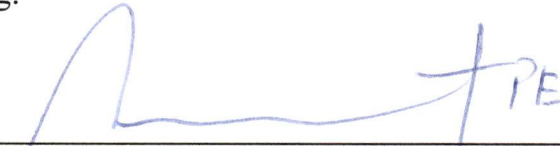


To the Graduate Council:

I am submitting herewith a thesis written by Randall Z. Kerr entitled "Use of Predicted Rainfall for Forecasting Inflows for Reservoir Operations." I have examined the final copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Environmental Engineering.



Bruce A. Tschantz, Major Professor

We have read this thesis
and recommend its acceptance:





Accepted for the Council:



Associate Vice Chancellor and
Dean of the Graduate School

**Use of Predicted Rainfall
in Forecasting Inflows
for Reservoir Operations**

A Thesis

Presented for the

Master of Science

Degree

The University of Tennessee, Knoxville

Randall Z. Kerr

August 1997

DEDICATION

**This thesis is dedicated to all
of those who have influenced my life
through their teachings.**

**May I be able to pass along only
a small part of the education
they have given me.**

ACKNOWLEDGMENTS

I would like to thank my major professor, Dr. Bruce Tschantz for his guidance and advice. I would also like to thank my other committee members, Dr. James Smoot, Dr. William Miller and Dr. Vahid Alavian for their comments and assistance. I would like to thank all of my fellow employees at TVA for their support and technical expertise. I would also like to thank TVA for providing me with financial assistance and the opportunity for a wonderful and exciting career in managing the reservoir system. Finally, I would like to thank my family whose love and support I will always cherish. Especially my wife and best friend Stacy who is extremely supportive and understanding.

ABSTRACT

The purpose of this study is to determine if an improved and more accurate schedule of a reservoir system is obtained by incorporating an increase in hydrologic inflows from short-term (10 days) predicted rainfall on tributary reservoir watersheds. The TVA reservoir system is used to illustrate the analysis. The TVA reservoir system is operated and scheduled on a daily basis with the intent on maximizing the benefits for which the reservoir system was designed. The ability to forecast the inflows to the reservoir system for a 10 to 14 day period is a very challenging process. Although incorporating the increase in hydrologic inflows from predicted rainfall may not be entirely accurate due to the reliability of weather forecasts, it is the purpose of this study to prove there are significant benefits, particularly with regards to predicting hydroelectric generation, in using the increase in hydrologic inflows when scheduling the TVA reservoir system.

Hydroelectric generation totals, for 6 to 10 days into the future, were compared from reservoir schedules based on predicted rainfall and those with hydrologic inflows based on observed rainfall. The generation

totals from the observed rain schedules were underestimated by an average of 30 to 50 percent. The schedules using predicted rainfall were only underestimated by an average of 10 percent. Hypothesis testing, by using the rank-sum test, indicate the data are significantly different, with confidence levels of at least 95 percent. The central tendency of the means of the predicted rainfall schedules were also closer to actual observed reservoir conditions. All the data clearly indicate a significant improvement in the reservoir system schedule by incorporating predicted rainfall.

As a direct result of this study initiative the TVA reservoir system recently began scheduling the tributary reservoirs using short-term predicted rainfall.

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GLOSSARY

Drawdown - Lowering of reservoir levels, typically for flood control

Dry forecast - Reservoir system schedule based on observed rainfall only

Flood guide level - Elevation reservoirs are maintained at or below to provide adequate flood control space

Hydroelectric generation - Electricity generated by passing water through the turbines at a dam

Hydrologic inflows - Inflows to a reservoir or drainage area from runoff resulting from rainfall, either observed or predicted

Inflow model - Mathematical model for determining hydrologic inflows based on given rainfall amounts, either observed or predicted

Inflow model sub-basin - Smaller component of an inflow model used to forecast hydrologic inflows

Locals - Sum of all hydrologic inflows to a particular drainage basin

Main river reservoir - Reservoir formed by a dam located on the Tennessee River

Maximum flexibility zone - Reservoir elevations between flood guide and minimum operating guide levels

Minimum operating guide - Reservoirs are scheduled to provide only minimum discharge requirements if levels are below these elevations

Predicted rain runs - Reservoir system schedule which includes hydrologic inflows from both observed and predicted rainfall

Predicted rainfall - Rainfall which is expected to fall sometime in the near future, usually provided by a weather forecast

Project - A reservoir or dam

Recreational levels - Reservoir elevations which are necessary to provide adequate recreational benefits

Regulating zone - Levels where reservoirs are either scheduled to maximize turbine releases or supplement turbine releases with spillway discharges to recover flood storage space

Reservoir schedule - A schedule of reservoir releases, inflows and predicted elevations. Also referred to as “routings” in TVA

Runoff - Inflow to a drainage area which results from precipitation, generally in the form of rainfall. Includes both surface and groundwater runoff

Spillway releases - Discharges from a dam other than through the turbines

Tributary reservoir - Reservoir formed by a dam located on one of the tributaries to the Tennessee River

Watershed - Drainage area

Week study - Reservoir system schedule for at least 10 days, includes Monday through Friday of the following week

CHAPTER 1

INTRODUCTION

The ability to provide the best forecast for hydrologic inflows for a reservoir system can have significant economic impacts. River navigation, hydroelectric generation, flood control, and reservoir operating levels all depend on accurate and timely hydrologic inflow forecasts. This study will use the Tennessee Valley Authority (TVA) reservoir system as a model in incorporating an increase in hydrologic inflows, on tributary reservoir watersheds, from predicted rainfall into the reservoir scheduling process. TVA provides a reservoir system schedule on a daily basis for ten to fourteen days in the future. The reservoir schedule provides predicted lake levels and discharges from all the TVA reservoirs. The reliability of this schedule depends heavily on the predicted hydrologic inflows over the same period. The ability to predict hydrologic inflows over this period can have significant benefits in scheduling the reservoir system. All benefits provided by the TVA reservoir system are directly linked to the hydrologic inflow forecast. The objective of this study is to show that, by incorporating the increase

in hydrologic inflows from predicted rainfall on the tributary reservoirs, an improved reservoir operating schedule results. This should result in an increase in the benefits from the reservoir system, particularly for hydroelectric generation.

Since the watersheds feeding the TVA reservoir system receive an average of 4 to 5 inches of rainfall monthly, the inflows to the reservoirs can be greatly affected by the rainfall which will occur over this ten to fourteen day period. Technological advancements in computers, both software and hardware, along with significant improvements in the ability to predict rainfall amounts over the next 10 days are the major forces behind this study. The TVA reservoir system was scheduled prior to April 1996 based on hydrologic inflows from observed rainfall. This study will point out the advantages of including the increases in hydrologic inflows from predicted rainfall on the tributary reservoirs from a scheduling standpoint. These advantages will include, but are not limited to, the expected increase in revenues from hydroelectric generation, predicted lake levels, the ability to "move" water downstream prior to forecasted heavy rainfall events and the reliability of the reservoir system schedule.

There are limits to including predicted inflows from weather forecasts due to constraints in the system, particularly on the main river projects. This thesis study will focus on using the increase in hydrologic inflows on tributary projects, where water withdrawn based on predicted rain, will not significantly impact the reservoir system if the rainfall does not develop as forecast. The advantages of using the increase in hydrologic inflows will be shown by comparing the hydrologic inflows and projected hydroelectric generation from reservoir system schedules based on a “no rain” forecast and those including predicted rainfall on the tributary reservoirs. Significant hydroelectric generation benefits should result from the increase in discharges from the tributary reservoirs. The increase in discharge will result from having to schedule the reservoirs to maintain desired levels with an increase in hydrologic inflows from predicted rainfall. The increase in these discharges must be accounted for in the scheduling process. The predicted hydroelectric generation totals for the TVA system will increase not only from an increase in discharges from the tributary reservoirs, but having to schedule the larger releases through the main river reservoirs as well.

CHAPTER 2

SCHEDULING THE TVA RESERVOIR SYSTEM

THE TENNESSEE RIVER BASIN

The Tennessee Valley River headwaters are in the mountains of east Tennessee, west Virginia, and north Georgia. The Holston and French Broad Rivers unite just above Knoxville, Tennessee to form the Tennessee River. The drainage area for the Tennessee Valley Authority (TVA) reservoir system is 40,200 square miles. This is just slightly less than the 40,910 square mile drainage area of the Tennessee River. Although the drainage basin lies mostly in the state of Tennessee it also lies partly in six other states. The topography of the region ranges from the Appalachian Mountains in the east to the relatively flat regions in the mid-western part of Tennessee. Differences in elevation vary from slightly less than 7,000 feet in the eastern mountains to 300 feet at the Kentucky Dam tailwater. The outline of the Tennessee Valley watershed is shown in Figure 1.

The Tennessee Valley receives an abundance of precipitation. Mean annual rainfall over the drainage area has averaged between 51 and

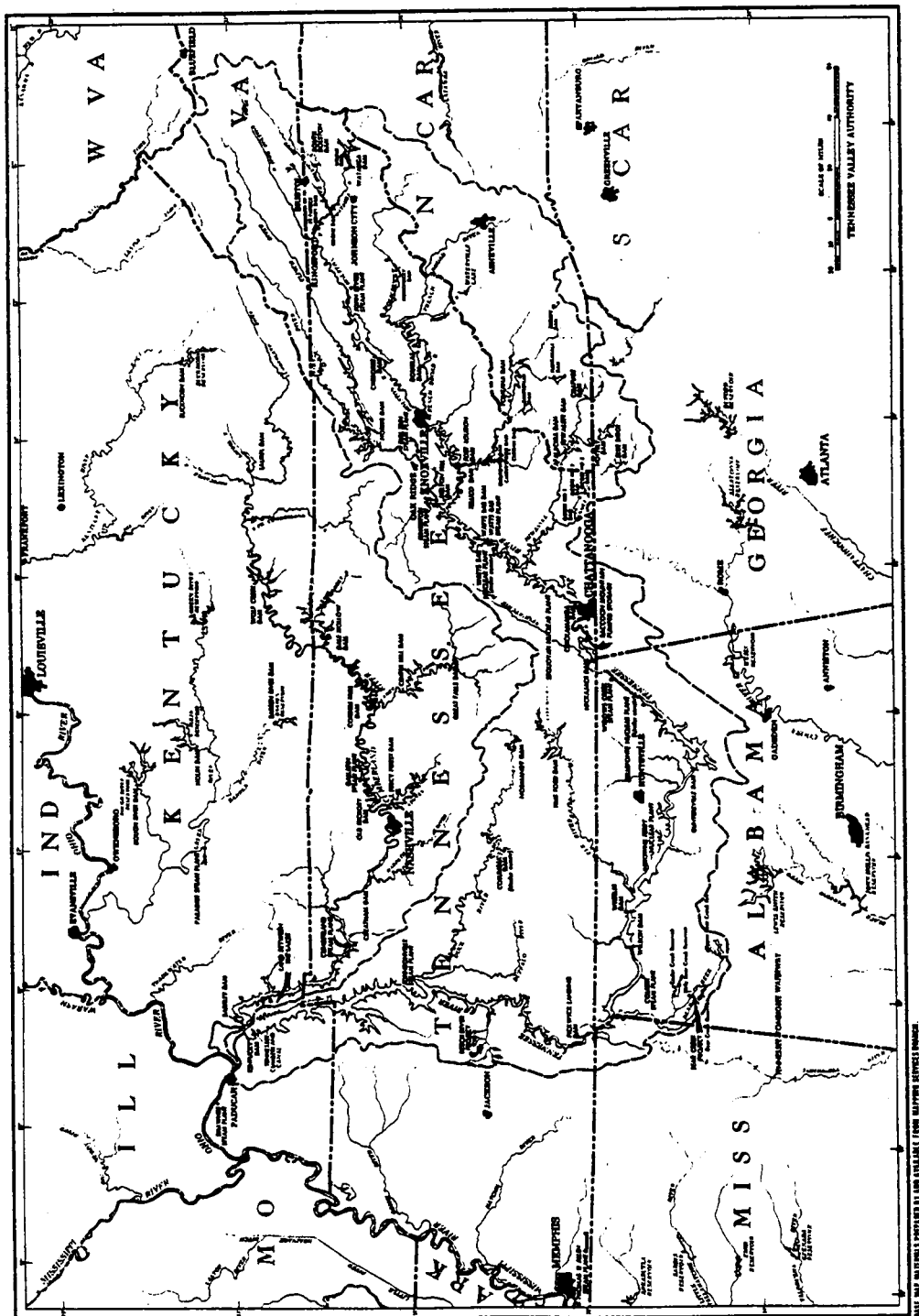


Figure 1. Tennessee Valley Watershed Map

52 inches for the period of record. Yearly rainfall totals have ranged from a low of 38 inches to a high of 65 inches. The heaviest precipitation occurs over the mountain areas along the headwaters of the tributaries where the mean annual precipitation totals can reach 80 to 90 inches. In portions of the French Broad, Clinch, and Holston Valleys the mean annual rainfall is as low as 40 inches (Miller, et al, 1995).

Mean annual runoff of the Tennessee River is approximately 42 percent of the annual precipitation. The majority of the runoff occurs in the late winter and early spring. Although the historic, monthly rainfall totals average between 3.5 and 5.5 inches, runoff from the precipitation will vary significantly. Figure 2 is a bar chart showing the relationship between monthly rainfall and runoff amounts for the Tennessee Valley watershed above Chattanooga, TN, a drainage area of slightly over 20,000 square miles.

MULTI-PURPOSE RESERVOIR OPERATIONS

The TVA reservoir system includes 45 TVA-owned dams and reservoirs in the Tennessee River basin. An additional six dams provide inflow into the TVA System but are owned and operated by other entities

AVERAGE RAINFALL AND RUNOFF ABOVE CHATTANOOGA

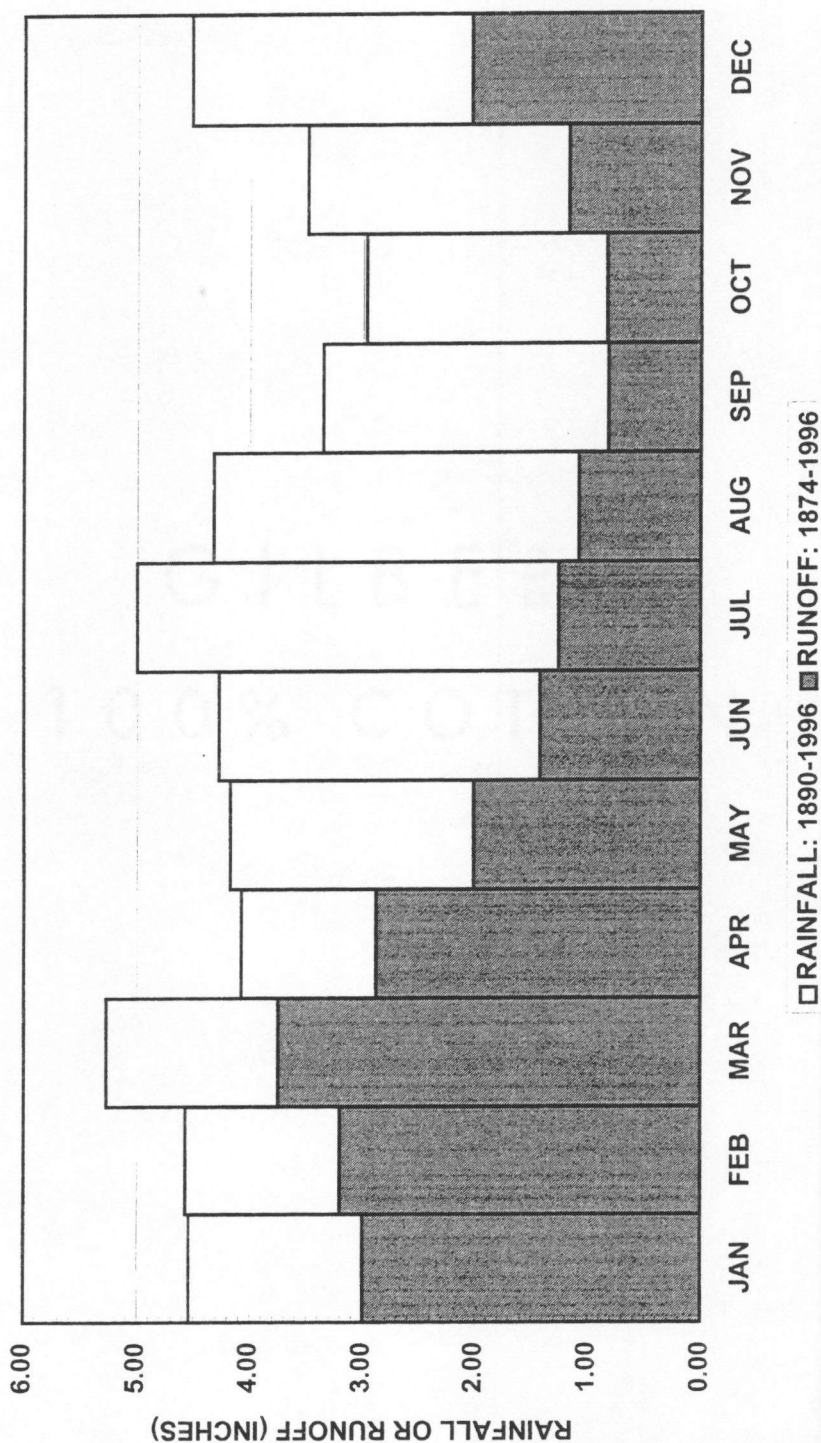


Figure 2. Average Monthly Rainfall and Runoff Above Chattanooga, TN

(four by Tapoco, Inc., a subsidiary of ALCOA, and two by Nantahala Power and Light). Under agreement with the Corps of Engineers (COE) and the Southeastern Power Administration, TVA also coordinates flow releases at nine major dams in the Cumberland River Basin, eight of which are owned by the COE and one of which is owned by TVA. Consequently, from the standpoint of reservoir operations and electrical power generation, 60 dams are integrated in the TVA water control system, see Figure 3 (Miller, 1993).

The reservoir system is operated as an integrated, multipurpose system. The objectives of the reservoir system are to provide for navigation, flood control, hydroelectric generation, recreational benefits, and minimum flows for water quality and aquatic habitat. Additional demands on the system include condenser cooling water for fossil and nuclear generation to dissipate thermal waste loads and numerous "special operations" for which particular flows or elevations might be required. Special operations generally average around 200 per year. Examples of special operations are specific flow requirements for index tests, certain reservoir levels for recreational events (such as Regattas or

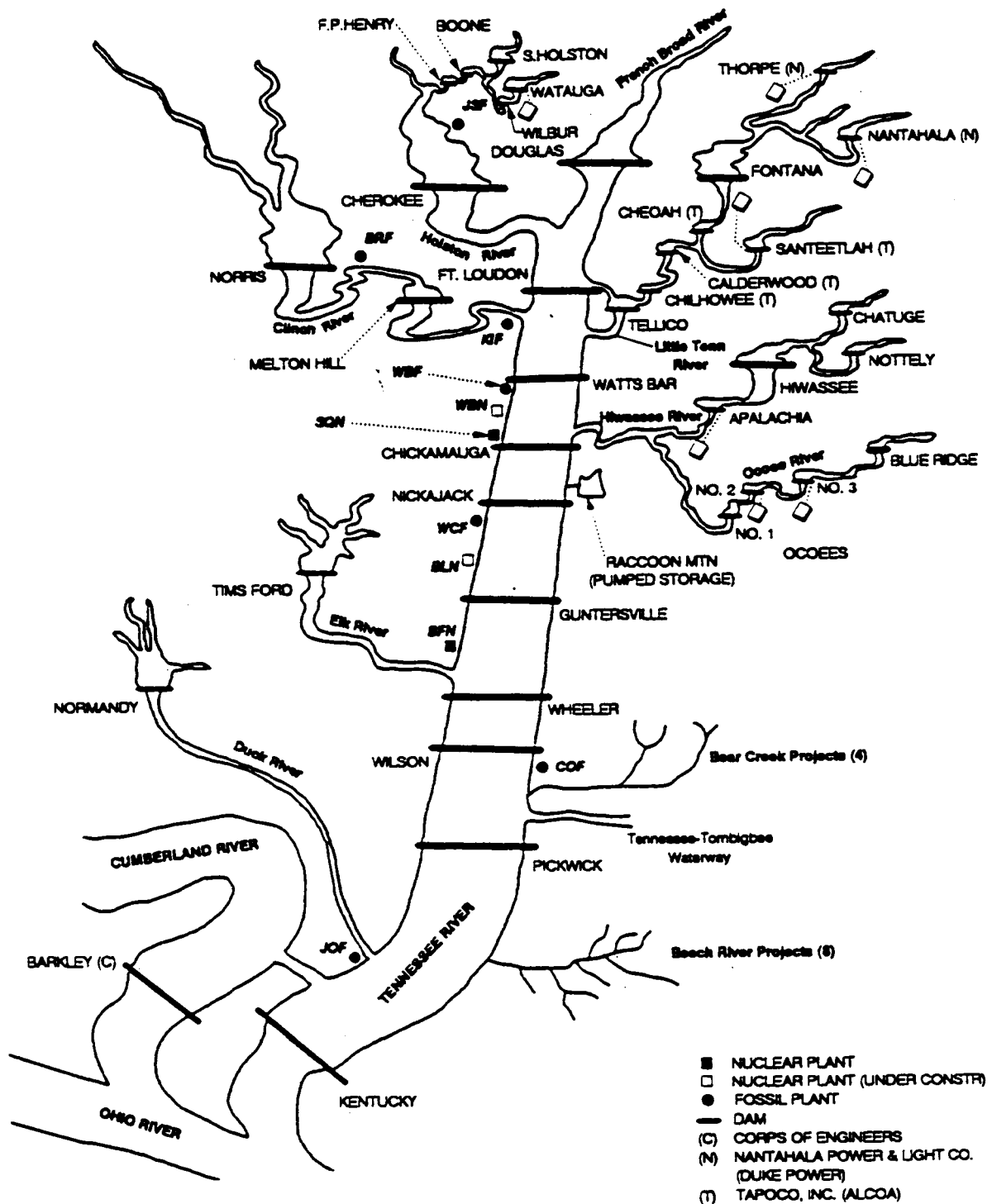


Figure 3. Tennessee River Reservoir System

fishing tournaments) and reservoir drawdowns for dam safety inspections.

Most reservoir projects are operated on an annual cycle which is primarily driven by flood control mandates and summer recreational levels. A typical operating guide curve for TVA tributary reservoirs is shown in Figure 4. Tributary operating curves generally coincide with the hydrologic cycle and are represented by four main periods: winter flood season, filling period, recreation season and drawdown period. During the winter flood control season (January 1 to March 15) tributary projects are drawn down to flood guide levels to provide flood control downstream. In the spring fill period (March 15 to June 1) inflows to the reservoirs are stored to allow the projects to reach summer recreation levels. From January 1 to June 1 the reservoirs are scheduled to try and maintain elevations between the flood guide and minimum operating guide curves. In the summer months of June and July, the reservoirs are scheduled to maintain the minimum summer recreational levels. The minimum summer recreational levels are reservoir elevations which were deemed necessary to promote adequate economic benefits to the regional areas (TVA, 1990). After July 31, the drawdown period begins in an

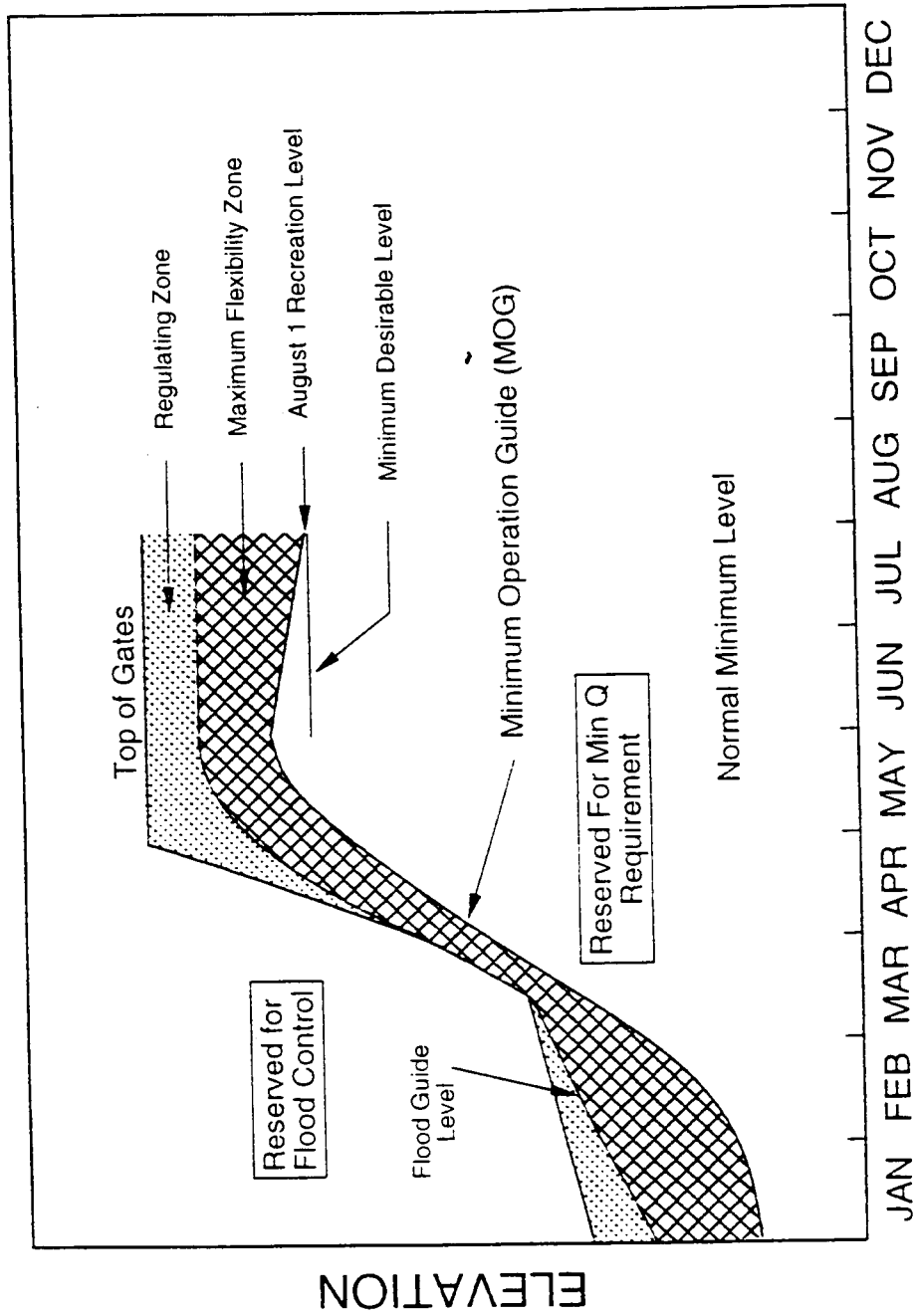


Figure 4. General Tributary Operating Guide Curve

effort to economically dispatch water through the system while drawing towards winter flood control levels. There are essentially no “guide curves” during the drawdown period. Reservoirs are simply lowered to flood control levels while attempting to maximize other multi-purpose objectives. Mainstream projects are operated in a similar manner with regards to navigation requirements which maintain a minimum 9 foot draft for barge traffic. Pool levels on mainstream projects will vary only a few feet during the year, generally 2 to 6 feet, while tributary projects can fluctuate as much as 75 feet during the year. A typical operating guide curve for main river projects is shown in Figure 5.

FORECASTING PROCEDURES

The operating guide curves provide target levels to maximize the system benefits while ensuring the basic mandates for which the system was designed are followed. Daily scheduling of the reservoir system is a complex process which must account for numerous factors which can affect the benefits the schedule is trying to maximize. These factors include weather conditions, power load predictions, water in storage, predicted hydrologic inflows, travel time through the system, seasonal operating elevations, and any special operations. By use of computers,

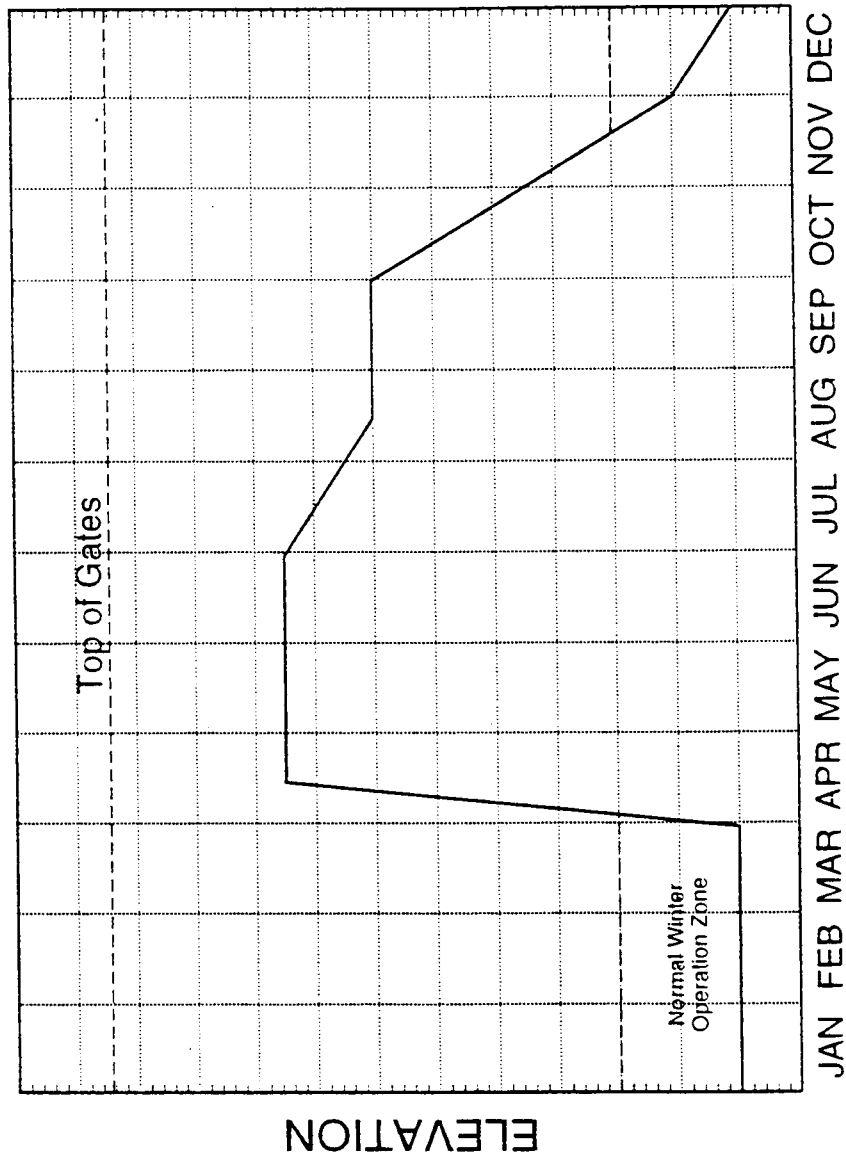


Figure 5. General Main River Operating Guide Curve

an extensive data collection system, and mathematical models a detailed schedule with regards to hydrologic inflows, discharges, and reservoir elevations is derived each day to determine the quantity of water to be released at each reservoir for 10 to 14 days into the future. There are essentially six major areas of the scheduling and implementation process: (1) data collection, (2) data validation and processing, (3) computing hydrologic inflows, (4) scheduling of the reservoir system, (5) dissemination of the operating plan, and (6) monitoring. The major focus of this study will be on determining future hydrologic inflows and scheduling the reservoir system.

Each morning, following the data validation and processing of 292 precipitation and 74 streamflow gages (see Figure 6), the observed hydrologic inflows for each reservoir system are determined. Also, based on the previous 24 hours rainfall, an "inflow model" will determine additional hydrologic inflows from the observed rainfall. The inflow predictions are derived from an Antecedent Precipitation Index (API) and Runoff Index (RI) empirical hydrologic model using 6-hour unit hydrographs for each sub-basin. The model uses a combination of the time of the year, previous rainfall, and local topography to determine the

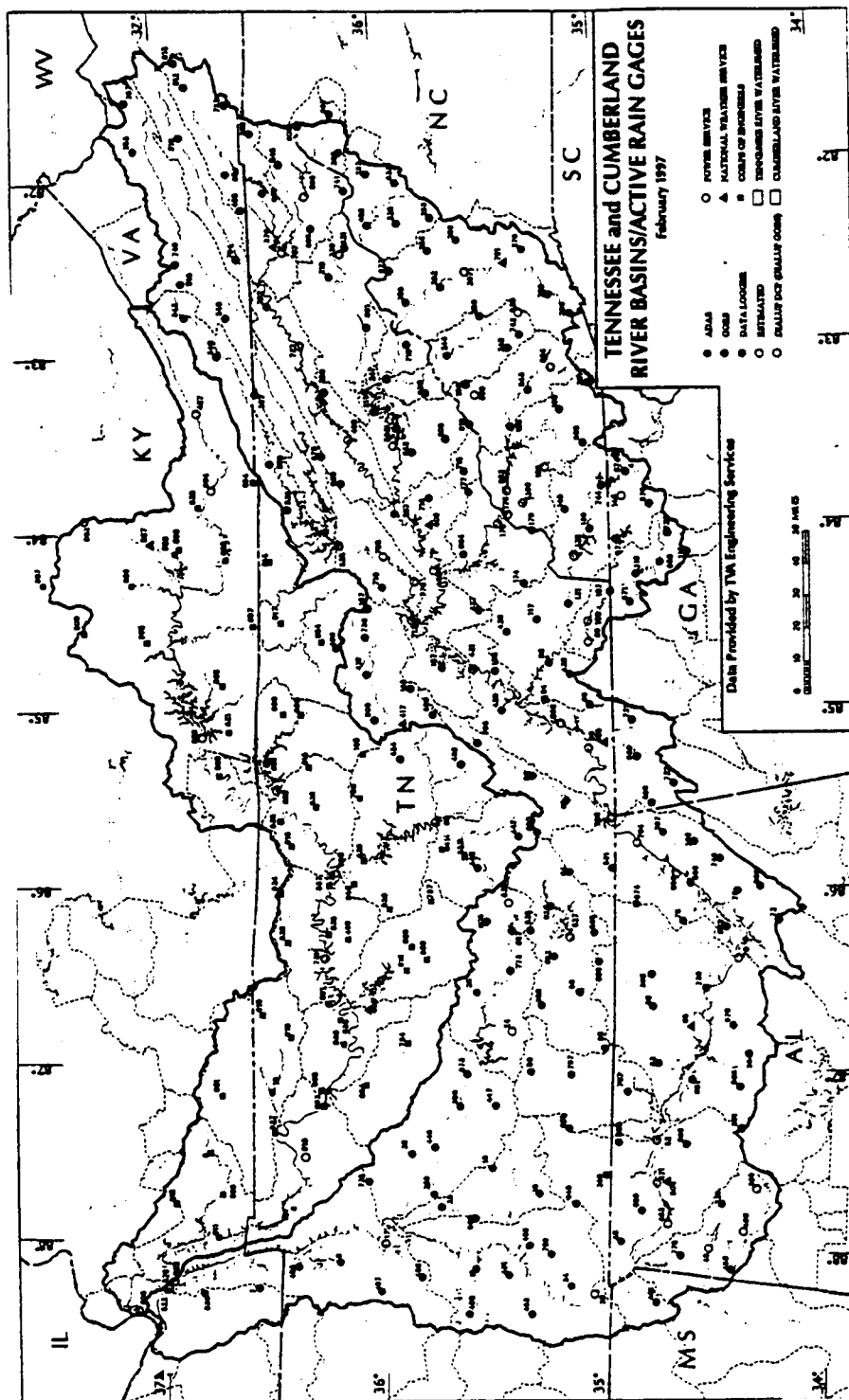


Figure 6. Tennessee Valley Rain Gage Network

amount of surface runoff and groundwater runoff for each sub-basin. The forecasters can then adjust the hydrologic inflow prediction by changing any number of parameters. A typical example of an inflow model sub-basin is shown in Figure 7.

The forecasters have the options of adjusting the groundwater recession factor (2 hour ground K factor, denoted as grk), the amount of surface runoff (sro) or the amount of groundwater runoff (gro). Forecasters can also change the shape of the predicted hydrograph by adjusting the Horizontal, Vertical or Shift parameters of the inflow model. Precipitation, denoted as “ pcp ” in Figure 7, is considered a known quantity and cannot be adjusted.

After the 96 sub-basins have been adjusted, this determines the hydrologic inflows for the TVA reservoir system for the next 14 days based on observed precipitation or “rain on the ground”. It is important to note that although the hydrologic inflows are generally updated once every 24 hours, the ability exists to update every 6 hours during heavy rainfall events, if needed.

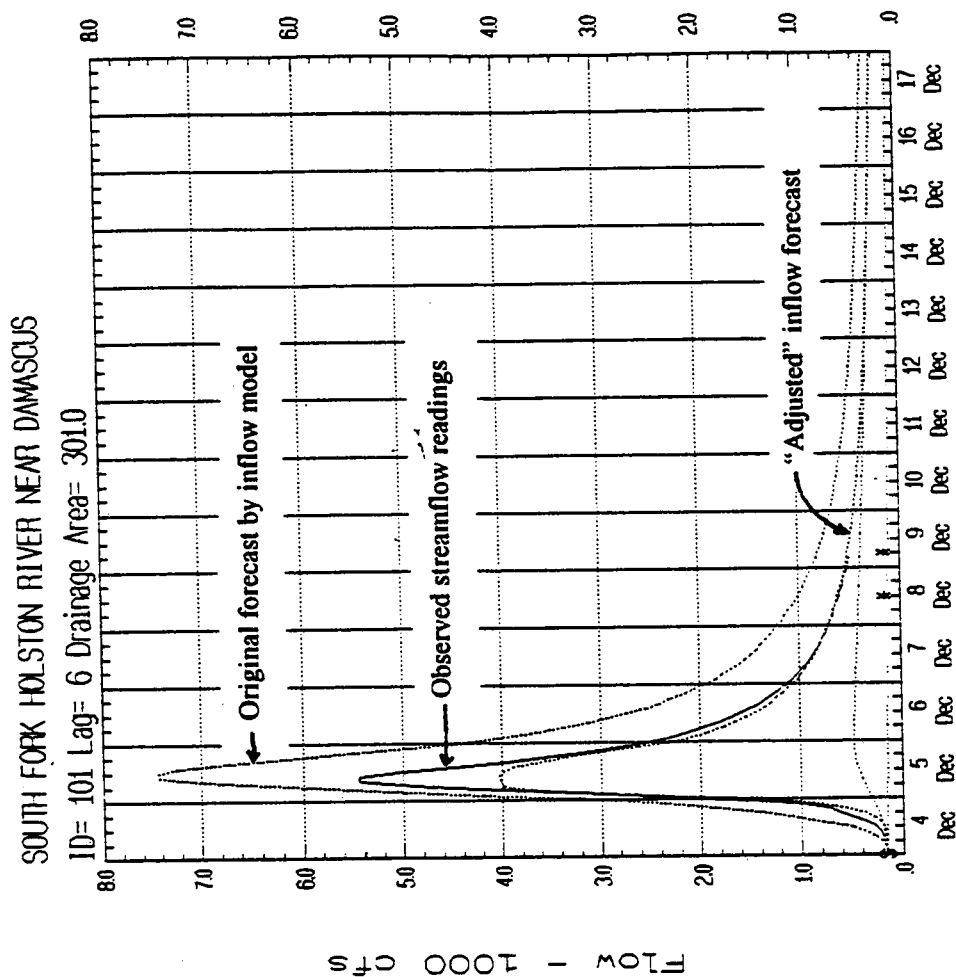
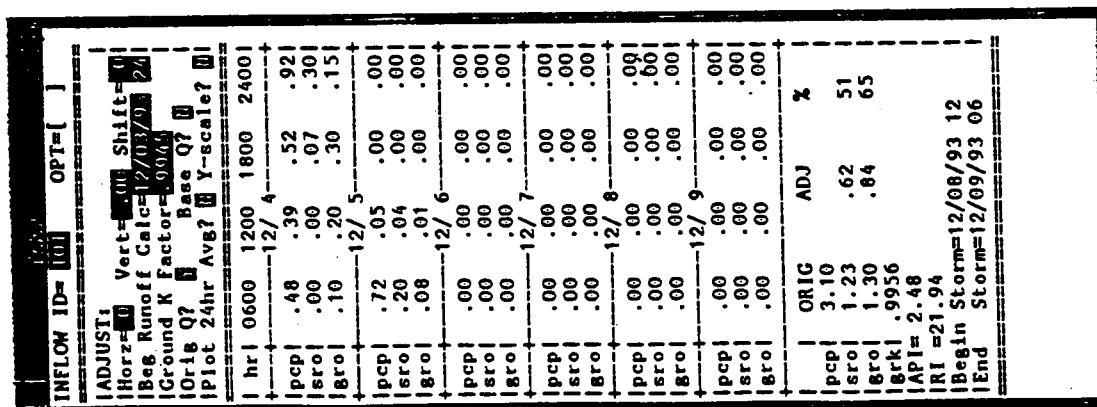


Figure 7. Inflow Model Sub-basin

TVA receives a weather forecast from Weather Services Corporation (WSC) three times a day, which includes predicted quantitative precipitation amounts for the next 10 days starting at 6 am of the current day. WSC also provides text discussion and temperature forecasts over the same period, as shown in Figure 8. The precipitation amounts are actually forecast in 6 hour periods for the next 48 hours and in daily averages for days 2 to 10. The forecasted rainfall amounts are for five separate drainage areas across the Tennessee Valley, see Figure 9. These five areas were chosen based on geographical similarities and watershed basins.

The rainfall amounts are processed through the inflow model to provide predicted hydrologic inflows for each reservoir based on the current API and RI associated with each sub-basin. An example of the predicted rainfall and resulting inflows are shown in Figure 10. The resulting predicted inflows can then be added to the forecasted inflows from observed rainfall to be used in scheduling the TVA reservoir system.

WEATHER SERVICES CORPORATION
 LEXINGTON, MASSACHUSETTS
 TELEPHONE: (617) 676-1000
 KEVIN ROTH FROM THE TVA FORECAST DESK

TENNESSEE VALLEY AUTHORITY
 TUESDAY 18-FEB-97 10:35AM

SYNOPTIC DISCUSSION

0-48 HOURS: Very warm temperatures are on tap for the next 48 hours as high pressure anchors itself in the Western Atlantic. The high is in a similar set up to the Bermuda High of summer so temperatures should be very nice for late February with maxes in the 60s to lower 70s and overnight lows in the 40s and 50s. A cold front will try and drop southward through the region later tomorrow and tomorrow night, but it should have little affect on the temperatures. There may be a few showers along the front tomorrow afternoon and evening as it moves through the region, but amounts should generally be 1/10 of an inch or less.

Confidence: Above Average.

3-5 DAYS: A big storm will develop in Texas later tomorrow, then rip off to the northeast and pass through the Northern Ohio Valley on Friday. Clouds from this storm should overrun the frontal system in the region on Thursday causing a cooler day with the chance of some rain. Temperatures should be in the 50s to middle 60s for maxes with the warmest region being Northern Alabama. The rainfall on Thursday should be fairly light with 0.20-0.40" expected. Heavier rain is likely on Friday as a squall line forms along the storms cold front and moves eastward through the region during the day. The thunderstorms in the squall line may be locally heavy to severe with gusty wind and hail possible. Rainfall should be on the order of 0.50-1.00" in all the basins. Temperatures should warm during the day Friday, then cool off to slightly above normal readings behind the front Friday night and Saturday.

Confidence: Average to below average due to timing and intensity differences between the models on the Thursday and Friday storm.

6-10 DAYS: High pressure should drop in behind the storm for a sunny, but cooler weekend with temperatures close to or slightly above normal levels. The "cooler" pattern should continue into early next week with the next rain event possible in the later half of the period as the atmosphere tries to warm.

Confidence: Below average.

SEVERE WEATHER POTENTIAL

None until Friday.

PRECIPITATION FORECAST

	NW	SW	CN	ET	NE
TODAY	0.0	0.0	0.0	0.0	0.0
TONIGHT	0.0	0.0	0.0	0.0	0.0
TOMORROW	0.1	0.0	0.2	0.2	0.1
TOTAL	0.1	0.0	0.2	0.2	0.1
HI SPOTS	0.7	0.5	0.5	0.7	0.7
THURSDAY	0.3	0.4	0.4	0.3	0.2
FRIDAY	0.4	0.6	0.6	0.6	0.4
SATURDAY	0.0	0.0	0.0	0.1	0.1
SUNDAY	0.0	0.0	0.0	0.0	0.0
MONDAY	0.0	0.0	0.0	0.0	0.0
TUESDAY	0.0	0.0	0.0	0.0	0.0
WEDNESDAY	0.3	0.4	0.3	0.5	0.3
THURSDAY	0.2	0.5	0.4	0.4	0.2

Figure 8. Typical Weather Forecast

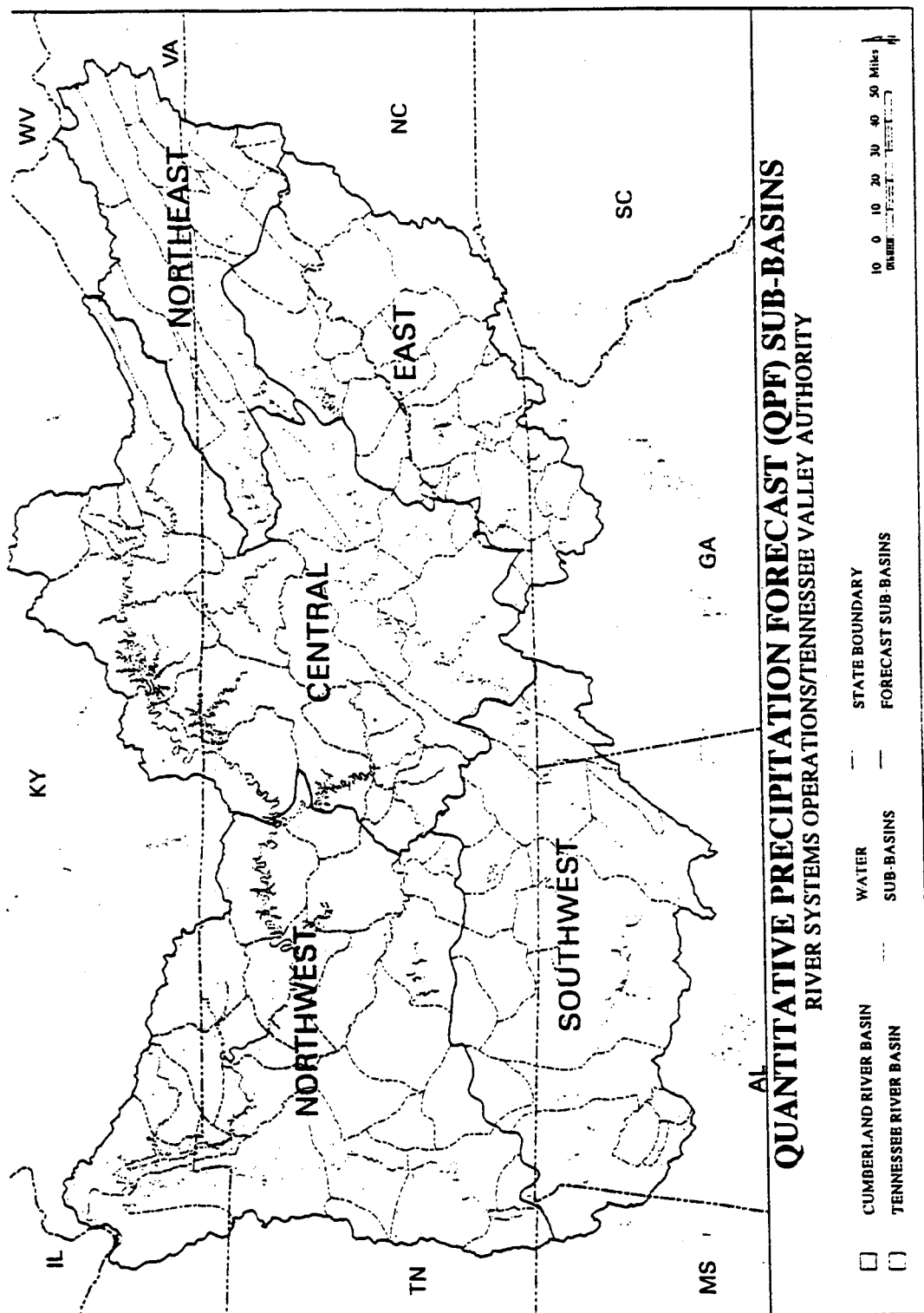


Figure 9. Quantitative Precipitation Forecast Sub-Basins

INFLOW MODEL PREDICTED RAIN LOAD SHEET

	DAY 1				DAY1 TOTAL	DAY 2				DAY2 TOTAL
	12	18	24	06		12	18	24	06	
NE	.00	.00	.10	.00	.10	.00	.00	.00	.00	.00
E	.00	.10	.20	.00	.30	.00	.10	.00	.00	.10
C	.00	.10	.10	.00	.20	.00	.00	.00	.00	.00
SW	.10	.20	.10	.00	.40	.00	.10	.10	.00	.20
NW	.00	.10	.00	.00	.10	.00	.00	.00	.00	.00

	DAY 3	DAY 4	DAY 5	DAY 6	DAY 7	DAY 8	DAY 9	DAY 10	TOTAL
NE	.30	.10	.10	.10	.00	.10	.10	.20	1.10
E	.30	.30	.20	.20	.10	.10	.10	.20	1.90
C	.30	.10	.10	.10	.00	.10	.10	.20	1.20
SW	.30	.20	.20	.30	.10	.10	.20	.30	2.30
NW	.30	.10	.00	.10	.00	.00	.10	.20	.90

Precip zeroed for DAY 1 thru hour 06

Lump daily precip into a single 6hr period N

Input file=data/precip.max

! Issue Date: 19970707 Time: 0530 Vendor: W Probability: c

TENNESSEE VALLEY AUTHORITY											RIVER SYSTEM OPERATIONS			
P R E D I C T E D R A I N T E N N E S S E E R I V E R											JUL 7, 1997 11:49			
FLOW VOL	JUL 7	JUL 8	JUL 9	JUL 10	JUL 11	JUL 12	JUL 13	JUL 14	JUL 15	JUL 16	JUL 17	JUL 18	JUL 19	
SOUTH HOL	.03	.00	.07	.05	.03	.03	.01	.02	.03	.05	.02	.00	.00	
WATAUGA	.03	.00	.06	.04	.03	.03	.01	.02	.03	.04	.01	.00	.00	
BOONE	.02	.00	.04	.03	.02	.02	.00	.01	.02	.03	.01	.00	.00	
FT PAT	.00	.00	.01	.01	.00	.00	.00	.00	.00	.01	.00	.00	.00	
CHEROKEE	.09	.00	.21	.18	.16	.18	.10	.15	.16	.23	.11	.07	.06	
DOUGLAS	.31	.11	.24	.33	.64	1.23	2.00	2.04	1.30	1.02	.74	.62	.58	
THORPE	.02	.01	.01	.02	.01	.02	.02	.01	.01	.01	.00	.00	.00	
NANT	.02	.01	.01	.02	.02	.05	.06	.03	.02	.02	.01	.01	.01	
FONTANA	.12	.04	.09	.12	.13	.55	.95	.57	.32	.26	.18	.14	.13	
SANT	.03	.01	.02	.03	.03	.15	.14	.06	.04	.04	.02	.02	.02	
CHEOAH	.01	.00	.01	.01	.02	.03	.03	.01	.01	.01	.01	.00	.00	
CALD	.01	.00	.01	.01	.02	.07	.07	.03	.02	.02	.01	.01	.01	
CHILH	.02	.01	.02	.03	.05	.13	.12	.06	.03	.03	.02	.02	.01	
NORRIS	.12	.00	.28	.21	.17	.18	.09	.15	.18	.27	.11	.05	.04	
MEL H	.04	.00	.06	.05	.05	.05	.03	.04	.04	.06	.03	.01	.01	
TIMS F	.17	.10	.12	.16	.27	.49	.60	.43	.35	.34	.25	.21	.20	
GREAT FAL	.01	.00	.02	.01	.01	.01	.00	.01	.01	.01	.00	.00	.00	
CHATUGE	.08	.03	.06	.08	.06	.12	.14	.07	.06	.07	.03	.02	.02	
NOTTELY	.04	.01	.03	.04	.03	.10	.12	.05	.04	.04	.02	.01	.01	
HIWAS	.07	.02	.05	.07	.09	.42	.45	.23	.15	.13	.09	.07	.06	
APAL	.01	.00	.01	.01	.01	.04	.05	.02	.01	.01	.01	.01	.01	
BLUE RIDG	.04	.01	.03	.04	.03	.07	.11	.06	.03	.04	.02	.01	.01	
OCCEE 3	.00	.00	.00	.00	.01	.09	.18	.07	.03	.03	.02	.02	.02	
OCCEE 1	.02	.01	.02	.02	.03	.09	.07	.02	.02	.02	.01	.01	.01	
FORT LOUD	.12	.02	.16	.17	.30	.63	.71	.69	.49	.46	.34	.27	.25	
WATTS BAR	.32	.08	.52	.53	.61	.60	.44	.48	.48	.57	.39	.36	.34	
CHICKAMAU	.28	.00	.32	.21	.14	.14	.04	.11	.14	.25	.07	.00	.00	
NICKAJACK	.18	.09	.10	.14	.19	.47	.75	.66	.48	.43	.34	.29	.27	
GUNTERSVI	1.18	1.11	1.64	2.15	2.88	3.63	4.08	3.10	2.50	2.69	2.46	2.24	2.06	
WHEELER	1.05	.74	.95	1.56	2.57	4.17	5.91	4.70	3.39	2.82	2.23	2.03	1.89	
WILSON	.30	.33	.52	.82	1.37	1.87	2.45	2.13	1.49	1.22	.99	.92	.85	
PICKWICK	.75	.82	1.00	1.35	2.05	2.71	3.50	2.85	2.03	1.78	1.34	1.22	1.12	
U.BEAR	.03	.04	.05	.06	.08	.13	.12	.07	.06	.07	.06	.05	.05	
B.BEAR	.01	.02	.02	.03	.04	.08	.13	.06	.04	.04	.04	.04	.03	
L.BEAR	.03	.02	.02	.03	.03	.06	.06	.03	.03	.03	.02	.02	.02	
CEDAR	.07	.07	.08	.11	.14	.21	.24	.15	.11	.12	.10	.09	.08	
NORMANDY	.01	.00	.03	.02	.00	.01	.00	.00	.01	.02	.01	.00	.00	
KENTUCKY	.64	.00	1.45	1.07	.41	.77	.44	.26	.72	1.35	.54	.23	.22	
BARKLEY	.23	.00	.53	.39	.13	.24	.11	.05	.21	.44	.14	.02	.02	
WOLF CREE	.39	.03	.51	.46	.55	.69	.54	.56	.55	.64	.35	.22	.19	
DALE HOLL	.22	.00	.24	.18	.14	.15	.07	.12	.14	.22	.08	.03	.03	
CENTER HI	.15	.00	.16	.11	.07	.07	.02	.05	.07	.13	.04	.00	.00	
CORDELL H	.09	.00	.10	.07	.05	.05	.01	.03	.05	.08	.02	.00	.00	
OLD HICKO	.09	.00	.21	.14	.02	.07	.02	.00	.07	.16	.05	.00	.00	
J.P. PRIE	.06	.00	.13	.09	.01	.04	.01	.00	.04	.10	.03	.00	.00	
CHEATHAM	.03	.00	.07	.05	.01	.02	.01	.00	.02	.05	.02	.00	.00	
NATURAL FLOWS														
CHICKAMAU	1.86	.37	2.33	2.30	2.71	5.02	5.94	5.01	3.67	3.72	2.29	1.73	1.60	
ABOVE CHATT	SRO=	.02	GRO=	.07	TotRO=	.09	Precip=	1.39						
BELOW CHATT	SRO=	.05	GRO=	.21	TotRO=	.26	Precip=	1.56						

Figure 10. Typical Example of Predicted Rainfall and Resulting Inflows

FORECASTING HISTORY

In the 1980s and early 1990s, TVA also received weather forecasts from WSC. However, the forecast only had predicted daily precipitation amounts for 5 days in the future to the nearest quarter-inch, as shown in Figure 11. Also, there was no weather radar, except as shown during the 6 and 11 o'clock news, and there was no such thing as the "Weather Channel." Also, based on TVA's experience with the weather forecasts, the reliability and accuracy of the predicted rainfall amounts were not much better than historical data (Arnwine, 1995).

Scheduling of the TVA Reservoir System was still done on a daily basis, with the number of days scheduled depending on the day of the week. This was partly due to the technology available at the time. Most forecasts were 7 days or less because that was all the schedulers could get on the computer screens. The only time the schedule exceeded more than 7 days was on Wednesdays and Thursdays when the schedule would be extended to Friday of the next week. This was done in order to give the Power Generation section in TVA an outlook on what to expect for hydroelectric generation from the reservoir system for Monday to Friday of the next week. The Generation section would then use this

ST. LOUIS MO... 4-344-8822

TYS & CHA TENNESSEE

5:30AM CT FORECAST SAT day 12/21/91

SYNOPTIC DISCUSSION

A COLD FRONT WILL PUSH THROUGH THE SYSTEM TODAY. RAINFALL WILL ACCOMPANY THE FRONTAL PASSAGE. BY TONIGHT, THE FRONT WILL BE JUST TO THE SOUTH OF THE AREA AND IT SHOULD BE DRY OVERNIGHT. RAIN SHOULD RETURN TO THE WESTERN SECTIONS ON SUNDAY AND THE EASTERN SECTIONS ON MONDAY AS A STORM CENTER SLOWLY APPROACHES FROM THE WEST. RAINFALL WILL END FROM WEST EAST ON MONDAY AND TUESDAY. TEMPERATURES WILL BE ON THE MILD SIDE THROUGH THE PERIOD.

TODAY...RAINFALL WILL SPREAD FROM THE WESTERN SECTIONS INTO THE EASTERN SECTIONS. WINDS S TO NE 5 TO 15.

TNT....MOSTLY CLOUDY. WINDS NE TO E 4 TO 8.

TMRW...RAIN DEVELOPING IN THE WEST. PARTLY CLOUDY TO CLOUDY IN THE CENTRAL AND EASTERN SECTIONS. WINDS NE TO SE 4 TO 8.

MON day RAIN.

TUE day CLEARING WEST. RAIN ENDING IN THE CENTRAL AND EASTERN SECTIONS.

WED day MOSTLY CLEAR.

PRECIPITATION FORECAST

(Today=7A-7P; Tongt=7P-7A; Tomru=7A-7A)

	W/WCB/WC/SW	ECB	EC	NE	E/SE
TODAY:	1/4-1/2	1/4-1/2	LT 1/4	1/4-1/2	LT 1/4
TONGT:	NIL	NIL	NIL	NIL	NIL
TOMRW:	LT 1/4	NIL	NIL	NIL	NIL
TOTAL:	1/4	1/4	LT 1/4	1/4	LT 1/4
HI SPT:	1	1/2	1/4	1/2	1/4

MON day: 1/4 TO 1/2 WEST AND CENTRAL SECTIONS. 1/4 EAST

TUE day: NONE WEST. 1/4 CENTRAL. 1/4 TO 1/2 EAST

WED day: NONE

SUR WX PTNL: NONE TODAY...

	TEMPERATURES			CLOUD COVER			
	MAX	MIN	MAX	AM	PM	AM	PM
TYS	51	36	54	4	3	3	2
CHA	54	37	55	3	4	3	3
BNA	51	41	55	4	3	3	4
MEM	53	44	57	4	4	3	4
AUG	52	40	55				

	08	09	12	15	18	21	24	03	06	07	08	09	12	15	18	21	24
TYS	40	42	49	50	44	41	39	37	36	36	38	41	51	53	46	43	41
CHA	43	45	52	54	48	44	41	38	37	37	40	43	52	55	51	48	46
BNA	47	47	49	50	46	44	43	42	41	41	43	45	53	55	51	48	47
MEM	49	50	52	53	50	48	46	45	44	44	45	45	52	57	54	53	52
AUG	45	46	51	52	47	44	42	41	40	40	42	44	52	55	51	48	47

	EAST	WEST	AUG	SUN day	MON day	TUE day	WED day
MON day	/	/	/	/	/	/	/
MIN	38/ 6	44/24	41	/	/	/	/
MAX	58/14	59/14	59	/	/	/	/
TUE day	/	/	/	/	/	/	/
MIN	34/24	39/ 6	37	/	/	/	/
MAX	53/14	55/14	54	/	/	/	/
WED day	/	/	/	/	/	/	/
MIN	29/ 6	34/ 6	32	/	/	/	/
MAX	54/15	56/15	55	/	/	/	/
	/	/	/	/	/	/	/
	/	/	/	/	/	/	/
	/	/	/	/	/	/	/
	/	/	/	/	/	/	/

Figure 11. Typical Weather Forecast From 1980s and Early 1990s

information as a guide in helping make decisions on buying or selling electricity for the upcoming week. Many of these “buys” or “sales” would actually be made before the weekend.

The extended reservoir schedules, or routings, were accomplished by lagging the first routing on the computer 5 days and running an entirely new schedule for 5 or more days, examples of which are given in Figures 12 and 13. In other words, it was almost twice the work normally required during a given day. The extended schedule was always based entirely on hydrologic inflows from observed rainfall, as were all the other forecasts which were disseminated to the public and the Power Generation section in TVA.

Then in the late 1980s, TVA’s computer hardware was updated to where the reservoir system could be scheduled up to 14 days on one computer screen, see Figure 14. Also during this time, more sophisticated weather forecasting techniques and weather radar were being developed and made available to TVA. TVA now has a dedicated computer monitor for weather radar and a TV monitor tuned into the weather channel on a 24 hour basis.

OBS. RAIN 8/29/84		RESERVOIR ROUTING COMPUTATIONS					
TIME 9:55	8/28	8/29	8/30	8/31	9/1	9/2	
	TUE	WED	THU	FRI	SAT	SUN	
----- BLUE RIDGE -----							
ADJUST		0.00	0.00	0.00	0.00	0.00	
TOT LO	.980	.40	.37	.35	.34R	.33	
TOT IN		.40	.37	.35	.34	.33	
DEL ST		-.31	-.40	-.50	-.59	-.60	
STORAG	76.60	76.29	75.89	75.39	74.80	74.20	
ELEVAT	1677.01	1676.8	1676.5	1676.2	1675.8	1675.4	
POWER		157X	170X	187C	204C	204	
FACTOR		220C	220	220	220	220	
RATIO		0.00	0.00	0.00	0.00	0.00	
CRYOVR	.46	.46C	.46	.46	.46	.46	
TOTL Q		.71	.77	.85	.93	.93	
----- OCOEE # 3 -----							
PR ARR		.71	.77	.85	.93	.93	
ADJUST		0.00	0.00	0.00	0.00	0.00	
TOT LO	.980	.27	.25R	.25	.24	.24	
TOT IN		.98	1.02	1.10	1.17	1.17	
DEL ST		-.12	-.08	-.03	.03	.03	
STORAG	1.22	1.10	1.02	.99	1.02	1.05	
ELEVAT	1432.80	1432.1	1431.5	1431.3	1431.5	1431.7	
POWER		600C	600	616X	624C	624	
FACTOR		545C	545	545	545	545	
RATIO		0.00	0.00	0.00	0.00	0.00	
CRYOVR	.14	.14C	.14	.14	.14	.14	
TOTL Q		1.10	1.10	1.13	1.14	1.14	
----- OCOEE # 1 -----							
#3 ARR		1.10	1.10	1.13	1.14	1.14	
ADJUST		0.00	0.00	0.00	0.00	0.00	
TOT LO	.950	.15	.12	.10R	.10	.09	
TOT IN		1.25	1.22	1.23	1.24	1.23	
DEL ST		.05	-.10	-.09	-.08	-.09	
STORAG	41.07	41.12	41.02	40.93	40.85	40.76	
ELEVAT	829.30	829.3	829.2Z	829.1	829.1	829.0	
POWER		200X	221	221	221	221	
FACTOR		174C	174	174	174	174	
TOTL Q		1.20	1.32	1.32	1.32	1.32	

Figure 12. First Five Days of Week Study Schedule

WK STUDY 8/29/84		RESERVOIR ROUTING COMPUTATIONS				
TIME 11:30	9/2	9/3	9/4	9/5	9/6	9/7
		MON	TUE	WED	THU	FRI
----- BLUE RIDGE -----						
ADJUST		0.00	0.00	0.00	0.00	0.00
TOT LO	.530	.33R	.32	.32	.31	.30
TOT IN		.33	.32	.32	.31	.30
DEL ST		-.60	-.53	-.53	-.54	-.55
STORAG	74.20	73.60	73.07	72.54	72.00	71.45
ELEVAT	1675.40	1674.9	1674.6	1674.2	1673.8	1673.4
POWER		204X	187C	187	187	187
FACTOR		220C	220	220	220	220
RATIO		0.00	0.00	0.00	0.00	0.00
CRYOVR	.46	.46C	.46	.46	.46	.46
TOTL Q		.93	.85	.85	.85	.85
----- OCCEE # 3 -----						
BR ARR		.93	.85	.85	.85	.85
ADJUST		0.00	0.00	0.00	0.00	0.00
TOT LO	.980	.23R	.23	.22	.22	.21
TOT IN		1.16	1.08	1.07	1.07	1.06
DEL ST		.02	-.02	-.03	-.03	-.04
STORAG	1.05	1.07	1.05	1.02	.99	.95
ELEVAT	1431.70	1431.9	1431.7	1431.5	1431.3	1431.0
POWER		620X	600C	600	600	600
FACTOR		545C	545	545	545	545
RATIO		0.00	0.00	0.00	0.00	0.00
CRYOVR	.14	.14C	.14	.14	.14	.14
TOTL Q		1.14	1.10	1.10	1.10	1.10
----- OCCEE # 1 -----						
#3 ARR		1.14	1.10	1.10	1.10	1.10
ADJUST		0.00	0.00	0.00	0.00	0.00
TOT LO	.950	.09R	.09	.08	.08	.07
TOT IN		1.23	1.19	1.18	1.18	1.17
DEL ST		-.01	-.05	-.06	-.06	-.07
STORAG	40.76	40.75	40.70	40.64	40.58	40.51
ELEVAT	829.00	829.0Z	828.9	828.8	828.8	828.7Z
POWER		207	207	207	207	207
FACTOR		174C	174	174	174	174
TOTL Q		1.24	1.24	1.24	1.24	1.24

Figure 13. Additional Five Days of Week Study Schedule

RESERVOIR FORECASTS - ISSUED BY RIVER SYSTEM OPERATIONS									
(data observed)									
MAY 7, 1997									
TIME: 11:11									
05/07	05/08	05/09	05/10	05/11	05/12	05/13	05/14	05/15	05/16
2400	2400	2400	2400	2400	2400	2400	2400	2400	2400
Med	Thu	Fri	Sat	Sun	Mon	Tue	Wed	Thu	Fri
SOUTH HOLSTON									
In	1.1	1.1	1.0	1.0	.9	.8	.8	.7	.7
El	1728.6	1728.6	1728.7	1728.8	1728.8	1728.7	1728.7	1728.6	1728.5
Out	1.2	1.2	1.2	1.2	1.2	1.0	1.0	1.0	1.0
MWh	480	480	480	480	480	404	404	404	404
WATAUGA									
In	.7	.8	.7	.6	.6	.6	.5	.5	.4
El	1958.5	1958.5	1958.7	1958.8	1958.8	1958.7	1958.6	1958.5	1958.5
Out	.8	.7	.7	.7	.7	.7	.7	.7	.7
MWh	420	368	368	368	368	372	372	372	372
MILBUR									
In	.7	.6	.6	.6	.6	.6	.6	.6	.6
El	1958.5	1958.5	1958.7	1958.8	1958.8	1958.7	1958.6	1958.5	1958.5
Out	.8	.7	.7	.7	.7	.7	.7	.7	.7
MWh	420	368	368	368	368	372	372	372	372
BOONE									
In	.9	.9	.8	.8	.8	.7	.7	.6	.5
El	1381.5	1381.6	1381.7	1381.8	1381.7	1381.7	1381.7	1381.7	1381.7
Out	2.9	2.6	2.6	2.6	2.3	2.3	2.3	2.3	2.3
MWh	624	552	552	552	500	500	500	500	500
FORT PAT									
In	.2	.1	.1	.1	.1	.1	.1	.1	.1
El	1260.4	1261.0	1261.0	1261.0	1261.0	1261.0	1261.0	1261.0	1261.0
Out	3.3	2.5	2.7	2.4	2.4	2.4	2.4	2.4	2.4
MWh	302	294	324	185	184	292	292	289	288
CHEROKEE									
In	2.3	2.3	2.0	1.9	1.8	1.7	1.7	1.6	1.5
El	1064.9	1065.3	1065.8	1066.0	1066.2	1066.4	1066.6	1066.9	1067.1
Out	1.1	1.0	1.0	.8	.6	1.0	1.0	1.0	1.0
MWh	256	236	236	140	140	236	236	236	236
DOUGLAS									
In	10.7	10.3	9.5	9.1	8.7	8.3	8.0	7.6	7.2
El	993.3	993.4	993.5	993.6	993.7	993.7	993.7	993.6	993.5
Out	7.9	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0
MWh	1730	1744	1744	1744	1744	1744	1744	1744	1744
FONTANA									
In	6.9	6.7	6.4	6.2	6.0	5.8	5.7	5.6	5.4
El	1700.4	1700.5	1700.6	1700.6	1700.6	1700.5	1700.4	1700.3	1700.2
Out	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
MWh	3868	3872	3872	3872	3872	3872	3872	3872	3872
CHATUGE									
In	.7	.7	.6	.6	.5	.5	.5	.4	.4
El	1925.3	1925.2	1925.0	1924.9	1924.7	1924.6	1924.3	1924.2	1924.0
Out	1.1	1.1	1.1	1.1	1.1	.9	.9	.9	.9
MWh	240	240	240	240	240	188	188	188	188
HOTELLY									
In	.6	.6	.5	.5	.5	.5	.5	.5	.4
El	1776.7	1776.5	1776.3	1776.2	1776.0	1775.9	1775.6	1775.7	1775.6
Out	.9	.9	.9	.8	.8	.7	.6	.6	.5
MWh	0	0	0	0	0	0	0	0	0
HIVASSEE									
In	1.7	1.6	1.5	1.4	1.3	1.2	1.2	1.1	1.0
El	1519.0	1519.3	1519.6	1519.9	1520.1	1520.2	1520.2	1520.2	1520.1
Out	3.0	2.7	2.6	2.6	2.6	2.7	2.7	2.7	2.7
MWh	1348	1194	1158	1162	1168	1173	1176	1181	1184
APALACHIA									
In	.2	.2	.2	.2	.2	.1	.1	.1	.1
El	1276.8	1277.0	1277.0	1277.0	1277.0	1277.0	1277.0	1277.0	1277.0
Out	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8
MWh	1806	1824	1824	1824	1824	1824	1824	1824	1824
SANTERLAH									
In	.7	.7	.7	.6	.6	.6	.6	.6	.5
El	1816.8	1816.7	1816.6	1816.4	1816.3	1816.1	1815.9	1815.5	1815.3
Out	.8	.8	.8	.8	.8	.8	.8	.8	.8
MWh	979	984	984	984	984	984	984	984	984
CHEOAH									
In	.1	.1	.1	.1	.1	.1	.1	.1	.0
El	1154.3	1153.0	1153.0	1153.0	1153.0	1153.0	1153.0	1153.0	1153.0
Out	6.2	7.3	6.9	6.9	6.9	6.9	6.9	6.9	6.9
MWh	2076	2438	2292	2291	2288	2288	2288	2288	2284
CALDERWOOD									
In	.6	.6	.6	.6	.6	.6	.6	.6	.6
El	963.1	963.0	963.0	963.0	963.0	963.0	963.0	963.0	963.0
Out	6.9	7.9	7.4	7.3	7.2	7.2	7.2	7.2	7.2
MWh	2533	2849	2742	2682	2672	2669	2669	2667	2662
CHILHOWEE									
In	.2	.2	.2	.2	.2	.2	.2	.2	.2
El	871.7	872.5	872.5	872.5	872.5	872.5	872.5	872.5	872.5
Out	.8	.7	.7	.7	.7	.7	.7	.7	.7
MWh	949	805	825	806	804	800	800	797	792
GREAT FALLS									
In	4.1	3.9	4.2	3.5	3.1	2.8	2.6	2.4	2.2
El	805.3	805.3	805.3	805.1	804.5	803.5	802.3	800.8	799.1
Out	4.9	3.9	4.2	3.7	3.7	3.7	3.7	3.7	3.6
MWh	892	887	892	888	892	892	887	881	874
BLUE RIDGE									
In	1.0	1.0	.9	.8	.8	.8	.7	.7	.6
El	1688.8	1688.4	1688.0	1687.8	1687.7	1687.5	1687.2	1687.0	1687.0
Out	1.6	1.6	1.6	1.1	1.1	1.1	1.1	1.1	1.1
MWh	384	384	384	256	256	256	256	256	128
OCCEE # 3									
In	1.3	1.2	1.2	1.1	1.1	1.0	1.0	.9	.8
El	1431.9	1430.7	1432.6	1433.4	1433.2	1432.8	1432.4	1431.9	1433.1
Out	3.0	3.0	2.4	2.2	2.2	2.2	2.1	2.1	1.5
MWh	672	672	672	672	672	672	672	672	672
OCCEE # 2									
In	4.56	4.56	4.56	285	285	456	456	456	456
El	1688.8	1688.4	1688.0	1687.8	1687.7	1687.5	1687.2	1687.0	1687.0
Out	1.6	1.6	1.6	1.1	1.1	1.1	1.1	1.1	1.1
MWh	384	384	384	256	256	256	256	256	128
OCCEE # 1									
In	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2
El	828.2	828.4	828.4	828.5	828.5	828.8	829.0	829.2	828.9
Out	2.8	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9
MWh	520	560	560	560	560	560	560	560	560
NORRIS									
In	5.1	4.9	4.3	4.0	3.8	3.6	3.5	3.3	3.0
El	1015.1	1015.4	1015.6	1015.8	1015.9	1016.1	1016.2	1016.4	1016.5
Out	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
MWh	356	344	344	344	344	344	344	344	344
MELTON HILL									
In	1.0	1.0	.9	.9	.8	.8	.7	.7	.6
El	793.6	793.8	793.8	793.9	794.0	794.0	794.0	794.0	794.0
Out	2.1	1.9	1.9	1.9	1.6	1.6	1.7	1.7	1.6
MWh	180	164	164	164	136	136	152	152	144
TIMS FORK									
In	.9	1.2	.9	.7	.6	.5	.5	.5	.4
El	887.3	887.2	887.1	887.2	887.3	887.2	887.2	887.1	887.0
Out	.9	1.5	1.5	.1	.1	.1	.1	.1	.1
MWh	195	350	350	0	0	168	168	168	168

Figure 14. Ten Day Reservoir Schedule

Whereas reservoir system schedules would normally only use 5 to 7 days of a “no rain” forecast, schedules were now being generated each day from 10 to 14 days in length using a “dry” forecast. Despite the fact that the Tennessee Valley receives, on average, one inch of rainfall per week, there seemed to be good reasons for not using predicted rainfall in scheduling the reservoir system.

First of all, predicted rain runs (schedules incorporating predicted rainfall) were actually being made if the rainfall in the forecast was deemed significant enough to effect short-term (one to two days) reservoir operations. Releases from the reservoirs based on a predicted rainfall forecast would then be incorporated into the no rain schedule, at least for the first day or two. For example, if the reservoir schedule based on predicted rainfall would show the need to increase the releases from a reservoir in order to move water downstream, every effort would be made to schedule the increased releases on the no rain schedule. This would then be the reservoir system schedule released to the public and the TVA Power Generation Section.

Another reason for not using predicted rainfall in the scheduling process was the lack of flexibility on the main river reservoirs due to

navigation constraints and insignificant storage space. This is especially true during the winter flood season when every effort is made to maintain main river pool levels near the middle of the winter operating zone, which has a total range of only two feet. If rainfall did not develop as forecast, then reductions in generation would be necessary to prevent drawing main river reservoirs below minimum navigation levels and this was not considered feasible with regard to planning purposes in the TVA Power Generation section.

A third reason for using inflows based on a dry forecast was the prevailing mindset when scheduling the TVA reservoir system. Reservoir Operations managers always knew in the back of their mind that the tendency would be for rainfall to occur over the next 10 days. The reservoir managers even had a guide for how much rainfall might occur based on the weather forecast from WSC. Therefore, the schedule for the reservoir system would always be developed, not entirely on a no rain forecast, but one which would actually have the rainfall “potential” factored in. However, the tendency for scheduling the reservoir system frequently leaned to a “dry forecast”. With the TVA region receiving, on average, at least one inch of rainfall per week, the resulting runoff from .

this rainfall during flood season would be near one-half inch. For many reservoirs this corresponds to an increase of 3 to 6 feet in elevation. During the flood control season, reservoir levels may already be drawn down to "normal" flood control levels. Using a no rain forecast the tendency would be to schedule the reservoirs at these same levels or only slightly lower, no more than one to two feet. TVA would certainly not go public with a reservoir forecast showing significant drawdowns (3 to 6 feet) on the tributary projects even if they were expected to remain at present levels due to rain in the forecast.

PREDICTED RAIN FORECASTS

Historical records indicate, as illustrated in Figure 2, the TVA region receives, on the average, almost 52 inches of precipitation each year and the monthly totals are fairly uniform.

Runoff, on the average, is around 22 inches per year Valley-wide or roughly 42 percent of the rainfall. However, runoff varies seasonally across the Tennessee Valley. During the winter months and early spring, or flood season, when evapotranspiration losses are at a minimum, runoff will average 3 to 4 inches or over 60 percent of the rainfall. (Miller, et

al, 1995). From June to November runoff will average slightly less than 1 inch. It is during the high runoff periods in the winter the weather forecasts can be significantly beneficial. This study will focus on the advantages of using predicted rain forecasts during the period from December to May.

TVA receives, at least three time a day, a quantitative precipitation forecast for the next ten days. The forecast is for five separate areas of the TVA system, see Figure 9. Once the weather forecast is received and other data processing requirements are satisfied, the quantitative precipitation forecast is processed through the inflow model. The resulting hydrologic inflow forecast, see Figure 10, can then be used in the reservoir scheduling process. This study will make no attempt to verify the accuracy of the quantitative precipitation forecasts. Although, statistics kept by TVA indicate predicted rain forecasts are usually on the low side (underforecast for the 10 day period) with no significant forewarning of rainfall events totaling more than one inch (see Appendix for predicted rainfall statistics for the period December 1996 to May 1996).

CHAPTER 3

LITERATURE REVIEW

Most hydrologic forecasters for a reservoir system can attest that future rainfall events will significantly affect the operation of that system. However, based on conversations with other officials responsible for operating reservoir systems, no government agency, other than TVA at this time, actually incorporate the increase in hydrologic locals expected from predicted rainfall into the reservoir system schedule.

David Buelow, Hydraulic Engineer with the Corps of Engineers (COE), Water Management Division, in Cincinnati, Ohio stated that although from time to time the COE will make model runs using predicted rainfall, they have never provided these schedules to the public (Buelow, 1996). The results from the predicted rain runs are only used as “what if” type scenarios to provide guidance to schedules using the observed rainfall. John Farley, Senior Engineer, Water Management Group, Nashville District, COE, who is responsible for the daily scheduling of the Cumberland River System, confirmed this point (Farley, 1996). Although the Cumberland River System sometimes will

process a “predicted rain” schedule for the reservoir system, they would not make any operational decisions based on rainfall in the forecast. The reservoir schedules based on predicted rainfall are only used to make operational decisions if the predicted rainfall develops. Also, the predicted rainfall reservoir schedules are only made if significant (more than one inch) rainfall events are in the forecast.

However, the National Weather Service, which provides flood forecasts for uncontrolled streams, has been using quantitative precipitation forecasts for hydrologic model runs for slightly over a year. Conclusions from a NOAA Technical Report state “use of Quantitative Precipitation Forecasts adds value to the river forecasting process” (Reed, et al, 1997). But this is for forecasting uncontrolled streams, not for fully developed integrated reservoir systems.

There have been studies for forecasting reservoir inflows based on anticipated snowmelt runoff (Zhang and Zeng, 1997 and Kawata et al, 1997). However, these studies were based on only using precipitation which has already occurred, abide, in this case was in the form of snowfall.

A paper was published in the Journal of Water Resources describing the use of forecasted hydrologic inflows based on stochastic dynamic programming for reservoir operations (Huang et al, 1991). This method used a simple hydrologic forecast based on conditional probabilities to maximize the expected annual hydropower generation. Although the study provided efficient long-term operating policies, it did not address the issue of relatively short (one to two weeks) hydrologic inflow forecasts.

There have also been studies linking future hydrologic inflows to the El Nino Southern Oscillation (ENSO) phenomenon (McGowan and Sturman, 1996 and McGowan and Sturman, 1997). Although the findings of these reports did substantiate correlation between ENSO phases and hydrologic inflows based on annual cycles, the study did not find a reasonable relationship for basing a hydrologic inflow forecast for one season or one month in advance.

CHAPTER 4

STUDY ANALYSIS

The primary purpose of this study is to confirm using an increase in hydrologic locals based on predicted rainfall will result in a more accurate reservoir system schedule for the next 10 to 14 days. To achieve a more accurate reservoir system schedule the forecasted hydrologic inflows must closely resemble the observed hydrologic inflows over the same time period. It stands to reason if the hydrologic inflow forecast for the next 10 to 14 days is more accurate, the benefits for which the TVA reservoir system were designed will be enhanced. For instance, if an increase in hydrologic locals is forecast based on predicted rain for 3 days or more in the future, the reservoir system can be scheduled to increase discharges from tributary projects prior to heavy runoff occurring. Frequently, from December to February, this results in supplementing turbine releases with spillway releases on TVA's main river reservoirs which have limited storage capacity. Therefore, it is possible to avoid "spilling water" which could be used for hydroelectric generation by moving the water downstream sooner.

For reasons mentioned previously, predicted rain locals for main river reservoirs were not included as a part of this study. The predicted rain hydrologic inflows were only incorporated into the scheduling process for tributary watersheds. The total drainage area of the tributary reservoirs, on which predicted rainfall will be used, is 15,431 square miles, or just over 38 percent of the entire TVA watershed. By limiting the increase in hydrologic inflows due to predicted rainfall, scheduling conflicts can be avoided. First, if the rainfall in the forecast does not develop to the extent predicted, the main river reservoirs levels will not be scheduled abnormally low. This could have significant impacts on navigation, especially during the winter months when reservoirs may already be near minimum levels. Secondly, the hydroelectric generation needs to be considered in the forecast. If the predicted rainfall does not develop, hydroelectric generation totals can still be met at the expense of lowering the tributary reservoir levels, if necessary. However, since the predicted rainfall is being used on only slightly more than a third of the TVA watershed, chances are hydroelectric generation predictions can still be met without significantly lowering the tributary projects, provided some rainfall does occur.

For the purposes of this study, the three time periods of December 1994 through May 1995, December 1995 through May 1996, and December 1996 through May 1997 were evaluated for predicted hydroelectric generation from the TVA reservoir system. During these time periods, the focus point of the study will be on the reservoir system schedules which were developed on Wednesdays. This particular day was chosen because of its importance to the TVA Generation Section. Data were analyzed pertaining to the hydroelectric generation totals in the reservoir schedule for the following Monday to Friday timeframe. Also, for the period January through early June of 1997 a comparison of the hydrologic inflow forecasts were made using actual observed inflows, observed rainfall inflows, and observed rainfall plus predicted rainfall inflows.

CHAPTER 5

STUDY RESULTS

WEEKLY HYDRO GENERATION TOTALS

Two separate periods were analyzed. They were divided based on runoff periods and the typical mode of reservoir scheduling. The “winter” period from December through February was used because of the amount of runoff received during “flood season”; also, during this period the tributary reservoirs are usually scheduled to maintain flood control levels. The “spring” period March through May was chosen primarily because this is the time of the year the tributary reservoirs are allowed to fill towards summer recreation levels. In all cases, the hydroelectric generation totals of Monday through Friday based on the previous Wednesday forecast were compared to the actual observed generation totals.

For the period December 1994 through February 1995, before predicted rainfall was used in the scheduling process, the average weekly hydroelectric generation totals provided to the TVA Generation section from the reservoir schedule were 198,040 megawatt hours (MWhs). The

actual average weekly generation totals for the same period were 287,950 MWhs, a difference of 89,910 MWhs or 45 percent. Again, for the period December 1995 through February 1996, the average weekly totals based on the reservoir forecast were 247,870 MWhs. The weekly observed generations totals for the period were 318,130 MWhs. The average weekly difference between predicted and observed for this period was 70,260 MWhs or about 28 percent. In mid-April of 1996, the TVA reservoir system was scheduled using the increase in hydrologic inflows based on predicted rain for the tributary projects. The average weekly generation totals provided to the Generation section from December 1996 through February 1997 was 309,480 MWhs. This was, of course, based on the predicted rainfall in the weather forecast. By using the increase in hydrologic inflows on tributary reservoirs from predicted rainfall in the scheduling process the average forecasted weekly generation totals were only 28,020 MWhs, or 9 percent, less than the observed weekly average of 337,500 MWhs.

For the spring period March through May, 1995 the predicted weekly generation totals averaged 122,360 MWhs. The observed generation over the same period averaged 159,770 MWhs. A difference

of 37,410 MWhs or slightly more than 30 percent. From March through May, 1996 the average weekly generation was forecast at 141,680 MWhs. The observed weekly generation averaged 211,980 MWhs. A difference of 70,300 MWhs or almost 50 percent. For the period March through May, 1997, when predicted rain locals were incorporated in the scheduling process for the entire time period, the projected weekly totals during this time were 230,870 MWhs. The observed weekly generation totals averaged 255,740 MWhs, a difference of 24,870 MWhs, or 11 percent. This information is summarized in the tabulated material below.

TIME PERIOD	PREDICTED GENERATION (AVG WEEKLY TOTALS - MWhs)	OBSERVED GENERATION	OBS - PRED (MWhs)	% DIFF
DEC 94 - FEB 95	198,040	287,950	+89,910	45
DEC 95 - FEB 96	247,870	318,130	+70,260	28
*DEC 96 - FEB 97	309,480	337,500	+28,020	9
MAR - MAY 95	122,360	159,770	+37,410	30
MAR - MAY 96	141,680	211,980	+70,300	50
*MAR - MAY 97	230,870	255,740	+24,870	11

* Time periods using predicted rainfall

The data were further analyzed graphically in Relative Frequency Histograms shown in Figures 15 and 16, respectively. For the Histograms the frequency of the difference between the observed weekly

RELATIVE FREQUENCY HISTOGRAM DECEMBER TO FEBRUARY

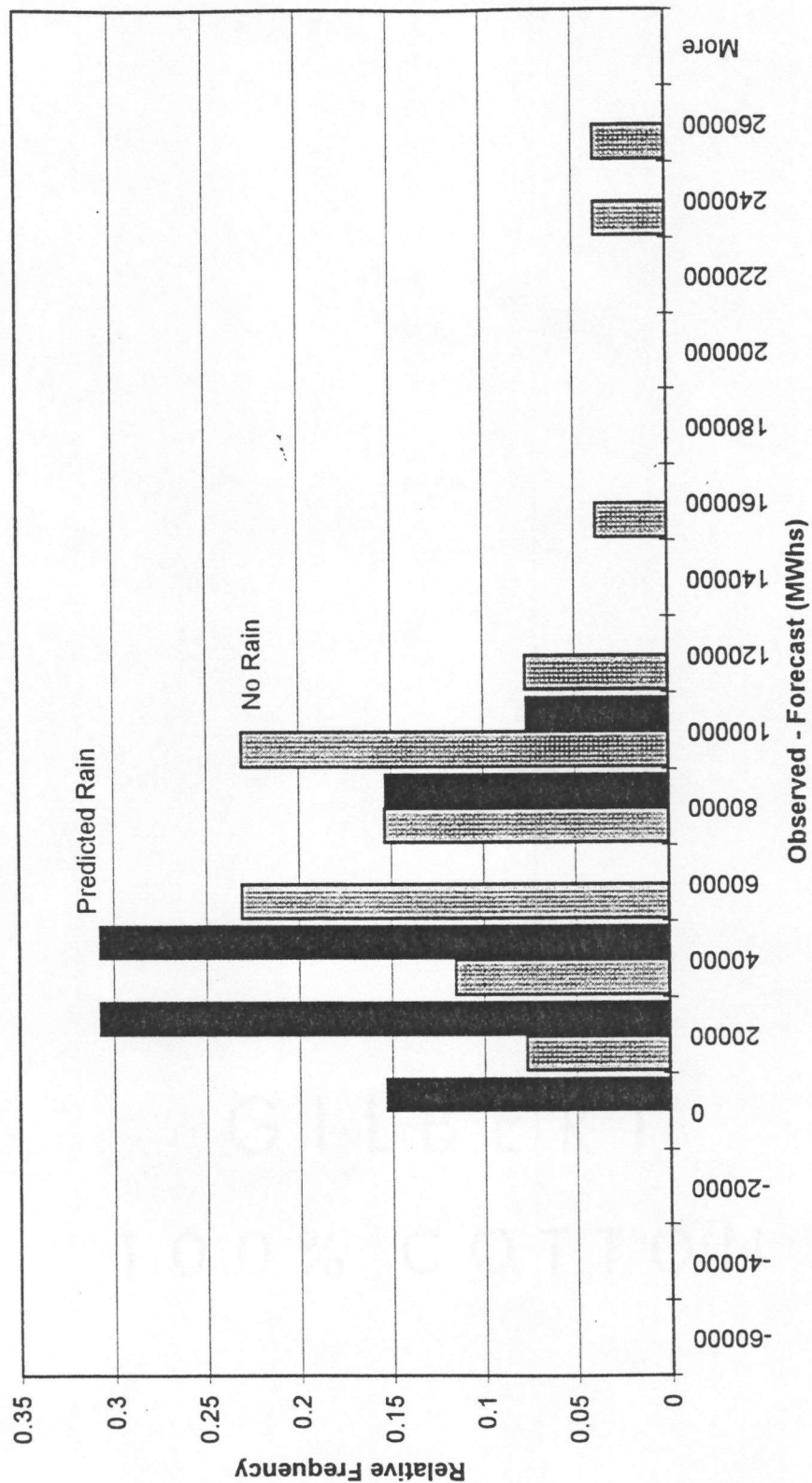


Figure 15. Relative Frequency Histogram for December to February

RELATIVE FREQUENCY HISTOGRAM MARCH TO MAY

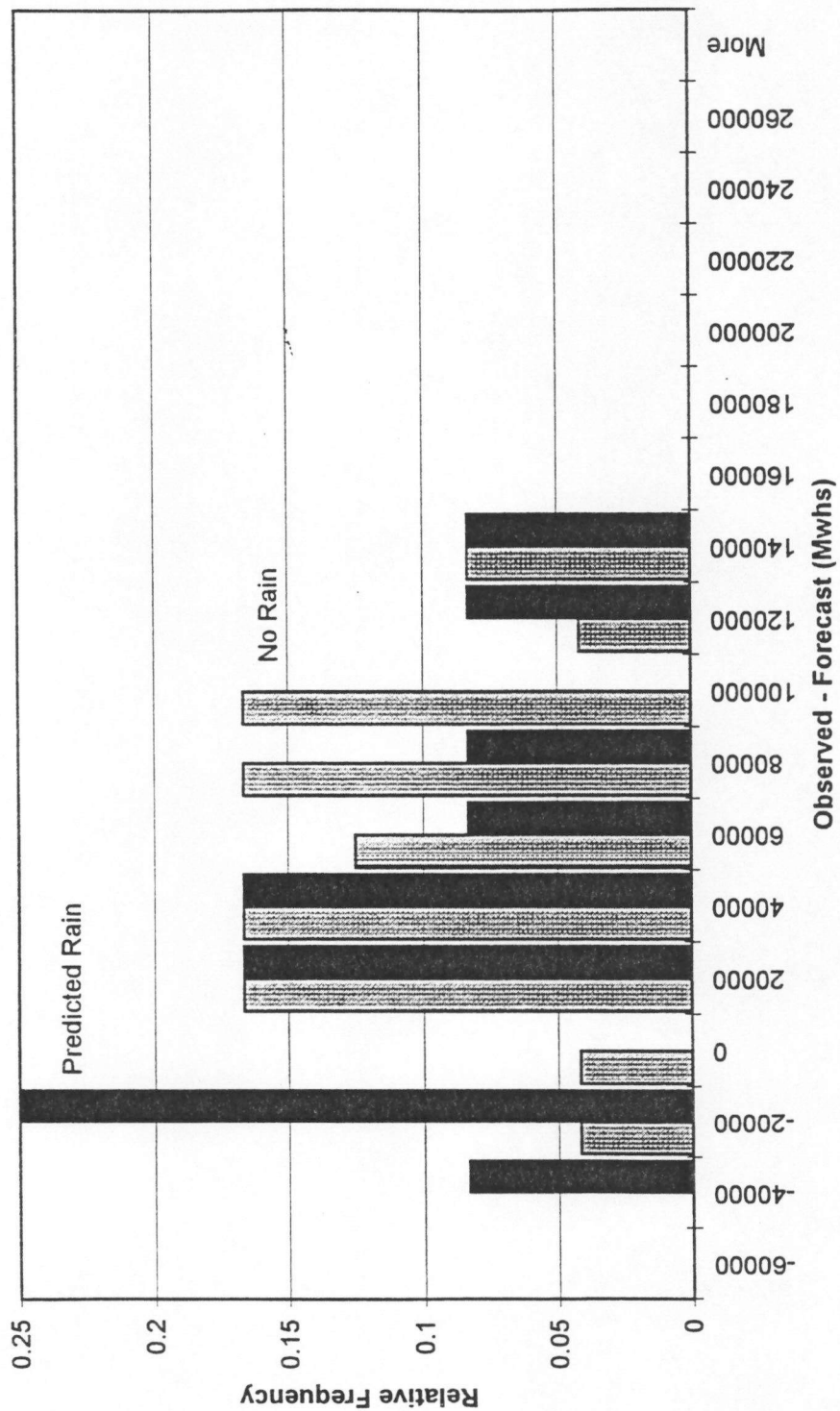


Figure 16. Relative Frequency Histogram for March to May

generation totals and the predicted weekly generation totals were used for the two periods December through February and March through May, respectively.

Twenty-six weeks of the generation difference, or data points, between the “no rain” reservoir schedules were plotted along with thirteen weeks of the generation difference from “predicted rainfall” reservoir schedules for the period December through February shown in Figure 15. For the spring filling period of March through May twenty-four weeks were used for the “no rain” reservoir schedules and twelve weeks of “predicted rain” reservoir schedules as shown in Figure 16.

In both cases an obvious “shift” of the data to the left occurs when using the increase in hydrologic inflows from predicted rainfall. This “shifting” effect indicates the forecasted hydroelectric generation totals are more closely related to the observed generation totals.

The rank-sum test was used to show the statistical significance of using predicted rain on the magnitude of forecast errors. The rank-sum test, the Wilcoxon rank-sum test, the Mann-Whitney test, and the Wilcoxon-Mann-Whitney rank-sum test are all the same test (Maidment,

1993). The null hypothesis H_0 is that the two groups are identically distributed. The alternative H_1 is that one group tends to produce larger observations than the second. No assumptions are made about how the data are distributed. The test's results are not affected by monotonic transformations of the data (such as the log transformation). This has advantages over other types of tests where transformation is an additional step of data manipulation. The null hypothesis H_0 for this test is that both sets of data are from the same distribution. The alternative hypothesis H_1 is that the distributions differ in level (their means or medians are different). The computational procedure for the rank-sum test is:

1. Assign ranks from 1 (smallest) to N (largest) to all of the data.
2. Compute the test statistic W as the sum of the ranks of the n observations in the *smaller* group.
3. For the sample size, compute the theoretical mean and standard deviation of W under H_0 . They are, respectively,

$$\mu = (n(N+1))/2 \quad \text{and} \quad \sigma = (nm(N+1)/12)^{1/2}$$

The standardized form of the test statistic Z_{rs} is computed as

$$(W - \frac{1}{2} - \mu)/\sigma \quad \text{if } W > \mu \quad \text{or}$$

$$(W + \frac{1}{2} - \mu)/\sigma \quad \text{if } W < \mu$$

For the period of December through February, the following values were obtained,

$$\mu = 13(39 + 1)/2 = 260$$

$$\sigma = ((13 \times 26)(39 + 1)/12)^{1/2} = 33.56$$

$$W = 152$$

$$Z_{rs} = (152 + \frac{1}{2} - 260)/33.56 = -3.203$$

The null hypothesis is rejected if the absolute value of Z_{rs} is greater than the $1 - \alpha/2$ point on the standard normal probability distribution. For the period December through February the absolute value of $Z_{rs} > 2.58$ results in a significance level of 0.005. The confidence level that the two groups are different is 99.5 percent. The mean of differences between the observed weekly generation totals and forecasted weekly totals for the “no rain” schedules is 80,085 MWhs. The mean of the differences for the “predicted rain” schedules is only 28,020 MWhs. This indicates the central tendency of the predicted rain schedules are closer to the actual observed hydroelectric generation totals.

For the period March through May the following values were used in determining the significance level,

$$\mu = 12(36 + 1)/2 = 222$$

$$\sigma = ((12 \times 24)(36 + 1)/12)^{1/2} = 29.80$$

$$W = 170$$

$$Z_{rs} = (170 + \frac{1}{2} - 222)/29.80 = -1.728$$

The data for March through May yields an absolute value of $Z_{rs} > 1.64$. This corresponds to a significance level of 0.05. The confidence level of the data being different is 95 percent. Although the results are not as good as those obtained during the December to February time period, the data still indicates the more accurate reservoir scheduling forecast is obtained using the increase in hydrologic inflows on the tributary reservoirs. This is reflected by a difference in the means of 28,985 MWhs (an average of 53,855 MWhs for the “no rain” forecasts compared to a mean of 24,870 MWhs for schedules based on predicted rainfall). Once again, the central tendency of the predicted rain schedules are closer to the actual observed hydroelectric generation totals.

It is also interesting to note the hydrologic conditions which occurred during the study periods. The observed rainfall amounts are summarized in the following tabulated material.

TIME PERIOD	OBSERVED RAINFALL (INCHES)	NORMAL RAINFALL (INCHES)
DEC 94 - FEB 95	12.2	13.6
DEC 95 - FEB 96	12.9	13.6
*DEC 96 - FEB 97	13.8	13.6
MAR - MAY 95	9.5	13.6
MAR - MAY 96	13.1	13.6
*MAR - MAY 97	14.9	13.6

* Time periods using predicted rainfall

Based on rainfall received, the observed rainfall forecasts should be closer to the actual values during periods of less than normal rainfall. However, even when rainfall totals were 4 inches below normal for the period March to May, 1995 the average difference was 37,410 MWWhs. Compare this number to the period March to May, 1997 when rainfall totals were 1.3 inches above normal. The average difference was only 24,870 MWWhs when using the increase in hydrologic inflows from predicted rainfall in the weather forecast in the scheduling process.

INFLOW COMPARISON

From January 8, 1997 to June 11, 1997 an inflow comparison was made each Wednesday. This data summed the inflows for the tributary

reservoirs based on three different scenarios; the observed rainfall, observed rain plus predicted rain inflows, and the observed inflows. The observed rain inflow forecast averaged 264.6 thousand-day-second-feet (tdsf) over the 10 day period. The observed plus predicted rain inflows averaged 376.0 tdsf. The actual observed inflows averaged 451.1 tdsf over the same period.

For one forecast period during this time, the observed rain forecast was actually slightly higher than the observed inflows (on May 7). This can be explained by “over forecasting” following a period of heavy rainfall. Only during 7 out of 23 inflow forecasts was the predicted rain forecast higher than the observed. From the graphical representation of the data in Figure 17, one can easily see how the hydrologic inflows using predicted rainfall are more closely related to the actual observed inflows than the “no rain” inflows.

10 DAY INFLOW TOTALS

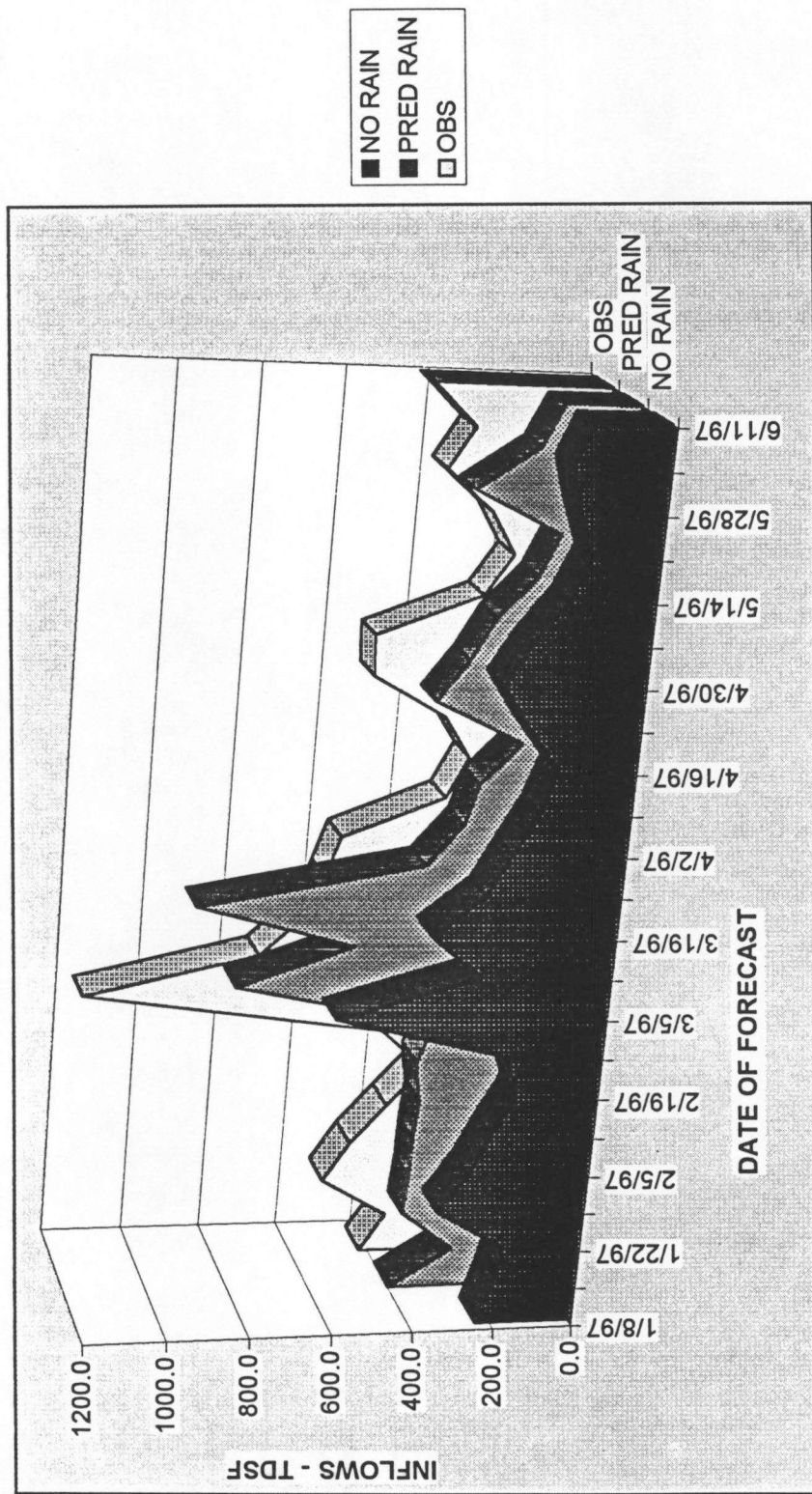


Figure 17. Inflow Comparison

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

Although the study period is relatively short, because of limited hydrologic records available, the results are promising. The high attained significant levels indicate scheduling the reservoir system by using the increase in hydrologic inflows from predicted rainfall on the tributary reservoirs produces positive results. The weekly generation data shows an improved hydro generation schedule when using the increase in hydrologic inflows from predicted rainfall in the weather forecast. The inflow comparison results also favor incorporating the increase in hydrologic inflows from predicted rain into the reservoir scheduling process. In fact, most hydrologic inflow forecasts using predicted rain were less than the actual observed hydrologic inflows.

In addition to the hydro power component, there are other benefits which result, but are beyond the scope of this study. More detailed analysis would be necessary to define the improved reservoir elevation forecasts, reduced spilling due to being proactive to rainfall rather than

reactive, and improved flood control operations which result when using the predicted rainfall.

It is the recommendation of this study for TVA to continue using the increase in hydrologic locals on tributary watersheds in the reservoir scheduling process. Furthermore, future efforts should be made to possibly include some portion of the predicted rainfall forecast on the entire TVA watershed. Possibilities include omitting the first 48 hours of rainfall in the forecast on main river watersheds or using some percentage of the rainfall in the forecast. This could solve the problem of drawing main river reservoirs below minimum navigation levels while providing a method for projecting an increase in hydrologic inflows.

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APPENDIX

TENNESSEE VALLEY AUTHORITY
FORECASTER CALIBRATION TABLE
For 31-day period from 12/01/1996 to 12/31/1996
Retrieved: 7/ 3/1997 11:31

Weather Services Corp. 48 Hr Forecast									
Observed Events	0 to .5	.5 to 1	1 to 1.5	1.5 to 2	2 to 3	3 to 4	Total		
0 to .5	109	17	0	0	0	0	126		
.5 to 1	19	5	1	0	0	0	25		
1 to 1.5	0	0	0	0	0	0	0		
1.5 to 2	1	1	0	0	0	0	2		
2 to 3	2	0	0	0	0	0	2		
3 to 4	0	0	0	0	0	0	0		
Total	131	23	1	0	0	0	155		

Weather Services Corp. 48 Hr Forecast									
Percent Observed	0 to .5	.5 to 1	1 to 1.5	1.5 to 2	2 to 3	3 to 4	Total		
0 to .5	(83%)	74% (22%)	0%	0%	0%	0%	81.3%		
.5 to 1	15%	0%	(0%)	0%	0%	0%	16.1%		
1 to 1.5	0%	0%	(0%)	0%	0%	0%	0.0%		
1.5 to 2	1%	4%	0%	(0%)	0%	0%	1.3%		
2 to 3	2%	0%	0%	0%	(0%)	0%	0.0%		
3 to 4	0%	0%	0%	0%	0%	(0%)	0.0%		
Expected Value	0.37	0.42	0.75	0.00	0.00	0.00	0.38		

TENNESSEE VALLEY AUTHORITY
FORECASTER CALIBRATION TABLE
For 31-day period from 12/01/1996 to 12/31/1996
Retrieved: 7/ 3/1997 11:31

Weather Services Corp. 3 to 5 Day Forecast									
Observed Events	0 to .5	.5 to 1	1 to 1.5	1.5 to 2	2 to 3	3 to 4	Total		
0 to .5	94	4	2	0	0	0	100		
.5 to 1	44	4	1	0	0	0	49		
1 to 1.5	0	0	0	0	0	0	0		
1.5 to 2	1	1	1	0	0	0	3		
2 to 3	1	2	0	0	0	0	3		
3 to 4	0	0	0	0	0	0	0		
Total	140	11	4	0	0	0	155		

Weather Services Corp. 3 to 5 Day Forecast									
Percent Observed	0 to .5	.5 to 1	1 to 1.5	1.5 to 2	2 to 3	3 to 4	Total		
0 to .5	(67%)	36%	50%	0%	0%	0%	64.5%		
.5 to 1	31%	(36%)	25%	0%	0%	0%	31.4%		
1 to 1.5	0%	0%	(0%)	0%	0%	0%	0.0%		
1.5 to 2	1%	9%	25%	(0%)	0%	0%	1.9%		
2 to 3	1%	18%	0%	0%	(0%)	0%	1.9%		
3 to 4	0%	0%	0%	0%	0%	(0%)	0.0%		

TENNESSEE VALLEY AUTHORITY
FORECASTER CALIBRATION TABLE
For 31-day period from 12/01/1996 to 12/31/1996
Retrieved: 7/ 3/1997 11:31

Weather Services Corp. 6 to 10 Day Forecast									
Observed Events	0 to .5	.5 to 1	1 to 1.5	1.5 to 2	2 to 3	3 to 4	Total		
0 to .5	42	9	0	0	0	0	51		
.5 to 1	73	11	0	0	0	0	84		
1 to 1.5	6	3	0	0	0	0	9		
1.5 to 2	3	2	0	0	0	0	5		
2 to 3	6	0	0	0	0	0	6		
3 to 4	0	0	0	0	0	0	0		
Total	130	25	0	0	0	0	155		

Weather Services Corp. 6 to 10 Day Forecast									
Percent Observed	0 to .5	.5 to 1	1 to 1.5	1.5 to 2	2 to 3	3 to 4	Total		
0 to .5	(32%)	36%	0%	0%	0%	0%	32.0%		
.5 to 1	56%	(44%)	0%	0%	0%	0%	54.2%		
1 to 1.5	5%	12%	(0%)	0%	0%	0%	5.8%		
1.5 to 2	2%	8%	0%	(0%)	0%	0%	3.2%		
2 to 3	5%	0%	0%	0%	(0%)	0%	3.0%		
3 to 4	0%	0%	0%	0%	0%	(0%)	0.0%		
Expected Value	0.72	0.71	0.00	0.00	0.00	0.00	0.71		

Predicted Rainfall Statistics

TENNESSEE VALLEY AUTHORITY
 FORECASTER CALIBRATION TABLE
 For 31-day period from 01/01/1997 to 01/31/1997
 Retrieved: 7/ 3/1997 11:32

Weather Services Corp. 48 Hr Forecast									
Observed Events	0 to .5	.5 to 1	1 to 1.5	1.5 to 2	2 to 3	3 to 4	Total		
0 to .5	97	7	2	0	0	0	106		
.5 to 1	22	15	2	0	0	0	37		
1 to 1.5	4	7	1	0	0	0	12		
1.5 to 2	0	0	0	0	0	0	0		
2 to 3	0	0	0	0	0	0	0		
3 to 4	0	0	0	0	0	0	0		
Total	123	27	5	0	0	0	155		

Weather Services Corp. 48 Hr Forecast									
Percent Observed	0 to .5	.5 to 1	1 to 1.5	1.5 to 2	2 to 3	3 to 4	Total		
0 to .5	(79%)	28% (48%)	40% (20%)	0% (0%)	0% (0%)	0% (0%)	68.7% (23.9%)		
.5 to 1	18% (3%)	26% (40%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)	7.7% (0.0%)		
1 to 1.5	0% (0%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)	0.0% (0.0%)		
1.5 to 2	0% (0%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)	0.0% (0.0%)		
2 to 3	0% (0%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)	0.0% (0.0%)		
3 to 4	0% (0%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)	0.0% (0.0%)		
Expected Value	0.37	0.75	0.65	0.00	0.00	0.00	0.45		

TENNESSEE VALLEY AUTHORITY
 FORECASTER CALIBRATION TABLE
 For 31-day period from 01/01/1997 to 01/31/1997
 Retrieved: 7/ 3/1997 11:32

Weather Services Corp. 3 to 5 Day Forecast									
Observed Events	0 to .5	.5 to 1	1 to 1.5	1.5 to 2	2 to 3	3 to 4	Total		
0 to .5	69	9	0	0	0	0	78		
.5 to 1	30	24	0	0	0	0	54		
1 to 1.5	12	9	1	0	0	0	22		
1.5 to 2	0	1	0	0	0	0	1		
2 to 3	0	0	0	0	0	0	0		
3 to 4	0	0	0	0	0	0	0		
Total	111	43	1	0	0	0	155		

Weather Services Corp. 3 to 5 Day Forecast									
Percent Observed	0 to .5	.5 to 1	1 to 1.5	1.5 to 2	2 to 3	3 to 4	Total		
0 to .5	(62%)	21% (56%)	0% (100%)	0% (0%)	0% (0%)	0% (0%)	50.3% (34.8%)		
.5 to 1	27% (11%)	21% (28%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)	14.2% (0.6%)		
1 to 1.5	0% (0%)	2% (0%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)	0.0% (0.0%)		
1.5 to 2	0% (0%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)	0.0% (0.0%)		
2 to 3	0% (0%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)	0.0% (0.0%)		
3 to 4	0% (0%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)	0.0% (0.0%)		

TENNESSEE VALLEY AUTHORITY
 FORECASTER CALIBRATION TABLE
 For 31-day period from 01/01/1997 to 01/31/1997
 Retrieved: 7/ 3/1997 11:32

Weather Services Corp. 6 to 10 Day Forecast									
Observed Events	0 to .5	.5 to 1	1 to 1.5	1.5 to 2	2 to 3	3 to 4	Total		
0 to .5	33	11	0	0	0	0	44		
.5 to 1	54	9	0	0	0	0	63		
1 to 1.5	28	8	1	0	0	0	37		
1.5 to 2	5	2	2	0	0	0	9		
2 to 3	2	0	0	0	0	0	2		
3 to 4	0	0	0	0	0	0	0		
Total	122	30	3	0	0	0	155		

Weather Services Corp. 6 to 10 Day Forecast									
Percent Observed	0 to .5	.5 to 1	1 to 1.5	1.5 to 2	2 to 3	3 to 4	Total		
0 to .5	(27%)	37% (30%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)	28.7% (40.6%)		
.5 to 1	44% (23%)	27% (33%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)	23.9% (5.8%)		
1 to 1.5	23% (1%)	7% (67%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)	1.3% (0.0%)		
1.5 to 2	2% (0%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)	0.0% (0.0%)		
2 to 3	0% (0%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)	0.0% (0.0%)		
3 to 4	0% (0%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)	0.0% (0.0%)		
Expected Value	0.80	0.77	1.58	0.00	0.00	0.00	0.81		

Predicted Rainfall Statistics

TENNESSEE VALLEY AUTHORITY
 FORECASTER CALIBRATION TABLE
 For 28-day period from 02/01/1997 to 02/28/1997
 Retrieved: 7/ 3/1997 11:35

Weather Services Corp. 48 Hr Forecast									
Observed Events	0 to .5	.5 to 1	1 to 1.5	1.5 to 2	2 to 3	3 to 4	Total		
0 to .5	77	21	0	0	0	0	98		
.5 to 1	4	19	4	0	0	0	27		
1 to 1.5	5	6	1	0	0	0	12		
1.5 to 2	0	1	0	0	0	0	1		
2 to 3	1	0	0	0	0	0	1		
3 to 4	0	1	0	0	0	0	1		
	87	48	5	0	0	0	140		

Weather Services Corp. 48 Hr Forecast									
Percent Observed	0 to .5	.5 to 1	1 to 1.5	1.5 to 2	2 to 3	3 to 4	Total		
0 to .5	(89%)	42%	0%	0%	0%	0%	70.0%		
.5 to 1	5%	(40%)	80%	0%	0%	0%	19.3%		
1 to 1.5	6%	12%	(20%)	0%	0%	0%	8.6%		
1.5 to 2	0%	2%	0%	(0%)	0%	0%	0.7%		
2 to 3	1%	0%	0%	0%	(0%)	0%	0.7%		
3 to 4	0%	2%	0%	0%	0%	(0%)	0.7%		
Expected Value	0.36	0.67	0.85	0.00	0.00	0.00	0.48		

TENNESSEE VALLEY AUTHORITY
 FORECASTER CALIBRATION TABLE
 For 28-day period from 02/01/1997 to 02/28/1997
 Retrieved: 7/ 3/1997 11:35

Weather Services Corp. 3 to 5 Day Forecast									
Observed Events	0 to .5	.5 to 1	1 to 1.5	1.5 to 2	2 to 3	3 to 4	Total		
0 to .5	67	10	0	0	0	0	77		
.5 to 1	10	17	5	0	0	0	32		
1 to 1.5	1	4	0	0	0	0	5		
1.5 to 2	2	7	1	0	0	0	10		
2 to 3	10	3	0	0	0	0	13		
3 to 4	3	0	0	0	0	0	3		
	93	41	6	0	0	0	140		

Weather Services Corp. 3 to 5 Day Forecast									
Percent Observed	0 to .5	.5 to 1	1 to 1.5	1.5 to 2	2 to 3	3 to 4	Total		
0 to .5	(72%)	24%	0%	0%	0%	0%	55.0%		
.5 to 1	11%	(41%)	83%	0%	0%	0%	22.9%		
1 to 1.5	1%	10%	(0%)	0%	0%	0%	3.6%		
1.5 to 2	2%	17%	17%	(0%)	0%	0%	7.1%		
2 to 3	11%	7%	0%	0%	(0%)	0%	9.3%		
3 to 4	3%	0%	0%	0%	0%	(0%)	2.1%		

TENNESSEE VALLEY AUTHORITY
 FORECASTER CALIBRATION TABLE
 For 28-day period from 02/01/1997 to 02/28/1997
 Retrieved: 7/ 3/1997 11:35

Weather Services Corp. 6 to 10 Day Forecast									
Observed Events	0 to .5	.5 to 1	1 to 1.5	1.5 to 2	2 to 3	3 to 4	Total		
0 to .5	27	13	0	0	0	0	40		
.5 to 1	17	28	5	0	0	0	50		
1 to 1.5	5	7	0	0	0	0	12		
1.5 to 2	3	7	0	0	0	0	10		
2 to 3	5	5	0	0	0	0	10		
3 to 4	11	9	0	0	0	0	20		
	68	67	5	0	0	0	140		

Weather Services Corp. 6 to 10 Day Forecast									
Percent Observed	0 to .5	.5 to 1	1 to 1.5	1.5 to 2	2 to 3	3 to 4	Total		
0 to .5	(48%)	19%	0%	0%	0%	0%	28.2%		
.5 to 1	25%	(42%)	100%	0%	0%	0%	35.7%		
1 to 1.5	7%	7%	(0%)	0%	0%	0%	7.1%		
1.5 to 2	4%	10%	0%	(0%)	0%	0%	7.1%		
2 to 3	7%	7%	0%	0%	(0%)	0%	7.1%		
3 to 4	16%	13%	0%	0%	0%	(0%)	14.3%		
Expected Value	1.21	1.29	0.75	0.00	0.00	0.00	1.23		

Predicted Rainfall Statistics

TENNESSEE VALLEY AUTHORITY
 FORECASTER CALIBRATION TABLE
 For 31-day period from 03/01/1997 to 03/31/1997
 Retrieved: 4/16/1997 16:57

TENNESSEE VALLEY AUTHORITY
 FORECASTER CALIBRATION TABLE
 For 31-day period from 03/01/1997 to 03/31/1997
 Retrieved: 4/16/1997 16:57

Weather Services Corp. 48 Hr Forecast									
Observed Events	0 to .5	.5 to 1	1 to 1.5	1.5 to 2	2 to 3	3 to 4	Total		
0 to .5	86	15	6	0	0	0	107		
.5 to 1	3	11	4	3	0	0	21		
1 to 1.5	3	4	5	3	0	0	15		
1.5 to 2	1	1	1	1	1	1	6		
2 to 3	0	0	1	1	0	3	5		
3 to 4	0	0	0	0	1	0	1		
Total	93	31	17	8	2	4	155		

Weather Services Corp. 48 Hr Forecast									
Percent Observed	0 to .5	.5 to 1	1 to 1.5	1.5 to 2	2 to 3	3 to 4	Total		
0 to .5	[92%]	48%	35%	0%	0%	0%	49.0%		
.5 to 1	3%	[35%]	24%	38%	0%	0%	13.5%		
1 to 1.5	3%	13%	[29%]	38%	0%	0%	9.7%		
1.5 to 2	0%	0%	6%	[12%]	50%	22%	3.2%		
2 to 3	0%	0%	0%	6%	[0%]	72%	0.6%		
3 to 4	0%	0%	0%	0%	50%	[0%]	0.0%		
Expected Value	0.31	0.60	0.88	1.28	2.62	2.31	0.57		

TENNESSEE VALLEY AUTHORITY
 FORECASTER CALIBRATION TABLE
 For 31-day period from 03/01/1997 to 03/31/1997
 Retrieved: 4/16/1997 16:57

Weather Services Corp. 3 to 5 Day Forecast									
Observed Events	0 to .5	.5 to 1	1 to 1.5	1.5 to 2	2 to 3	3 to 4	Total		
0 to .5	64	33	0	1	0	0	98		
.5 to 1	10	14	5	1	0	0	30		
1 to 1.5	13	7	1	0	0	0	21		
1.5 to 2	5	1	0	0	0	0	6		
2 to 3	0	0	0	0	0	0	0		
3 to 4	0	0	0	0	0	0	0		
Total	92	55	6	2	0	0	155		

Weather Services Corp. 3 to 5 Day Forecast									
Percent Observed	0 to .5	.5 to 1	1 to 1.5	1.5 to 2	2 to 3	3 to 4	Total		
0 to .5	[70%]	60%	0%	50%	0%	0%	63.2%		
.5 to 1	11%	[25%]	83%	50%	0%	0%	19.4%		
1 to 1.5	14%	13%	[17%]	0%	0%	0%	13.5%		
1.5 to 2	5%	2%	0%	[0%]	0%	0%	3.2%		
2 to 3	0%	0%	0%	0%	[0%]	0%	0.0%		
3 to 4	0%	0%	0%	0%	0%	[0%]	0.0%		

Weather Services Corp. 6 to 10 Day Forecast									
Observed Events	0 to .5	.5 to 1	1 to 1.5	1.5 to 2	2 to 3	3 to 4	Total		
0 to .5	29	35	3	0	0	0	67		
.5 to 1	11	36	2	1	2	0	52		
1 to 1.5	13	17	0	1	0	0	31		
1.5 to 2	3	2	0	0	0	0	5		
2 to 3	0	0	0	0	0	0	0		
3 to 4	0	0	0	0	0	0	0		
Total	56	90	5	2	2	0	155		

Weather Services Corp. 6 to 10 Day Forecast									
Percent Observed	0 to .5	.5 to 1	1 to 1.5	1.5 to 2	2 to 3	3 to 4	Total		
0 to .5	[52%]	39%	60%	0%	0%	0%	43.2%		
.5 to 1	20%	[40%]	40%	50%	100%	0%	33.5%		
1 to 1.5	23%	19%	[0%]	50%	0%	0%	20.0%		
1.5 to 2	5%	2%	0%	[0%]	0%	0%	3.2%		
2 to 3	0%	0%	0%	0%	[0%]	0%	0.0%		
3 to 4	0%	0%	0%	0%	0%	[0%]	0.0%		
Expected Value	0.66	0.67	0.45	1.00	0.75	0.00	0.67		

Predicted Rainfall Statistics

TENNESSEE VALLEY AUTHORITY
 FORECASTER CALIBRATION TABLE
 For 29-day period from 04/02/1997 to 04/30/1997
 Retrieved: 5/14/1997 11:20

TENNESSEE VALLEY AUTHORITY
 FORECASTER CALIBRATION TABLE
 For 29-day period from 04/02/1997 to 04/30/1997
 Retrieved: 5/14/1997 11:20

Weather Services Corp. 48 Hr Forecast									
Observed Events	0 to .5	.5 to 1	1 to 1.5	1.5 to 2	2 to 3	3 to 4	4 to 5	Total	
0 to .5	101	11	3	0	0	0	0	115	
.5 to 1	9	5	5	2	0	0	0	21	
1 to 1.5	0	4	4	1	0	0	0	9	
1.5 to 2	0	0	0	0	0	0	0	0	
2 to 3	0	0	0	0	0	0	0	0	
3 to 4	0	0	0	0	0	0	0	0	
Total	110	20	12	3	0	0	0	145	

Weather Services Corp. 48 Hr Forecast									
Percent Observed	0 to .5	.5 to 1	1 to 1.5	1.5 to 2	2 to 3	3 to 4	4 to 5	Total	
0 to .5	(92%)	55%	25%	0%	0%	0%	0%	79.3%	
.5 to 1	8%	(25%)	43%	67%	0%	0%	0%	14.5%	
1 to 1.5	0%	20%	(33%)	33%	0%	0%	0%	6.2%	
1.5 to 2	0%	0%	0%	(0%)	0%	0%	0%	0.0%	
2 to 3	0%	0%	0%	0%	(0%)	0%	0%	0.0%	
3 to 4	0%	0%	0%	0%	0%	(0%)	0%	0.0%	
Expected Value	0.29	0.57	0.79	0.92	0.00	0.00	0.00	0.38	

TENNESSEE VALLEY AUTHORITY
 FORECASTER CALIBRATION TABLE
 For 29-day period from 04/02/1997 to 04/30/1997
 Retrieved: 5/14/1997 11:20

Weather Services Corp. 3 to 5 Day Forecast									
Observed Events	0 to .5	.5 to 1	1 to 1.5	1.5 to 2	2 to 3	3 to 4	4 to 5	Total	
0 to .5	61	21	5	0	0	0	0	87	
.5 to 1	17	11	2	2	0	0	0	32	
1 to 1.5	6	7	4	2	0	0	0	19	
1.5 to 2	4	0	0	0	0	0	0	4	
2 to 3	2	1	0	0	0	0	0	3	
3 to 4	0	0	0	0	0	0	0	0	
Total	90	46	11	4	0	0	0	145	

Weather Services Corp. 3 to 5 Day Forecast									
Percent Observed	0 to .5	.5 to 1	1 to 1.5	1.5 to 2	2 to 3	3 to 4	4 to 5	Total	
0 to .5	(68%)	52%	45%	0%	0%	0%	0%	60.0%	
.5 to 1	19%	(28%)	18%	50%	0%	0%	0%	22.1%	
1 to 1.5	7%	18%	(36%)	50%	0%	0%	0%	15.1%	
1.5 to 2	4%	0%	0%	(0%)	0%	0%	0%	2.8%	
2 to 3	2%	2%	0%	0%	(0%)	0%	0%	2.1%	
3 to 4	0%	0%	0%	0%	0%	(0%)	0%	0.0%	
Expected Value	0.29	0.57	0.79	0.92	0.00	0.00	0.00	0.38	

Weather Services Corp. 6 to 10 Day Forecast									
Observed Events	0 to .5	.5 to 1	1 to 1.5	1.5 to 2	2 to 3	3 to 4	4 to 5	Total	
0 to .5	25	33	4	0	0	0	0	62	
.5 to 1	11	22	8	0	0	0	0	41	
1 to 1.5	8	5	9	2	0	0	0	24	
1.5 to 2	5	6	0	0	0	0	0	11	
2 to 3	3	3	0	1	0	0	0	7	
3 to 4	0	0	0	0	0	0	0	0	
Total	52	69	21	3	0	0	0	145	

Weather Services Corp. 6 to 10 Day Forecast									
Percent Observed	0 to .5	.5 to 1	1 to 1.5	1.5 to 2	2 to 3	3 to 4	4 to 5	Total	
0 to .5	(48%)	46%	19%	0%	0%	0%	0%	42.8%	
.5 to 1	21%	(32%)	38%	0%	0%	0%	0%	28.3%	
1 to 1.5	15%	7%	(43%)	67%	0%	0%	0%	16.6%	
1.5 to 2	10%	9%	0%	(0%)	0%	0%	0%	7.6%	
2 to 3	6%	4%	0%	33%	(0%)	0%	0%	4.8%	
3 to 4	0%	0%	0%	0%	0%	(0%)	0%	0.0%	
Expected Value	0.78	0.71	0.87	1.67	0.00	0.00	0.00	0.78	

Predicted Rainfall Statistics

TENNESSEE VALLEY AUTHORITY
 FORECASTER CALIBRATION TABLE
 For 31-day period from 05/01/1997 to 05/31/1997
 Retrieved: 7/ 3/1997 11:12

TENNESSEE VALLEY AUTHORITY
 FORECASTER CALIBRATION TABLE
 For 31-day period from 05/01/1997 to 05/31/1997
 Retrieved: 7/ 3/1997 11:12

Weather Services Corp. 48 Hr Forecast									
Observed Events	0 to .5	.5 to 1	1 to 1.5	1.5 to 2	2 to 3	3 to 4	Total		
0 to .5	88	11	7	3	0	0	109		
.5 to 1	11	6	7	3	1	0	28		
1 to 1.5	4	6	0	0	1	0	11		
1.5 to 2	0	2	1	1	0	0	4		
2 to 3	1	2	0	0	0	0	3		
3 to 4	0	0	0	0	0	0	0		
Total	104	27	15	7	2	0	155		

Weather Services Corp. 48 Hr Forecast									
Percent Observed	0 to .5	.5 to 1	1 to 1.5	1.5 to 2	2 to 3	3 to 4	Total		
0 to .5	(85%)	41%	47%	43%	0%	0%	70.3%		
.5 to 1	11%	(22%)	47%	43%	50%	0%	18.1%		
1 to 1.5	4%	22%	(0%)	0%	50%	0%	7.1%		
1.5 to 2	0%	7%	7%	(14%)	0%	0%	2.6%		
2 to 3	1%	7%	0%	0%	(0%)	1.9%	1.9%		
3 to 4	0%	0%	0%	0%	0%	(0%)	0.0%		
Expected Value	0.36	0.86	0.58	0.68	1.00	0.00	0.49		

TENNESSEE VALLEY AUTHORITY
 FORECASTER CALIBRATION TABLE
 For 31-day period from 05/01/1997 to 05/31/1997
 Retrieved: 7/ 3/1997 11:12

TENNESSEE VALLEY AUTHORITY
 FORECASTER CALIBRATION TABLE
 For 31-day period from 05/01/1997 to 05/31/1997
 Retrieved: 7/ 3/1997 11:12

Weather Services Corp. 3 to 5 Day Forecast									
Observed Events	0 to .5	.5 to 1	1 to 1.5	1.5 to 2	2 to 3	3 to 4	Total		
0 to .5	92	7	2	0	0	0	101		
.5 to 1	20	12	0	0	0	0	32		
1 to 1.5	9	6	0	0	0	0	15		
1.5 to 2	2	2	0	0	0	0	4		
2 to 3	2	1	0	0	0	0	3		
3 to 4	0	0	0	0	0	0	0		
Total	125	28	2	0	0	0	155		

Weather Services Corp. 3 to 5 Day Forecast									
Percent Observed	0 to .5	.5 to 1	1 to 1.5	1.5 to 2	2 to 3	3 to 4	Total		
0 to .5	(74%)	25%	100%	0%	0%	0%	65.2%		
.5 to 1	16%	(43%)	0%	0%	0%	0%	20.6%		
1 to 1.5	7%	21%	(0%)	0%	0%	0%	9.7%		
1.5 to 2	2%	7%	0%	(0%)	0%	0%	2.6%		
2 to 3	2%	4%	0%	0%	(0%)	1.9%	1.9%		
3 to 4	0%	0%	0%	0%	0%	(0%)	0.0%		

Weather Services Corp. 6 to 10 Day Forecast									
Observed Events	0 to .5	.5 to 1	1 to 1.5	1.5 to 2	2 to 3	3 to 4	Total		
0 to .5	47	19	1	0	0	0	67		
.5 to 1	20	11	6	0	0	0	37		
1 to 1.5	16	9	2	0	0	0	27		
1.5 to 2	4	10	0	0	0	0	14		
2 to 3	3	7	0	0	0	0	10		
3 to 4	0	0	0	0	0	0	0		
Total	90	56	9	0	0	0	155		

Weather Services Corp. 6 to 10 Day Forecast									
Percent Observed	0 to .5	.5 to 1	1 to 1.5	1.5 to 2	2 to 3	3 to 4	Total		
0 to .5	(52%)	34%	11%	0%	0%	0%	43.2%		
.5 to 1	22%	(20%)	67%	0%	0%	0%	21.9%		
1 to 1.5	16%	18%	(22%)	0%	0%	0%	17.4%		
1.5 to 2	4%	18%	0%	(0%)	0%	0%	9.0%		
2 to 3	3%	12%	0%	0%	(0%)	0%	6.5%		
3 to 4	0%	0%	0%	0%	0%	(0%)	0.0%		
Expected Value	0.68	1.06	0.81	0.00	0.00	0.00	0.82		

Predicted Rainfall Statistics

DAILY HYDRO REPORT FORECASTED MEGAWATTS

DATE OF REPORT	FORECAST MWh's					FORECAST TOTAL	OBS TOTAL
1994	MON	TUE	WED	THU	FRI		
11/30	51303	49211	43946	43674	43280	231414	316530
12/7	52131	50855	50437	50042	49280	252745	302154
12/14	50351	50414	50429	47687	45829	244710	254797
12/21	25670	34749	34795	34411	33904	163529	173737
12/28	22917	23316	23328	21906	21474	112941	188375
1/4	17672	17632	17632	17610	17610	88156	206311
1/11	25897	25891	25888	25882	25848	129406	360024
1/18	66732	61356	61606	61118	61510	312322	347976
1/26	44147	43472	43096	42686	41922	215323	326459
2/1	53112	49958	45514	45365	44763	238712	292520
2/8	35422	35444	35400	35382	35357	177005	270125
2/15	26583	26425	26398	26532	26372	132310	373289
2/22	58567	56389	54634	54226	52127	275943	331029
					TOTAL	2574516	3743326
					AVG WKLY	198039.7	287948.2
3/1	51708	51650	50576	50550	50529	255013	342841
3/8	59852	57916	52506	53271	52638	276183	355230
3/15	45993	44437	43903	43172	43041	220546	266144
3/22	25637	25604	25527	25261	25225	127254	155413
3/29	16908	16908	16953	16937	16937	84643	106072
4/5	15128	15241	15228	15212	15242	76051	87017
4/12	13094	13157	13163	13302	13294	66010	79661
4/19	11918	11900	11908	11901	11896	59523	98764
4/26	17214	17158	17102	16983	16693	85150	84238
5/3	11471	11400	26741	10750	10382	70744	103220
5/10	13114	13064	13000	12921	12889	64988	140447
5/17	16477	16460	16429	16410	16405	82181	98249
					TOTAL	1468286	1917296
					AVG WKLY	122357.2	159774.7
12/6	44124	43283	42995	42902	42856	216160	268859
12/13	39088	39097	39082	38851	39203	195321	283713
12/20	41121	50584	50196	50161	50094	242156	264923
12/27	24270	38358	38307	38280	38244	177459	252898
1/3	47936	47864	47790	47628	43891	235109	319872
1/10	47205	46912	46898	46786	46896	234697	287577
1/17	38267	38324	38739	38043	38037	191410	342757
1/24	58221	57445	57582	57834	58184	289266	372357
1/31	66743	65669	65396	63383	63254	324445	386512
2/7	63660	62548	64277	62745	62708	315938	387903
2/14	62770	61472	61474	61587	61297	308600	360385
2/21	53871	53816	53862	53844	53549	268942	303560
2/28	45522	45252	44918	43612	43544	222848	304422
					TOTAL	3222351	4135738
					AVG WKLY	247873.2	318133.7

Hydroelectric Generation Data

DAILY HYDRO REPORT FORECASTED MEGAWATTS

3/6	46966	37798	36712	36638	35894	194008	315291
3/13	38386	37871	37850	37983	37969	190059	289804
3/20	39084	38782	39050	36361	36023	189300	263185
3/27	24966	24737	24451	23639	23630	121423	227095
4/3	21443	21219	21246	19753	20094	103755	152376
4/10	20419	20414	20124	19867	20272	101096	113636
4/17	18790	17606	17737	17877	17857	89867	214036
4/24	20560	20608	22005	22320	21867	107360	163404
5/1	24374	22069	21959	21817	21725	111944	192480
5/8	39590	40950	40661	40654	40446	202301	174160
5/15	24283	25087	24038	24486	24512	122406	183221
5/22	35496	32867	32750	32793	32731	166637	255078
TOTAL						1700156	2543766
AVG WKLY						141679.7	211980.5

12/4	74697	68979	68934	68901	68854	350365	354062
12/11	68019	68259	68255	68328	68361	341222	363010
12/18	68526	69578	68876	68748	68765	344493	328852
12/25	58904	58861	58849	58854	49465	284933	321502
1/1	69496	69296	69174	69051	68926	345943	359356
1/8	76357	76065	72394	72302	72149	369267	375767
1/15	60468	59845	58519	58480	58373	295685	330188
1/22	58789	58761	57796	58023	58002	291371	359063
1/29	66844	65767	66273	66375	66523	331782	344076
2/5	54792	53805	54134	54179	54115	271025	301890
2/12	58323	58238	58254	58171	58041	291027	286867
2/19	49026	49768	49992	49664	49551	248001	312079
2/26	51520	51615	51680	51632	51681	258128	350762
TOTAL						4023242	4387474
AVG WKLY						309480.2	337498.0

3/5	75074	75062	75404	75015	75116	375671	381769
3/12	67372	67994	68165	68066	68052	339649	349294
3/19	71525	71263	71689	72878	73081	360436	339497
3/26	64635	64114	64295	64529	64330	321903	268150
4/2	33638	32598	32616	32026	32113	162991	193996
4/9	24756	24733	24722	24723	24722	123656	147249
4/16	26459	26722	27754	27098	27117	135150	178941
4/23	35740	35796	35729	35708	35703	178676	243024
4/30	40559	40553	39448	39580	39456	199596	318550
5/7	50615	50652	50679	50508	50452	252906	229236
5/14	39052	39160	39351	39078	39071	195712	169903
5/21	18869	26745	26197	26185	26156	124152	249240
TOTAL						2770498	3068849
AVG WKLY						230874.8	255737.4

Hydroelectric Generation Data

INFLOW COMPARISON

DATE	OBS	NO RAIN	PRED RAIN
1/8/97	420.5	233.5	398.4
1/15/97	360.6	204.1	245.3
1/22/97	532.4	182.1	380.0
1/29/97	470.6	356.9	373.6
2/5/97	385.6	291.1	371.7
2/12/97	298.5	244.7	364.4
2/19/97	413.4	190.7	381.2
2/26/97	1164.9	227.1	348.1
3/5/97	740.6	648.0	841.6
3/12/97	632.7	308.4	558.7
3/19/97	593.4	437.2	949.1
3/26/97	560.0	318.4	407.4
4/2/97	310.9	265.3	323.1
4/9/97	261.1	212.0	294.6
4/16/97	330.8	177.9	200.2
4/23/97	514.6	258.4	420.2
4/30/97	519.7	327.8	347.7
5/7/97	265.4	270.5	293.5
5/14/97	200.1	192.4	203.7
5/21/97	263.0	151.0	160.0
5/28/97	383.0	188.7	375.2
6/4/97	323.2	219.6	228.9
6/11/97	431.4	179.5	181.9
TOTAL	10376.4	6085.3	8648.5
AVERAGE	451.1	264.6	376.0

Hydrologic Inflow Data

VITA

Randall Z. Kerr was born in Knoxville, Tennessee on October 10, 1959. He attended McCampbell and Brickey elementary schools, and Powell High School. Upon graduating from Powell High School in 1977, he entered the Civil Engineering Department at the University of Tennessee, where he received a Bachelor of Science Degree in June 1983. He entered the Graduate School at the University of Tennessee in 1991 and received his Master of Science Degree in August 1997. He is a registered Professional Engineer in the State of Tennessee. He is presently employed by the Tennessee Valley Authority as a Technical Specialist in River System Operations.