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CENTRAL REGION TECHNICAL ATTACHMENT 91-26

A COMPARISON OF QUANTITATIVE PRECIPITATION FORECASTS TO OBSERVED MEAN AREAL PRECIPITATION

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1. Introduction

Hydrologists at the Missouri Basin River Forecast Center (MBRFC) can use a Quantitative Precipitation Forecast (QPF) to issue contingency river forecasts at the request of a National Weather Service Forecast Office (WSFO) in their area of responsibility. They might also initiate contingency forecasts on their own if their analysis of hydrologic conditions and guidance from WSFOs or the National Meteorological Center indicate the potential for heavy rain over an already saturated area. The contingency forecasts represent a "What if...?" scenario produced through the use of forecast rainfall amounts in hydrologic models.

QPF is not routinely provided to MBRFC by any WSFOs at the present. This report examines a test period from June through October of 1990 where WSFO Topeka, Kansas, did provide daily QPF to MBRFC. Results of the test are presented here since plans call for all River Forecasts Centers to issue river forecasts using QPF input in the modernized National Weather Service (NWS). QPF Risk Reduction exercises are under way at Ohio River Forecast Center in Cincinnati and are planned for 1992 at North Central River Forecast Center in Minneapolis using QPF provided by WSFO Milwaukee/Sullivan.

If a WSFO in the NWS Central Region requests a contingency river forecast, the following procedure is generally followed. Initially, the non-QPF river forecast is provided to the WSFO for public dissemination. Then a river forecast using QPF is made available to the WSFO as a contingency forecast. The WSFO then updates the non-QPF forecast using the contingency forecast if actual rainfall observations approach or exceed the input QPF.

The National Weather Service River Forecast System (NWSRFS) hydrologic model computes Mean Areal Precipitation (MAP) from point precipitation totals. Since both represent mean precipitation over an entire runoff zone, QPF can be treated as future MAP. This paper analyzes the value of QPF based on comparison with observed MAP from June through October of 1990 over a portion of Kansas.

NWSRFS ingests point rainfall values for the hydrologic day and returns MAP values for 754 runoff zones in the Missouri River Basin. Files were created to store the MAP values for 60 runoff zones in Kansas for comparison to QPF.

Claims have been made that any river forecast using QPF is automatically better than one not using QPF when rainfall occurs over the same runoff zones, since the former can only use observed rainfall up to the forecast time and the latter can estimate additional rainfall in the future. The converse argument is that QPF is not currently accurate enough to avoid falsely forecasting rises on rivers and streams due to incorrect timing, location, or amount of the rainfall forecast. By comparing the forecast rainfall to the observed, insight can be gained as to whether or not it is advisable to use QPF on a continuous basis for river forecasts.

2. Project Area

WSFO Topeka provided QPF for 11 adjacent "QPF zones" over the Lower Smoky Hill and Kansas River Basins from north-central through northeast Kansas (Fig. 1). The Lower Smoky Hill River Basin includes the north and south forks of the Solomon River from below Webster and Kirwin Reservoirs, the Saline River from below Wilson Reservoir, and the Smoky Hill River from below Kanopolis Reservoir through Enterprise, Kansas. The Kansas River Basin includes the Kansas River and its tributaries from below Enterprise, Kansas, and downstream of Milford and Tuttle Creek Reservoirs to Kansas City, where it joins the Missouri River. Rain gages in the test area are also shown in Figure 1.

These 11 QPF zones were selected by grouping from three to eight MBRFC runoff zones together in an attempt to have some homogeneity of climate and topology, and yet to minimize the amount of work required by the QPF forecasters. Sixty MBRFC runoff zones were involved (Fig. 2).

These two river basins are contained entirely in one state and fall under the jurisdiction of one WSFO and one RFC. The total area of the 60 runoff (RO) zones involved is 13,398 mi**2 (21,562 km**2). The length from west end to east end is 265 mi (426 km), and the largest width from north to south is 75 mi (121 km). The average area of the RO zones is 223 mi**2 (359 km**2), while the average area of QPF zones is 1218 mi**2 (1960 km**2).

3. Methodology

The standard hydrologic day is a 24 hour period from 1200 UTC to 1200 UTC. The day is divided into four 6-hour periods, with period 1 from

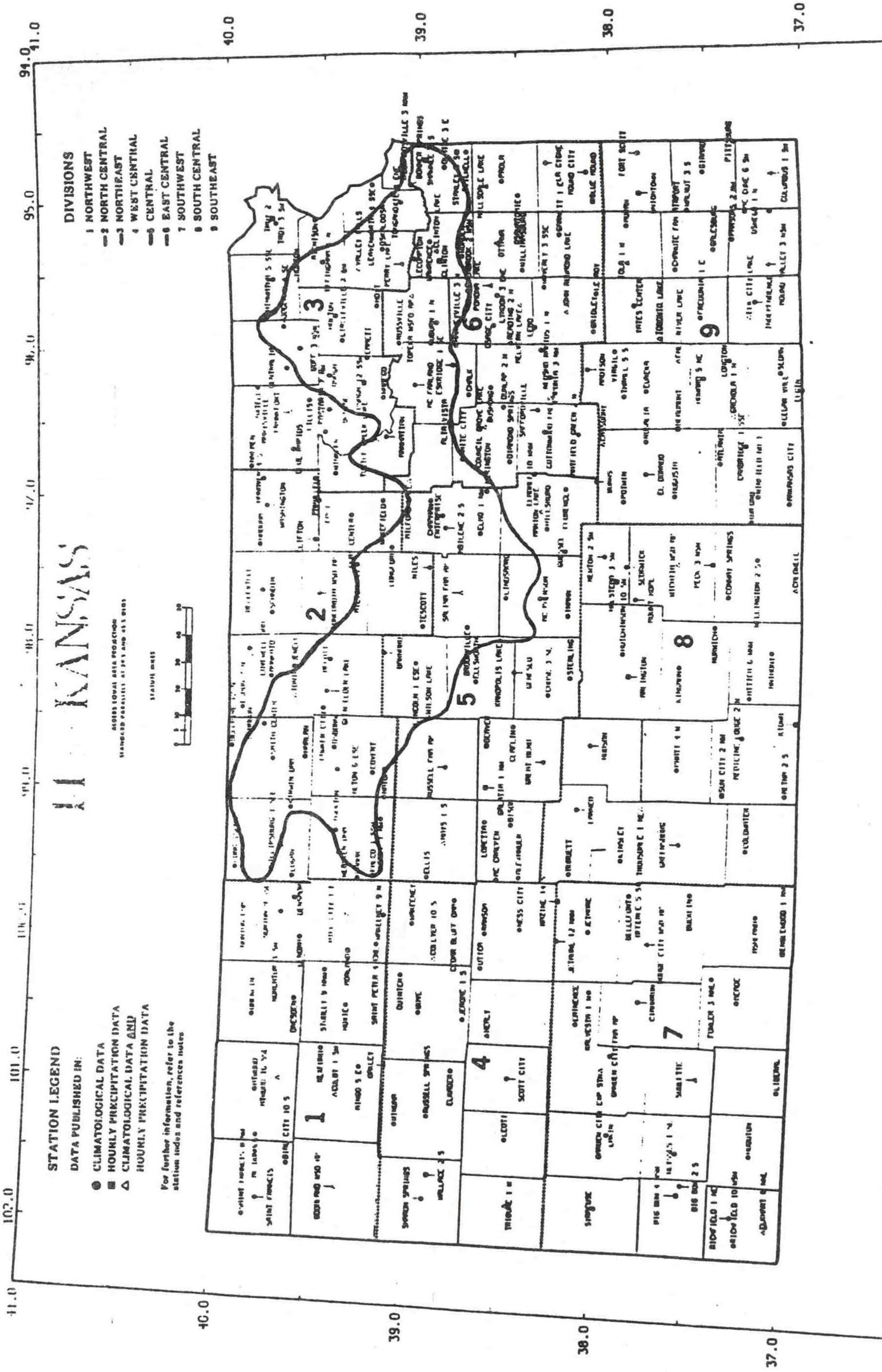

FIGURE 1
LOCATION OF QPF TEST AREA IN KANSAS

1200-1800 UTC, period 2 from 1800-0000 UTC, period 3 from 0000-0600 UTC, and period 4 from 0600-1200 UTC. WSFO Topeka provided QPF for periods 1 and 2 only.

The QPF was received at MBRFC at 1100 UTC and represented 0-6 hour and 6-12 hour forecasts. In visiting WSFO Topeka to discuss the project with the QPF Focal Point, it was noted that the forecasting was done manually by analyzing all available data, guidance, and model products then assigning QPF values to each of the 11 QPF zones for the first two periods. Work was in progress to adapt the computer software from WSFO Cleveland to assist the forecasters in this duty.

Values of QPF provided were to the nearest 0.25 inch for each of the 11 QPF zones. Refer to Figure 2 for the locations of the QPF zones. Table 1 is a sample of the QPF provided to MBRFC. These values represented mean areal precipitation forecast for the entire QPF zone, not just point values. The zone QPF value was then broken down into the associated 60 runoff zones by MBRFC.

TABLE 1: QPF As Provided to MBRFC by WSFO Topeka

```
TOPQPSTOP
TTAA00 KTOP 201105
TOPEKA FLOOD SUPPORT QPF
.B TOP 0920 Z DH12 / DC09201105 /DRH+6/PPQFZ/DHR+12/PPQFZ
:      MMDD     HH     MMDDHHNN        (ALL TIMES Z)
:QPF IN .25 INCH INCREMENTS FOR 6 HOUR PERIODS ENDING 6 AND 12 HOURS
:AFTER ISSUANCE. FORECAST SECTORS ARE DESCRIBED FIRST BY PUBLIC ZONE
:AND THEN BY CITIES WITHIN THE SECTOR.
:       HH+6    HH+12
KSQ01   0.00 /  0.25  :1  ZN7       OSBORNE/PHILLIPSBURG/SMITH CENTER
KSQ02   0.00 /  0.25  :2  SW ZN 10  BELOIT
KSQ03   0.00 /  0.25  :3  NW ZN 11  LINCOLN
KSQ04   0.00 /  0.25  :4  NC ZN 11  SALINA/MINNEAPOLIS
KSQ05   0.00 /  0.25  :5   C ZN 11  LINDSBORG
KSQ06   0.00 /  0.25  :6  NE ZN 11  ABILENE
KSQ07   0.25 /  0.25  :7  SW ZN 13  MANHATTAN/JUNCTION CITY
KSQ08   0.25 /  0.25  :8  SE ZN 13 & W ZN 15  ROSSVILLE/ONAGA
KSQ09   0.25 /  0.25  :9   N ZN 15  HOLTON
KSQ10   0.25 /  0.50  :10  S ZN 15  TOPEKA
KSQ11   0.50 /  0.50  :11  E ZN 15 & KC  KANSAS CITY/LAWRENCE/ATCHISON
.END
```

This QPF was issued the morning of September 20, 1990 at 1105Z, valid for the periods 12-18Z and 18-00Z.

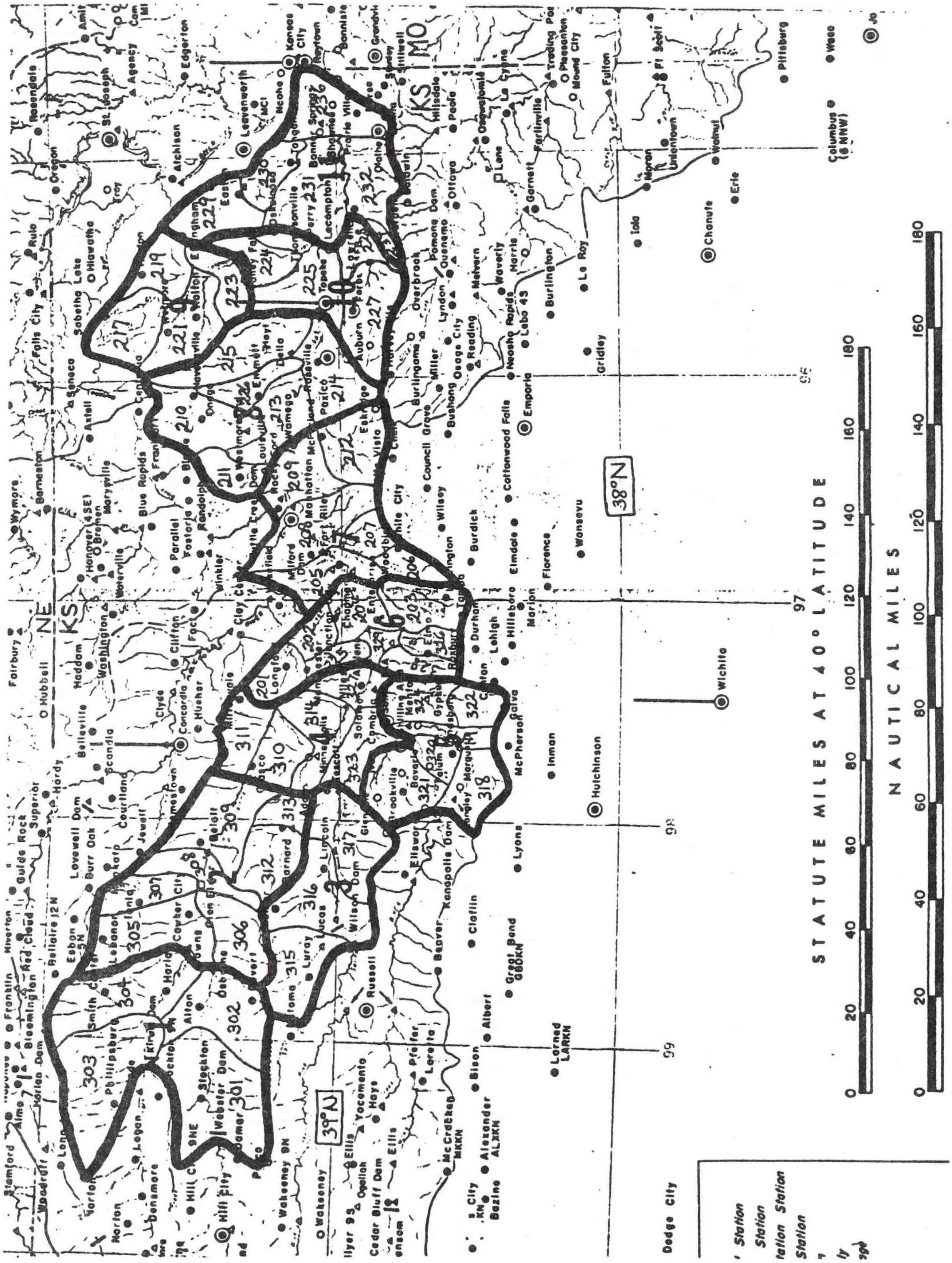

Figure 2. Runoff zones, QPF zones, and rivers in the test area.

The QPF forecasts were received at MBRFC on AFOS (Automation of Field Operations and Services), transferred to the PRIME computer at the MBRFC, printed on a line printer, and stored in files by month. These QPF files were set up in the same format as the MAP files for the 60 runoff zones of interest.

Some of the QPF data were missed at MBRFC due to product scheduling or dissemination problems. For all but six days of missing data, WSFO Topeka was able to supply us with either a hard copy of the QPF or an assumption of zero-QPF for the days in question. Zero-QPF was assumed when archived QPF data were missing but no precipitation was mentioned in the morning public zone forecasts archived on station.

4. Results

The QPF files were compared to the MAP files on a month-by-month basis for June through October of 1990. For each month there is a summary of QPF and of MAP by zone and by period.

The summaries include the following for each month...
- Number of periods RAIN was forecast and observed
- Number of periods NO RAIN was forecast and NO RAIN observed
- Number of periods NO RAIN was forecast, RAIN observed
- Number of periods RAIN was forecast, NO RAIN observed

There were two (6-hour) forecasts for each runoff zone per day, and a total of 60 runoff zones. That made a total of 60 X 2 X 30 or 3600 possible forecasts for a 30-day month. Half, or 1800, were for the first 6-hour period (12Z-18Z) and half for the second period (18Z-00Z). This corresponds to the total number of "periods" for which QPF and MAP were available. There were 3600 possible periods for the entire test area for a 30-day month.

MAP returned by NWSRFS was used as observed rainfall for each runoff zone since it represents the actual data available to work with in real time at MBRFC. By comparing the MAP generated for a runoff zone with the previous day's QPF for that zone for the same time period, an objective way to measure the reliability of QPF was obtained.

Table 2 and Figure 3 is a straight comparison, allowing any nonzero MAP value to represent rainfall observed and any zero MAP value to represent no rainfall observed. A nonzero QPF value represented rainfall forecast and a zero QPF value represented no rain forecast. The data was stratified to determine the total number of periods for the month that rain was forecast, not forecast, observed, and not observed for the entire test area.

		FORECAST Yes	FORECAST No	
OBSERVED	Yes	675	1876	2551
	No	1594	13495	15089
		2269	15371	

Figure 3. Contingency table of QPF (≥ .25) versus observed precipitation (MAP ≥ 0.0).

TABLE 2
SUMMARY OF QPF vs. MAP

	JUN	JUL	AUG	SEP	OCT	TOTAL
Number of days reviewed -	27	29	30	30	31	147
Number of runoff zone forecasts -	3240	3480	3600	3600	3720	17640
1st period -	1620	1740	1800	1800	1860	8820
2nd period -	1620	1740	1800	1800	1860	8820
Number of periods RAIN forecast and RAIN observed -	201	227	236	7	4	675
1st period -	115	52	110	1	0	278
2nd period -	86	175	126	6	4	397
Number of periods NO RAIN forecast and NO RAIN observed -	2337	2427	2739	2902	3090	13495
1st period -	1156	1250	1375	1537	1566	6884
2nd period -	1181	1177	1364	1365	1524	6611
Number of periods NO RAIN forecast and RAIN observed -	283	484	307	412	390	1876
1st period -	173	246	184	187	227	1017
2nd period -	110	238	123	225	163	859
Number of periods RAIN forecast and NO RAIN observed -	419	342	318	279	236	1594
1st period -	176	192	131	75	67	641
2nd period -	243	150	187	204	169	953

The number of periods where rain was forecast and observed, not forecast and not observed, not forecast but observed, and forecast but not observed was then counted. For example, in Table 2, any nonzero MAP value for the first period for runoff zone 301 along with a non-zero QPF value for the first period for runoff zone 301 would meet condition one (rain forecast and observed). Amounts were not considered other than zero or nonzero. It is interesting to note that of the 2269 forecasts for any amount .25 or greater, only 675 verified. This represents about a 29.7% success rate.

For Table 3 and Figure 4, the MAP values were confined to the same constraints as the QPF. Since the forecasters provided QPF rounded to the nearest 0.25 inch, the MAP values were rounded before comparing them to the QPF. Therefore, any MAP of 0.00 - 0.12 would be called 0.00... any value in the range 0.13 - 0.37 became 0.25...etc. The same summaries were examined as in Table 2, but with respect to the rounded MAP values. Again, amounts were not considered other than the fact that they were either zero or nonzero after rounding. Notice the influence of smaller MAP values on the overall skill. Consideration of all MAP amounts really improved the success rate (29.7%) as compared to 9.7% when small amounts of MAP (<.12) were ignored.

		FORECAST Yes	FORECAST No	
OBSERVED	Yes	198	454	652
OBSERVED	No	2071	14917	16988
		2269	15371	

Figure 4. Contingency table of QPF ($\geq$ .25) versus observed precipitation (MAP $\geq$ .12).

TABLE 3
SUMMARY OF QPF vs. ROUNDED-OFF MAP

	JUN	JUL	AUG	SEP	OCT	TOTAL
Number of days reviewed -	27	29	30	30	31	147
Number of runoff zone forecasts -	3240	3480	3600	3600	3720	10920
1st period -	1620	1740	1800	1800	1860	8820
2nd period -	1620	1740	1800	1800	1860	8820
Number of periods RAIN forecast and observed -	68	35	95	0	0	198
1st period -	37	0	50	0	0	87
2nd period -	31	35	45	0	0	111
Number of periods NO RAIN forecast and observed -	2548	2782	2953	3224	3410	14917
1st period -	1272	1420	1498	1689	1732	7611
2nd period -	1276	1362	1455	1535	1678	7306
Number of periods NO RAIN forecast and RAIN observed -	72	129	93	90	70	454
1st period -	57	76	61	35	61	290
2nd period -	15	53	32	55	9	164
Number of periods RAIN forecast and NO RAIN observed -	552	534	459	286	240	2071
1st period -	254	244	191	76	67	832
2nd period -	298	290	268	210	173	1239

Table 4 takes an additional step, and by comparing when a nonzero QPF value equal a rounded MAP value. Basically, the number of periods that rain was observed, using the rounded MAP values (from Table 3), was compared to the number of periods that the QPF was equal to that value. That is, if the rounded MAP for the first period for zone 301 was 0.50 inch for June 10, then only a QPF value of 0.50 inch was considered equal for zone 301 for the first period for that day.

Nonzero rounded MAP values were observed in 652 periods over the five months as shown in Table 4. QPF equalled MAP on only 57 of those occasions...22 in the first period and 35 in the second period. This amounts to about a 8.7% success rate (57/652).

TABLE 4
SUMMARY OF QPF vs. ROUNDED MAP

	JUN	JUL	AUG	SEP	OCT
Number of days reviewed -	27	29	30	30	31
Number of periods of RAIN observed -	140	164	188	90	70
1st period -	94	76	111	35	61
---(from Table 3)---- 2nd period -	46	88	77	55	9
Number of periods nonzero QPF amount EQUALLED Rounded MAP -	20	19	18	0	0
1st period -	17	0	5	0	0
2nd period -	3	19	13	0	0

TOTAL : QPF = Rounded MAP 57 times out of 652 possible

5. Considerations

One thing to consider when looking at these comparison data is that the MAP values are not perfect. They are produced by interpolation of somewhat sparse point precipitation totals, with no guarantee that there is even one rainfall report from each runoff zone. To counter the argument that there may be too much MAP calculated for some zones due to the lack of a more dense gage network, one can claim that it is likely that no gage recorded the maximum point rainfall total, and thus MAP was underestimated. However, the working assumption for this paper was that MAP was as accurate as possible given the current gage network.

Another thing to consider is the lack of accurate real-time precipitation data available for daily operational use at MBRFC. An evaluation of the rainfall reported for 62 stations in the publication Climate Data for Kansas for June through October of 1990 showed that only 58% of that total was received in real time at MBRFC. This does not mean that MAP is in error by over 42% on a daily basis. It does show that, due to the missing data, estimation techniques and manual overrides must be applied at MBRFC. However, those stations not reporting data daily contribute to a significant portion of the error. The arrival of the WSR-88D radar will add even more complications to this situation, when we have to be alert for errors in rainfall estimation.

Another factor in the comparison is the zonal groupings of QPF versus the individual zone values for MAP. The forecaster at the WSFO was forced to group 3 to 8 runoff zones together and give a QPF for that entire cluster, whereas the MAP was calculated for each individual runoff zone. Grouping was an attempt to make the QPF task a little less tedious for the forecasters.

Aside from MAP and QPF, to get better river forecasts, there is still the matter of having good antecedent conditions (soil moisture), reliable unitgraphs and routings, and accurate runoff calculations.

One last point that must be made concerns the relative importance of the rain forecasts. This test period was not an excessively wet one and the antecedent conditions were about normal (Antecedent Index in the 3.0-3.5 range) on June 1 for these two basins in Kansas. The streamflow during May is normal for the test area in May (Fig. 5). The point is that the conditions during the test were such that a QPF of less than 1.50 inches was not likely to warrant a forecast from the RFC, as it would take around 2.00 inches of rain to produce 0.25 inch of runoff. For these 62 stations, only 57.80% of the precipitation observed (according to the publication Climate Data for Kansas) was reported to Missouri Basin RFC in real time for inclusion in the data set used by NWSRFS to calculate MAP.

6. Conclusions

Forecasting precipitation location, amount, and time of occurrence is one of the most difficult challenges facing operational meteorologists today. The comparison of QPF to MAP indicates that perhaps the skill required to correctly predict rainfall to the degree of accuracy required for input into an RFC's river forecast model may be much greater than the current level of expertise.

Rainfall forecasts that are off by any of those three parameters (location, amount, or time) could lead to erroneous river forecasts if QPF is used unconditionally. A spatial discrepancy of only a mile can put the runoff in the wrong watershed. A miss in timing would cause the time to peak wave to be off. Missing the amount can underforecast a flood.

7. Suggestions

With respect to the comparison of QPF and MAP, any repeat of this test should contain 24 hours (all four periods) of data. This would require sending QPF at all scheduled times, and that the forecast office involved must give the QPF a high priority. It must be treated like a real-time forecast test that includes an evaluation of the impact on the forecast office staff. Monthly status reports should be provided by the RFC to the WSFO and vice versa.

Other comparisons may be implemented as suggestions arise to look at the results in another manner. One possibility would be to set up parallel files to carry the QPF runs through generation of runoff. This is the ultimate test of QPF...determining if the rainfall forecast versus observed actually shows any difference in runoff, which would then cause a direct difference in river forecasts.

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National Water Conditions

UNITED STATES
Department of the Interior
Geological Survey

CANADA
Department of the Environment
Water Resources Branch

MAY 1990

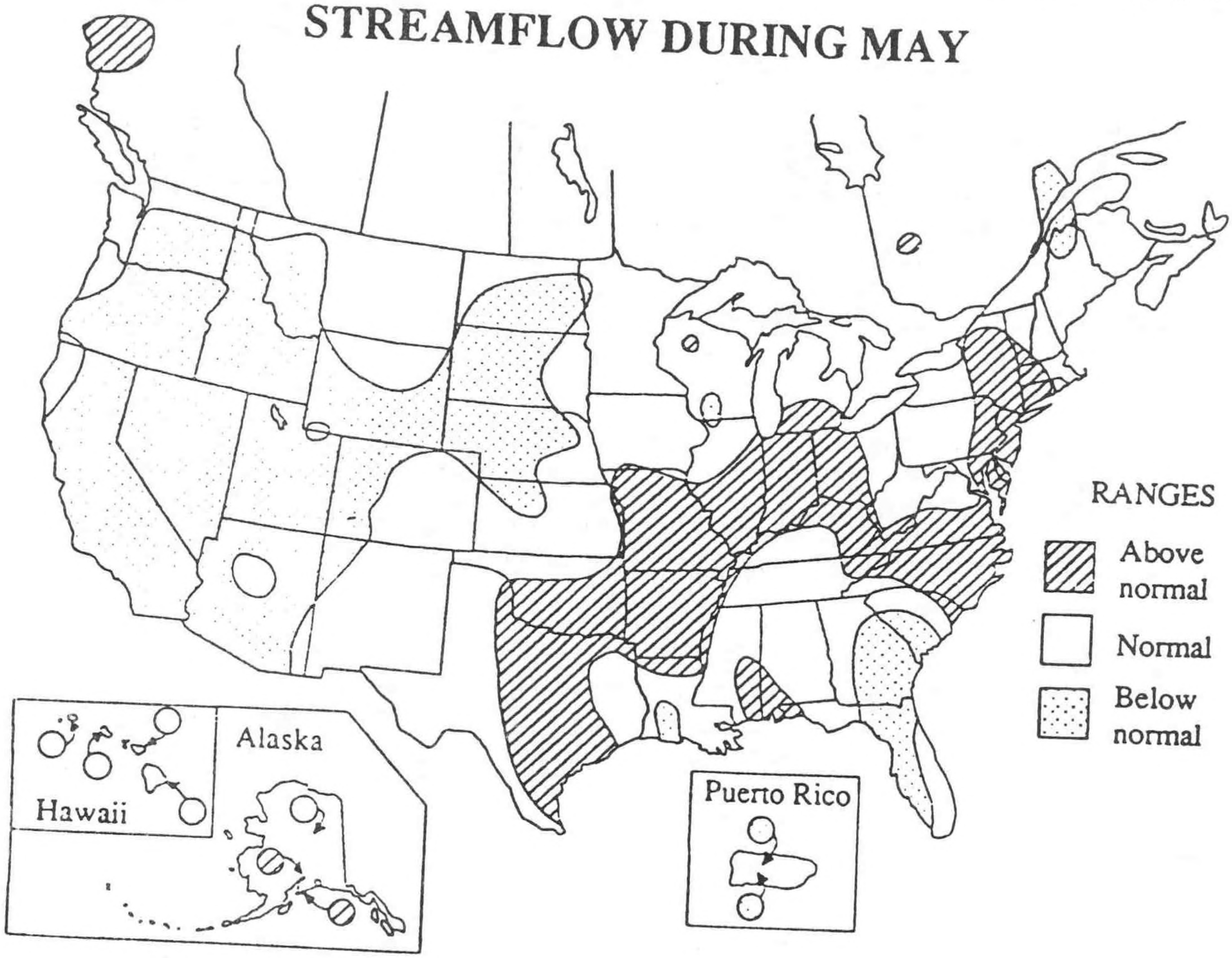

FIGURE 5

STREAMFLOW DURING MAY 1990

8. Summary

In closing, this report notes two problems. First of all, there is a data flow problem. Less than 60% of the rainfall reports available are received in real time. This combined with a sparse river gage network makes trying to forecast river flooding quite problematic.

Secondly, the level of accuracy of QPF required by hydrologic models is pushing the current state of the art. The success rate presented in this paper for QPF versus MAP values, rounded MAP values, and actual amount is 29.7%, 9.5%, and 8.7% respectively.

An attempt should be made to carry NWSRFS runs with QPF through calculation of runoff, in order to compare forecast runoff with observed runoff. Monthly reports should be issued.

ADDENDUM

In the time that elapsed between the first drafts of this report and its completion, a QPF Risk Reduction exercise has been proposed between the North Central River Forecast Center and WSFO Milwaukee/Sullivan. Some of the suggestions presented in this report will be adopted into that experiment. The most notable are the use of 24 hours of QPF and the intent to generate runoff and river forecasts using QPF to compare to non-QPF forecasts and verify both with observed stage data.

9. Acknowledgements

Thanks to WSFO Topeka and the QPF Focal Point, Steve Schurr, for their support in providing QPF. Again, this is not an attempt make any kind of statement about the forecasting capability of the staff at WSFO Topeka. All at MBRFC realize that forecasting rainfall to the degree of accuracy required in hydrology is virtually an impossible task.

Larry Black, Hydrologist-In-Charge, set up the data transfer code and storage files on the NAS-9000 computer, and reviewed the text. Bob Cox, Special Projects Hydrologist, and Billy Olsen, Operations Hydrologist, answered many questions and edited the text. Thanks to Dr. Joe Schaefer and Dr. Richard Livingston for comments and final editing. Thanks to Beverly Lambert for typing and proofreading the manuscript.