LOUZIE: An Operational Quality Control Procedure at the Lower Mississippi River Forecast Center

Prepared by the NOAA/NWS/Lower Mississippi River Forecast Center (LMRFC)
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1. INTRODUCTION

The Lower Mississippi River Forecast Center (LMRFC), an office of the National Oceanic and Atmospheric Administration's (NOAA) National Weather Service (NWS), has developed an operational, manual quality control (QC) procedure for gauged precipitation data across the Lower Mississippi River Valley. The QC procedure was developed in fall 2005 by the hydrometeorological analysis and support (HAS) forecasters to enhance and streamline the former procedures employed at the LMRFC. The LOUZIE program and spreadsheet was developed to track rain gauge values flagged as potentially erroneous by the LMRFC staff. This report provides a description of the data sources and methodology used to develop the LOUZIE program and spreadsheet.

2. STUDY AREA

The LMRFC's area of responsibility includes the entire drainage of the Lower Mississippi River Valley below Smithland, IL on the Ohio River and below Chester, IL, on the mainstem Mississippi, including the major river basins of the White, Ouachita, Yazoo, local tributaries of the Tennessee River, Pearl River, Red River, and the mainstem Mississippi, among others (Fig. 1). The LMRFC domain covers a region of nearly 210,000 square miles, including the southern Appalachian Mountains in the east, the Ozarks and Ouachita Mountains to the north, and the delta region of the Mississippi River and Gulf Coast to the south. The varied topography of the area generates a wide variety of hydrologic responses from flash flooding (on time scales of hours) to long duration, major river flooding (on time scales of days to weeks).

Figure 1. *LMRFC Forecast Groups. LMRFC domain outline in black. Forecast groups in blue.*

The LMRFC is responsible for providing daily hydrologic forecasts to 18 WFOs for over 220 sites (Fig. 2). To perform these hydrologic forecasts, it is imperative that the hydrologic models are well-calibrated and receive high-quality input in the form of precipitation data. To meet this requirement, the LMRFC ingests precipitation data from over 4000 rainfall gauges distributed across 17 states and uses this data in conjunction with radar precipitation estimates to generate a region-wide multi-sensor precipitation dataset at hourly intervals.

The climate of the LMRFC domain is diverse with snowfall frequently occurring across the northern tier during the winter months, and coastal regions receiving tropical storms during the summer. The impact of these weather phenomena on the quality of rain gauge and *in situ* precipitation datasets is discussed in Section 3.2.

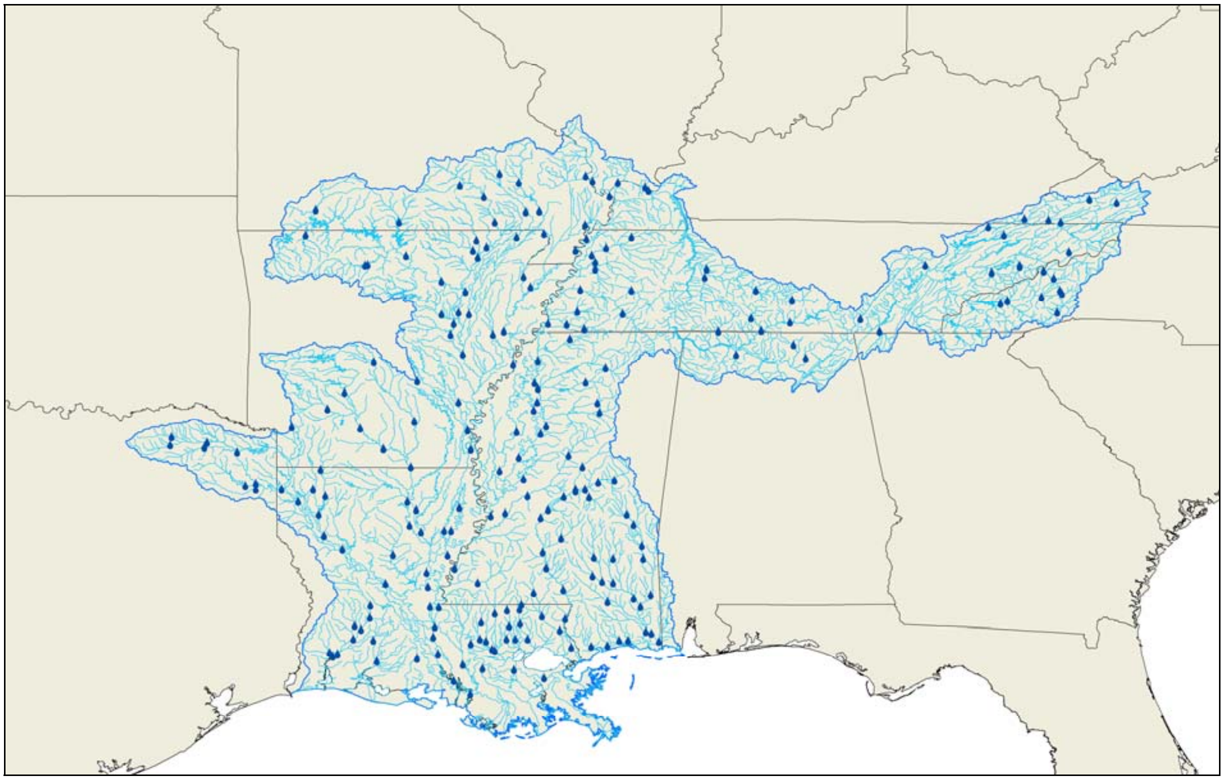


Figure 2. *LMRFC Forecast Points. LMRFC domain outline in blue. Rivers in light blue. Forecast points as raindrops.*

3. LOUZIE METHODOLOGY

The aptly-named, LOUZIE (pronounced “lousy”) spreadsheet is used to track rain gauge values flagged as potentially erroneous by the forecasters at the LMRFC during quality control processing using the Multi-sensor Precipitation Estimation (MPE) Editor, XNAV, XDAT, and Contour software packages.

LOUZIE was an original acronym for the flags used to identify the types of potential error in the gauge report and how to treat the offending gauges with respect to the maintenance of the precipitation database. The ‘L’, ‘O’, ‘U’, ‘Z’, and ‘E’ represent the types of errors (identification flags; Table 1); and, the ‘I’ represents the action taken by the forecaster (treatment flags; Table 2) when the precipitation report is deemed reasonable and the identification flag is ignored (i.e. the gauge data is not removed from the database). A second treatment flag, ‘R’ - intentionally left out of the acronym for phonetic purposes - is used when the gauge report is found to be in error and requires removal from the database.

Table 1. *Identification flags used in the LOUZIE spreadsheet.*

L	Light precipitation gauge reports. Gauge is reporting precipitation <= 0.10" with no precipitation observed on radar or at surrounding gauges. Common for dripping gauges after rainfall has ended, fog/mist, and snowmelt.
O	Over-estimated gauge reports. Gauge is over-estimating the amount of precipitation observed on radar and at surrounding gauges. Occsaionally observed with clogged/obstructed gauges and gauges experiencing other issues (e.g., double tipping).
U	Under-estimated gauge reports. Gauge is under-estimating the amount of precipitation observed on radar and at surrounding gauges. Common for clogged/obstructed gauges.
Z	Zero precipitation gauge reports. Gauge is reporting zero precipitation with precipitation observed on radar and at surrounding gauges. Common for clogged/obstructed gauges.
E	Extreme precipitation gauge reports. Gauge is reporting precipitation > 0.10" with no precipitation observed on radar or at surrounding gauges. Common for equipment malfunctions, gauge resets, or decoding problems.

Table 2. *Treatment flags used in the LOUZIE spreadsheet.*

I	Ignored gauge. 24-hour precipitation totals for the gauge were representative of the radar estimates and surrounding gauge reports. The data is not removed from the database (i.e. "ignored") and used in operations.
R	Removed gauge. 24-hour precipitation totals for the gauge were NOT representative of the radar estimates and surrounding gauge reports. The data is removed from the database and not used in operations.

LOUZIE was developed in fall 2005 by hydrometeorologist (HAS) forecasters at the LMRFC to assist in the accounting of bad gauges identified during standard quality control procedures. The former hand-written method (Fig. 3) was not suitable for archive; and, the ability to track poorly performing gauges for longer than 24 hours was limited. Therefore, the LOUZIE project simply streamlines and organizes the quality control procedures already in place at the LMRFC. As a result, the project allows the LMRFC to significantly enhance the quality of MPE and gauge-only precipitation datasets and assists in adding consistency to each operational shift.

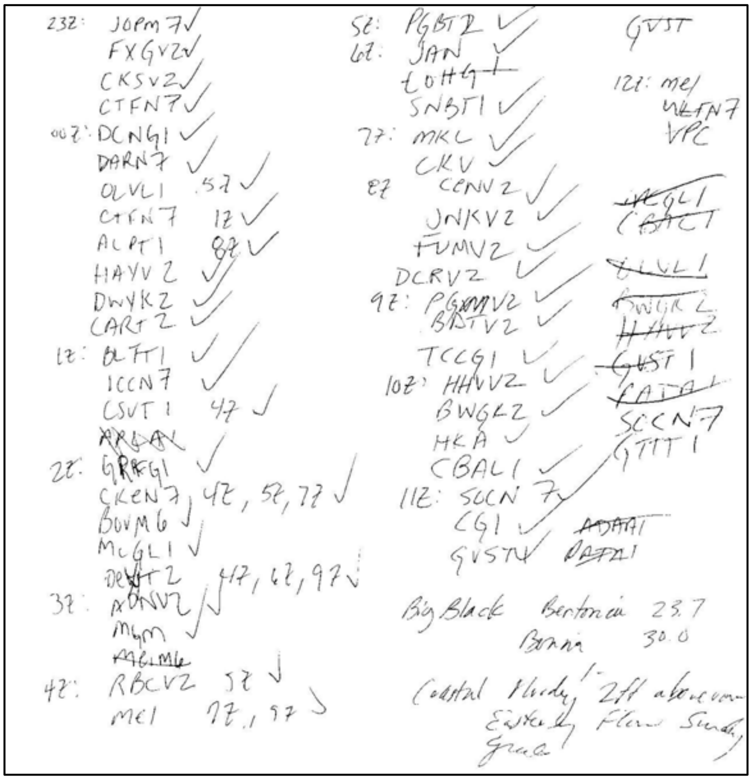


Figure 3. *Example of the former hand-written accounting methodology used for gauge quality control.*

3.1 Rationale

The primary focus of the LOUZIE program is to improve the quality of gauge precipitation data entering the National Weather Service Operational Forecast System (OFS). Errors in gauge precipitation data lead to errors in the computation of radar biases in the MPE software package. Calculations of mean areal precipitation for use in the hydrologic models at the LMRFC include values for gauge-only mean areal precipitation (MAP) and MPE-generated mean areal precipitation (MAPX). Since the quality of gauges influence both MAP and MAPX values, these errors extrapolate to errors in hydrologic forecasts. Additionally, the temporal and spatial distribution of precipitation is important to forecasting a basin's hydrologic response.

Implementation of the LOUZIE program and spreadsheet allowed a continuous monitoring of gauges throughout the LMRFC with significant benefits and no additional manpower requirements. Poor-quality gauges with recurring mechanical or maintenance issues could be turned off in the Weather Forecast Office Hydrologic Forecast System (WHFS) Hydrobase ingest filter to improve time efficiency in operational quality control. In addition, the program provided an avenue for communication and collaboration between the LMRFC, WFOs, and gauge owners (e.g. USGS, USACE), thereby improving site maintenance, data quality, and knowledge of the gauge network. In 2006, the LMRFC provided a survey (Appendix A) to the WFOs to inquire of the benefits of the program. The results justify and further support the LOUZIE program.

Quality control of precipitation is important beyond the immediate needs of the LMRFC. Besides assisting the forecasters in identifying quality issues in the multi-sensor precipitation estimates, problematic gauges can be identified and fixed. Many numerical weather prediction models rely on both gridded and gauge-only precipitation datasets for initialization. As a result, the enhanced quality of these datasets will assist in improving forecast model accuracy in hydrological or meteorological modeling efforts. Furthermore, the precipitation datasets are used to verify quantitative precipitation forecasts made by the Hydrometeorological Prediction Center (HPC) and the LMRFC; quality control ensures our performance metrics are calculated appropriately.

3.2 Data Sources & Processing

Gauge and radar precipitation datasets are obtained from several federal agencies, including: NOAA's National Weather Service, the U.S. Geological Survey (USGS), and the U.S. Army Corps of Engineers (USACE). In addition, several programs such as Cooperative Huntsville Areas Rainfall Measurements (CHARM) and Integrated Flood Observing and Warning System (IFLOWS) provide gauge precipitation data through jointly funded programs between federal agencies and local or state governments. Figure 4 shows the locations of the radars and gauges across the LMRFC domain.

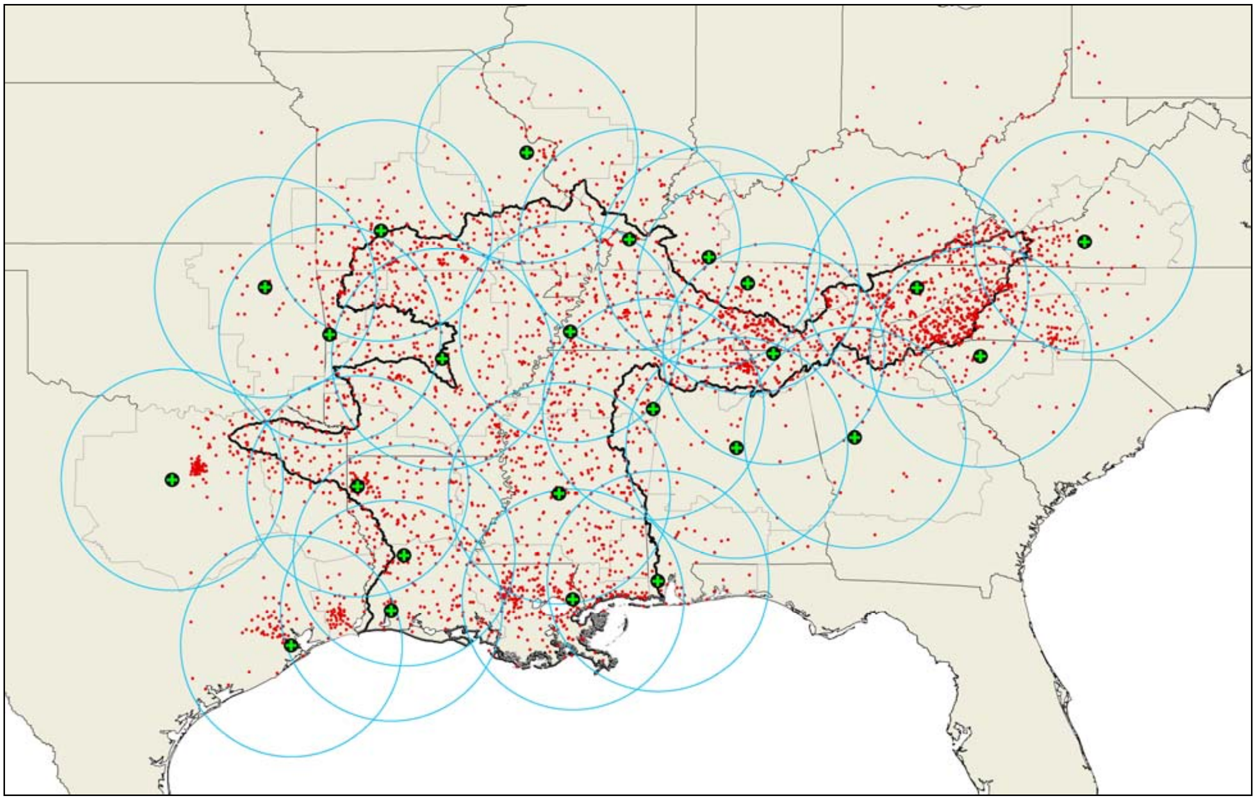


Figure 4. *LMRFC radar sites and gauges. Radars as green crosses, gauges in red. Blue circles represent the 124 km radial extent of the radar.*

3.2.1 Gauge Data

Gauge precipitation data across the LMRFC domain are provided primarily from the USGS and USACE networks. These precipitation datasets come into OFS through the Hydrometeorological Automated Data System (HADS) to the NWS River Forecast System (NWSRFS; http://www.nws.noaa.gov/oh/hrl/nwsrfs/users_manual/htm/xrfsdocpdf.php), the LMRFC hydrologic forecast model. As the data are ingested into NWSRFS, there is an initial data quality control processing performed that checks the data for threshold value exceedance (Table 3).

Table 3. *Automated quality control thresholds from NWSOFS.*

Time Increment	Gauge Precipitation Report Threshold
1 min	5.0 inches
15 min	10.0 inches
30 min	15.0 inches
1 hour	15.0 inches
2-4 hours	15.0 inches
6 hours	20.0 inches
8 hours	30.0 inches
24 hours	30.0 inches
1 week	200 inches
1 month	300 inches
1 year/seasonal	500 inches
Period of record	10000 inches

1) Processing

Gauge precipitation data are ingested as either a cumulative (PC) or incremental (PP) values. PC gauges are reset periodically but, generally, are additive in nature. To determine hourly precipitation amounts from PC gauges, the previous hourly total is subtracted from the new hourly total to produce an hourly precipitation amount. To obtain 24-hour PC gauge totals, the 1200 UTC PC value for the current calendar day is subtracted from the 1200 UTC PC value from the previous calendar day. PP gauges report at each time interval (e.g. 5 minutes, 15 minutes) and the values are additive to produce hourly, 3-hour, 6-hour, 12-hour, and 24-hour totals. Missing values in the PP data are not included in the cumulative total for the multi-hour period and; therefore, the multi-hour sums must be checked for quality. If no precipitation occurred the values may be accepted; however, if precipitation occurred, the multi-hour PP accumulations are removed from the database.

2) Quality Concerns

Precipitation gauges exhibit numerous errors of varying causes, including: gauge malfunctions (e.g. double tipping, transmission errors), clogged/obstructed gauges, delayed reporting from frozen/freezing precipitation, delayed reports from large reporting intervals of 0.04 or 0.10 inches, spurious errors as a result of gauge siting, suspect light precipitation reports in regions of fog/mist, and under-reporting by gauges during intense rainfall or wind, such as during tropical storms.

3.2.2 Radar Data

The LMRFC utilizes radar data from 24 radars across the domain. A primary responsibility of the HAS forecaster is to recognize the limitations of the radar, understand the algorithm computations in MPE, and make the appropriate changes to ensure the highest quality gauge and multi-sensor precipitation grid.

1) Processing

Radar data is received and processed at each of the respective WFOs to produce the Digital Precipitation Array (DPA) product, a radar-estimated precipitation grid based solely on relationships between reflectivity (Z) and rainfall rate (R). These Z-R relationships vary depending on site and seasonality and may be changed at the WFO to represent the current atmospheric conditions or time of year.

The DPA products from the WFOs are ingested at the LMRFC and are subjected to additional calculations through the MPE software. Gauges within a reasonable distance of the radar location are used to compute biases to alleviate potential errors arising from the selected Z-R relationships.

2) Quality Concerns

Inherent radar quality issues such as bright-banding, anomalous propagation, and ground clutter can create unreliable multi-sensor estimates in the hourly MPE grids. In addition, gauges closer to the radar can influence the bias of the entire radar coverage map due to a weighting function in the MPE software. To compute a bias, the radar must have at least four radar-gauge pairs with a minimum gauge report of 0.03”. All of the sites used in the computation must fall within the radar umbrella (see Fig. 4). These types of issues highlight the importance of features within the MPE software, where gauges can be set to missing before running the bias computation program and Fieldgen (see Sect. 3.2.3), can be run to correct such errors by recalculating biases. In addition, MPE allows scaling of regional precipitation in isolated areas associated with radar-specific errors, such as bright-banding.

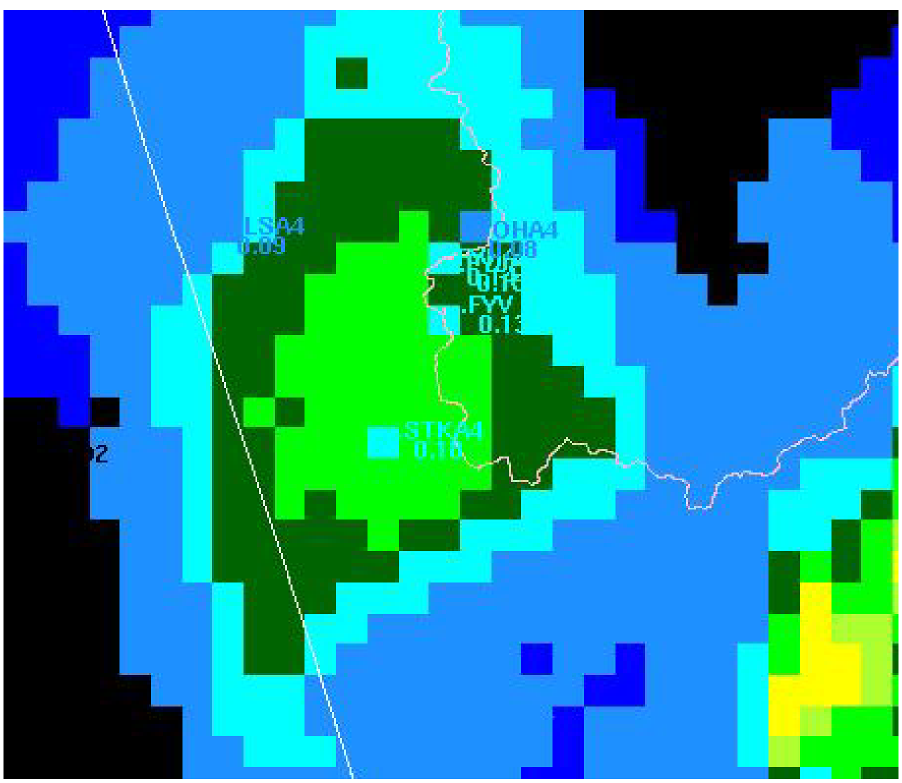


Figure 5. *Example of brightbanding. Precipitation estimates from MPE are significantly higher than corresponding gauge measurements. It is determined that the radar is measuring high reflectivity due to snowmelt aloft, which is causing precipitation overestimation. As a result, gauge reports beneath this area of brightbanding are not considered erroneous and would not be recorded in the LOUZIE spreadsheet.*

Radar precipitation estimates can exhibit other errors as well. Conversion of radar reflectivity to rainfall rate is determined using a set of Z-R relationships as described above. These relationships have been developed to best represent particular atmospheric conditions. In the vicinity of frontal zones and low pressure systems, a single radar site can be experiencing both stratiform and convective rainfall simultaneously. This limitation can lead to over- and under-estimation of precipitation by the Z-R calculation. Related to the Z-R relationship is another possible source of error in radar estimates, brightbanding. Brightbanding occurs in radars as the beam of the radar intercepts the freezing level. Frozen and or freezing hydrometeors reflect a greater amount of energy back to the radar leading to over-estimates in the actual precipitation amounts reaching the ground (see Fig. 5). Anomalous propagation and ground clutter can also produce erroneous precipitation estimates in regions where other objects are reflecting energy back to the radar in regions where no precipitation is occurring. This is particularly significant in the early morning hours during the winter months when surface temperature inversions create enhanced refraction of the radar beam.

3.2.3 Operational Quality Control

At the LMRFC, several tools are used to assist in the quality control of hourly and 24-hour precipitation totals. The LMRFC has standard operating procedures to ensure thorough quality control of both the multi-sensor estimates and gauge-only precipitation data through the day. The following section describes the procedures and software used at the LMRFC.

1) Multi-sensor Precipitation Estimator (MPE) Editor

MPE (http://www.nws.noaa.gov/oh/hrl/pps/pps.htm) is a graphical user interface (GUI) that allows operational forecasters to view, edit, and save changes to both the multi-sensor gridded estimates and observed, precipitation gauge data. MPE focuses on estimations of rainfall amounts based on both remotely sensed data (radar, satellite) and "ground truth" observations (rain gauges). The software creates hourly, gridded, multi-sensor precipitation estimates on a 4-km Hydrologic Rainfall Analysis Project (HRAP) grid. The primary inputs to MPE are the gridded Digital Precipitation Array (DPA) products, which provide radar estimates on a 4-kilometer grid, and precipitation gauge data. Satellite-based estimates of precipitation are may also be used but are not a primary source of estimates at the LMRFC due to relatively good radar coverage across the area of responsibility. Using the available gauge observations, a mean field bias adjustment is applied to each available radar as an attempt to account for over- and under-estimation. To generate the multi-sensor precipitation estimate, a bias-adjusted, multi-radar mosaic is created and merged with the gauge observations. The final, quality-controlled, quantitative precipitation estimate (QPE) grid, otherwise known as the 'best-estimate', multi-sensor grid is then used to produce mean areal precipitation (MAPX) time series for use in NWSRFS. Since MAPX values are used by default as input into the hydrologic modeling system at LMRFC, the quality of the gridded precipitation datasets must be high to ensure river forecast accuracy.

As each hourly MPE grid is evaluated, staff working the hydrometeorologist (HAS) shift record questionable or erroneous gauge IDs in a spreadsheet (Fig. 6), along with the flags in Table 4. For each hour a gauge is flagged for possible problems, a record with the first seven fields is created in the spreadsheet. At the end of the 1200UTC to 1200UTC period, the HAS forecaster evaluates each record in the spreadsheet created during the prior 24 hours. This primarily involves: (1) cross-referencing the gauge values with the 24-hour MPE value for the corresponding and neighboring grid cells [using XNAV and/or Contour]; (2) investigating the surrounding precipitation patterns at nearby gauges for consistency [using XNAV and/or Contour]; and, (3) inspecting the decoded SHEF precipitation reports in text form for continuity and anomalous reports [using XDAT]. This process may also require reviewing hourly or multiple-hour MPE values, as well as radar, satellite, surface, topographic, and other data.

1	YEAR	MONTH	DAY	HOUR	ID	FLAG1	FLAG2	FIRST_HAS	LAST_HAS	COMMENTS
2	2006	06	01	00	NANN7	Z	R	ETJ	JSG	
3	2006	06	01	01	MRBN7	Z	R	ETJ	JSG	
4	2006	06	01	01	NANN7	Z	R	ETJ	JSG	
5	2006	06	01	02	ALLA4	L	I	JSG	JSG	

Figure 6. *Screenshot of the LOUZIE spreadsheet from June 2006.*

Table 4. *Fields in the LOUZIE spreadsheet.*

Field	Description
Year	Year of the potentially erroneous report
Month	Month of the potentially erroneous report
Day	Day of the potentially erroneous report
Hour	Hour of the potentially erroneous report
Flag1	L, O, U, Z, E - identification flag indicating the type of gauge error suspected or observed
Flag2	I, R - treatment flag indicating the non-removal/removal of the gauge report from the database
HAS1	Initials for the staff member that creates the record and completes the Flag1 field
HAS2	Initials for the staff member that completes the Flag2 field and removes, ignores, or modifies the precipitation database
Comments	Code for the type of error exhibited by the gauge (subjectively assigned by the forecast staff.

While assessing the quality of each gauge report, the staff accounts for multiple MPE and gauge shortcomings (see Sections 3.2.1 and 3.2.2). Precipitation gauge reports are not expected to exactly match the MPE grid cell values. Instead, the goal is to conclude whether or not the errors observed on the hourly scale result in "unreasonable" accumulated gauge values. For example, obstructed gauges may report related precipitation after the event occurs. The timing of the precipitation may be incorrect; however, the gauge reports all the precipitation within the 1200 UTC to 1200 UTC time frame. While errors abound on the hourly or sub-hourly scale, the 24-hour accumulated value may be within an acceptable margin of error and deemed "reasonable" after proceeding through the consistency checks using XNAV, XDAT, and Contour.

The above circumstance has different impacts on the quality control of PP vs. PC gauge data. First, consider the PP physical element. When the 24-hour total precipitation value is determined to be "reasonable", the gauge's 24-hour reports (e.g., 2001, 5004) are "ignored" and given the treatment flag 'I'. Reports representing the 3-, 6-, and 12-hour accumulations (e.g., 1003, 1006) that are unaffected by poor hourly reports are also "ignored". Only the erroneous hourly (e.g., 1001), sub-hourly (i.e., 15), and affected 3-, 6-, and 12-hour accumulations are set to missing or otherwise modified to reflect the proper rainfall accumulation. Obviously, "unreasonable" 24-hour reports are not ignored and are appropriately set to missing or otherwise modified as well. All erroneous reports are given the treatment flag 'R' in the LOUZIE spreadsheet. Second, consider the PC physical element. In the case of the obstructed gauge described above, the gauge's hourly values are "ignored" to preserve legitimate accumulations of the hourly reports. On the other hand, "unreasonable" accumulations of the hourly reports result in setting each hourly and sub-hourly report in the 24-hour period to missing.

In addition, while reviewing 24-hour gauge and MPE values, the LMRFC staff evaluates the quality of gauges from cooperative and other observers that do not occur on the hourly scale and, thus, do not influence hourly MPE grids. When erroneous reports from these sources are recorded in the LOUZIE spreadsheet, the hourly field is set to "99".

For the 'Comments' section in the LOUZIE spreadsheet (Fig. 7), either the HAS1 or HAS2 forecaster may enter a number code to subjectively describe the type of error observed in the gauge report. The identification of the reasoning behind the report may highlight the specific problem associated with individual gauges. The addition of the 'Comments' section to the LOUZIE program and spreadsheet in June 2006 marked the last update prior to operational implementation at the LMRFC.

LOUZIE COMMENT CODES

0	*Reporting All Zeroes* *Typical Code(s): Z*	*The gauge is located in a region of precipitation and fails to report precipitation, thereby reporting all zeroes. The gauge may either be clogged or missing.*
1	Precipitation in period *Typical Code(s): L*	Precipitation falls at a gauge early (late) in the 12Z-12Z period and drips followed (preceded) the majority of the rainfall.
2	*Fog/Mist?* *Typical Code(s): L*	*Gauges report light amounts when high, levels of near-surface moisture exist (fog/mist). Typical offending gauges are ASOS.*
3	Dripping Gauge *Typical Code(s): L*	Often, gauges are partially obstructed or the rainfall rate is beyond the capacity of the gauge. Continued light precipitation readings following the main precipitation event. Snowmelt can also qualify as a dripping gauge.
4	*Multiple Day/Weekend Report* *Typical Code(s): E or O*	*COOP sites often report precipitation sporadically. These reports are often multi-day reports following a weekend.*
5	Malfunction *Typical Code(s): E*	Equipment malfunctions are self-explanatory. Usually associated with large, spurious precipitation values
6	*Periodic Up/Downward Adjustment of Gauge* *Typical Code(s): L or E*	*The gage periodically increases/decreases the accumulated total by a particular amount (usually 0.10", ex. KSOM6). Also, different type sources can be responsible for these fluctuations in values.*
7	Possible Clog/Obstruction to Gauge *Typical Code(s): L, U, or Z*	Gauges that drip for multiple hours following a rainfall event or report zeroes during a significant rainfall event are signals of clogged/obstructed gauges.
8	*Reset Gauge* *Typical Code(s): E*	*Gauges that are reset by a partner agency (USGS/COE) will exhibit large values in regions of lighter or no precipitation.*
9	No Comment/Miscellaneous/Unknown *Typical Code(s): Any Code*	The gauge problem is not known or cannot be identified. Therefore, no comment can be provided.

Note: An additional code 99 is used for gauges which are turned off using the ingest filter in WHFS.

Figure 7. *Comment codes used in the LOUZIE spreadsheet.*

2) XNAV

XNAV (Fig. 8; http://www.nws.noaa.gov/oh/hrl/nwsrfs/users_manual/part6/_pdf/654xnav.pdf) is a graphical program used to display data from the PostgreSQL database, gridded data in XMRG format (e.g., hourly MPE grids), point and area data in the Operational Forecast System (OFS), and spatial data in a text file format. XNAV can also be used to plot precipitation gauge accumulations over MPE estimates. Zero and multiple day rain gauge reports are often identified using XNAV, particularly when comparing 24-hour MPE and gauge-only totals at 1200 UTC.

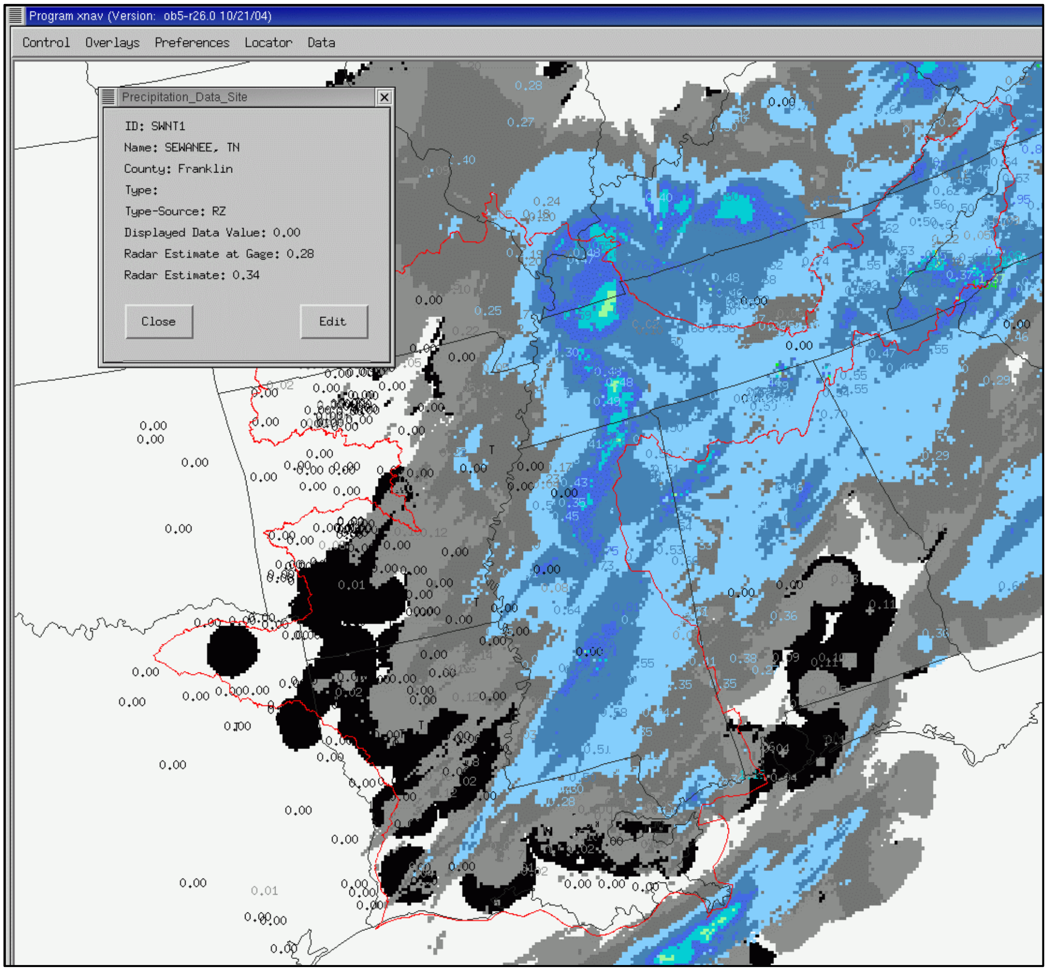


Figure 8. *Screenshot of the XNAV software with 24-hour accumulated MPE displayed along with gauge reports. Color scale for gauge values and radar estimates are identical.*

3) Contour

Contour (Fig. 9; http://www.srh.noaa.gov/lmrfc) is a graphical program developed by the LMRFC in ESRI ArcView for editing PC and PP precipitation reports that are used to generate the HYDORN and Contour Analysis products. The HYDORN product provides a listing of 24-hour precipitation accumulations for select gauges across the LMRFC domain. The program allows the user to interactively edit the data, while simultaneously viewing the gridded 24-hour MPE data. Toggle switches within the Contour software allow the forecaster to identify zero and light gauges within the areas of precipitation. Once quality control is complete, a spatial analysis of the gage-only data is generated for 1-, 3-, 5-, and 7-day precipitation totals.

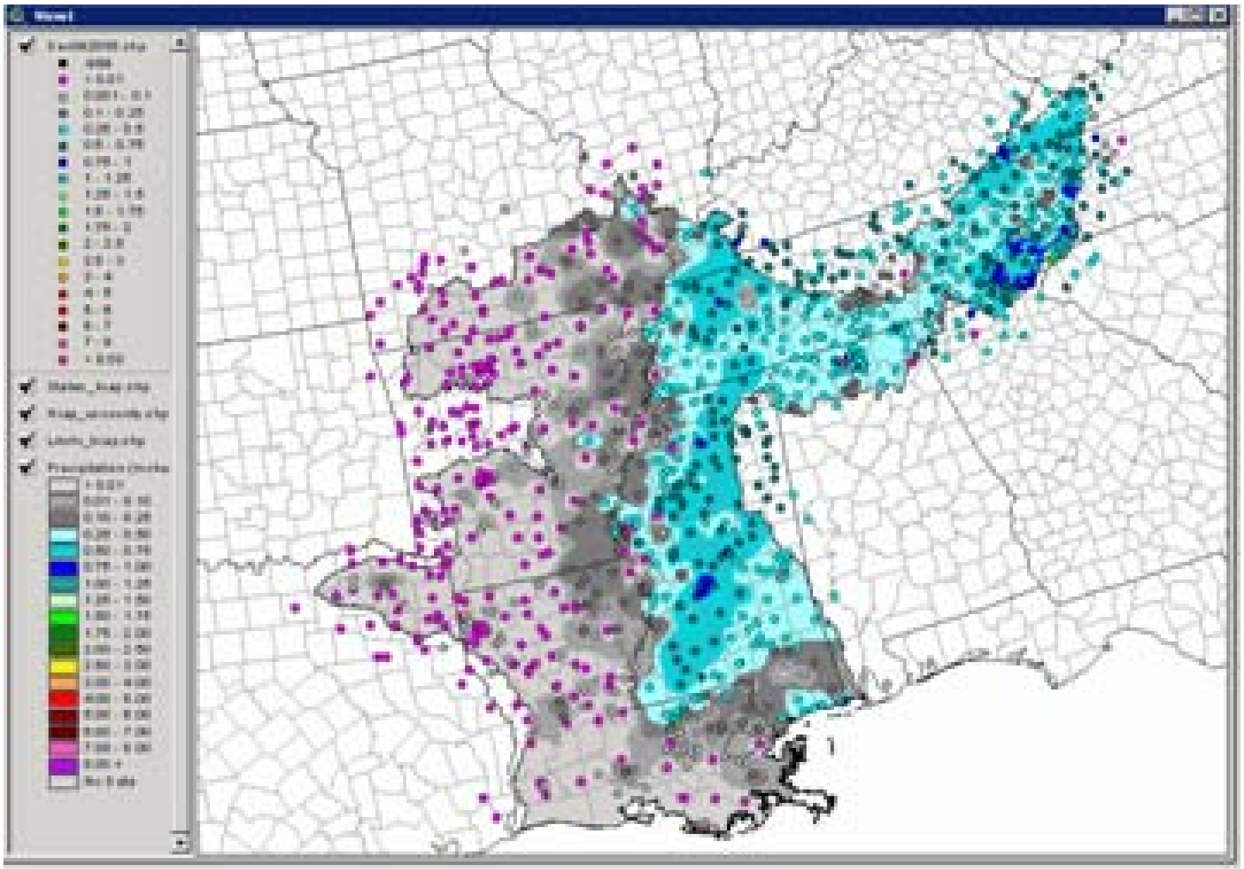


Figure 9. *Screenshot of the Contour program with 24-hour accumulated gauge analysis along with gauge reports.*

4) XDAT

XDAT (Fig. 10; http://www.nws.noaa.gov/oh/hrl/nwsrfs/users_manual/part6/_pdf/654xdat.pdf) is a graphical program used to display, insert, edit, save, and print Standard Hydrologic Exchange Format (SHEF) data from the PostgreSQL hydrologic database. Once gauge data is identified as potentially erroneous in the LOUZIE spreadsheet, XDAT is utilized to investigate the hourly and 24-hour precipitation values for the site before making the decision to remove the data from the database. When available, METAR reports are consulted for verification. PP values are generally removed for a specific hour and multiple hour values are adjusted or removed to reflect the new totals. PC values are removed for the entire 24-hour period if the data is not representative of the actual totals.

Each day, the HAS shifts are denoted as H1, H2, and H3, for the first, second, and third shifts, respectively. For the LOUZIE program, the H1 forecaster must examine the prior day's hourly and 24-hour data (1200 UTC-1200 UTC) for R or I treatment flag designation. Based on the decision to remove or ignore the suspect report, the H1 forecaster then edits the precipitation database using XDAT as required. Quality control and data entry in the LOUZIE spreadsheet continues through 1400 LST. The H2 and H3 forecasters continue the quality control and data entry into the LOUZIE spreadsheets through 2200 LST and 0600 LST, respectively, but do not have the responsibility of adding the treatment flags. Each shift is responsible for removing gauges with spurious errors that impact radar biases in the MPE software or that would greatly impact the computation of MAP in NWSRFS.

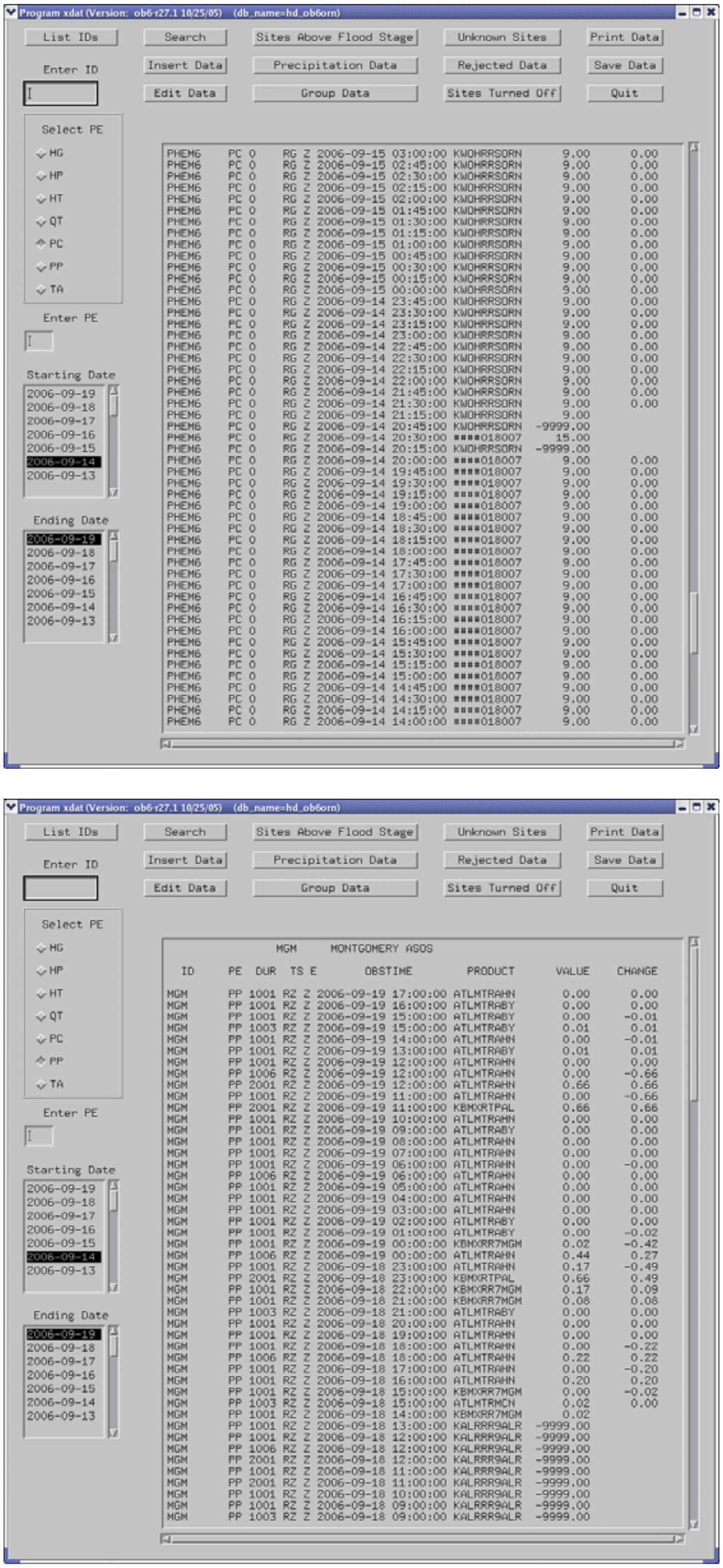


Figure 10. *Screenshot of the XDAT software examples of PC (top) and PP (bottom) gauge data displayed.*

3.2.4 Examples from MPE Software

1) Light Reports (L)

Light precipitation reports occur when a gauge reports hourly precipitation less than or equal to 0.10” in a region of no precipitation (Fig. 11).

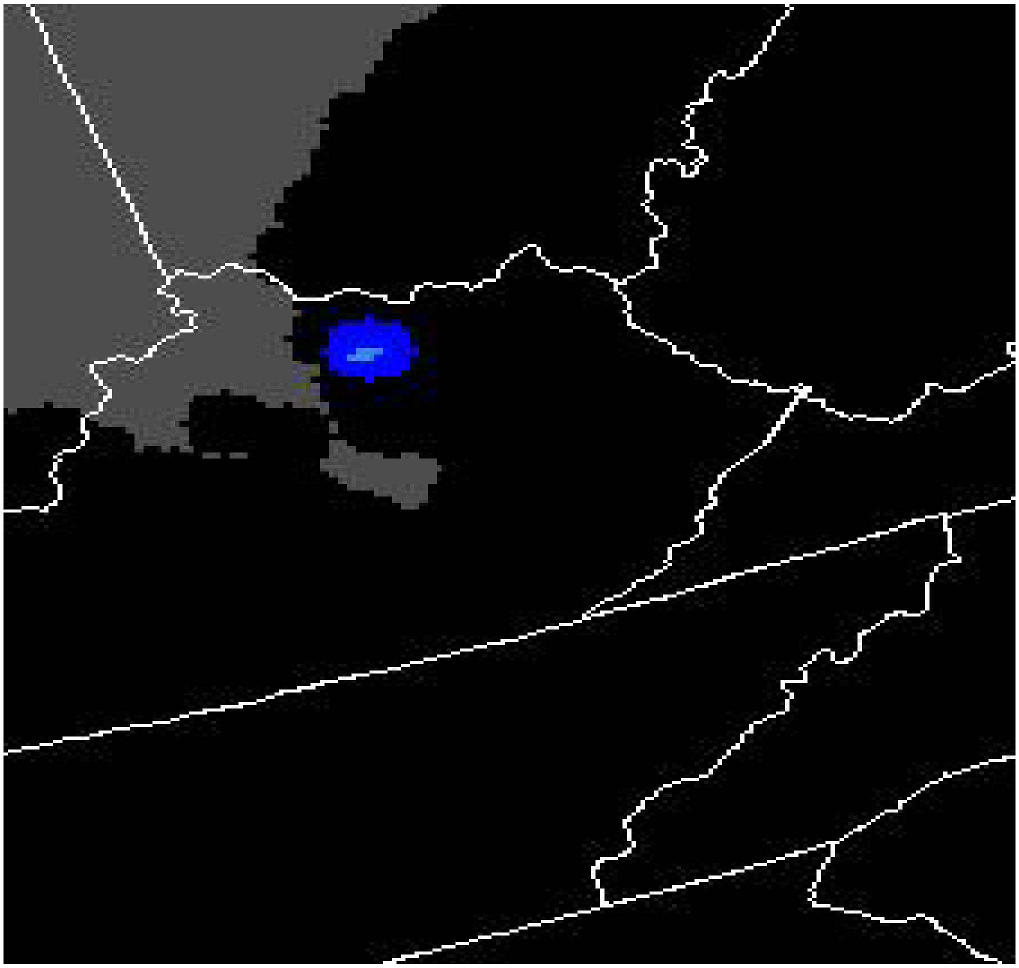


Figure 11. *Example of an L report. No precipitation is observed on radar in the region of thegauge report of 0.01” in the MPE hourly grid at 1000 UTC. Color scale for gauge values and radar estimates are identical.*

2) Over-estimated Report (O)

Over-estimated reports occur when a gauge unreasonably reports more precipitation during a given hour than either MPE or surrounding gauges. Precipitation must be occurring at the site of the gauge.

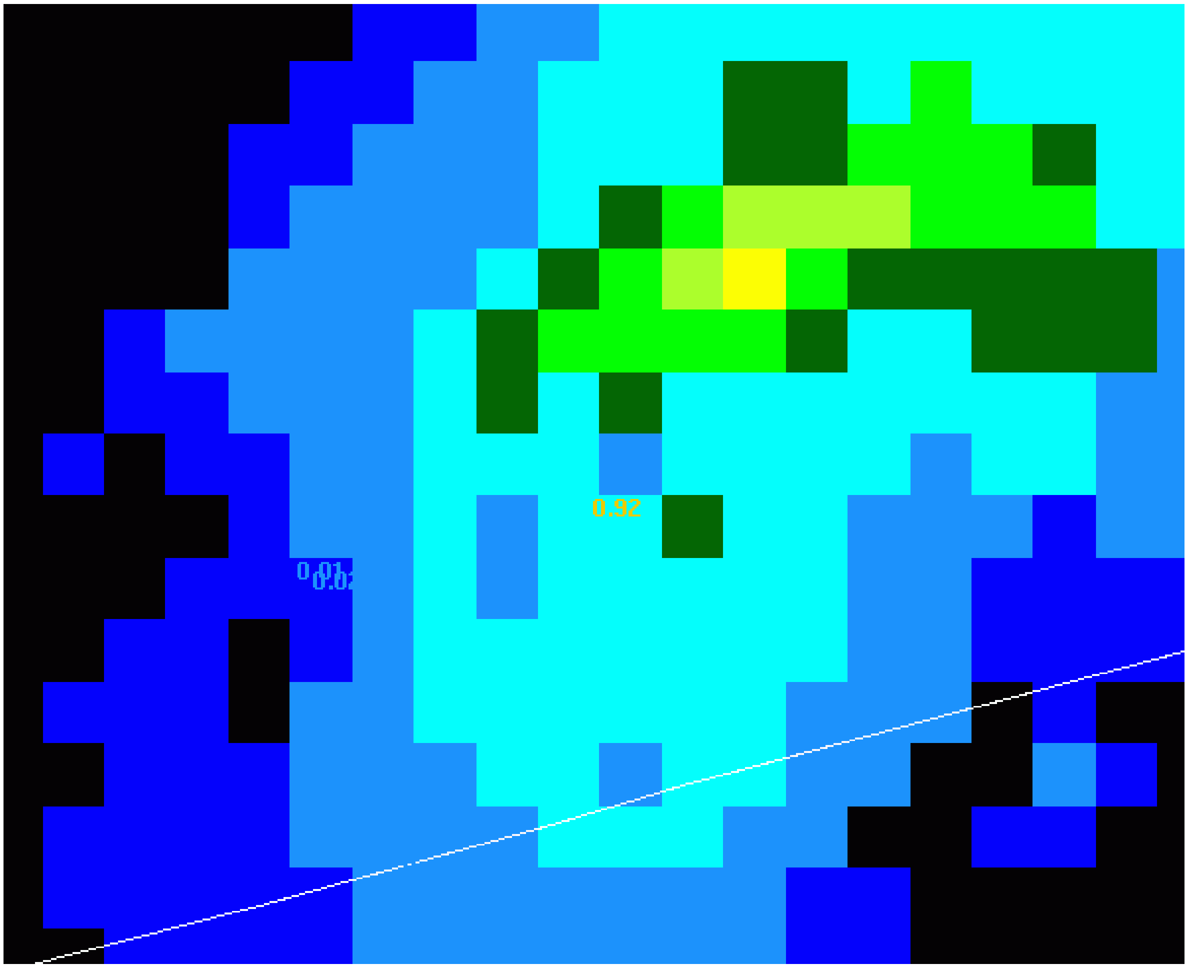


Figure 12. *Example of an O report. The gauge is reporting an hourly precipitation amount of 0.92". Surrounding gauge reports and radar estimates support lower hourly accumulations. Color scale for gauge values and radar estimates are identical.*

3) Under-estimated Report (U)

Under-estimated reports occur when a gauge unreasonably reports less precipitation during a given hour than either MPE or surrounding gauges.

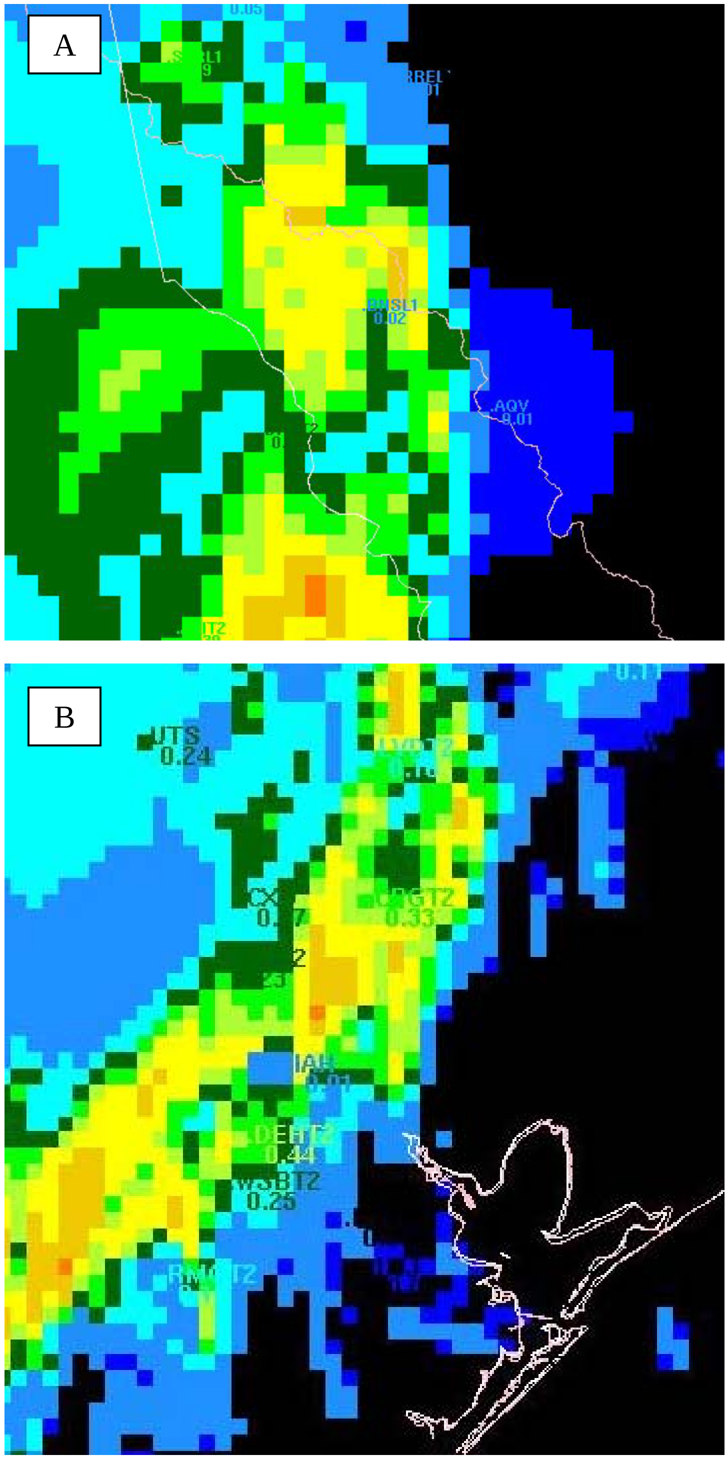


Figure 13. *Examples of a U report. (a) The gauge BNSL1 is reporting an hourly precipitation amount of 0.02". Surrounding gauges and radar estimates support higher hourly accumulations. (b) Same as (a) but for gauge IAH with an hourly precipitation amount of 0.01". Color scale for gauge values and radar estimates are identical.*

4) Zero Report (Z)

Zero reports occur when a gauge reports zero precipitation during a given hour when MPE or surrounding gauge reports suggest that precipitation occurred.

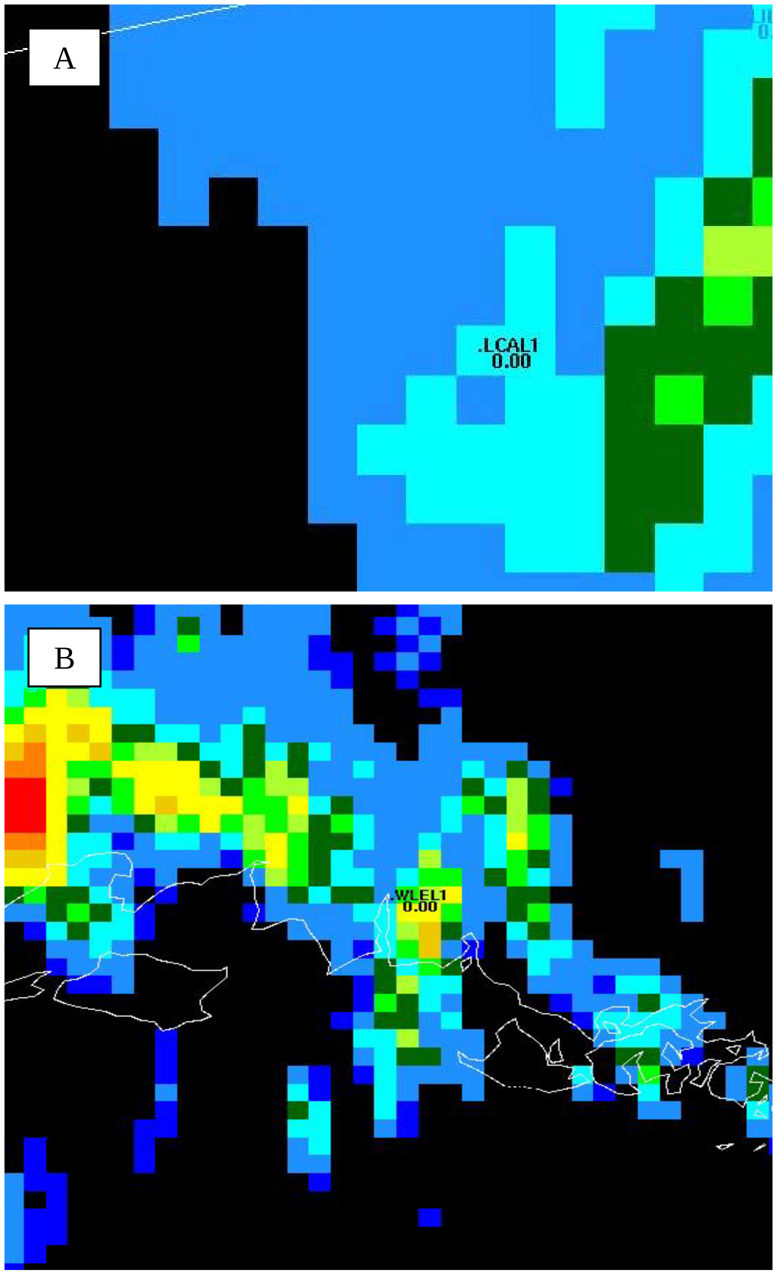


Figure 14. *Examples of a Z report. (a) The gauge LCAL1 is reporting an hourly precipitation amount of 0.00". Surrounding gauges and radar estimates support at least light precipitation in the region. (b) Same as (a) but for gauge WLEL1 in a region of heavier precipitation. Color scale for gauge values and radar estimates are identical.*

5) Extreme Report (E)

Extreme reports occur when a gauge reports greater than 0.10" of precipitation during a given hour and MPE or surrounding gauge reports suggest no precipitation occurred. No precipitation is occurring at the gauge site.

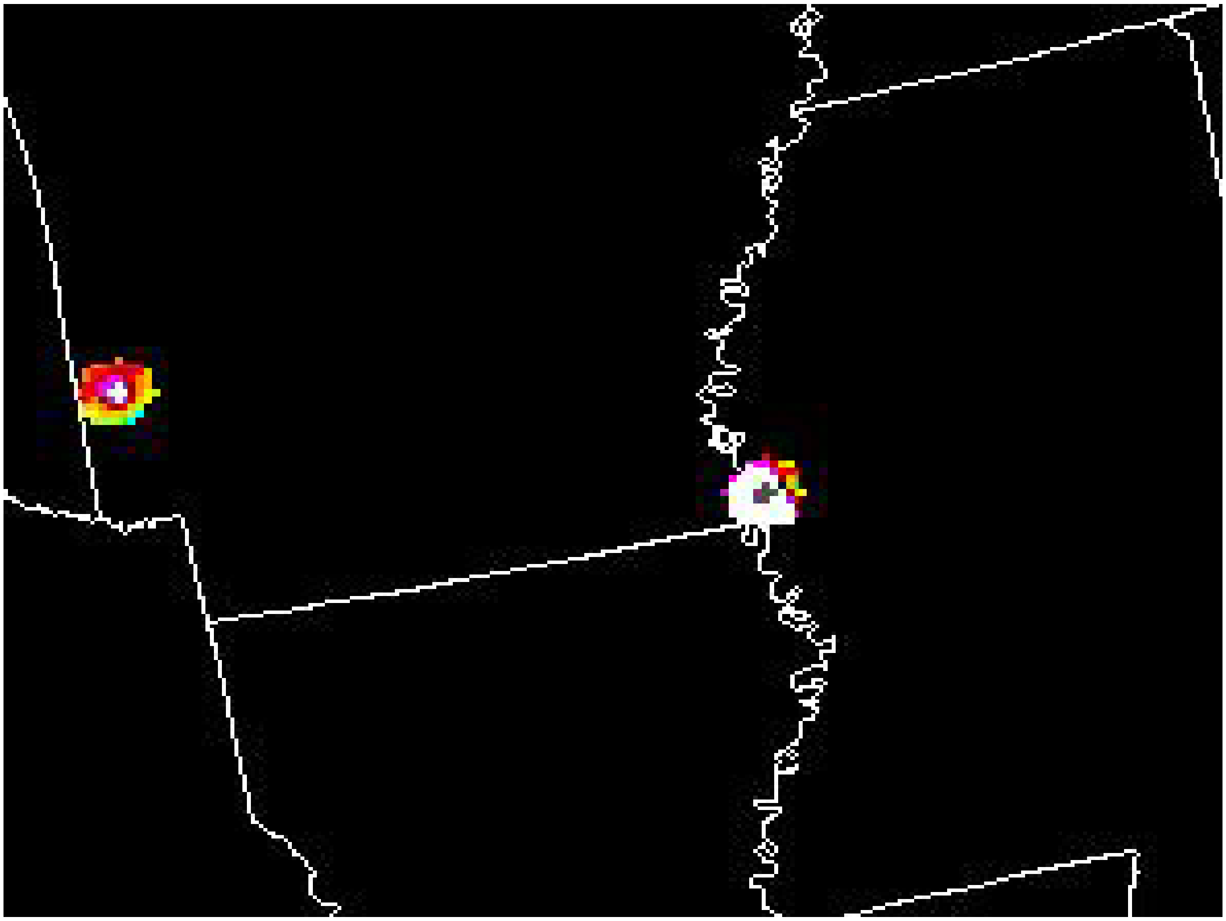


Figure 15. *Example of an E report. No precipitation is observed on radar in the regions of the extreme gauge reports (each over 10.00") in the MPE hourly grid. If the extreme gauge had occurred in a region of precipitation, the radar bias would be greatly impacted and the MPE data for that hour within the radar coverage would require correction. Color scale for gauge values and radar estimates are identical.*

3.2.5 Monthly Summary Files

Each month, the LMRFC produces summary files from the LOUZIE spreadsheet by converting the monthly file to a database file. Perl scripts are used to extract quality control information from the database by gauge and exports the summary in text format to distribute to the Service Hydrologists and/or Hydrologic Focal Points at each of the WFOs. Each monthly summary file (MSF) is specific to the WFO's hydrologic service area (HSA) and includes statistics for a single month (Fig. 16). Besides the HSA ID, the total number of gauges with at least one record in the LOUZIE spreadsheet is listed. Separate MSFs are provided for gauges with treatment flags of 'R' and 'I'. While the 'R' MSFs provide information on the gauges deemed as having the most blatant errors, the 'I' MSFs are also significant in that they may identify gauges with reasonable 24-hour totals but problematic hourly measurements (e.g., obstructed gauges). Figure 16 is an example of an 'R' report and an evaluation of several fields.

A separate spreadsheet is maintained for gauges that have been flagged a repeated number of times each month for several consecutive months and are determined to be of poor overall quality (Fig. 17). These gauges are excluded from ingest into the WHFS database by using the Hydrobase software ingest filter toggle. This toggle allows the forecasters to allow/disallow the data from being included in the calculation of multi-sensor estimates and the generation of hydrologic forecasts in the NWSRFS software. The "99" comment code is used in the monthly LOUZIE spreadsheet to denote gauges that have been turned off using Hydrobase.

```
(1)    Unk 60
       --------------------------------------------------------------
       ID    NAME                              L   O   U   Z   E TOTAL
       _____ _______________________________ ___ ___ ___ ___ ___ _____
       AUSG1 SWEETWATER CK/AUSTELL             1   0   0   0   0     1
       BBUL1 BLACK BAYOU                       4   1   2   3   0    10
(2)    BBYL1 BLACK BAYOU LAKE NR MONROE        1   1   2   4   1     9
       BCCM7 ANDERSON                          1   0   0   0   0     1
       BLDA1 BANKHEAD L/D                      2   0   1   2   0     5
       BMCV2 GATE CITY IFLOW                   2   0   0   0   0     2
       BNRI2 BEAN RIDGE RAWS, IL               1   0   0   0   0     1
       BOOK2 BOONEVILLE, KY                    1   0   0   0   2     3
(3)    BSGM7 PINEVILLE                         0   0   0   0   1     1
       CHKN7 CHEROKEE RAWS                     1   0   0   0   0     1
       CNNG1 ETOWAH/CANTON                     2   1   0   0   1     4
       CRKA4 CLARKSVILLE, AR                   2   0   0   0   0     2
       CTVG1 ETOWAH RIVER/CARTERSVILLE         0   0   0   0   1     1
       CWAN7 COWANS FORD DAM IFLOWS            1   0   0   0   0     1
       DCNG1 DUNCAN BRIDGE, GA                 2   0   0   0   1     3
       DEYT2 DIME BOX, TX                      2   0   0   0   1     3
(4)    DLDA1 DEMOPOLIS L&D, AL                 1   0   0  15   0    16
       DWSG1 ETOWAH/DAWSONVILLE                3   0   0   0   0     3
       .
       .
       .
```

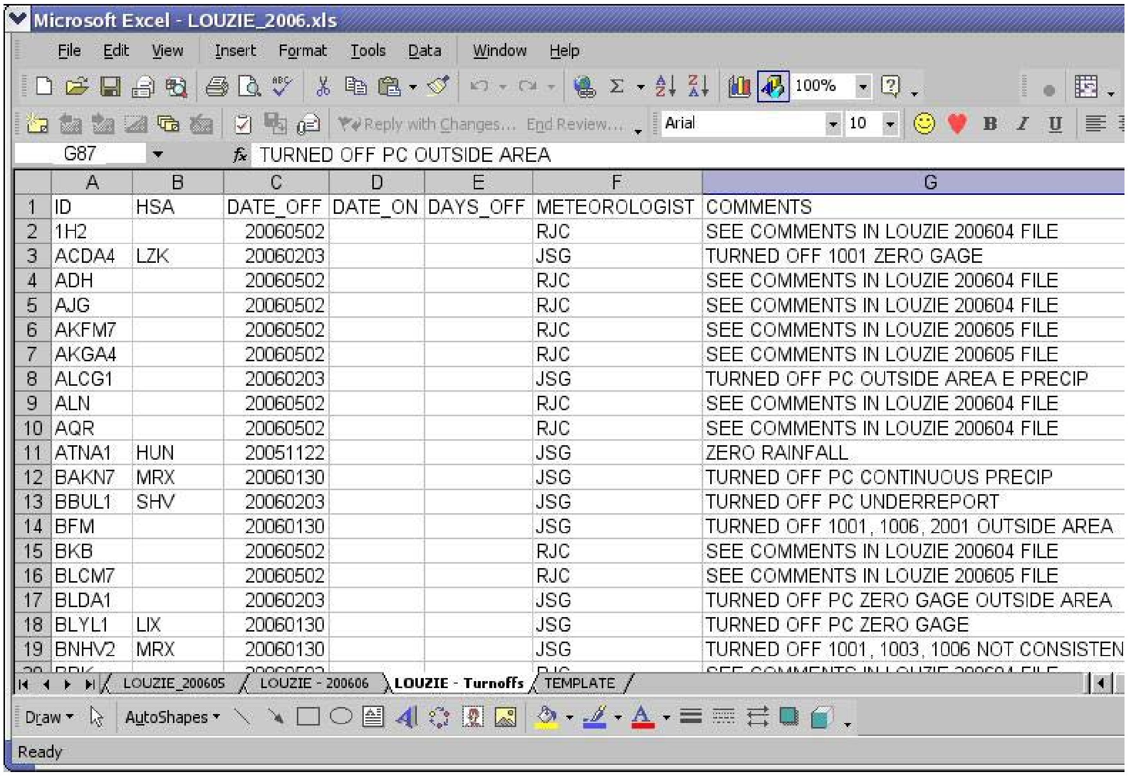
(1) Notice the HSA = "Unk". Not all gauges have a defined HSA at this time. This report would be provided to all WFOs to gather the proper HSA information for correction in the LMRFC databases. The number 60 represents the number of gauges that had at least one hourly or accumulation report that required modification (Flag2 = "R").

(2) BBYL1 experienced a variety of issues during the month. Nine reports were considered questionable, and the majority of the records involved significant over- or under-estimation. This is probably a gauge worth monitoring more closely for potential malfunctioning.

(3) BSGM7 likely experienced a gauge reset at one point during the month. At this time, there is little reason to question the operation of this gauge.

(4) DLDA1 likely experienced significant malfunctions or obstructions for multiple events during the month of January. This is a gauge that may be worth investigating.

Figure 16. *Example of a monthly summary report provided to the WFOs.*



	A	B	C	D	E	F	G
1	ID	HSA	DATE_OFF	DATE_ON	DAYS_OFF	METEOROLOGIST	COMMENTS
2	1H2		20060502			RJC	SEE COMMENTS IN LOUZIE 200604 FILE
3	ACDA4	LZK	20060203			JSG	TURNED OFF 1001 ZERO GAGE
4	ADH		20060502			RJC	SEE COMMENTS IN LOUZIE 200604 FILE
5	AJG		20060502			RJC	SEE COMMENTS IN LOUZIE 200604 FILE
6	AKFM7		20060502			RJC	SEE COMMENTS IN LOUZIE 200605 FILE
7	AKGA4		20060502			RJC	SEE COMMENTS IN LOUZIE 200605 FILE
8	ALCG1		20060203			JSG	TURNED OFF PC OUTSIDE AREA E PRECIP
9	ALN		20060502			RJC	SEE COMMENTS IN LOUZIE 200604 FILE
10	AQR		20060502			RJC	SEE COMMENTS IN LOUZIE 200604 FILE
11	ATNA1	HUN	20051122			JSG	ZERO RAINFALL
12	BAKN7	MRX	20060130			JSG	TURNED OFF PC CONTINUOUS PRECIP
13	BBUL1	SHV	20060203			JSG	TURNED OFF PC UNDERREPORT
14	BFM		20060130			JSG	TURNED OFF 1001, 1006, 2001 OUTSIDE AREA
15	BKB		20060502			RJC	SEE COMMENTS IN LOUZIE 200604 FILE
16	BLCM7		20060502			RJC	SEE COMMENTS IN LOUZIE 200605 FILE
17	BLDA1		20060203			JSG	TURNED OFF PC ZERO GAGE OUTSIDE AREA
18	BLYL1	LIX	20060130			JSG	TURNED OFF PC ZERO GAGE
19	BNHV2	MRX	20060130			JSG	TURNED OFF 1001, 1003, 1006 NOT CONSISTEN

Figure 17. *Example of the gauges turned off using the WHFS ingest filter.*

During the first three months of the operational LOUZIE program (July-September 2006), the LMRFC received substantial feedback from the WFOs. Updates to over 80 gauge sites for name changes and HSA/WFO corrections were made to the WHFS database. Over 50 sites were turned on/off using the WHFS ingest filter based on gauge quality, maintenance, and repairs. As a result of the LOUZIE program, the number of gauge reports each month decreased significantly (Fig. 18) during the period from 491 in July to 311 in September. The number of reports was normalized using the average precipitation in each HSA to ensure a more accurate performance metric for the LOUZIE program; wet months, inherently, should have more erroneous gauge reports than dry months.

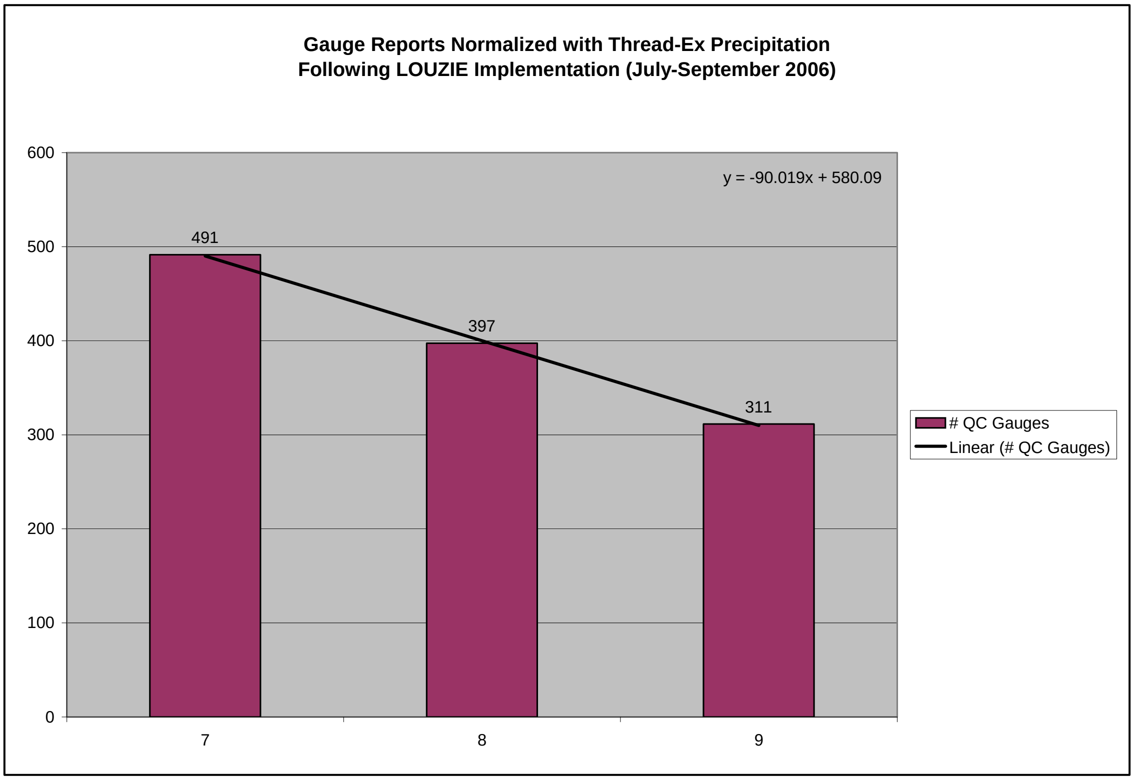


Figure 18. *Normalized gauge reports during the first three months of the operational LOUZIE program.*

Most importantly, 10 of the 18 WFOs across the LMRFC domain were already active participants in the program, providing monthly feedback and guidance for decision-making at the operational level. The WFO input is invaluable to the LOUZIE program, particularly since many WFOs have region-specific knowledge on the gauges, the observers, the gauge owners, and the meteorology/climatology in their HSA.

4. SUMMARY AND CONCLUSIONS

The LOUZIE program was designed to improve the quality of both gauge and radar-estimated precipitation datasets at the LMRFC. By entering reports of suspect gauges into a centralized spreadsheet, the quality and consistency of gauge datasets can be monitored closely. These reports are made by comparing the radar and gauge precipitation datasets using several software packages – most notably MPE Editor, XNAV, Contour, and XDAT. At the end of each monthly cycle, the spreadsheet is saved and Perl scripts are used to export text summary files for the WFOs. In turn, the gauge owners and operators are notified to properly maintain the poor-quality gauges. Through this operational quality control procedure, collaboration and communication is improved. The survey provided to the WFOs shows evidence of this collaboration and provides additional areas for improvement.

Recommendations to improve the LOUZIE project, based on the WFO survey, are listed below:

- Generate feedback on poor quality gauges at more regular intervals than monthly.
- Include comment codes within the text reports to identify the types of errors exhibited by the gauges.
- Provide training to the WFOs and gauge owners/operators on the LOUZIE project.
- List the gauge owner/operator within the text reports for contact purposes.
- Serve the data through the intranet or internet.
- Coordinate with other RFCs to expand LOUZIE to a continental US scope.
- Engage with real-time data provider, namely, the Office of Hydrologic Development HADS program

5. ACKNOWLEDGMENTS

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6. DATA PROCESSING SOFTWARE

ArcView v. 3.0, developed and licensed by ESRI, Redlands, California, http://www.esri.com/

Contour Instructions, 2009. National Weather Service Lower Mississippi River Forecast Center. http://www.srh.noaa.gov/lmrfc/

MPE Editor Users Guide, Build 9.0, 2008. National Weather Service Office of Hydrologic Development. http://www.nws.noaa.gov/oh/

Paul, James, XDAT Documentation, 1999. http://www.nws.noaa.gov/oh/hrl/nwsrfs/users_manual/part6/_pdf/654xdat.pdf

Paul, J. and B. Lawrence, XNAV Documentation, 1999. http://www.nws.noaa.gov/oh/hrl/nwsrfs/ users_manual/part6/_pdf/654xnav.pdf

APPENDIX A. LOUZIE SURVEY AND SELECTED RESPONSES

LOUZIE QUESTIONNAIRE

FOR SERVICE HYDROLOGISTS

(responses in red)

1) The LOUZIE Summary files provide each WFO with a list of potentially problematic gauges in each HSA. Please rate the usefulness of this product. Use the scale of 1-10 with 1 being of no use and 10 being extremely useful.
   -Scores ranged from 5 to 10 with an average of 7.5

2) Please describe how you use the LOUZIE reports. List any threshold values for the number of reports that you use to denote significant issues/maintenance requirements?
   -Identify clogged gauges, contact USGS/USACE for maintenance, provides opportunity to show appreciation to gauge owners
   -Double digit numbers used for L reports, >3 for Z and E reports
   -Excellent for quality control, much more difficult without LOUZIE reports

3) Do you utilize the data as an opportunity to verify gauge names, CWA, HSA, or other gauge characteristics? If so, which ones?
   -Checks for the proper service area, warning area, and gauge name completed by 2/3 of respondents

4) Please evaluate the clarity of the product. Use the scale of 1-10 with 1 being complicated and 10 being easy to understand.
   -Scores ranged from 5 to 10 with an average of 7.4

5) Please evaluate the timeliness of the product. Is monthly preparation of these products sufficient?
   -Monthly time-step for receiving the products is sufficient with suggestions to update more frequently for problematic gauges

6) If the LMRFC offered access to the data online, would you use the summary files more or less often than you do now? Is the email format appropriate for your needs?
   -Additional access through the intranet or internet may be helpful; however, email method provides a 'trigger' for doing the quality control regularly

7) Would comments be useful information to have for identifying problem gauges from the lists? For example, comment codes may include "possible obstruction/clogged gauge", "equipment malfunction", and "fog/mist".
   -Comments would be helpful but, generally, investigating the data reveals the problem at each gauge
   -Results indicate the request for codes/no codes is about 50/50

8) Please provide any comments/suggestions/feedback on the LOUZIE program that you feel will guide us in the direction of making a product best suited for hydrologic operations at the WFO.
   -Internal method for distribution
   -Add a column with the gauge owner
   -Requests for training
   -Excellent systematic process for providing the weather offices feedback