CRH SSD
OCTOBER 1988

CENTRAL REGION TECHNICAL ATTACHMENT 88-39

Three Day Mainstem River Forecast Verification

Dean T. Braatz
North Central River Forecast Center
Minneapolis, Minnesota

1. Introduction

The North Central River Forecast Center (NCRFC) has been verifying three day mainstem Mississippi River forecasts since January 1981. For a majority of the locations, three day forecasts are prepared daily throughout the year. Several locations are forecasted daily only during the navigation season. Monthly statistics include the mean error, variance, standard deviation, and mean absolute error. Also documented are the number of times the forecast error exceeds 1.5 feet for the first day forecast; if the observed stage is above flood stage; the total number of forecasts processed; and the number of observed stages and first day forecasts above flood stage. The approach is simple, and consists of compiling a data base from which one might evaluate the three day forecast accuracy at various forecast locations along the mainstem Mississippi River. In June of 1987 the number of stations verified expanded from five on the Mississippi River to 13 on both the Mississippi and Illinois Rivers (Table 1).

Since January 1981	Since June 1987
Mississippi River	
1. Guttenberg, IA (L/D 10 TW)	1. St. Paul, MN
2. Grafton, IL	2. LaCrosse, WI
3. Alton, IL (L/D 26 TW)	3. Quad Cities, IL (L/D 15)
4. St. Louis, MO	4. Burlington, IA
5. Chester, IL	5. Hannibal, MO
Illinois River	
	1. LaSalle, IL
	2. Peoria, IL
	3. Beardstown, IL

Table 1. Locations where three day forecasts are prepared daily and verified monthly during the navigation season.

The mean absolute error from the original five Mississippi River sites (Table 1) has been placed in a PC data file allowing for further analysis (e.g., to find the statistical absolute mean error, study each site versus a composite of all sites, and display the data and results in graphic form). The purpose of this paper is to document the mainstem verification effort the NCRFC has started, to stimulate input from others on various verification approaches, and to help establish an ongoing mainstem verification program for continuous operational evaluation.

2. Verification Computer Program

The original computer program for verifying three day mainstem forecasts was written by Lee Larson in the late 1970's while at the MBRFC. This program has undergone many revisions and additions during the past eight years (see Item 8). The most notable recent changes include the ability to read input data randomly and print a monthly list for each forecast point. This listing details observed stages, the three day forecasts and their forecast error, mean stage for the month, the mean absolute error for the month, the number of days above flood stage, and the historical average stage for the month. This information is forwarded to Central Region Hydrology Division and the Office of Hydrology. Table 2 illustrates the monthly list for July 1988 for Chester, Illinois, Mississippi River.

3. PC-Data Base

In the NCRFC's IBM-PC, a file was created using the output statistics of the verification computer program. Monthly values for each forecast site include the mean error, variance, standard deviation, and the mean absolute error. Using the Lotus Symphony software, a spreadsheet was developed using the mean absolute error data. Symphony has the capability to provide statistics and graphics. Therefore, a seven year average mean absolute error by month was determined and plotted for each of the five sites. In addition, a monthly plot was made of all five Mississippi River sites lumped together. Figure 1 from Guttenberg, Iowa and Figure 2 from Chester, Illinois (both Mississippi River sites) are examples of the monthly seven year average mean absolute error. Notice that January and February for Guttenberg, Iowa does not show any forecasts. This is due to the closed navigation season for these two months. Figure 3 illustrates the monthly plot for all five Mississippi River sites.

4. Office Display

The plots and lists discussed above for the five Mississippi sites are displayed on a bulletin board in the operations area. At the end of each month the mean absolute error is plotted on the seven year average graphic. This provides a visual view of monthly average error at each of the five mainstem Mississippi sites relative to the seven year average error. The display also has the tabulated data by month per each site. Included on this list are the observed stages, the three day forecasts, and the three day errors (observed minus forecast stage). At a glance, one can compare the current month's average to the seven-year monthly average.

NORTH CENTRAL RIVER FORECAST CENTER
DAILY FORECAST DATA
7/ 1/88 - 7/31/88

CHESTER, IL MISSISSIPPI R FS = 27 FT

MO/DA/YR	OBS STG	DAY 1 FCST STAGE	DAY 1 FCST ERR	DAY 2 FCST STAGE	DAY 2 FCST ERR	DAY 3 FCST STAGE	DAY 3 FCST ERR
7/ 1/88	0.9	0.6	0.0	0.5	0.1	0.6	0.3
7/ 2/88	0.6	0.3	-0.1	0.2	-0.1	0.3	0.1
7/ 3/88	0.4	0.2	-0.1	0.1	-0.1	0.4	0.2
7/ 4/88	0.3	0.3	0.1	0.4	0.2	0.7	0.2
7/ 5/88	0.2	0.1	-0.1	0.4	-0.1	0.5	-0.2
7/ 6/88	0.2	0.3	-0.2	0.5	-0.2	0.3	-0.2
7/ 7/88	0.5	0.2	-0.5	0.2	-0.3	-0.1	0.2
7/ 8/88	0.7	0.2	-0.3	-0.1	0.2	-0.3	0.0
7/ 9/88	0.5	-0.1	0.2	-0.3	0.0	-0.3	0.2
7/10/88	-0.3	-0.3	0.0	-0.2	0.3	0.0	0.2
7/11/88	-0.3	-0.5	0.0	-0.4	-0.2	-0.2	-1.1
7/12/88	-0.5	-0.2	0.0	0.2	-0.7	0.6	-0.8
7/13/88	-0.2	0.3	-0.6	1.0	-0.4	1.3	-0.1
7/14/88	0.9	1.2	-0.2	1.4	0.0	1.2	0.3
7/15/88	1.4	1.4	0.0	1.4	0.5	1.2	-0.1
7/16/88	1.4	0.9	0.0	0.7	-0.6	0.6	-0.6
7/17/88	0.9	1.0	-0.3	0.9	-0.3	0.7	-1.1
7/18/88	1.3	1.2	0.0	1.3	-0.5	1.0	-0.3
7/19/88	1.2	1.3	-0.5	1.2	-0.1	1.0	-0.3
7/20/88	1.8	1.8	0.5	1.3	0.0	1.3	0.4
7/21/88	1.3	1.1	-0.2	1.1	0.2	1.3	0.5
7/22/88	1.3	1.0	0.1	1.2	0.4	1.3	0.2
7/23/88	0.9	1.0	0.2	1.0	-0.1	1.1	-0.1
7/24/88	0.8	1.1	0.0	1.2	0.0	1.1	-0.9
7/25/88	1.1	1.0	-0.2	0.9	-1.1	0.7	-0.8
7/26/88	1.2	1.6	-0.4	1.2	-0.3	1.0	0.1
7/27/88	2.0	1.7	0.2	1.4	0.5	1.2	0.8
7/28/88	1.5	0.8	-0.1	0.5	0.1	0.4	-0.2
7/29/88	0.9	0.4	0.0	0.2	-0.4	0.2	0.0
7/30/88	0.4	1.0	0.4	0.8	0.0	0.6	0.0
7/31/88	0.6	0.0	0.0	0.0	0.0	0.2	0.0
	----		----		----		----
MEAN STAGE:	0.8						
MEAN ABSOLUTE ERROR:			0.2		0.3		0.3

NO. OF DAYS ABOVE FLOODSTAGE: 0

7-YR AVG STAGE FOR THE MONTH: 19.2

Table 2. July 1988 Data Listing for Chester, IL.

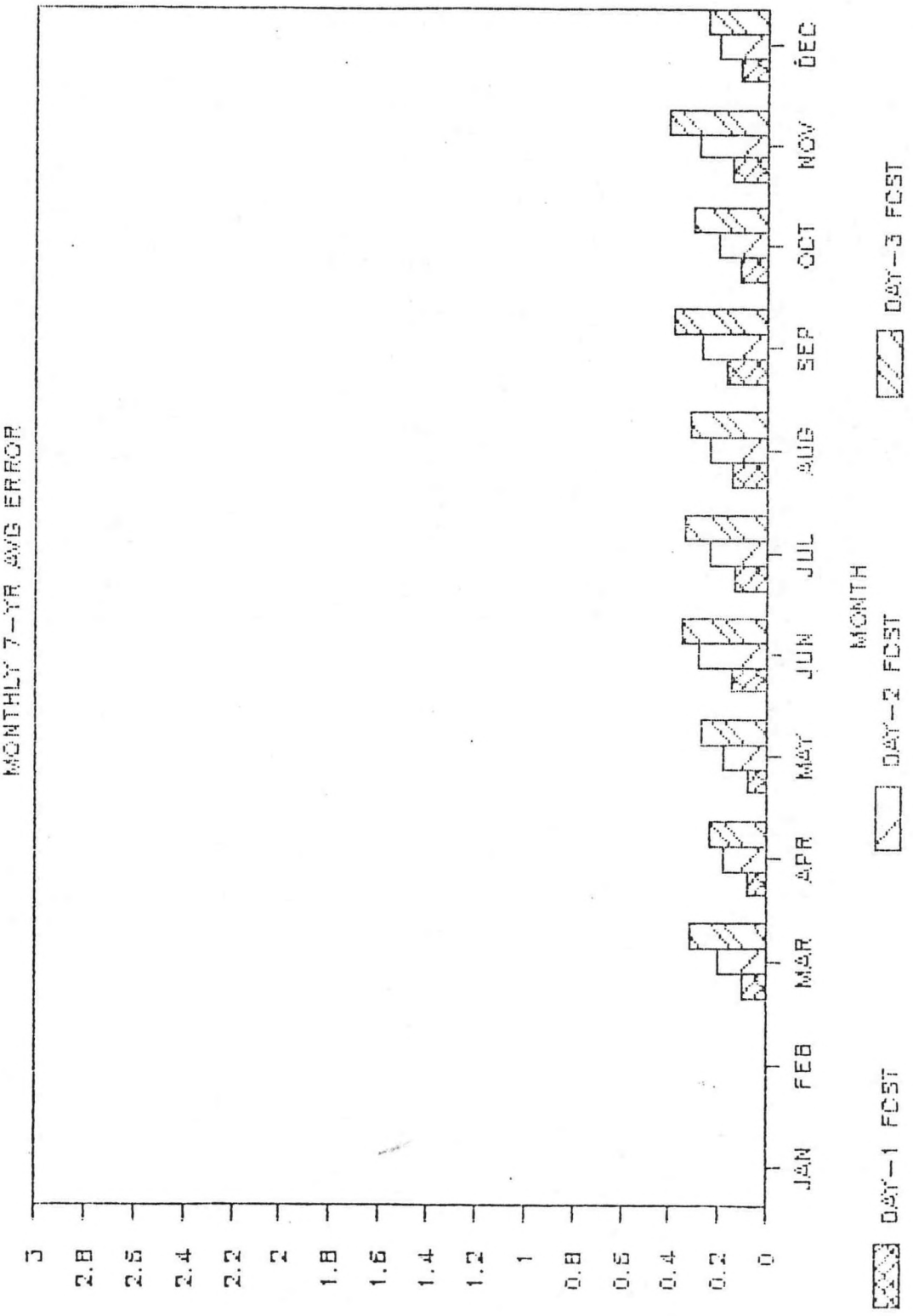

Figure 1. Monthly Plot of the Seven Year Mean Absolute Error for Guttenberg, IA.

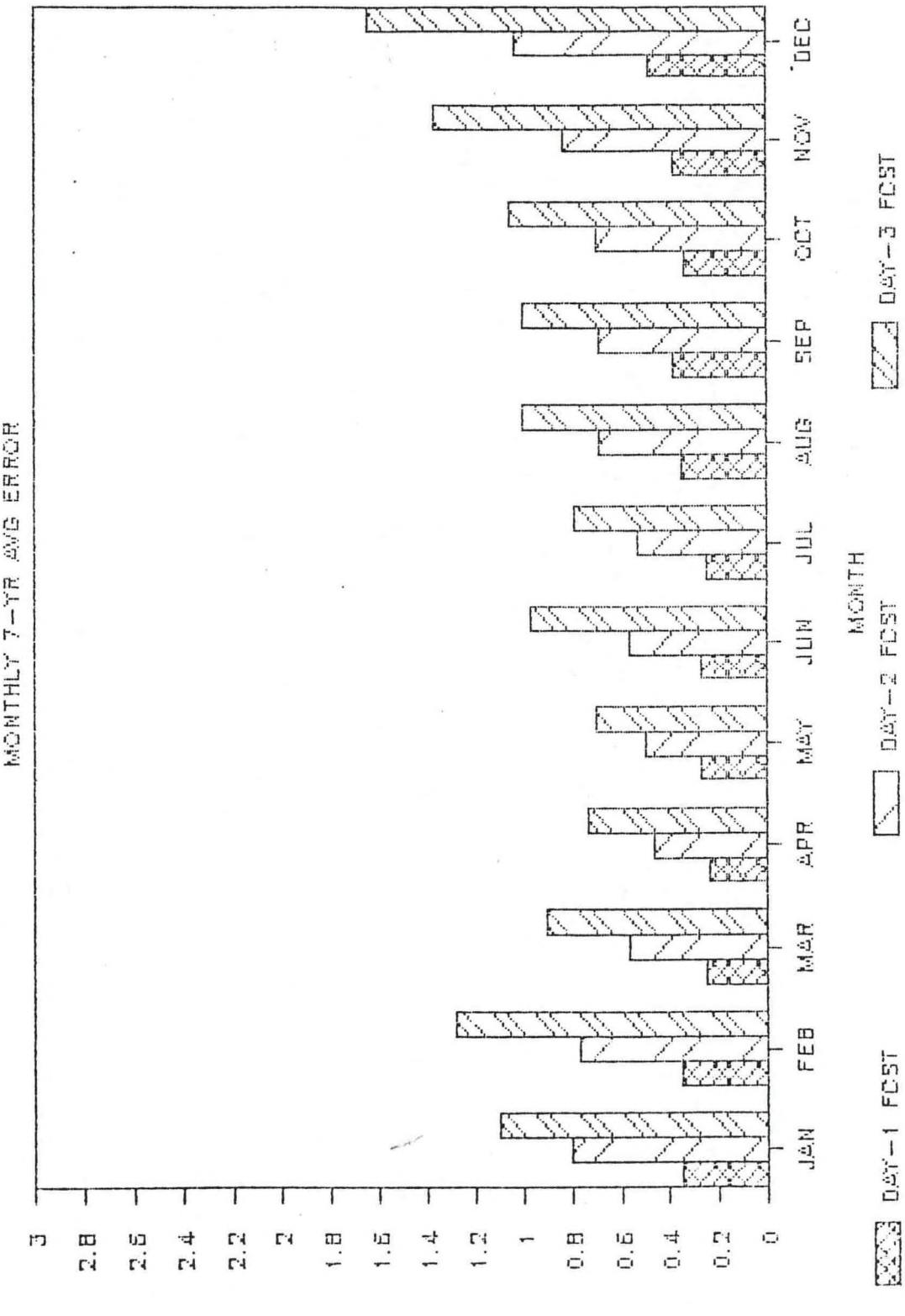

Figure 2. Monthly Plot of the Seven Year Mean Absolute Error for Chester, IL.

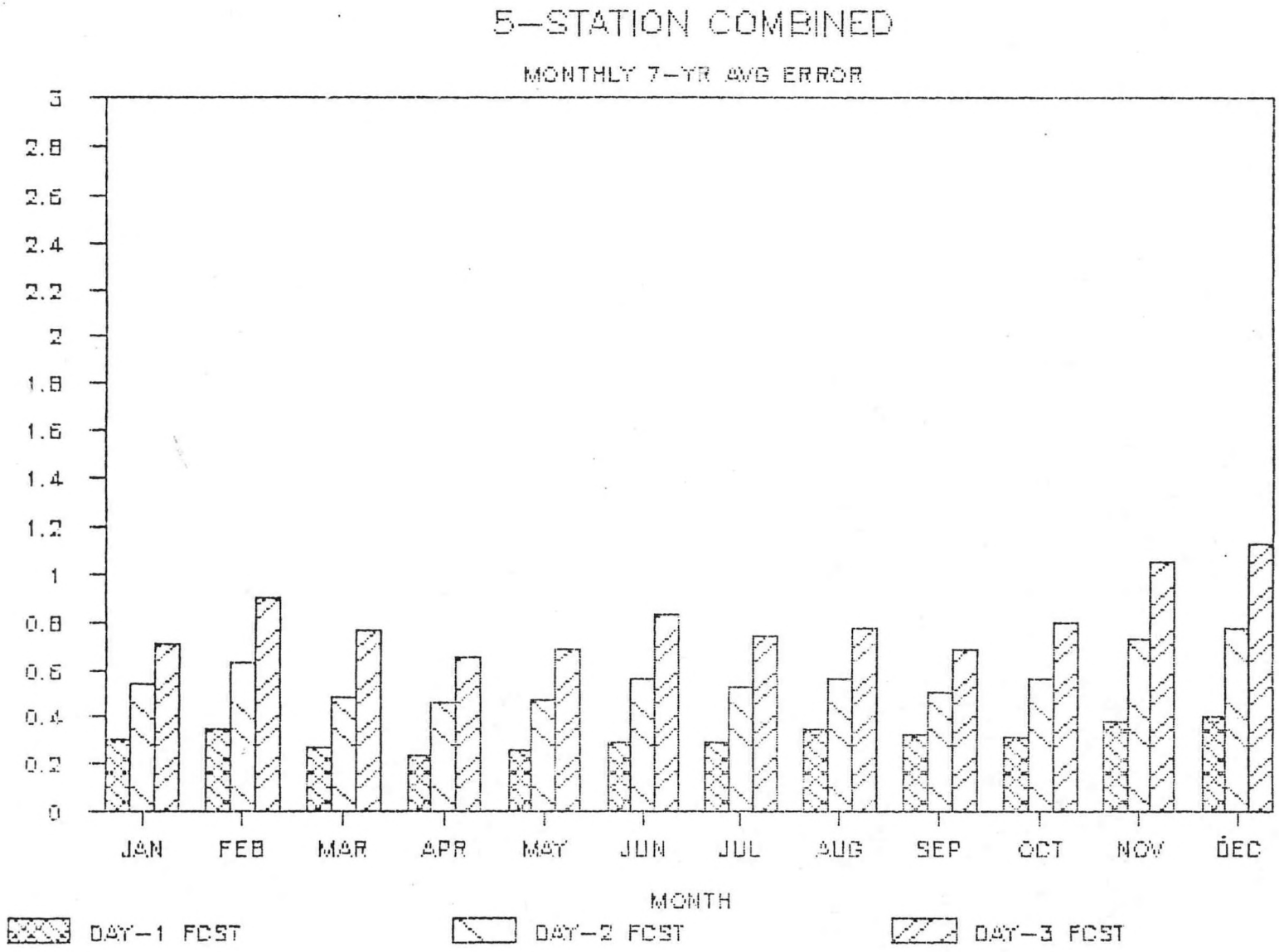

Figure 3. Monthly Plot of the Seven Year Mean Absolute Error Combined from the following locations: Guttenberg, IA; Grafton, IL; Alton, IL; St. Louis, MO; and Chester, IL.

CR TA 88-39
OCTOBER 1988

5. Operational Significance

It is not the intent of this verification procedure to be national in scope or to measure an individual's forecast skills, but rather to have available a measure of the accuracy of the three day forecasts. We are frequently asked the question, "How accurate are your three day forecasts?" This procedure for the mainstem river verification has begun to meet that need.

The significance of the three day river forecasts, especially for regions below locks and dams, can be measured by the very large economic impact on navigation interests. These forecasts, coupled with the four week extended outlooks in the St. Louis area, are utilized in planning for barge operations. Commercial shipping interests determine the loading of barges based on projected river stages, and therefore, the barge's draft for the duration of their journey of several days or even weeks. Every one-tenth foot of stage represents a significant volume of commodity and profit margin (or loss). Barge draft considerations wer especially critical during the low flow period of 1988.

6. Annual Trends

As a result of seven years of documentation and analysis of three day mainstem Mississippi River forecasts, trends have emerged. Figures 4 and 5 are graphical displays of the average annual forecast error for Guttenberg, Iowa and Chester, Illinois, respectively. As indicated in these graphics, improvement in years 1986 and 1987 were more pronounced in the second and third day forecasts. This effect is due in part to the development of additional data points on tributary basins.

The contrast between these two sites is striking. Guttenberg, the Lock/Dam 10 tailwater gage, is greatly influenced by differences in hydraulic capacity and lock and dam regulation. Open river operations (flood conditions when all gates are open) have rarely occurred here during this seven year period. On the other hand, Chester is below the series of locks and dams above St. Louis, Missouri. As a result of Missouri River flow changes and lock and dam regulation, fluctuations of $\pm$ two feet within a 24 hour period may occur. Due to the travel time from St. Louis to Chester the second and third day mean absolute error can be three to four times larger than the first day mean absolute error. This relationship is not the case at Guttenberg.

The monthly seven year average graphs of the mean absolute error (Figures 1 and 2) show similar trends at these two sites. Lock and dam operations greatly influence the second and third day forecasts at Chester except for the months of April and May when higher flows dampen the effects from reservoir regulation.

Consistent data regarding first day forecast errors greater than 1.5 feet were available from the five Mississippi River three day forecast locations only for the period 1984 to 1987. Table 3 provides a summary of this data. The percent of forecast errors greater than 1.5 feet for above flood stage conditions was less than one percent, while the percent for all forecasts greater than 1.5 feet, regardless of flow, was three percent.

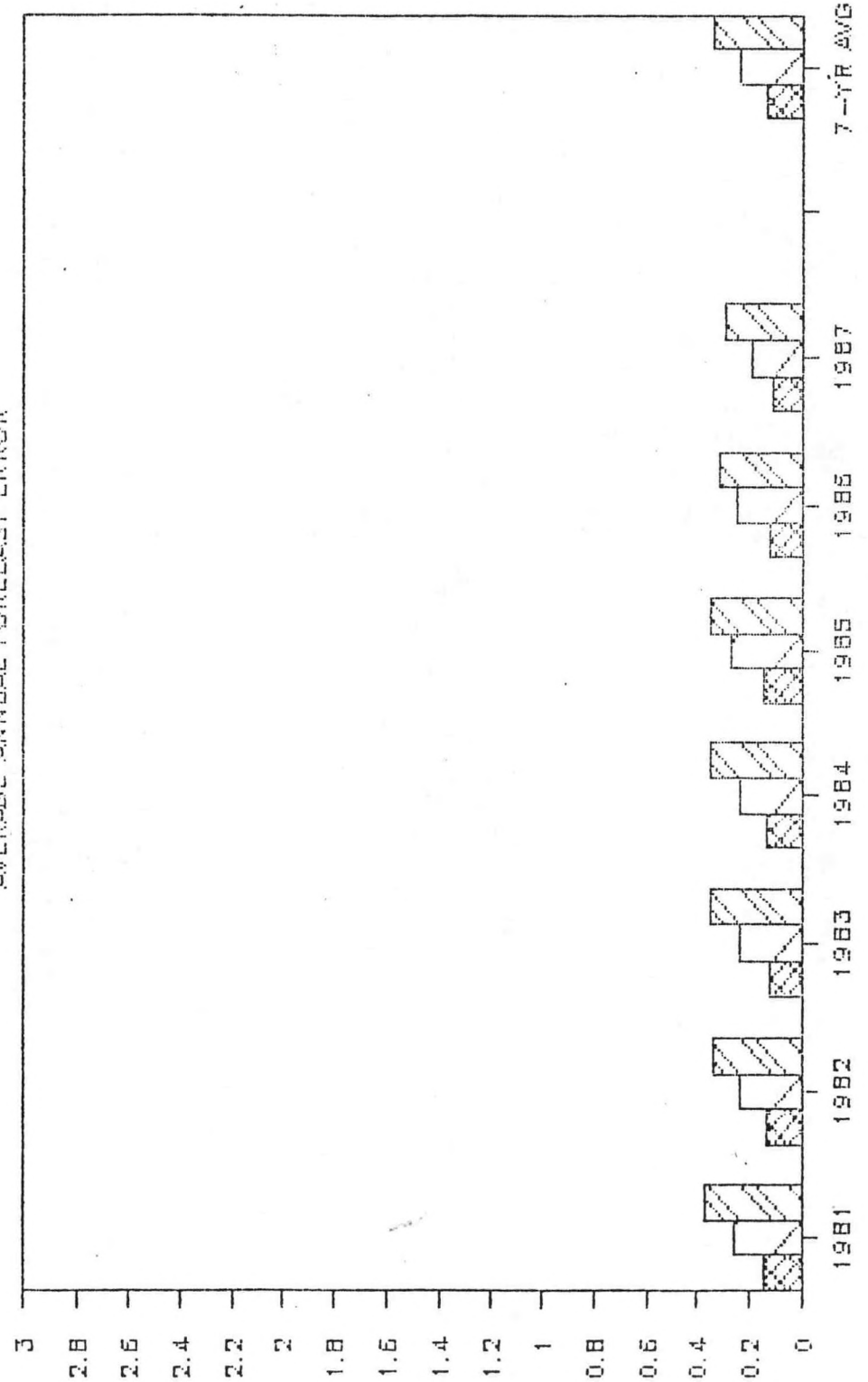

Figure 4. Annual Plot of the Mean Absolute Error for Guttenberg, IA.

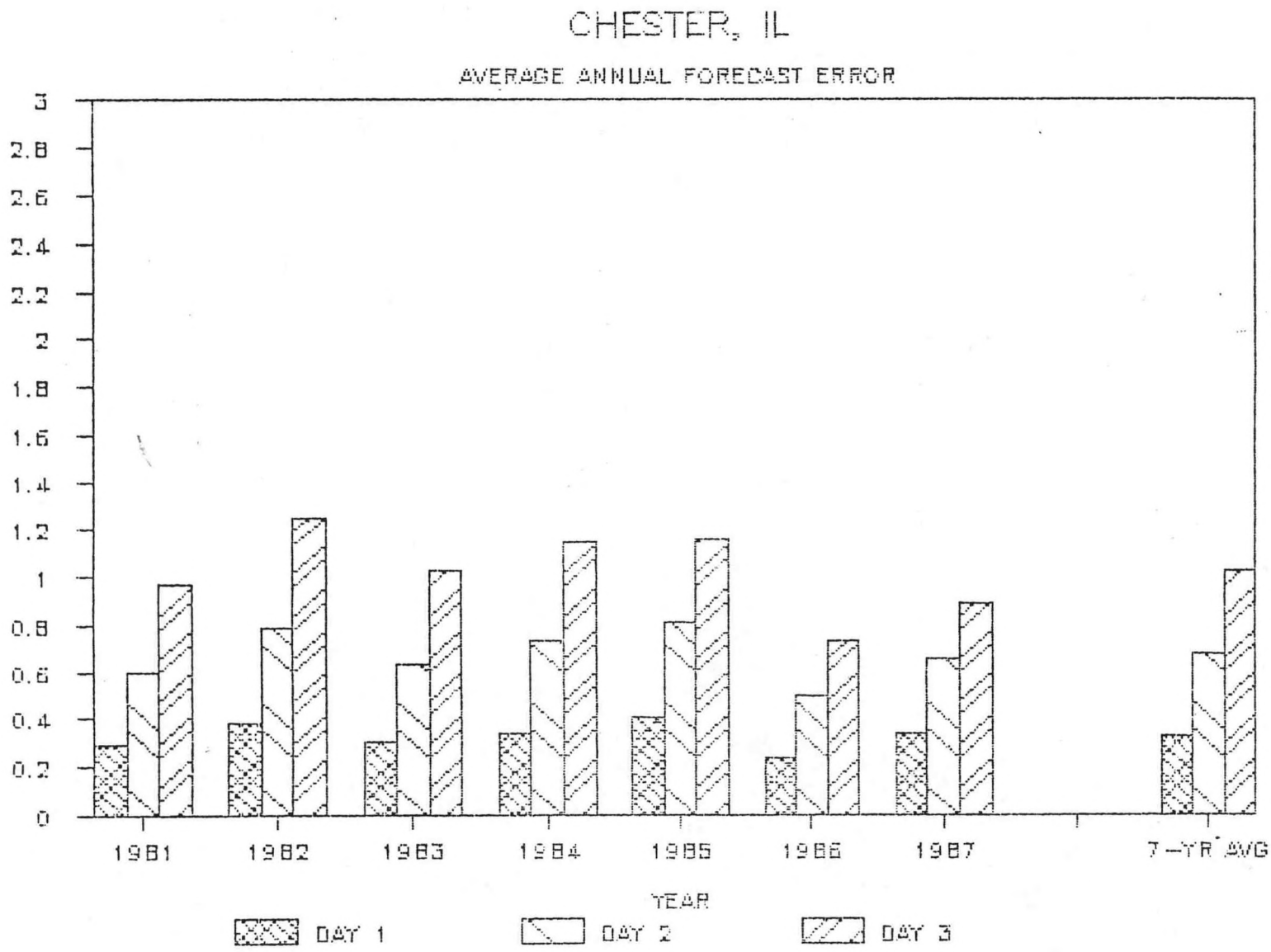

Figure 5. Annual Plot of the Mean Absolute Error for Chester, IL.

Year	Occurrences above Flood Stage	Percent of Occurrence*	All Occurrences	Percent of Occurrence*
1984	6	0.38	52	3.28
1985	15	0.95	73	4.61
1986	3	0.19	23	1.45
1987	1	0.06	60	3.79
TOTAL	25		208	
Percent of Occurrence#		0.39		3.28

*Based on 1,585 forecasts per year.
#Based on 6,340 forecasts for four years.

Table 3. Total annual first day forecast errors greater than 1.5 feet for the five mainstem Mississippi River sites, Guttenberg, Iowa; Grafton, Illinois; Alton, Illinois; St. Louis, Missouri; and Chester, Illinois

It is noteworthy that 1986 Mississippi River flows were above normal for an extended period of time. Yet the percentage of first day forecast errors greater than 1.5 feet for the year (for all occurrences) was the lowest of the four year period (with less than two percent). The other three years, in general, had more normal flows. Lock and dam regulations have a larger impact when flows are at levels below open river conditions.

One can draw the same conclusion from the data provided in the average annual forecast error graph for Chester (Figure 5) for the year 1986. The lowest mean absolute error is indicated for this year. The other three years, (1984, 1985, and 1987) show that average annual forecast forecast errors for Chester to somewhat follow the same trends as shown in the annual first day forecast errors greater than 1.5 feet (Table 3).

The first day forecasts are the most stable, as indicated for these seven years. Efforts to improve the second and third day forecasts show a positive trend for 1986 and 1987 at Chester (Figure 5). Model revisions, the addition of tributary data points, and automation providing hourly data at many mainstem sites have improved error rates in the last two to three years. In addition, NCRFC hydrologists are assigned a basin for the first six months of the year to provide consistency during the snowmelt period. This action has been positive, both for the error rate and the confidence level of the forecaster.

The impact from interagency coordination in regard to lock and dam regulation varies depending on flow levels. Frequently, gate settings are made that aren't available to the NWS until the next morning. Additional emphasis on interagency coordination will be required if significant improvement for the second and third day error rate is to be achieved.

7. Closing Remarks

As this data base expands, the longer term average mean absolute error is expected to become more conservative with time. As such, this verification procedure will provide a measurement tool regarding model performance, data needs, and an individual's model interpretation. Comparisons made between similar past flow situations and a current month's verification may reveal needs for procedural and model revisions. Continual study in a dynamic discipline such as hydrologic modeling is necessary to progressively improve public service. To meet these goals, the NCRFC will continue to study a variety of approaches to account for the accuracy of the three day mainstem forecasts. Therefore, comments and recommendations regarding the NCRFC verification procedures are welcomed and encouraged.

8. Acknowledgement

The verification computer program revisions and additions were programmed by Vera Matich, who also produced the PC data base, Symphony spreadsheet, and graphics. She oversees the monthly verification program.

The daily observed and forecast stages were prepared for input into the monthly verification program by Kathy Giese, who also does preliminary quality control of the input data. She prepared this text for printing.

My thanks to Vera Matich (Hydrologist, NCRFC) and Lee Larson (Regional Hydrologist, NWS Central Region) for their review of this text.