The peak for MainStem1 reach in the Watershed Peak Table has a value of 723 cubic feet per second. This peak represents the peak of the added hydrographs for the UpperMain and CountyRoad sub-areas. That is, the hydrographs for UpperMain and CountyRoad sub-areas added together produce a peak of 723 cubic feet per second for the 5-year storm event. Notice, also, that there is a Peak Discharge of 694 cubic feet per second listed on the Watershed Peak Table for the Downstream end of MainStem1

reach. This value represents the peak discharge for the routed hydrograph resulting from the runoff from the UpperMain and CountyRoad sub-areas. In summary, the runoff from UpperMain and CountyRoad produced hydrographs that when added together produced a peak of 723 cubic feet per second at the upper end of the MainStem1 reach. When this hydrograph was routed through the MainStem1 reach, a hydrograph with a peak discharge of 694 cubic feet per second resulted. At this point, the runoff from the MiddleMain sub-area is not yet included.

For this example, the peaks listed for MainStem2 reach become somewhat more complicated because two tributaries enter the system. However, applying the concepts of adding the hydrographs and developing peaks as explained in the previous paragraph, it should be obvious to the user that the peak discharge at the upper end of the MainStem2 reach represents the combination of the following:

- Resultant hydrograph obtained from the runoff produced by the UpperMain and CountyBranch sub-areas routed through MainStem1 reach.

- Runoff hydrograph produced by MiddleMain sub-area.

- Runoff hydrograph produced by UpperWest sub-area routed through WestReach reach.

- Runoff hydrograph produced by LowerWest sub-area.

- Runoff hydrograph produced by UpperEast sub-area routed through EastReach.

- Runoff hydrograph produced by LowerEast sub-area.

From the Watershed Peak Table, the peak at this point for the 5-year storm event is 1,529 cubic feet per second. Notice at the downstream end of this reach that the peak is reduced to 1,518 cubic feet per second. The 1,518 cubic feet per second represents the peak of the hydrograph as it is routed downstream through MainStem2 reach. The only thing left at this point is to add the runoff produced by the LowerMain sub-area. The hydrograph for the LowerMain sub-area produces a peak discharge of 300 cubic feet per second. When these final two hydrographs are added, the resultant peak at the watershed outlet is 1,808 cubic feet per second.

Example 2—Hydrology Peak/Peak Time Table

Region: Any State, Locale: Any County
Hydrograph Peak/Peak Time Table

Sub-area or Reach	- - - - - - - - - - - Peak Flow and Peak Time (hr) by rainfall return period - - - - - - - - - -					
	2-yr (ft³/s) (hr)	5-yr (ft³/s) (hr)	10-yr (ft³/s) (hr)	25-yr (ft³/s) (hr)	50-yr (ft³/s) (hr)	100-yr (ft³/s) (hr)
SUB-AREAS						
Upper Main	238.68	374.75	461.00	563.70	667.55	771.28
	12.16	12.15	12.14	12.14	12.14	12.12
CountyRoad	210.65	349.76	439.14	548.08	659.56	772.67
	12.17	12.16	12.15	12.16	12.15	12.16
MiddleMain	66.78	123.68	161.77	208.63	257.83	308.30
	12.05	12.03	12.03	12.03	12.02	12.02
UpperEast	216.21	338.62	414.28	505.19	598.04	691.70
	12.07	12.07	12.07	12.06	12.06	12.05
LowerEast	106.90	186.20	238.00	300.97	366.78	432.73
	12.14	12.13	12.13	12.11	12.11	12.10
UpperWest	99.73	156.06	191.43	233.60	276.23	319.74
	12.10	12.10	12.10	12.10	12.10	12.08
LowerWest	172.93	257.14	309.28	370.29	432.36	494.33
	12.01	12.01	12.00	12.01	12.00	12.00
Lower Main	195.22	299.62	363.91	441.53	518.96	599.27
	12.14	12.14	12.13	12.14	12.13	12.14
REACHES						
MainStem1	448.17	723.38	898.13	1,107.93	1,324.56	1,541.91
	12.16	12.15	12.14	12.14	12.14	12.15
Down	427.46	694.49	863.71	1,067.59	1,277.31	1,487.27
	12.24	12.21	12.20	12.19	12.20	12.20
MainStem2	928.30	1529.20	1912.16	2375.30	2849.98	3328.69
	12.16	12.13	12.13	12.12	12.12	12.12
Down	920.08	1517.87	1898.20	2357.34	2826.53	3303.47
	12.22	12.19	12.18	12.17	12.17	12.15
EastReach	216.21	338.62	414.28	505.19	598.04	691.70
	12.07	12.07	12.07	12.06	12.06	12.05
Down	210.62	329.64	404.58	494.83	585.57	678.49
	12.16	12.14	12.13	12.13	12.11	12.11
WestReach	99.73	156.06	191.43	233.60	276.23	319.74
	12.10	12.10	12.10	12.10	12.10	12.08
Down	98.51	154.48	189.71	231.77	274.49	317.10
	12.19	12.19	12.17	12.17	12.17	12.17
OUTLET	1103.46	1808.47	2255.51	2793.31	3342.75	3898.08

Example 3   Custom Dimensionless Unit Hydrograph

This example demonstrates the use of a custom Dimensionless Unit Hydrograph (DUH) instead of the standard one preloaded in the program. In certain areas of the country, different DUH's are applicable due to variations among geomorphic regions and differences in urbanization, channelization, and available storage (in wetlands, flood plains, and/or reservoirs) in watersheds. Users should contact the NRCS state conservation engineer if they have questions on whether to use the standard DUH in a location. This example uses the Coastal Delmarva DUH named for Delaware, Maryland, and Virginia.

This Delmarva DUH is currently part of the program install package, but example 3 describes it as though it is being entered for the first time for illustrative purposes.

Background

Owen Davies owns a 12.5-acre site in Talbot County on Maryland's eastern shore. Forest covers 1.5 acres of the property, and the remaining 11 acres are presently in Silver Queen sweet corn production, planted in straight rows. He uses conventional tillage with no special conservation practices, and the vegetative cover is typically in good condition. The soils on the cropland portion of the property are hydrologic soil group C. Hydrologic soil group D soils underlie the wooded part.

His plot is almost rectangular, with the cropland located on higher ground and the wooded part in a forested stream corridor, although the stream itself lies outside of his property. No defined channels run through his property, but there is evidence of sheet flows and shallow concentrated flows. The sheet flow path is 100 feet long with a slope of 10 percent. The shallow concentrated flow path through the cornfield is 858 feet long, also at a slope of 10 percent. The path of the flow through the woods is 131 feet long at a slope of 9.5 percent.

Owen has considered leaving crop residue on his field to reduce erosion and pollutant discharge into the stream. His daughter Branwen wants to show him what a difference crop residue can make. She will use WinTR–55 to calculate the peak discharge from a range of storms for his land. She will also use the Delmarva Unit Hydrograph (Welle, Woodward, and Fox Moody 1980), which applies to the eastern shore of Maryland, instead of the standard NRCS one. The Delmarva Unit Hydrograph was developed specifically for this area and reflects the discharge measured by USGS stream gages over years of monitoring.

Solution

This analysis has three parts. First, enter the Delmarva DUH into the data file. Second, determine the peak discharge and runoff volume for the present field tillage condition. Third, determine the peak discharge and runoff volume for the future condition with crop residue. Since the pollutants are carried by the runoff from the fields, reducing runoff results in a reduction in soluble pollutant load, if other factors are constant.

Part 1 Enter custom dimensionless unit hydrograph

Step 1:   Branwen starts the WinTR–55 program, and selects **New** from the pulldown choice list for **File**. She enters User ID, Project Name, Subtitle, State and County, and specifies sub-area units as acres. The Dimensionless Unit Hydrograph, the Storm Data Source and the Rainfall Distribution identifier have default values given when the program starts up, based on the last file used. The default DUH is the standard NRCS one, with a peak factor of 484.

Branwen can click on **GlobalData** in the **WinTR–55 Main Window** menu bar and then on **Storm Data** in the pulldown choice list (a) or on the Storm Data icon (b) on the button bar to bring up the **Storm Data** window.
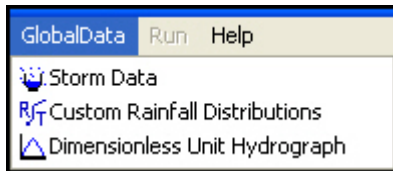
(a)   Pulldown choice list

(b)   Storm Data icon

Clicking the **NRCS Storm Data** button will fill in the data for Talbot County, Maryland. Maryland uses the Type II Rainfall Distribution.

Storm Data

Storm Data

Talbot County, MD (NRCS)

To replace these storm data with those compiled by the NRCS for Talbot County, MD, click on the command button below.

Rainfall Return Period (yr)	24-Hr Rainfall Amount (in)
2	3.4
5	4.5
10	5.3
25	6
50	6.8
100	7.6
1	2.8

NRCS Storm Data

Please select a rainfall distribution type from the list below. The list includes the standard WinTR-20 / WinTR-55 types and any number of user-defined distributions.

Rainfall Distribution Type:

Type II   Edit

? | Help | Cancel | Accept

File: <new file>   3/29/2006   9:38 AM

By clicking the **Accept** button, Branwen selects this as the Storm Data Source, which reflects on the **WinTR–55 Main Window**. She is ready to concentrate on the DUH.

Step 2:   Branwen visited the Talbot County Agricultural Service Center and has a table with the values for the
Delmarva DUH. She can click on GlobalData in the **WinTR–55 Main Window** menu bar and then on
Dimensionless Unit Hydrograph in the pulldown choice list (a) or click on the icon for the dimensionless
unit hydrograph (b) on the button bar to bring up the **Dimensionless Unit Hydrograph** window.
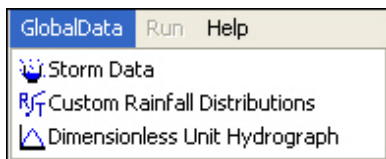
(b)   Dimensionless Unit Hydrograph icon

(a)   Pulldown choice list
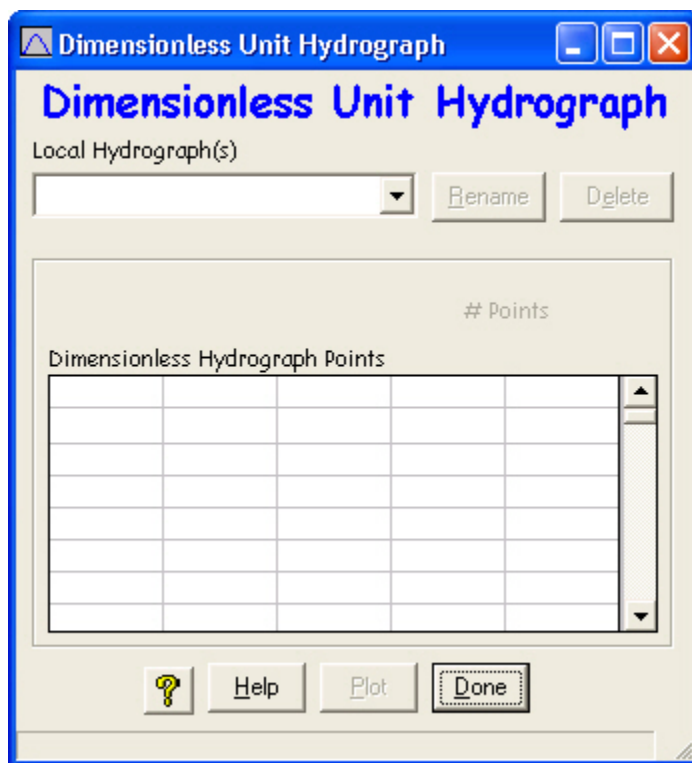
Step 3:   The **Dimensionless Unit Hydrograp**h window allows entry of a custom DUH. Branwen enters Delmar-
va for the DUH in the Local Hydrograph combo entry box. She then enters the points that define the DUH
in the Dimensionless Hydrograph Points grid. The points should begin and end at 0.0 and should be no
greater than 1.0. The program will calculate and show the number of points automatically.

Dimensionless Unit Hydrograph

Local Hydrograph(s)

delmarva   [Rename] [Delete]

delmarva:

Points   50

Dimensionless Hydrograph Points

0.33100	0.29600	0.26500	0.23700	0.21200
0.19000	0.17000	0.15300	0.13800	0.12300
0.10900	0.09700	0.08600	0.07600	0.06600
0.05700	0.04900	0.04100	0.03300	0.02700
0.02400	0.02100	0.01800	0.01500	0.01300
0.01200	0.01100	0.00900	0.00800	0.00800
0.00600	0.00600	0.00500	0.00500	0.00000

[Help] [Plot] [Done]

C:\Documents and Settings\quan.quan\Application Data\WinTR-5

Step 4:   If she wants, she can click on the **Plot** button and plot the DUH. The second line of the title gives the path where her work is located. Closing the plot returns her to the **Dimensionless Unit Hydrograp**h window, and she can click on the **Done** button to save the hydrograph and return to the main window.
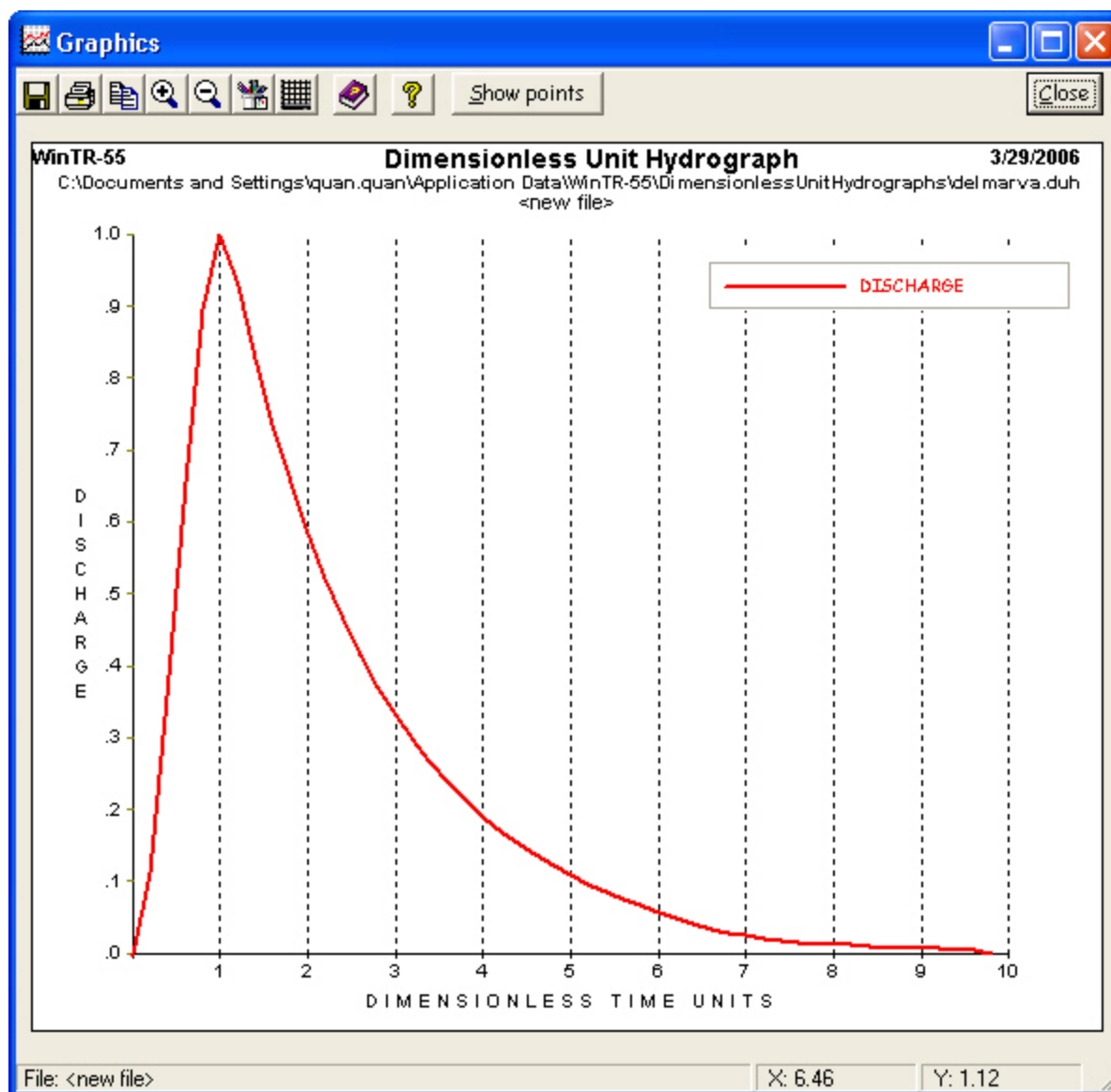
Step 5:   After returning to the **WinTR–55 Main Window**, she must select the Delmarva Dimensionless Unit Hydrograph from the choices displayed by the DUH pulldown for the program to actually use the Delmarva hydrograph in its calculations. After highlighting Delmarva in the pulldown choice list, she double clicks on it to enter it as her choice for use. If she wants to use this DUH in another job, all she needs to do is click on its name in the hydrograph list during the other job's data entry.

Part 2   Determine peak discharge and runoff volume for the present field tillage conditions.

Step 1:   Branwen now enters the Sub-area Name, Sub-area Description, and where the water leaving this sub-area flows in the Sub-area Flows to Reach/Outlet box to set up her watershed, ready to do her land use and time of concentration calculations.

Step 2:   Branwen can double click on the Area (ac) label, the Weighted CN label, or on either of the two blank cells in the entry grid below them to open the **Land Use Details** window. In the **Land Use Details** window, for each land use, she enters the area involved under the appropriate hydrologic soil group. She can click the Summary Screen On to see all her land use categories. Clicking <u>A</u>**ccept** returns the program to the **WinTR–55 Main Window**.

The sub-area and runoff curve number now appear in the Sub-area Entry and Summary portion of the **WinTR–55 Main Window**.

Step 3:   Branwen opens the **Time of Concentration Details** window the same way as the **Land Use Details**
window. She enters the appropriate information to compute the sub-area time of concentration and clicks
Accept to return to the **WinTR–55 Main Window**. The note below the Time of Concentration Details
window reminds her that since the calculated time of concentration is 0.094 hours, it will be replaced by
the minimum allowed value of 0.1 hour.

Flow Type	Length (ft)	Slope (ft/ft)	Surface (Manning's n)	n	Area (ft²)	WP (ft)	Velocity (f/s)	Time (hr)
Sheet	100	0.1000	Cultivated <= 20% residue (0.06) ▼					0.040
Shallow Concentrated	858	0.1000	Unpaved ▼					0.047
Shallow Concentrated	131	0.0950	Unpaved ▼					0.007
Channel								
Channel								
Total	1,089						3.2181	0.094

Sub-area Name: corn1

2-Year Rainfall (in): 3.4

Time of Concentration Details

* - Your computed subarea Tc is less than, and will be replaced with, the required minumum of 0.1 hours.

File: <new file>   3/29/2006   9:59 AM

The sub-area time of concentration now appears in the Sub-area Entry and Summary portion of the **WinTR–55 Main window**.

***Step 4***:   Branwen clicks the Run menu option from the **WinTR–55 Main Window**, or the **Run** button, , to open
the **Run WinTR–55** window and selects the storm events for which she would like output. Then she
clicks the **Run** button to execute the run. While the program is running, a processing bar appears and dis-
plays the program's progress as a series of little blue rectangles that runs from left to right. This reassures
Branwen that something is happening, even if she is not sure what. The appearance of this processing bar
excludes user entry of new data.

Step 5:   When the run is complete, the **File Display** window opens showing the **Hydrograph Peak/Peak Time Table**. Branwen can review other output by clicking **WinTR– 20 Reports** or **WinTR–55 Reports**, and selecting the reports to view. She clicks **<u>C</u>lose** to close the **File Display** window and return to the **Win-TR–55 Main Window**.

File Display

Print   Edit   WinTR-20 Reports   WinTR-55 Reports   Help

Hydrograph Peak/Peak Time Table

```
ccs                           Dad's farm
                       Cornfield near Bug Creek
                       Talbot County, Maryland

                   Hydrograph Peak/Peak Time Table

  Sub-Area        Peak Flow and Peak Time (hr) by Rainfall Return Period
  or Reach       2-Yr        5-Yr       10-Yr       25-Yr       50-Yr      100-Yr        1-Yr
 Identifier     (cfs)       (cfs)       (cfs)       (cfs)       (cfs)       (cfs)       (cfs)
                (hr )       (hr )       (hr )       (hr )       (hr )       (hr )       (hr )
 -------------------------------------------------------------------------------------------
 SUBAREAS
 corn1           28.84       43.41       54.16       63.74       74.71       85.70       21.18
                12.01       12.00       11.96       11.96       11.95       11.95       12.01


 REACHES

 OUTLET          28.84       43.41       54.16       63.74       74.71       85.70       21.18
```

C:\Documents and Settings\quan.quan\Application Data\WinTR-55\tr55rpts.out   3/29/2006   10:01 AM

Step 6:   From the **WinTR–55 Main Window**, Branwen can click on the **Output Definition** button, [icon], to get a
list of output summary reports available for printing or viewing. She selects the Watershed Peak Table to
show her Dad.
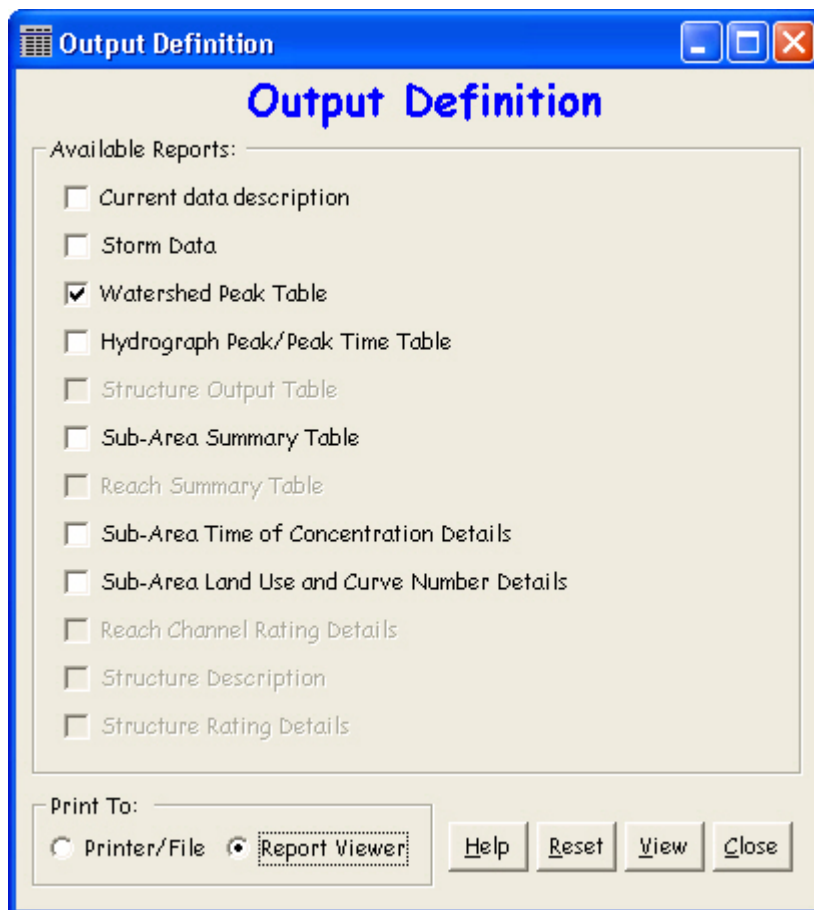
The menu items of the **File Display** window will let her view and print various WinTR–20 and WinTR–55 reports.
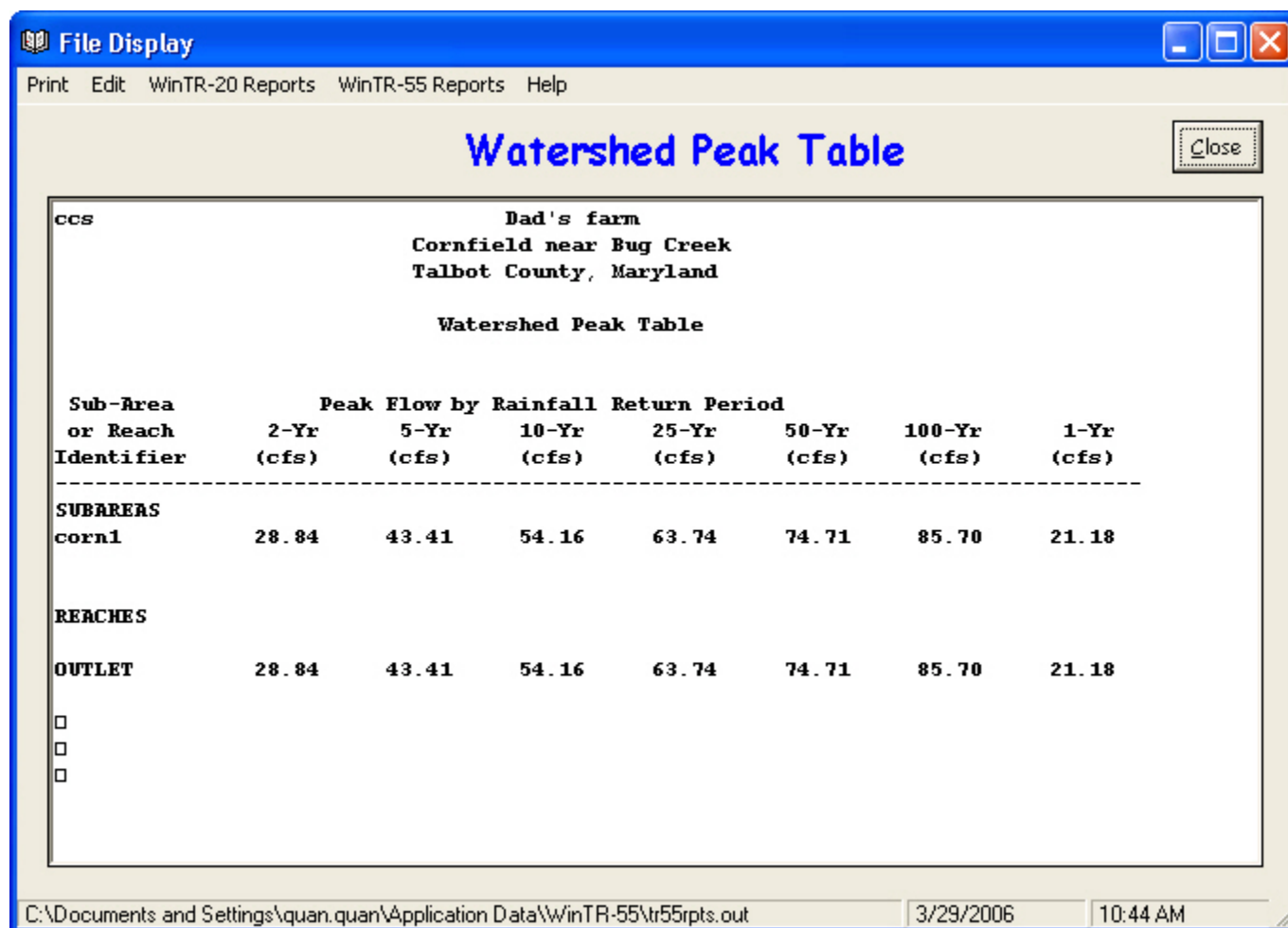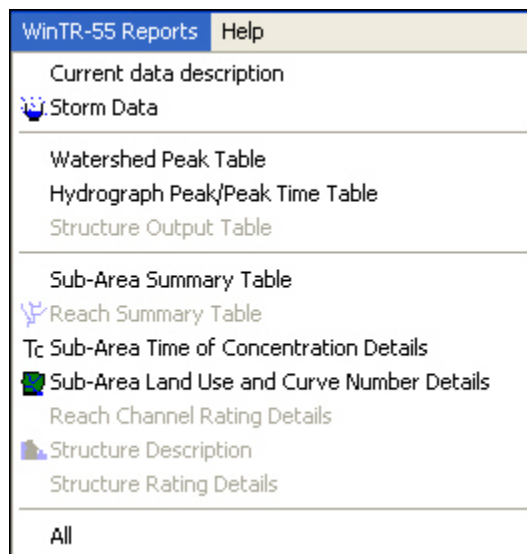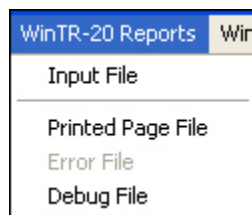
Step 7:   To save the data, she returns to the **Win TR–55 Main Window** by clicking <u>**Close**</u> on the **File Display** window and <u>**Close**</u> on the **Output Definitions Summary** window. She then clicks **File** on the Menu Bar and **SaveAs**. In the **Save a WinTR–55 data file as…** popup window, she specifies a file name (Ex 3-till for corn, conventional tillage) and clicks **Sav**e. The data are now saved, the popup window closes, and the **WinTR–55 Main Window** is redisplayed.
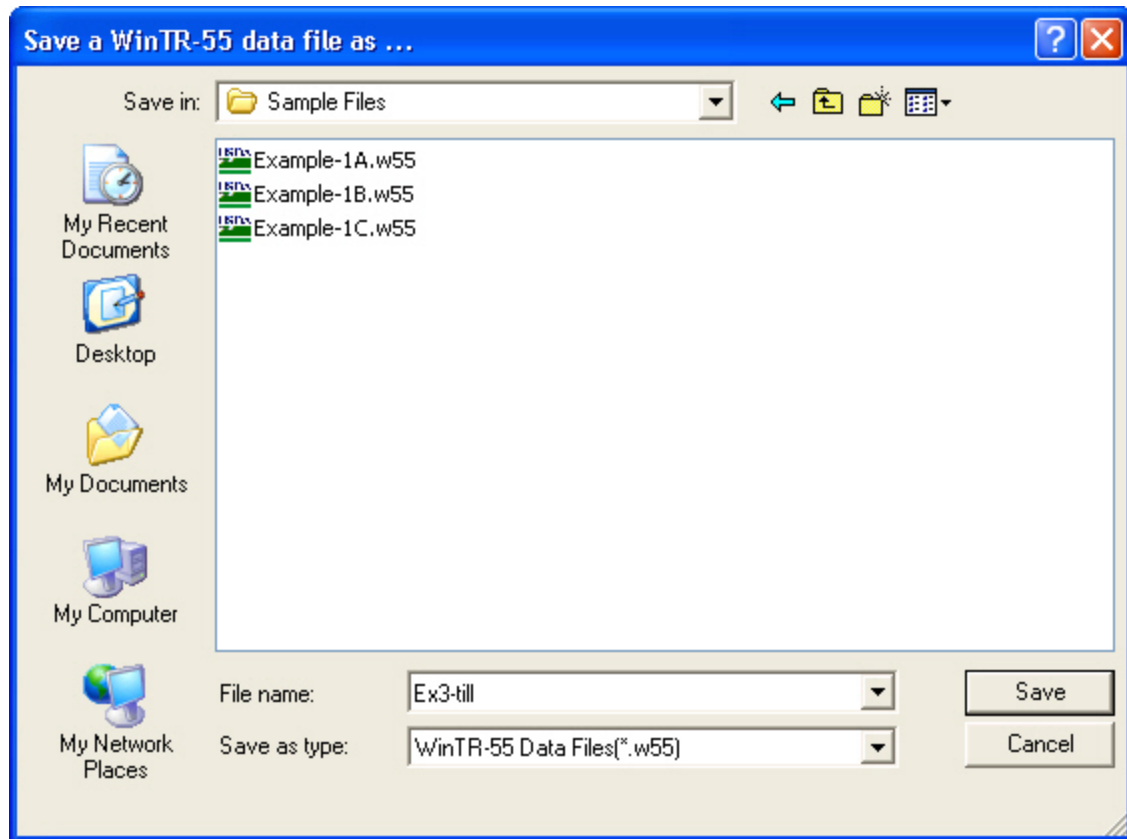
Part 2 Results

Conventional tillage discharge

Frequency	1-year	2-year	5-year	10-year	25-year	50-year	100-year
Discharge	21.2 ft^3/s	28.8 ft^3/s	43.4 ft^3/s	54.2 ft^3/s	63.7 ft^3/s	74.7 ft^3/s	85.7 ft^3/s
Volume*	1.4 in	1.8 in	2.8 in	3.5 in	4.2 in	4.9 in	5.7 in

* The Runoff Volume is available from the **File Display** window by selecting View and **WinTR–20 Printed Page File**.

Part 3   Determine peak discharge and runoff volume 'with crop residue management' condition

Rather than beginning with a completely new file to determine the peak discharge and runoff volume for the crop residue condition, Branwen decides to edit the existing condition data file previously created and save it under a different name.

Step 1:   She starts the WinTR–55 Program and opens the Existing Conditions file by selecting **Open** from the **File** menu and locating the file using the **Open a WinTR–55 data file** popup window.

She may also go into the pulldown choice list under File and select Ex 3-till.w55 from the last files used displayed in the history list.
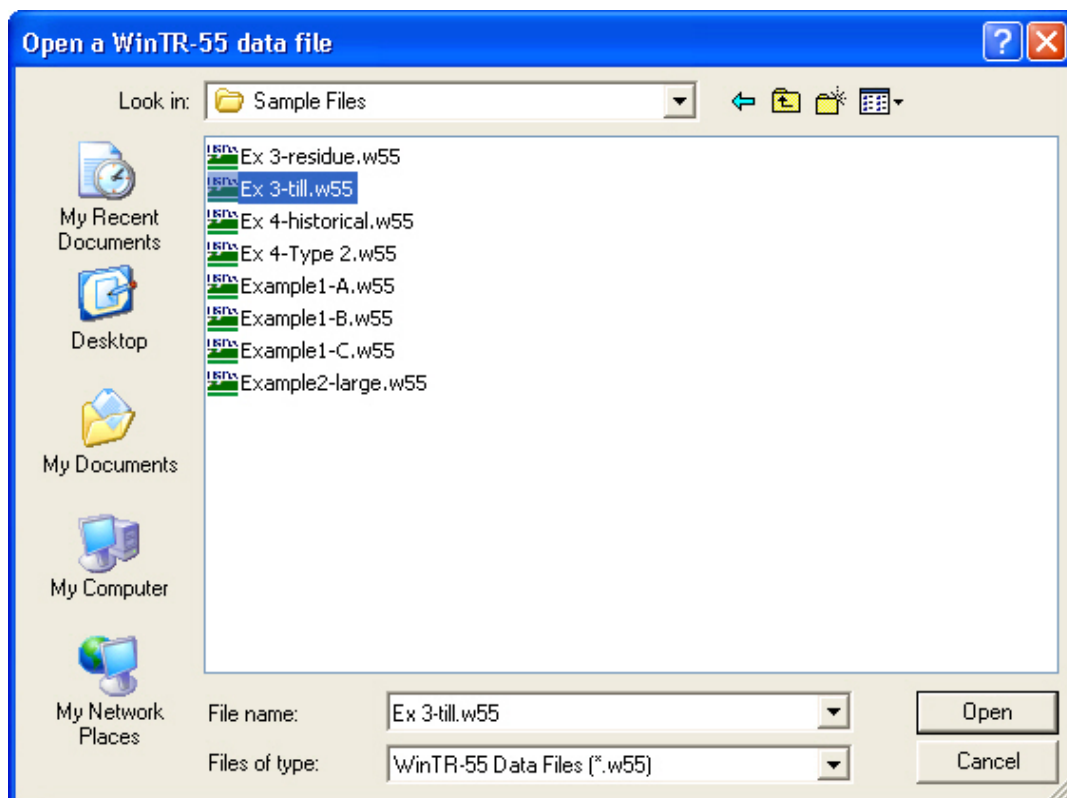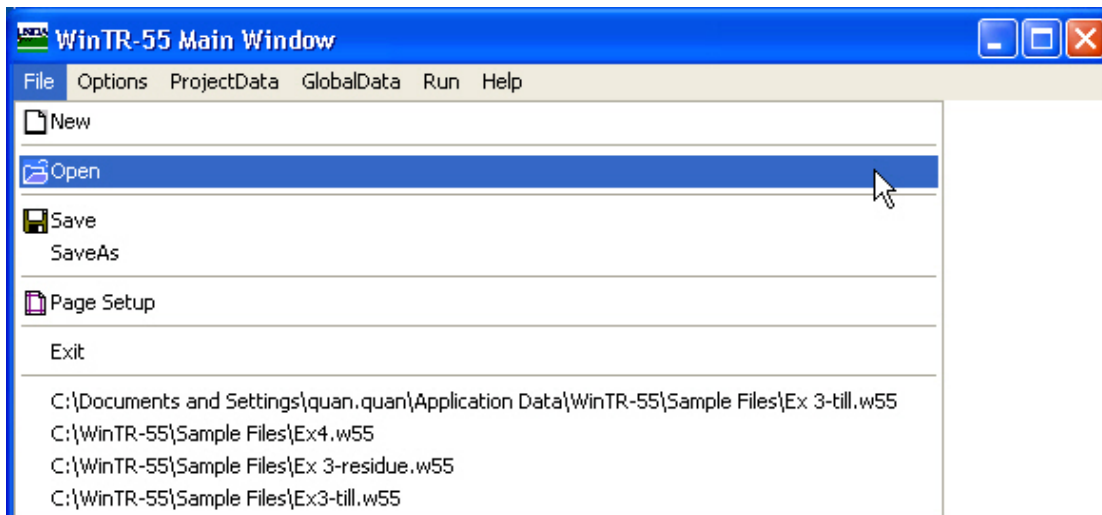
Step 2:   Branwen edits the Subtitle and the Sub-area Name to reflect crop residue conditions. She will need to also edit the CN and Tc to account for the new practice. Clicking the **Land Use Details** button, , opens the **Land Use Details** window.

She edits the land use and clicks **A**ccept to return to **WinTR–55 Main Window**.

Land Use Details

Sub-area Name: corn1 new | Rename | Clear

Land Use Categories
- ⦿ Urban Area
- ○ Developing Urban
- ○ Cultivated Agriculture
- ○ Other Agriculture
- ○ Arid Rangeland

Area (Acres) for Hydrologic Soil Groups

Cover Description	Condition	A	CN	B	CN	C	CN	D	CN
CULTIVATED AGRICULTURAL LANDS									
Fallow Bare soil	----		77		86		91		94
Fallow Crop residue (CR)	poor		76		85		90		93
Fallow Crop residue (CR)	good		74		83		88		90
Row crop Straight row (SR)	poor		72		81		88		91
Straight row (SR)	good		67		78		85		89
SR + Crop residue	poor		71		80		87		90
SR + Crop residue	good		64		75	11.000	82		85
Contoured (C)	poor		70		79		84		88
Contoured (C)	good		65		75		82		86
C + Crop residue	poor		69		78		83		87
C + Crop residue	good		64		74		81		85
Cont & terraced(C&T)	poor		66		74		80		82
Cont & terraced(C&T)	good		62		71		78		81

Project Area(ac): 12.50

Summary Screen: ⦿ Off ○ On

Sub-Area Area (ac): 12.50   Weighted CN: 81

Help | Cancel | Accept

File: C:\Documents and Settings\quan.quan\Application Data\WinTR-55\Sample Files\Ex 3-till.w55   3/31/2006   9:09 AM

The sub-area area and the new runoff curve number now appear in the Sub-area Entry and Summary portion of the **WinTR–55 Main Window**.

Step 3:   Branwen opens the **Time of Concentration Details** window and edits the data (assuming her Dad will have greater than 20% residue) to compute the new sub-area time of concentration. Clicking **Accept** returns her to the **WinTR–55 Main Window**.

The sub-area time of concentration now appears in the Sub-area Entry and Summary portion of the **WinTR–55 Main Window**.

Step 4:   Branwen saves her data now using SaveAs to give it a new name (Ex3-residue), and then clicks the **Run WinTR–55** button to open the **Run WinTR–55** window. The program saves the storm events for which the last run was made, so she can click **Run** to execute the run. When the run is complete, the **File Display** window opens showing the **Hydrograph Peak/Peak Time Table**. She can click **WinTR–20 Reports** or **WinTR–55 Reports** and select the reports to view. When complete, she clicks the **Close** button to close the **File Display** window and return to the **WinTR–55 Main Window**.

Part 3   Results

Branwen can now carry these results to her Dad and demonstrate the advantages of residue in reducing flows from his corn field.

Crop Residue Tillage Discharge

Frequency	1-year	2-year	5-year	10-year	25-year	50-year	100-year
Discharge	15.8 ft^3/s	22.4 ft^3/s	35.0 ft^3/s	44.6 ft^3/s	53.0 ft^3/s	62.7 ft^3/s	72.4 ft^3/s
Volume*	1.2 in	1.6 in	2.5 in	3.2 in	3.9 in	4.6 in	5.4 in

* The Runoff Volume is available from the **File Display** window by selecting **View** and **WinTR–20 Printed Page File**.

Step 5:   Summary of Results

Crop Residue vs. Conventional Tillage Discharge

Frequency	1-year	2-year	5-year	10-year	25-year	50-year	100-year
Discharge (conv. tillage)	21.2 ft^3/s	28.8 ft^3/s	43.4 ft^3/s	54.2 ft^3/s	63.7 ft^3/s	74.7 ft^3/s	85.7 ft^3/s
Volume (conv. tillage)	1.4 in	1.8 in	2.8 in	3.5 in	4.2 in	4.9 in	5.7 in
Discharge (residue)	15.8 ft^3/s	22.4 ft^3/s	35.0 ft^3/s	44.6 ft^3/s	53.0 ft^3/s	62.7 ft^3/s	72.4 ft^3/s
Volume (residue)	1.2 in	1.6 in	2.5 in	3.2 in	3.9 in	4.6 in	5.4 in
Discharge decrease (w/residue)	5.4 ft^3/s	6.4 ft^3/s	8.4 ft^3/s	9.6 ft^3/s	10.7 ft^3/s	12.0 ft^3/s	13.3 ft^3/s
Volume decrease (w/residue)	0.2 in	0.2 in	0.3 in	0.3 in	0.3 in	0.3 in	0.3 in

Example 4   Custom Rainfall Distribution

Background

Minor Lake Subdivision in Champaign County, Illinois, has an existing stormwater detention basin designed with the 100-year rainfall amount and the Type II rainfall distribution. A nearby watershed recently experienced a 7-inch, 24-hour storm for which hourly precipitation data are available. A local hydraulic engineer estimated the recurrence interval of this event to be 110 years.

The local homeowners want to know how their existing detention basin would perform during such an event. For comparison purposes, the engineer completed a 100-year Type II distribution design analysis first. The historical event was analyzed second.

Watershed and basin data

The existing hydrologic design listed the drainage area as 25 acres of 0.25-acre residential lots on hydrologic soil group B soils – curve number 75. The time of concentration had been computed at 0.45 hours. The 100-year rainfall depth is 6.61 inches.

The existing detention basin has a surface area of 2.0 acres at the spillway crest. The surface area is 2.4 acres at 3 feet above the spillway crest. The inlet crest of the 15-inch diameter pipe is 3.5 feet above the outlet.

Existing Conditions – Type II Rainfall Distribution

Step 1:   Enter the existing data on the **WinTR–55 Main Window**, **Structure Data** window, and **Reach Data** window.

Structure Data

Structure Name

det pond ▾ | CLear | Delete | Rename |

Structure Data

Pond Surface Area

| @ spillway crest | 2.0 | acres |

(optional) | 3 | feet above spillway | 2.4 | acres |

Accept

Plot

Cancel

Help

Discharge Description

Spillway Type
- ● Pipe
- ○ Weir

Diameter(in)

| Trial #1 | Trial #2 | Trial #3 |
| 15 | | |

Height (ft)
Pipe invert to spillway

3.5

--- Orifice flow assumed ---

Pipe Flow Rating – det pond

Stage [ft]	Diameter1 15(in) Pipe Head [ft]	Flow cfs	Diameter2 (in) Pipe Head [ft]	Flow cfs	Diameter3 (in) Pipe Head [ft]	Flow cfs	Temporary Storage [ac-ft]
0.00	2.875	0.000					0.00
0.63	3.500	11.020					1.28
1.25	4.125	11.964					2.60
2.50	5.375	13.657					5.42
6.25	9.125	17.794					15.10
12.50	15.375	23.097					35.42

File: <new file> | 3/31/2006 | 9:18 AM

The resulting flow path schematic is shown.

Step 2:   Go to the Global Data menu on the **WinTR–55 Main Window** and select <u>**S**</u>**torm Data**. On the **Storm Data** window, click the <u>**N**</u>**RCS Storm Data** button to choose the NRCS Champaign County rainfall data. Note that the Type II rainfall distribution is the default distribution.

Step 3:   Click the **Accept** button to accept the data and return to the **WinTR–55 Main Window**. Save this data as
Ex 4-Type 2. Run the 100-year design storm.

```
 File Display

Print   Edit   WinTR-20 Reports   WinTR-55 Reports   Help

                    Hydrograph Peak/Peak Time Table                    [ Close ]

  KKV                       Minor Lake Detention Check
              Analyze detention basin with Type II distribution
                        Champaign County, Illinois

                     Hydrograph Peak/Peak Time Table

   Sub-Area          Peak Flow and Peak Time (hr) by Rainfall Return Period
   or Reach          100-Yr
  Identifier          (cfs)
                       (hr)
  ----------------------------------------------------------------------
  SUBAREAS
  Minor Lake      89.59
                 12.15


  REACHES
  basin           89.59
                 12.15
       Down        12.58
                 12.98


  OUTLET           12.58


C:\Documents and Settings\quan.quan\Application Data\WinTR-55\tr55rpts.out    3/31/2006    9:21 AM
```

Step 4: The first report to display after computing a run is the **Hydrograph Peak/Peak Time Table**. However, if peak discharge is the only variable of interest, the Watershed Peak Table is less confusing because it omits the peak time and shows only the peak discharge. Using the Type II rainfall distribution, the peak flow from the Minor Lake Watershed area is nearly 90 cubic feet per second into the basin. The flow out of the basin is approximately 13 cubic feet per second. To look at the respective 100-year design hydrographs, click the **Hydrographs** icon on the **WinTR–55 Main Window**. Select the Sub-areas segment type, Minor Lake and Outlet Sub-areas, the 100-year storm, and click on the **Plot** button to produce the graph.
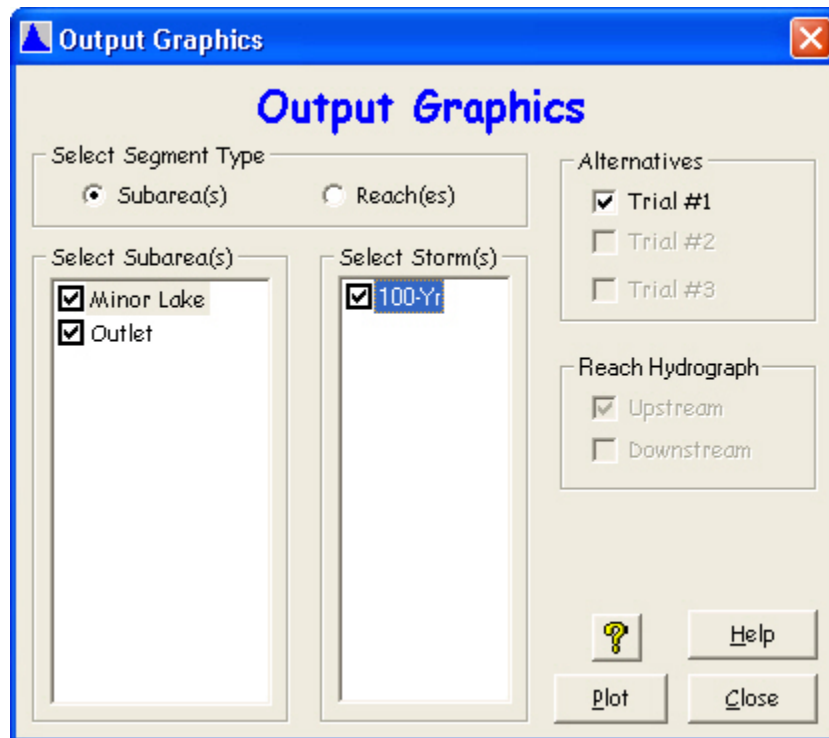
The short-duration, highly-peaked line hydrograph is from subdivision houses; the long, low line represents outflow from the basin.
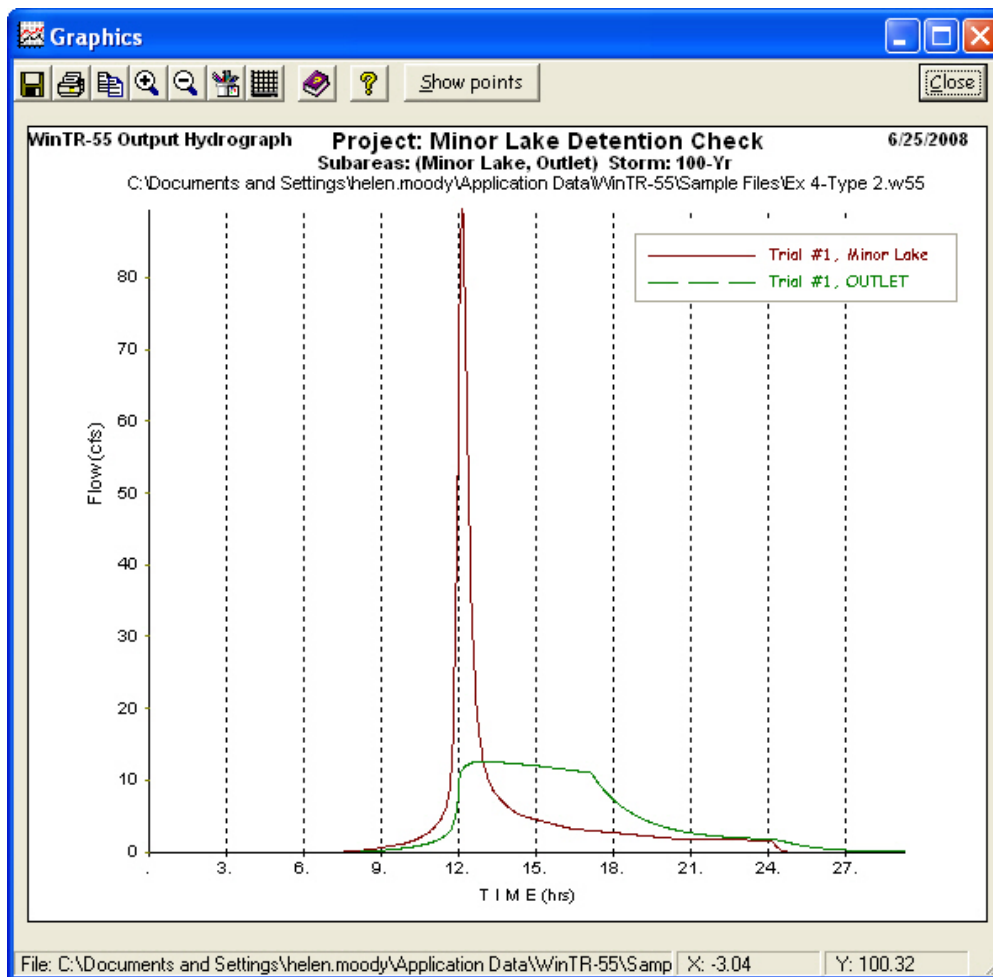
Enter historic rainfall distribution

Step 1   Since the data for running the 100-year Type II storm has been saved in the file Ex 4-Type 2, open this file
(if it is not already open), and save it as Ex 4-historical. This new file will be edited to provide a run on the
historical storm. Click the **Custom Rainfall Distributions** icon on the **WinTR–55 Main Window**, and
enter the recorded hourly rainfall distribution as shown below. The values are a ratio of the total rainfall.
For example, 0.21 inches of rain fell during the first hour, so the first data point after 0 is 0.03000
(0.21/7 = 0.03).

The plot shows how the rainfall was distributed during the 24-hour storm.
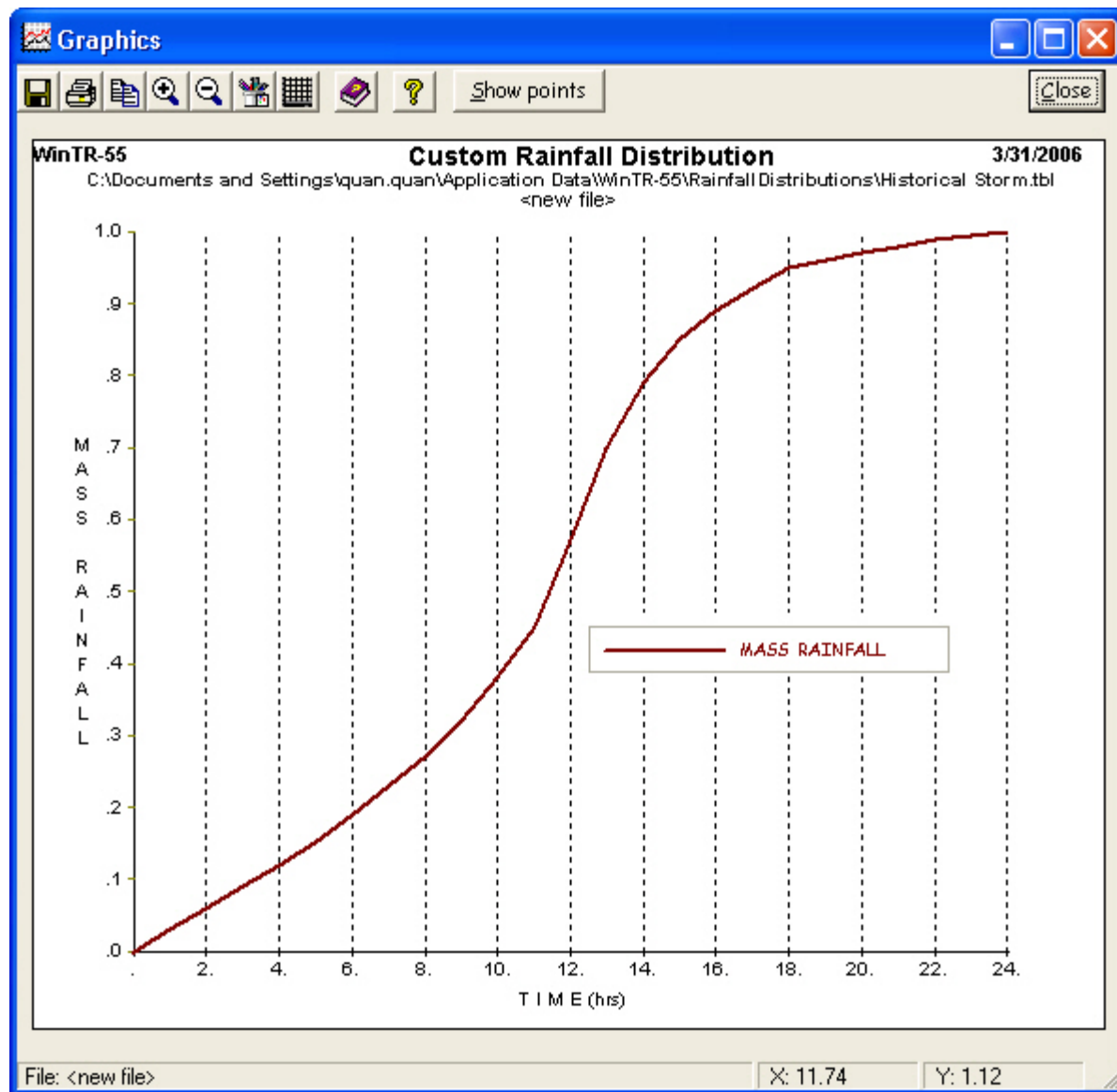
Step 2   Now that the custom rainfall distribution has been entered and saved, click on the **Storm Data** icon on
the **WinTR–55 Main Window**. Select the previously defined distribution, Historical Storm, from the pull-
down list for distribution types. Enter 7.00 inches for the 110-year rainfall on the right side of the window.

Step 3   Click the **<u>A</u>ccept** button to close the **Storm Data** window and return to the **WinTR–55 Main Window**.

Step 4   The storm data source now reads User-provided custom storm data. Click the **Run** icon to compute the
hydrographs using the historical rainfall distribution and depth.
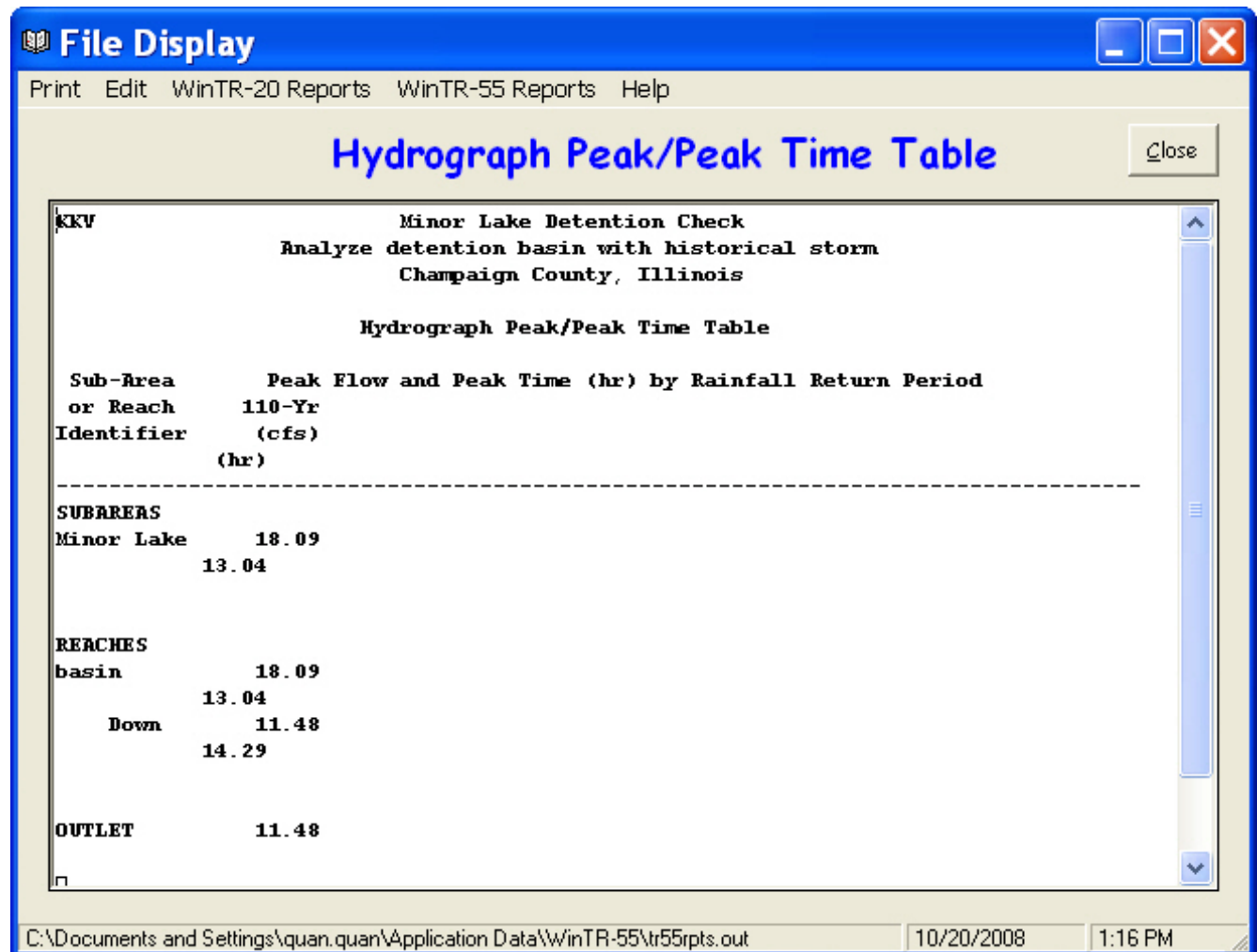
Step 5 The historical peak is estimated at 18 cubic feet per second from Minor Lake sub-area. The detention basin lowers the peak to approximately 11.5 cubic feet per second. The hydrographs are plotted next.

The jagged line represents the flow from the subdivision and into the basin. The more rounded line represents the estimated outflow from the detention basin during the historical rainfall event.
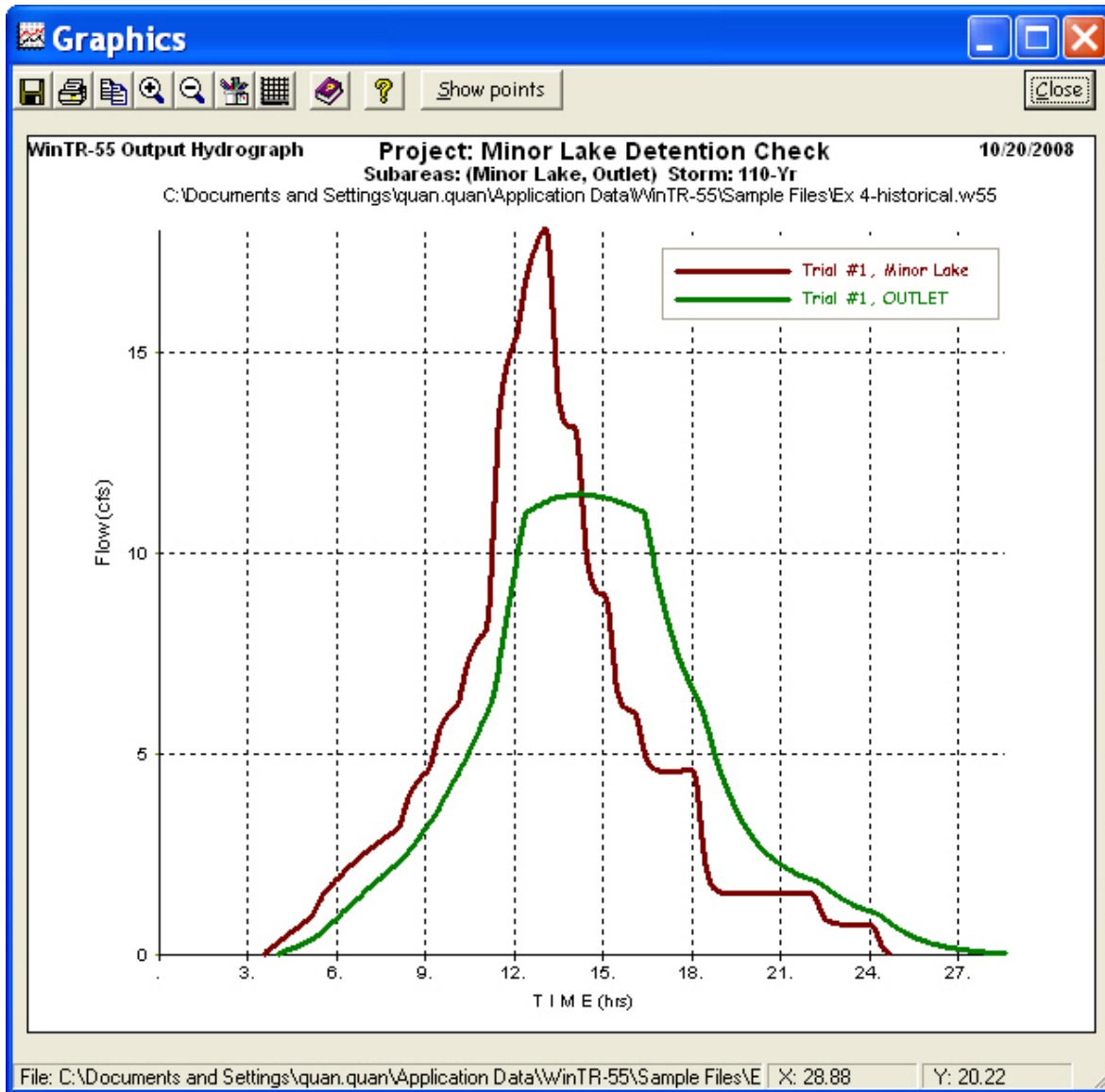
Step 6 If detailed information is needed, such as a table of hydrograph points, go to the **Output Definition** window, and view any report to open the **File Display** window. Click **WinTR–20 Printed Page File** to see the tabulated hydrograph. This WinTR–20 printed page report is a text file in the WinTR–55 subdirectory labeled tr20.out.

Results

The peak inflow to the existing stormwater detention basin was reduced from the 90 cubic feet per second for the Type II design storm down to 18 cubic feet per second for the historical storm. This dramatic pea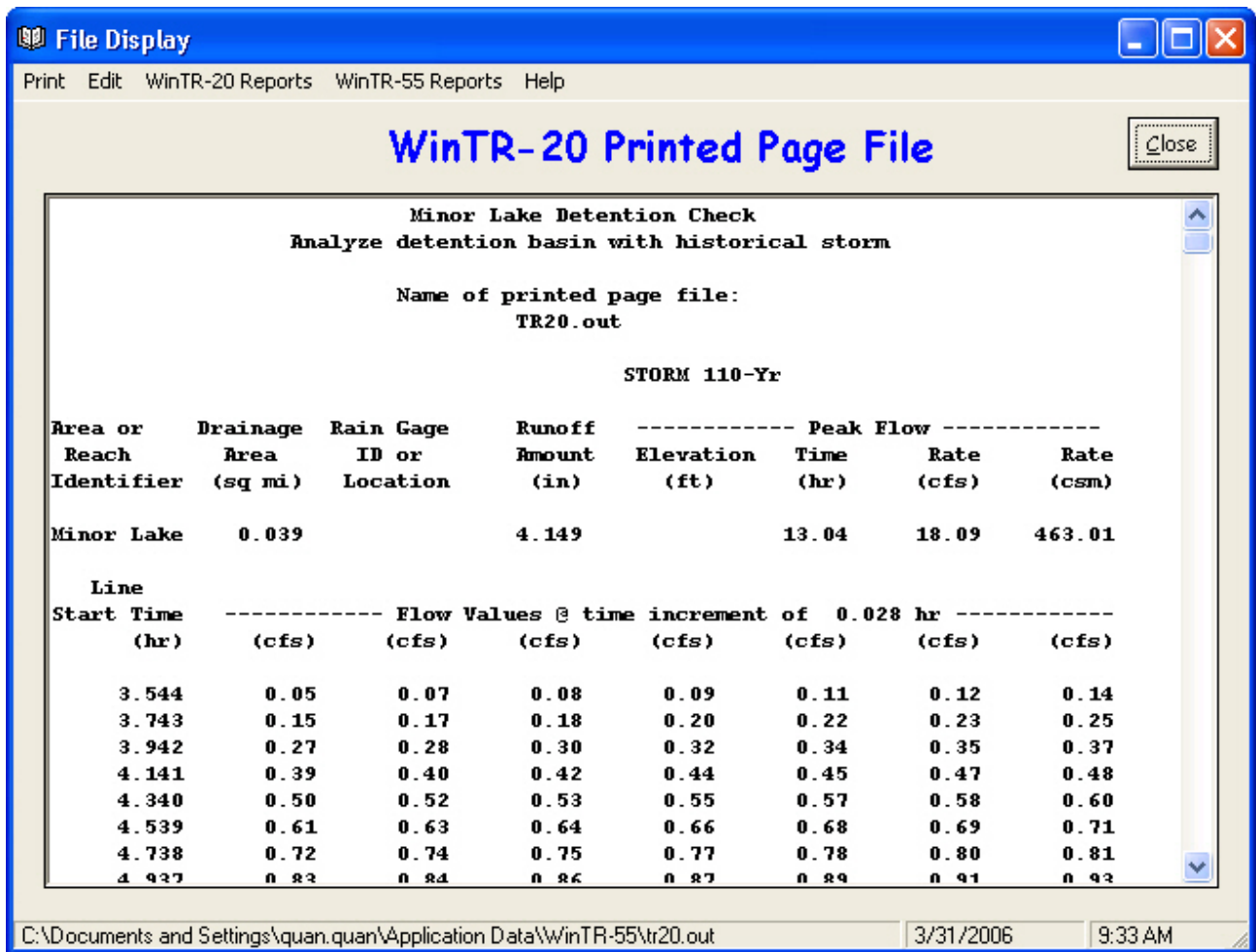k flow reduction is due to the less intense historical rainfall distribution. The peak discharge decreased even though the rainfall depth increased slightly from 6.6-inch design depth to 7-inch historical depth.

However, the peak outflow from the detention basin is reduced only slightly, from 13 cubic feet per second to 11 cubic feet per second. Therefore, this analysis demonstrates that the existing stormwater detention basin would have performed adequately during the historical storm event that occurred in the nearby watershed.

Appendix B   Equations

Runoff equation

$$Q = \frac{\left[P - 0.2\left(\frac{1000}{CN} - 10 \right) \right]^2}{P + 0.8\left(\frac{1000}{CN} - 10 \right)}$$

where:
Q   = runoff (in)
P   = rainfall (in)
CN = runoff curve number

Weighted Curve Number (CN)

$$CN_w = \frac{\sum \left(A_x \times CN_x \right)}{\sum A_x}$$

where:
CN_w = weighted curve number
A_x = area of land use–soil complex
CN_x = curve number of land use–soil complex

Composite CN (connected impervious area)

$$CN_c = CN_p + \left(\frac{P_{im}}{100} \right)\left(98 - CN_p \right)$$

where:
CN_c = composite runoff curve number
CN_p = pervious runoff curve number
P_{im} = percent imperviousness

Composite CN (unconnected w/<30% impervious)

$$CN_c = CN_p + \left(\frac{P_{im}}{100} \right)\left(98 - CN_p \right)\left(1 - 0.5R \right)$$

where:
R   = ratio of unconnected impervious area to total impervious area

Sheet flow

$$T_t = \frac{0.007 \left(n L \right)^{0.8}}{\left(P_2 \right)^{0.5} S^{0.4}}$$

where:
T_t = travel time (hr)
n = Manning's roughness coefficient (for sheet flow)
L   = flow length (ft)
P_2 = 2-year, 24-hour rainfall (in)
S   = slope of hydraulic grade line (land slope, ft/ft)

Shallow concentrated flow

$$V = 16.1345\sqrt{S} \qquad \text{(Unpaved)}$$

$$V = 20.3282\sqrt{S} \qquad \text{(Paved)}$$

where:
V   = average velocity (ft/s)
S   = slope of hydraulic grade line (watercourse slope, ft/ft)

These two equations are based on a solution of the Manning's equation with different assumptions for n (Manning's roughness coefficient) and r (hydraulic radius, ft). For unpaved areas, n is 0.05 and r is 0.4; for paved areas, n is 0.025 and r is 0.2.

Channel flow (Manning's n equation)

$$V = \frac{1.49 r^{\frac{2}{3}} \sqrt{S}}{n}$$

where:
V   = average velocity (ft/s)
r   = hydraulic radius (ft) and is equal to a/p_w
a   = cross sectional flow area (ft^2)
p_w = wetted perimeter (ft)
S   = slope of hydraulic grade line (channel slope, ft/ft)
n = Manning's roughness coefficient (for open channel flow)

Channel rating equations

$$TW = BW + (2 \times Stage \times Z)$$

$$EA = \frac{(BW + TW)}{2} \times Stage$$

$$WP = BW + 2 \times \sqrt{\left(\frac{TW - BW}{2}\right)^2 + (Stage)^2}$$

$$Flow_{channel} = \frac{1.486}{Manning's\ n} \times EA^{\frac{5}{3}} \times \frac{\sqrt{Friction\ slope}}{WP^{\frac{2}{3}}}$$

where:
EA	=	end area, ft^2
Flow$_{channel}$	=	ft^3/s
TW	=	top width, ft
BW	=	bottom width, ft
Stage	=	ft
WP	=	wetted perimeter, ft
Z	=	side slope, dimensionless
Friction slope	=	no units

Storage rating equations

Temporary storage

$$Storage_{temporary} = Stage \times \left(\frac{(2 \times A_{crest}) + (Stage \times \Delta)}{2}\right)$$

$$\Delta = \frac{(A_{above\ crest}) - (A_{crest})}{(Ht_{above\ crest})}$$

where:
Δ	=	delta, ft
Ht$_{above\ crest}$	=	ft
Stage	=	ft
A$_{crest}$	=	acre
A$_{above\ crest}$	=	acre
Storage$_{temporary}$	=	acre-ft

Short tube flow (for analyzing pipe flows)

$$Head_{pipe} = Height + Stage - \frac{D_{pipe}}{24}$$

$$A_{pipe} = \pi \left(\frac{D_{pipe}}{24}\right)^2$$

$$Flow_{pipe} = A_{pipe} c_d \sqrt{2g Head_{pipe}}$$

For g = gravity and c$_d$ = 0.6

$$Flow_{pipe} = 4.81 \times A_{pipe} \sqrt{Head_{pipe}}$$

where:
Height	=	ft
Head$_{pipe}$	=	ft
Stage	=	ft
D$_{pipe}$	=	in
A$_{pipe}$	=	ft^2
Flow$_{pipe}$	=	ft^3/s

Weir flow

$$Flow_{broad-crested\ weir} = 2.8 \times L_{weir} \times Stage^{1.5}$$

For V-notch weir:

$$Flow_{90° V-notch\ weir} = 2.5 \times Stage^{2.5}$$

where:
L$_{weir}$	=	weir length, ft
Stage	=	ft
Flow$_{weir}$	=	ft^3/s

Storage indication structure routing

$$\Delta s = (I - O)\Delta t$$

where:
Δs	=	change in storage
I	=	inflow
O	=	outflow
Δt	=	time interval

Appendix C   References

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