ASSOCIATED ATTACHMENTS/ENCLOSURES:

Attachment 02.04.03-09C: Wheeler Dam Watershed Unit Hydrograph (Subbasins 51, 52, 54, 55, 56, 58, 63, 64 and 65) CDQ000020080072, Rev. 0

(101 Pages including Cover Sheet)

NPG CALCULATION COVERSHEET/CCRIS UPDATE

REV A EDMS/RIMS NO.	EDMS TYPE:	EDMS ACCESSION NO (N/A for REV. 0)
L58 091130 001	calculations(nuclear)	N/A

Calc Title: Wheeler Dam Watershed (Subbasins 51, 52, 54, 55, 56, 58, 63, 64, and 65) Unit Hydrograph Validation

CALC ID	TYPE	ORG	PLANT	BRANCH	NUMBER	CUR REV	NEW REV	REVISION APPLICABILITY
CURRENT								Entire calc ☐ Selected pages ☐
NEW	CN	NUC	GEN	CEB	CDQ000020080072	N/A	0	

ACTION	NEW ☒ REVISION ☐	DELETE ☐ RENAME ☐	SUPERSEDE ☐ DUPLICATE ☐	CCRIS UPDATE ONLY ☐ (Verifier Approval Signatures Not Required)	No CCRIS Changes ☐ (For calc revision, CCRIS been reviewed and no CCRIS changes required)

UNITS	SYSTEMS	UNIDS
N/A	N/A	N/A

DCN,EDC,N/A	APPLICABLE DESIGN DOCUMENT(S)	CLASSIFICATION
See** Below	N/A	"E"

QUALITY RELATED?	SAFETY RELATED? (If yes, QR = yes)	UNVERIFIED ASSUMPTION	SPECIAL REQUIREMENTS AND/OR LIMITING CONDITIONS?	DESIGN OUTPUT ATTACHMENT?	SAR/TS and/or ISFSI SAR/CoC AFFECTED
Yes ☒ No ☐	Yes ☒ No ☐	Yes ☐ No ☒	Yes ☐ No ☒	Yes ☐ No ☒	Yes ☐ No ☒

PREPARER ID	PREPARER PHONE NO	PREPARING ORG (BRANCH)	VERIFICATION METHOD	NEW METHOD OF ANALYSIS
HSSAWYER	(615) 252-4362	CEB	See Page 8	☐ Yes ☒ No

PREPARER SIGNATURE	DATE	CHECKER SIGNATURE	DATE
Heather Smith Sawyer	11/18/09	Karl E. Stickley	11/18/09
VERIFIER SIGNATURE	**DATE**	**APPROVAL SIGNATURE**	**DATE**
Mark Crisp	11/18/09	K. E. Spates PES for KES 11-27-09	11/27/09

STATEMENT OF PROBLEM/ABSTRACT

11/18/09

Validate existing unit hydrographs for the subbasins of the Wheeler Dam watershed (Subbasins 51, 52, 54, 55, 56, 58, 63, 64, and 65) using the 1973 and 2004 floods of record.

This calculation contains electronic attachments and must be stored in EDMS as an Adobe .pdf file to maintain the ability to retrieve the electronic attachments.

** EDCN-22404A (SQN), EDCN-54018A (WBN), EDCN-LATER (BFN)

MICROFICHE/EFICHE Yes ☐ No ☒ FICHE NUMBER(S)

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CALC ID	TYPE	ORG	PLANT	BRANCH	NUMBER	REV
	CN	NUC	GEN	CEB	CDQ000020080072	0

ALTERNATE CALCULATION IDENTIFICATION

BLDG	ROOM	ELEV	COORD/AZIM	FIRM	Print Report Yes ☐
				BWSC	

CATEGORIES NA

KEY NOUNS (A-add, D-delete)

ACTION (A/D)	KEY NOUN	A/D	KEY NOUN
A	PMF		
A	Rain		
A	Flood		
A	River		

CROSS-REFERENCES (A-add, C-change, D-delete)

ACTION (A/C/D)	XREF CODE	XREF TYPE	XREF PLANT	XREF BRANCH	XREF NUMBER	XREF REV
A	S	CN	GEN	CEB	CDQ000020080054	
A	P	CN	GEN	CEB	CDQ000020080055	
A	P	CN	GEN	CEB	CDQ000020080051	
A	P	CN	GEN	CEB	CDQ000020080052	
A	P	CN	GEN	CEB	CDQ000020080053	
A	S	CN	GEN	CEB	CDQ000020080042	
A	P	EN	WBN	CEB	54018A	
A	P	EN	SQN	CEB	22404A	
A	P	CO	GEN	CEB	FLDHYDRO Version1.0	

CCRIS ONLY UPDATES:
Following are required only when making keyword/cross reference CCRIS updates and page 1 of form NEDP-2-1 is not included:

PREPARER SIGNATURE	DATE	CHECKER SIGNATURE	DATE
PREPARER PHONE NO.	EDMS ACCESSION NO.		

NPG CALCULATION RECORD OF REVISION	
CALCULATION IDENTIFIER CDQ000020080072	
Title	Wheeler Dam Watershed (Subbasins 51, 52, 54, 55, 56, 58, 63, 64, and 65) Unit Hydrograph Validation
Revision No.	DESCRIPTION OF REVISION
0	Initial issue: 100 Pages

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Attachment 1- Input Excel Spreadsheets (17 files)		N/A
Attachment 2- Data and Output Files (4 files)		N/A
Attachment 3- Spreadsheets (4 files)		N/A

NOTE: N/A indicates an electronically attached file(s).

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NPG CALCULATION VERIFICATION FORM

Calculation Identifier CDQ000020080072 Revision 0

Method of verification used:		
1. Design Review	☒	Verifier Mark Crisp Date 11/18/09
2. Alternate Calculation	☐	
3. Qualification Test	☐	

Comments:

The calculation entitled, "Wheeler Dam Watershed (Subbasins 51, 52, 54, 55, 56, 58, 63, 64, and 65) Unit Hydrograph Validation" was verified by an independent verification process. The engineering methods and approaches utilized in this report are correctly applied. The summaries and conclusions, developed from proper hydrologic and hydraulic methodologies, have been verified and are consistent with proper engineering practices.

NPG COMPUTER INPUT FILE STORAGE INFORMATION SHEET

Document	CDQ000020080072	Rev. 0	Plant: GEN

Subject: Wheeler Dam Watershed (Subbasins 51, 52, 54, 55, 56, 58, 63, 64, and 65) Unit Hydrograph Validation

☐ Electronic storage of the input files for this calculation is not required. Comments:

☒ Input files for this calculation have been stored electronically and sufficient identifying information is provided below for each input file. (Any retrieved file requires re-verification of its contents before use.)

See listing of electronically attached spreadsheets and input/output files on the two following page.

☐ Microfiche/eFiche

ELECTRONIC FILE ATTACHMENTS

Document: CDQ000020080072	Rev. 0	Plant: Gen	

Subject: Wheeler Dam Watershed (Subbasins 51, 52, 54, 55, 56, 58, 63, 64, and 65) Unit Hydrograph Validation

The files listed below, which contain both input and output data, are electronically attached to the parent Adobe .pdf calculation file. The listed files are therefore stored in an unalterable medium and are retrievable through the EDMS number for this calculation. Click on the "Attachments" Tab within Adobe to view the attachment listing, to access and view the files as needed.

Electronic Attachment Number		Attachment Name
1-01		Attachment 1-01_Table2-TVA UHParameters.xls
1-02		Attachment 1-02_Wheeler_March_1973_Model.xls
1-03		Attachment 1-03_Wheeler_Model_December_2004.xlsx
1-04		Attachment 1-04_IND-Convol-51.xls
1-05		Attachment 1-05_IND-Convol-52.xls
1-06		Attachment 1-06_IND-Convol-54.xls
1-07		Attachment 1-07_IND-Convol-55.xls
1-08		Attachment 1-08_IND-Convol-56.xls
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1-11		Attachment 1-11_IND-Convol-64.xls
1-12		Attachment 1-12_IND-Convol-65.xls
1-13		Attachment 1-13_Rainfall Data.xls
1-14		Attachment 1-14_Wheeler_Reservoir-Rain.xls
1-15		Attachment 1-15_Validated_Unit_Hydrograph_Ordinates.xls
1-16		Attachment 1-16_wheeler_Rev0.xls
1-17		Attachment 1-17_2004_Wheeler_Watershed_Hourly_Precip_Data.xls
2-01		Attachment 2-1_Wheeler_0373_Q.dat
2-02		Attachment 2-2_Wheeler_0373_Q.out
2-03		Attachment 2-3_Wheeler_1204_M.dat
2-04		Attachment 2-4_Wheeler_1204_M.out
3-01		Attachment 3-1_Observed vs SOCH Mar1973 Hydrographs 1029809.xls
3-02		Attachment 3-2_Observed vs SOCH Dec2004 Hydrographs 102909.xls
3-03		Attachment 3-3_03-73 Instantaneous Routing for SOCH.xls
3-04		Attachment 3-4_04-12 Instantaneous Routing for SOCH.xls

1 Purpose

The Tennessee Valley Authority's (TVA) Water Management Group has adapted computer codes and data sets developed from flood studies carried out over the past 40 years to develop a dynamic hydrologic model [6] of the Tennessee River upstream of the Wheeler Dam for use in the Probable Maximum Flood (PMF) and dam break analysis for the Sequoyah, Watts Bar, Browns Ferry and planned Bellefonte (BLN) Nuclear Plant sites.

Inputs to the dynamic model include inflow developed from convoluted design rainfall and unit hydrographs developed specifically for each of the 15 subbasins of Wheeler Dam watershed. The model inputs are grouped into six inflow hydrographs by creek or river basin, Paint Rock River (Subbasins 51 and 52); Flint River (Subbasins 53 and 54); Cotaco Creek (Subbasins 55 and 56); Limestone Creek (Subbasins 57 and 58); Elk River (Subbasins 59, 60, 61, 62, 63, and 64); and Wheeler Local (Subbasin 65). These unit hydrographs were developed by TVA in previous studies utilizing observed rainfall and stream flow and reservoir headwater and discharge data, and are being validated by checking their performance in reproducing recent floods. The unit hydrographs for the 9 subbasins in this calculation were indirectly validated by using them as input to a dynamic hydrologic model to replicate observed stage and flows.

This calculation (CDQ000020080072) presents the development of the initial simulated inflows used in the calibration of the SOCH model which will indirectly validation of unit hydrographs developed by the TVA for 9 subbasins (51, 52, 54, 55, 56, 58, 63, 64 and 65) of the Wheeler watershed. Reliable stream flow or suitable precipitation data is not available for these 9 subbasins, necessitating indirect validation. The validation occurs by simulating flows from each subbasin for the March 1973 and December 2004 floods, using these simulated flows as input to the SOCH model, then comparing SOCH model output to observed Wheeler Reservoir stage and outflow data. Elevation and discharge hydrographs are produced by the SOCH at selected locations for the unit hydrograph validation.

The locations of the subbasins assessed in this calculation in relation to other relevant features of the Tennessee River Valley are illustrated in Figure 1.

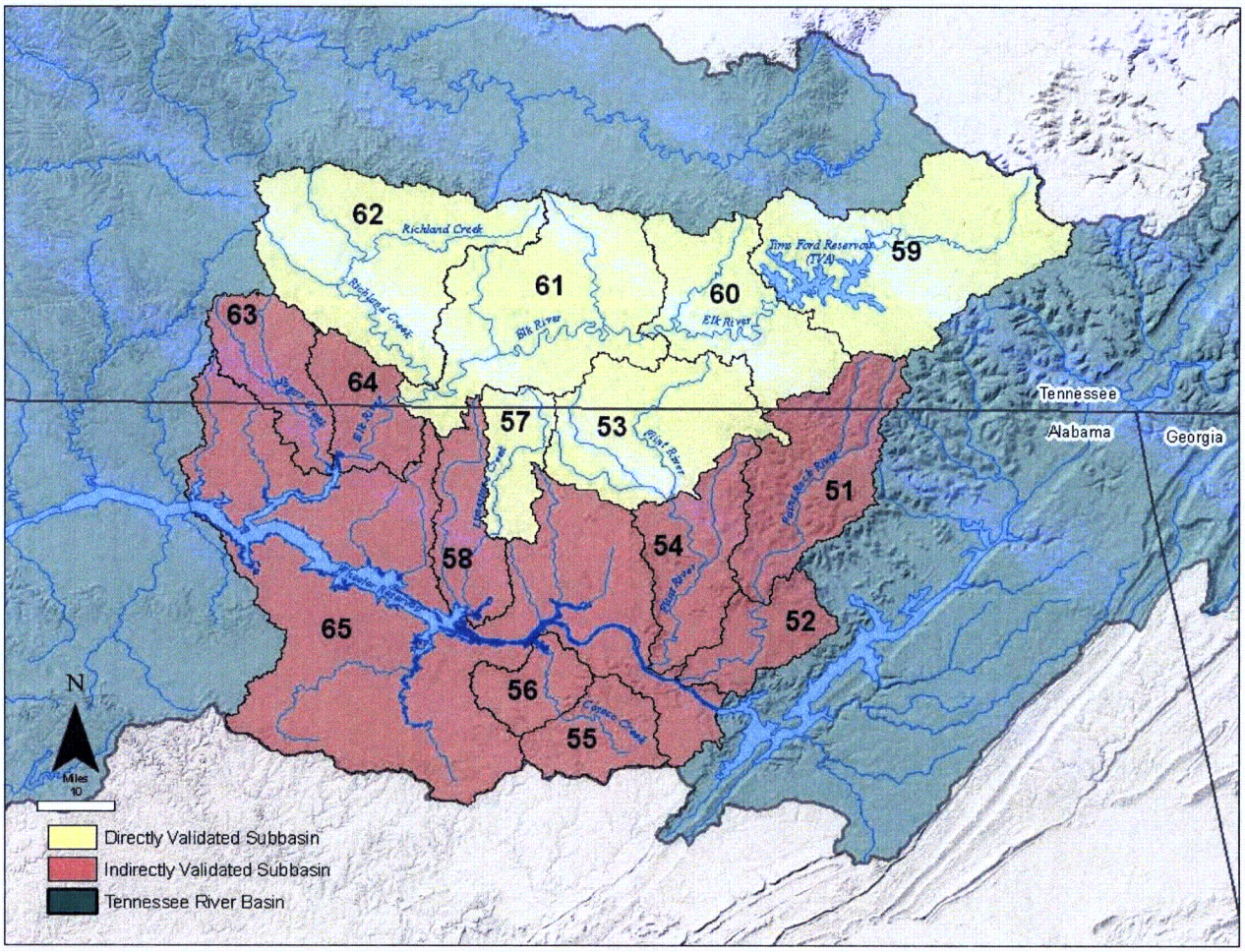

Figure 1: Location of the Nine Wheeler Dam Subbasins (in Brown) Considered in this Calculation within the Tennessee River Watershed

2 References

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2.2. Chow, V.T., D.R. Maidment, and L.W. Mays. *Applied Hydrogeology*, McGraw-Hill: New York, 1988.

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2.5. U.S. Nuclear Regulatory Commission. "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants, LWR Edition." Office of Nuclear Reactor Regulation, Office of New Reactors., Washington, DC, March, 2007. NUREG-0800, Revision 4. Chapter 2.4.3. Probable Maximum Flood (PMF) on Streams and Rivers.

2.6. Tennessee Valley Authority. *Simulated Open Channel Hydraulics (SOCH) User's Manual, Version 1.0*. 2008, TVA: Knoxville, Tenn. (EDMS No. L58 090528 002).

2.7. Tennessee Valley Authority. "UNITGRAPH-FLDHYDRO-TRBROUTE-CHANROUT User's Manual." Version 1.0, March, 2009. (EDMS No. L58 090325 001).

2.8. Tennessee Valley Authority. Unit Area 51, Paint Rock River near Woodville, File Book Reference. (EDMS No. L58 091130 800)

2.9. Tennessee Valley Authority. Unit Area 52, Paint Rock Local, File Book Reference. (EDMS No. L58 090611 801)

2.10. Tennessee Valley Authority. Unit Area 54, Flint River Local, File Book Reference. (EDMS No. L58 090611 803)

2.11. Tennessee Valley Authority. Unit Area 55, Cotaco Creek at Florette, File Book Reference. (EDMS No. L58 090611 804)

2.12. Tennessee Valley Authority. Unit Area 56, Cotaco Creek Local, File Book Reference. (EDMS No. L58 090611 805)

2.13. Tennessee Valley Authority. Unit Area 58, Limestone Creek Local, File Book Reference. (EDMS No. L58 090611 807)

2.14. Tennessee Valley Authority. Unit Area 63, Sugar Creek at Mouth, File Book Reference. (EDMS No. L58 090611 812)

2.15. Tennessee Valley Authority. Unit Area 64, Elk River Local, Mile 16.5 to Prospect Gage, File Book Reference. (EDMS No. L58 090611 813)

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2.17. Tennessee Valley Authority, "Processing and Validation of National Weather Service'sNEXRAD Stage III Hourly Precipitation Data for Hydrologic and Hydraulic Analysis of Watersheds." Revision No. Rev. 2, Calculation No. CDQ000020080055, February, 2009. (EDMS No. L58090921002)

2.18. Kohler, M.A. and R.K. Linsley. "Predicting the runoff from storm rainfall." Research Paper No. 34, U.S. Weather Bureau, U.S. Department of Commerce, Washington, DC, 1951. (EDMS No. L58 090424 004).

2.19. Tennessee Valley Authority. "Bellefonte Nuclear Plant - White Paper, Hydrologic Analysis." Rev. 1, July 25, 2008. (EDMS No. L58 081219 000)

2.20 Tennessee Valley Authority. "Guntersville Dam Watershed (Subbasins 49 and 50) Unit Hydrogrpah Validation." Rev 0, Calculation No. CDQ000020059, May, 6, 2009. (L58 090603 002).

2.21 Tennessee Valley Authority. "Wheeler Dam Watershed (Subbasins 53, 57, 59, 60, and 61) Unit Hydrograph Validation." Rev. 0, Calculation No. CDQ000020080073, November 2009 (L58 091125 001).

2.22 Tennessee Valley Authority, "Reservoir Storage Tables." Revision No. 1, Calculation No. CDQ000020080051, July, 2009. (L58 090911 001)

2.23 Tennessee Valley Authority. "1973 Precipitation Data Processing." Rev 1, Calculation No. CDQ000020080049, September 2009. (L58 090612 001).

2.24 Intentionally Left Blank

2.25 Tennessee Valley Authority, "SOCH Geometry Verification for Wheeler Reservoir." Revision No. 0, Calculation No. CDQ000020080033, October 2009. (L58 091023 003)

2.26 Tennessee Valley Authority, "SOCH Model Calibration, Wheeler." Revision No. 0, Calculation No. CDQ000020080042, November 2009 (L58 091130 002).

3 Assumptions

3.1 General Assumptions

None

3.2 Unverified Assumptions

None

4 Background

The *unit hydrograph* is used to predict the runoff response at the outlet of a watershed, or subbasin, to the input of one inch of excess rainfall applied over a given duration of time. Runoff from other depths of excess rainfall can be obtained by scaling [2-4].

The direct runoff hydrograph (i.e. stream flow minus base flow) can be calculated from a series of M excess rainfall inputs of any depth and the K ordinates of the unit hydrograph using the process of "convolution." The N = K + M – 1 ordinates of the direct runoff hydrograph are given by the discrete convolution equation, which states that the direct runoff at a given time n (Q_n) is obtained from the excess runoff (P_m) and the unit hydrograph ordinate (U_{n-m+1}, where $U_i = 0$ for all $i = n-m+1 > K$) as follows [2]:

$$Q_n = \sum_{m=1}^{n \le M} P_m U_{n-m+1} \qquad (1)$$

The reverse process, called deconvolution, can be used to derive the ordinates of the unit hyrograph (U), from excess rainfall (P) and direct runoff (Q) derived from observed data.

Unit Hydrograph theory is applicable under the following conditions [2, 3]:

1. Excess rainfall has constant intensity within the effective duration;
2. Excess rainfall is uniformly distributed over the entire basin;
3. The duration of direct runoff resulting from a unit of excess rainfall is constant;
4. The ordinates of the unit hydrograph are directly proportional to the amount of direct runoff (linear response);and
5. The surface runoff hydrograph reflects all of the unique physical characteristics and runoff processes in the drainage basin in a given "epoch."

5 Methodology

Direct runoff originating within 9 of the 15 subbasins of the Wheeler watershed that drain into the Tennessee River cannot be accurately calculated because 1.) the observed flow at the subbasin outlets is not available, 2.) suitable precipitation data is not available, or 3.) the subbasin empties directly into the

Wheeler Reservoir. For these 9 subbasins, the dynamic stream flow SOCH model results are used to validate the unit hydrograph. The SOCH model uses estimated flood hydrographs from these 9 subbasins convoluted from rainfall records and unit hydrographs and gaged stream flow data from the remaining 6 subbasins as input. The SOCH model for this calculation includes the reach of the Tennessee River between Guntersville Dam (TRM 349.0) and Wheeler Dam (TRM 274.9). Inputs to the model include observed upstream inflows from the main stem and tributaries, inflow hydrographs for the drainage area between dams, and rainfall over the reservoir area.

For the Wheeler watershed calculations, the required dynamic modeling was carried out using the Simulated Open Channel Hydraulic Model (SOCH) developed by TVA [6]. SOCH output provides stage and discharge hydrographs for specified locations in the model for each design storm. The stage and discharge hydrographs simulated in SOCH were compared with the corresponding observed series to effect an indirect validation of the unit hydrographs previously developed by TVA.

The inflow hydrographs are developed by convolution of the TVA unit hydrographs with effective rainfall developed for 9 subbasins using observed rainfall from two large storms on the Wheeler watershed, March 1973 and December 2004. The indirect validation process differs slightly for subbasins 51 and 55 as is explained in section 7.3.4 of this report. The simulation of the 2004 flood provides the opportunity to check whether changes in watershed characteristics over the intervening years might have altered the rainfall-runoff response of the watershed to such an extent as to invalidate the original TVA unit hydrographs.

The methodology followed for unit hydrograph validation follows that described in ANSI/ANS 2.8-1992 [1]. This document is included as a reference in the NRC's Standard Review Plan for Section 2.4.3, Probable Maximum Flood on Streams and Rivers [5]. With regard to verifying runoff models, ANSI/ANS-2.8-1992 indicates that

> Deterministic simulation models including unit hydrographs should be verified or calibrated by comparing results of the simulation with the highest two or more floods for which suitable precipitation data are available [1].

The validation procedure includes the following steps:

1. Develop a daily mass balance for the entire Wheeler Watershed and determine total direct inflow over the duration of the flood.
2. Baseflow is separated to obtain direct runoff.
3. Obtain rainfall data for Subbasins 51,52, 54, 55, 56, 58, 63, 64 and 65 for the periods of interest and determine effective rainfall using FLDHYDRO [7]. Input to FLDHYDRO includes observed daily antecedent rainfall and observed hourly rainfall for the duration of the flood. Observed rainfall data for the 1973 storm were obtained from the 1973 Precipitation Data Processing Calculation [23]; rainfall for the 2004 storm was obtained from NWS gridded one-hour rainfall data sets.

4. Use the direct runoff volumes calculated in Step 2 as the CHKVOL input in FLDHYDRO to ensure that the effective rainfall volumes calculated by FLDHYDRO approximately equals the observed runoff volumes.
5. Use convolution to convert the effective rainfall series obtained in Step 4 into direct local runoff hydrographs.
6. Add base flow calculated in FLDHYDRO to the direct local runoff hydrographs to obtain initial total local inflow hydrographs, and provide for input to the SOCH model.
7. Calculate the flow series for the volumes of precipitation falling directly on the reservoir area and provide as input to the SOCH model.
8. Compare the SOCH model-simulated and the observed stage and discharge hydrographs for appropriate stations along the Tennessee River to indirectly validate the performance of the original unit hydrographs in simulating local runoff along the study reach of the Tennessee River.

Detailed discussions of these procedures are provided in the following sections of this calculation.

6 Design Input Data

The input data necessary for developing SOCH inflow hydrographs include:

- Unit hydrograph ordinates and durations for Subbasins 51, 52, 54, 55, 56, 58, 63, 64 and 65
- Observed discharge records for the Elk, Paint Rock, and Flint Rivers and for Limestone Creek
- Observed outflows from Wheeler Dam and from Guntersville Dam
- Observed reservoir elevations at the Wheeler Dam
- The stage-volume relationships for the Wheeler Reservoir
- Observed rainfall data associated with the selected validation floods

Each of these inputs is described in more detail in the following subsections.

6.1 Subbasin Areas

Wheeler Reservoir is located between Wheeler Dam (Tennessee River Mile 274.9) and Guntersville Dam (TRM 349.0) on the Tennessee River in Northern Alabama. The Wheeler watershed is divided into 15 subbasins for hydrologic modeling as shown in the key map presented as Figure 2 and as summarized in Table 1. The original unit hydrograph calculations are based on the areas shown in the 3rd column of Table 1 labeled "TVA UH Area" derived from TVA File Reference Books [8-16]. The difference between the reference areas and the areas recently calculated using Geographic Information System (GIS) software (which are used in this calculation) are presented in Table 1 in the column labeled "% difference." The areas differ marginally for the total watershed; however, because of slight differences in the location of boundaries of select basins, there are some notable differences in areas for individual basins.

Table 1: Wheeler Reservoir Subbasin Areas (in square miles).

Basin ID	Subbasin Name	TVA UH areas	GIS Corrected UH Areas	% of difference
51	Paint Rock River Near Woodville	320	321.07	-0.33%
52	Paint Rock Local	138	138.09	-0.07%
53	Flint River Near Chase	342	343.06	-0.31%
54	Flint River Local	226	224.85	0.51%
55	Cotaco Creek @ Florette	136	136.21	-0.15%
56	Cotaco Creek Local	107	101.05	5.89%
57	Limestone Creek Near Athens	119	121.31	-1.90%
58	Limestone Creek Local	167	157.42	6.09%
59	Tims Ford Dam	529	533.22	-0.79%
60	Elk River Local, Tims Ford to Fayetteville	298	293.36	1.58%
61	Elk River Local, Fayetteville to Prospect	469	490.2	-4.32%
62	Richland Creek at Mouth	488	487.97	0.01%
63	Sugar Creek at Mouth	177	176.95	0.03%
64	Elk River Local, Mile 16.5 to Prospect Gage	167	145.12	15.08%
65	Wheeler Local (excludes reservoir area)	1357	1379.95	-1.66%
Total Indirectly validated Areas		2795	2780.71	0.51%
Total Wheeler Local Area		5040	5049.83	-0.19%

$$\%\text{difference} = \frac{2\times(A_1 - A_2)}{A_1 + A_2}\times 100 \quad \text{where A is area}$$

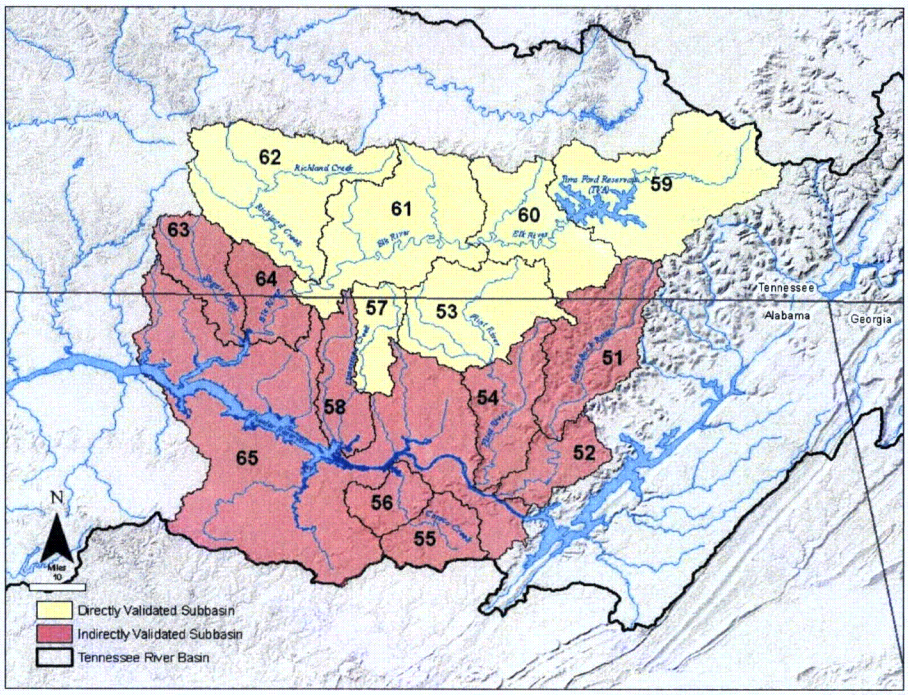

Figure 2: Wheeler Reservoir Subbasins—Key Map

6.2 Unit Hydrographs

The original unit hydrographs were developed for the 9 Wheeler subbasins addressed in this calculation based on data from the 1940s to the1970s by TVA's Water Management Group [8-16]. Because areas calculated for some of the subbasins changed based on GIS studies (see previous section), the ordinates of each of the unit hydrographs have been adjusted by a linear scale factor to provide a total runoff depth of one inch (Attachment 1-1). The revised hydrographs for subbasins in the Wheeler Watershed are plotted in the following subsections.

Key parameters associated with the original TVA unit hydrographs and the revised unit hydrographs adjusted for drainage area changes are presented in Table 2. As shown in the final column of the table, the volume of runoff is one inch for each unit hydrograph. The volume determination is based on the calculation of the area under the unit hydrograph, as shown in the following subsections.

Table 2: TVA Unit Hydrograph Parameters for the Wheeler Local Inflow Subbasins

Subbasin		Effective Duration, hours	Time Step, Hours	Number of Ordinates	Q Peak, cfs	Peak Time, Hours	Area, Sq. Mile	Volume, acft	Volume inches
51	TVA UH areas	6	6	18	11329	18	320.00	17,073	1.000
	GIS Corrected UH Areas	6	6	18	11363	18	321.07	17,124	1.000
52	TVA UH areas	6	6	13	6100	24	138.00	7,361	1.000
	GIS Corrected UH Areas	6	6	13	6103	24	138.09	7,364	1.000
53	TVA UH areas	6	6	11	16306	12	342.00	18,240	1.000
	GIS Corrected UH Areas	6	6	11	16356	12	343.06	18,297	1.000
54	TVA UH areas	6	6	14	7959	24	226.00	12,050	1.000
	GIS Corrected UH Areas	6	6	14	7962	24	224.85	11,993	1.000
55	TVA UH areas	6	6	17	3169	18	136.00	7,254	1.000
	GIS Corrected UH Areas	6	6	17	3174	18	136.21	7,264	1.000
56	TVA UH areas	6	6	15	2800	24	107.00	5,707	1.000
	GIS Corrected UH Areas	6	6	15	2644	24	101.05	5,390	1.000
57	TVA UH areas	4	4	11	10421	12	119.00	6,350	1.001
	GIS Corrected UH Areas	4	4	11	10618	12	121.31	6,470	1.000
58	TVA UH areas	6	6	10	6800	12	167.00	8,911	1.000
	GIS Corrected UH Areas	6	6	10	6407	12	157.42	8,395	1.000
59	TVA UH areas	6	6	14	17416	6	529.00	28,213	1.000
	GIS Corrected UH Areas	6	6	14	17555	6	533.22	28,439	1.000
60	TVA UH areas	6	6	14	7155	18	298.00	15,893	1.000
	GIS Corrected UH Areas	6	6	14	7044	18	293.36	15,646	1.000
61	TVA UH areas	6	3	35	8500	30	469.00	25,041	1.001
	GIS Corrected UH Areas	6	3	35	8874	30	490.20	26,144	1.000
62	TVA UH areas	6	3	31	11530	30	488.00	26,028	1.000
	GIS Corrected UH Areas	6	3	31	11529	30	487.97	26,026	1.000
63	TVA UH areas	4	4	24	8518	16	177.00	9,444	1.000
	GIS Corrected UH Areas	4	4	24	8512	16	176.95	9,437	1.000
64	TVA UH areas	6	6	13	6800	24	167.00	8,901	0.999
	GIS Corrected UH Areas	6	6	13	5913	24	145.12	7,739	1.000
65	TVA UH areas	6	3	27	46000	12	1357.00	72,421	1.001
	GIS Corrected UH Areas	6	3	27	46747	12	1379.95	73,597	1.000

6.2.1 Subarea 51 Unit Hydrograph

A unit hydrograph for the Paint Rock River near Woodville was developed by the TVA from stream flow and rainfall data from the two following floods (i.e., gaged data):

- March 12, 1963
- March 16, 1973

In addition, the February 13, 1948 flood was considered, but was not used in the final adopted unit hydrograph. Stream gage data is available for Subbasin 51; however, because of discrepancies between the NEXRAD [17] gridded rainfall data and USGS stream gage data [24] could not be resolved, the hydrograph is indirectly validated.

The two floods were used by TVA to develop a composite six-hour unit hydrograph. Flow routing to the mouth of the Paint Rock River was accomplished with Autoregressive Moving Average (ARMA) routing parameters. The Subbasin 51 unit hydrograph is shown in Figure 3 and Table 3.

Table 3: Ordinates and Volume Calculations for Six-hour Unit Hydrograph for Subbasin 51 - Paint Rock River near Woodville.

Time, hrs	Discharge, cfs/in	Average Q, cfs/in (1*)	Wedge Volume, acft (2*)
0	0	88.5	43.884
6	177	1803	894.050
12	3429	7396	3667.438
18	11363	8323.5	4127.355
24	5284	4834.5	2397.273
30	4385	3935.5	1951.488
36	3486	2845.5	1410.992
42	2205	1564	775.537
48	923	865.5	429.174
54	808	751	372.397
60	694	637	315.868
66	580	523	259.339
72	466	409	202.810
78	352	295	146.281
84	238	180.5	89.504
90	123	71.5	35.455
96	20	10	4.959
102	0	0	0.000
Total Volume, acft			17123.802
Basin Area, sq. mi.			321.070
Total volume, inches (3)			1.000

(*See page 32)

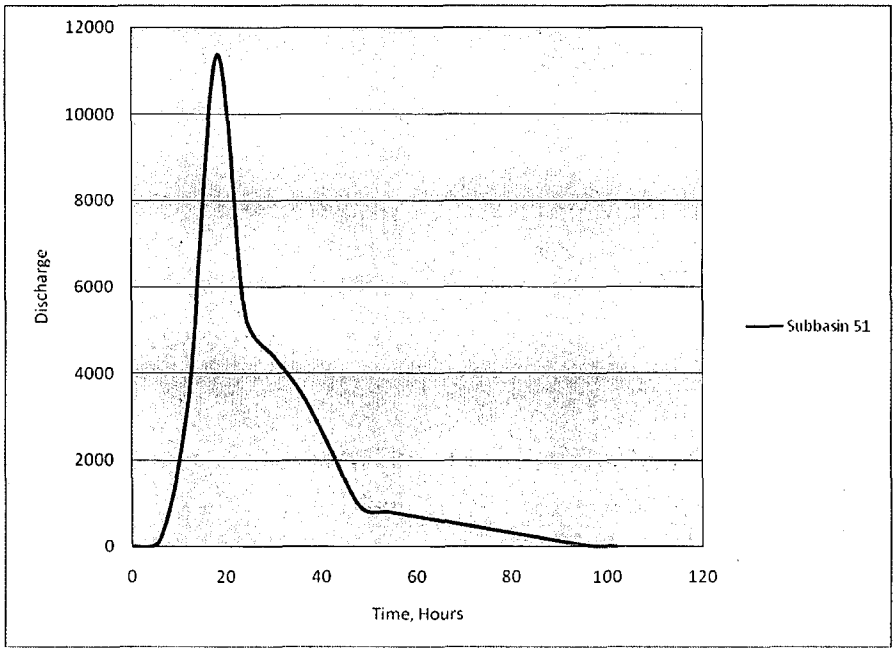

Figure 3: Six-hour Unit Hydrograph for Subbasin 51 (Paint Rock River near Woodville Using Adjusted Subbasin Area)

6.2.2 Subarea 52 Unit Hydrograph

A unit hydrograph for Paint Rock River Local was developed using relationships from similar watersheds relating the unit hydrograph peak flow to the drainage area size, time to peak to the length and slope of the watershed, and the shape to the unit hydrograph peak discharge (cfs) per square mile. The Subbasin 52 unit hydrograph is shown in Figure 4 and Table 4.

Table 4: Ordinates and Volume Calculations for Six-hour Unit Hydrograph for Subbasin 52 - Paint Rock River Local.

Time, hrs	Discharge, cfs/in	Average Q, cfs/in (1*)	Wedge Volume, acft (2*)
0	0	70	34.711
6	140	505	250.413
12	870	1685.5	835.785
18	2501	4302	2133.223
24	6103	4302	2133.223
30	2501	1836	910.413
36	1171	920.5	456.446
42	670	547.5	271.488
48	425	337.5	167.355
54	250	200	99.174
60	150	110	54.545
66	70	35	17.355
72	0	0	0.000
Total Volume, acft			7364.132
Basin Area, sq. mi.			138.090
Total volume, inches (3)			1.000

(*See page 32)

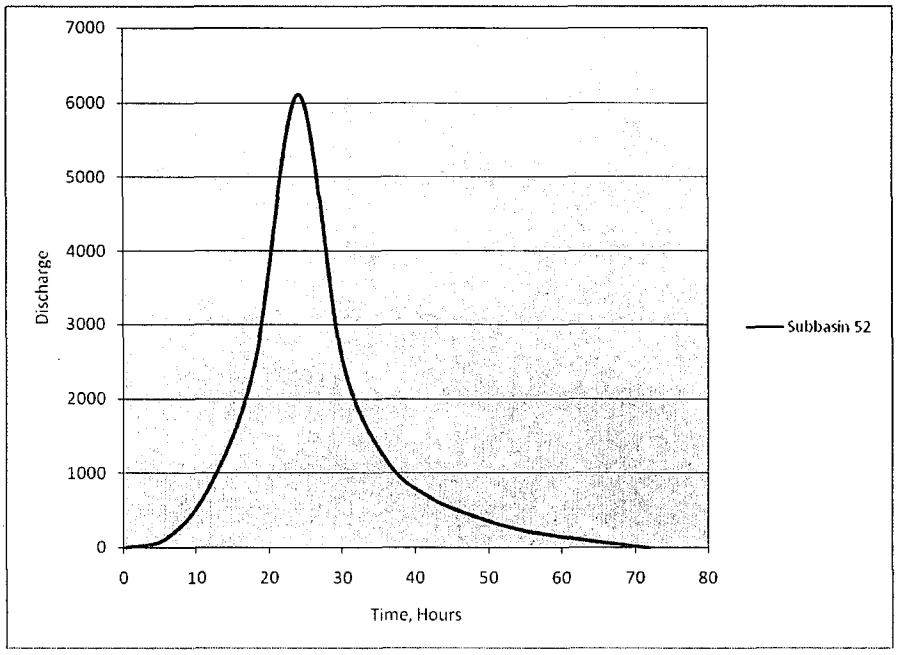

Figure 4: Six-hour Unit Hydrograph for Subbasin 52 (Paint Rock River Local Using Adjusted Subbasin Area)

6.2.3 Subarea 54 Unit Hydrograph

A unit hydrograph for Flint River Local was developed using relationships from similar watersheds relating the unit hydrograph peak flow to the drainage area size, time to peak to the length and slope of the watershed, and the shape to the unit hydrograph peak discharge (cfs) per square mile. The Subbasin 54 unit hydrograph is shown in Figure 5 and Table 5.

Table 5: Ordinates and Volume Calculations for Six-hour Unit Hydrograph for Subbasin 54 - Flint River Local.

Time, hrs	Discharge, cfs/in	Average Q, cfs/in (1*)	Wedge Volume, acft (2*)
0	0	249	123.471
6	498	1144.5	567.521
12	1791	3234.5	1603.884
18	4678	6320	3133.884
24	7962	6320	3133.884
30	4678	3334	1653.223
36	1990	1492.5	740.083
42	995	796	394.711
48	597	497.5	246.694
54	398	348.5	172.810
60	299	249	123.471
66	199	149.5	74.132
72	100	50	24.793
78	0	0	0.000
Total Volume, acft			11992.562
Basin Area, sq. mi.			224.850
Total volume, inches (3)			1:000

(*See page 32)

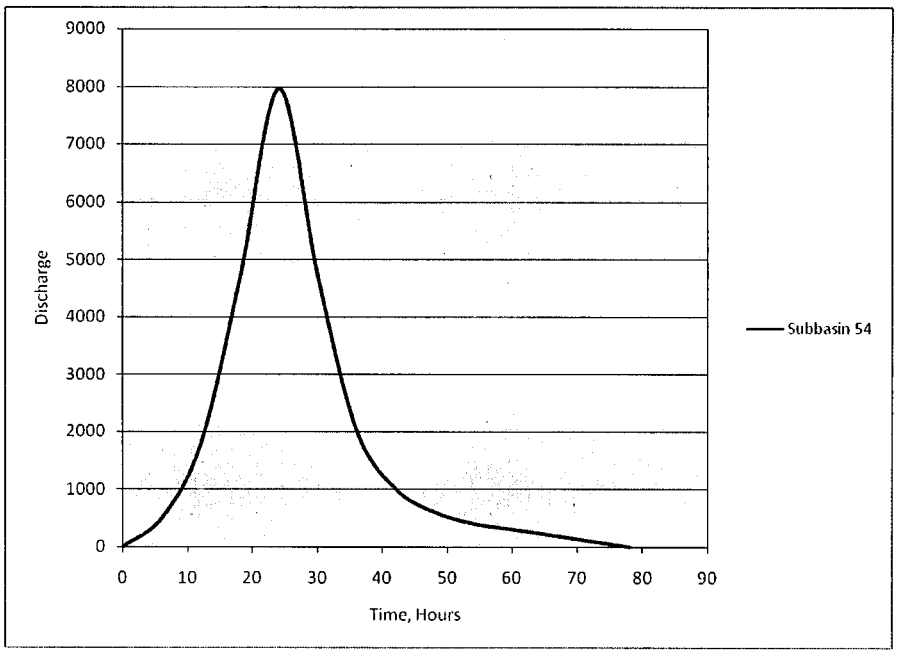

Figure 5: Six-hour Unit Hydrograph for Subbasin 54 (Flint River Local Using Adjusted Subbasin Area)

6.2.4 Subarea 55 Unit Hydrograph

A unit hydrograph for Cotaco Creek at Florette was developed by the TVA from stream flow and rainfall data from the three following floods (i.e., gaged data):

- March 17, 1973
- December 26, 1973
- July 7, 1975

Single unit hydrographs were computed for each of the three floods. Two composite unit hydrographs were computed:

- A six-hour unit hydrograph from the March 1973 and July 1975 floods;
- A four-hour unit hydrograph using all three floods.

The six-hour composite unit hydrograph from the March 1973 and July 1975 floods was adopted. Flow routing to the mouth of Cotaco Creek was accomplished with a simple 4-hour lag. The Subbasin 55 unit hydrograph is shown in Figure 6 and Table 6.

Gaged data no longer exists to allow for direct validation of this subbasin; therefore, it is being validated indirectly.

Table 6: Ordinates and Volume Calculations for Six-hour Unit Hydrograph for Subbasin 55 - Cotaco Creek at Florette.

Time, hrs	Discharge, cfs/in	Average Q, cfs/in (1*)	Wedge Volume, acft (2*)
0	0	126.5	62.727
6	253	857	424.959
12	1461	2317.5	1149.174
18	3174	2988.5	1481.901
24	2803	2326.5	1153.636
30	1850	1631.5	809.008
36	1413	1229	609.421
42	1045	897.5	445.041
48	750	653	323.802
54	556	498	246.942
60	440	382	189.421
66	324	266	131.901
72	208	187	92.727
78	166	145	71.901
84	124	103	51.074
90	82	41	20.331
96	0	0	0.000
Total Volume, acft			7263.967
Basin Area, sq. mi.			136.210
Total volume, inches (3)			1.000

(*See page 32)

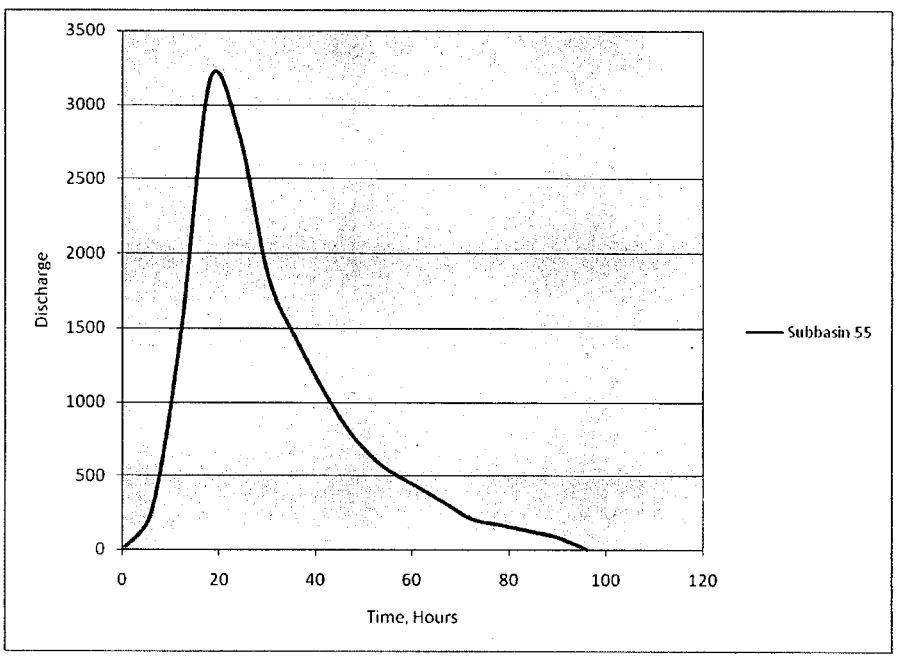

Figure 6: Six-hour Unit Hydrograph for Subbasin 55 (Cotaco Creek at Florette Using Adjusted Subbasin Area)

6.2.5 Subarea 56 Unit Hydrograph

A six-hour unit hydrograph for Subbasin 56 was developed by scaling the unit hydrograph ordinates of the unit hydrograph at an upstream gage. The Subbasin 56 unit hydrograph is shown in Figure 7 and Table 7.

Table 7: Ordinates and Volume Calculations for Six-hour Unit Hydrograph for Subbasin 56 - Cotaco Creek at Florette.

Time, hrs	Discharge, cfs/in	Average Q, cfs/in (1*)	Wedge Volume, acft (2*)
0	0	47	23.306
6	94	259.5	128.678
12	425	920.5	456.446
18	1416	2030	1006.612
24	2644	2299.5	1140.248
30	1955	1657.5	821.901
36	1360	1152	571.240
42	944	816.5	404.876
48	689	590	292.562
54	491	425	210.744
60	359	307	152.231
66	255	208	103.140
72	161	118.5	58.760
78	76	38	18.843
84	0	0	0.000
Total Volume, acft			5389.587
Basin Area, sq. mi.			101.050
Total volume, inches (3)			1.000

(*See page 32)

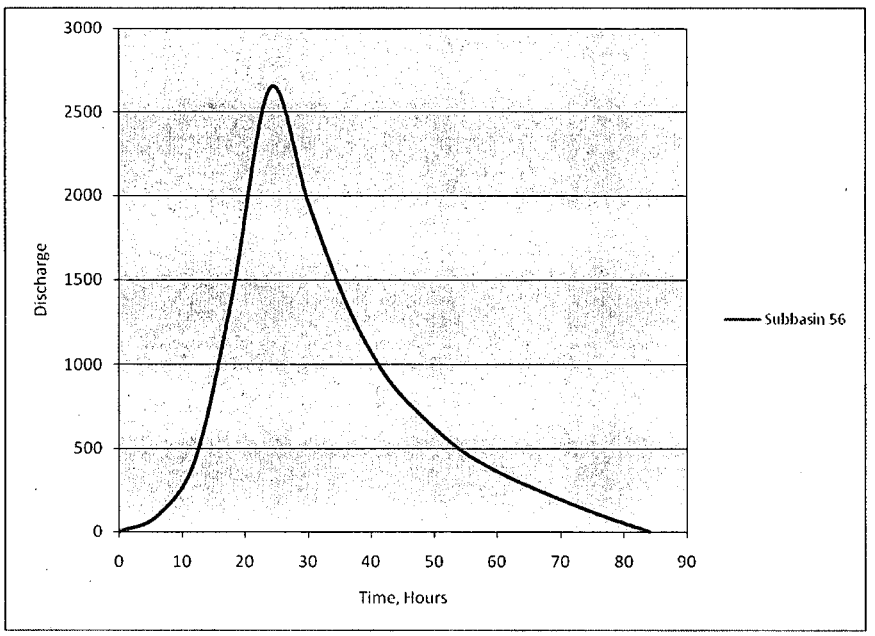

Figure 7: Six-hour Unit Hydrograph for Subbasin 56 (Cotaco Creek at Florette Using Adjusted Subbasin Area)

6.2.6 Subarea 58 Unit Hydrograph

A unit hydrograph for Limestone Creek Local was developed using relationships from similar watersheds relating the unit hydrograph peak flow to the drainage area size, time to peak to the length and slope of the watershed, and the shape to the unit hydrograph peak discharge (cfs) per square mile. The Subbasin 58 unit hydrograph is shown in Figure 8 and Table 8.

Table 8: Ordinates and Volume Calculations for Six-hour Unit Hydrograph for Subbasin 58 - Limestone Creek Local.

Time, hrs	Discharge, cfs/in	Average Q, cfs/in (1*)	Wedge Volume, acft (2*)
0	0	1578	782.479
6	3156	4781.5	2370.992
12	6407	4805	2382.645
18	3203	2449.5	1214.628
24	1696	1375.5	682.066
30	1055	904.5	448.512
36	754	612.5	303.719
42	471	329.5	163.388
48	188	94	46.612
54	0	0	0.000
Total Volume, acft			8395.041
Basin Area, sq. mi.			157.420
Total volume, inches (3)			1.000

(*See page 32)

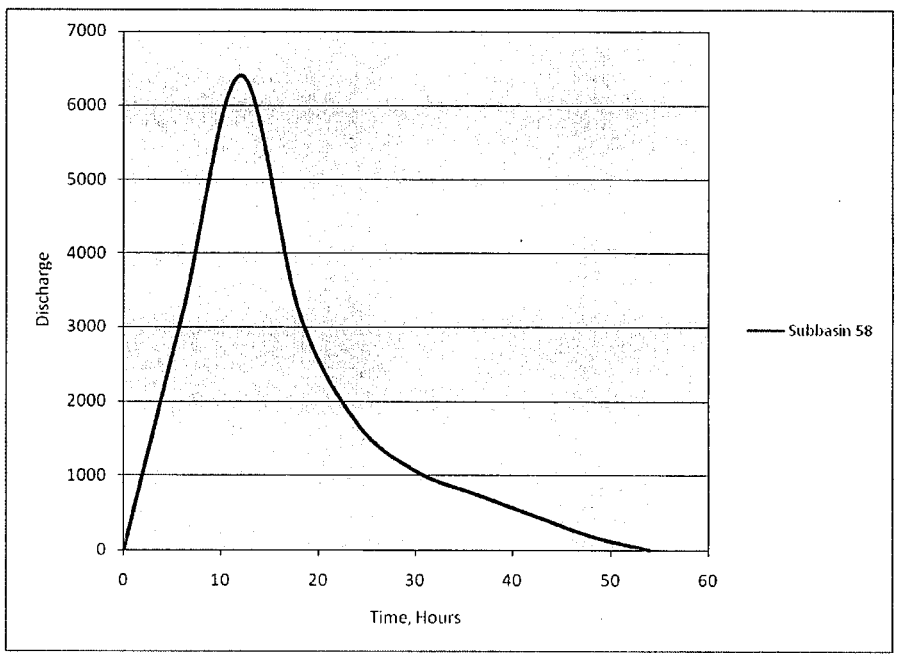

Figure 8: Six-hour Unit Hydrograph for Subbasin 58 (Limestone Creek Local Using Adjusted Subbasin Area)

6.2.7 Subarea 63 Unit Hydrograph

A unit hydrograph for Sugar Creek at Mouth was developed by TVA from stream flow and rainfall data from the three following floods (i.e., gaged data):

- March 8, 1961
- March 12, 1963
- April 4, 1964

A composite unit hydrograph was computed using the three floods. The computed unit hydrograph is for the 152 square mile area above the stream gage near Good Springs, Alabama (stream mile 8.1).

To translate the unit hydrograph down to the mouth, the unit hydrograph was adjusted for difference in drainage area (177 mi^2 at the mouth vs. 152 mi^2 at the gage). The peak discharge was adjusted by the ratio of the square root of the drainage area ($\sqrt{177} / \sqrt{152} \times$ peak discharge) [14] with the remaining unit hydrograph ordinates adjusted by the ratio of drainage areas (177 / 152 = 1.164).

The Subbasin 63 unit hydrograph is shown in Figure 9 and Table 9.

Gaged data no longer exists to allow for direct validation of this subbasin; therefore, it is being validated indirectly.

Table 9: Ordinates and Volume Calculations for Four-hour Unit Hydrograph for Subbasin 63 - Sugar Creek at Mouth.

Time, hrs	Discharge, cfs/in	Average Q, cfs/in (1*)	Wedge Volume, acft (2*)
0	0	191	63.140
4	382	1445.5	477.851
8	2509	3766	1244.959
12	5023	6767.5	2237.190
16	8512	6204.5	2051.074
20	3897	3149.5	1041.157
24	2402	1925.5	636.529
28	1449	1236.5	408.760
32	1024	873.5	288.760
36	723	634	209.587
40	545	505.5	167.107
44	466	426.5	140.992
48	387	346.5	114.545
52	306	266.5	88.099
56	227	187	61.818
60	147	138.5	45.785
64	130	121.5	40.165
68	113	104	34.380
72	95	86.5	28.595
76	78	70	23.140
80	62	53	17.521
84	44	35.5	11.736
88	27	13.5	4.463
92	0	0	0.000
Total Volume, acft			9437.355
Basin Area, sq. mi.			176.950
Total volume, inches (3)			1.000

(*See page 32)

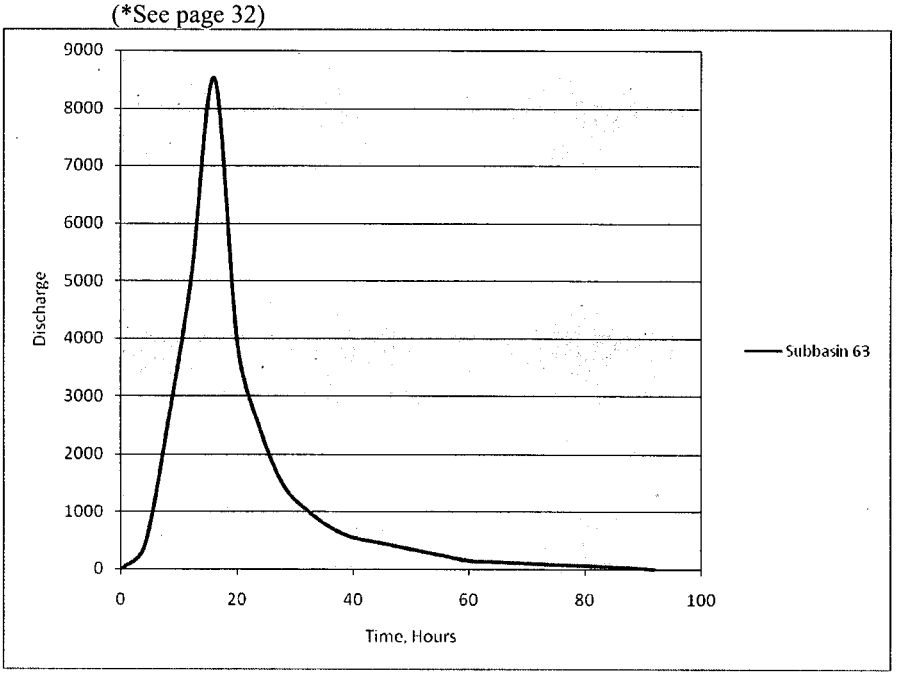

Figure 9: Four-hour Unit Hydrograph for Subbasin 63 (Sugar Creek at Mouth Using Adjusted Subbasin Area)

6.2.8 Subarea 64 Unit Hydrograph

A unit hydrograph for Elk River Local, Mile 16.5 to Prospect Gage was developed using relationships from similar watersheds relating the unit hydrograph peak flow to the drainage area size, time to peak to the length and slope of the watershed, and the shape to the unit hydrograph peak discharge in cfs per square mile. The Subbasin 64 unit hydrograph is shown in Figure 10 and Table 10.

The Prospect flows are routed down to mile 16.5 using ARMA routing parameters and added to the flow from the local area to obtain total flow at mile 16.5, using the following routing equation [15] with a routing period of 2 hours:

$$O(T) = 1.4212 \times O(T-1) - 0.562 \times O(T-2) + 0.5702 \times O(T-3) - 0.7869 \times O(T-4) + 0.1978 \times O(T-5) + 0.0803 \times O(T-6) +$$
$$0.0793 \times I(T) - 0.0829 \times I(T-1) - 0.0064 \times I(T-2) + 0.3071 \times I(T-3) - 0.4207 \times I(T-4) + 0.255 \times I(T-5) - 0.052 \times I(T-6)$$

Table 10: Ordinates and Volume Calculations for Six-hour Unit Hydrograph for Subbasin 64 - Elk River Local, Mile 16.5 to Prospect Gage.

Time, hrs	Discharge, cfs/in	Average Q, cfs/in (1*)	Wedge Volume, acft (2*)
0	0	174	86.281
6	348	695.5	344.876
12	1043	2043	1013.058
18	3043	4478	2220.496
24	5913	4434.5	2198.926
30	2956	1999.5	991.488
36	1043	826	409.587
42	609	478.5	237.273
48	348	261	129.421
54	174	130.5	64.711
60	87	65	32.231
66	43	21.5	10.661
72	0	0	0.000
Total Volume, acft			7739.008
Basin Area, sq. mi.			145.120
Total volume, inches (3)			1.000

(*See page 32)

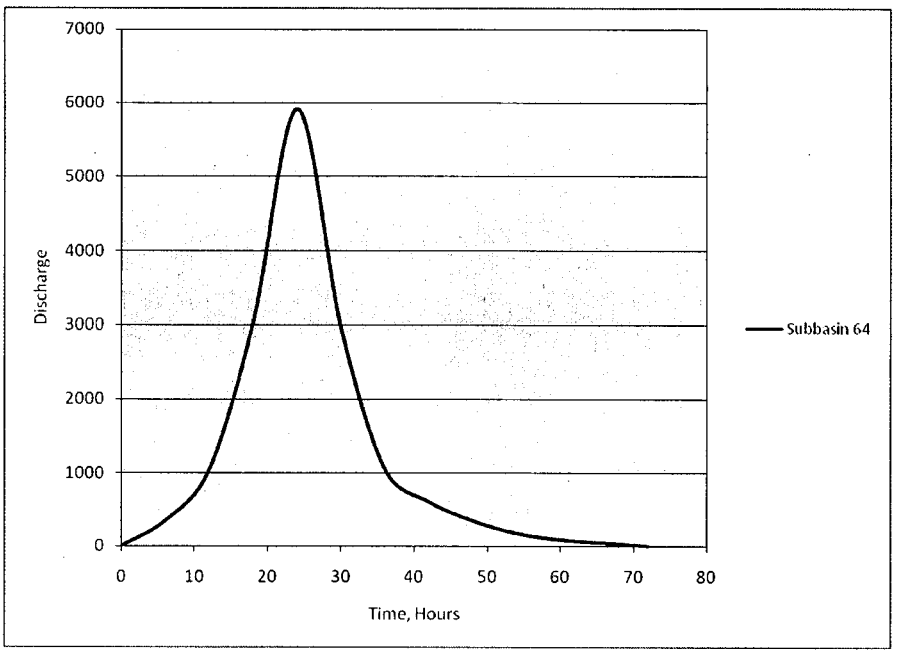

Figure 10: Six-hour Unit Hydrograph for Subbasin 64 (Elk River Local, Mile 16.5 to Prospect Gage Using Adjusted Subbasin Area)

6.2.9 Subarea 65 Unit Hydrograph

A unit hydrograph for Wheeler Local was developed using relationships from similar watersheds relating the unit hydrograph peak flow to the drainage area size, time to peak to the coefficient Cp, and the shape to the unit hydrograph peak discharge in cfs per square mile. The Subbasin 65 unit hydrograph is shown in Figure 11 and Table 11.

Table 11: Ordinates and Volume Calculations for Six-hour Unit Hydrograph for Subbasin 65 - Wheeler Local.

Time, hrs	Discharge, cfs/in	Average Q, cfs/in (1*)	Wedge Volume, acft (2*)
0	0	4065	1007.851
3	8130	14989.5	3716.405
6	21849	29725	7369.835
9	37601	42174	10456.364
12	46747	43952.5	10897.314
15	41158	37347	9259.587
18	33536	29471	7306.860
21	25406	22103	5480.083
24	18800	16513.5	4094.256
27	14227	12448.5	3086.405
30	10670	9247.5	2292.769
33	7825	6961	1725.868
36	6097	5436.5	1347.893
39	4776	4319	1070.826
42	3862	3608	894.545
45	3354	3099.5	768.471
48	2845	2642	655.041
51	2439	2235.5	554.256
54	2032	1778	440.826
57	1524	1397	346.364
60	1270	1143	283.388
63	1016	889	220.413
66	762	635	157.438
69	508	406.5	100.785
72	305	203.5	50.455
75	102	51	12.645
78	0	0	0.000
Total Volume, acft			73596.942
Basin Area, sq. mi.			1379.950
Total volume, inches (3)			1.000

(*See page 32)

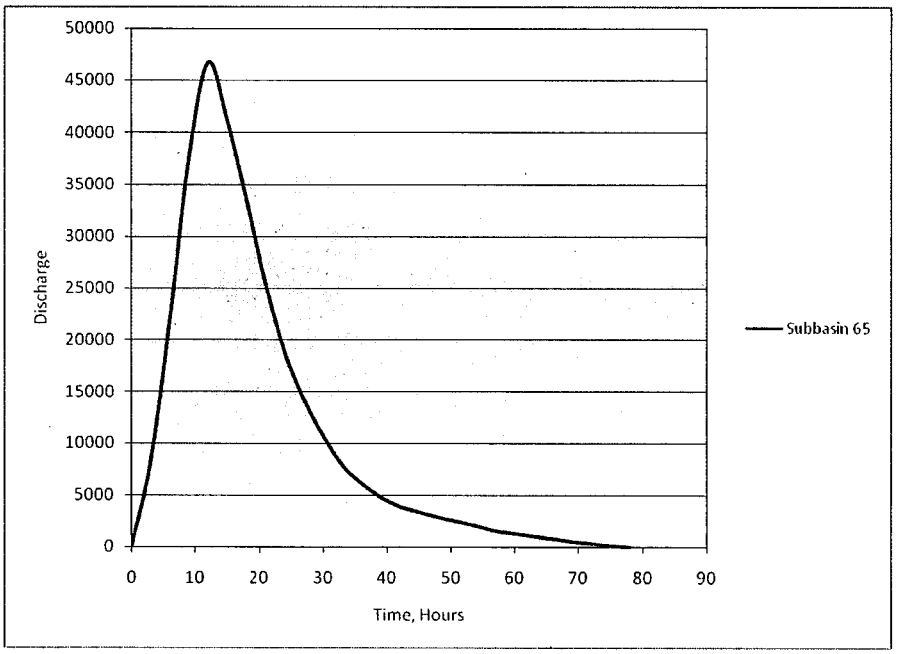

Figure 11: Six-hour Unit Hydrograph for Subbasin 65 (Wheeler Local Using Adjusted Subbasin Area)

Notes:

1) $Q_{ave} = 0.5(Q_t + Q_{t-1})$

2) $Volume = Qave \frac{ft^3}{\sec} * 3600 \frac{\sec}{hr} * 3hr * \frac{1acft}{43560 ft^3}$

3) $Depth = \frac{Volume.acft}{Area.mi^2} \frac{mi^2}{640.acre} \frac{12.inch}{ft}$

Effective rainfall hyetographs developed for each subbasin are convoluted with the unit hydrographs, and the calculated direct runoff is used as input to a SOCH model simulation of the Tennessee River between Guntersville and Wheeler Dams for the 1973 and 2004 storms of record. The comparison of the observed and simulated discharge and water surface elevations at specific cross sections within the reach, as discussed in Section 7.4, is used to provide an indirect validation of the unit hydrographs.

6.3 Observed Stream Flow

Gaged stream flows from directly validated subbasins were obtained from the Wheeler Dam Watershed (Subbasins 53, 57 and 61) Unit Hydrograph Validation Calculation [21]. The use and routing of these stream flows is described in subsequent section 7.3.4.

6.4 Observed Dam Outflows and Headwater Elevations

Daily discharge values from Guntersville Dam were obtained from the Guntersville Dam Watershed (Subbasins 49 and 50) Unit Hydrograph Validation Calculation [20] in the spreadsheet "guntersville_rev0.xls."

The hourly stage and hourly outflow (including spills and turbine discharges) from the Wheeler Dam were obtained from TVA in the spreadsheet "wheeler_rev0.xls" (Attachment 1-16). The observed flows and elevation were used in the water budget analysis which is presented in Section 7.1.

6.5 Stage-Volume Relationship

The stage-volume relationship was obtained from the Reservoir Storage Calculation [22]. The stage-volume relationship, along with the stage and outflow data provided by TVA (Attachment 1-16), were utilized to calculate the average daily inflows to the Wheeler reservoir with reverse reservoir routing.

6.6 Observed Rainfall

Basin average hourly rainfall depths for the 1973 flood were obtained from the 1973 Precipitation Data Processing Calculation [23].

Basin average hourly rainfall depths for the 2004 flood were developed from National Weather Service (NWS) gridded precipitation data sets. NWS NEXRAD Stage III hourly precipitation data were obtained from the Lower Mississippi River Forecast Center (LMRFC) from 1997 to 2008 for unit hydrograph validation. A Microsoft.Net utility was developed to generate radar-based Mean Areal Precipitation (MAPX) time series for each of the subbasins [17].

The utility reads the raw hourly precipitation depth data for each 4-km square grid cell, performs necessary coordinate system and projection calculations, and then calculates the average precipitation depth within each subbasin, grouping output into a matrix of MAPX elements arrayed by subbasin and time (Greenwich Mean Time, GMT). Each column of this matrix is equivalent to an annual hyetograph for each subbasin in the TVA model.

The results are stored in an Excel spreadsheet for each year of record. The NEXRAD Calculation [17] describes the methodology used to process the precipitation data and includes resulting subbasin-averaged hourly values for the 1997 to 2008 period of record.

Observed average basin rainfall for the December 2004 storm was obtained from NEXRAD Data. The hourly precipitation series developed from NWS gridded data for use in the calculation are provided in the spreadsheet "2004_Wheeler_Watershed_Hourly_Precip_Data.xls" (Attachment 1-17)

The hourly precipitation data obtained from the NEXRAD files is indexed in Greenwich Mean Time (GMT). The unit conversion (millimeters to inches) and the conversion of the time base of the

precipitation time series to Central Standard Time (CST) for the events are carried out in the storm hydrograph convolution files:

- IND_Convol_51.xls (Attachment 1-4)
- IND_Convol_52.xls (Attachment 1-5)
- IND_Convol_54.xls (Attachment 1-6)
- IND_Convol_55.xls (Attachment 1-7)
- IND_Convol_56.xls (Attachment 1-8)
- IND_Convol_58.xls (Attachment 1-9)
- IND_Convol_63.xls (Attachment 1-10)
- IND_Convol_64.xls (Attachment 1-11)
- IND_Convol_65.xls (Attachment 1-12)

7 Computations and Analysis

Computations required for the development of the local inflow hydrographs for input to the SOCH model and the use of SOCH model output for validation of the TVA unit hydrographs are presented in the following sections.

7.1 Determination of Local Inflow Volumes

As mentioned above, the March 1973 and December 2004 floods have been selected for analysis by the SOCH model. Because of data limitations, the direct runoff volume cannot be determined for each subbasin separately, so the total direct volume is determined for the total period of the flood using a daily water budget as shown schematically in Figure 12.

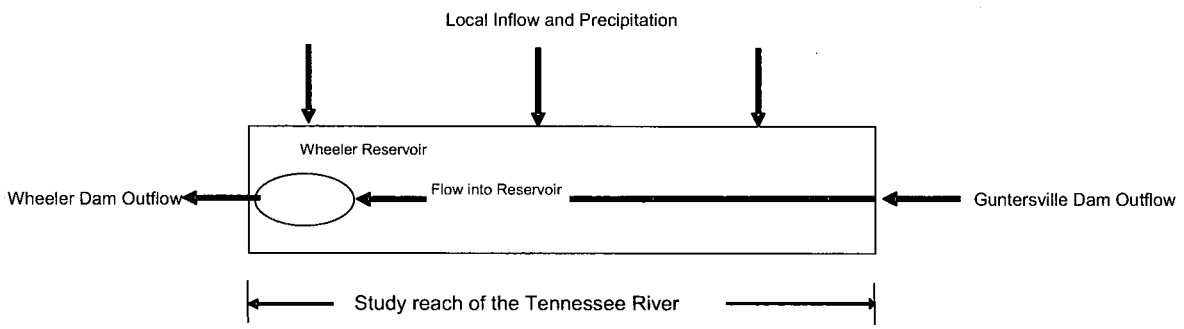

Figure 12: Mass Balance Schematic for the Wheeler Reach of the Tennessee River

The volume of local inflow is determined from a mass balance developed for the study reach (i.e. the Tennessee River between the Guntersville and Wheeler Dams). Daily inflows and reservoir stage-volume relationships were provided by TVA for the 1973 and 2004 floods in the spreadsheet "wheeler_rev0.xls" (Attachment 1-16) as discussed in Sections 6.4 and 6.5. The outflow from Guntersville Dam is subtracted from the reverse routed flows at Wheeler Dam to determine the local inflow to Wheeler Reservoir. This mass balance calculation is carried in Tables 12 and 13 for each day of the 1973 and 2004 floods, respectively (see Attachments 1-2 and 1-3).

Subbasin 59 on the Elk River is impounded by the Tim's Ford Dam, which has minimal impact on the mass balance calculations. To minimize the Tims Ford impact, the mass balances used in this calculation account for inflows occurring several days after the completion of significant rainfall, allowing storage within the Tim's Ford Reservoir to return to a near pre-storm conditions and inflows within the Wheeler Dam Basin to stabilize. Due to this, the effect of Tim's Ford Reservoir is insignificant and neglected in this calculation.

Table 12: Surface Water Flows into and out of Study Reach for March 1973 Flood

Date	HW 1973	Wheeler Daily Average Storage	Wheeler Daily Average Inflow (O +ΔS)	Guntersville Daily Average Discharge	Observed Wheeler Local	Baseflow Separation	Est. Wheeler Local Surface Runoff
	(ft)	(ac-ft)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)
12-Mar-73	551.84	807,796	91158	47,900	43,258		
13-Mar-73	552.54	844,375	84252	50,300	33,952		
14-Mar-73	552.65	850,439	75510	57,300	18,210	18,210	0
15-Mar-73	552.72	854,186	120028	68,500	51,528	18,252	33,276
16-Mar-73	555.26	1,003,774	308736	182,500	126,236	18,294	107,942
17-Mar-73	555.09	992,526	411982	253,000	158,982	18,336	140,646
18-Mar-73	555.58	1,023,681	413618	295,800	117,818	18,378	99,440
19-Mar-73	555.29	1,004,983	384945	304,400	80,545	18,420	62,125
20-Mar-73	555.02	988,199	355197	266,500	88,697	18,462	70,235
21-Mar-73	554.99	986,521	335861	196,200	139,661	18,504	121,157
22-Mar-73	555.37	1,010,516	255807	147,200	108,607	18,546	90,061
23-Mar-73	554.44	952,088	204191	124,500	79,691	18,588	61,103
24-Mar-73	553.70	907,819	162345	119,300	43,045	18,630	24,415
25-Mar-73	552.73	854,980	137672	119,000	18,672	18,672	0
26-Mar-73	552.29	830,705	149707	110,100	39,607		
27-Mar-73	552.45	839,470	135110	101,600	33,510		
28-Mar-73	552.56	845,465	127573	100,500	27,073		
29-Mar-73	552.69	852,937	124180	100,900	23,280		
30-Mar-73	552.79	858,114	126150	100,500	25,650		
Total surface runoff, in DSF (summation of last column in table)							810,402

Table 13: Surface Water Flows into and out of Study Reach for December 2004 Flood

Date	HW 2004	Wheeler Daily Average Storage	Wheeler Daily Average Inflow (O +ΔS)	Guntersville Daily Average Discharge	Observed Wheeler Local	Baseflow Separation	Est. Wheeler Local Surface Runoff
	(ft)	(ac-ft)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)
01-Dec-04	556.04	1,053,669	147,422	90,376	57,046		
02-Dec-04	555.41	1,013,007	145,626	104,957	40,669		
03-Dec-04	555.00	987,281	150,821	128,041	22,780		
04-Dec-04	554.60	961,791	154,898	137,410	17,488	17,488	0
05-Dec-04	554.37	947,472	157,071	136,433	20,638	18,548	2,090
06-Dec-04	554.47	953,504	196,186	141,017	55,169	19,609	35,560
07-Dec-04	554.96	984,396	255,852	196,099	59,753	20,670	39,083
08-Dec-04	554.80	974,431	288,904	209,934	78,970	21,730	57,240
09-Dec-04	555.06	990,664	330,897	205,916	124,981	22,791	102,190
10-Dec-04	554.94	983,400	319,397	223,925	95,472	23,852	71,620
11-Dec-04	554.89	980,148	313,753	208,189	105,564	24,912	80,652
12-Dec-04	554.84	976,713	285,193	191,776	93,417	25,973	67,445
13-Dec-04	554.56	959,588	242,008	174,152	67,856	27,033	40,823
14-Dec-04	554.08	929,478	214,794	161,843	52,951	28,094	24,857
15-Dec-04	553.45	894,199	194,216	163,562	30,654	29,155	1,499
16-Dec-04	552.67	851,574	178,313	125,053	53,260	30,215	23,045
17-Dec-04	551.82	807,150	122,825	91,549	31,276	31,276	0
18-Dec-04	551.78	804,781	108,487	94,629	13,858		
19-Dec-04	551.31	782,432	102,686	94,587	8,099		
20-Dec-04	551.12	773,139	104,362	98,849	5,513		
21-Dec-04	551.08	771,574	109,782	102,787	6,995		
22-Dec-04	551.01	767,988	109,725	102,000	7,725		
Total surface runoff, in DSF (summation of last column in table)							546,105

The base flow separation shown in the second-to-last column in Tables 12 and 13 is accomplished with a straight-line assumption, as shown in Figures 13 and 14.

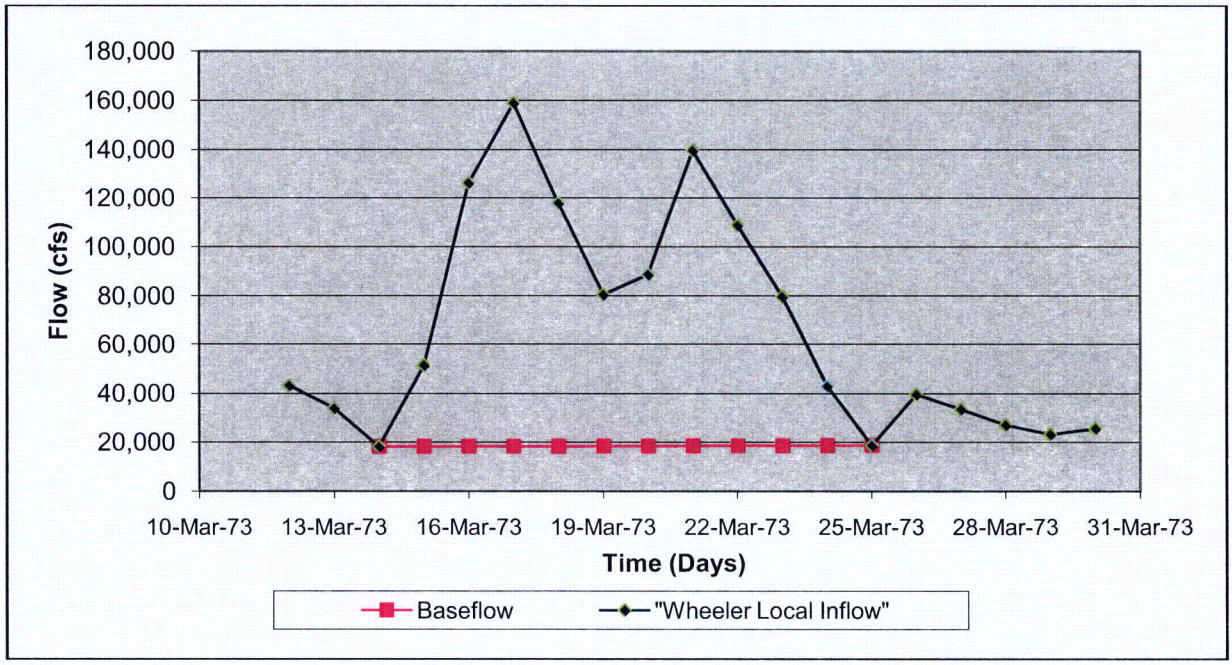

Figure 13: Base Flow Separation at Wheeler for March 1973 Flood

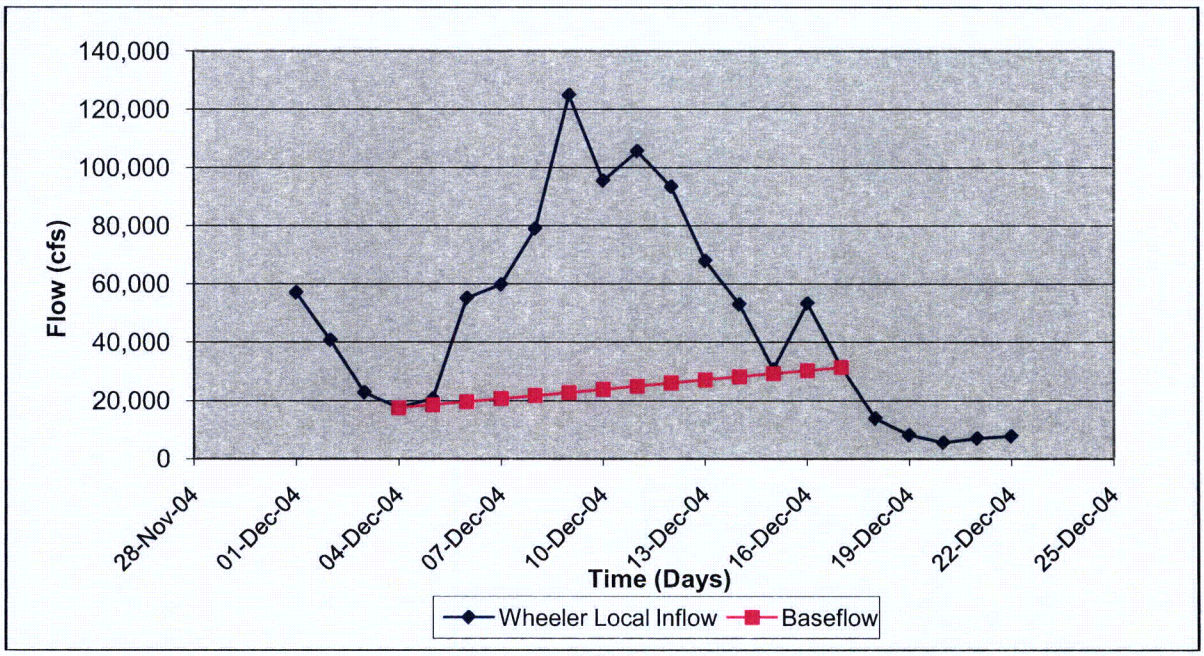

Figure 14: Base Flow Separation at Wheeler for December 2003 Flood

Subtracting the base flow from the stream flow calculated at Wheeler gives the runoff volume in DSF (second-foot-days, i.e. 1 cfs x 86,400 seconds per day) including runoff originating within the basin and rain falling directly on the reservoir. The volume of the rainfall over the reservoir is removed to provide the direct runoff volume from the land area of the subbasin.

The volume of rainfall is determined from the sum of the basin average rainfall depth over the Subbasins. The reservoir is divided into sections based on transects provided by TVA, as shown in Table 14, with surface areas based on a constant water surface elevation of 556 feet [25].

Considering the fact that the total range in the water surface elevation is between 551.84 and 555.58 in 1973 and between 551.01 and 556.04 feet in 2004, as can be seen Tables 12 and 13, the assumption of a constant water surface elevation introduces minimal error into the mass balance.

Table 14: Surface Area (in acres) per Transect of Wheeler Reservoir [25]

Section_Name	Portion	RvMi_Range	*Area in Acres (Albers Equal Area Projection)*						
			556 Lake	560	580	590	600	620	630
Section 1 - 2	Wheeler	TRM 349.00 - 346.94	324	426	1611	1959	2299	2744	2924
Section 2 - 3	Wheeler	TRM 346.94 - 344.88	297	359	1976	2242	2477	2644	2698
Section 3 - 4	Wheeler	TRM 344.88 - 342.83	239	840	10694	21881	32074	46004	51049
Section 4 - 5	Wheeler	TRM 342.83 - 340.94	223	244	979	1228	1392	1609	1665
Section 5 - 6	Wheeler	TRM 340.94 - 338.71	337	1393	9294	14114	22251	36090	41782
Section 6 - 7	Wheeler	TRM 338.71 - 336.90	232	330	1364	1570	1734	1974	2066
Section 7 - 8	Wheeler	TRM 336.90 - 334.59	355	448	2761	3228	3599	4023	4164
Section 8 - 9	Wheeler	TRM 334.59 - 332.53	362	580	2973	3742	4440	5880	6576
Section 9 - 10	Wheeler	TRM 332.53 - 330.02	414	729	4766	5824	6653	7447	7647
Section 10 - 11	Wheeler	TRM 330.02 - 328.47	186	286	715	762	808	908	962
Section 11 - 12	Wheeler	TRM 328.47 - 326.36	290	556	2052	2536	2976	3698	4014
Section 12 - 13	Wheeler	TRM 326.36 - 324.20	627	1737	11409	14138	17170	23085	25559
Section 13 - 14	Wheeler	TRM 324.20 - 322.24	851	2306	7163	8403	9441	11254	12196
Section 14 - 15	Wheeler	TRM 322.24 - 320.18	451	1976	8398	10566	12685	16296	17703
Section 15 - 16	Wheeler	TRM 320.18 - 317.83	1204	3108	12212	17021	23240	33508	38607
Section 16 - 17	Wheeler	TRM 317.83 - 316.07	349	1494	5127	6299	7214	8361	8640
Section 17 - 18	Wheeler	TRM 316.07 - 314.25	548	1563	2995	3456	3741	4158	4314
Section 18 - 19	Wheeler	TRM 314.25 - 312.57	693	1304	1895	2123	2419	3010	3191
Section 19 - 20	Wheeler	TRM 312.57 - 309.44	3996	7373	17445	23898	31202	44220	49081
Section 20 - 21	Wheeler	TRM 309.44 - 307.73	3312	7467	26753	41759	58540	91348	107165
Section 21 - 22	Wheeler	TRM 307.73 - 305.78	1499	2616	4239	5194	5829	6126	6130
Section 22 - 23	Wheeler	TRM 305.78 - 303.72	1856	2606	3033	3254	3409	3497	3498
Section 23 - 24	Wheeler	TRM 303.72 - 301.66	2359	4049	8544	11748	13023	15054	15284
Section 24 - 25	Wheeler	TRM 301.66 - 299.60	3422	3993	7197	9472	12556	17991	19987
Section 25 - 26	Wheeler	TRM 299.60 - 297.54	3729	4129	6493	7830	9382	12805	14643
Section 26 - 27	Wheeler	TRM 297.54 - 295.62	2724	3172	6994	9312	11445	15138	16577
Section 27 - 28	Wheeler	TRM 295.62 - 293.75	2069	2454	3601	4261	4730	5445	5704
Section 28 - 29	Wheeler	TRM 293.75 - 291.37	2772	3256	7933	12173	16990	23674	25752
Section 29 - 30	Wheeler	TRM 291.37 - 289.80	1607	1629	1734	1806	1914	2313	2559
Section 30 - 31	Wheeler	TRM 289.80 - 287.16	3215	3240	3525	3786	4170	5143	5757
Section 31 - 32	Wheeler	TRM 287.16 - 285.19	1934	1941	2191	2434	2715	3386	3618
Section 32 - 33	Wheeler	TRM 285.19 - 283.13	6673	7860	18092	23703	30956	50134	61690
Section 33 - 34	Wheeler	TRM 283.13 - 281.08	3024	3534	8524	11820	13923	16131	16835
Section 34 - 35	Wheeler	TRM 281.08 - 278.60	2062	2098	2305	2508	2754	3228	3382
Section 35 - 36	Wheeler	TRM 278.60 - 276.80	1634	1728	2226	2585	3085	4389	5284
Section 36 - 37	Wheeler	TRM 276.80 - 274.90	2302	2407	2965	3352	3846	5357	6165
		Total	**58170**	**85227**	**222177**	**301985**	**387080**	**538072**	**604870**

The volume of precipitation over the basins is calculated from observed rainfall depths, accounting for rainfall over the land and reservoir separately. The areas used in the calculation of the rainfall volumes and the basin average depths of runoff are summarized in Table 15.

Table 15: Reference Areas for Mass Balance Equation

Area	Area, sq. mi.
Wheeler Local	5,049.8
Wheeler Lake Surface	90.9
Total	5,140.7

The daily rainfall depths used for the runoff volume calculation are summed from the hourly rainfall series output in the following FLDHYDRO output files, discussed further in Section 7.2:

- Wheeler_0373_O.out (Attachment 2-2)
- Wheeler_1204_M.out (Attachment 2-4)

The daily rainfall depths for the March 1973 and December 2004 storms are summarized in Table 16.

Table 16: Rainfall Depths, in Inches, Used for Indirectly Validate Subbasin Runoff Calculation

	Basin Average Daily Precipitation Depth, Inches												
Subbasin	3/14/73	3/15/73	3/16/73	3/17/73	Total	12/4/04	12/5/04	12/6/04	12/7/04	12/8/04	12/9/04	12/10/04	Total
UA 51	0.00	3.41	5.24	0.01	8.65	0.00	0.56	3.37	0.74	0.00	2.50	0.04	7.22
UA 52	0.00	2.85	5.73	0.01	8.59	0.00	0.52	2.37	0.51	0.00	1.93	0.11	5.44
UA 53	0.00	4.16	4.75	0.00	8.91	0.00	0.67	2.98	0.88	0.00	2.08	0.03	6.64
UA 54	0.00	3.52	4.34	0.00	7.86	0.00	0.58	2.99	0.69	0.00	2.39	0.07	6.73
UA 55	0.00	1.61	3.58	0.01	5.20	0.00	0.42	1.72	0.57	0.00	1.89	0.07	4.67
UA 56	0.00	2.17	3.69	0.01	5.87	0.00	0.46	2.16	0.62	0.00	1.93	0.01	5.17
UA 57	0.00	4.19	4.75	0.00	8.94	0.00	0.68	2.79	1.02	0.00	1.80	0.00	6.29
UA 58	0.00	4.23	4.96	0.00	9.19	0.00	0.62	2.71	1.01	0.00	1.85	0.01	6.20
UA 59	0.00	3.97	4.15	0.04	8.17	0.00	0.36	1.89	0.75	0.00	2.50	0.26	5.76
UA 60	0.00	4.33	4.10	0.01	8.44	0.00	0.54	2.25	0.81	0.00	2.29	0.01	5.90
UA 61	0.12	4.26	3.83	0.01	8.22	0.00	0.56	2.08	0.94	0.00	1.76	0.00	5.35
UA 62	1.21	4.20	2.43	0.00	7.84	0.00	0.53	1.77	1.11	0.01	1.74	0.00	5.17
UA 63	0.79	4.32	3.32	0.00	8.43	0.00	0.58	2.19	0.85	0.00	1.66	0.00	5.27
UA 64	0.14	3.97	4.08	0.00	8.19	0.00	0.62	2.51	0.86	0.00	1.54	0.00	5.51
UA 65	0.12	3.64	4.50	0.00	8.26	0.00	0.56	2.35	0.83	0.00	1.89	0.02	5.65

The calculation of the local area runoff depth over the land mass of the subbasin is summarized in Table 17 (see Attachments 1-2 and 1-3). The direct runoff volume, in inches, calculated in Table 17 was used as the CHKVOL input values for FLDHYDRO for the March 1973 and December 2004 floods, as described in Section 7.2.

Table 17: Calculation of Runoff Depth over the Land Area of Subbasins

Volume Description	March-73	December-04
Volume of rainfall on North Lake Surface (cu.ft.) =	1,858,247,437	1,248,067,181
Lake Surface Runoff Volume (DSF) =	21,507	14,445
Wheeler SRO Volume (DSF) =	810,402	546,105
Without lake SRO Volume (DSF) =	788,895	531,660
Without lake SRO Volume (in. of RO) =	5.81	3.92

7.2 Calculation of Effective Precipitation

The effective (or excess) rainfall hyetograph is the series that is convoluted with the unit hydrograph to provide the direct runoff for each subbasin. This is developed from the observed rainfall hyetograph by the application of a loss rate function which accounts for the hydrologic abstractions of evaporation and transpiration, interception, depression storage, and infiltration [4].

Effective rainfall is obtained from observed rainfall data with the FLDHYDRO program [7]. The FLDHYDRO program was developed by TVA to implement the Antecedent Precipitation Index (API)/Runoff Index (RI) methodology developed by the United States Weather Bureau (USWB), as described in [18]. In brief, the method uses the API for a given day, which is calculated on the basis of a recession constant normally reported to range from 0.85 to 0.98 [4]. A recession constant of 0.9 is assumed for this calculation. The API is used to obtain a RI that has been determined for the Tennessee River Valley region as a function of precipitation, location, and season. The RI is then used to obtain precipitation losses for each increment of rainfall.

The use of the loss function is discussed in the TVA White Paper [19], and the methodology is described in detail in the USWB publication [18]. Input to FLDHYDRO is via a column delimited batch file. Input includes:

- Hourly precipitation gage readings for a maximum of 30 recording gages and daily precipitation readings for a maximum of 100 non-recording gages (For the gridded precipitation data sets, daily precipitation depths were calculated by summing hourly rainfall depths.)
- Indices to relate each non-recording gage record to a recording gage record for interpolation
- Thiessen coefficients to weight gage records for the calculation of basin average precipitation depths (not used for gridded precipitation data)
- Depth of runoff for the period of rainfall

For this calculation, input for each run included the following data and "flags".

- NARFE = 1 to obtain a printout of flood hydrographs only
- NRI = 1 for the number of Runoff Indices to be used per basin
- NCPTS = 1 for the number of sites for surface runoff volume check (set to zero if a runoff check volume is not supplied)
- NSUBW = 9 for number of sub-watersheds
- NREC = 15 for the number of recorders (using only one time series per basin as one "recorder")
- NSTNS = 15 for total number of stations (i.e. no non-recording stations used)
- STAB = 2 when API areas vary with watershed
- ITDGR = 0 for the hour at which each gage is read
- NAMSTA = The name of each recording gage (name of subbasin for this application)
- BEGDR = The starting date (entered in MMDDYY format)
- BEGTR = Time at which the first hour of rainfall has been recorded (between 01 to 24)
- NHR = The number of hourly readings for the storm

- SHRAIN = The time series of hourly rainfall readings (in 10F8.0 format) obtained from processing of NWS gridded rainfall
- NDRAPI = The number of days of antecedent rainfall listed before the storm
- API = The initial API at the beginning of the antecedent daily rainfall series (setting this value to 1.0 is sufficient when a month of data is used because the initial condition has negligible impact on the final API for a sufficiently long series)
- APRAIN = The time series of daily rainfall readings (in 10F8.0 format) obtained from the sum of hourly rainfall data for approximately one month prior to the start of the hourly rainfall
- BAREA = The subbasin area in square miles
- APITYPE = The API zone with SE = 1, E = 2, NE = 3, N = 4, W = 5, and S = 6 (see Figure 15).
- NSPW = 1 for number of rainfall stations for each sub-watershed (for gridded data there are no Thiessen weighting factors)
- NUMVOL = Number of watersheds above surface runoff volume check point
- CHKVOL = The volume of surface runoff in inches (calculated from outflow hydrographs after base flow separation)

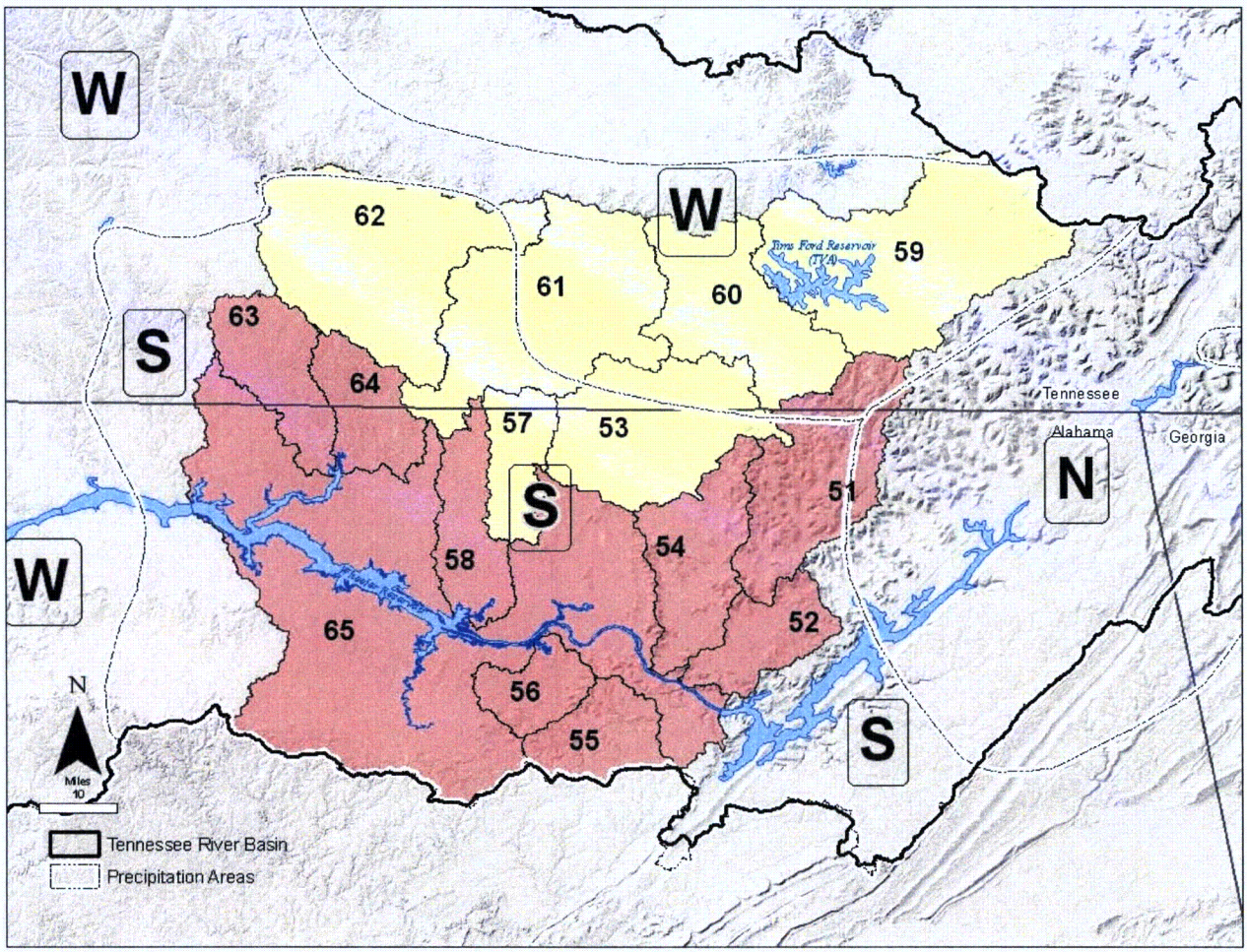

Figure 15: API Regions for Application of TVA FLDHYDRO Program

Input data and parameters for running FLDHYDRO to get effective basin average rainfall for the dry land areas of Subbasins 51, 52, 54, 55, 56, 58, 63, 64, and 65 were written to the following batch input files and included as attachments to this calculation:

- Attachment 2-1 Wheeler_0373_Q.dat
- Attachment 2-3 Wheeler_1204_M.dat

The corresponding FLDHYDRO output files are also provided as attachments:

- Attachment 2-2 Wheeler_0373_Q.out
- Attachment 2-4 Wheeler_1204_M.out

FLDHYDRO can also carry out the convolution of the unit hydrograph with the effective rainfall. The input files for the FLDHYDRO runs were set up in this manner, but convolution was done in a spreadsheet for this calculation because the convolution routines in FLDHYDRO had not been validated at the time of execution.

The cumulative precipitation and excess rainfall depths for the two validation runs for each of the subbasins are plotted in Figures 16 to 33 (Attachment 1-13). The use of the excess rainfall, or runoff, time series as input to the convolution calculation is described in the next section.

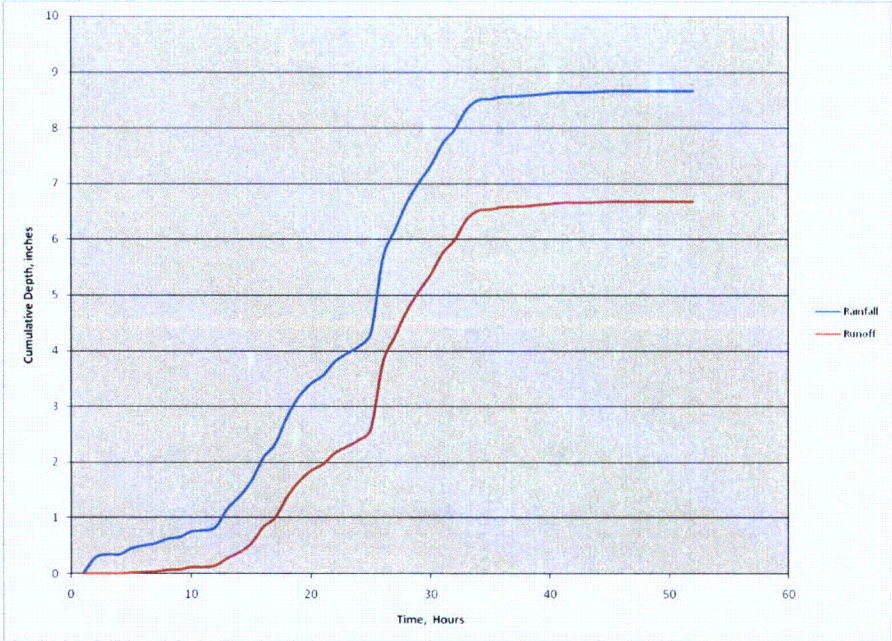

Figure 16: Cumulative Precipitation and Runoff Series for March 1973 Event in Subbasin 51

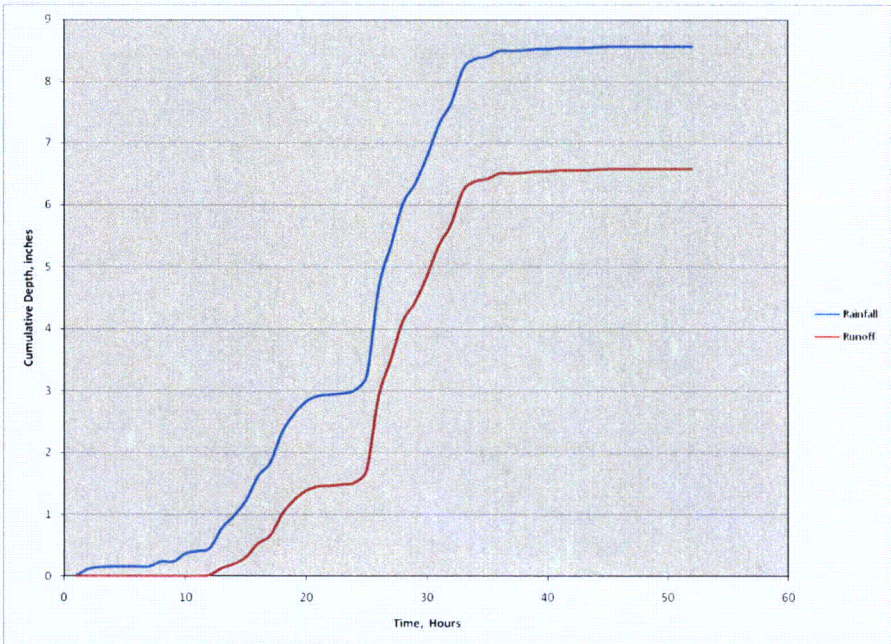

Figure 17: Cumulative Precipitation and Runoff Series for March 1973 Event in Subbasin 52

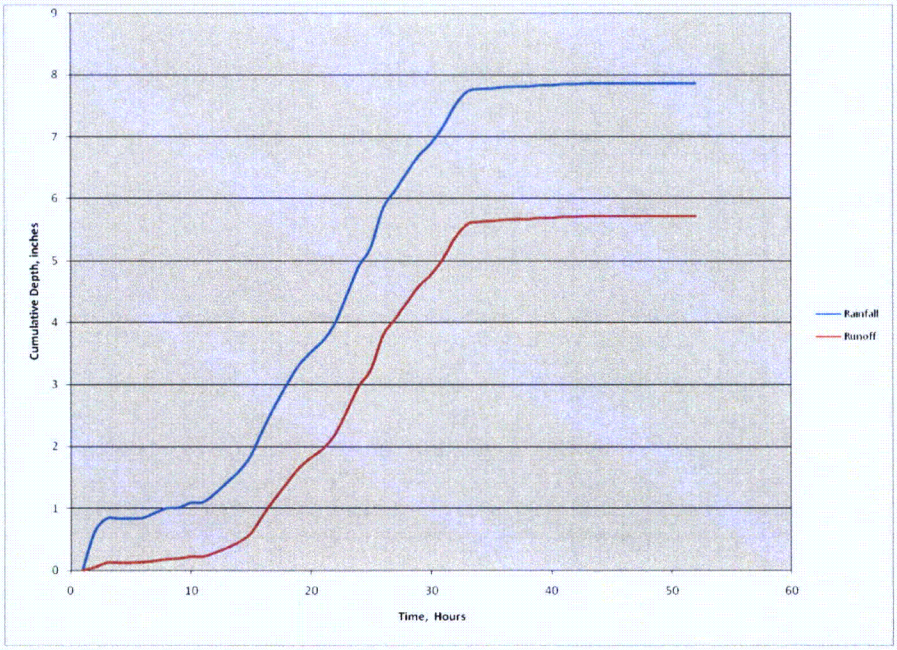

Figure 18: Cumulative Precipitation and Runoff Series for March 1973 Event in Subbasin 54

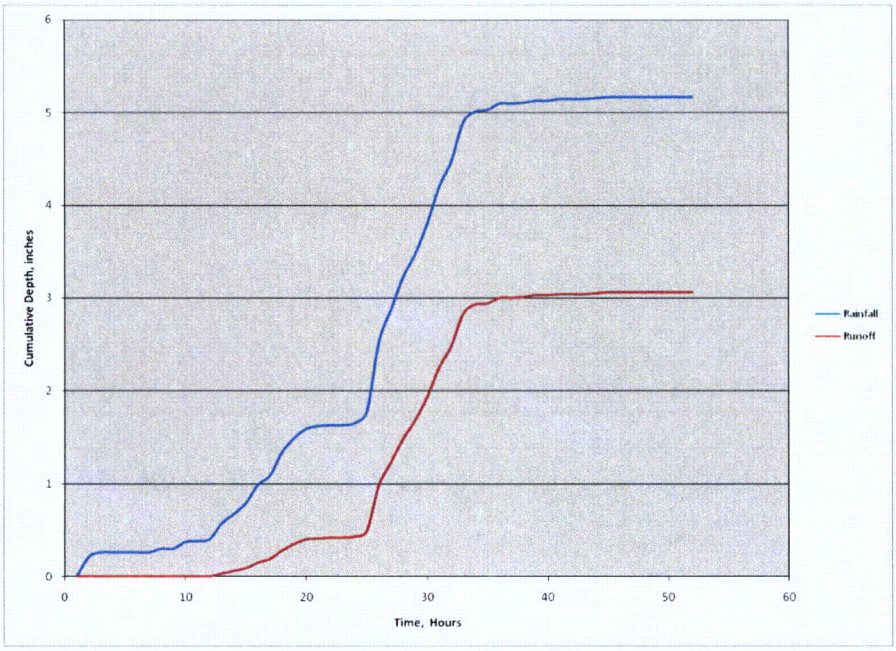

Figure 19: Cumulative Precipitation and Runoff Series for March 1973 Event in Subbasin 55

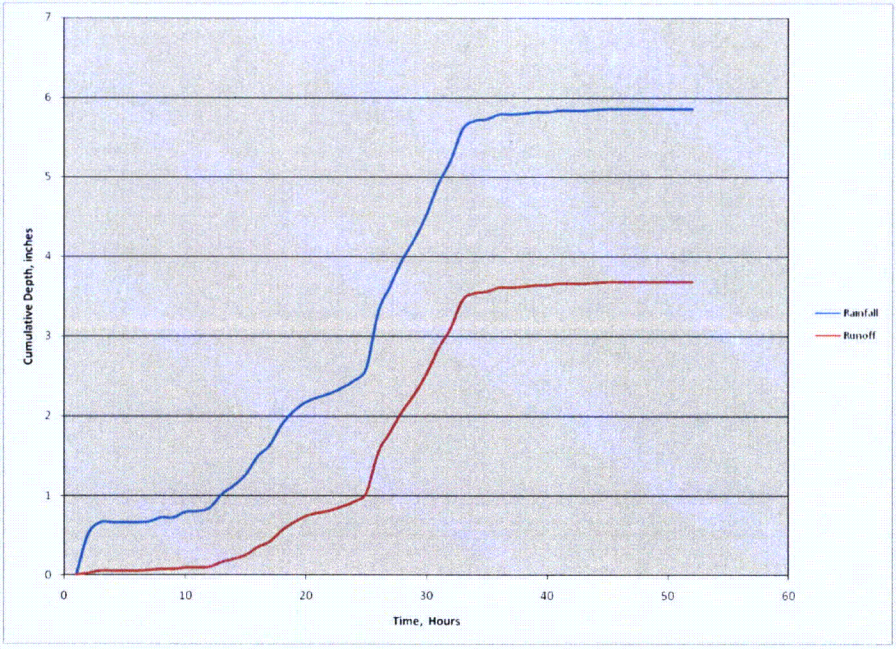

Figure 20: Cumulative Precipitation and Runoff Series for March 1973 Event in Subbasin 56

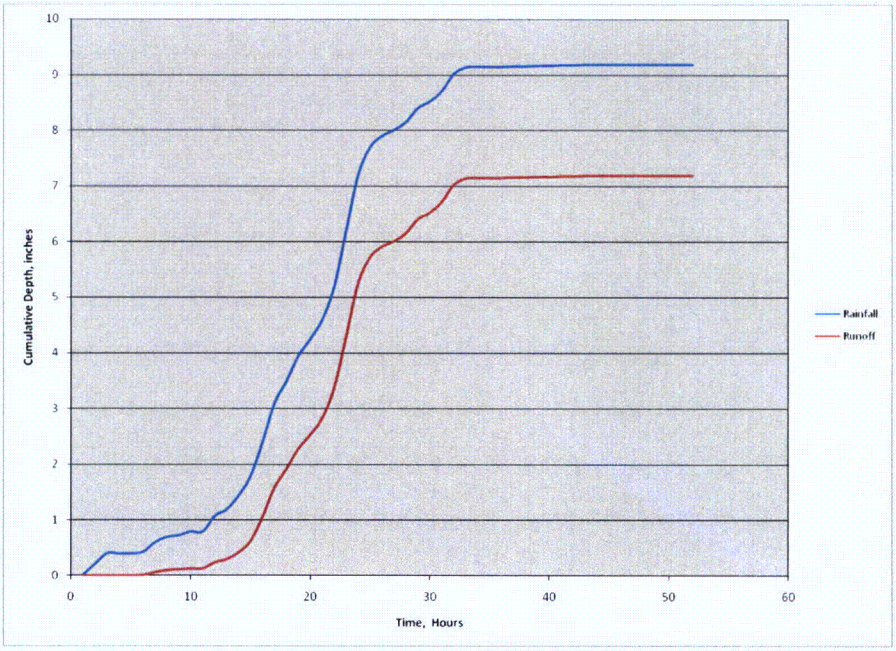

Figure 21: Cumulative Precipitation and Runoff Series for March 1973 Event in Subbasin 58

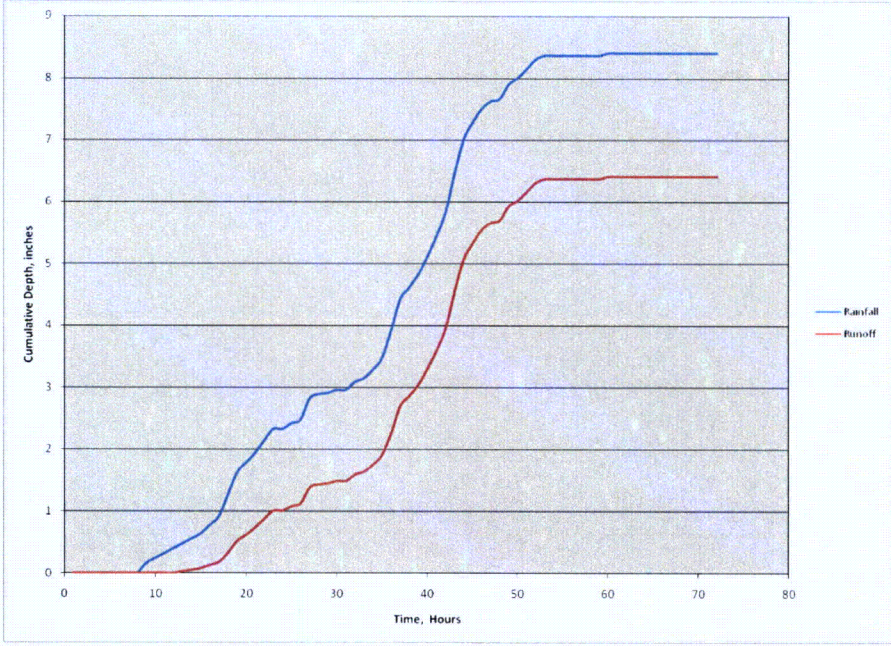

Figure 22: Cumulative Precipitation and Runoff Series for March 1973 Event in Subbasin 63

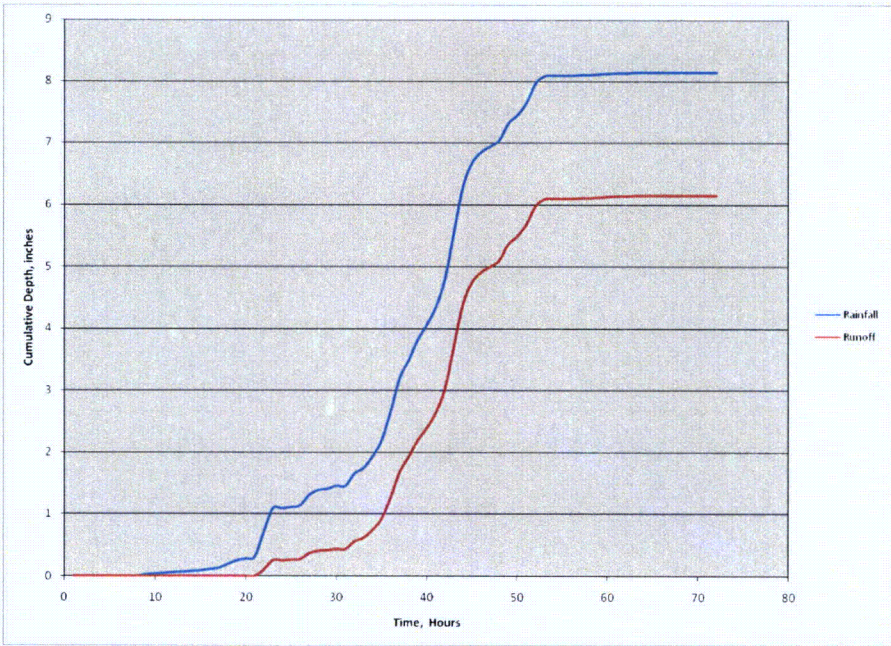

Figure 23: Cumulative Precipitation and Runoff Series for March 1973 Event in Subbasin 64

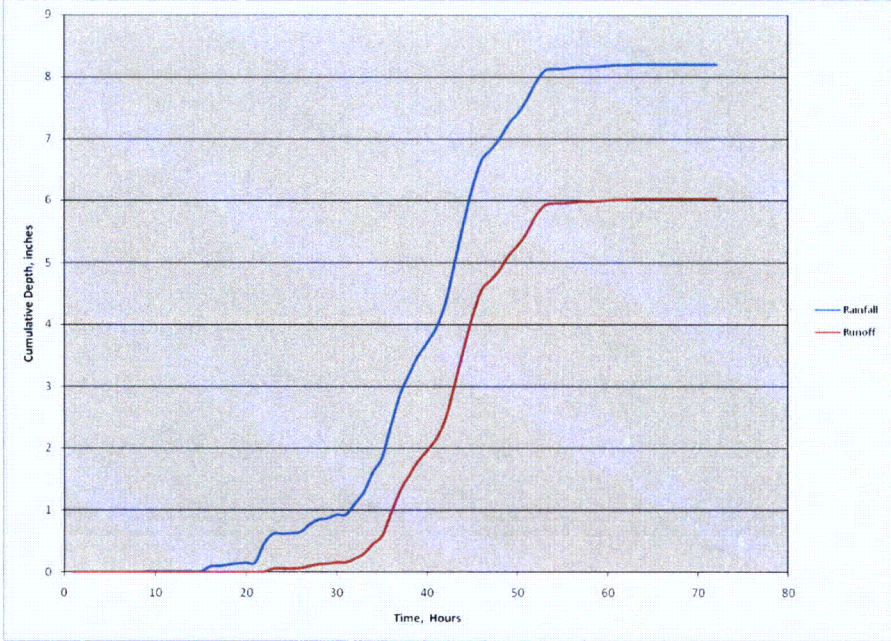

Figure 24: Cumulative Precipitation and Runoff Series for March 1973 Event in Subbasin 65

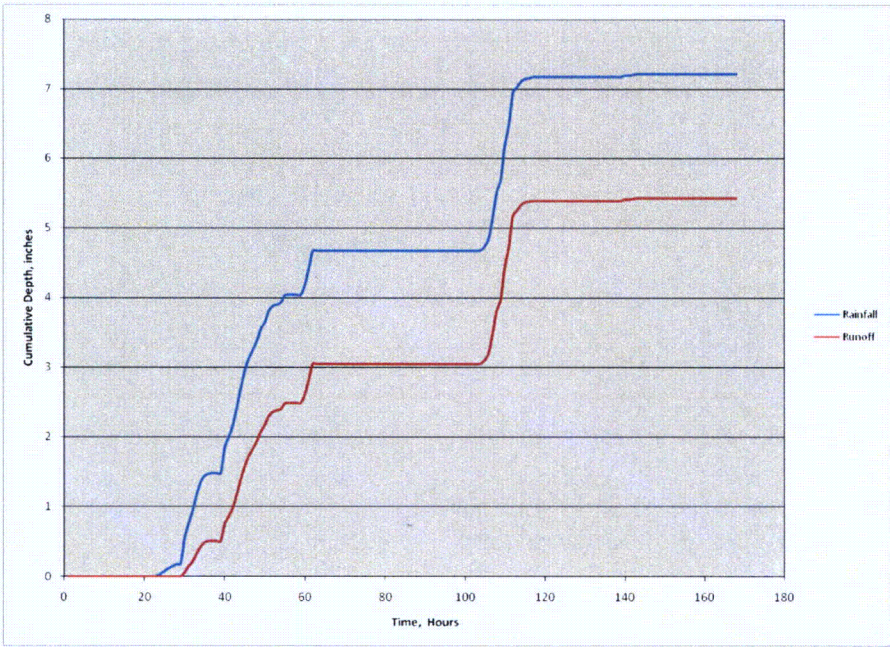

Figure 25: Cumulative Precipitation and Runoff Series for December 2004 Event in Subbasin 51

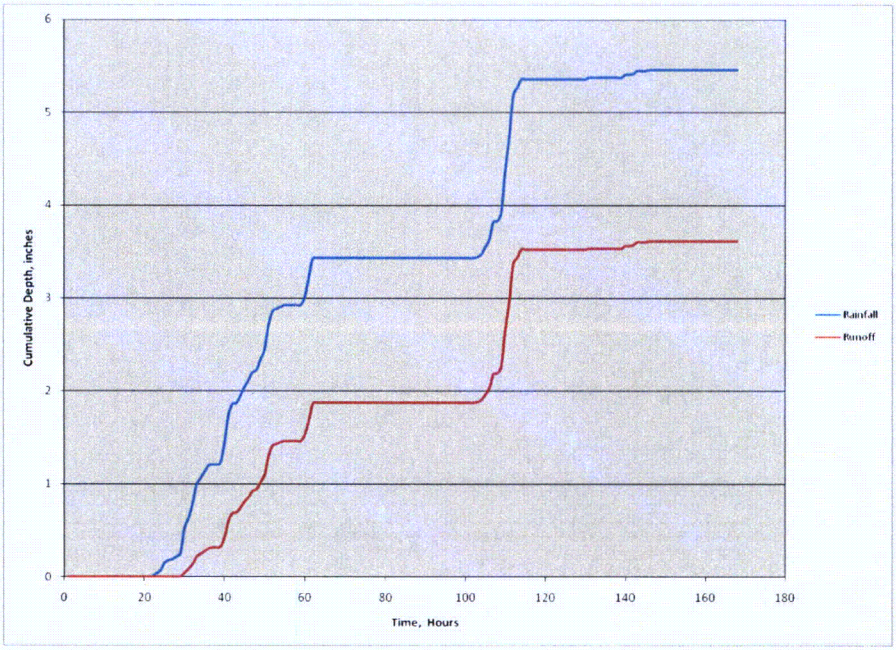

Figure 26: Cumulative Precipitation and Runoff Series for December 2004 Event in Subbasin 52

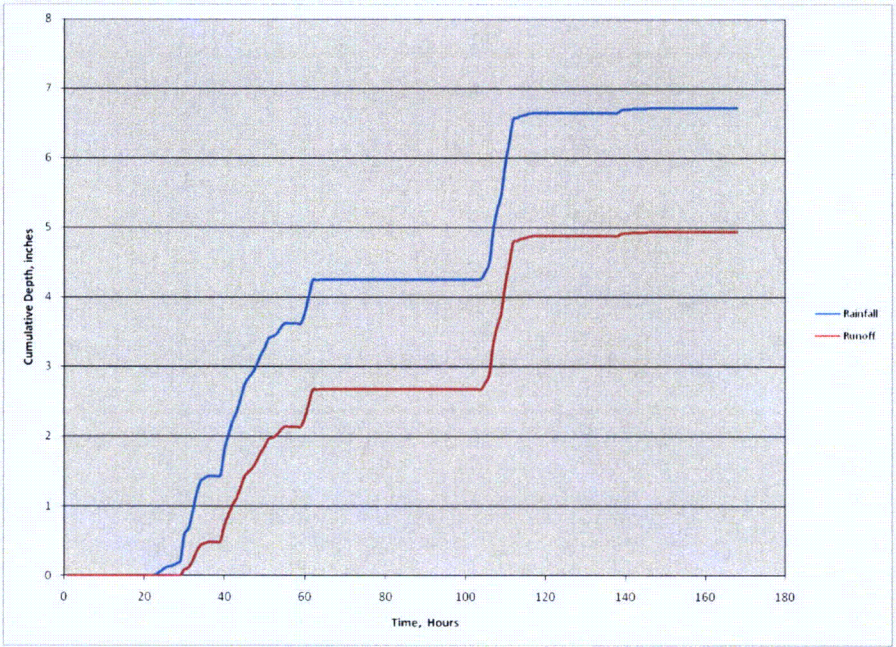

Figure 27: Cumulative Precipitation and Runoff Series for December 2004 Event in Subbasin 54

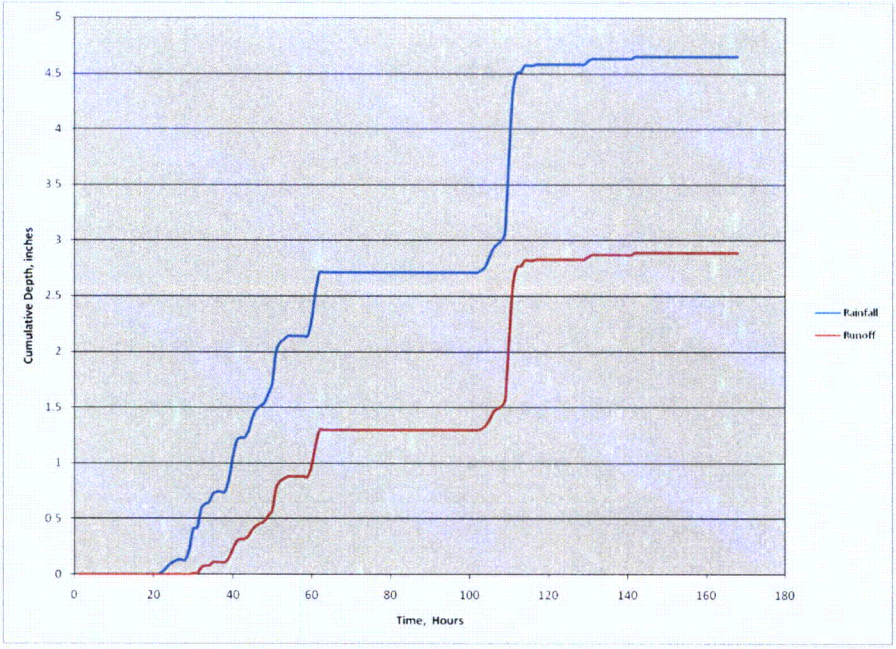

Figure 28: Cumulative Precipitation and Runoff Series for December 2004 Event in Subbasin 55

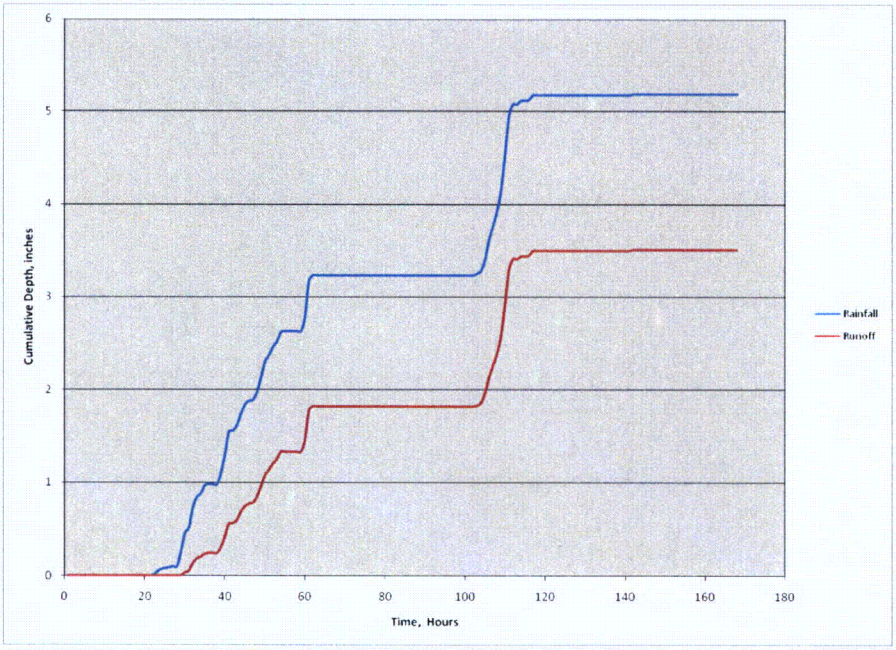

Figure 29: Cumulative Precipitation and Runoff Series for December 2004 Event in Subbasin 56

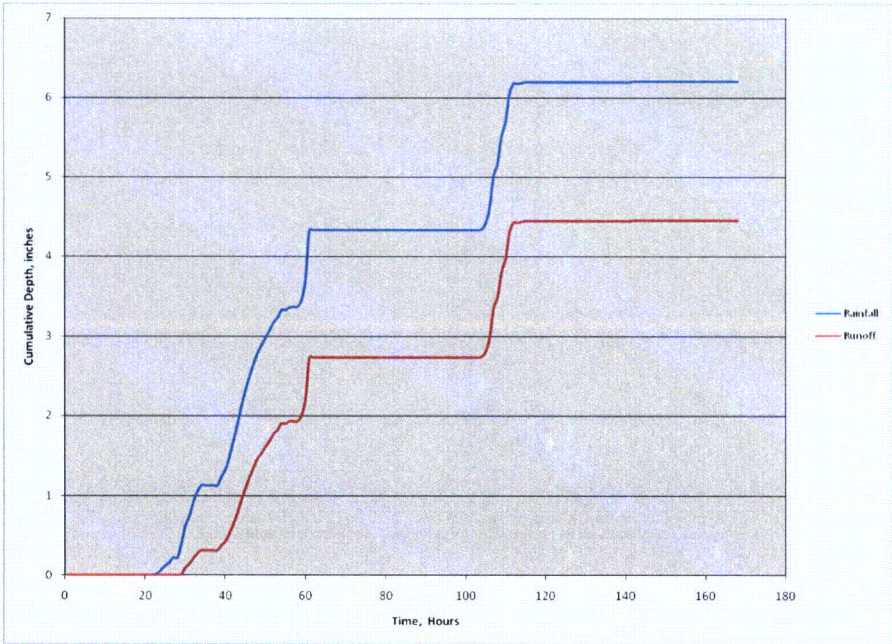

Figure 30: Cumulative Precipitation and Runoff Series for December 2004 Event in Subbasin 58

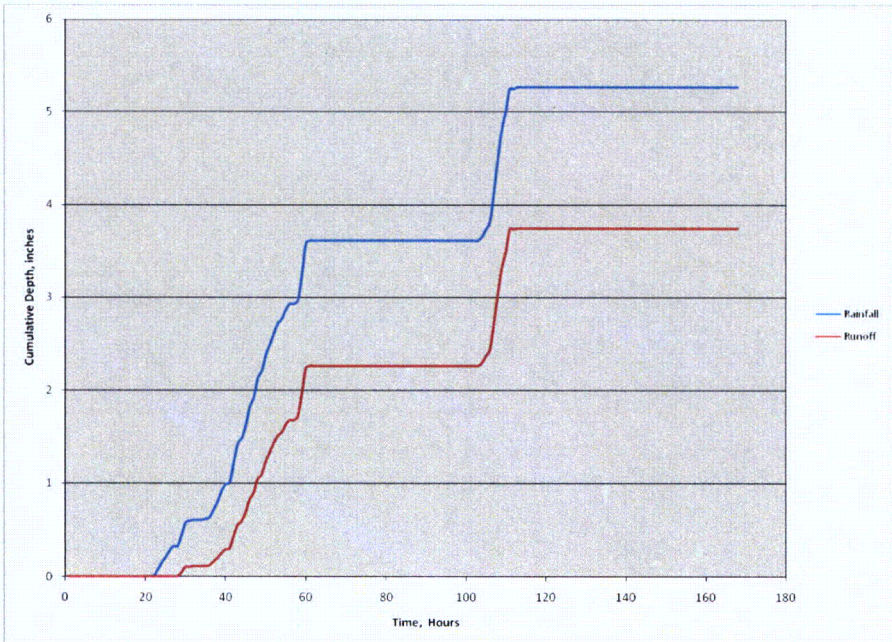

Figure 31: Cumulative Precipitation and Runoff Series for December 2004 Event in Subbasin 63

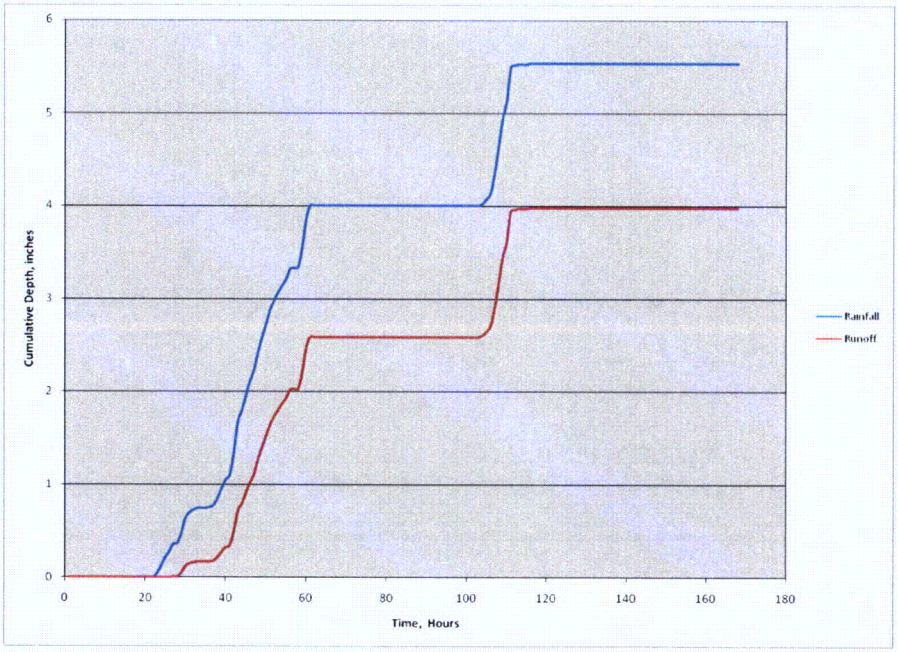

Figure 32: Cumulative Precipitation and Runoff Series for December 2004 Event in Subbasin 64

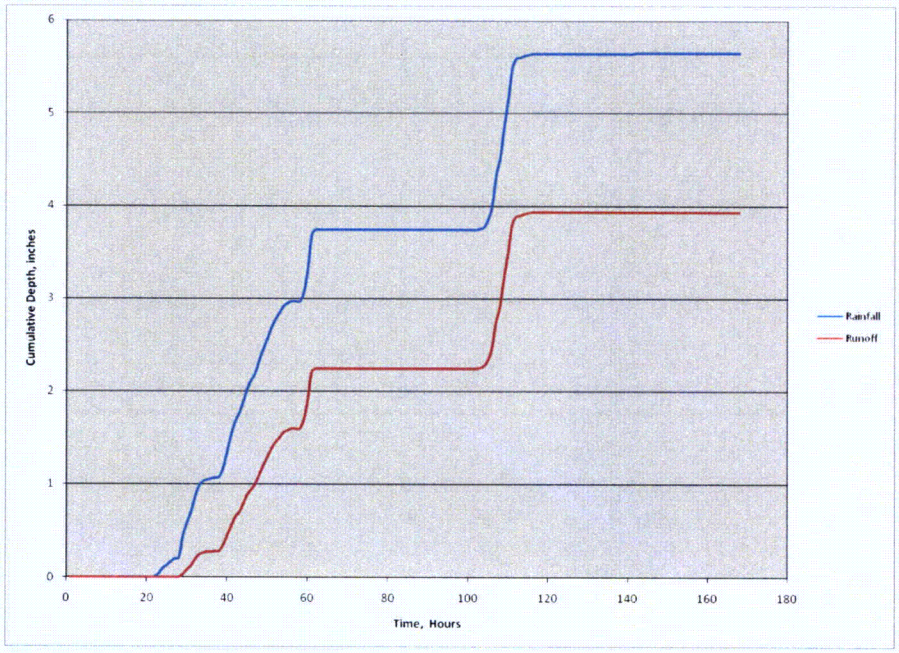

Figure 33: Cumulative Precipitation and Runoff Series for December 2004 Event in Subbasin 65

7.3 Development of Local Inflow Hydrographs

Local inflow hydrographs were developed for input to the SOCH model of the Tennessee River between Wheeler and Guntersville Dams for the March 1973 and December 2004 floods, as described below.

7.3.1 Convolution of Dry Land Hydrographs

Hydrographs for the local runoff from each of the subbasins are developed by convolution of the TVA unit hydrograph ordinates with the effective rainfall time series as developed in FLDHYDRO using standard engineering procedures, as summarized in Section 4 [2, 3].

The convolutions for the Subbasins are provided in Tables 18 through 26, for the March 1973 flood and in Tables 27 through 35 for the December flood.

The calculations, including the conversion of one-hour rainfall depths to 6-hour depths (4-hour depths for subbasin 63) to coincide with the duration of the unit hydrographs are presented in the following spreadsheets:

- IND_Convol_51.xls (Attachment 1-4)
- IND_Convol_52.xls (Attachment 1-5)
- IND_Convol_54.xls (Attachment 1-6)
- IND_Convol_55.xls (Attachment 1-7)
- IND_Convol_56.xls (Attachment 1-8)
- IND_Convol_58.xls (Attachment 1-9)
- IND_Convol_63.xls (Attachment 1-10)
- IND_Convol_64.xls (Attachment 1-11)
- IND_Convol_65.xls (Attachment 1-12)

Table 18: Subbasin 51 Convolution for March 1973 Flood

Date	Time	6hr UH	Rainfall Excess, inches								Q
	hrs	cfs/in	0.12	0.72	1.33	2.54	1.80	0.12	0.04	0.00	cfs
3/15/73 07:00	0	0	0								0
3/15/73 13:00	6	177	18	0							21
3/15/73 19:00	12	3429	343	115	0						539
3/16/73 01:00	18	11363	1,136	2,229	230	0					4,068
3/16/73 07:00	24	5284	528	7,386	4,458	443	0				13,826
3/16/73 13:00	30	4385	439	3,435	14,772	8,573	313	0			28,472
3/16/73 19:00	36	3486	349	2,850	6,869	28,408	6,069	21	0		45,659
3/17/73 01:00	42	2205	221	2,266	5,701	13,210	20,113	411	7	0	42,900
3/17/73 07:00	48	923	92	1,433	4,532	10,963	9,353	1,364	137	0	28,485
3/17/73 13:00	54	808	81	600	2,867	8,715	7,761	634	455	0	21,530
3/17/73 19:00	60	694	69	525	1,200	5,513	6,170	526	211	0	14,506
3/18/73 01:00	66	580	58	451	1,050	2,308	3,903	418	175	0	8,551
3/18/73 07:00	72	466	47	377	902	2,020	1,634	265	139	0	5,514
3/18/73 13:00	78	352	35	303	754	1,735	1,430	111	88	0	4,565
3/18/73 19:00	84	238	24	229	606	1,450	1,228	97	37	0	3,758
3/19/73 01:00	90	123	12	155	458	1,165	1,027	83	32	0	2,998
3/19/73 07:00	96	20	2	80	309	880	825	70	28	0	2,238
3/19/73 13:00	102	0	0	13	160	595	623	56	23	0	1,495
3/19/73 19:00	108			0	26	308	421	42	19	0	828
3/20/73 01:00	114				0	50	218	29	14	0	315
3/20/73 07:00	120					0	35	15	10	0	60
3/20/73 13:00	126						0	2	5	0	7
3/20/73 19:00	132							0	1	0	1
3/21/73 01:00	138								0	0	0
3/21/73 07:00	144									0	0
3/21/73 13:00	150										0
3/21/73 19:00	156										0
3/22/73 01:00	162										0
3/22/73 07:00	168										0
3/22/73 13:00	174										0
3/22/73 19:00	180										0
3/23/73 01:00	186										0
3/23/73 07:00	192										0
3/23/73 13:00	198										0
3/23/73 19:00	204										0
3/24/73 01:00	210										0
3/24/73 07:00	216										0
3/24/73 13:00	222										0

Table 19: Subbasin 52 Convolution for March 1973 Flood

Date	Time	6hr UH	Rainfall Excess, inches						Q
	hrs	cfs/in	0.59	0.80	2.87	1.97	0.14	0.02	cfs
3/15/73 13:00	0	0	0						0
3/15/73 19:00	6	140	83	0					83
3/16/73 01:00	12	870	513	112	0				625
3/16/73 07:00	18	2501	1,476	696	402	0			2,573
3/16/73 13:00	24	6103	3,601	2,001	2,497	276	0		8,374
3/16/73 19:00	30	2501	1,476	4,882	7,178	1,714	20	0	15,269
3/17/73 01:00	36	1171	691	2,001	17,516	4,927	122	3	25,259
3/17/73 07:00	42	670	395	937	7,178	12,023	350	17	20,900
3/17/73 13:00	48	425	251	536	3,361	4,927	854	50	9,979
3/17/73 19:00	54	250	148	340	1,923	2,307	350	122	5,189
3/18/73 01:00	60	150	89	200	1,220	1,320	164	50	3,042
3/18/73 07:00	66	70	41	120	718	837	94	23	1,833
3/18/73 13:00	72	0	0	56	431	493	59	13	1,052
3/18/73 19:00	78		0	0	201	296	35	8	540
3/19/73 01:00	84			0	0	138	21	5	164
3/19/73 07:00	90				0	0	10	3	13
3/19/73 13:00	96					0	0	1	1
3/19/73 19:00	102						0	0	0
3/20/73 01:00	108							0	0
3/20/73 07:00	114								0
3/20/73 13:00	120								0
3/20/73 19:00	126								0
3/21/73 01:00	132								0
3/21/73 07:00	138								0
3/21/73 13:00	144								0
3/21/73 19:00	150								0
3/22/73 01:00	156								0
3/22/73 07:00	162								0
3/22/73 13:00	168								0
3/22/73 19:00	174								0
3/23/73 01:00	180								0
3/23/73 07:00	186								0
3/23/73 13:00	192								0
3/23/73 19:00	198								

Table 20: Subbasin 54 Convolution for March 1973 Flood

Date	Time	6hr UH	Rainfall Excess, inches								Q
	hrs	cfs/in	0.15	0.21	1.29	1.60	1.79	0.62	0.05	0.00	cfs
3/15/73 04:00	0	0	0								0
3/15/73 10:00	6	498	75	0							75
3/15/73 16:00	12	1791	269	105	0						373
3/15/73 22:00	18	4678	702	376	642	0					1720
3/16/73 04:00	24	7962	1194	982	2310	797	0				5284
3/16/73 10:00	30	4678	702	1672	6035	2866	891	0			12165
3/16/73 16:00	36	1990	299	982	10271	7485	3206	309	0		22551
3/16/73 22:00	42	995	149	418	6035	12739	8374	1110	25	0	28850
3/17/73 04:00	48	597	90	209	2567	7485	14252	2900	90	0	27592
3/17/73 10:00	54	398	60	125	1284	3184	8374	4936	234	0	18197
3/17/73 16:00	60	299	45	84	770	1592	3562	2900	398	0	9351
3/17/73 22:00	66	199	30	63	513	955	1781	1234	234	0	4810
3/18/73 04:00	72	100	15	42	386	637	1069	617	99	0	2864
3/18/73 10:00	78	0	0	21	257	478	712	370	50	0	1888
3/18/73 16:00	84			0	129	318	535	247	30	0	1259
3/18/73 22:00	90				0	160	356	185	20	0	721
3/19/73 04:00	96					0	179	123	15	0	317
3/19/73 10:00	102						0	62	10	0	72
3/19/73 16:00	108							0	5	0	5
3/19/73 22:00	114								0	0	0
3/20/73 04:00	120									0	0
3/20/73 10:00	126										0
3/20/73 16:00	132										0
3/20/73 22:00	138										0
3/21/73 04:00	144										0
3/21/73 10:00	150										0
3/21/73 16:00	156										0
3/21/73 22:00	162										0
3/22/73 04:00	168										0
3/22/73 10:00	174										0
3/22/73 16:00	180										0
3/22/73 22:00	186										0
3/23/73 04:00	192										0
3/23/73 10:00	198										0

Table 21: Subbasin 55 Convolution for March 1973 Flood

Date	Time	6hr UH	Rainfall Excess, inches						Q
	hrs	cfs/in	0.28	0.15	1.50	1.07	0.04	0.02	cfs
3/15/73 15:00	0	0	0						0
3/15/73 21:00	6	253	71	0					71
3/16/73 03:00	12	1461	409	38	0				447
3/16/73 09:00	18	3174	889	219	380	0			1,487
3/16/73 15:00	24	2803	785	476	2192	271	0		3,723
3/16/73 21:00	30	1850	518	420	4761	1563	10	0	7,273
3/17/73 03:00	36	1413	396	278	4205	3396	58	5	8,337
3/17/73 09:00	42	1045	293	212	2775	2999	127	29	6,435
3/17/73 15:00	48	750	210	157	2120	1980	112	63	4,641
3/17/73 21:00	54	556	156	113	1568	1512	74	56	3,478
3/18/73 03:00	60	440	123	83	1125	1118	57	37	2,543
3/18/73 09:00	66	324	91	66	834	803	42	28	1,863
3/18/73 15:00	72	208	58	49	660	595	30	21	1,413
3/18/73 21:00	78	166	46	31	486	471	22	15	1,072
3/19/73 03:00	84	124	35	25	312	347	18	11	747
3/19/73 09:00	90	82	23	19	249	223	13	9	535
3/19/73 15:00	96	0	0	12	186	178	8	6	391
3/19/73 21:00	102		0	0	123	133	7	4	266
3/20/73 03:00	108			0	0	88	5	3	96
3/20/73 09:00	114				0	0	3	2	6
3/20/73 15:00	120					0	0	2	2
3/20/73 21:00	126						0	0	0
3/21/73 03:00	132							0	0
3/21/73 09:00	138								0
3/21/73 15:00	144								0
3/21/73 21:00	150								0
3/22/73 03:00	156								0
3/22/73 09:00	162								0
3/22/73 15:00	168								0
3/22/73 21:00	174								0
3/23/73 03:00	180								0
3/23/73 09:00	186								0
3/23/73 15:00	192								0
3/23/73 21:00	198								0
3/24/73 03:00	204								0
3/24/73 09:00	210								0

Table 22: Subbasin 56 Convolution for March 1973 Flood

Date	Time	6hr UH	Rainfall Excess, inches								Q
	hrs	cfs/in	0.06	0.10	0.50	0.37	1.82	0.76	0.05	0.02	cfs
3/15/73 04:00	0	0	0								0
3/15/73 10:00	6	94	6	0							6
3/15/73 16:00	12	425	26	9	0						35
3/15/73 22:00	18	1416	85	43	47	0					174
3/16/73 04:00	24	2644	159	142	213	35	0				548
3/16/73 10:00	30	1955	117	264	708	157	171	0			1418
3/16/73 16:00	36	1360	82	196	1322	524	774	71	0		2968
3/16/73 22:00	42	944	57	136	978	978	2577	323	5	0	5053
3/17/73 04:00	48	689	41	94	680	723	4812	1076	21	2	7450
3/17/73 10:00	54	491	29	69	472	503	3558	2009	71	9	6720
3/17/73 16:00	60	359	22	49	345	349	2475	1486	132	28	4886
3/17/73 22:00	66	255	15	36	246	255	1718	1034	98	53	3454
3/18/73 04:00	72	161	10	26	180	182	1254	717	68	39	2475
3/18/73 10:00	78	76	5	16	128	133	894	524	47	27	1773
3/18/73 16:00	84	0	0	8	81	94	653	373	34	19	1262
3/18/73 22:00	90		0	0	38	60	464	273	25	14	873
3/19/73 04:00	96			0	0	28	293	194	18	10	543
3/19/73 10:00	102				0	0	138	122	13	7	281
3/19/73 16:00	108					0	0	58	8	5	71
3/19/73 22:00	114						0	0	4	3	7
3/20/73 04:00	120							0	0	2	2
3/20/73 10:00	126								0	0	0
3/20/73 16:00	132									0	0
3/20/73 22:00	138										0
3/21/73 04:00	144										0
3/21/73 10:00	150										0
3/21/73 16:00	156										0
3/21/73 22:00	162										0
3/22/73 04:00	168										0
3/22/73 10:00	174										0
3/22/73 16:00	180										0
3/22/73 22:00	186										0
3/23/73 04:00	192										0
3/23/73 10:00	198										0

Table 23: Subbasin 58 Convolution for March 1973 Flood

Date	Time	6hr UH	Rainfall Excess, inches							Q
	hrs.	cfs	0.13	1.46	2.69	2.12	0.75	0.03	0.01	cfs
3/15/73 08:00	0	0	0							0
3/15/73 14:00	6	3156	410	0						410
3/15/73 20:00	12	6407	833	4608	0					5441
3/16/73 02:00	18	3203	416	9354	8490	0				18260
3/16/73 08:00	24	1696	220	4676	17235	6691	0			28822
3/16/73 14:00	30	1055	137	2476	8616	13583	2367	0		27179
3/16/73 20:00	36	754	98	1540	4562	6790	4805	95	0	17891
3/17/73 02:00	42	471	61	1101	2838	3596	2402	192	32	10222
3/17/73 08:00	48	188	24	688	2028	2237	1272	96	64	6409
3/17/73 14:00	54	0	0	274	1267	1598	791	51	32	4014
3/17/73 20:00	60		0	0	506	999	566	32	17	2118
3/18/73 02:00	66		0	0	0	399	353	23	11	785
3/18/73 08:00	72		0	0	0	0	141	14	8	163
3/18/73 14:00	78		0	0	0	0	0	6	5	10
3/18/73 20:00	84			0	0	0	0	0	2	2
3/19/73 02:00	90				0	0	0	0	0	0
3/19/73 08:00	96					0	0	0	0	0
3/19/73 14:00	102						0	0	0	0
3/19/73 20:00	108							0	0	0
3/20/73 02:00	114								0	0
3/20/73 08:00	120									0
3/20/73 14:00	126									0
3/20/73 20:00	132									0
3/21/73 02:00	138									0
3/21/73 08:00	144									0
3/21/73 14:00	150									0
3/21/73 20:00	156									0
3/22/73 02:00	162									0
3/22/73 08:00	168									0
3/22/73 14:00	174									0
3/22/73 20:00	180									0
3/23/73 02:00	186									0

Table 24: Subbasin 63 Convolution for March 1973 Flood

Date	Time	4hr UH	Rainfall Excess, inches													Q
	hrs.	cfs	0.08	0.44	0.49	0.37	0.11	0.42	1.13	1.50	1.11	0.51	0.21	0.00	0.04	cfs
3/15/73 02:00	0	0	0													0
3/15/73 06:00	4	382	31	0												31
3/15/73 10:00	8	2509	201	168	0											369
3/15/73 14:00	12	5023	402	1104	187	0										1693
3/15/73 18:00	16	8512	681	2210	1229	141	0									4262
3/15/73 22:00	20	3897	312	3745	2461	928	42	0								7489
3/16/73 02:00	24	2402	192	1715	4171	1859	276	160	0							8373
3/16/73 06:00	28	1449	116	1057	1910	3149	553	1054	432	0						8270
3/16/73 10:00	32	1024	82	638	1177	1442	936	2110	2835	573	0					9793
3/16/73 14:00	36	723	58	451	710	889	429	3575	5676	3764	424	0				15974
3/16/73 18:00	40	545	44	318	502	536	264	1637	9619	7535	2785	195	0			23433
3/16/73 22:00	44	466	37	240	354	379	159	1009	4404	12768	5576	1280	80	0		26285
3/17/73 02:00	48	387	31	205	267	268	113	609	2714	5846	9448	2562	527	0	0	22588
3/17/73 06:00	52	306	24	170	228	202	80	430	1637	3603	4326	4341	1055	0	15	16112
3/17/73 10:00	56	227	18	135	190	172	60	304	1157	2174	2666	1987	1788	0	100	10751
3/17/73 14:00	60	147	12	100	150	143	51	229	817	1536	1608	1225	818	0	201	6891
3/17/73 18:00	64	130	10	65	111	113	43	196	616	1085	1137	739	504	0	340	4959
3/17/73 22:00	68	113	9	57	72	84	34	163	527	818	803	522	304	0	156	3547
3/18/73 02:00	72	95	8	50	64	54	25	129	437	699	605	369	215	0	96	2750
3/18/73 06:00	76	78	6	42	55	48	16	95	346	581	517	278	152	0	58	2194
3/18/73 10:00	80	62	5	34	47	42	14	62	257	459	430	238	114	0	41	1742
3/18/73 14:00	84	44	4	27	38	35	12	55	166	341	340	197	98	0	29	1342
3/18/73 18:00	88	27	2	19	30	29	10	47	147	221	252	156	81	0	22	1017
3/18/73 22:00	92	0	0	12	22	23	9	40	128	195	163	116	64	0	19	789
3/19/73 02:00	96			0	13	16	7	33	107	170	144	75	48	0	15	628
3/19/73 06:00	100				0	10	5	26	88	143	125	66	31	0	12	506
3/19/73 10:00	104					0	3	18	70	117	105	58	27	0	9	408
3/19/73 14:00	108						0	11	50	93	87	48	24	0	6	319
3/19/73 18:00	112							0	31	66	69	40	20	0	5	230
3/19/73 22:00	116								0	41	49	32	16	0	5	142
3/20/73 02:00	120									0	30	22	13	0	4	69
3/20/73 06:00	124										0	14	9	0	3	26
3/20/73 10:00	128											0	6	0	2	8
3/20/73 14:00	132												0	0	2	2
3/20/73 18:00	136													0	1	1
3/20/73 22:00	140														0	0
3/21/73 02:00	144															0
3/21/73 06:00	148															0
3/21/73 10:00	152															0
3/21/73 14:00	156															0
3/21/73 18:00	160															0
3/21/73 22:00	164															0
3/22/73 02:00	168															0
3/22/73 06:00	172															0
3/22/73 10:00	176															0

Table 25: Subbasin 64 Convolution for March 1973 Flood

Date	Time	6hr UH	Rainfall Excess, inches								Q
	hrs	cfs/in	0.36	0.25	1.58	2.56	0.93	0.43	0.04	0.00	cfs
3/15/73 12:00	0	0	0								0
3/15/73 18:00	6	348	125	0							125
3/16/73 00:00	12	1043	375	87	0						462
3/16/73 06:00	18	3043	1095	261	550	0					1906
3/16/73 12:00	24	5913	2129	761	1648	891	0				5428
3/16/73 18:00	30	2956	1064	1478	4808	2670	324	0			10344
3/17/73 00:00	36	1043	375	739	9343	7790	970	150	0		19367
3/17/73 06:00	42	609	219	261	4670	15137	2830	448	14	0	23580
3/17/73 12:00	48	348	125	152	1648	7567	5499	1308	42	0	16342
3/17/73 18:00	54	174	63	87	962	2670	2749	2543	122	0	9195
3/18/73 00:00	60	87	31	44	550	1559	970	1271	237	0	4661
3/18/73 06:00	66	43	15	22	275	891	566	448	118	0	2336
3/18/73 12:00	72	0	0	11	137	445	324	262	42	0	1221
3/18/73 18:00	78		0	0	68	223	162	150	24	0	626
3/19/73 00:00	84			0	0	110	81	75	14	0	280
3/19/73 06:00	90				0	0	40	37	7	0	84
3/19/73 12:00	96					0	0	18	3	0	22
3/19/73 18:00	102						0	0	2	0	2
3/20/73 00:00	108							0	0	0	0
3/20/73 06:00	114								0	0	0
3/20/73 12:00	120									0	0
3/20/73 18:00	126										0
3/21/73 00:00	132										0
3/21/73 06:00	138										0
3/21/73 12:00	144										0
3/21/73 18:00	150										0
3/22/73 00:00	156										0
3/22/73 06:00	162										0
3/22/73 12:00	168										0
3/22/73 18:00	174										0
3/23/73 00:00	180										0
3/23/73 06:00	186										0

Table 26: Subbasin 65 Convolution for March 1973 Flood

Date	Time	6hr UH	Rainfall Excess, Inches								Q
	hrs	cfs/in	0.10	0.20	1.50	2.34	1.34	0.50	0.04	0.00	cfs
3/15/73 12:00	0	0	0								0
3/15/73 15:00	3	8130	813								813
3/15/73 18:00	6	21849	2185	0							2185
3/15/73 21:00	9	37601	3760	1626							5386
3/16/73 00:00	12	46747	4675	4370	0						9045
3/16/73 03:00	15	41158	4116	7520	12195						23831
3/16/73 06:00	18	33536	3354	9349	32774	0					45477
3/16/73 09:00	21	25406	2541	8232	56402	19024					86198
3/16/73 12:00	24	18800	1880	6707	70121	51127	0				129834
3/16/73 15:00	27	14227	1423	5081	61737	87986	10894				167121
3/16/73 18:00	30	10670	1067	3760	50304	109388	29278	0			193797
3/16/73 21:00	33	7825	783	2845	38109	96310	50385	4065			192497
3/17/73 00:00	36	6097	610	2134	28200	78474	62641	10925	0		182983
3/17/73 03:00	39	4776	478	1565	21341	59450	55152	18801	325		157111
3/17/73 06:00	42	3862	386	1219	16005	43992	44938	23374	874	0	130788
3/17/73 09:00	45	3354	335	955	11738	33291	34044	20579	1504	0	102446
3/17/73 12:00	48	2845	285	772	9146	24968	25192	16768	1870	0	79000
3/17/73 15:00	51	2439	244	671	7164	18311	19064	12703	1646	0	59803
3/17/73 18:00	54	2032	203	569	5793	14267	14298	9400	1341	0	45871
3/17/73 21:00	57	1524	152	488	5031	11176	10486	7114	1016	0	35462
3/18/73 00:00	60	1270	127	406	4268	9037	8170	5335	752	0	28095
3/18/73 03:00	63	1016	102	305	3659	7848	6400	3913	569	0	22795
3/18/73 06:00	66	762	76	254	3048	6657	5175	3049	427	0	18686
3/18/73 09:00	69	508	51	203	2286	5707	4494	2388	313	0	15443
3/18/73 12:00	72	305	31	152	1905	4755	3812	1931	244	0	12830
3/18/73 15:00	75	102	10	102	1524	3566	3268	1677	191	0	10338
3/18/73 18:00	78	0	0	61	1143	2972	2723	1423	154	0	8476
3/18/73 21:00	81		0	20	762	2377	2042	1220	134	0	6556
3/19/73 00:00	84		0	0	458	1783	1702	1016	114	0	5072
3/19/73 03:00	87		0	0	153	1189	1361	762	98	0	3563
3/19/73 06:00	90		0	0	0	714	1021	635	81	0	2451
3/19/73 09:00	93			0	0	239	681	508	61	0	1488
3/19/73 12:00	96			0	0	0	409	381	51	0	840
3/19/73 15:00	99				0	0	137	254	41	0	431
3/19/73 18:00	102				0	0	0	153	30	0	183
3/19/73 21:00	105					0	0	51	20	0	71
3/20/73 00:00	108					0	0	0	12	0	12
3/20/73 03:00	111						0	0	4	0	4
3/20/73 06:00	114						0	0	0	0	0
3/20/73 09:00	117							0	0	0	0
3/20/73 12:00	120							0	0	0	0
3/20/73 15:00	123								0	0	0
3/20/73 18:00	126								0	0	0
3/20/73 21:00	129									0	0
3/21/73 00:00	132									0	0
3/21/73 03:00	135										0
3/21/73 06:00	138										0
3/21/73 09:00	141										0
3/21/73 12:00	144										0
3/21/73 15:00	147										0
3/21/73 18:00	150										0
3/21/73 21:00	153										0
3/22/73 00:00	156										0
3/22/73 03:00	159										0
3/22/73 06:00	162										0
3/22/73 09:00	165										0
3/22/73 12:00	168										0
3/22/73 15:00	171										0
3/22/73 18:00	174										0
3/22/73 21:00	177										0
3/23/73 00:00	180										0
3/23/73 03:00	183										0
3/23/73 06:00	186										0
3/23/73 09:00	189										0
3/23/73 12:00	192										0
3/23/73 15:00	195										0
3/23/73 18:00	198										0
3/23/73 21:00	201										0

Table 27: Subbasin 51 Convolution for December 2004 Flood

Date	Time	6hr UH	Rainfall Excess, inches																				Q
	hrs	cfs/in	0.43	0.32	0.98	0.63	0.13	0.56	0.00	0.00	0.00	0.00	0.00	0.00	0.17	1.95	0.22	0.00	0.00	0.00	0.03	0.01	cfs
12/5/04 23:00	0	0	0																				0
12/6/04 05:00	6	177	76	0																			76
12/6/04 11:00	12	3429	1474	57	0																		1,531
12/6/04 17:00	18	11363	4886	1097	173	0																	6,157
12/6/04 23:00	24	5284	2272	3636	3360	112	0																9,380
12/7/04 05:00	30	4385	1886	1691	11136	2160	23	0															16,895
12/7/04 11:00	36	3486	1499	1403	5178	7159	446	99	0														15,784
12/7/04 17:00	42	2205	948	1116	4297	3329	1477	1920	0	0													13,087
12/7/04 23:00	48	923	397	706	3416	2763	687	6363	0	0	0												14,332
12/8/04 05:00	54	808	347	295	2161	2196	570	2959	0	0	0	0											8,529
12/8/04 11:00	60	694	298	259	905	1389	453	2456	0	0	0	0	0										5,759
12/8/04 17:00	66	580	249	222	792	581	287	1952	0	0	0	0	0	0									4,084
12/8/04 23:00	72	466	200	186	680	509	120	1235	0	0	0	0	0	0	0								2,930
12/9/04 05:00	78	352	151	149	568	437	105	517	0	0	0	0	0	0	30	0							1,958
12/9/04 11:00	84	238	102	113	457	365	90	452	0	0	0	0	0	0	583	345	0						2,508
12/9/04 17:00	90	123	53	76	345	294	75	389	0	0	0	0	0	0	1932	6687	39	0					9,889
12/9/04 23:00	96	20	9	39	233	222	61	325	0	0	0	0	0	0	898	22158	754	0	0				24,699
12/10/04 05:00	102	0	0	6	121	150	46	261	0	0	0	0	0	0	745	10304	2500	0	0	0			14,133
12/10/04 11:00	108			0	20	77	31	197	0	0	0	0	0	0	593	8551	1162	0	0	0	0		10,631
12/10/04 17:00	114				0	13	16	133	0	0	0	0	0	0	375	6798	965	0	0	0	5	0	8,304
12/10/04 23:00	120					0	3	69	0	0	0	0	0	0	157	4300	767	0	0	0	103	2	5,400
12/11/04 05:00	126						0	11	0	0	0	0	0	0	137	1800	485	0	0	0	341	34	2,809
12/11/04 11:00	132							0	0	0	0	0	0	0	118	1576	203	0	0	0	159	114	2,169
12/11/04 17:00	138								0	0	0	0	0	0	99	1353	178	0	0	0	132	53	1,814
12/11/04 23:00	144									0	0	0	0	0	79	1131	153	0	0	0	105	44	1,511
12/12/04 05:00	150										0	0	0	0	60	909	128	0	0	0	66	35	1,197
12/12/04 11:00	156											0	0	0	40	686	103	0	0	0	28	22	879
12/12/04 17:00	162												0	0	21	464	77	0	0	0	24	9	596
12/12/04 23:00	168													0	3	240	52	0	0	0	21	8	325
12/13/04 05:00	174														0	39	27	0	0	0	17	7	90
12/13/04 11:00	180															0	4	0	0	0	14	6	24
12/13/04 17:00	186																0	0	0	0	11	5	15
12/13/04 23:00	192																	0	0	0	7	4	11
12/14/04 05:00	198																		0	0	4	2	6
12/14/04 11:00	204																			0	1	1	2
12/14/04 17:00	210																				0	0	0
12/14/04 23:00	216																					0	0
12/15/04 05:00	222																						0

Table 28: Subbasin 52 Convolution for December 2004 Flood

Date	Time	6hr UH															Rainfall Excess, inches						Q
	hrs	cfs/in	0.27	0.33	0.32	0.51	0.03	0.41	0.00	0.00	0.00	0.00	0.00	0.00	0.31	1.25	0.09	0.00	0.01	0.00	0.07	0.01	cfs
12/5/04 23:00	0	0	0																				0
12/6/04 05:00	6	140	38	0																			38
12/6/04 11:00	12	870	235	46	0																		281
12/6/04 17:00	18	2501	675	287	45	0																	1007
12/6/04 23:00	24	6103	1648	825	278	71	0																2823
12/7/04 05:00	30	2501	675	2014	800	444	4	0															3937
12/7/04 11:00	36	1171	316	825	1953	1276	26	57	0														4453
12/7/04 17:00	42	670	181	386	800	3113	75	357	0	0													4912
12/7/04 23:00	48	425	115	221	375	1276	183	1025	0	0	0												3195
12/8/04 05:00	54	250	68	140	214	597	75	2502	0	0	0	0											3597
12/8/04 11:00	60	150	41	83	136	342	35	1025	0	0	0	0	0										1661
12/8/04 17:00	66	70	19	50	80	217	20	480	0	0	0	0	0	0									865
12/8/04 23:00	72	0	0	23	48	128	13	275	0	0	0	0	0	0	0								486
12/9/04 05:00	78		0	0	22	77	8	174	0	0	0	0	0	0	43	0							324
12/9/04 11:00	84			0	0	36	5	103	0	0	0	0	0	0	270	175	0						587
12/9/04 17:00	90				0	0	2	62	0	0	0	0	0	0	775	1088	13	0					1939
12/9/04 23:00	96					0	0	29	0	0	0	0	0	0	1892	3126	78	0	0				5125
12/10/04 05:00	102						0	0	0	0	0	0	0	0	775	7629	225	0	1	0			8631
12/10/04 11:00	108							0	0	0	0	0	0	0	363	3126	549	0	9	0	0		4047
12/10/04 17:00	114								0	0	0	0	0	0	208	1464	225	0	25	0	10	0	1931
12/10/04 23:00	120									0	0	0	0	0	132	838	105	0	61	0	61	1	1198
12/11/04 05:00	126										0	0	0	0	78	531	60	0	25	0	175	9	878
12/11/04 11:00	132											0	0	0	47	313	38	0	12	0	427	25	861
12/11/04 17:00	138												0	0	22	188	23	0	7	0	175	61	474
12/11/04 23:00	144													0	0	88	14	0	4	0	82	25	212
12/12/04 05:00	150														0	0	6	0	2	0	47	12	67
12/12/04 11:00	156															0	0	0	1	0	30	7	38
12/12/04 17:00	162																0	0	1	0	18	4	22
12/12/04 23:00	168																	0	0	0	11	2	13
12/13/04 05:00	174																		0	0	5	1	6
12/13/04 11:00	180																			0	0	1	1
12/13/04 17:00	186																				0	0	0
12/13/04 23:00	192																					0	0
12/14/04 05:00	198																						

Table 29: Subbasin 54 Convolution for December 2004 Flood

Date	Time	6hr UH	Rainfall Excess, inches																				Q
	hrs	cfs/in	0.46	0.41	0.68	0.47	0.12	0.54	0.00	0.00	0.00	0.00	0.00	0.00	0.64	1.49	0.07	0.00	0.00	0.00	0.05	0.01	cfs
12/5/04 23:00	0	0	0																				0
12/6/04 05:00	6	498	229	0																			229
12/6/04 11:00	12	1791	824	204	0																		1028
12/6/04 17:00	18	4678	2152	734	339	0																	3225
12/6/04 23:00	24	7962	3663	1918	1218	234	0																7032
12/7/04 05:00	30	4678	2152	3264	3181	842	60	0															9499
12/7/04 11:00	36	1990	915	1918	5414	2199	215	269	0														10930
12/7/04 17:00	42	995	458	816	3181	3742	561	967	0	0													9725
12/7/04 23:00	48	597	275	408	1353	2199	955	2526	0	0	0												7716
12/8/04 05:00	54	398	183	245	677	935	561	4299	0	0	0	0											6901
12/8/04 11:00	60	299	138	163	406	468	239	2526	0	0	0	0	0										3939
12/8/04 17:00	66	199	92	123	271	281	119	1075	0	0	0	0	0	0									1959
12/8/04 23:00	72	100	46	82	203	187	72	537	0	0	0	0	0	0	0								1127
12/9/04 05:00	78	0	0	41	135	141	48	322	0	0	0	0	0	0	319	0							1006
12/9/04 11:00	84			0	68	94	36	215	0	0	0	0	0	0	1146	742	0						2301
12/9/04 17:00	90				0	47	24	161	0	0	0	0	0	0	2994	2669	35	0					5930
12/9/04 23:00	96					0	12	107	0	0	0	0	0	0	5096	6970	125	0	0				12311
12/10/04 05:00	102						0	54	0	0	0	0	0	0	2994	11863	327	0	0	0			15239
12/10/04 11:00	108							0	0	0	0	0	0	0	1274	6970	557	0	0	0	0		8801
12/10/04 17:00	114								0	0	0	0	0	0	637	2965	327	0	0	0	25	0	3954
12/10/04 23:00	120									0	0	0	0	0	382	1483	139	0	0	0	90	5	2098
12/11/04 05:00	126										0	0	0	0	255	890	70	0	0	0	234	18	1466
12/11/04 11:00	132											0	0	0	191	593	42	0	0	0	398	47	1271
12/11/04 17:00	138												0	0	127	446	28	0	0	0	234	80	914
12/11/04 23:00	144													0	64	297	21	0	0	0	99	47	528
12/12/04 05:00	150														0	149	14	0	0	0	50	20	233
12/12/04 11:00	156															0	7	0	0	0	30	10	47
12/12/04 17:00	162																0	0	0	0	20	6	26
12/12/04 23:00	168																	0	0	0	15	4	19
12/13/04 05:00	174																		0	0	10	3	13
12/13/04 11:00	180																			0	5	2	7
12/13/04 17:00	186																				0	1	1
12/13/04 23:00	192																					0	0
12/14/04 05:00	198																						

Table 30: Subbasin 55 Convolution for December 2004 Flood

Date	Time	6hr UH	Rainfall Excess, inches																			Q
	hrs	cfs/in	0.11	0.19	0.16	0.40	0.02	0.42	0.00	0.00	0.00	0.00	0.00	0.00	0.19	1.28	0.06	0.00	0.04	0.00	0.02	cfs
12/5/04 23:00	0	0	0																			0
12/6/04 05:00	6	253	28	0																		28
12/6/04 11:00	12	1461	161	48	0																	209
12/6/04 17:00	18	3174	349	278	40	0																667
12/6/04 23:00	24	2803	308	603	234	101	0															1,246
12/7/04 05:00	30	1850	204	533	508	584	5	0														1,833
12/7/04 11:00	36	1413	155	352	448	1270	29	106	0													2,360
12/7/04 17:00	42	1045	115	268	296	1121	63	614	0	0												2,478
12/7/04 23:00	48	750	83	199	226	740	56	1333	0	0	0											2,636
12/8/04 05:00	54	556	61	143	167	565	37	1177	0	0	0	0										2,150
12/8/04 11:00	60	440	48	106	120	418	28	777	0	0	0	0	0									1,497
12/8/04 17:00	66	324	36	84	89	300	21	593	0	0	0	0	0	0								1,123
12/8/04 23:00	72	208	23	62	70	222	15	439	0	0	0	0	0	0	0							831
12/9/04 05:00	78	166	18	40	52	176	11	315	0	0	0	0	0	0	48	0						660
12/9/04 11:00	84	124	14	32	33	130	9	234	0	0	0	0	0	0	278	324	0					1,052
12/9/04 17:00	90	82	9	24	27	83	6	185	0	0	0	0	0	0	603	1870	15	0				2,822
12/9/04 23:00	96	0	0	16	20	66	4	136	0	0	0	0	0	0	533	4063	88	0	0			4,925
12/10/04 05:00	102		0	0	13	50	3	87	0	0	0	0	0	0	352	3588	190	0	10	0		4,293
12/10/04 11:00	108			0	0	33	2	70	0	0	0	0	0	0	268	2368	168	0	58	0	0	2,968
12/10/04 17:00	114				0	0	2	52	0	0	0	0	0	0	199	1809	111	0	127	0	5	2,304
12/10/04 23:00	120					0	0	34	0	0	0	0	0	0	143	1338	85	0	112	0	29	1,741
12/11/04 05:00	126						0	0	0	0	0	0	0	0	106	960	63	0	74	0	63	1,266
12/11/04 11:00	132							0	0	0	0	0	0	0	84	712	45	0	57	0	56	953
12/11/04 17:00	138								0	0	0	0	0	0	62	563	33	0	42	0	37	737
12/11/04 23:00	144									0	0	0	0	0	40	415	26	0	30	0	28	539
12/12/04 05:00	150										0	0	0	0	32	266	19	0	22	0	21	360
12/12/04 11:00	156											0	0	0	24	212	12	0	18	0	15	281
12/12/04 17:00	162												0	0	16	159	10	0	13	0	11	208
12/12/04 23:00	168													0	0	105	7	0	8	0	9	130
12/13/04 05:00	174														0	0	5	0	7	0	6	18
12/13/04 11:00	180															0	0	0	5	0	4	9
12/13/04 17:00	186																0	0	3	0	3	7
12/13/04 23:00	192																	0	0	0	2	2
12/14/04 05:00	198																		0	0	2	2
12/14/04 11:00	204																			0	0	0
12/14/04 17:00	210																				0	0

Table 31: Subbasin 56 Convolution for December 2004 Flood

Date	Time	6hr UH	Rainfall Excess, inches																			Q
	hrs	cfs/in	0.23	0.32	0.23	0.47	0.08	0.49	0.00	0.00	0.00	0.00	0.00	0.00	0.44	1.15	0.09	0.00	0.00	0.00	0.01	cfs
12/5/04 23:00	0	0	0																			0
12/6/04 05:00	6	94	22	0																		22
12/6/04 11:00	12	425	98	30	0																	128
12/6/04 17:00	18	1416	326	136	22	0																483
12/6/04 23:00	24	2644	608	453	98	44	0															1203
12/7/04 05:00	30	1955	450	846	326	200	8	0														1829
12/7/04 11:00	36	1360	313	626	608	666	34	46	0													2292
12/7/04 17:00	42	944	217	435	450	1243	113	208	0	0												2666
12/7/04 23:00	48	689	158	302	313	919	212	694	0	0	0											2598
12/8/04 05:00	54	491	113	220	217	639	156	1296	0	0	0	0										2642
12/8/04 11:00	60	359	83	157	158	444	109	958	0	0	0	0	0									1909
12/8/04 17:00	66	255	59	115	113	324	76	666	0	0	0	0	0	0								1352
12/8/04 23:00	72	161	37	82	83	231	55	463	0	0	0	0	0	0	0							950
12/9/04 05:00	78	76	17	52	59	169	39	338	0	0	0	0	0	0	41	0						715
12/9/04 11:00	84	0	0	24	37	120	29	241	0	0	0	0	0	0	187	108	0					746
12/9/04 17:00	90		0	0	17	76	20	176	0	0	0	0	0	0	623	489	8	0				1410
12/9/04 23:00	96			0	0	36	13	125	0	0	0	0	0	0	1163	1628	38	0	0			3004
12/10/04 05:00	102				0	0	6	79	0	0	0	0	0	0	860	3041	127	0	0	0		4113
12/10/04 11:00	108					0	0	37	0	0	0	0	0	0	598	2248	238	0	0	0	0	3122
12/10/04 17:00	114						0	0	0	0	0	0	0	0	415	1564	176	0	0	0	1	2156
12/10/04 23:00	120							0	0	0	0	0	0	0	303	1086	122	0	0	0	4	1515
12/11/04 05:00	126								0	0	0	0	0	0	216	792	85	0	0	0	14	1108
12/11/04 11:00	132									0	0	0	0	0	158	565	62	0	0	0	26	811
12/11/04 17:00	138										0	0	0	0	112	413	44	0	0	0	20	589
12/11/04 23:00	144											0	0	0	71	293	32	0	0	0	14	410
12/12/04 05:00	150												0	0	33	185	23	0	0	0	9	251
12/12/04 11:00	156													0	0	87	14	0	0	0	7	109
12/12/04 17:00	162														0	0	7	0	0	0	5	12
12/12/04 23:00	168															0	0	0	0	0	4	4
12/13/04 05:00	174																0	0	0	0	3	3
12/13/04 11:00	180																	0	0	0	2	2
12/13/04 17:00	186																		0	0	1	1
12/13/04 23:00	192																			0	0	0
12/14/04 05:00	198																				0	0

Table 32: Subbasin 58 Convolution for December 2004 Flood

Date	Time	6hr UH	Rainfall Excess, inches																			Q
	hrs	cfs/in	0.31	0.11	0.81	0.54	0.16	0.81	0.00	0.00	0.00	0.00	0.00	0.00	0.24	1.44	0.02	0.00	0.00	0.00	0.01	cfs
12/5/04 22:00	0	0	0																			0
12/6/04 04:00	6	3156	978	0																		978
12/6/04 10:00	12	6407	1986	347	0																	2333
12/6/04 16:00	18	3203	993	705	2556	0																4254
12/6/04 22:00	24	1696	526	352	5190	1704	0															7772
12/7/04 04:00	30	1055	327	187	2594	3460	505	0														7073
12/7/04 10:00	36	754	234	116	1374	1730	1025	2556	0													7035
12/7/04 16:00	42	471	146	83	855	916	512	5190	0	0												7701
12/7/04 22:00	48	188	58	52	611	570	271	2594	0	0	0											4156
12/8/04 04:00	54	0	0	21	382	407	169	1374	0	0	0	0										2352
12/8/04 10:00	60		0	0	152	254	121	855	0	0	0	0	0									1382
12/8/04 16:00	66		0	0	0	102	75	611	0	0	0	0	0	0								788
12/8/04 22:00	72		0	0	0	0	30	382	0	0	0	0	0	0	0							412
12/9/04 04:00	78		0	0	0	0	0	152	0	0	0	0	0	0	757	0						910
12/9/04 10:00	84			0	0	0	0	0	0	0	0	0	0	0	1538	4545	0					6082
12/9/04 16:00	90				0	0	0	0	0	0	0	0	0	0	769	9226	63	0				10058
12/9/04 22:00	96					0	0	0	0	0	0	0	0	0	407	4612	128	0	0			5148
12/10/04 04:00	102						0	0	0	0	0	0	0	0	253	2442	64	0	0	0		2760
12/10/04 10:00	108							0	0	0	0	0	0	0	181	1519	34	0	0	0	0	1734
12/10/04 16:00	114								0	0	0	0	0	0	113	1086	21	0	0	0	32	1251
12/10/04 22:00	120									0	0	0	0	0	45	678	15	0	0	0	64	803
12/11/04 04:00	126										0	0	0	0	0	271	9	0	0	0	32	312
12/11/04 10:00	132											0	0	0	0	0	4	0	0	0	17	21
12/11/04 16:00	138												0	0	0	0	0	0	0	0	11	11
12/11/04 22:00	144													0	0	0	0	0	0	0	8	8
12/12/04 04:00	150														0	0	0	0	0	0	5	5
12/12/04 10:00	156															0	0	0	0	0	2	2
12/12/04 16:00	162																0	0	0	0	0	0
12/12/04 22:00	168																	0	0	0	0	0
12/13/04 04:00	174																		0	0	0	0
12/13/04 10:00	180																			0	0	0
12/13/04 16:00	186																				0	0

Table 33: Subbasin 63 Convolution for December 2004 Flood

Date	Time	4hr UH	Rainfall Excess, Inches																						Q
	hrs	cfs/in	0.11	0.01	0.17	0.30	0.45	0.39	0.25	0.55	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.74	0.70	0.01	cfs
12/5/04 22:00	0	0	0																						0
12/6/04 02:00	4	382	42	0																					42
12/6/04 06:00	8	2509	276	4	0																				280
12/6/04 10:00	12	5023	553	25	65	0																			643
12/6/04 14:00	16	8512	936	50	427	115	0																		1528
12/6/04 18:00	20	3897	429	85	854	753	172	0																	2292
12/6/04 22:00	24	2402	264	39	1447	1507	1129	149	0																4535
12/7/04 02:00	28	1449	159	24	662	2554	2260	979	96	0															6734
12/7/04 06:00	32	1024	113	14	408	1169	3830	1959	627	210	0														8331
12/7/04 10:00	36	723	80	10	246	721	1754	3320	1256	1380	11	0													8777
12/7/04 14:00	40	545	60	7	174	435	1081	1520	2128	2763	75	0	0												8243
12/7/04 18:00	44	466	51	5	123	307	652	937	974	4682	151	0	0	0											7882
12/7/04 22:00	48	387	43	5	93	217	461	565	601	2143	255	0	0	0	0										4382
12/8/04 02:00	52	306	34	4	79	164	325	399	362	1321	117	0	0	0	0	0									2805
12/8/04 06:00	56	227	25	3	66	140	245	282	256	797	72	0	0	0	0	0	0								1886
12/8/04 10:00	60	147	16	2	52	116	210	213	181	563	43	0	0	0	0	0	0	0							1396
12/8/04 14:00	64	130	14	1	39	92	174	182	136	398	31	0	0	0	0	0	0	0	0						1067
12/8/04 18:00	68	113	12	1	25	68	138	151	117	300	22	0	0	0	0	0	0	0	0	0					833
12/8/04 22:00	72	95	10	1	22	44	102	119	97	256	16	0	0	0	0	0	0	0	0	0	0				669
12/9/04 02:00	76	78	9	1	19	39	66	89	77	213	14	0	0	0	0	0	0	0	0	0	11	0			537
12/9/04 06:00	80	62	7	1	16	34	59	57	57	168	12	0	0	0	0	0	0	0	0	0	75	283	0		768
12/9/04 10:00	84	44	5	1	13	29	51	51	37	125	9	0	0	0	0	0	0	0	0	0	151	1857	267	0	2594
12/9/04 14:00	88	27	3	0	11	23	43	44	33	81	7	0	0	0	0	0	0	0	0	0	255	3717	1756	4	5977
12/9/04 18:00	92	0	0	0	7	19	35	37	28	72	4	0	0	0	0	0	0	0	0	0	117	6299	3516	25	10160
12/9/04 22:00	96			0	5	13	28	30	24	62	4	0	0	0	0	0	0	0	0	0	72	2884	5958	50	9130
12/10/04 02:00	100				0	8	20	24	20	52	3	0	0	0	0	0	0	0	0	0	43	1777	2728	85	4761
12/10/04 06:00	104					0	12	17	16	43	3	0	0	0	0	0	0	0	0	0	31	1072	1681	39	2914
12/10/04 10:00	108						0	11	11	34	2	0	0	0	0	0	0	0	0	0	22	758	1014	24	1876
12/10/04 14:00	112							0	7	24	2	0	0	0	0	0	0	0	0	0	16	535	717	14	1315
12/10/04 18:00	116								0	15	1	0	0	0	0	0	0	0	0	0	14	403	506	10	950
12/10/04 22:00	120									0	1	0	0	0	0	0	0	0	0	0	12	345	382	7	746
12/11/04 02:00	124										0	0	0	0	0	0	0	0	0	0	9	286	326	5	627
12/11/04 06:00	128											0	0	0	0	0	0	0	0	0	7	226	271	5	509
12/11/04 10:00	132												0	0	0	0	0	0	0	0	4	168	214	4	390
12/11/04 14:00	136													0	0	0	0	0	0	0	4	109	159	3	275
12/11/04 18:00	140														0	0	0	0	0	0	3	96	103	2	205
12/11/04 22:00	144															0	0	0	0	0	3	84	91	1	179
12/12/04 02:00	148																0	0	0	0	2	70	79	1	153
12/12/04 06:00	152																	0	0	0	2	58	67	1	127
12/12/04 10:00	156																		0	0	1	46	55	1	103
12/12/04 14:00	160																			0	1	33	43	1	78
12/12/04 18:00	164																				0	20	31	1	51
12/12/04 22:00	168																					0	19	0	19
12/13/04 02:00	172																						0	0	0
12/13/04 06:00	176																							0	0

Table 34: Subbasin 64 Convolution for December 2004 Flood

Date	Time	6hr UH	Rainfall Excess, inches															Q
	hrs	cfs/in	0.16	0.06	0.57	0.73	0.50	0.57	0.00	0.00	0.00	0.00	0.00	0.00	0.02	1.00	0.37	cfs
12/5/04 20:00	0	0	0															0
12/6/04 02:00	6	348	56	0														56
12/6/04 08:00	12	1043	167	21	0													188
12/6/04 14:00	18	3043	487	63	198	0												748
12/6/04 20:00	24	5913	946	183	595	254	0											1977
12/7/04 02:00	30	2956	473	355	1735	761	174	0										3498
12/7/04 08:00	36	1043	167	177	3370	2221	522	198	0									6656
12/7/04 14:00	42	609	97	63	1685	4316	1522	595	0	0								8277
12/7/04 20:00	48	348	56	37	595	2158	2957	1735	0	0	0							7536
12/8/04 02:00	54	174	28	21	347	761	1478	3370	0	0	0	0						6006
12/8/04 08:00	60	87	14	10	198	445	522	1685	0	0	0	0	0					2874
12/8/04 14:00	66	43	7	5	99	254	305	595	0	0	0	0	0	0				1264
12/8/04 20:00	72	0	0	3	50	127	174	347	0	0	0	0	0	0	0			700
12/9/04 02:00	78		0	0	25	64	87	198	0	0	0	0	0	0	7	0		380
12/9/04 08:00	84			0	0	31	44	99	0	0	0	0	0	0	21	348	0	543
12/9/04 14:00	90				0	0	22	50	0	0	0	0	0	0	61	1043	129	1304
12/9/04 20:00	96					0	0	25	0	0	0	0	0	0	118	3043	386	3572
12/10/04 02:00	102						0	0	0	0	0	0	0	0	59	5913	1126	7098
12/10/04 08:00	108							0	0	0	0	0	0	0	21	2956	2188	5165
12/10/04 14:00	114								0	0	0	0	0	0	12	1043	1094	2149
12/10/04 20:00	120									0	0	0	0	0	7	609	386	1002
12/11/04 02:00	126										0	0	0	0	3	348	225	577
12/11/04 08:00	132											0	0	0	2	174	129	305
12/11/04 14:00	138												0	0	1	87	64	152
12/11/04 20:00	144													0	0	43	32	75
12/12/04 02:00	150														0	0	16	16
12/12/04 08:00	156															0	0	0
12/12/04 14:00	162																0	0
12/12/04 20:00	168																	0
12/13/04 02:00	174																	0
12/13/04 08:00	180																	0
12/13/04 14:00	186																	0

Table 35: Subbasin 65 Convolution for December 2004 Flood

Date	Time	6hr UH	Rainfall Excess, inches															Q
	hrs	cfs/in	0.26	0.18	0.50	0.51	0.15	0.64	0.00	0.00	0.00	0.00	0.00	0.00	0.22	1.42	0.05	cfs
12/5/04 22:00	0	0	0															0
12/6/04 01:00	3	8130	2114															2114
12/6/04 04:00	6	21849	5681	0														5681
12/6/04 07:00	9	37601	9776	1463														11240
12/6/04 10:00	12	46747	12154	3933	0													16087
12/6/04 13:00	15	41158	10701	6768	4065													21534
12/6/04 16:00	18	33536	8719	8414	10925	0												28058
12/6/04 19:00	21	25406	6606	7408	18801	4146												36961
12/6/04 22:00	24	18800	4888	6036	23374	11143	0											45441
12/7/04 01:00	27	14227	3699	4573	20579	19177	1220											49247
12/7/04 04:00	30	10670	2774	3384	16768	23841	3277	0										50045
12/7/04 07:00	33	7825	2035	2561	12703	20991	5640	5203										49132
12/7/04 10:00	36	6097	1585	1921	9400	17103	7012	13983	0									51005
12/7/04 13:00	39	4776	1242	1409	7114	12957	6174	24065	0									52959
12/7/04 16:00	42	3862	1004	1097	5335	9588	5030	29918	0	0								51973
12/7/04 19:00	45	3354	872	860	3913	7256	3811	26341	0	0								43052
12/7/04 22:00	48	2845	740	695	3049	5442	2820	21463	0	0	0							34208
12/8/04 01:00	51	2439	634	604	2388	3991	2134	16260	0	0	0							26011
12/8/04 04:00	54	2032	528	512	1931	3109	1601	12032	0	0	0	0						19713
12/8/04 07:00	57	1524	396	439	1677	2436	1174	9105	0	0	0	0						15227
12/8/04 10:00	60	1270	330	366	1423	1970	915	6829	0	0	0	0	0					11831
12/8/04 13:00	63	1016	264	274	1220	1711	716	5008	0	0	0	0	0					9193
12/8/04 16:00	66	762	198	229	1016	1451	579	3902	0	0	0	0	0	0				7375
12/8/04 19:00	69	508	132	183	762	1244	503	3057	0	0	0	0	0	0				5881
12/8/04 22:00	72	305	79	137	635	1036	427	2472	0	0	0	0	0	0	0			4786
12/9/04 01:00	75	102	27	91	508	777	366	2147	0	0	0	0	0	0	1789			5704
12/9/04 04:00	78	0	0	55	381	648	305	1821	0	0	0	0	0	0	4807	0		8016
12/9/04 07:00	81		0	18	254	518	229	1561	0	0	0	0	0	0	8272	11545		22397
12/9/04 10:00	84		0	0	153	389	191	1300	0	0	0	0	0	0	10284	31026	0	43342
12/9/04 13:00	87		0	0	51	259	152	975	0	0	0	0	0	0	9055	53393	407	64293
12/9/04 16:00	90		0	0	0	156	114	813	0	0	0	0	0	0	7378	66381	1092	75934
12/9/04 19:00	93			0	0	52	76	650	0	0	0	0	0	0	5589	58444	1880	66692
12/9/04 22:00	96			0	0	0	46	488	0	0	0	0	0	0	4136	47621	2337	54628
12/10/04 01:00	99				0	0	15	325	0	0	0	0	0	0	3130	36077	2058	41605
12/10/04 04:00	102				0	0	0	195	0	0	0	0	0	0	2347	26696	1677	30915
12/10/04 07:00	105					0	0	65	0	0	0	0	0	0	1722	20202	1270	23259
12/10/04 10:00	108					0	0	0	0	0	0	0	0	0	1341	15151	940	17433
12/10/04 13:00	111						0	0	0	0	0	0	0	0	1051	11112	711	12874
12/10/04 16:00	114						0	0	0	0	0	0	0	0	850	8658	534	10041
12/10/04 19:00	117							0	0	0	0	0	0	0	738	6782	391	7911
12/10/04 22:00	120							0	0	0	0	0	0	0	626	5484	305	6415
12/11/04 01:00	123								0	0	0	0	0	0	537	4763	239	5538
12/11/04 04:00	126								0	0	0	0	0	0	447	4040	193	4680
12/11/04 07:00	129									0	0	0	0	0	335	3463	168	3966
12/11/04 10:00	132									0	0	0	0	0	279	2885	142	3307
12/11/04 13:00	135										0	0	0	0	224	2164	122	2510
12/11/04 16:00	138										0	0	0	0	168	1803	102	2073
12/11/04 19:00	141											0	0	0	112	1443	76	1631
12/11/04 22:00	144											0	0	0	67	1082	64	1213
12/12/04 01:00	147												0	0	22	721	51	795
12/12/04 04:00	150												0	0	0	433	38	471
12/12/04 07:00	153													0	0	145	25	170
12/12/04 10:00	156													0	0	0	15	15
12/12/04 13:00	159														0	0	5	5
12/12/04 16:00	162														0	0	0	0
12/12/04 19:00	165															0	0	0
12/12/04 22:00	168															0	0	0
12/13/04 01:00	171																0	0
12/13/04 04:00	174																0	0
12/13/04 07:00	177																	0
12/13/04 10:00	180																	0
12/13/04 13:00	183																	0
12/13/04 16:00	186																	0
12/13/04 19:00	189																	0
12/13/04 22:00	192																	0
12/14/04 01:00	195																	0
12/14/04 04:00	198																	0
12/14/04 07:00	201																	0

7.3.2 Flow Series for Rainfall on Reservoirs

The hourly average flow series for rainfall on the reservoirs is developed by dividing the total volume of rain falling each hour [volume/hour] by 3,600 [seconds/hour]. The volume of rainfall falling each hour is obtained as the product of total surface area and the measured rainfall for each subbasin.

Calculations are presented in the spreadsheet "Wheeler_Reservoir_Rain.xls," provided as Attachment 1-14 to this calculation, and summarized in Tables 36 and 37.

Table 36: Calculation of Flow Series for Rainfall over Reservoir for March 1973 Storm

Mar-73				
Date and Time	Time, hours	Precipitation, in inches over Subbasin		Q (ft3/s)
		Cumulative	Increment	
3/15/73 0:00	1	0.00	0.00	0
3/15/73 1:00	2	0.00	0.00	0
3/15/73 2:00	3	0.00	0.00	0
3/15/73 3:00	4	0.00	0.00	0
3/15/73 4:00	5	0.00	0.00	0
3/15/73 5:00	6	0.25	0.25	14,886
3/15/73 6:00	7	0.41	0.16	9,261
3/15/73 7:00	8	0.41	0.00	0
3/15/73 8:00	9	0.41	0.00	0
3/15/73 9:00	10	0.43	0.02	1,360
3/15/73 10:00	11	0.57	0.13	7,708
3/15/73 11:00	12	0.65	0.08	4,652
3/15/73 12:00	13	0.67	0.02	1,360
3/15/73 13:00	14	0.73	0.06	3,358
3/15/73 14:00	15	0.73	0.00	26
3/15/73 15:00	16	0.94	0.22	12,761
3/15/73 16:00	17	1.12	0.18	10,513
3/15/73 17:00	18	1.48	0.36	21,207
3/15/73 18:00	19	1.73	0.25	14,422
3/15/73 19:00	20	2.31	0.58	33,885
3/15/73 20:00	21	2.89	0.58	34,304
3/15/73 21:00	22	3.24	0.34	20,109
3/15/73 22:00	23	3.58	0.34	19,895
3/15/73 23:00	24	3.80	0.23	13,263
3/16/73 0:00	25	4.08	0.28	16,505
3/16/73 1:00	26	4.56	0.48	28,163
3/16/73 2:00	27	5.36	0.80	46,908
3/16/73 3:00	28	6.16	0.80	46,960
3/16/73 4:00	29	6.85	0.68	40,174
3/16/73 5:00	30	7.15	0.31	17,908
3/16/73 6:00	31	7.24	0.09	5,349
3/16/73 7:00	32	7.36	0.11	6,557
3/16/73 8:00	33	7.63	0.27	16,009
3/16/73 9:00	34	7.74	0.11	6,541
3/16/73 10:00	35	7.91	0.17	9,805
3/16/73 11:00	36	8.20	0.29	16,960
3/16/73 12:00	37	8.31	0.12	6,810
3/16/73 13:00	38	8.32	0.01	523
3/16/73 14:00	39	8.32	0.00	2
3/16/73 15:00	40	8.32	0.00	5
3/16/73 16:00	41	8.33	0.01	515
3/16/73 17:00	42	8.33	0.00	1
3/16/73 18:00	43	8.34	0.01	517
3/16/73 19:00	44	8.36	0.02	1,138
3/16/73 20:00	45	8.37	0.01	517
3/16/73 21:00	46	8.37	0.00	0
3/16/73 22:00	47	8.38	0.01	515
3/16/73 23:00	48	8.38	0.00	1
3/17/73 0:00	49	8.38	0.00	1
3/17/73 1:00	50	8.38	0.00	0
3/17/73 2:00	51	8.38	0.00	0
3/17/73 3:00	52	8.38	0.00	0
3/17/73 4:00	53	8.38	0.00	0
3/17/73 5:00	54	8.38	0.00	0
3/17/73 6:00	55	8.38	0.00	0
3/17/73 7:00	56	8.38	0.00	0

Table 37: Calculation of Flow Series for Rainfall over Reservoir for December 2004 Storm

Date and Time	Time, hours	Precipitation, in inches		Q (ft3/s)
		Cumulative	Increment	
12/5/04 0:00	1	0.00	0.00	0
12/5/04 1:00	2	0.00	0.00	0
12/5/04 2:00	3	0.00	0.00	0
12/5/04 3:00	4	0.00	0.00	0
12/5/04 4:00	5	0.00	0.00	0
12/5/04 5:00	6	0.00	0.00	0
12/5/04 6:00	7	0.00	0.00	0
12/5/04 7:00	8	0.00	0.00	0
12/5/04 8:00	9	0.00	0.00	0
12/5/04 9:00	10	0.00	0.00	0
12/5/04 10:00	11	0.00	0.00	0
12/5/04 11:00	12	0.00	0.00	0
12/5/04 12:00	13	0.00	0.00	0
12/5/04 13:00	14	0.00	0.00	0
12/5/04 14:00	15	0.00	0.00	0
12/5/04 15:00	16	0.01	0.01	420
12/5/04 16:00	17	0.03	0.02	1,462
12/5/04 17:00	18	0.10	0.06	3,762
12/5/04 18:00	19	0.12	0.02	1,209
12/5/04 19:00	20	0.16	0.04	2,293
12/5/04 20:00	21	0.18	0.03	1,587
12/5/04 21:00	22	0.19	0.00	157
12/5/04 22:00	23	0.43	0.25	14,509
12/5/04 23:00	24	0.55	0.12	6,907
12/6/04 0:00	25	0.68	0.13	7,569
12/6/04 1:00	26	0.84	0.16	9,222
12/6/04 2:00	27	0.97	0.13	7,812
12/6/04 3:00	28	1.00	0.03	1,819
12/6/04 4:00	29	1.01	0.01	296
12/6/04 5:00	30	1.01	0.00	131
12/6/04 6:00	31	1.01	0.00	202
12/6/04 7:00	32	1.02	0.00	187
12/6/04 8:00	33	1.09	0.08	4,495
12/6/04 9:00	34	1.20	0.11	6,291
12/6/04 10:00	35	1.44	0.25	14,401
12/6/04 11:00	36	1.57	0.12	7,270
12/6/04 12:00	37	1.68	0.11	6,602
12/6/04 13:00	38	1.78	0.10	5,609
12/6/04 14:00	39	1.92	0.15	8,531
12/6/04 15:00	40	2.00	0.08	4,551
12/6/04 16:00	41	2.08	0.08	4,536
12/6/04 17:00	42	2.20	0.12	7,134
12/6/04 18:00	43	2.30	0.10	5,830
12/6/04 19:00	44	2.39	0.09	5,434
12/6/04 20:00	45	2.50	0.11	6,524
12/6/04 21:00	46	2.59	0.09	5,151
12/6/04 22:00	47	2.66	0.07	4,105
12/6/04 23:00	48	2.73	0.07	4,253
12/7/04 0:00	49	2.76	0.03	1,733
12/7/04 1:00	50	2.80	0.03	2,044
12/7/04 2:00	51	2.80	0.00	30
12/7/04 3:00	52	2.80	0.00	36
12/7/04 4:00	53	2.91	0.11	6,407
12/7/04 5:00	54	3.17	0.27	15,634
12/7/04 6:00	55	3.49	0.32	18,592
12/7/04 7:00	56	3.51	0.02	1,166
12/7/04 8:00	57	3.51	0.00	14
12/7/04 9:00	58	3.51	0.00	14
12/7/04 10:00	59	3.51	0.00	0
12/7/04 11:00	60	3.51	0.00	0
12/7/04 12:00	61	3.51	0.00	0
12/7/04 13:00	62	3.51	0.00	0
12/7/04 14:00	63	3.51	0.00	0
12/7/04 15:00	64	3.51	0.00	0
12/7/04 16:00	65	3.51	0.00	0
12/7/04 17:00	66	3.51	0.00	0
12/7/04 18:00	67	3.51	0.00	0
12/7/04 19:00	68	3.51	0.00	0
12/7/04 20:00	69	3.51	0.00	0
12/7/04 21:00	70	3.51	0.00	0
12/7/04 22:00	71	3.51	0.00	0
12/7/04 23:00	72	3.51	0.00	0
12/8/04 0:00	73	3.51	0.00	0
12/8/04 1:00	74	3.51	0.00	0
12/8/04 2:00	75	3.51	0.00	0
12/8/04 3:00	76	3.51	0.00	0
12/8/04 4:00	77	3.51	0.00	0
12/8/04 5:00	78	3.51	0.00	0
12/8/04 6:00	79	3.51	0.00	0
12/8/04 7:00	80	3.51	0.00	0
12/8/04 8:00	81	3.51	0.00	0
12/8/04 9:00	82	3.51	0.00	0
12/8/04 10:00	83	3.51	0.00	0
12/8/04 11:00	84	3.51	0.00	0
12/8/04 12:00	85	3.51	0.00	0
12/8/04 13:00	86	3.51	0.00	0
12/8/04 14:00	87	3.51	0.00	0
12/8/04 15:00	88	3.51	0.00	0
12/8/04 16:00	89	3.51	0.00	0
12/8/04 17:00	90	3.51	0.00	0
12/8/04 18:00	91	3.51	0.00	0
12/8/04 19:00	92	3.51	0.00	0
12/8/04 20:00	93	3.51	0.00	0
12/8/04 21:00	94	3.51	0.00	0
12/8/04 22:00	95	3.51	0.00	0
12/8/04 23:00	96	3.51	0.00	0
12/9/04 0:00	97	3.51	0.00	117
12/9/04 1:00	98	3.53	0.01	742
12/9/04 2:00	99	3.58	0.05	3,109
12/9/04 3:00	100	3.68	0.10	5,953
12/9/04 4:00	101	4.06	0.38	22,104
12/9/04 5:00	102	4.20	0.14	8,196
12/9/04 6:00	103	4.49	0.29	16,962
12/9/04 7:00	104	4.72	0.24	13,890
12/9/04 8:00	105	5.02	0.29	17,146
12/9/04 9:00	106	5.09	0.07	4,256
12/9/04 10:00	107	5.09	0.00	187
12/9/04 11:00	108	5.10	0.01	477
12/9/04 12:00	109	5.11	0.01	559
12/9/04 13:00	110	5.11	0.00	179
12/9/04 14:00	111	5.12	0.00	233
12/9/04 15:00	112	5.12	0.00	0
12/9/04 16:00	113	5.12	0.00	0
12/9/04 17:00	114	5.12	0.00	0
12/9/04 18:00	115	5.12	0.00	36
12/9/04 19:00	116	5.12	0.00	14
12/9/04 20:00	117	5.12	0.00	2
12/9/04 21:00	118	5.12	0.00	0
12/9/04 22:00	119	5.12	0.00	0
12/9/04 23:00	120	5.12	0.00	1
12/10/04 0:00	121	5.12	0.00	0
12/10/04 1:00	122	5.12	0.00	0
12/10/04 2:00	123	5.12	0.00	0
12/10/04 3:00	124	5.12	0.00	0
12/10/04 4:00	125	5.12	0.00	0
12/10/04 5:00	126	5.12	0.00	0
12/10/04 6:00	127	5.12	0.00	0
12/10/04 7:00	128	5.12	0.00	0
12/10/04 8:00	129	5.12	0.00	0
12/10/04 9:00	130	5.12	0.00	0
12/10/04 10:00	131	5.12	0.00	0
12/10/04 11:00	132	5.12	0.00	0
12/10/04 12:00	133	5.12	0.00	2
12/10/04 13:00	134	5.12	0.00	0
12/10/04 14:00	135	5.12	0.00	0
12/10/04 15:00	136	5.14	0.03	1,651
12/10/04 16:00	137	5.14	0.00	0
12/10/04 17:00	138	5.14	0.00	0
12/10/04 18:00	139	5.14	0.00	0
12/10/04 19:00	140	5.15	0.00	82
12/10/04 20:00	141	5.15	0.00	0
12/10/04 21:00	142	5.15	0.00	0
12/10/04 22:00	143	5.15	0.00	0
12/10/04 23:00	144	5.15	0.00	0
12/11/04 0:00	145	5.15	0.00	0

7.3.3 Base Flow

Base flow must be added back to the runoff from the land area to get the total local inflow for input to the SOCH model. The base flow ordinates series are determined by a straight line drawn between the points of tangency of the rising and falling limbs of the direct runoff hydrograph for the March 1973 and December 2004 floods as shown graphically in Figures 13 and 14, respectively. For convenience, this was done in FLDHYDRO by providing the starting and ending base flow discharges divided by the basin area, i.e. cfs/mi^2, as the parameters BBSFLW and EBSFLW ([7]). These parameters are provided in Table 38 for reference and can be seen in the input files for FLDHYDRO runs, provided as Attachments 2-1 and 2-3.

Table 38: Base Flow Input Parameters for FLDHYDRO Calculation of Base Flow Ordinates

	FLDHYDRO Parameter	March 1973	December 2004
Start of runoff	BBSFLW	3.606	3.463
End of runoff	EBSFLW	3.698	6.193

7.3.4 SOCH Model Input

The Wheeler Reservoir watershed is comprised of 15 subbasins (51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64 and 65). Stream gage or flow data that could be determined at basin outlets with standard hydraulic and hydrologic routing methods was available for the directly validated subbasins (53, 57, 59, 60, 61, and 62). Where gage or flow data was attainable through routing, it was used as input data for the SOCH Model.

Inflow hydrographs for the indirectly validated subbasins 52, 54, 56, 58, 63, 64 and 65 were developed via convolution using the unit hydrographs discussed in section 6.2 of this report and either rainfall data from historical gage records [23] or NEXRAD gridded rainfall data [17] and runoff volumes from the water budget computation.

Stream gage data is available for subbasin 51, the Paint Rock River. However, because discrepancies between volume calculations based on NEXRAD rainfall and USGS stream gage data could not be resolved, it was determined that subbasin 51 should be indirectly validated. The available stream gage data from 1973 for subbasin 51 was utilized as SOCH model input. For the 2004 validation run, SOCH model input for subbasin 51 was developed via convolution using the unit hydrograph discussed in section 6.2.1 and NEXRAD gridded rainfall data [17].

For subbasin 55, Cotaco Creek, stream gage data was available from 1966 to 1980. Therefore, stream gage data was available for the 1973 validation run, and unavailable for the 2004 validation run. The available stream gage data from 1973 for subbasin 55 was utilized as SOCH model input. For the 2004 validation run, SOCH model input for subbasin 55 was developed via convolution using the unit hydrograph discussed in section 6.2.4 4 and NEXRAD gridded rainfall data [17].

In most cases the inflows from upstream subbasins were routed and combined with downstream local subbasin flows before input into the SOCH model; the subsequent subsections of this report discuss each specific SOCH model input. SOCH model inputs for the March 1973 validation and the December 2004 validation are presented in Attachment 3-3 and Attachment 3-4, respectively

7.3.4.1 Paint Rock River

The Paint Rock River drainage area consists of an upstream subbasin 51 and a downstream subbasin 52. In order for subbasin 51 to be routed to the mouth of subbasin 52, where it enters Wheeler Reservoir, TVA developed an ARMA routing model [8]:

$$O(T)=1.5608*O(T-2) - 0.9337*O(T-4) + 0.2658*O(T-6) -0.1087*I(T) +0.2577*I(T-2) -0.0419*I(T-4)$$

where routing period = 4 hours and time interval = 2 hours

This ARMA routing model was used to develop a total flow hydrograph at the mouth of Paint Rock River, an input point to SOCH, for the validation runs of 1973 and 2004, which are presented below in Figures 34 and 35.

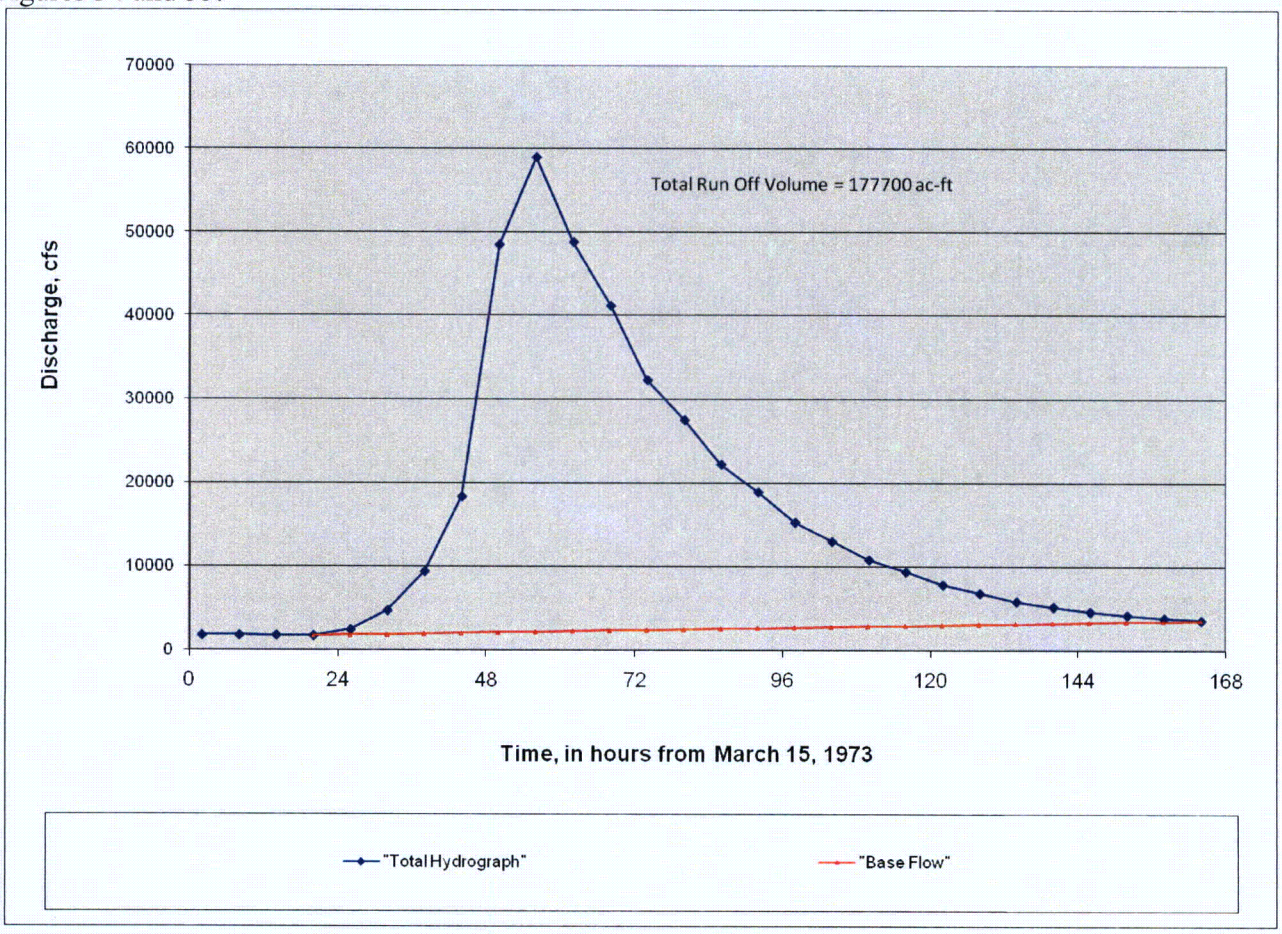

Figure 34: Paint Rock River Input to SOCH Model for March 1973 Validation

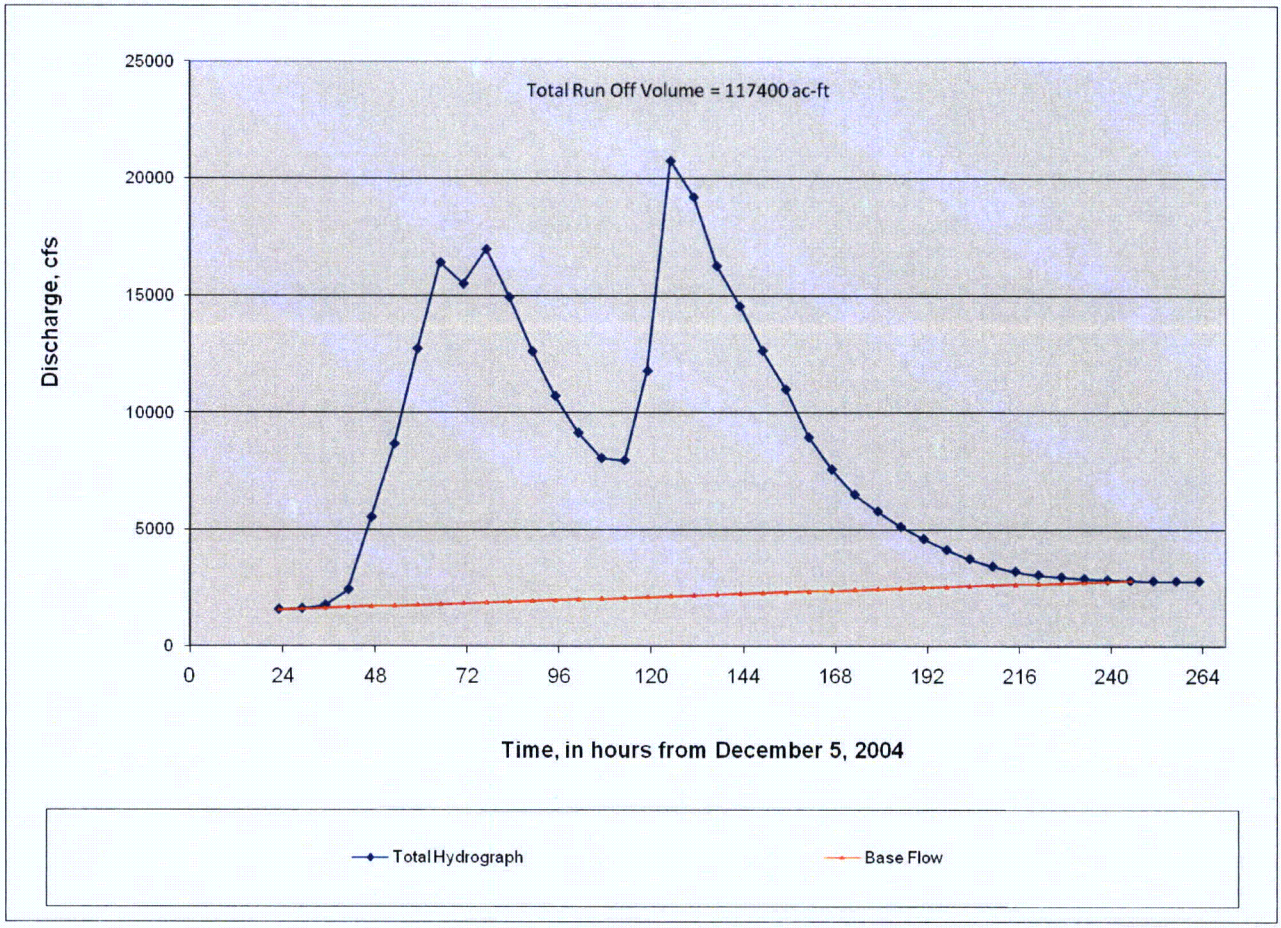

Figure 35: Paint Rock River Input to SOCH Model for December 2004 Validation

7.3.4.2 Flint River

The Flint River drainage area consists of an upstream subbasin 53 and a downstream subbasin 54. In order for subbasin 53 to be routed to the mouth of subbasin 54, where it enters Wheeler Reservoir, TVA developed an ARMA routing model [10]:

$$O(T)=0.6522*O(T-3)-0.1244*O(T-6)+0.0553*O(T-9)+0.0606*I(T)-0.2282*I(T-3)+0.5846*I(T-6),$$

where the routing period is 6 hours and the time interval is 2 hours

This ARMA routing model was used to develop a total flow hydrograph at the mouth of Flint River, an input point to SOCH, for the validation runs of 1973 and 2004, which are presented below in Figures 36 and 37.

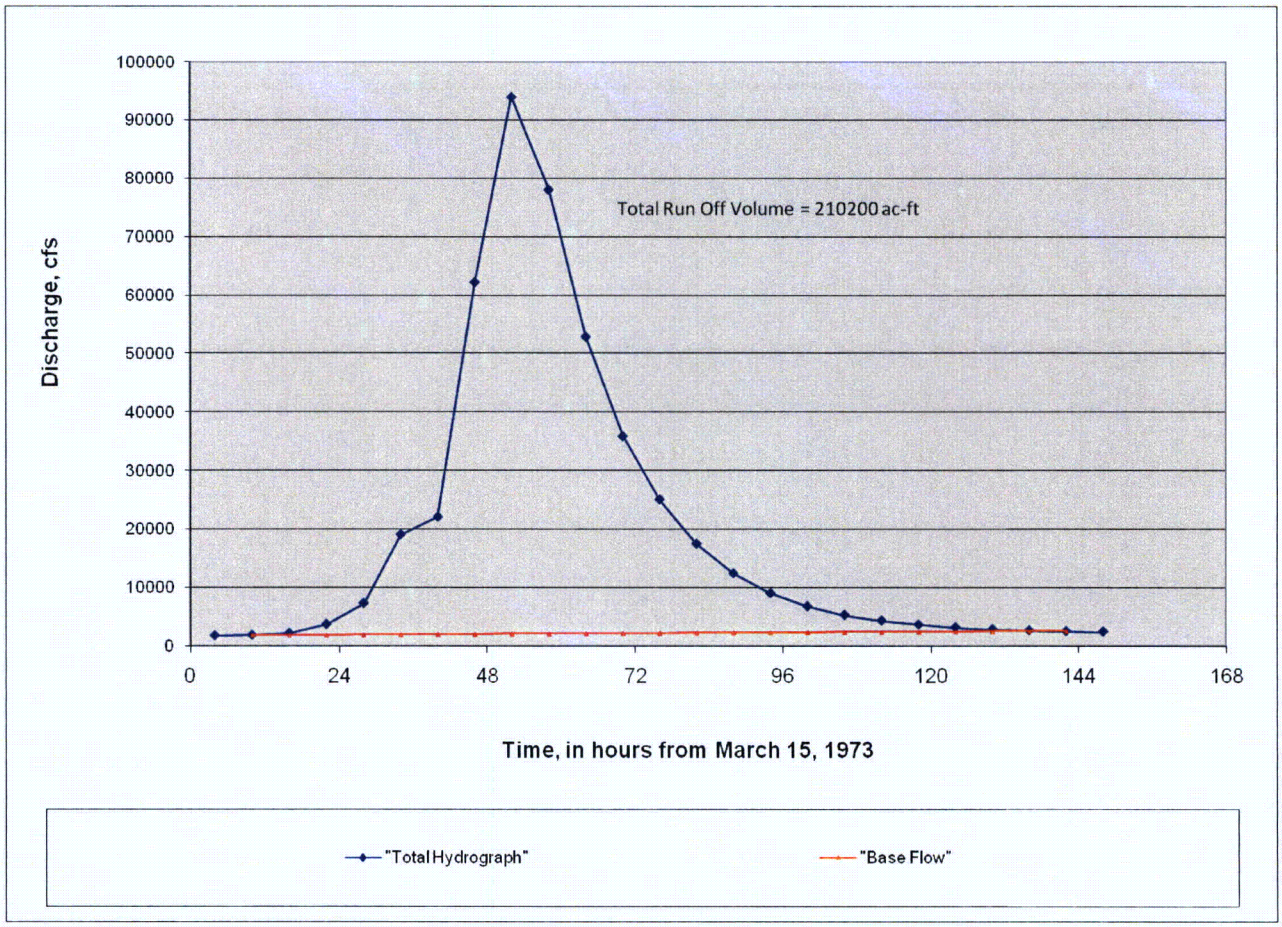

Figure 36: Flint River Input to SOCH Model for March 1973 Validation

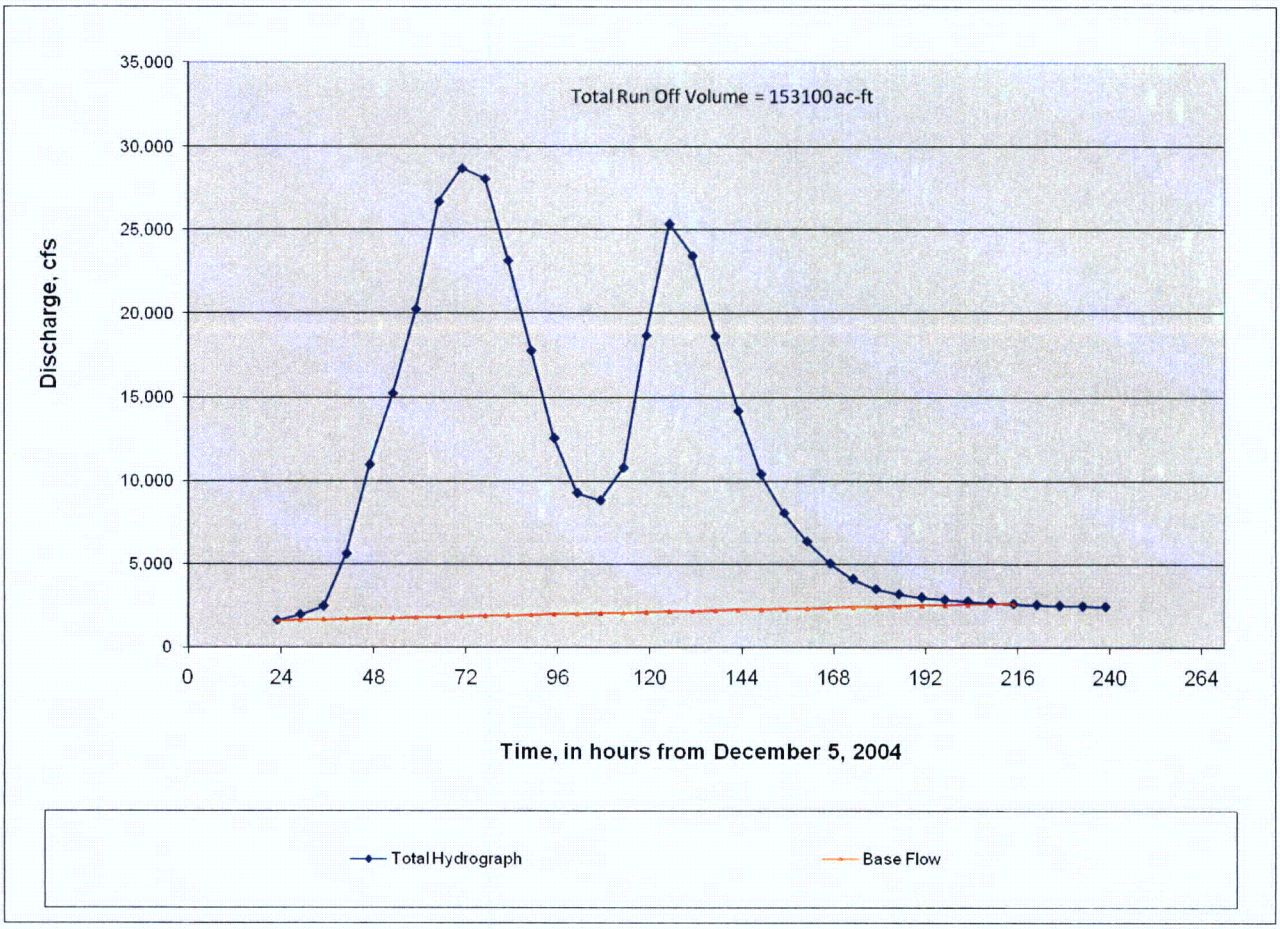

Figure 37: Flint River Input to SOCH Model for December 2004 Validation

7.3.4.3 Cotaco Creek

The Cotaco Creek drainage area consist of an upstream subbasin 55 and a downstream subbasin 56. In order for subbasin 55 to be routed to the mouth of subbasin 56, where it enters Wheeler Reservoir, a simple 4 hour lag was used. This lagging was used to develop a total flow hydrograph at the mouth of Cotaco Creek , an input point to SOCH, for the validation runs of 1973 and 2004, which are presented below in Figures 38 and 39.

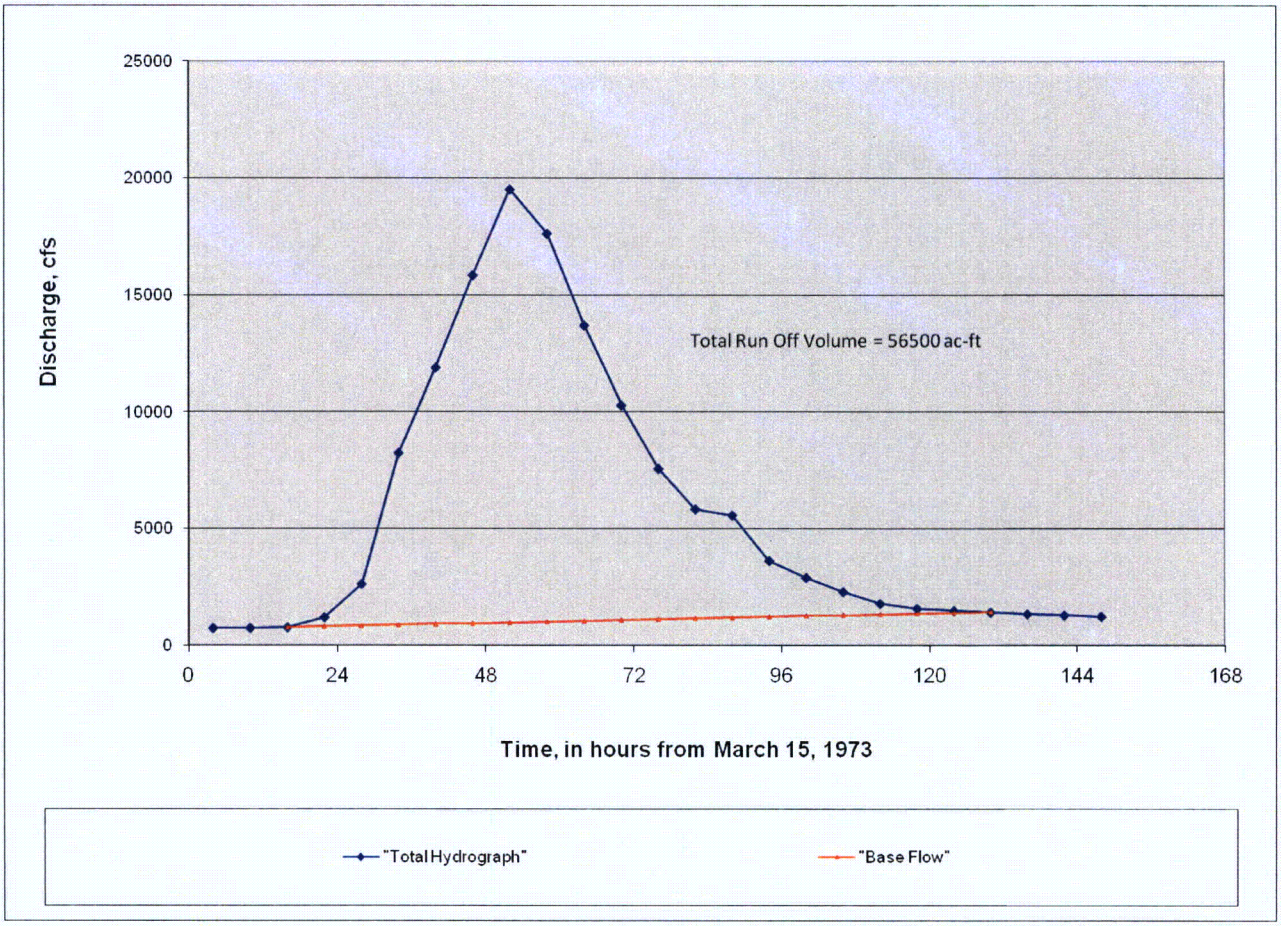

Figure 38: Cotaco Creek Input to SOCH Model for March 1973 Validation

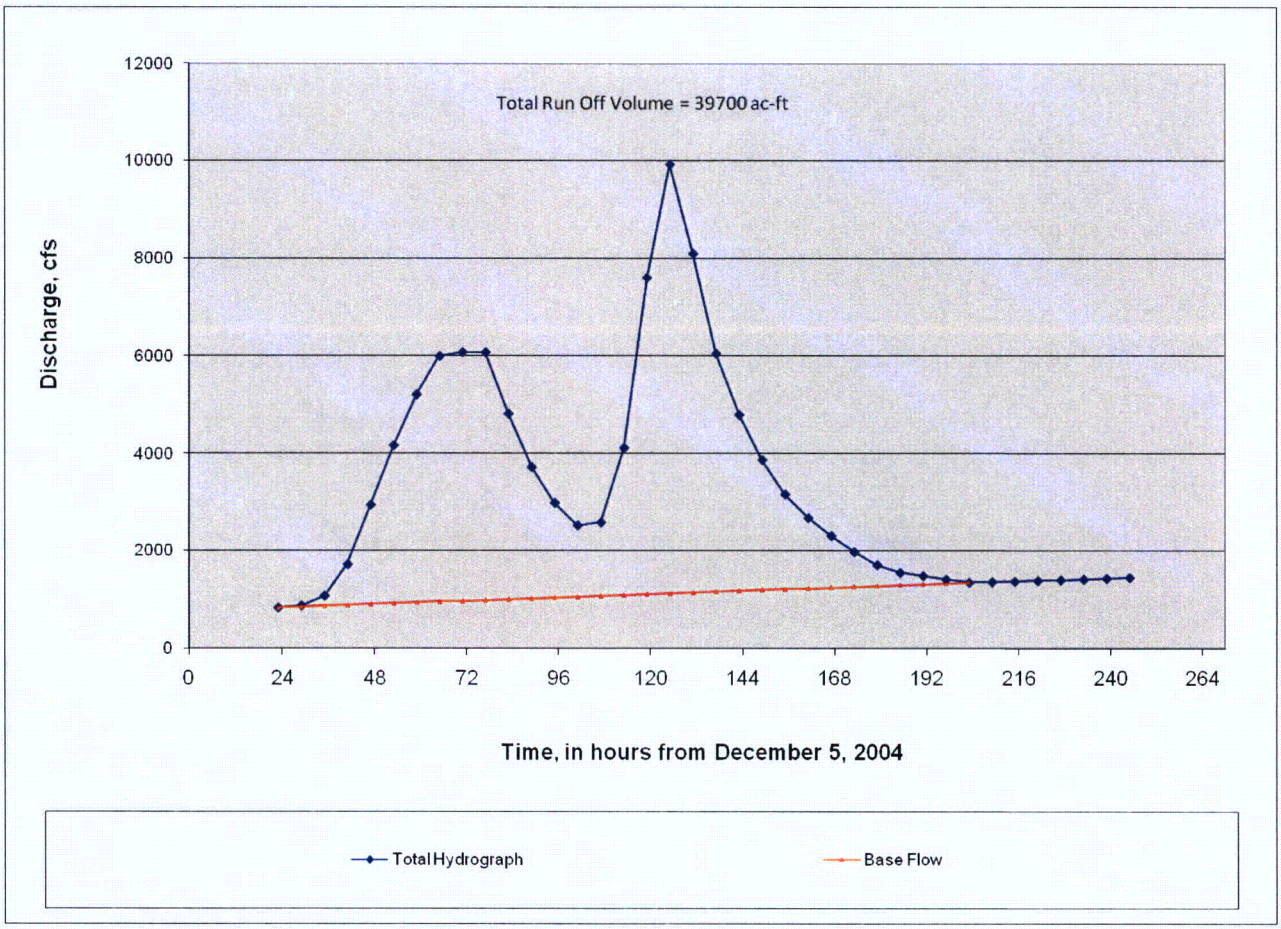

Figure 39: Cotaco Creek Input to SOCH Model for December 2004 Validation

7.3.4.4 Limestone Creek

The Limestone Creek drainage area consists of an upstream subbasin 57 and a downstream subbasin 58. In order for subbasin 57 to be routed to the mouth of subbasin 58, where it enters Wheeler Reservoir, a simple 2 hour lag was used. This lagging was used to develop a total flow hydrograph at the mouth of Limestone Creek, an input point to SOCH, for the validation runs of 1973 and 2004, which are presented below in Figures 40 and 41.

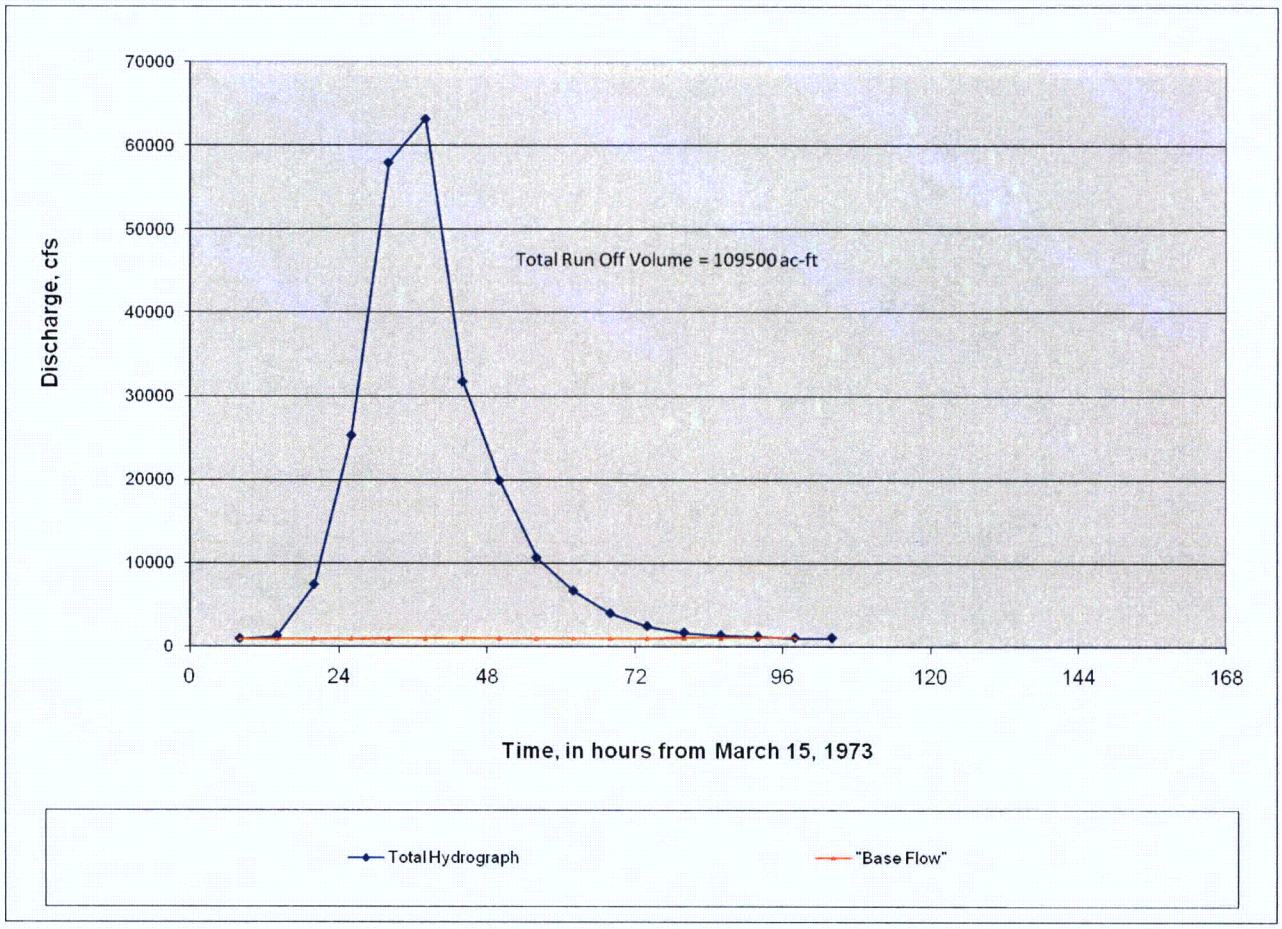

Figure 40: Limestone Creek Input to SOCH Model for March 1973 Validation

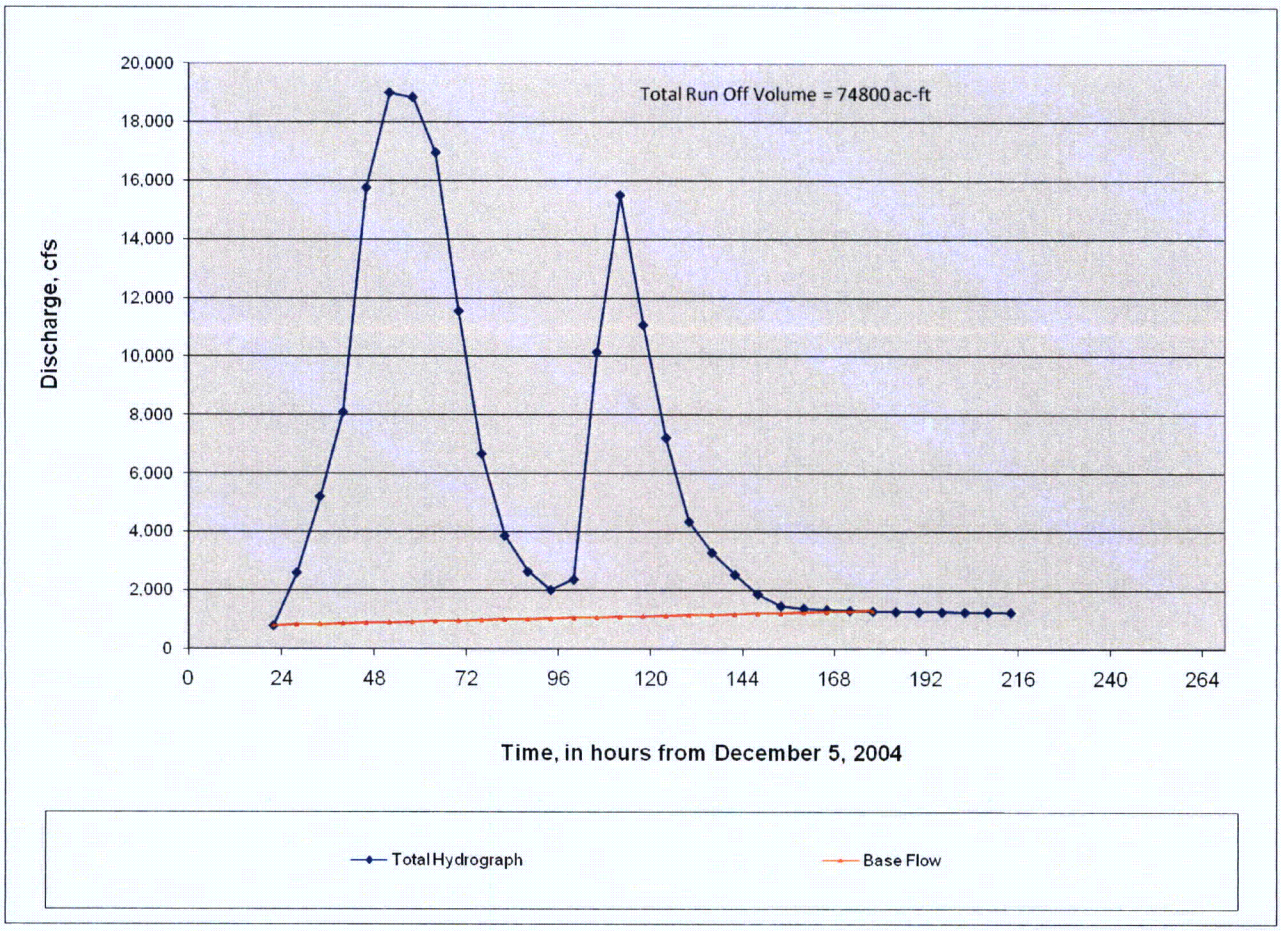

Figure 41: Limestone Creek Input to SOCH Model for December 2004 Validation

7.3.4.5 Elk River

The Elk River drainage area above mile 16.5 consists of subbasins 59, 60, 61, 62, 63 and 64. Subbasins 59, 60, 61 and 62 drain to the USGS stream gage located upstream at Prospect, TN on the Elk River at mile 41.5. This stream gage data was used to account for the inflows from subbasins 59, 60, 61, and 62. In order for the flows from Elk River at Prospect, TN to be routed downstream to mile 16.5 on the Elk River, TVA developed an ARMA routing model [15]:

$$O(T)=1.4212*O(T-1)-0.562*O(T-2)+0.5702*O(T-3)-0.7869*O(T-4)+0.1978*O(T-5)+0.0803*O(T-6)+0.0793*I(T)-0.0829*I(T-1)-.00064*I(T-2)+0.3071*I(T-3)-0.4207*I(T-4)+0.255*I(T-5)-0.052*I(T-6)$$

where the routing period is 2 hours and the time interval is 2 hours

Subbasin 63, Sugar Creek, enters the Elk River at mile 16.5. Subbasin 64 drains the local area between the Prospect gage and mile 16.5. The total Elk River flow at mile 16.5, an input point to SOCH, was developed by adding the routed Elk River flows at Prospect, TN to the inflow hydrographs for subbasins 63 and 64. The total Elk River flow at mile 16.5 is presented below in Figures 42 and 43.

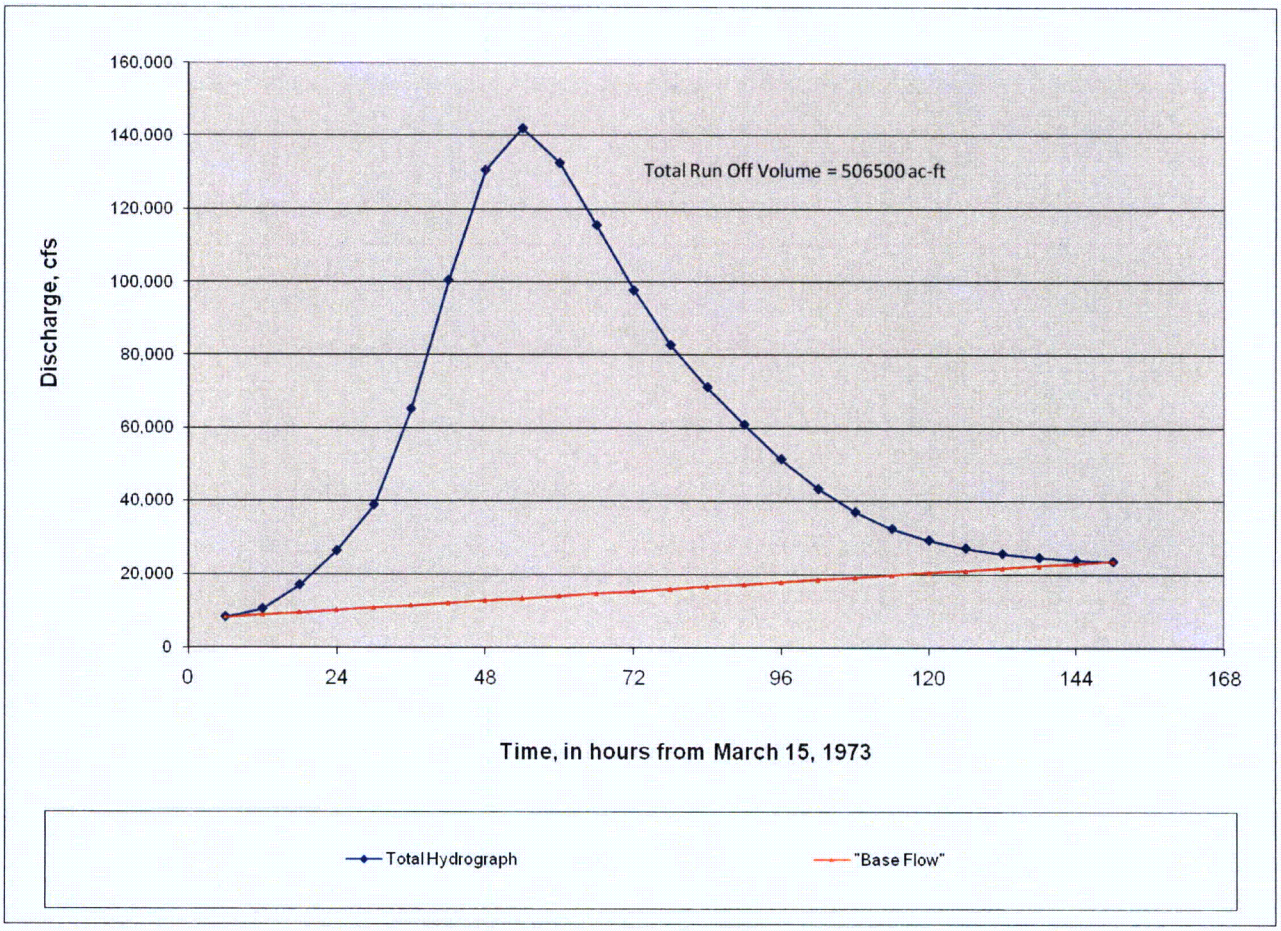

Figure 42: Elk River Input to SOCH Model for March 1973 Validation

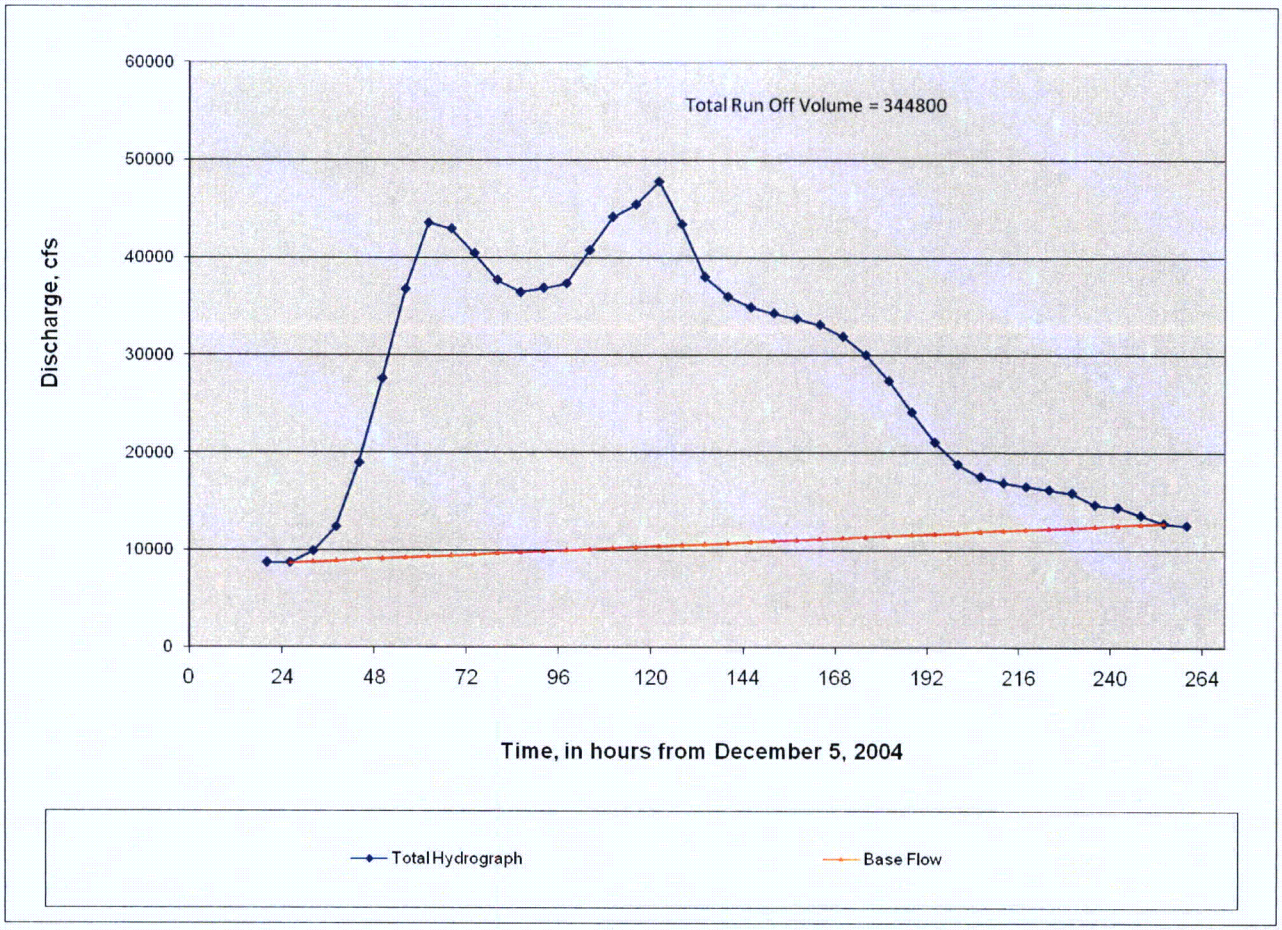

Figure 43: Elk River Input to SOCH Model for December 2004 Validation

7.3.4.6 Wheeler Local

The Wheeler Local drainage area consists of only subbasin 65. The combining of inflow hydrographs or routing was not required for Wheeler Local. The Wheeler Local or subbasin 65 hydrograph was enter directly into the SOCH model and is presented below in Figures 44 and 45.

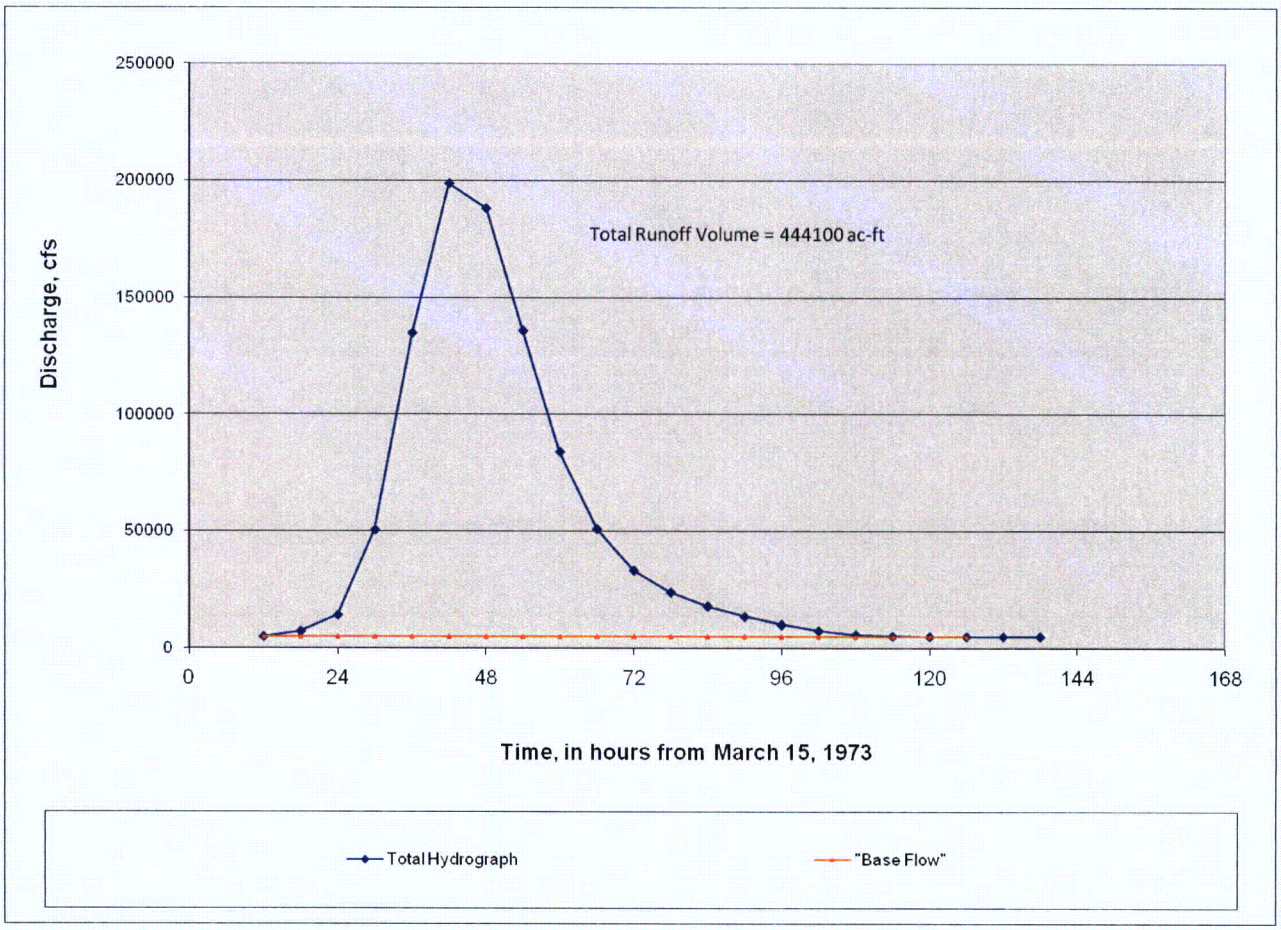

Figure 44: Wheeler Local Input to SOCH Model for March 1973 Validation

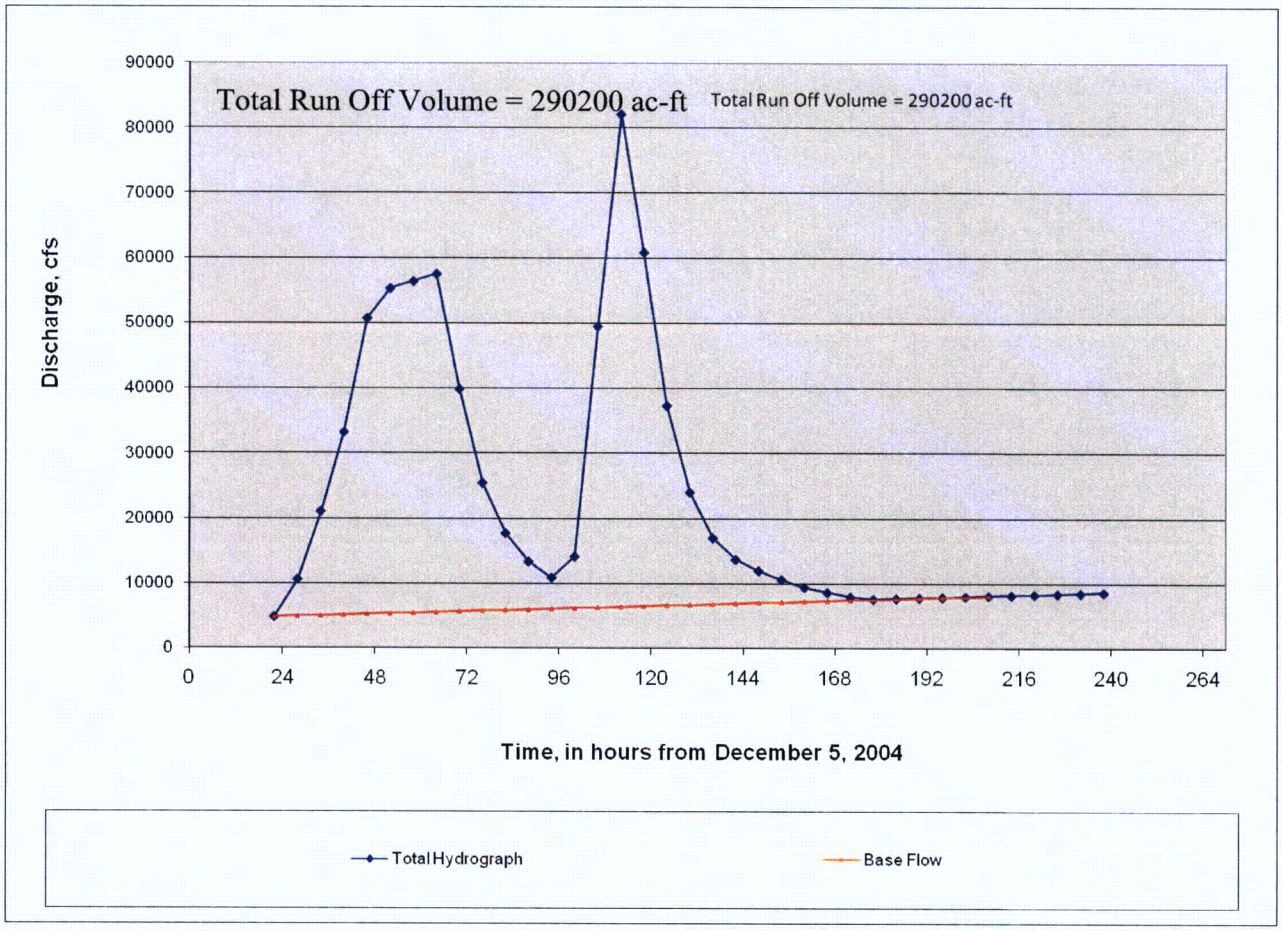

Figure 45: Wheeler Local Input to SOCH Model for December 2004 Validation

7.4 SOCH Model Output & Unit Hydrograph Validation

The component time series presented in Section 7.3 of this calculation are provided for use as inputs to a SOCH model of the reach of the Tennessee River between Guntersville and Wheeler Dams. Additional inputs to the model include observed discharge series for the Elk, Paint Rock, and Flint Rivers, and Limestone Creek; runoff from Wheeler Reservoir area; and outflow from Guntersville Dam as upstream boundary conditions (see Figure 12).

As described in Calculation CDQ000020080042 Rev 0 [26], simulated discharge and stage hydrographs output by the SOCH model compared well with observed values for the March 1973 and December 2004 floods, as shown in Figures 46 through 49. Data and simulation results for all these figures and the rest of the figures in this section of the calculation are provided in the spreadsheets "Observed vs SOCH Mar1973 Hydrographs 102909.xls" and "Observed vs SOCH Dec2004 Hydrographs 102909.xls," provided as Attachments 3-1 and 3-2, respectively.

For the March 1973 event, simulated and observed discharges were compared at the following location:

- Tennessee River Mile 274.9

For the March 1973 event, simulated and observed elevations were compared at the following locations:

- Tennessee River Mile 293.55
- Tennessee River Mile 305.0
- Tennessee River Mile 334.0
- Tennessee River Mile 349.0

For the December 2004 event, simulated and observed discharges were compared at the following location:

- Tennessee River Mile 274.9

For the December 2004 event, simulated and observed elevations were compared at the following locations:

- Tennessee River Mile 305.0
- Tennessee River Mile 334.0
- Tennessee River Mile 349.0

Observed and simulated discharges were compared at Wheeler for both floods. Figures 46 through 49 depict the comparisons. The close tracking of the observed water surface elevations provides an indirect validation of the local inflow unit hydrographs for the subbasins. Data and simulation results for the aforementioned figures are provided in Attachments 3-1 and 3-2.

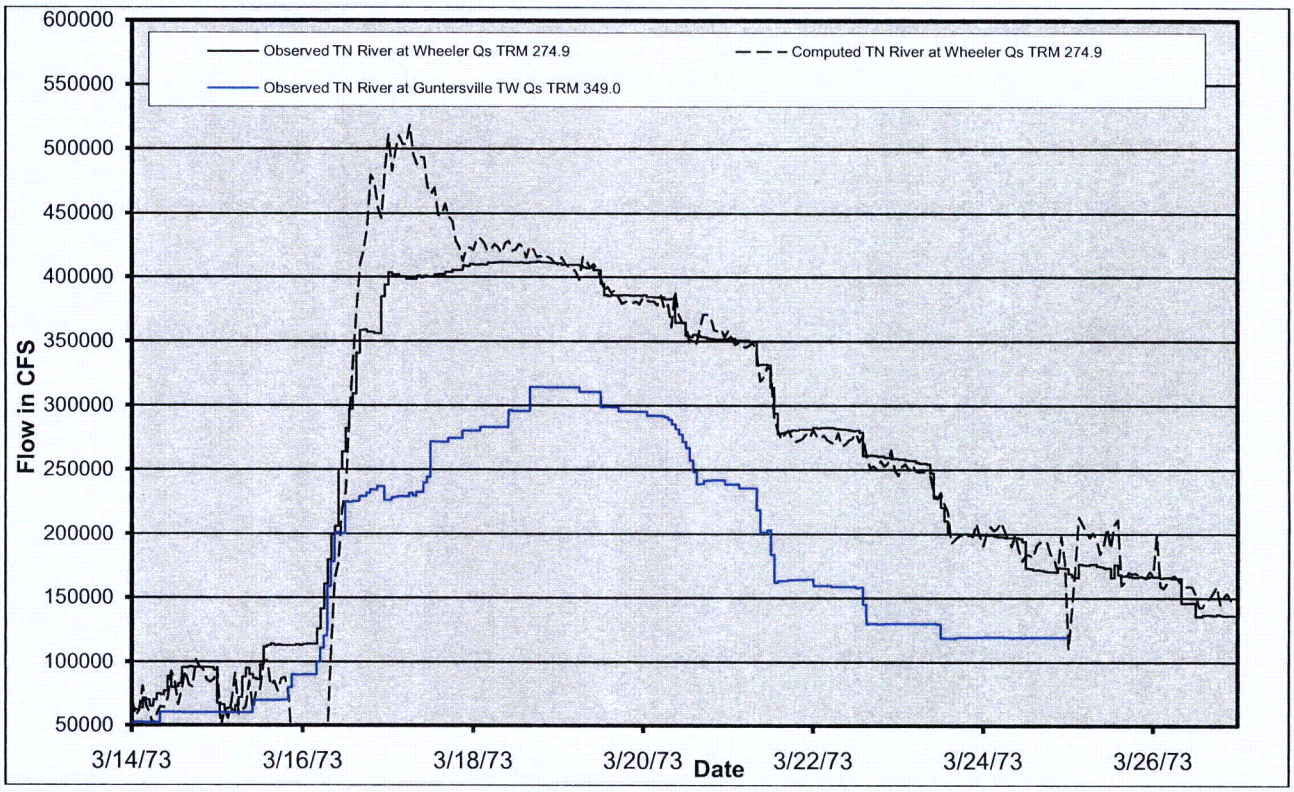

Figure 46: Observed and Simulated Discharge Hydrographs for the Tennessee River between Guntersville and Wheeler Dams, March 1973

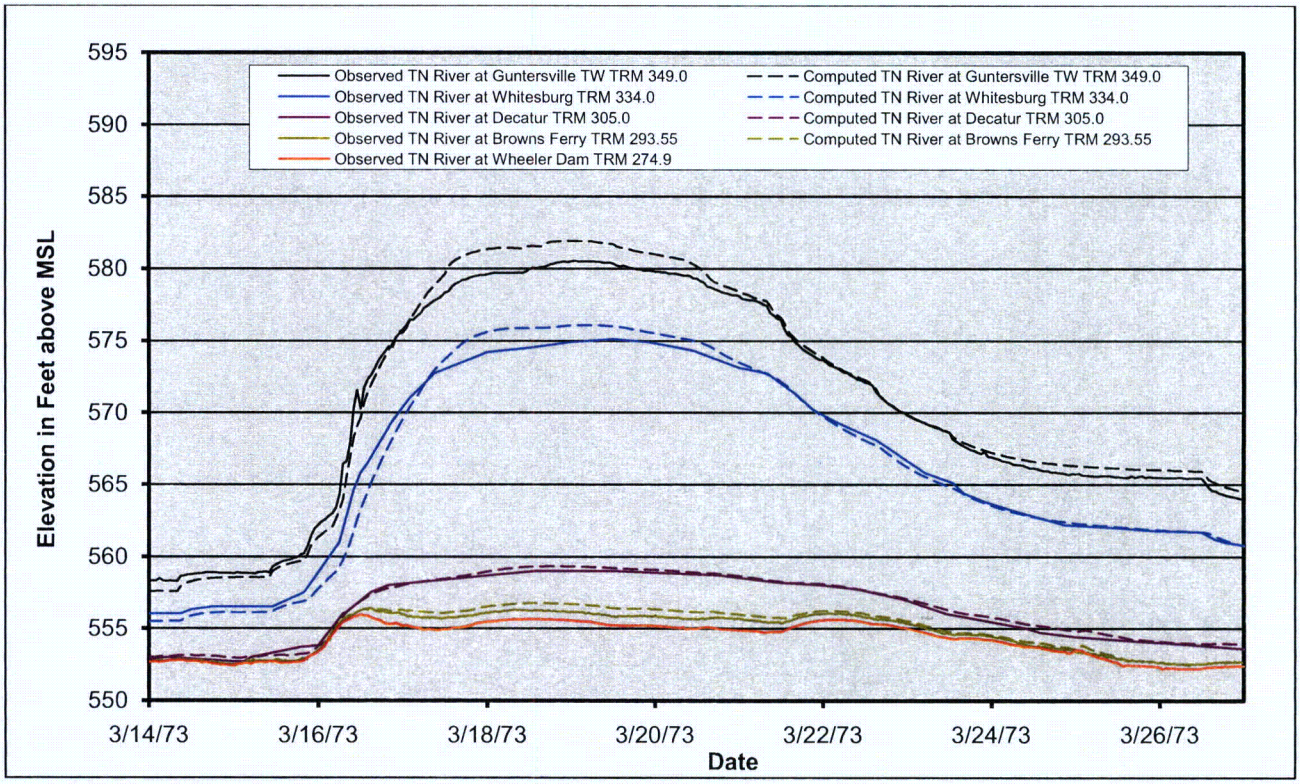

Figure 47: Observed and Simulated Stage Hydrographs for the Tennessee River between Guntersville and Wheeler Dams, March 1973

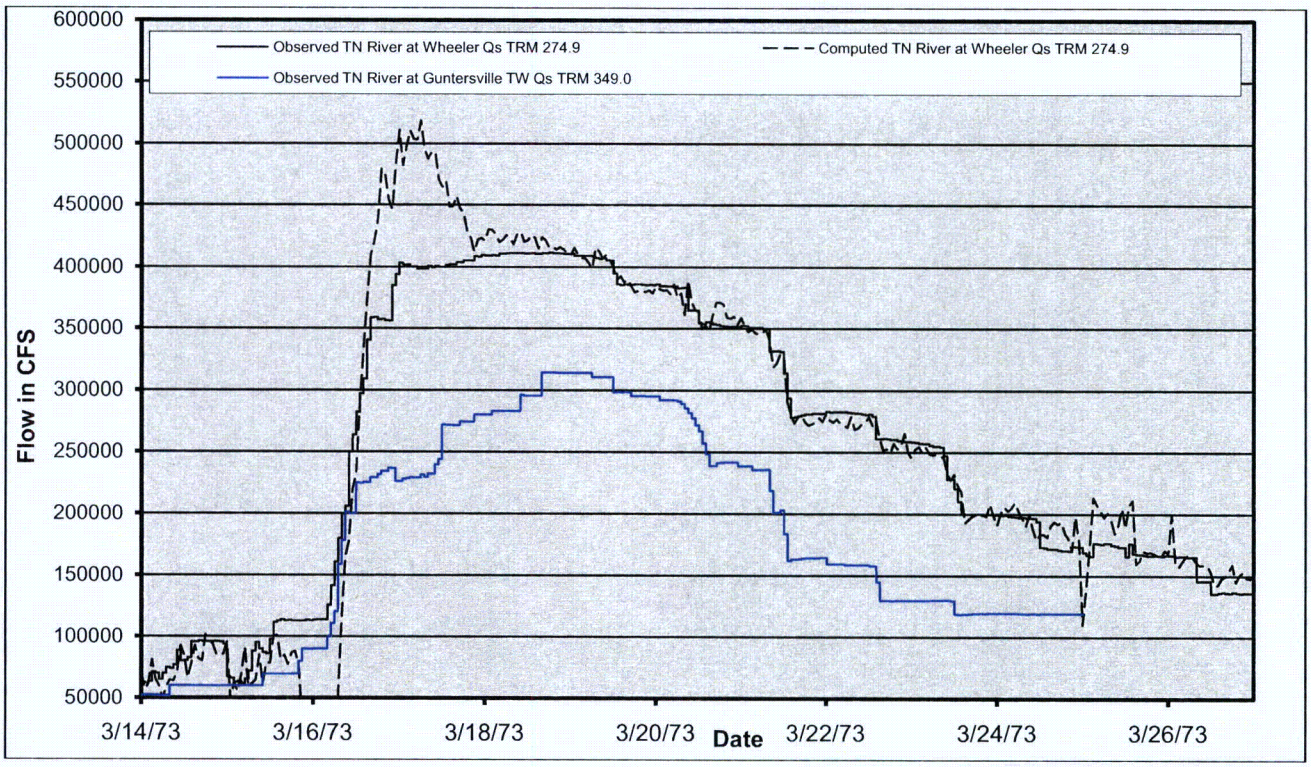

Figure 48: Observed and Simulated Discharge Hydrographs for the Tennessee River between Guntersville and Wheeler Dams, December 2004

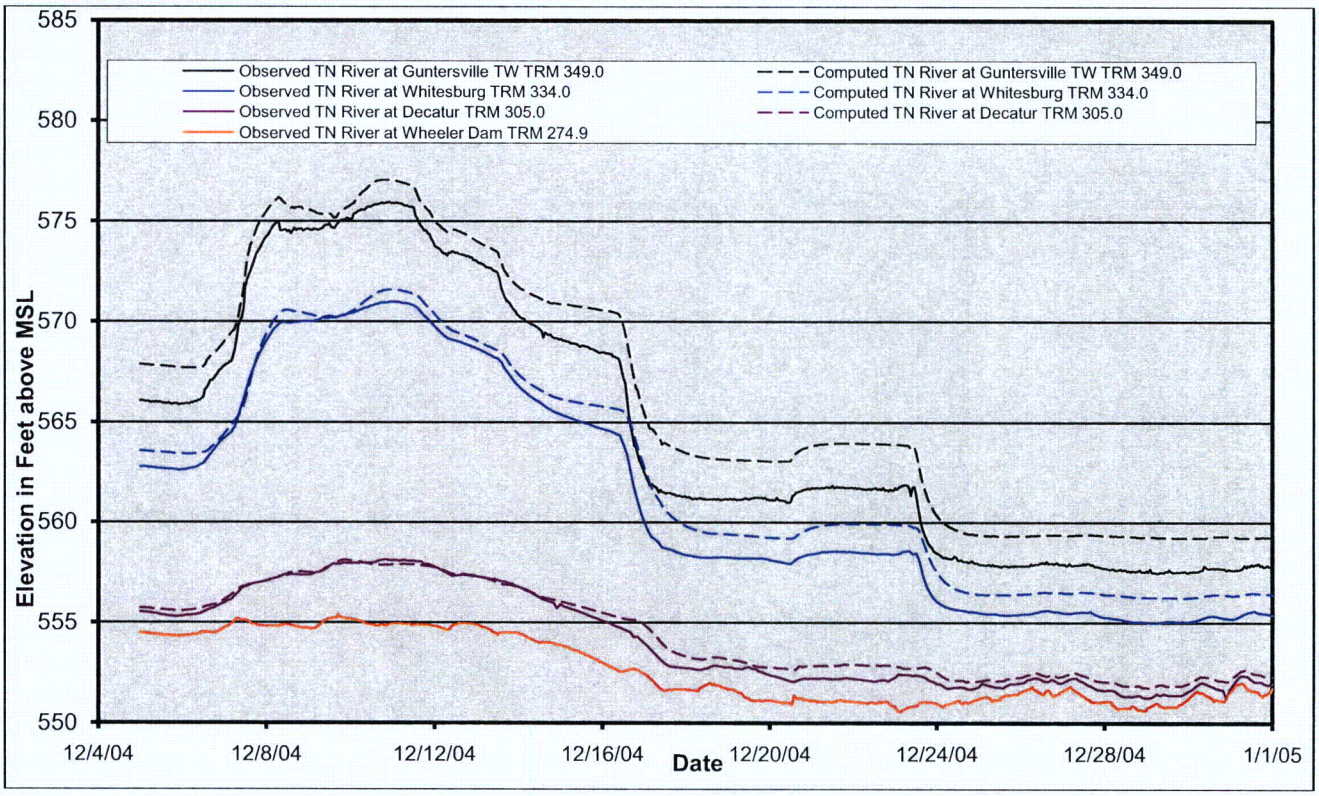

Figure 49: Observed and Simulated Stage Hydrographs for the Tennessee River between Guntersville and Wheeler Dams, December 2004

8 Summary & Conclusions

Unit hydrographs for Subbasins 51, 52, 54, 55, 56, 58, 63, 64, and 65 for the simulation of local inflow to the Tennessee River between Guntersville and Wheeler Dams were developed by TVA previously.

Direct runoff generated from the 9 subbasins cannot be accurately generated due to either lack of observed flood hydrograph information at the subbasin outlet or, in the instance of subbasins 51 and 55, either acceptable precipitation data or stream flow data is not available to directly validate the unit hydrographs. Therefore, it was necessary to validate the unit hydrographs indirectly. Local runoff hydrographs were developed from observed rainfall series for use as inputs to the SOCH model simulation of the reach of the Tennessee River between Guntersville and Wheeler Dams for the two validation runs. Since the stage and discharge hydrographs simulated in the SOCH model runs utilizing local inputs developed with the unit hydrographs conservatively predict observed data, it is concluded that the original unit hydrographs adequately describe the response of the local catchment area between the reservoirs and are valid for use in hydrologic studies to determine the Probable Maximum Flood (PMF).

8.1 Validated Unit Hydrographs

The original TVA unit hydrographs were indirectly validated for the March 1973 and December 2004 floods in this calculation and are produced in Tables 39 through 47 and as Attachment 1-15 to facilitate subsequent work on the TVA design basis PMF evaluations.

8.2 Validated Routing Parameters

The routing parameters utilized by TVA in modeling flows have been validated by use in the models described in the body of this report and are suitable for appropriate, joint use with the unit hydrographs in subsequent hydrologic studies to determine the Probable Maximum Flood at BLN.

Table 39: Routing Parameters used in Hydrologic Modeling of the Wheeler Dam Watershed (Directly Validated Unit Hydrographs)

Unit Area	Stream	Reach	ARMA Routing Coefficients
51	Pain Rock River	Woodville Stream Gage to Mile 8.87	O(T) = 1.5608 x O (T-2) - 0.9337 x O(T-4) + 0.2658 x O(T-6) – 0.1087 x I(T) + 0.2577 x I(T-2) – 0.0419 x I(T-4) Where routing period is 4 hours and the time interval is 2 hours.
53	Flint River	Chase Stream Gage to Mile 7.71	O(T) = 0.6522 x O(T-3) – 0.1244 x O(T-6) + 0.0553 x O(T-9) + 0.0606 x I(T) – 0.2282 x I(T-3) + 0.5846 x I(T-6) Where routing period is 6 hours and the time interval is 2 hours.
64	Elk River	Prospect Stream Gage to Mile 16.5	O(T) =1.4212 x O(T-1) - 0.562 x O(T-2) + 0.5702 x O(T-3) – 0.7869 x O(T-4) + 0.1978 x O(T-5) + 0.0803 x O(T-6) + 0.0793 x I(T) – 0.0829 x I(T-1) – 0.0064 x I(T-2) + 0.3071 x I(T-3) – 0.4207 x I(T-4) +0.255 x I(T-5) – 0.052 x I(T-6) Where routing period is 2 hours and the time interval is 2 hours

Table 40: Validated Unit Hydrograph Ordinates for Subbasin 51

Subbasin 51 6-hr Unit Hydrograph	
Time, hrs	Discharge, cfs/in
0	0
6	177
12	3429
18	11363
24	5284
30	4385
36	3486
42	2205
48	923
54	808
60	694
66	580
72	466
78	352
84	238
90	123
96	20
102	0

Table 41: Validated Unit Hydrograph Ordinates for Subbasin 52

Subbasin 52 6-hr Unit Hydrograph	
Time, hrs	Discharge, cfs/in
0	0
6	140
12	870
18	2,501
24	6,103
30	2,501
36	1,171
42	670
48	425
54	250
60	150
66	70
72	0

Table 42: Validated Unit Hydrograph Ordinates for Subbasin 54

Subbasin 54 6-hr Unit Hydrograph	
Time, hrs	Discharge, cfs/in
0	0
6	498
12	1,791
18	4,678
24	7,962
30	4,678
36	1,990
42	995
48	597
54	398
60	299
66	199
72	100
78	0

Table 43: Validated Unit Hydrograph Ordinates for Subbasin 55

Subbasin 55 6-hr Unit Hydrograph	
Time, hrs	Discharge, cfs/in
0	0
6	253
12	1,461
18	3,174
24	2,803
30	1,850
36	1,413
42	1,045
48	750
54	556
60	440
66	324
72	208
78	166
84	124
90	82
96	0

Table 44: Validated Unit Hydrograph Ordinates for Subbasin 56

Subbasin 56 6-hr Unit Hydrograph	
Time, hrs	Discharge, cfs/in
0	0
6	94
12	425
18	1,416
24	2,644
30	1,955
36	1,360
42	944
48	689
54	491
60	359
66	255
72	161
78	76
84	0

Table 45: Validated Unit Hydrograph Ordinates for Subbasin 58

Subbasin 58 6-hr Unit Hydrograph	
Time, hrs	Discharge, cfs/in
0	0
6	3,156
12	6,407
18	3,203
24	1,696
30	1,055
36	754
42	471
48	188
54	0

Table 46: Validated Unit Hydrograph Ordinates for Subbasin 63

Subbasin 63 4-hr Unit Hydrograph	
Time, hrs	Discharge, cfs/in
0	0
4	382
8	2,509
12	5,023
16	8,512
20	3,897
24	2,402
28	1,449
32	1,024
36	723
40	545
44	466
48	387
52	306
56	227
60	147
64	130
68	113
72	95
76	78
80	62
84	44
88	27
92	0

Table 47: Validated Unit Hydrograph Ordinates for Subbasin 64

Subbasin 64 6-hr Unit Hydrograph	
Time, hrs	Discharge, cfs/in
0	0
6	348
12	1,043
18	3,043
24	5,913
30	2,956
36	1,043
42	609
48	348
54	174
60	87
66	43
72	0

Table 48: Validated Unit Hydrograph Ordinates for Subbasin 65

Subbasin 65 6-hr Unit Hydrograph	
Time, hrs	Discharge, cfs/in
0	0
3	8,130
6	21,849
9	37,601
12	46,747
15	41,158
18	33,536
21	25,406
24	18,800
27	14,227
30	10,670
33	7,825
36	6,097
39	4,776
42	3862
45	3354
48	2845
51	2439
54	2032
57	1524
60	1270
63	1016
66	762
69	508
72	305
75	102
78	0