TWDB Report

Improving the Hydrologic Ensemble Forecast Service model of the Little River Basin to facilitate assessment of Forecast-Informed Reservoir Operation

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Final Report: A model-based Investigation of Streamflow Trends in Upper Brazos River Basin

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List of Acronyms

AORC	Analysis of Record for Calibration
BLNT2	Belton Lake
BS	Brier Score
BSS	Brier Skill Score
CBPR	Conditional Bias Penalizing Regression
CDF	Cumulative Density Function
CRPS	Continuously Ranked Probability Score
CRPSS	Continuously Ranked Probability Skill Score
CSGD	Censored-Shifted Gamma Distribution
EnsPost	Ensemble Postprocessor
FIRO	Forecast-Informed Reservoir Operation
GEFS	Global Ensemble Forecast System
GGLT2	Georgetown Lake
GNGT2	Granger Lake
HEFS	Hydrologic Ensemble Forecast Service
KGE	King-Gupta Efficiency
LRS	Little River System
MAE	Mean absolute error
MEFP	Meteorological Ensemble Forcing Processor
MMGD	Mixed Meta-Gaussian Distribution
MPE	Multisensor Precipitation Estimates
NSE	Nash-Sutcliffe Efficiency
NWS	National Weather Service
OWP	Office of Water Prediction
PBIAS	Percentage Bias
PQPF	Probabilistic Quantitative Precipitation Forecasts
QPF	Quantitative Precipitation Forecasts
ROC	Receiver Operating Characteristic
SAC-SMA	Sacramento Soil Moisture Accounting
STIT2	Lake Stillhouse Hollow
USACE	United States Army Corps of Engineers
USACE-SWF	United States Army Corps of Engineers - Fort Worth District
USGS	US Geological Survey
UTA	University of Texas at Arlington
WGRFC	West Gulf River Forecast Center

Executive Summary

The Texas Forecast-Informed Reservoir Operations (FIRO) Pilot was launched in 2022 as a collaborative effort among academia, federal and state agencies. Through the first phase of the project, the project team led by UT Arlington's Hydrometeorology Research Group evaluated the forecasts and simulations from the National Weather Service (NWS) West Gulf River Forecast Center (WGRFC)'s operational models at forecast points in the Texas FIRO Pilot. The team found appreciably negative biases in the forecasts/simulations for high flow events that can be traced to inadequate calibration of the hydrologic model (Sacramento Soil Moisture Accounting, or SAC-SMA), and to biases in the postprocessed precipitation forecasts in the Hydrologic Ensemble Forecast Service (HEFS).

As a result of the findings, the team undertook a project sponsored by the Texas Water Development Board (TWDB) to improve the calibration of the SAC-SMA for larger events, fill gaps in the earlier calibration, correct errors in the reservoir model used in the WGRFC operational system, and assess an enhanced postprocessing scheme for producing probabilistic precipitation forecasts. This project is in line with previous flood model calibration projects funded by the TWDB, including previous work in the Little River Basin (Lynker 2022). Results from this project will improve flood forecasting in the Little River Basin specifically and, more generally, provide insights for improving flood forecasting in basins with large reservoirs across the state.

The project comprises the following four major tasks:

Task 1: Adjust SAC-SMA parameters for selected forecast points in the Little River System (LRS) to address negative biases in HESF forecasts.

Task 2: Update/correct reservoir model configurations for four pilot reservoirs in the LRS.

Task 3: Produce HEFS hindcasts by integrating enhancements from Tasks 1 and 2; and perform evaluation of the resulting hindcasts.

Task 4: Evaluate conditional biases in raw and postprocessed quantitative precipitation forecasts (QPFs) and experiment with the Conditional Bias Penalizing Regression (CBPR).

The project team completed calibration of SAC-SMA at three forecast points upstream of Lake Belton and Lake Stillhouse Hollow using observations at United States Geological Survey (USGS), and for four ungauged, intermediate watersheds draining to the four reservoirs in the central Texas FIRO Pilot using daily reconstructed inflow series provided by the US Army Corps of Engineers – Fort Worth District (USACE-SWF). The project team also performed hindcasts using the updated SAC-SMA parameters.

Validation experiments confirmed that the new round of calibration slightly mitigated the negative biases in both flood peak and volume for major flood events observed over the 2010-2019 period. However, negative bias persisted at most forecast points for high flow conditions in general. In addition, small degradations were observed at Georgetown Lake during the June 2007 event with the updated parameter values.

Through the calibration, the project team found large phase discrepancies between model simulations of reservoir inflows and estimates from the USACE-SWF at Belton Lake. This phase error cannot be easily overcome with model calibration, thus pointing to potential issues with reservoir inflow estimates.

The project team reviewed the current configuration of the NWS reservoir model (RES-J) and found that the lakeside withdrawal has been deactivated. As a result, the model was unable to reproduce the severity of drawdowns in historical years for all four reservoirs. The team activated the lakeside withdrawal and fine-tuned the withdrawal amounts that led to improved representation of simulated water level series at three reservoirs, namely Belton Lake, Georgetown Lake, Granger Lake. At Lake Stillhouse Hollow, the impacts from introducing withdrawal were muted.

The project team implemented a gridded version of the CBPR algorithm and conducted a preliminary evaluation of the probabilistic QPFs (PQPFs) produced by CBPR and default parameter estimation scheme for the Mixed Meta-Gaussian Distribution (MMGD). The outcomes confirmed that the PQPFs produced by CBPR are more skillful when judged by the Brier Skill Scores for large amounts (> 60 and 90 mm/day) at shorter leads (day 1 and 2), but they underperform at longer leads (day 3-8), and in terms of Continuously Ranked Probability Skill Scores (CRPSS). The team also found a tendency for the CBPR PQPFs to overforecast for the lower probability values.

On the basis of the findings, the project team recommends the following actions in future endeavors:

I. Experimenting with alternative calibration algorithms to remedy negative bias in the streamflow simulations and forecasts produced by HEFS for high flow and major flood events. Developing an automated strategy to facilitate calibration of hydrologic models at WGRFC.

II. Formulating a systematic strategy to quality assure daily reservoir inflow estimates and flag periods when assumptions in the reservoir water balance approach may be violated, such as high wind, large backwater effects, and hysteresis in stage-flow relationships.

III. Further investigating and improving RES-J to allow for more accurate representation of drawdowns at all four reservoirs. Determine potential sources of remaining biases in RES-J after the current calibration effort. Evaluate the fidelity of lake evaporation estimates and withdrawal.

IV. Determine operational scenarios where it is advantageous to deploy the alternative RES-J parameter table that enables the seasonal guide curve. Assess the impacts of integrating the alternative RES-J parameter table on prediction of high flow episodes to reduce potential degradations to operation.

V. Expanding evaluations of gridded postprocessing schemes, including the MMGD with default parameterization scheme and CBPR, to cover ensemble precipitation and streamflow forecasts by leveraging concurrent efforts in developing a gridded version of Schaake Shuffle. Including both forecasted and observed major precipitation events in the evaluation to determine the potential of CBPR as an operational scheme.

1. Project Overview

The Texas Forecast-Informed Reservoir Operation (FIRO) Pilot project was launched in 2022 with the overarching aim of bridging the gap between forecast producers and reservoir operators, and thereby facilitating the adoption of ensemble weather and streamflow forecasts in routine reservoir operations. The FIRO pilot site is situated in central Texas in the Little River System (LRS), a tributary to the Brazos River (Fig 1-1).

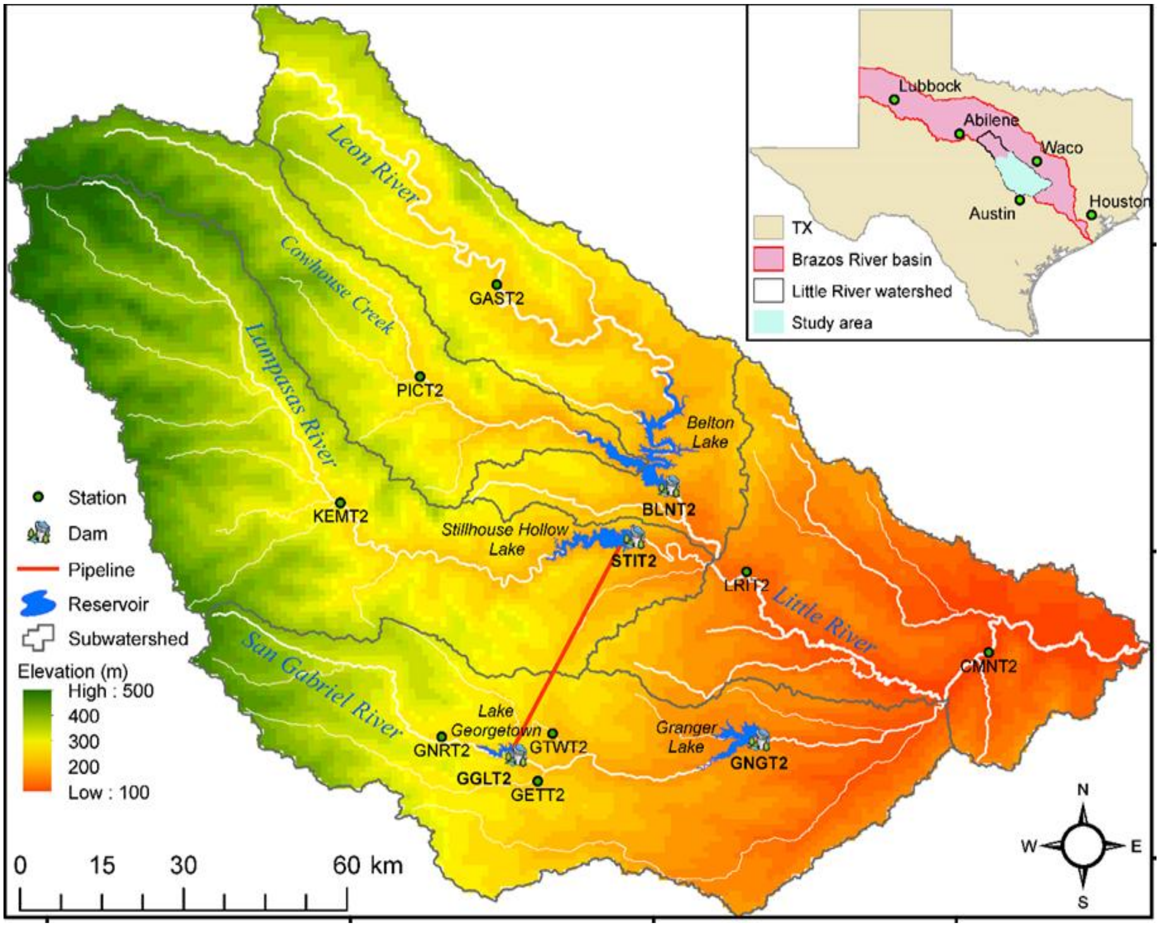


Figure 1-1: The central Texas FIRO Pilot on the Little River System, where four USACE multiuse reservoirs are situated, namely Georgetown, Granger, Stillhouse Hollow, and Belton.

The FIRO Pilot site housed four USACE multiuse reservoirs: namely, Georgetown Lake, Granger Lake, Lake Stillhouse Hollow and Belton Lake (Table 1-1).

Table 1-1: Four USACE Multipurpose Reservoirs in Texas FIRO Pilot

Reservoirs	NWS ID	Surface Area (acres)	Conservation Capacity (acre-ft)	Upstream Area (square miles)
Georgetown Lake	GGLT2	1.297	38,005	246
Granger Lake	GRNT2	4,064	51,822	709
Lake Stillhouse Hollow	STIT2	6,429	229,796	1318
Belton Lake	BLNT2	12,385	432,631	3560

Selected for calibration are inlets to the four reservoirs and seven forecast points on streams draining to these reservoirs. The gauging station ID, upstream area and availability of flow record are summarized in Table 1-2 and the geographic locations of watersheds are shown in Fig. 1-2. Note that additional stream gauges are present in the lower part of the Little River System but are not included in the calibration effort due to relatively short records, or that the forecast points have not been established.

Table 1-2: USGS gauging stations in the FIRO Pilot collocated with NWS forecast points.

Location	USGS ID	NWS ID	Upstream Area (square miles)	Length of Daily Flow Record
Sabana Rv near De Leon	08099300	DSBT2	264	1960-Present
Copperas Ck at FM 2247 nr Comanche	08099382	CPKT2	143	2015-Present
Leon Rv at Hamilton	08100000	HMLT2	1,891	1925-Present
Leon Rv at Gatesville	08100500	GAST2	2,342	1950-Present
Cowhouse Ck at Pidcoke	08101000	PICT2	455	1950-Present
Lampasas Rv nr Kempner	08103800	KEMT2	818	1950-Present
S Fk San Gabriel Rv at Georgetown	08104900	GETT2	133	1967-Present

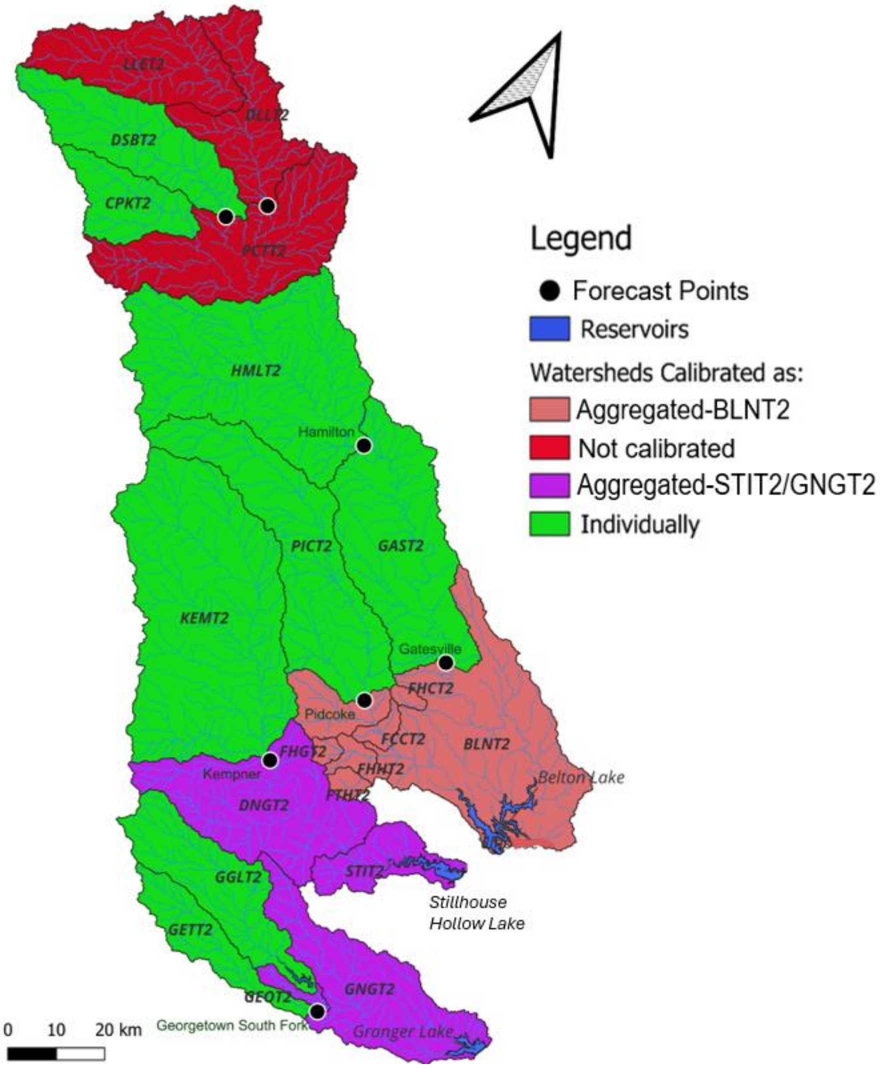
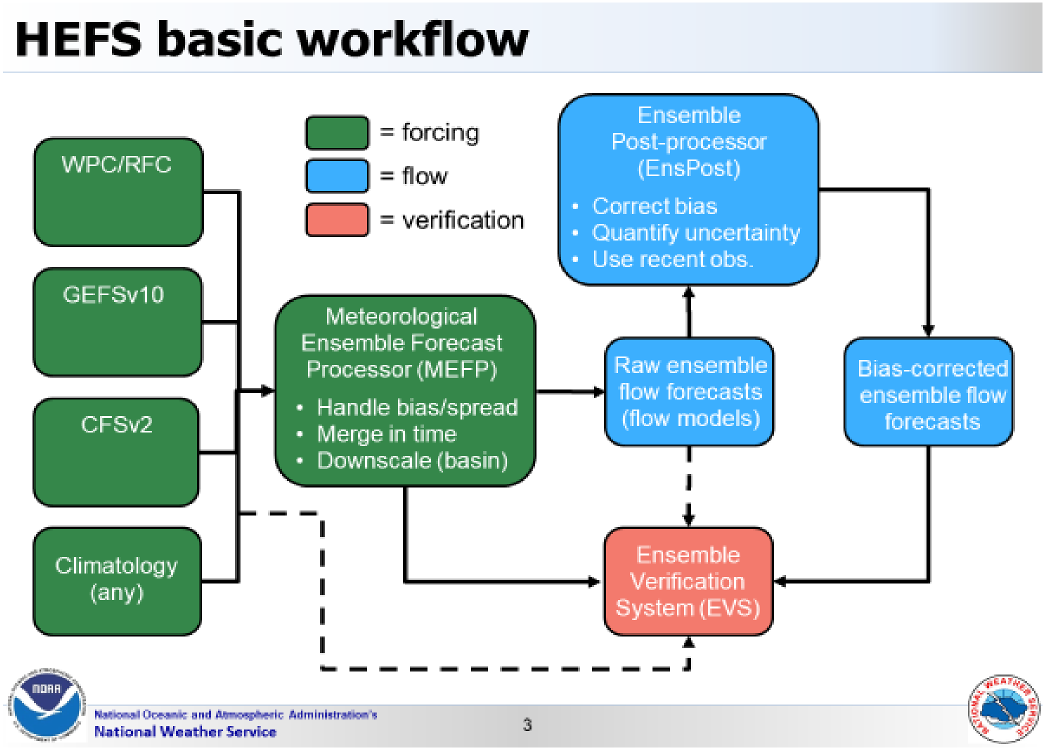


Figure 1-2: Forecast points in the Little River System. Forecast points with upstream watershed highlighted in dark red are not included in the calibration. Watersheds in green are calibrated individually whereas those in pink and purple are calibrated each as a group with identical scalar multipliers. Note that watersheds around Belton Lake are lumped into one group, and those surrounding Stillhouse Hollow and Granger into another group.

In the first phase of Texas FIRO Pilot, the project team led by UTA's Hydrometeorology Group performed detailed evaluations of ensemble streamflow and precipitation forecasts from the National Weather Service Hydrologic Ensemble Forecast Service (HEFS; Demargne et al., 2014; Kim et al., 2018). The team identified several major deficiencies in the modeling system that compromise the skills of ensemble forecasts and hinder their applications. Notable among these include:

- Insufficient skills of the streamflow forecasts to foresee major high flow events, including those produced by the June 2007 convective storm and Hurricane Harvey.

- Consistent, negative biases in the streamflow simulations over major high flow events using the parameter values from the previous calibration effort concluded in 2022.
- Underforecast of heavy to extreme rainfall as marked by near-zero probability of occurrence of these events.



HEFS basic workflow

🟩 = forcing

🟦 = flow

🟥 = verification

WPC/RFC

GEFSv10

CFSv2

Climatology (any)

Meteorological Ensemble Forecast Processor (MEFP)
- Handle bias/spread
- Merge in time
- Downscale (basin)

Ensemble Post-processor (EnsPost)
- Correct bias
- Quantify uncertainty
- Use recent obs.

Raw ensemble flow forecasts (flow models)

Bias-corrected ensemble flow forecasts

Ensemble Verification System (EVS)

National Oceanic and Atmospheric Administration's National Weather Service

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Figure 1-3: Workflow of Hydrologic Ensemble Forecast Service (HEFS). Source: NWS.

These observations bring to fore the needs for improving the calibration of hydrologic modeling as well as enhancing the mechanisms for producing ensemble precipitation and streamflow forecasts. As Fig. 1-3 illustrates, the HEFS produces ensemble streamflow forecasts by feeding ensemble forecasts of forcing variables such as precipitation and temperature to the NWS hydrologic modeling system. These ensemble forcing variables are produced using the Meteorological Ensemble Forecast Processor (MEFP; Wu et al., 2011). The resulting ensemble streamflow forecasts have the option of undergoing further adjustments using the Ensemble Postprocessor (EnsPost; Regonda and Seo, 2008).

Fig. 1-4 shows the schematic of MEFP workflow. For each given forecast point, the ensemble members of weather or climate forecasts at this upstream drainage are averaged to yield ensemble mean. The ensemble forecast means and coincident observations are collated and both undergo normal quantile transformation. The transformed forecast-observation pairs are used to establish a bivariate Mixed Meta-Gaussian Distribution (MMGD; Herr and Krystophwiz, 2005; Wu et al., 2010).

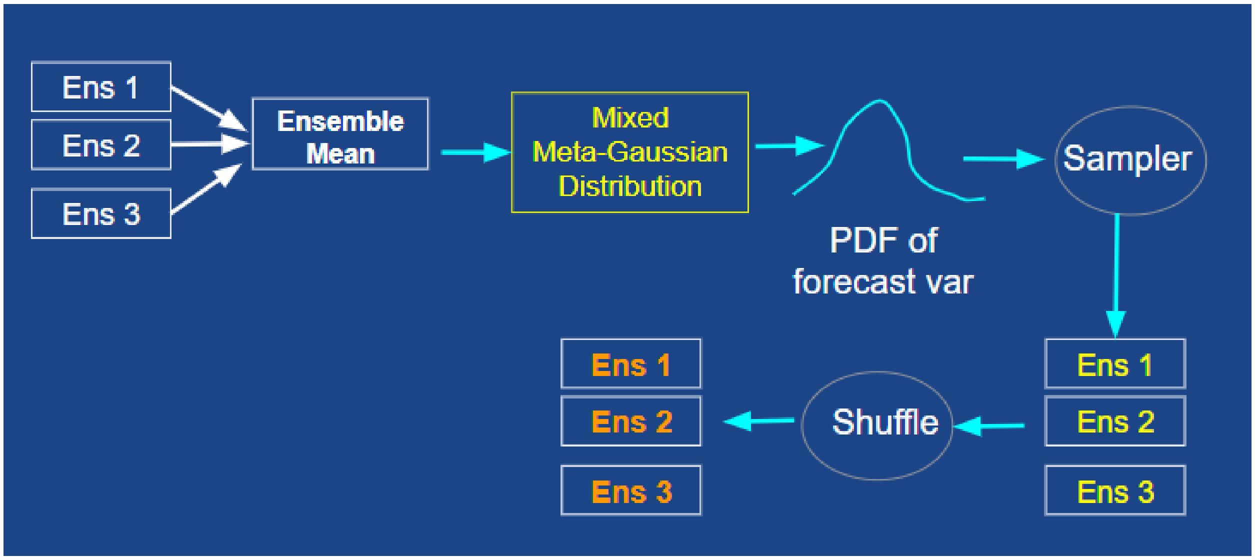

Figure 1-4: Schematic of the workflow of Meteorological Ensemble Forecast Processor (MEFP).

Once the parameters of MMGD are estimated, any future forecasts that are fed to the MMGD will serve as the conditional variable to produce conditional probability distribution of "observed" amounts. This conditional distribution, also known as probabilistic quantitative precipitation forecast (PQPF), is sampled to create ensemble traces of each forcing variable at each site (typically a subwatershed). As the sampling is done independently at each location and for each variable, the resulting resampled ensemble forcing traces no longer retain the spatial or cross-variable coherence of the original forecast. To address this issue, MEFP implements the Schaake Shuffle (Clark et al. 2004, Wu et al., 2018), a technique that uses ranked statistics of historical observations across locations or variables to reorder forecasts. The sampled ensemble forecast traces are reordered using the Schaake Shuffle to produce reordered ensembles for each segment, which then serve as forcings to the NWS hydrologic modeling system to produce ensemble flow forecasts at each forecast point (Fig. 1-4). The modeling system comprised of the Sacramento Soil Moisture Accounting (SAC-SMA; Burnash 1973), the rainfall-runoff model, Unit Hydrograph routing model, Lag-K channel routing model, and reservoir models.

Extant evaluations of the HEFS ensemble forecasts have pointed to persistent negative biases for large precipitation amounts and high flow events (Jozaghi et al., 2024). Fig. 1-5 shows the forecast amounts versus observations computed over the service area of California-Nevada River Forecast Center, with the former from the mean of raw forecasts from the Global Ensemble Forecast System (GEFS), the mean of MEFP postprocessed PQPFs, and the mean of PQPFs computed using an alternative technique, namely Conditional Bias Penalizing Regression (CBPR). It is evident that a) the raw GEFS suffers from a negative overall bias, and the bias is especially pronounced for the two events with the largest accumulations. Postprocessing with the operational MEFP systematically reduces the forecast amounts and amplifies the forecast bias.

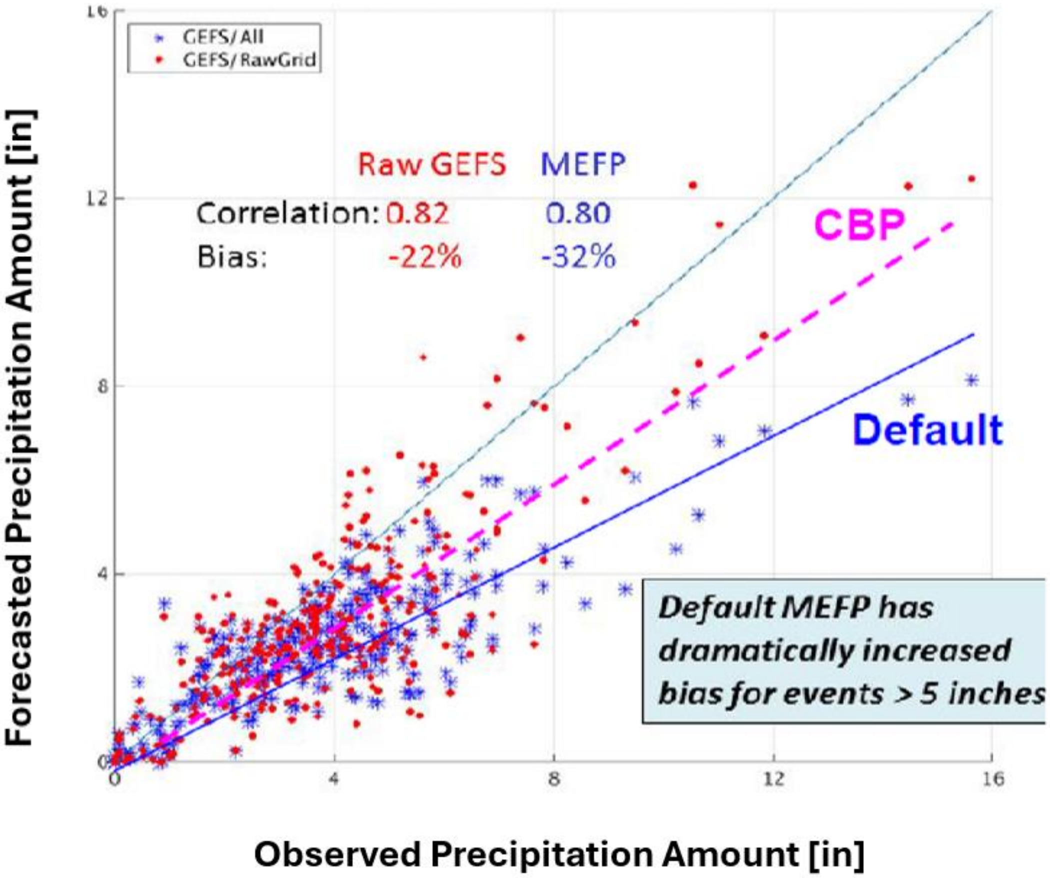

Figure 1-5: Precipitation forecasts versus observations compiled from the service area of NWS California-Nevada River Forecast Center. Included in the plots are ensemble means from raw GEFS forecasts, MEFP postprocessed PQPF, and PQPF based on Conditional Bias Penalizing Regression. Source: DJ Seo.

In addition to biases in precipitation forecasts, the FIRO Pilot team also uncovered severe, negative biases in the hydrologic model simulations that aggravated the overall biases in the HEFS forecasts for major historical events. As shown in Fig. 1-6, TWDB funded a recent calibration project that was completed in 2022 (Lynker, 2022). The calibration, however, introduced a severe, negative bias to the peak discharge and total volume of major flood events at Lampasas River at Kempner.

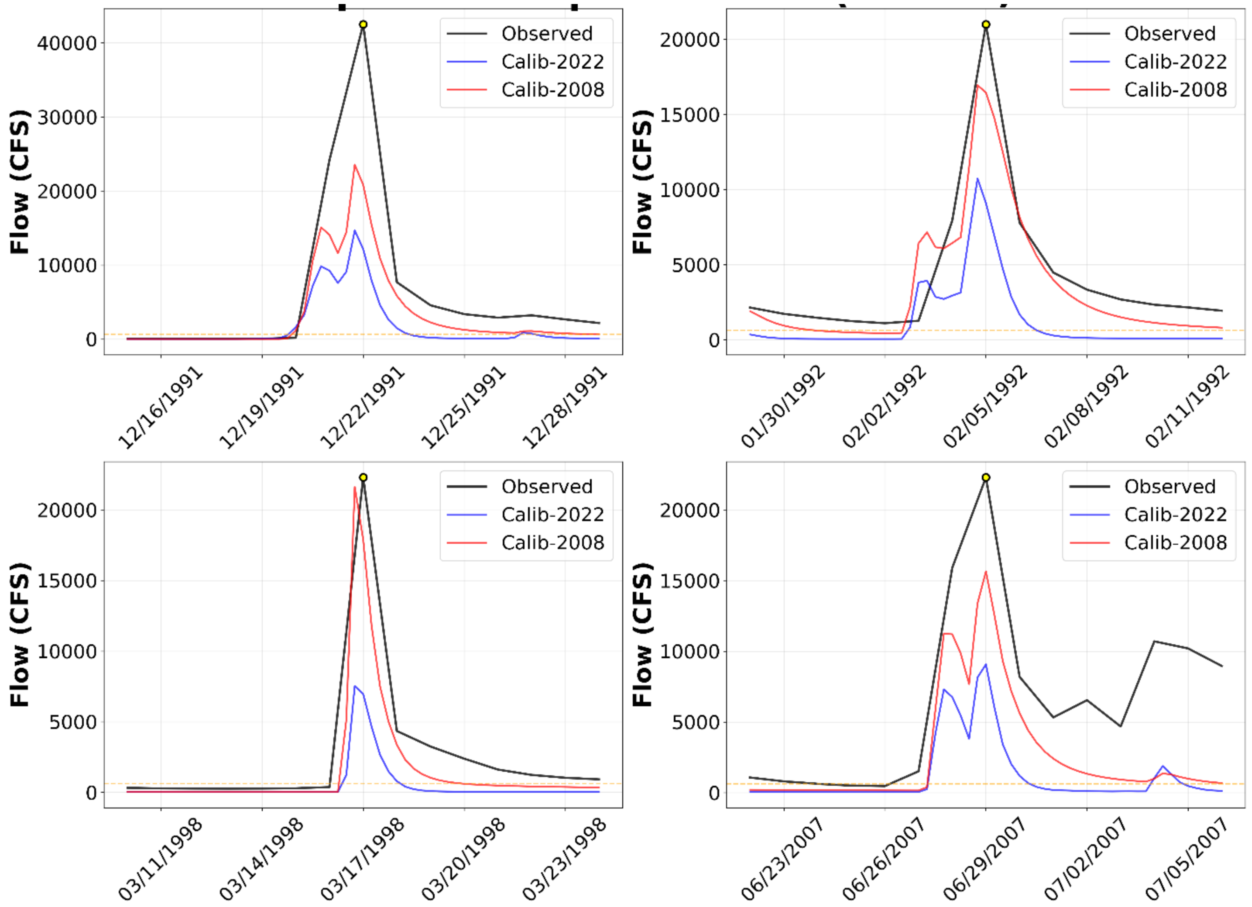

Figure 1-6: Simulated hydrographs from NWS hydrologic model for four major flood events at Lampasas River at Kempner using SAC-SMA parameter values from the calibration efforts completed in 2008 and 2022.

Discussions with reservoir operators from the USACE-SWF have brought to fore the biases and inaccuracies in streamflow forecasts for large inflow events as foremost impediments to their routine use in guiding operations. In addition, the WGRFC indicated that ungauged areas upstream of each reservoir inlet were not specifically calibrated in the previous efforts (in the 2022 calibration project, reservoir outflow rather than inflow was calibrated against observations).

Recognizing the need for overcoming these impediments, the Texas FIRO partners decided to launch a project led by the Texas FIRO Pilot team to mitigate the biases through recalibrating the NWS hydrologic model for the pilot domain and by examining an alternative scheme for estimating MMGD parameters. In addition, the project team reviewed the configurations of the reservoir model for each of the four USACE reservoirs in the domain to correct some of the conspicuous discrepancies between model simulated reservoir levels and observations.

The project comprises the following four technical tasks:

1. Adjust SAC-SMA parameters for selected LRS forecast points to address negative biases in HEFS forecasts
2. Update/correct reservoir model configurations for the LRS

3. Produce HEFS hindcasts by integrating enhancements in Tasks 2 and 3; and perform evaluation with GEFSv12
4. Evaluate conditional biases in raw and postprocessed QPFs and experiment with the Conditional Bias Penalizing Regression (CBPR)

The project team acquired the most recent Community Hydrologic Prediction System (CHPS) configurations from the WGRFC. With assistance from WGRFC staff, the team set up the hindcast workflow and produced hindcasts over the period of 2000-2019 which is the default one used in baseline validation performed at NWS Office of Water Prediction (OWP). The team then performed each task and shared the outcomes of each task with WGRFC and stakeholders.

The remaining part of the report is organized as follows. Section 2 presents the calibration-validation strategy and the outcomes. Section 3 describes the corrections to RES-J configurations and results. Section 4 presents the validation of hindcasts for selected years. Section 5 highlights the results from hindcast experiments using a gridded version of CBPR and the default MMGD. Section 6 summarizes the findings and recommendations.

2. Calibration of SAC-SMA for Selected Forecast Points

2.1. Model Parameters and Watersheds Undergoing Calibration

The parameters used in the operational NWS that undergo calibration are listed in Table 2-1. A total of eleven parameters will undergo calibration.

Table 2-1: SAC-SMA model parameters undergoing calibration

Parameter	Description	Unit
UZTWM	Upper Zone Tension Water Maximum: The capacity of the upper soil layer to hold water against gravity (soil moisture).	mm
UZFWM	Upper Zone Free Water Maximum: The capacity of the upper layer for water that can drain freely as interflow or percolate downward.	mm
LZTWM	Lower Zone Tension Water Maximum: The capacity of the lower soil layer to hold water against gravity.	mm
LZFPM	Lower Zone Primary Free Water Maximum: The capacity of the primary groundwater storage, which contributes to slow baseflow.	mm
LZFSM	Lower Zone Supplementary Free Water Maximum: The capacity of the supplementary groundwater storage, which contributes to faster baseflow.	mm
UZK	Upper Zone Free Water Depletion Rate: The fraction of water that drains from the upper zone free water storage as interflow per day.	Day^{-1}
LZPK	Lower Zone Primary Free Water Depletion Rate: The fraction of water that drains from the lower zone primary storage as baseflow per day.	Day^{-1}
LZSK	Lower Zone Supplementary Free Water Depletion Rate: The fraction of water that drains from the lower zone supplementary storage as baseflow per day.	Day^{-1}
ZPERC	Maximum Percolation Rate: The maximum rate at which water can move from the upper zone to the lower zone.	mm/day
REXP	Percolation Exponent: An exponent that controls the non-linear increase in percolation as the lower zone becomes saturated.	dimensionless

PFREE	Direct Percolation Fraction: The fraction of percolated water that bypasses the lower zone tension storage and goes directly to the free water storages.	fraction (0-1)

Calibration is performed for a total of eleven forecast points in the Little River System (Table 1-2; Fig. 1-2), including seven USGS stations (GAST2, PICT2, KEMT2, HMLT2, GETT2, CPKT2, and DSBT2) and four reservoir inlets (BLNT2, STIT2, GGLT2, and GNGT2). Note that the project task originally covered only seven forecast points, including three of the USGS stations, namely GAST2, PICT2 and KEMT2 and the reservoir inlets, as these are the most relevant to FIRO analysis. Though four additional USGS stations, HMLT2, GETT2, and CPKT2 and DSBT2, undergo calibration, we will focus on the impacts of the calibration on flow simulations at the former forecast points.

2.2. Calibration-Validation Strategy

A split-sample calibration-validation strategy is employed in this project. The calibration is done using a multi-objective approach for the 10-year period of 2010-2009, and the calibrated parameter values are used to produce simulations that underwent evaluations for 2000-2019. The multi-objective approach involves consideration of several objective functions jointly in determining the optimal parameter values. These include Percent Bias (PBIAS), Mean Absolute Error (MAE), correlation (R), Nash-Sutcliffe Efficiency (NSE; Nash and Sutcliffe, 1970), and Kling-Gupta Efficiency (KGE, Gupta and Kling, 2011). Percentage Bias is defined as:

$$PBIAS = \frac{\sum_{t=1}^{T}(Q_m(t) - Q_o(t))}{\sum_{t=1}^{T} Q_o(t)}$$

Where $Q_o(t)$ and $Q_m(t)$ are observed and modeled discharge at time t, respectively.

$$r = \frac{\sum_{t=1}^{T}\left(Q_m(t) - \underline{Q_m}(t)\right)\left(Q_o(t) - \underline{Q_o}(t)\right)}{\sqrt{\sum_{t=1}^{T}\left(Q_m(t) - \underline{Q_m}(t)\right)^2}\sqrt{\sum_{t=1}^{T}\left(Q_o(t) - \underline{Q_o}(t)\right)^2}}$$

Where $\underline{Q_m}(t)$ and $\underline{Q_o}(t)$ are means of modeled and observed discharge, respectively.

MAE is defined as:

$$MAE = \sum_{t=1}^{T} |Q_o(t) - Q_m(t)|$$

NSE takes the following form:

$$NSE = 1 - \frac{\sum_{t=1}^{T}(Q_o(t) - Q_m(t))^2}{\sum_{t=1}^{T}\left(Q_o(t) - \underline{Q_o}(t)\right)^2}$$

Where Q_o and Q_m are observed and modeled discharge, respectively, and $\underline{Q_o}(t)$ is the mean of observed discharge across t. The metric is a measure of error in the prediction versus variability (dispersion) in the observed series.

KGE is a composite measure of forecast accuracy that fuses correlation of prediction and observation, variability in prediction versus that in observation and bias. It is defined as follows:

$$KGE = 1 - \left((r-1)^2 + (\alpha-1)^2 + (\beta-1)^2\right)^{1/2}$$

Where r is the Pearson's correlation; α is the ratio of variance of simulated and observed series; and β is bias.

The calibration involves first a gridded search of possible value ranges for each SAC-SMA model parameter, and then manual adjustment of parameter values. This approach was selected over gradient-based optimization methods due to the non-convex nature of the objective function landscape and the need to identify multiple Pareto-optimal solutions rather than a single global optimum. The gridded search involves the following steps:

1. randomly selecting multiple combinations of parameter values to initialize the search
2. altering values of each parameter combination with prescribed increments and determining how metrics such as PBIAS and KGE change
   a. If changes are desirable, e.g., PBIAS declines and KGE increases, then step to the new location
   b. Otherwise, repeat step 2 but with smaller increments
   c. If changes in PBIAS and KGE are no longer desirable, then terminate the search.

A total of 1,250 parameter combinations were evaluated for each watershed, and multiple combinations were identified for further evaluations. For each of the forecast points, the above metrics are computed for windows with moderate-high flow (>30% observed daily quantile) and for four flood events with the highest peak discharge over the 10-year period. These serve as the basis for selecting the optimal parameter values. The results of the calibration are shown in the subsequent section.

2.3. Results

First presented are statistics computed for moderate-high flows (> 95% quantiles) over the calibration window using parameter values derived from the latest calibration. Table 2-2 present these along with the results from the 2022 Calibration project by Lynker (denoted by 2022).

Table 2-2: Summary Statistics for Moderate-High Flow for 2010-2019

Forecast Point	PBIAS		MAE [cfs]		R		KGE		NSE	
	2022	2025	2022	2025	2022	2025	2022	2025	2022	2025
BLNT2	-99	-42	235.50	126.29	0.14	0.09	-0.64	-0.08	-1.76	-0.59
CPKT2*	-	-34	-	13.19	-	0.77	-	0.57	-	0.52
DSBT2*	-	-33	-	13.22	-	0.8	-	0.53	-	0.6
GAST2	-98	0	118.64	24.17	0.47	0.86	-0.48	0.86	-2.54	0.72
GETT2	-99	-34	12.27	7.68	0.30	0.54	-0.56	0.21	-0.23	0.26
GGLT2	-99	-25	21.24	12.48	0.63	0.70	-0.45	0.60	-0.46	0.41
GNGT2	-99	-46	74.62	48.54	0.60	0.56	-0.45	0.33	-0.72	0.11
HMLT2	-99	3	96.25	27.06	0.41	0.82	-0.52	0.78	-2.15	0.57
KEMT2	-99	-63	47.89	35.64	0.58	0.65	-0.45	0.21	-0.58	0.19
PICT2	-98	-44	40.86	25.86	0.61	0.68	-0.45	0.29	-0.32	0.38
STIT2	-99	-10	88.99	35.52	0.65	0.75	-0.43	0.74	-0.86	0.50

*Streamflow simulations using the parameter values from 2022 were not available at CPKT2 and DSBT2.

At most forecast points, bias is much improved after the latest round of calibration. PBIAS from the 2022 calibration ranges from -98% to -99%, suggesting severe negative bias at almost all forecast points (Note simulations for CPKT2 and DSBT2 based on the 2022 parameter set are not available). With the latest calibration, PBIAS remains negative for a majority of forecast points but the severity has been much alleviated. At GAST2 and HMLT2, bias is close to zero. MAE sees broad improvements accordingly. The other three metrics, correlation, KGE and NSE also experience broad improvements, and only small degradation is seen for correlation at BLNT2.

The same statistics for the entire period (2000-2019) are shown in Table 2-3.

Table 2-3: Summary Statistics for Moderate-High Flow for 2000-2019

Forecast Point	PBIAS		MAE [cfs]		R		KGE		NSE	
	2022	2025	2022	2025	2022	2025	2022	2025	2022	2025
BLNT2	-99	-42	223.74	122.54	0.27	0.21	-0.58	0.05	-1.76	-0.52
CPKT2*	-	-34	-	13.19	-	0.77	-	0.57	-	0.52
DSBT2*	-	-39	-	11.71	-	0.79	-	0.5	-	0.58
GAST2	-98	-2	108.31	23.6	0.48	0.85	-0.48	0.85	-2.27	0.7
GETT2	-99	-44	14.34	9.91	0.29	0.50	-0.57	0.09	-0.14	0.21
GGLT2	-99	-43	23.91	15.61	0.69	0.62	-0.44	0.3	-0.33	0.32
GNGT2	-99	-50	74.36	47.95	0.50	0.44	-0.49	0.2	-0.80	-0.08
HMLT2	-99	3	87.36	25.93	0.42	0.79	-0.51	0.77	-1.91	0.53
KEMT2	-99	-72	58.16	46.09	0.52	0.60	-0.48	0.02	-0.54	0.05
PICT2	-99	-50	42.49	28.07	0.63	0.68	-0.44	0.24	-0.36	0.34
STIT2	-99	-17	99.75	41.88	0.55	0.74	-0.47	0.67	-0.74	0.49

*Streamflow simulations using the parameter values from 2022 were not available at CPKT2 and DSBT2.

The statistics for the entire period in several ways resemble those for the calibration window. The calibration has drastically alleviated the negative bias at nearly all forecast points. Meanwhile, other metrics also show conspicuous improvements. Only small degradation is seen at BLNT2. Several limitations of the present calibration include:

- Bias remains quite negative for most forecast points. At KEMT2, PBIAS is -72% for the entire period, consistent with that for the calibration window (-69%). At GNGT2, PBIAS for the entire period is -50% versus -46% for the calibration window.
- Correlation, KGE and NSE are slightly lower for the entire period than those for the calibration window for a majority of the forecast point. At BLNT2 and HMLT2, correlation is slightly higher for the entire time window.

Event Statistics

For each forecast point, model simulations for the largest four events are validated against observations (or estimates), and the results are compared against observations. The event-wise statistics (i.e., statistics computed by combining multiple events) are shown in Table 2-4.

Table 2-4: Event-wise statistics with latest calibration

Site	Start Date	End Date	PBIAS	MAE	R	KGE	NSE
BLNT2	2010-01-22	2010-02-05	-34	152	0.25	0.11	-0.19
BLNT2	2010-09-01	2010-09-15	-66	97	0.09	-0.37	-0.09

BLNT2	2012-03-13	2012-03-27	-51	95	0.14	-0.27	-0.07
BLNT2	2017-04-04	2017-04-18	-68	99	0.08	-0.57	-0.13
CPKT2	2015-07-01	2015-07-15	-28	13	0.46	0.37	0.05
CPKT2	2016-05-20	2016-06-03	-24	21	0.90	0.63	0.74
CPKT2	2018-10-10	2018-10-24	-44	5	0.67	0.39	0.27
CPKT2	2019-04-17	2019-05-01	-78	7	0.81	-0.10	0.20
DSBT2	2012-01-19	2012-02-02	-49	7	0.75	0.23	0.44
DSBT2	2015-05-21	2015-06-04	-29	11	0.65	0.38	0.39
DSBT2	2015-11-22	2015-12-06	-13	12	0.57	0.48	0.30
DSBT2	2016-05-24	2016-06-07	-21	49	0.73	0.52	0.48
GAST2	2010-01-22	2010-02-05	-42	35	0.88	0.39	0.60
GAST2	2015-05-24	2015-06-07	0	28	0.93	0.93	0.85
GAST2	2016-06-02	2016-06-16	4	22	0.90	0.80	0.79
GAST2	2018-10-10	2018-10-24	8	44	0.91	0.87	0.81
GETT2	2010-09-02	2010-09-16	12	18	0.33	0.29	-0.10
GETT2	2012-03-14	2012-03-28	38	4	0.42	0.31	-0.24
GETT2	2015-05-18	2015-06-01	-22	17	0.40	0.19	0.13
GETT2	2018-09-16	2018-09-30	-64	16	0.43	-0.17	0.09
GGLT2	2010-09-01	2010-09-15	43	12	0.89	0.55	0.73
GGLT2	2012-03-13	2012-03-27	7	7	0.95	0.80	0.89
GGLT2	2015-05-17	2015-05-31	-28	19	0.64	0.29	0.34
GGLT2	2018-10-09	2018-10-23	-22	12	0.94	0.59	0.79
GNGT2	2010-09-01	2010-09-15	12	56	0.75	0.65	0.56
GNGT2	2015-05-18	2015-06-01	-16	58	0.64	0.59	0.31
GNGT2	2016-05-12	2016-05-26	-18	44	0.20	0.14	-0.26
GNGT2	2018-10-09	2018-10-23	-39	46	0.19	-0.05	-0.10
HMLT2	2015-05-22	2015-06-05	14	54	0.63	0.49	0.36
HMLT2	2016-05-30	2016-06-13	18	29	0.96	0.75	0.75
HMLT2	2018-10-10	2018-10-24	37	72	0.40	0.29	-0.35
HMLT2	2019-05-05	2019-05-19	20	28	0.74	0.60	0.13
KEMT2	2010-01-23	2010-02-06	-70	62	0.60	-0.09	0.10
KEMT2	2015-05-23	2015-06-06	-40	31	0.56	0.35	0.14
KEMT2	2016-05-28	2016-06-11	-75	39	0.69	0.10	-0.09
KEMT2	2018-10-10	2018-10-24	-35	62	0.78	0.52	0.55
PICT2	2010-01-23	2010-02-06	-57	48	0.62	-0.01	0.21
PICT2	2015-10-18	2015-11-01	58	21	0.77	0.37	0.54
PICT2	2016-05-28	2016-06-11	-61	32	0.54	0.02	0.14
PICT2	2018-10-10	2018-10-24	-23	42	0.84	0.53	0.64
STIT2	2010-01-22	2010-02-05	-18	48	0.75	0.65	0.53
STIT2	2010-09-01	2010-09-15	0	46	0.62	0.54	0.37
STIT2	2012-03-13	2012-03-27	3	42	0.63	0.60	0.34
STIT2	2018-10-09	2018-10-23	15	49	0.92	0.75	0.77

To further illustrate the impacts of the latest calibration on the accuracy of model simulations for high flow events, we identified four historical flood events in 2000-2019 and compared the simulations using the default parameter values from the 2022 calibration effort and the values from the latest attempt. Shown in Table 2-5, these include one event in the pre-calibration window (2000-2009) and three in the calibration window (2010-2019).

Table 2-5: Major flood events for evaluation.

Event ID	Start-Date	End-Date	Window

1	2007-06-24	2007-07-02	Pre-calibration
2	2010-01-27	2010-02-04	Calibration
3	2015-05-21	2015-05-29	Calibration
4	2018-10-13	2018-10-21	Calibration

Figs. 2-1- 2.7 show the comparisons over the four events at seven forecast points, including three USGS stations upstream of Belton Lake and Lake Stillhouse Hollow, namely, GAST2, PICT2, and KEMT2, and the four reservoir inlets (BLNT2, STIT2, GGLT2, and GNGT2). Each figure shows those derived from the previous calibration effort concluded in 2022 (calib-2022), referred to hereinafter as the baseline, and the current one (calib-2025).

At GAST2, it is clear that the simulations using the baseline parameter sets are biased low for all four events (Fig. 2-1). The latest calibration results in improved simulated peaks and volumes for the three events in the calibration window, i.e., January-February 2010, May 2015 and October 2018, but slightly exacerbates the negative bias for the June 2007 event. Note that there appear to be phase errors between the simulated and observed for the May 2015 event. The latest calibration improves the bias but was unable to address the phase errors.

At PICT2, negative bias is observed in the simulations based on both sets of parameter values (Fig. 2-2). The latest calibration slightly improved the bias for three events, i.e., June 2007, January-February 2010, and May 2015, but degraded the bias for the October 2018 event. It is also worth noting that the simulated series based on the latest parameter values features crested slightly earlier in time, while the series based on the 2022 parameter set tracks more closely the observed series.

At KEMT2, negative bias is again observed in the simulated series with both baseline and the recent parameter values (Fig. 2-3). The latest calibration only slightly improved the bias for the January 2010 event, whereas for the remaining three events, the effects are either muted (for e.g., June 2007 and May 2015 events) or negative (for October 2018 event).

At BLNT2 (Belton Lake), negative bias is observed in the simulated inflow series with the baseline parameter values (Fig. 2-4). In addition, it is evident that the simulated hydrographs and the estimates from USACE exhibit large, persistent phase differences – the peaks from the simulations lag behind the observed by 3-6 days. The latest calibration improves the volume and peak bias for all four events, but is unable to close the phase lag. Among the events, the improvement in peak bias is the most pronounced for the June 2007 and January-February 2010 events.

At STIT2 (Lake Stillhouse Hollow), negative bias is again observed in the simulated inflow series with baseline parameter values (Fig. 2-5). The latest calibration improves the volume and peak bias for the first three events, resulting in nearly perfect match in the magnitude of peak inflow for the June 2007 and January-February 2010 events. However, for the October event, the latest calibration results in a large, positive bias, whereas the simulated series with the 2022 parameter suite is closer to bias-neutral.

At GGLT2 (Georgetown Lake), negative bias is again observed in the simulated inflow series with the baseline parameter values (Fig. 2-6). The bias is particularly severe for the June 2007 event. After the latest calibration, only minor changes are seen for the events in June 2007, January 2010 and May 2015, and severe, negative biases remain. For the first event, the recalibration slightly lowers the peak and volume, thereby degrading the accuracy of the simulation. For the other events, the recalibration results in slightly improved peak and volume, though the overall impacts are marginal. Only for the 2018 event, recalibration resulted in a drastic increase in simulated peak and volume that are quite close to the observed values.

At GGLT2 (Granger Lake), the results of simulations are mixed across four events (Fig. 2-7). Negative bias in the simulations with the baseline parameter values except for the May 2015 event, in which the simulated peak inflow exceeded the observation. The latest calibration yields much improved bias for the June 2007 event, and slightly improved bias for the October 2018 event. However, for the January-February 2010 event, using the latest parameter values slightly degraded the simulations by further suppressing the inflow magnitude. For the May 2015 event, it results in severe negative bias through the event.

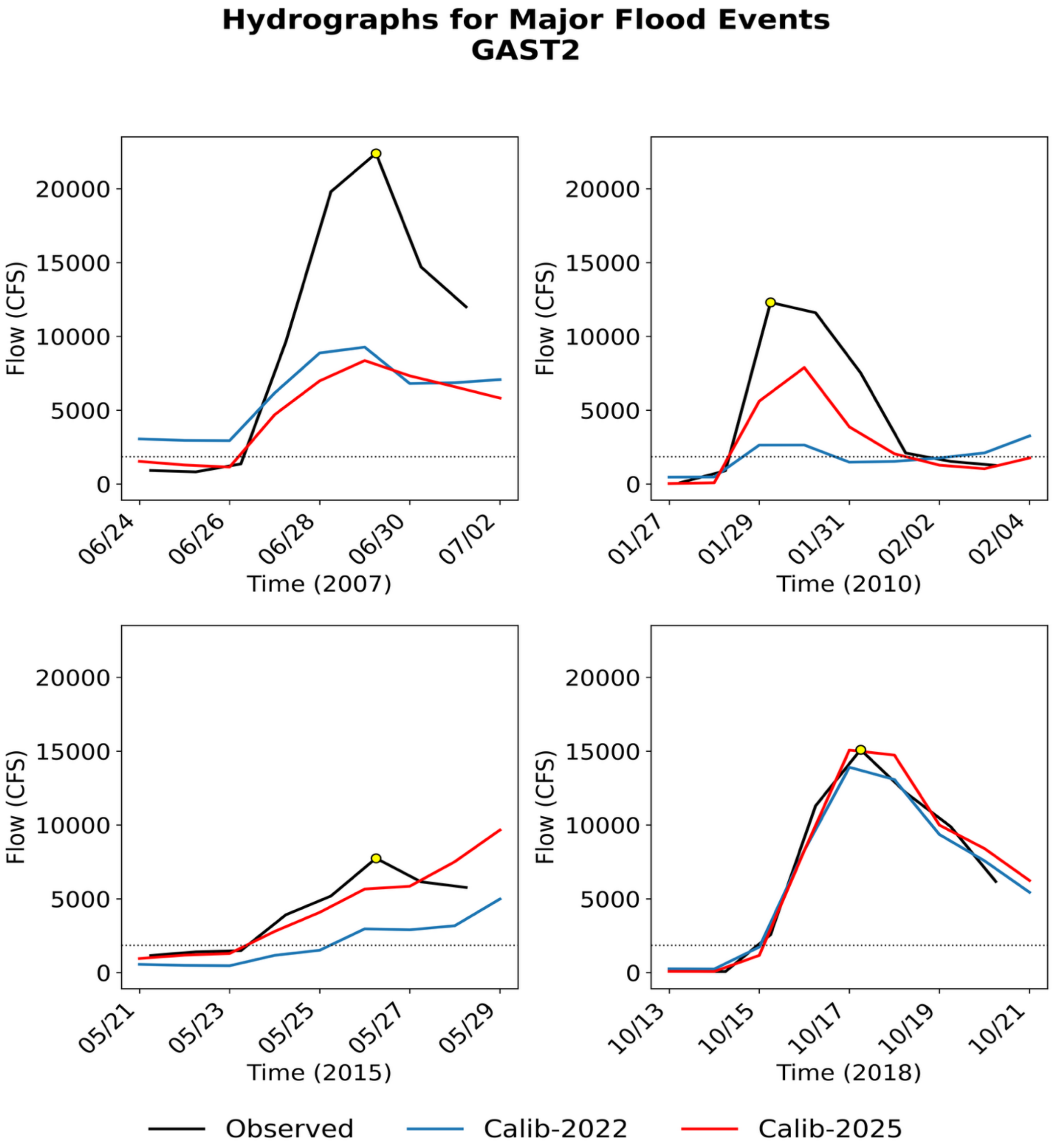

Figure 2-1: Simulated hydrographs at GAST2 for four major flood events with parameter values from the calibration done in 2022 and 2025 (this project). These events occurred in June 2007 (top left), January February 2010 (top right), May 2015 (bottom left), and October 2018 (bottom right).

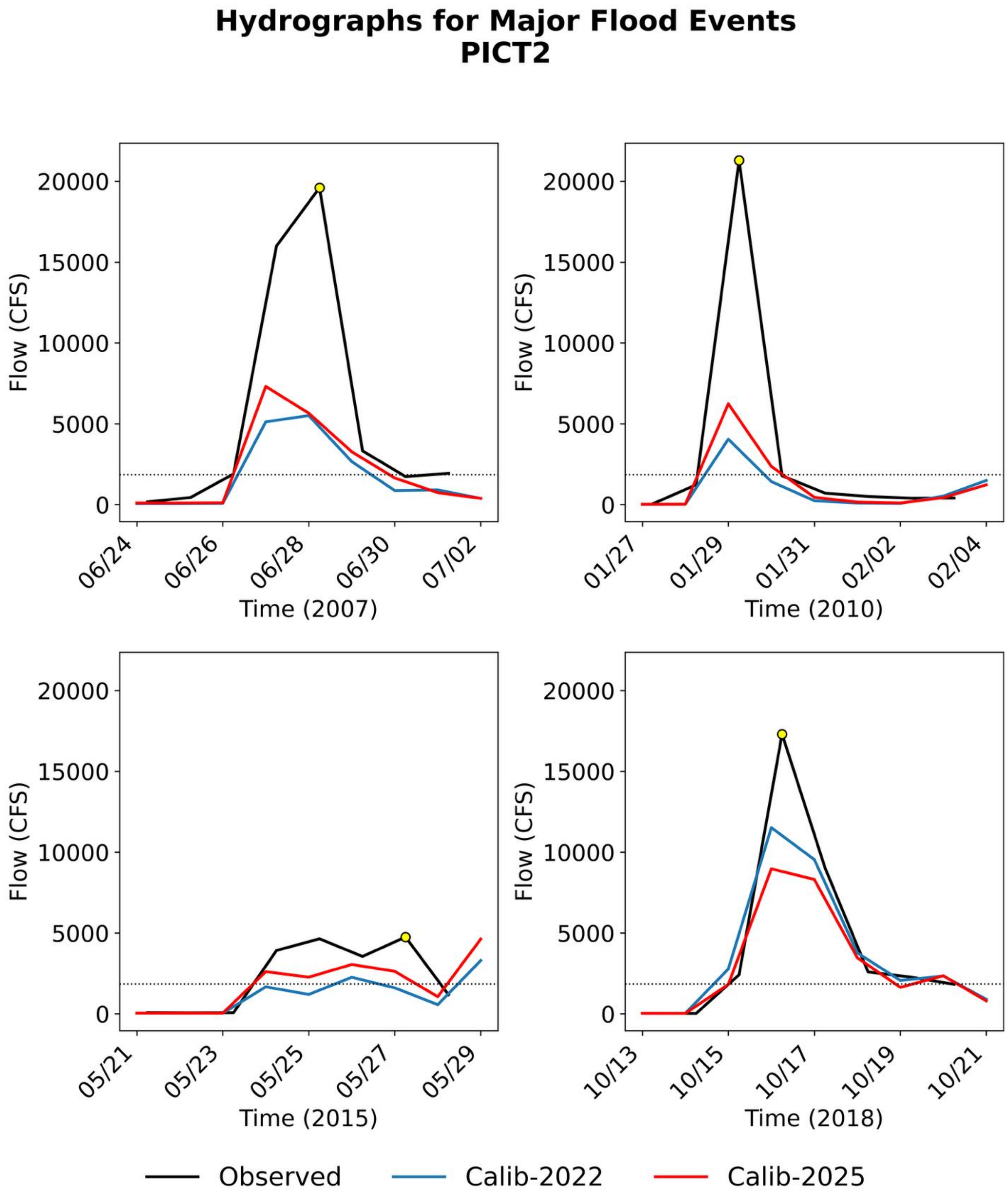

Figure 2-2: As Fig. 2-1, except for PICT2.

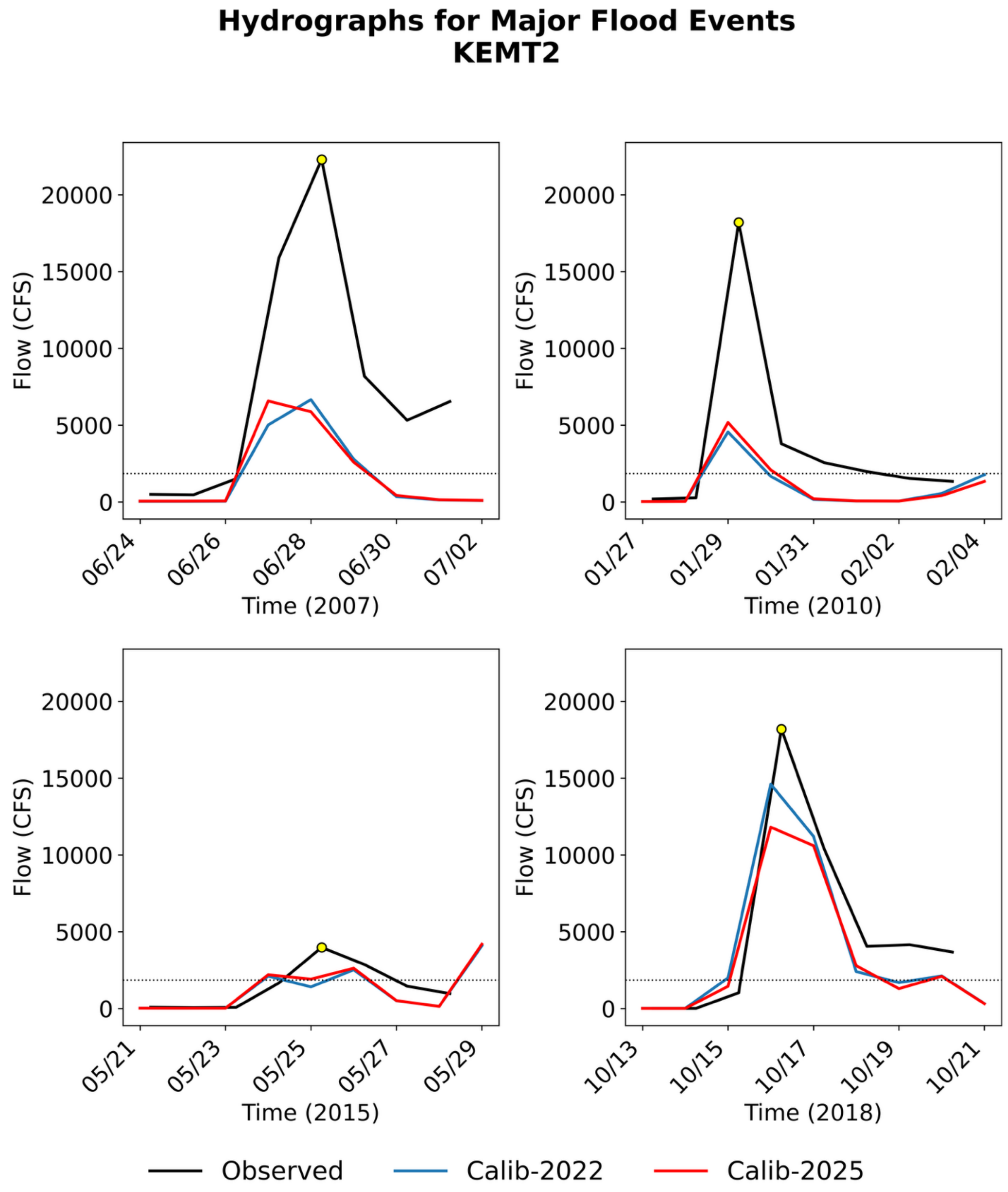

Figure 2-3: As Fig. 2-1, except for KEMT2.

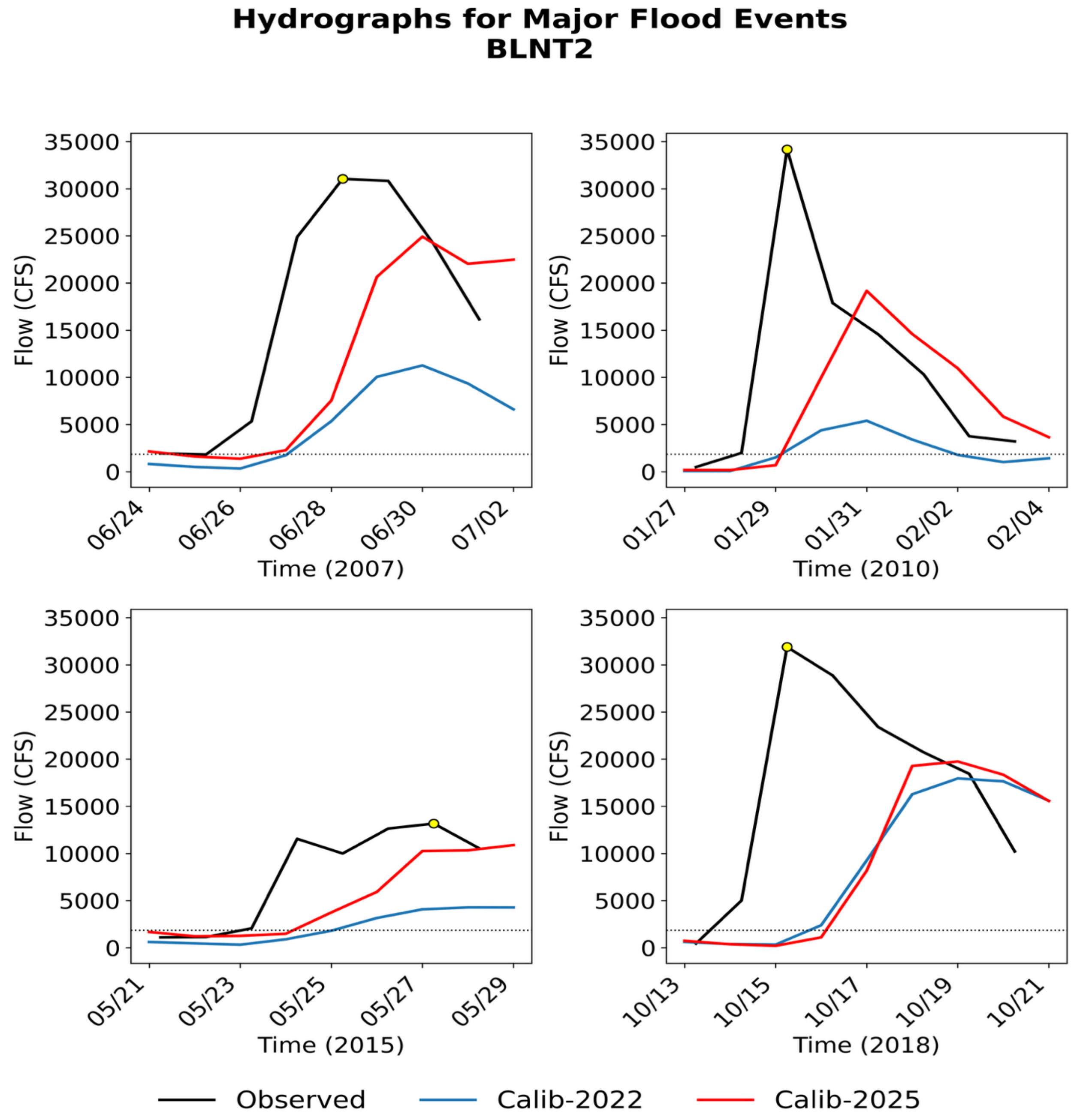

Figure 2-4: Simulated inflow to Belton Lake for four major flood events with parameter values from the calibration done in 2022 and 2025 (this project). These events occurred in June 2007 (top left), January February 2010 (top right), May 2015 (bottom left), and October 2018 (bottom right).

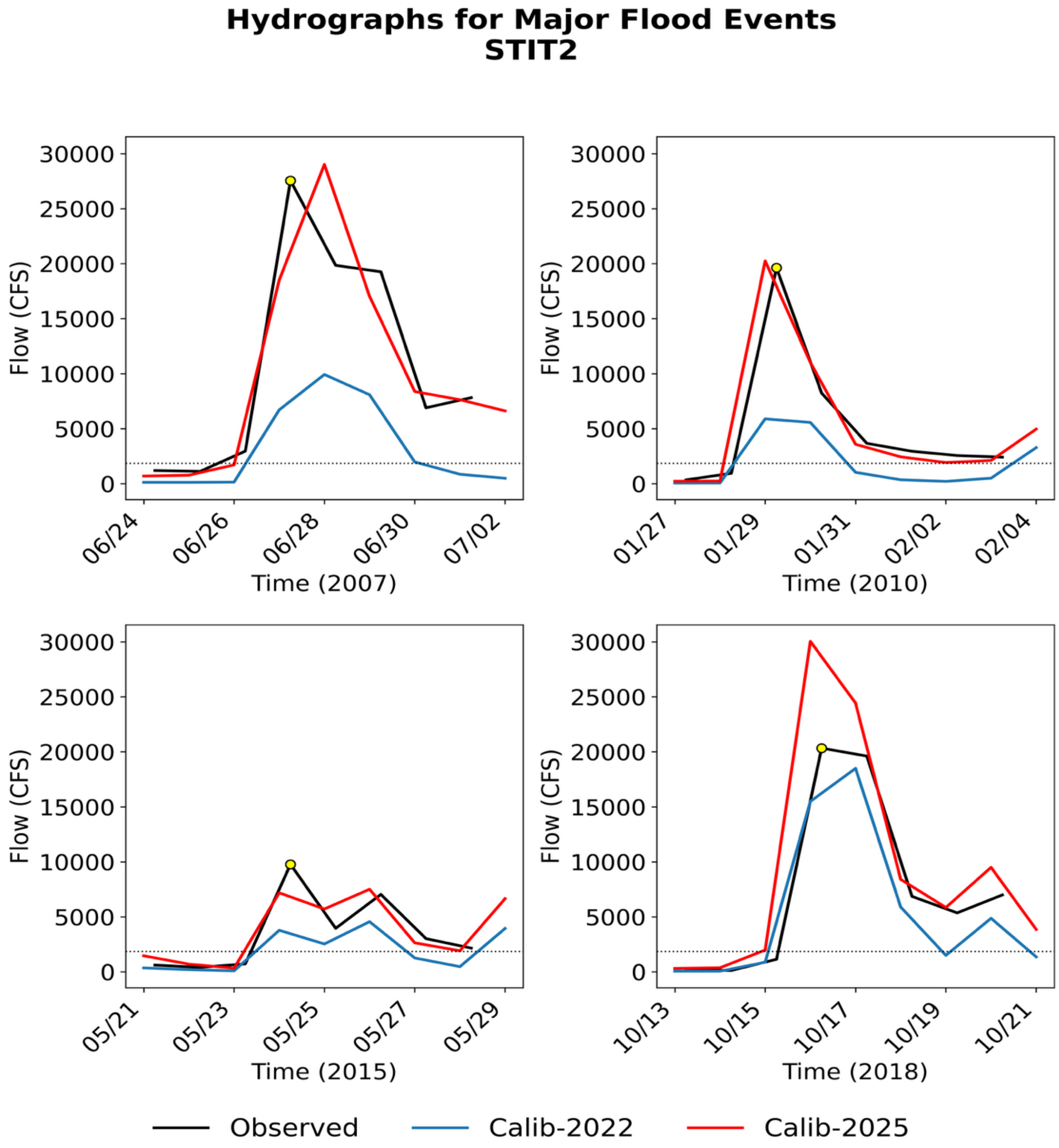

Figure 2-5: As Fig. 2-4, except for inflow to Lake Stillhouse Hollow.

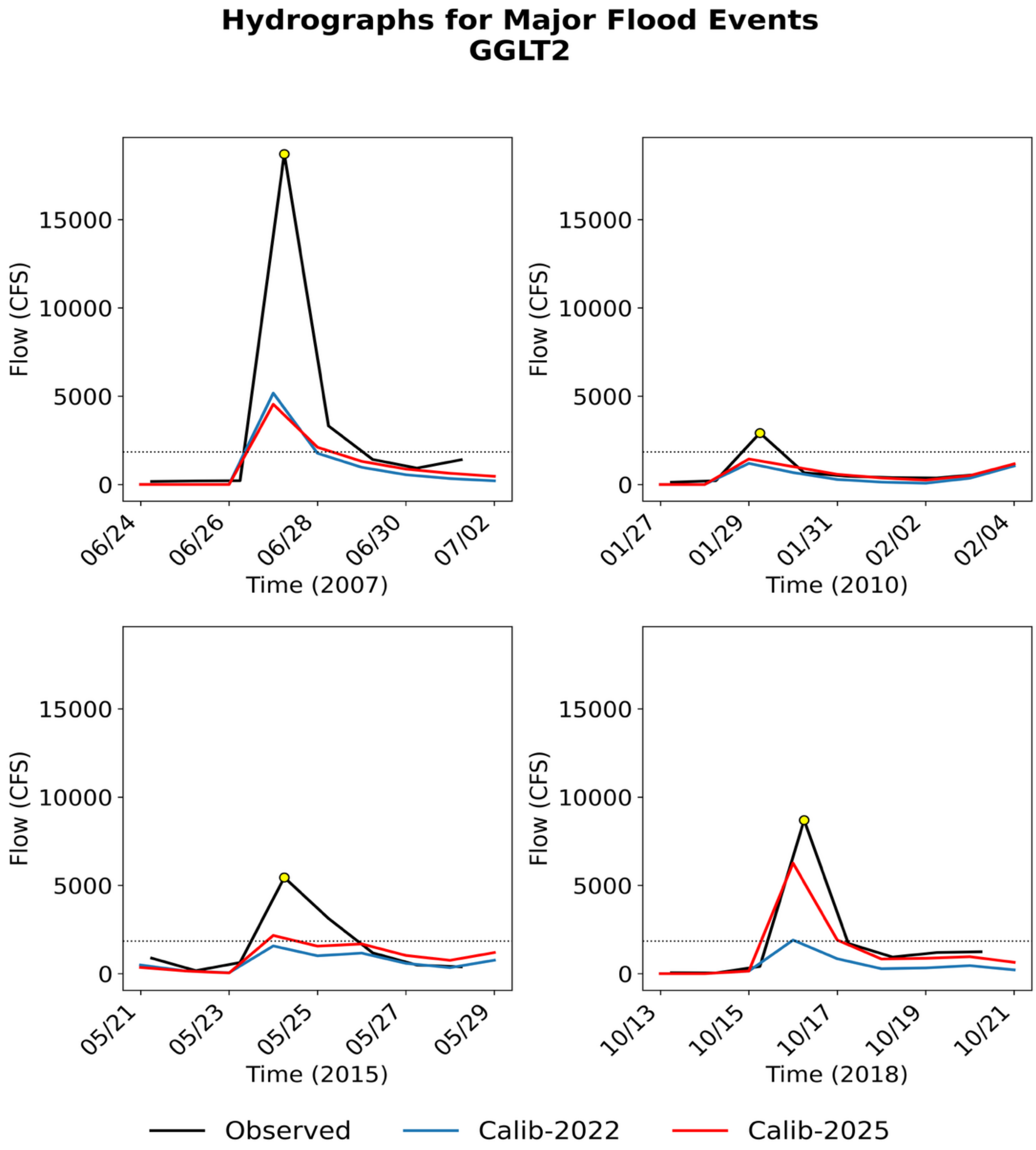

Figure 2-6: As Fig. 2-4, except for inflow to Georgetown Lake.

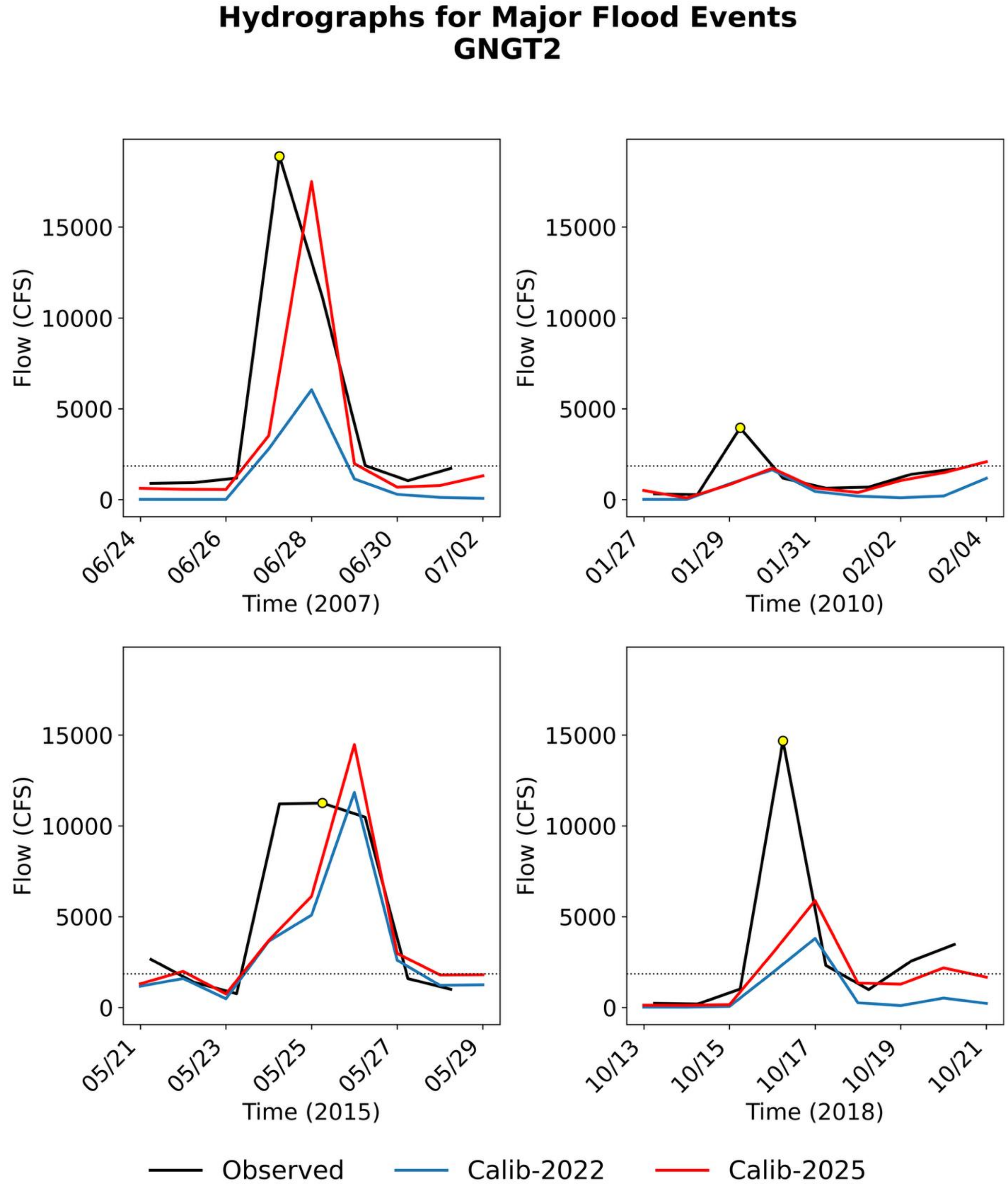

Figure 2-7: As Fig. 2-4, except for inflow to Granger Lake.

3. Correction of Reservoir Model Configuration

In an earlier phase of FIRO investigation, several limitations were found in the configuration of RES-J, the joint reservoir operation model in CHPS. These include:

1. Not accounting for customer withdrawal
2. Use of simplistic representation of lake evaporation
3. Inability to use forecast to determine release

As RES-J has been used primarily in the context of real-time flood operation where withdrawal and evaporation are dwarfed by inflows, these limitations have not had noticeable, adverse impacts on operations. Nonetheless, in order to perform FIRO analysis to estimate gains in water supply, it is important to realistically account for withdrawal and evaporation as these terms play large roles in determining storage changes during dry conditions. As shall be demonstrated, RES-J tends to vastly underrepresent the severity of drawdowns for reservoirs in the Pilot site due to the deactivation of withdrawal.

In this project, we undertook the effort to turn on and adjust withdrawal at each reservoir to better reproduce the drawdowns. The default configuration of RES-J uses the "NEG_INFLOW" approach, which specifies minimal withdrawal data (mostly zeros) and a binary on/off withdrawal patterns which results in limited operational realism. We switched it to the option of "WITHDRAWAL" which allows for specification of withdrawal schedules that vary seasonally and with pool elevation.

Specific Changes can be found in Table 3-1.

Table 3-1: Changes to RES-J configuration.

Parameter	WGRFC Default	Modified
Withdrawal	NEG_INFLOW	WITHDRAWAL
	Binary	Seasonal
	No interpolation	Interpolation
SETSUM	N/A	Activated

We manually calibrated the withdrawal table at each reservoir to better match the historical pool level observations, and the resulting RES-J parameter table can be found in Appendix B. The impacts from the calibration for the four Texas FIRO Pilot reservoirs are shown in Figs. 3-1 – 3-4. At each reservoir, it is evident that using the default configuration, RES-J was unable to reproduce the depth of drawdowns. For Belton Lake, a series of years with low flow resulted in progressively steep drawdowns that levelled off in 2015. RES-J with the default configuration completely missed this episode, whereas after calibration the model was able to nearly reproduce the depth of the drawdown at Belton Lake (Fig. 3-1). Similar improvements were found at Lake Georgetown and Granger Lake (Figs 3-3 and 3-4), but not at Lake Stillhouse Hollow (Fig. 3-2).

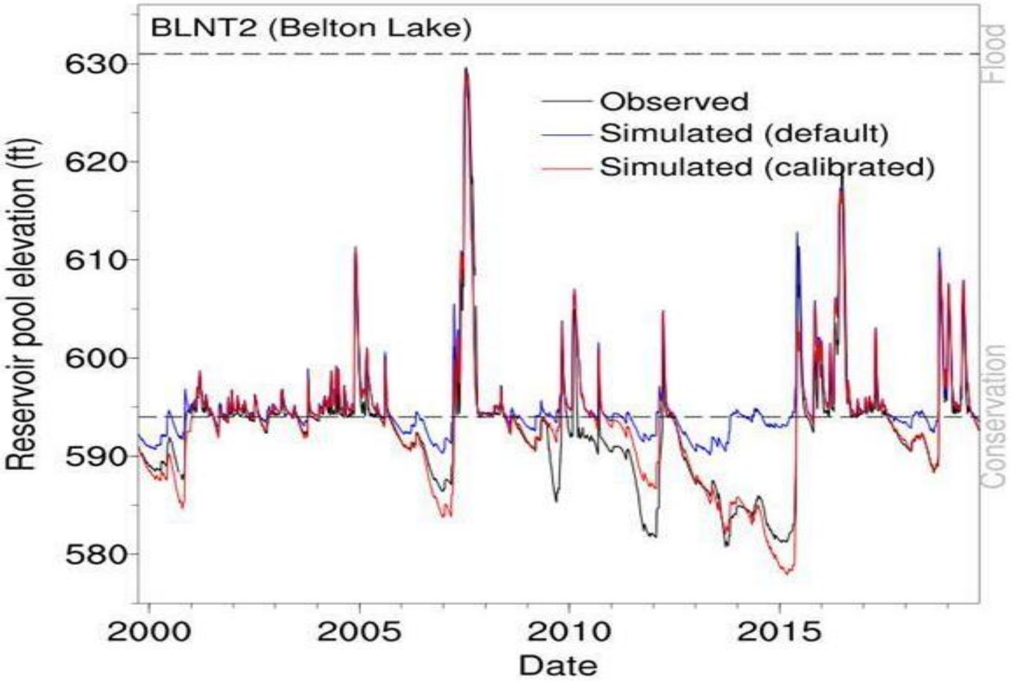

Figure 3-1: Simulated and observed reservoir pool level at Belton Lake. Two sets of simulations are shown here: a) with default withdrawal option; b) with modified withdrawal option and manual calibration.

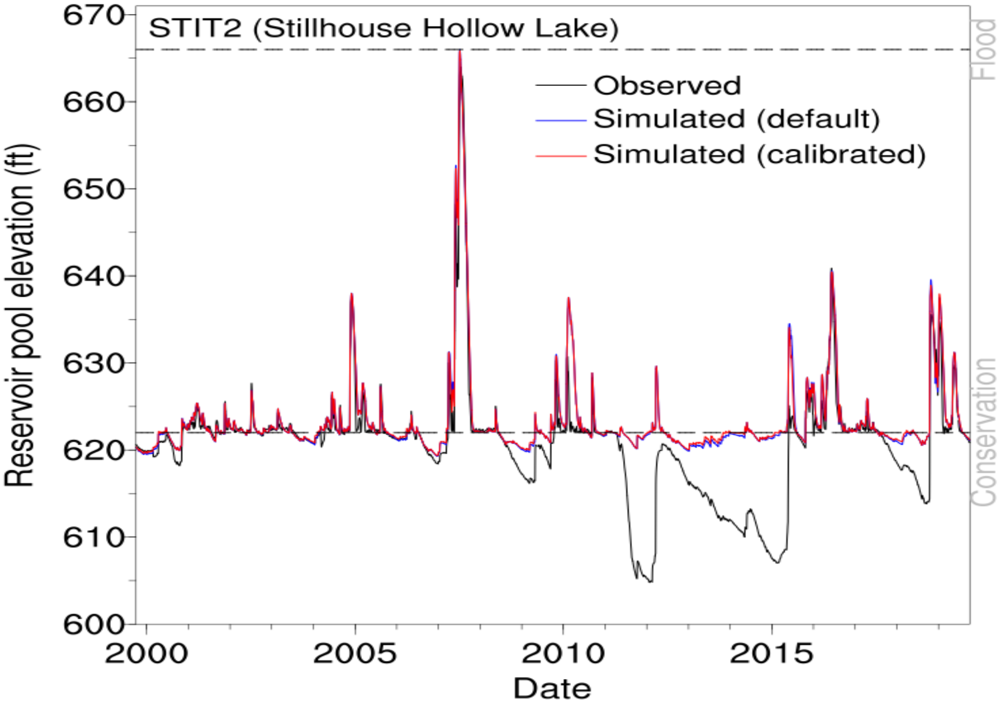

Figure 3-2: As Fig. 3-1, except for Lake Stillhouse Hollow.

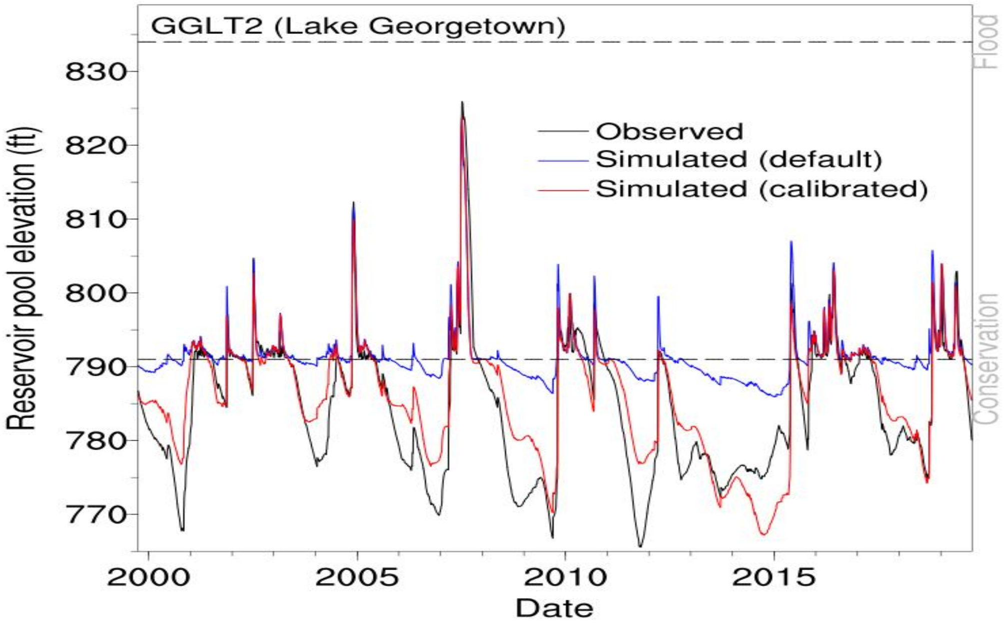

Figure 3-3: As Fig. 3-1, except for Georgetown Lake.

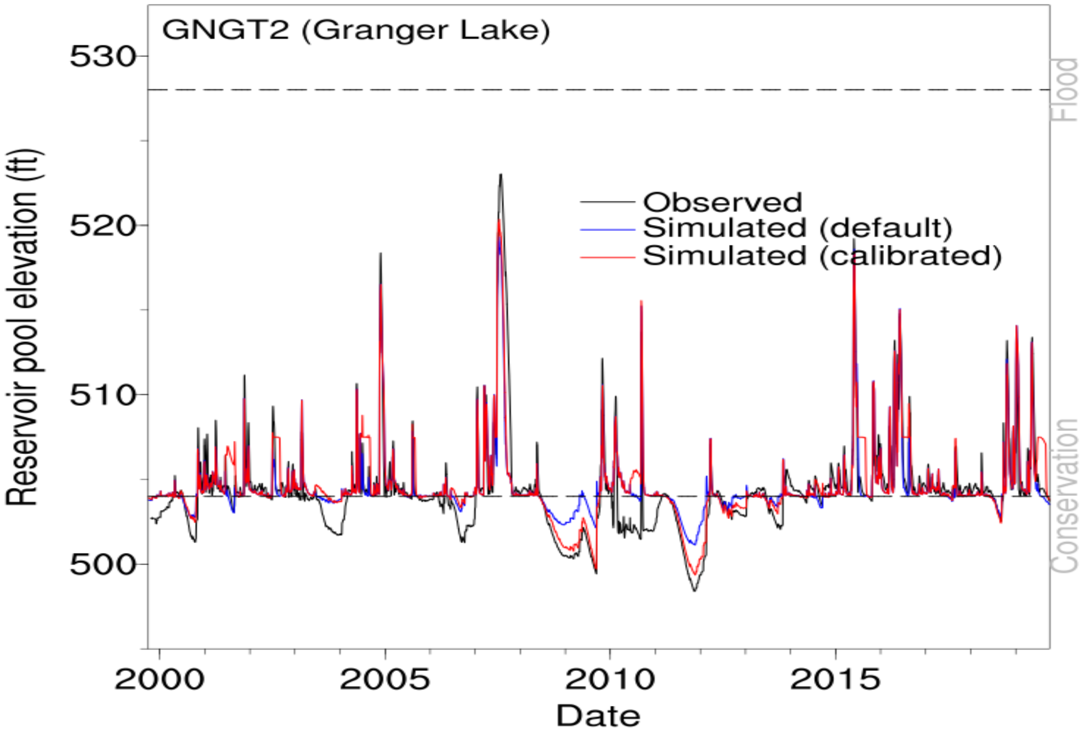

Figure 3-4: As Fig. 3-1, except for Granger Lake.

However, it should be noted that RES-J simulation of pool levels remains imperfect despite the calibration. At Lake Georgetown, the simulated drawdowns with calibrated withdrawal are much shallower than the observations for several episodes. It is worth pointing out that withdrawal and lake evaporation both serve to deplete reservoir storage, and their roles are confounded. The accuracy of lake evaporation did not undergo scrutiny in this project due to the time and resources constraints, but it should be in future efforts. In addition, a pipeline connecting Stillhouse Hollow Lake and Lake Georgetown began operations in 2011 that diverts water from the former to the latter. This diversion is currently not accounted for in RES-J and may have contributed to the errors.

4. Evaluation of Streamflow and Reservoir Level Hindcasts

With calibrated SAC-SMA and RES-J, the project team performed hindcast experiments to determine the impacts of calibration on skills of forecasts for selected historical events. To do so, the project team first collaborated with WGRFC staff to create a new set of warm states, i.e., SAC-SMA model states from model run for each time step. The impacts of calibration on skills of HEFS hindcasts are demonstrated for two historical flood episodes that occurred in June 2007 and October 2018.

<u>June 2007 Event</u>

The June 2007 flood event was produced by a stalled mesoscale convective system over central Texas for over a week, spawning a series of storm cells with intense rainfall. The most intense rain fell on 27 June to the southwest of Lake Georgetown (Fig. 4-1).

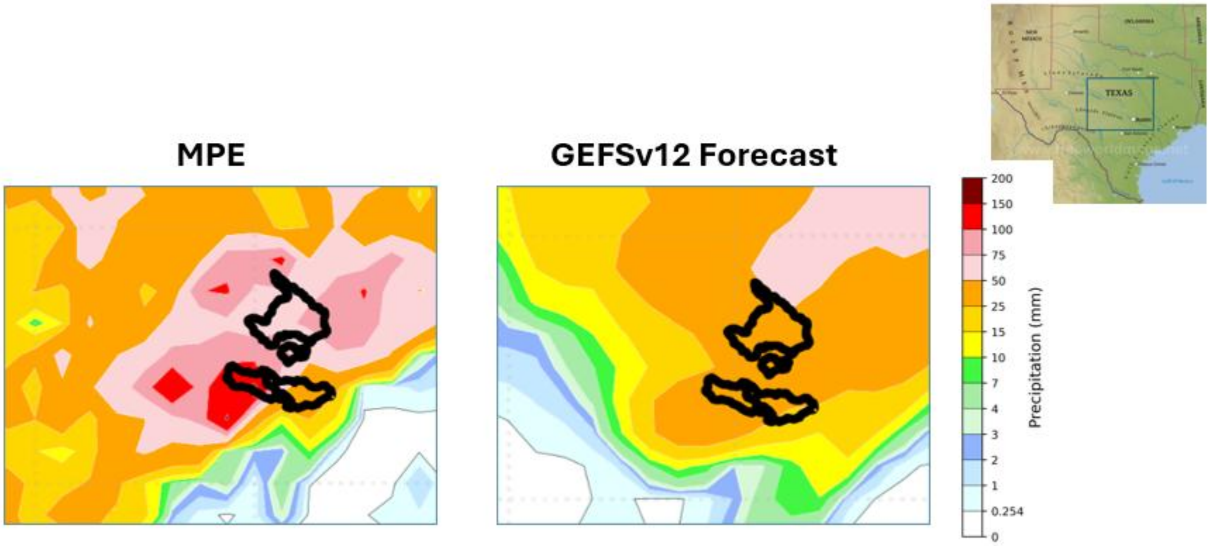

Figure 4-1: Rainfall accumulation for the 24-h window ending at 0 UTC on 28 June 2007 from NWS Multisensor Precipitation Estimates (MPE; left) and the control run of GEFSv12 reforecast (right).

The postprocessed ensemble precipitation forecasts produced by MEFP are shown in Fig. 4-2 for watersheds upstream of each reservoir in the Pilot. It is clear that the medians of ensemble forecasts are biased low at each site. The negative forecast bias is particularly appreciable at GGLT2 (Georgetown), where the peak 6-h rainfall rate approaches 120mm/h, much greater than the ensemble mean (~ 20mm/h) and beyond the upper bound of the ensemble.

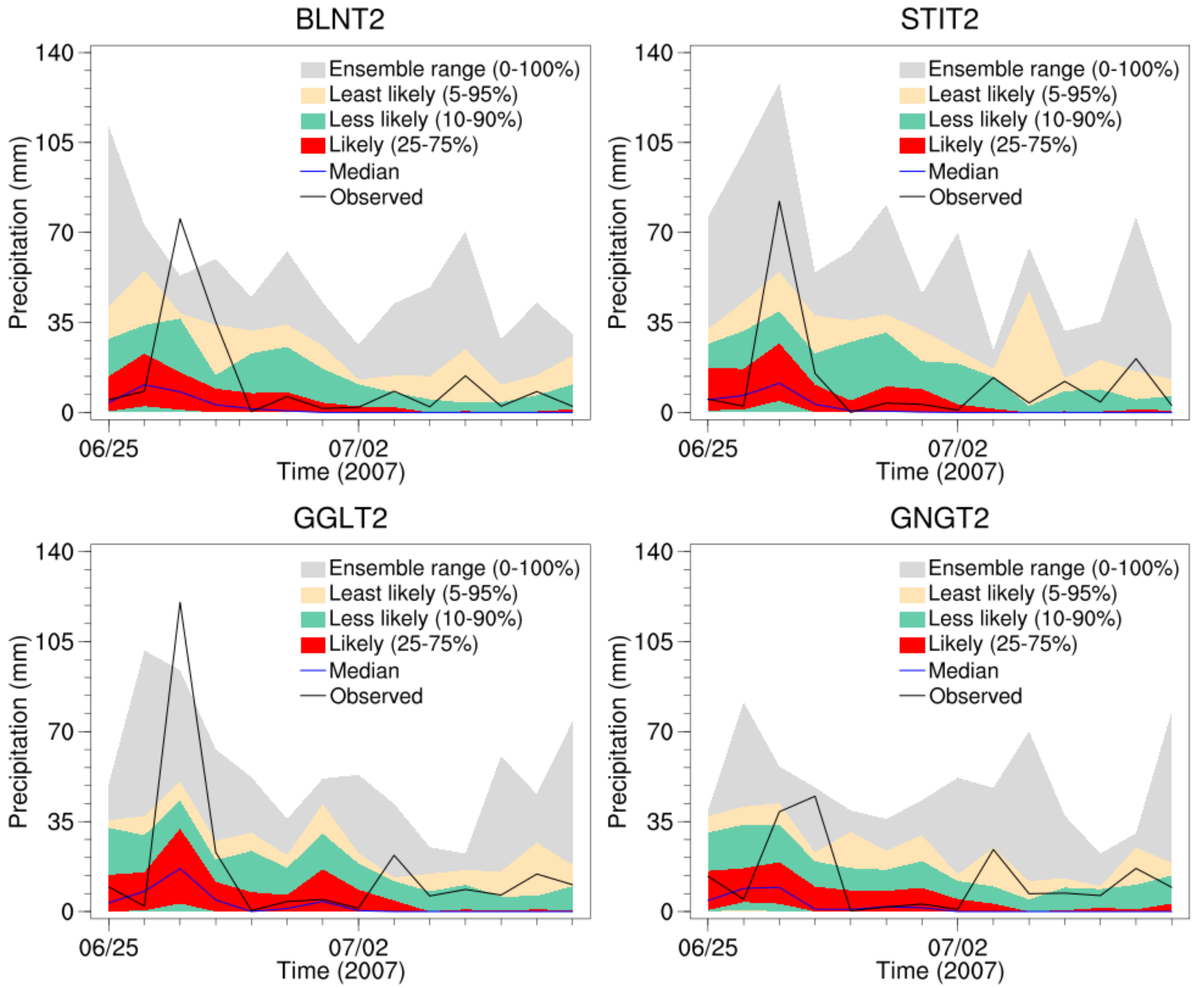

Figure 4-2: Ensemble precipitation forecasts from MEFP and observation at watersheds upstream of the four reservoirs in central Texas FIRO Pilot.

Figs. 4-3 – 4-10 show the hindcasts produced using the default and updated parameter values for the June 2007 episode at the three upstream forecast points, namely GAST2, PICT2 and KEMT2, and four reservoir inlets, BLNT2, STIT2, GNGT2, and GGLT2.

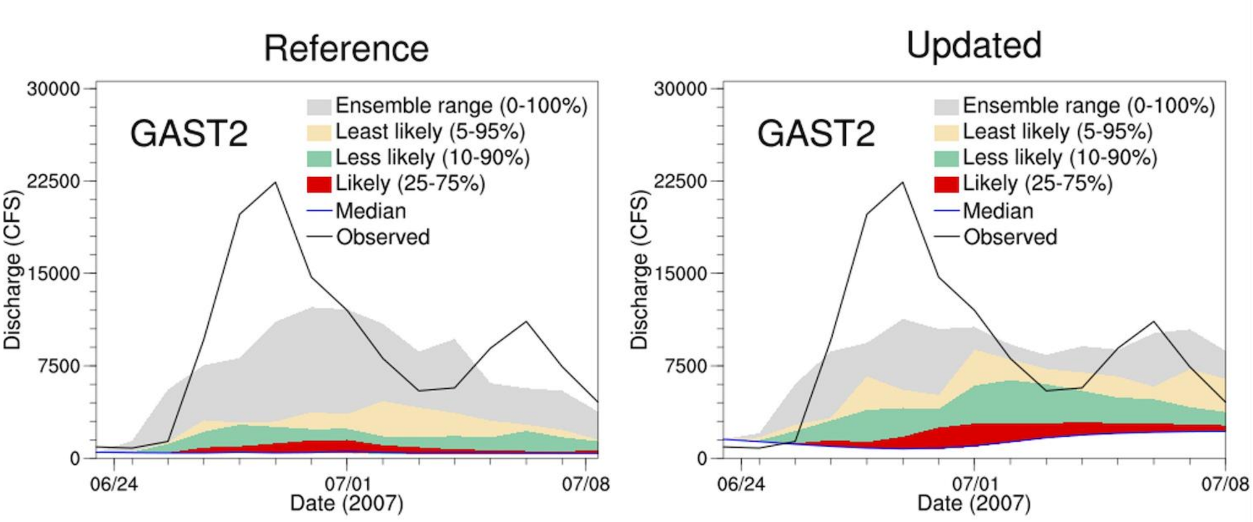

Figure 4-3: HEFS ensemble streamflow hindcasts for GAST2 issued at 0z 24 June 2007 with reference (left), and updated (right) SAC-SMA parameter values.

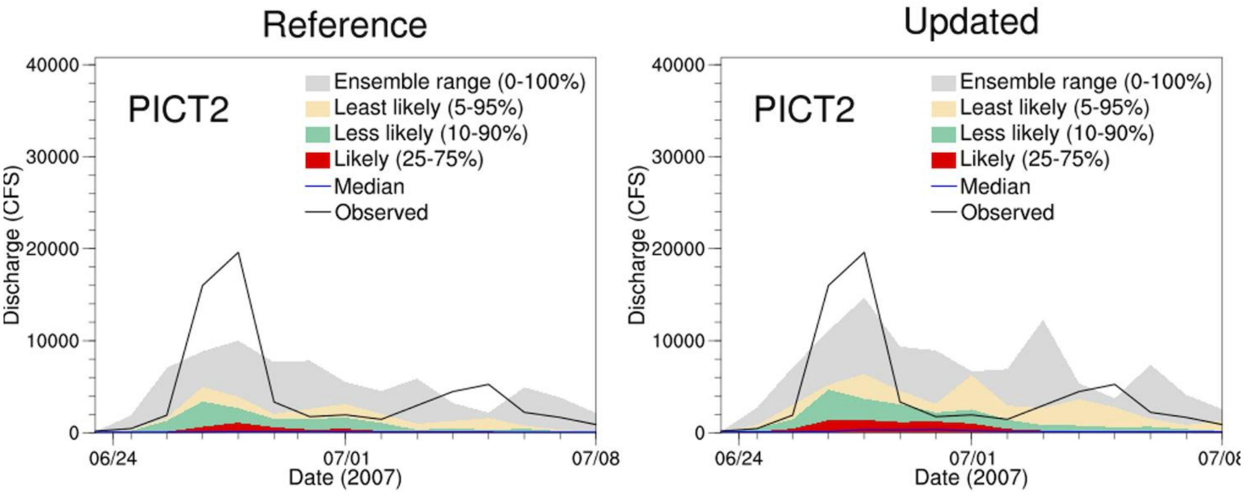

Figure 4-4: As Fig. 4-1, except at PICT2.

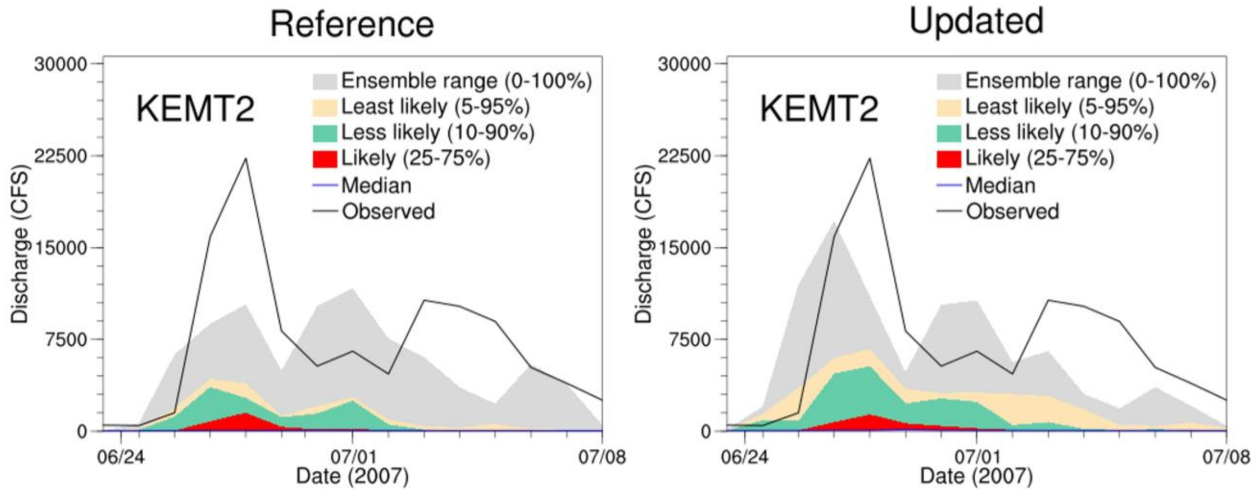

Figure 4-5: As Fig. 4-3, except at KEMT2.

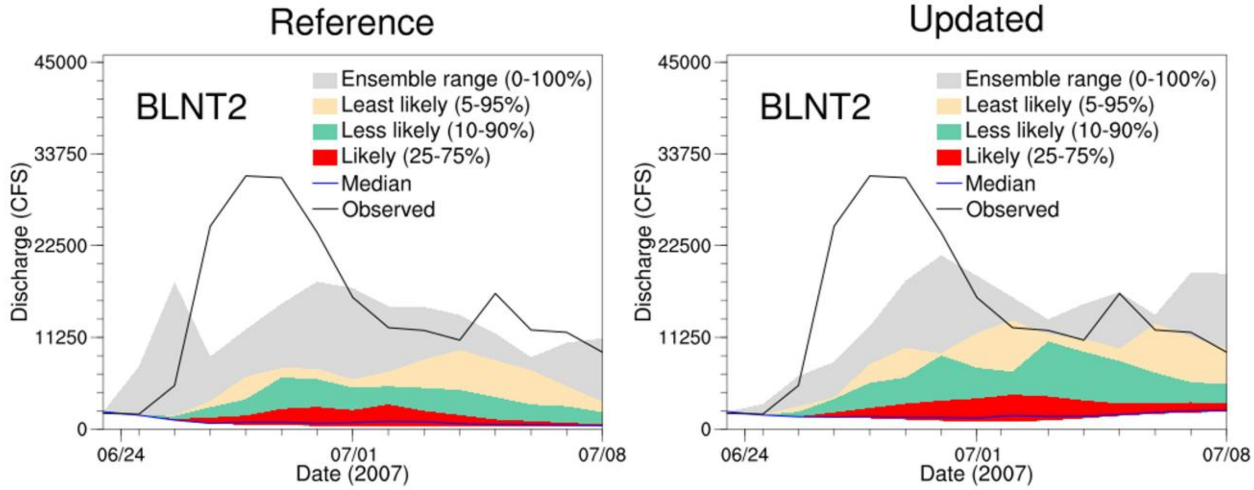

Figure 4-6: As Fig. 4-3, except for hindcasts of reservoir inflow to Belton Lake (BLNT2).

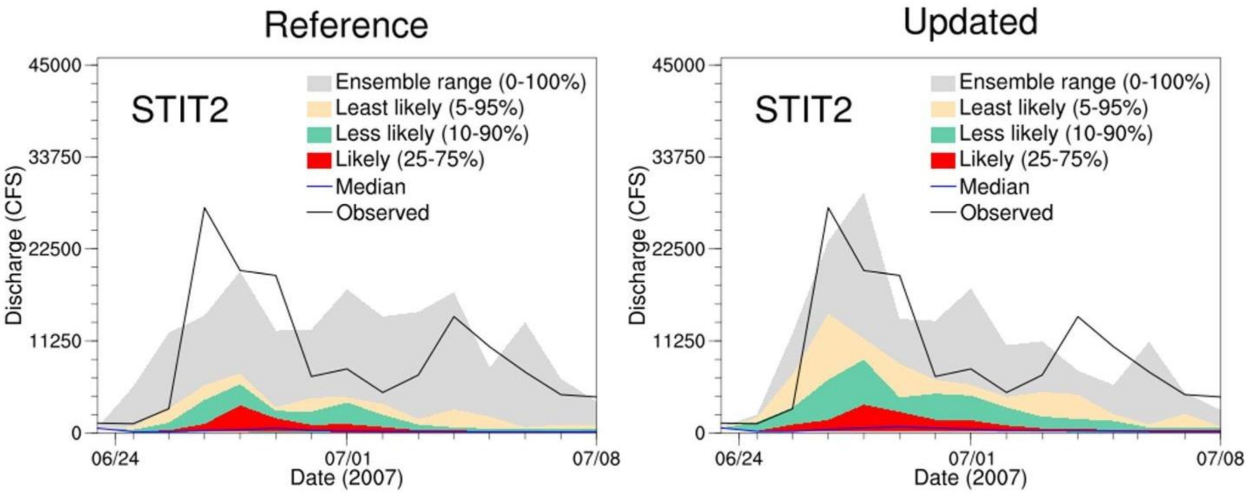

Figure 4-7: As Fig. 4-3, except for hindcasts of reservoir inflow to Lake Stillhouse Hollow (STIT2).

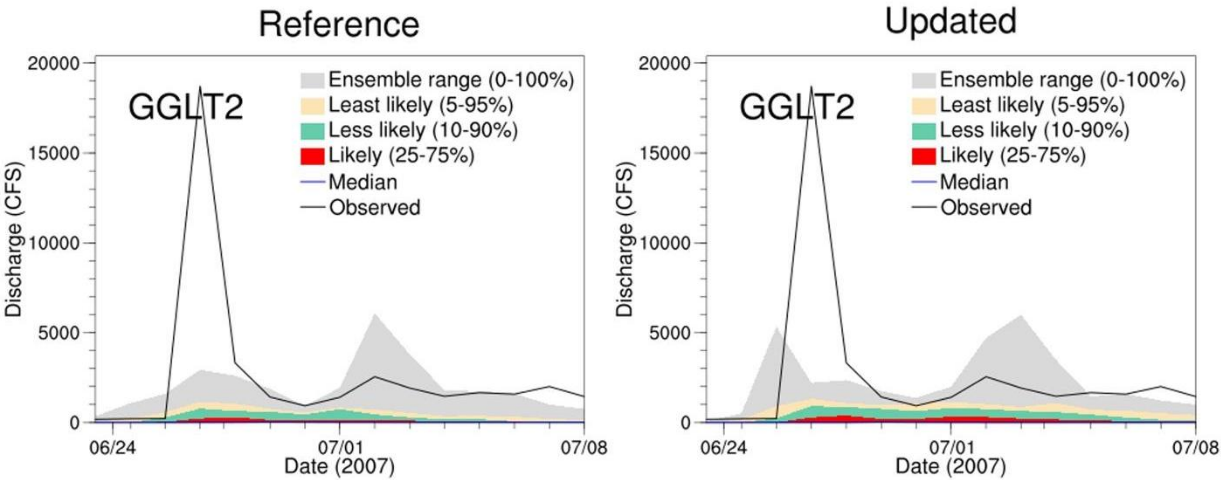

Figure 4-8: As Fig. 4-3, except for hindcasts of reservoir inflow to Georgetown Lake (GGLT2).

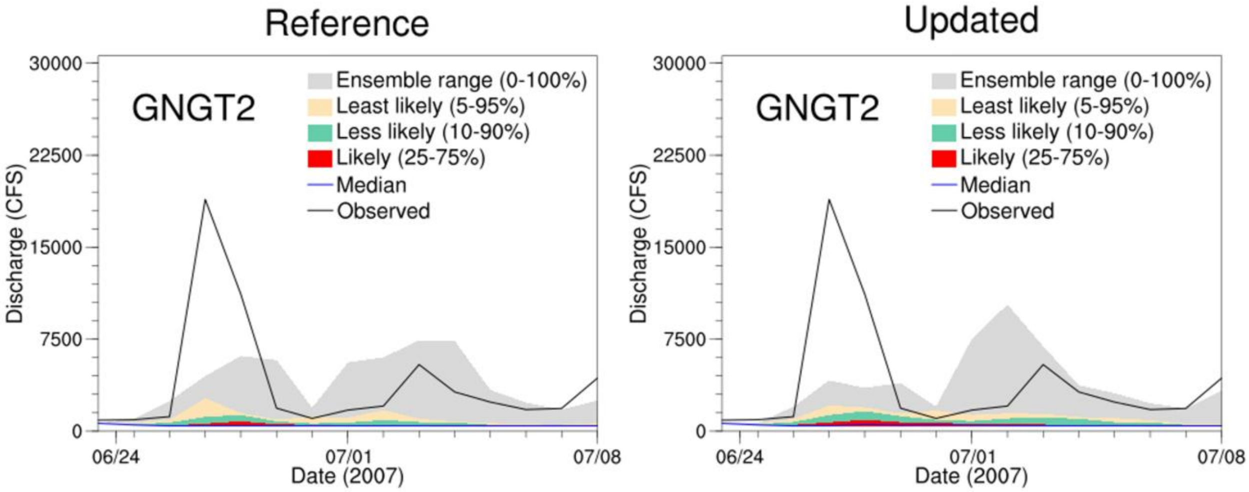

Figure 4-9: As Fig. 4-3, except for hindcasts of reservoir inflow to Granger Lake (GGLT2).

Key observations for the June 2007 event include:

- Small improvements are seen at all forecast points after the new round of calibration. The hindcasts produced with updated parameter values feature higher means and, in some cases, wider spread, slightly alleviating the negative bias evident in the hindcasts based on the parameter values from 2022 calibration.
- Among the three upstream forecast points, the improvements are rather small. Relatively speaking, the increase in mean is more evident in PICT2 and KEMT2, though the PBIAS for higher flow is overall closer to neutral at GAST2 (Tabel 2-1).
- For the reservoir inlets, largest improvements are seen at STIT2 (Lake Stillhouse Hollow). By contrast, improvements are rather minor for the remaining three reservoirs. This difference likely reflects the fact that PBIAS is closest to neutral at STIT2 for the entire period after the latest calibration (Table 2-2).

October 2018 Event

The October 2018 flooding in central Texas was produced by storm systems that formed as a result of interactions between a cold front and remnants of Hurricane Sergio that made landfall along the Pacific coast of Mexico. The maps of cumulative rainfall from observation and GEFSv12 reforecast at 3-day lead time for the October 2018 event are shown in Fig. 4-10. The rainfall maximum situated along central Texas is captured by the forecast, but the rainfall amount is severely underforecasted and the bullseye in the forecast is displaced northward.

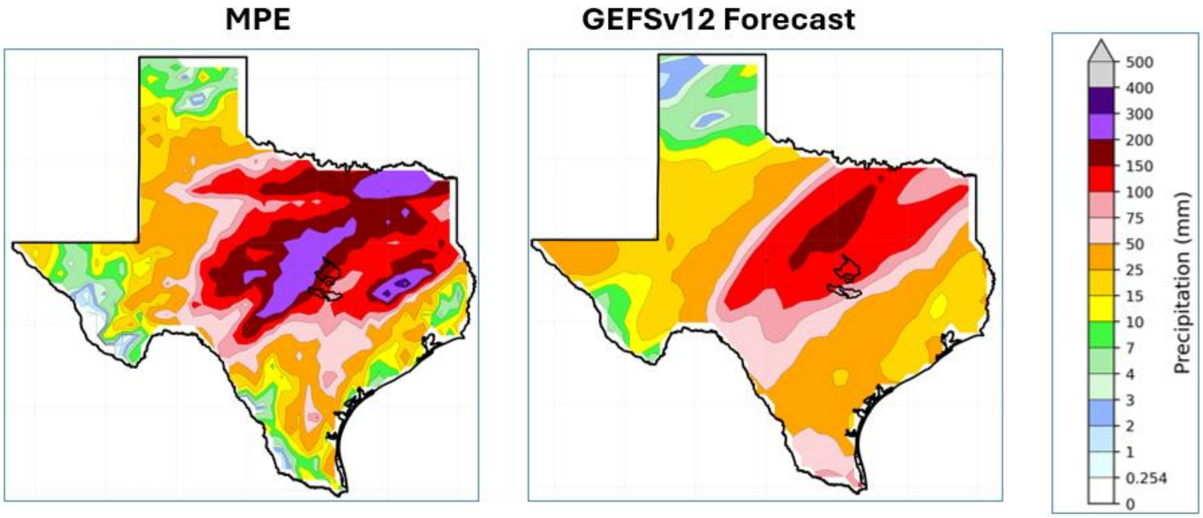

Figure 4-10: Rainfall accumulation for the 5-day window ending at 0 UTC on 16 October 2007 from NWS MPE (left) and the control run of GEFSv12 reforecast initialized at 0 UTC on 13 October 2007 (right).

The 3-day ensemble precipitation forecasts by MEFP are shown in Fig. 4-11 for the four watersheds draining to the pilot reservoirs. Again, there is a consistent, noticeable negative bias in the ensemble medians at each watershed, but broadly speaking the bias is not as severe as that for the June 2007 event.

Figs. 4-12 – 4-18 show the hindcasts produced using the default and updated parameter values for the June 2007 episode at the three upstream forecast points, namely GAST2, PICT2 and KEMT2, and four reservoir inlets, BLNT2, STIT2, GGLT2, and GNGT2.

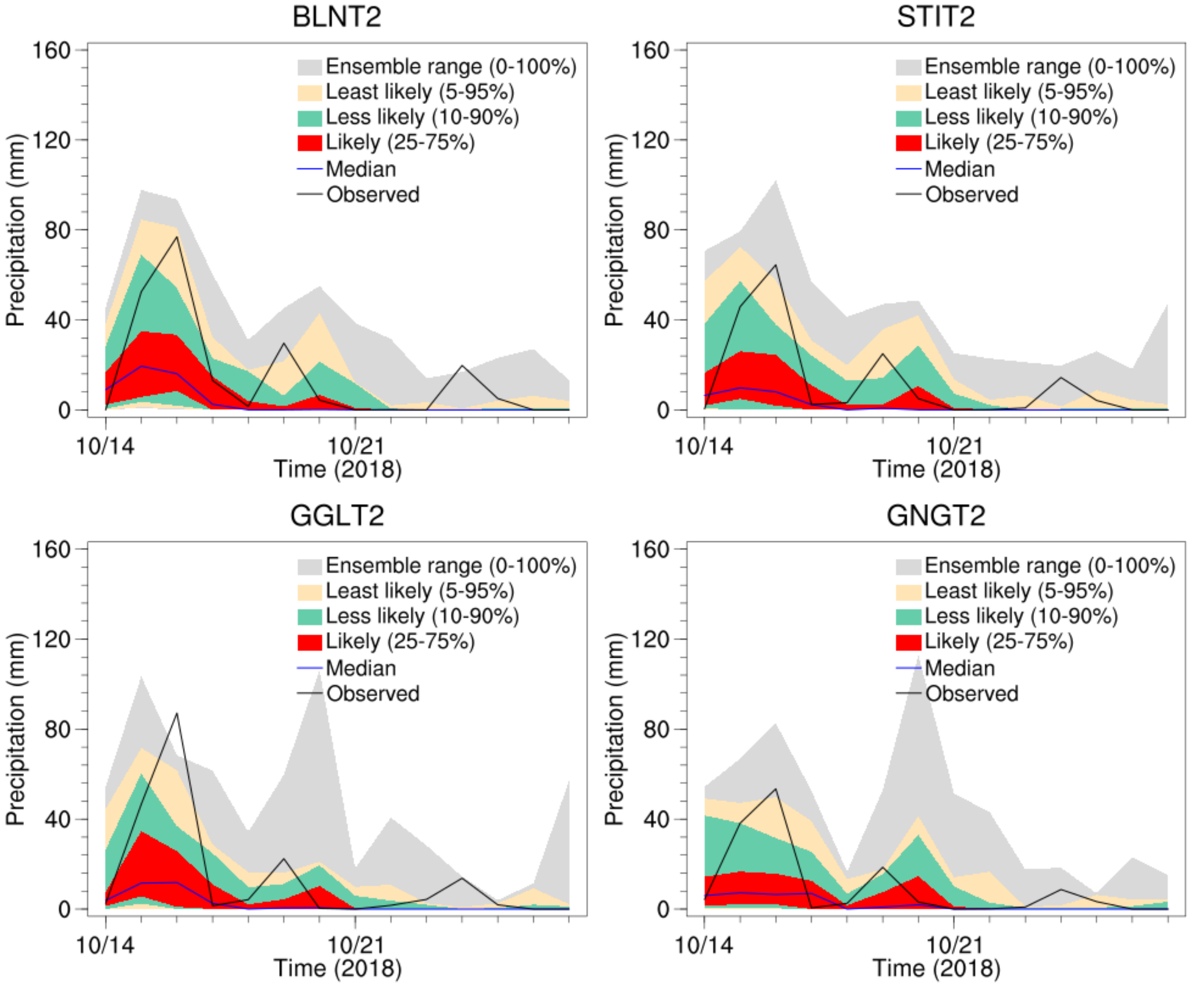

Figure 4-11: Ensemble precipitation forecasts from MEFP issued at 0UTC on 13 October 2018 for watersheds upstream of the four reservoirs in central Texas Pilot.

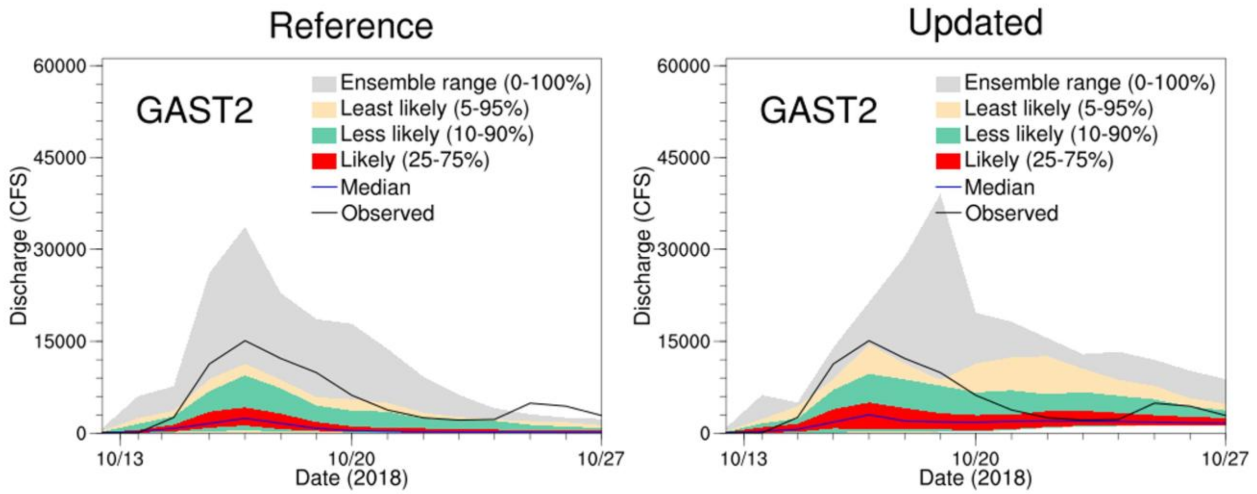

Figure 4-12: HEFS ensemble streamflow hindcasts for GAST2 issued at 0z 15 October 2018 with reference (left), and updated (right) SAC-SMA parameter values.

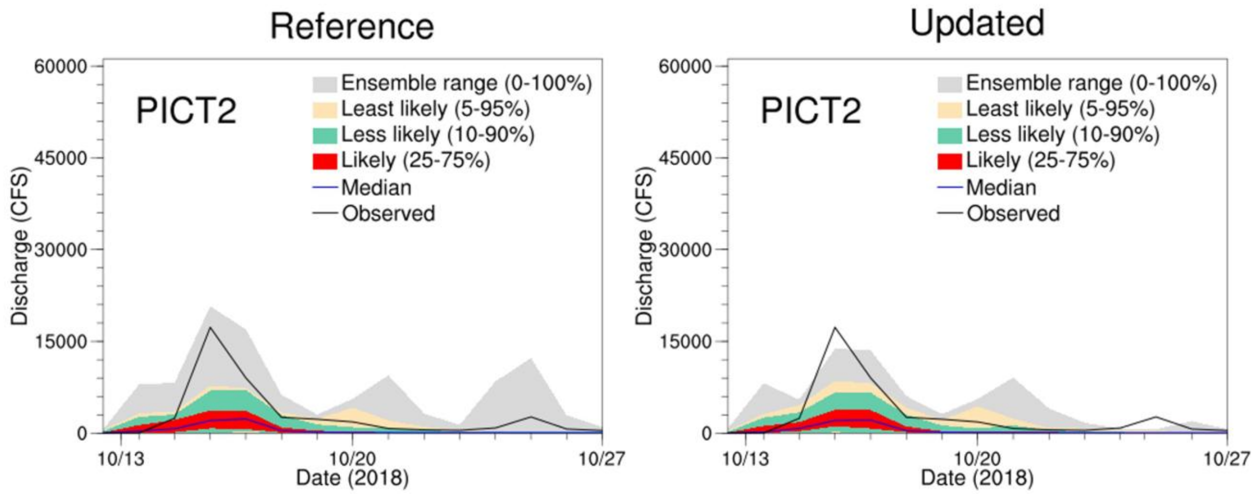

Figure 4-13: As Fig. 4-12, except for hindcasts issued for PICT2.

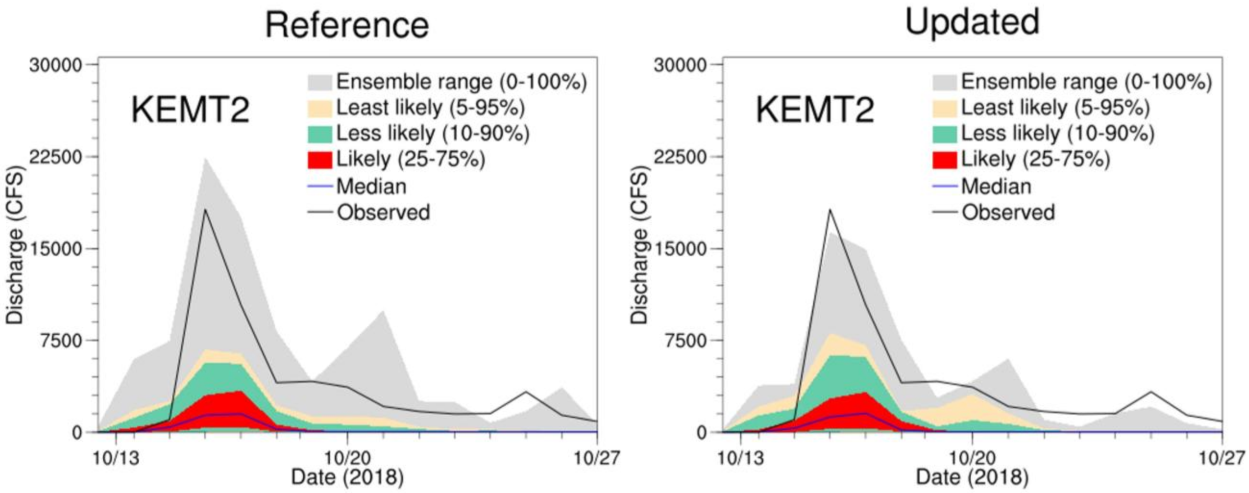

Figure 4-14: As Fig. 4-12, except for hindcasts issued for KEMT2.

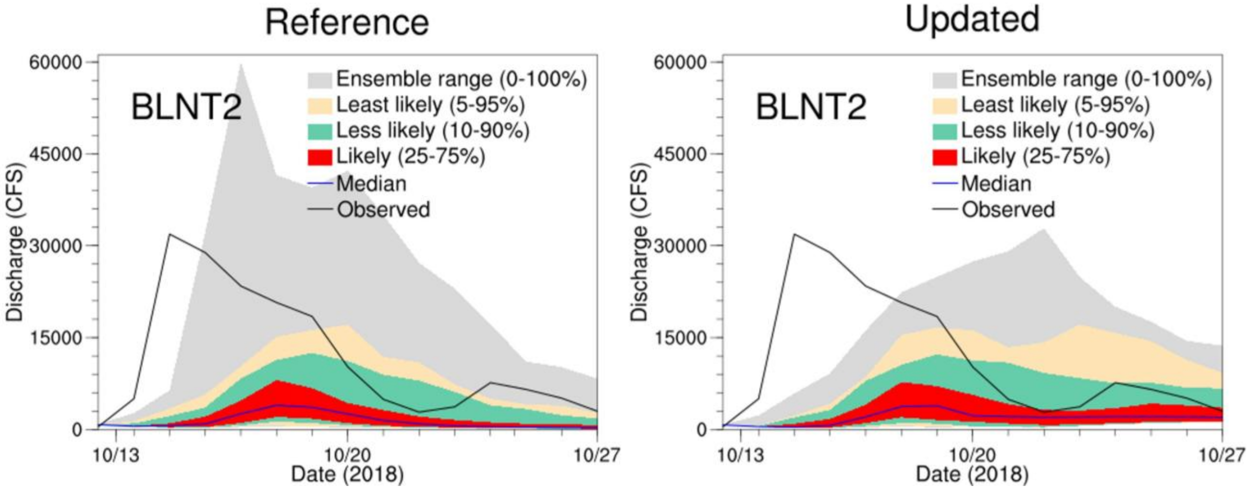

Figure 4-15: As Fig. 4-12, except for hindcasts of reservoir inflow to Belton Lake (BLNT2).

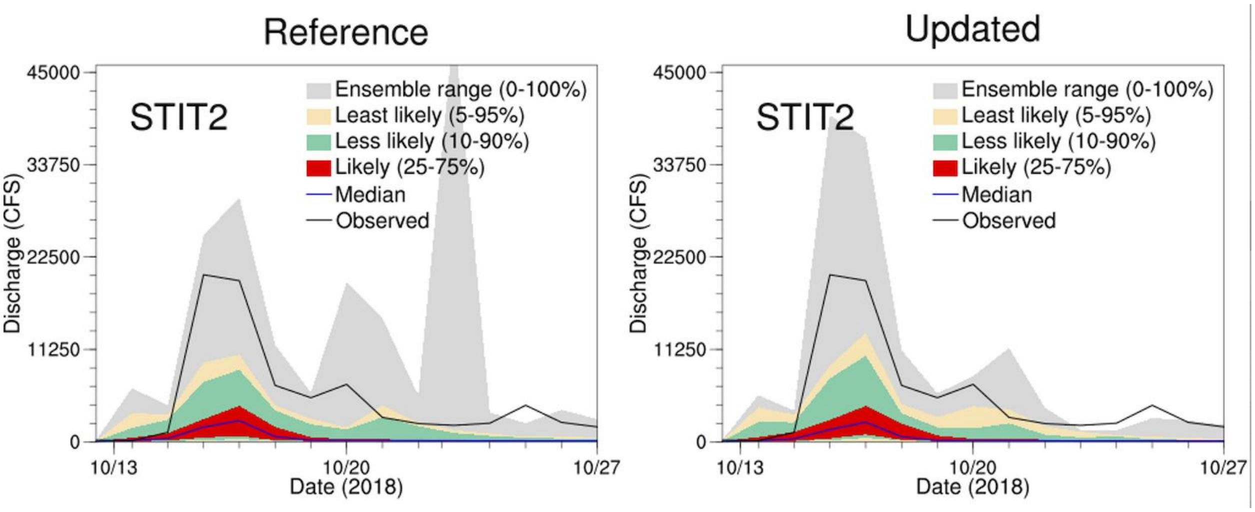

Figure 4-16: As Fig. 4-12, except for hindcasts of reservoir inflow to Lake Stillhouse Hollow (STIT2).

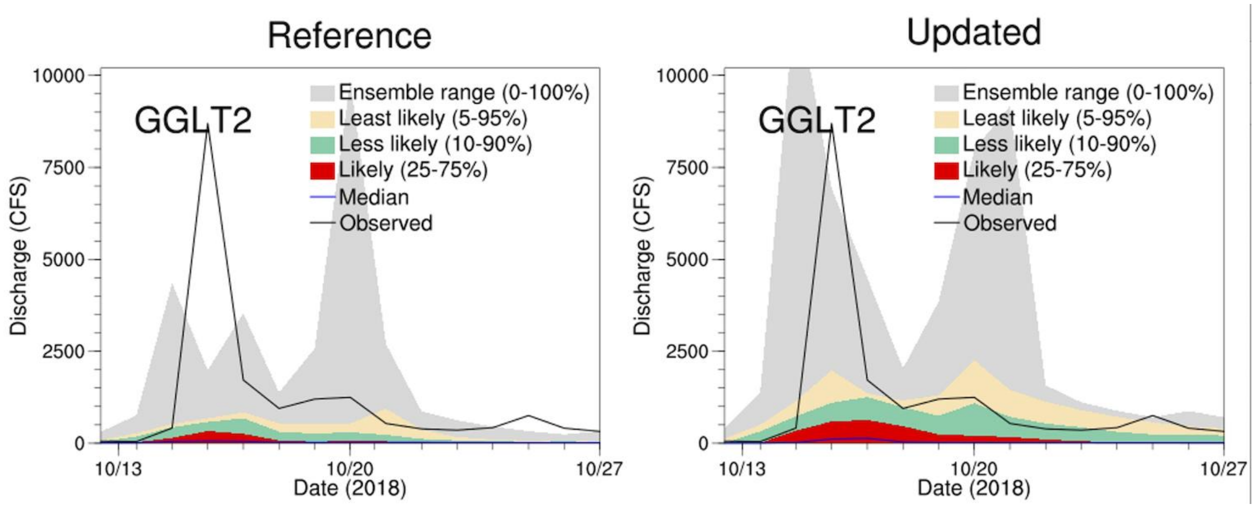

Figure 4-17: As Fig. 4-12, except for hindcasts of reservoir inflow to Georgetown Lake (GGLT2).

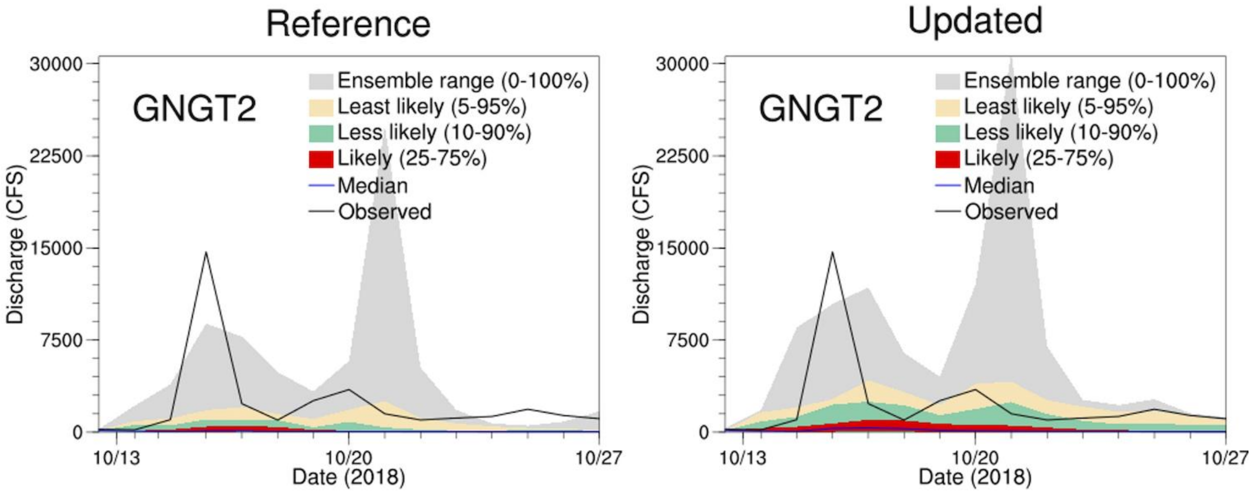

Figure 4-18: As Fig. 4-12, except for hindcasts of reservoir inflow to Granger Lake (GNGT2).

Key observations for the October 2018 event include:

- Similar to what was observed for the June 2007 event, small improvements in forecast bias for the October 2018 event are seen at a majority of forecast points after the new round of calibration. However, it is worth noting that at a minority of forecast points, namely PICT2, KEMT2 and BLNT2, the forecast bias deteriorates and the spread contracts.
- The improvements are most pronounced at STIT2, where latest calibration helped suppress a secondary peak at around October 23. At GGLT2 and GNGT2, however, latest calibration results in artificially wide ensemble spread over October 20-22, though the bias for the earlier peak at around October 15-18 is improved.
- There is a large phase difference between observed inflow and HEFS forecasts at BLNT2, with the former preceding the latter by about 5 days. It is unclear what gave rise to this discrepancy as precipitation forecasts were able to reasonably resolve the early spike over 13-14 October. Further analysis of model response at different tributaries that contribute to Belton Lake will be necessary.

5. Assessment of MMGD and CBPR Postprocessed PQPFs

Basics of CBPR

The negative biases in part arise from the intrinsic tendency of the default parameter estimation scheme of MMGD to reduce the forecast precipitation amounts (Wu et al., 2011; Zhang et al., 2017; Kim and Seo, 2025). In essence, the parameter estimation scheme assumes that the pair of normal quantile transformed forecast (Z) and observation (W) follow a bivariate normal distribution. With this assumption, W and Z can be expressed with the following regression relationship:

$$W = \rho Z + \varepsilon$$

where ρ is Pearson's correlation between W and Z, and ε is an error term that follows zero-mean normal distribution. It is evident that any estimate of observations from this regression equation will be lower than the forecast in the mean sense:

$$E[W] = \rho E[Z]$$

In reality, the bivariate normality assumption rarely holds, and as a result the regression equation using empirically estimated ρ is often a poor approximation of W and Z relationships. Indeed, earlier works reveal that Type-II conditional bias of postprocessed forecast, defined below as the difference between the forecast and observation conditional on observation, is consistently negative.

$$E_w[\widehat{W} - Z \big| W = w]|_{\forall w > 0} < 0$$

The conditional bias tends to be more severely negative approaching the upper tail of z.

This limitation of MMGD has been long recognized by the developers of HEFS. Wu et al. (2011) documented a more generalized form of MMGD which relaxes the assumption of bivariate normality, and instead uses a simple linear regression to relate an approximation of W, denoted as U, with raw forecast Z, i.e.:

$$U = bZ + \theta$$

where b is the regression coefficient and θ is the error term. It can be shown that θ still follows a zero-mean normal distribution $\theta \sim N(0, \sigma_\theta)$, and the standard error takes the form of $\sigma_\theta = 1 + b^2 - 2b\rho\sigma$. Rather than imposing Pearson correlation ρ as the slope of the regression line, this scheme provides freedom to relate U and Z.

Kim and Seo (2025) demonstrated that the regression relationship can be established through a technique that explicitly accounts for a quadratic form of Type-II conditional bias (CB): $E\left[\left\{E_w\left[\widehat{U} - Z|W = w\right]\right\}^2\right]$. The estimation of b is performed by minimizing a hybrid penalty function that includes the variance term and a weighted CB term, namely:

$$J = E\left[\left(\widehat{U} - W\right)^2\right] + \lambda CB$$

The role of CB can be finessed through adjusting the weight λ. Note that Seo (2013) was the first to explore the use of this hybrid penalty function in the context of spatial interpolation of precipitation products. Kim and Seo (2025) used the term Conditional Bias Penalizing Regression (CBPR) to describe the new estimation scheme. Earlier comparisons of PQPFs and postprocessed ensemble QPFs confirm the robustness of this approach in mitigating the conditional bias introduced by MMGD (Fig. 1-4).

Originally developed in the 2010s, the CBPR has been implemented recently into the baseline of HEFS by OWP. Kim and Seo (2025) performed a more extensive assessment for pilot basins across the Conterminous US, including several in the service area of WGRFC, and found varying degrees of improvements to the reliability of postprocessed ensemble QPFs. It is worth noting, however, that none of the basins in the Texas FIRO Pilot was covered in the assessment. As the negative conditional bias has been brought to fore in foregoing FIRO investigation, there is an impetus to perform more detailed analysis of the CBPR to determine its operational potential.

We implemented gridded versions of both the default parameter estimation scheme of MMGD and CBPR. Unlike the operational scheme embedded in the MEFP that performs parameter estimation using forecasts and observations of mean areal precipitation at each basin, the gridded schemes operate on the forecast-observation pairs at each ¼ degree grid. In order to reduce the impacts of spatial mismatch between forecasts and observations, we adopt the approach of Scheuerer and Hamill (2015) by forming a super-ensemble at each grid that comprises forecast-observation pairs at all grids within a 1-degree radius of the current one. The means of the forecasts and observations from the super-ensemble are then fed to each scheme to produce two sets of parameter values for the MMGD.

Hindcasts and Evaluation

We employ a six-fold cross-validation strategy to produce and evaluate the PQPFs produced using the default MMGD and CBPR schemes along with the raw quantitative precipitation forecasts (QPFs) from the GEFS -version 12 (GEFSv12). In this strategy, the 20 years of forecast-observation pairs are grouped into six contiguous blocks (folds), each 3 years in length. As illustrated in Fig. 5-1, the cross-validation is done six times. In each time, forecast-observation pairs from five out of the six folds are used for training and those for the remaining fold are for validation. The training is done either using the default parameter estimation scheme of MMGD, or CBPR.

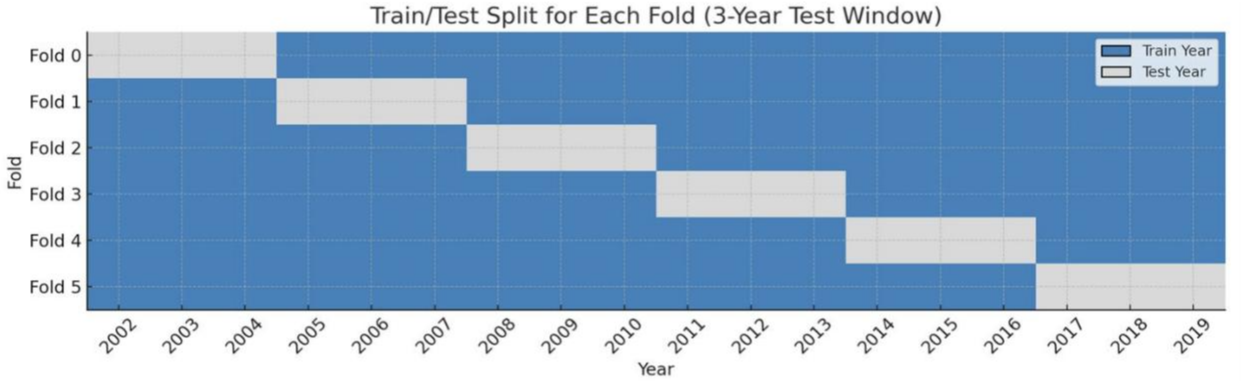

Figure 5-1: Schematic of the six-fold cross-validation.

Prior to the cross-validation experiment, both the GEFSv12 QPFs and a gridded precipitation analysis, namely the Analysis of Record for Calibration (AORC; Kitzmiller et al., 2018) were interpolated onto ¼ degree grid mesh. For each grid, a super-ensemble is constructed from GEFS ensemble forecast over an expanded spatial domain surrounding the target grid with a 1-degree radius. A weighted mean of the super-ensemble forecast is computed, where the inverse of distance to the center point serves as the weight. This forecast means and coincident AORC analyses are then used to construct the MMGD using either the default of the CBPR schemes. The MMGD thus constructed then undergoes validation in which the GEFSv12 QPF is fed to the

MMGD to produce the PQPFs conditioned on the forecast for the validation fold, and the PQPFs are evaluated using AORC analyses. Metrics of the evaluation include Continuous Ranked Probability Score (CRPS) and its Skill Score (CRPSS), Brier Score (BS) and Brier Skill Score (BSS), Reliability diagram, Receiver Operating Characteristic (ROC), and bias. Definitions of these metrics are provided below.

$$CRPS\ (F, x) = \int_{-\infty}^{\infty} (F(y) - I(y - x))^2 dy$$

Where F(y) is the cumulative density function (CDF) of predictive distribution; y is the threshold value for the forecast variable x; and I() is the Heaviside function that takes 1 once y exceeds x and 0 otherwise.

CRPSS is the complement of the ratio of the CRPS for the ensemble forecast being evaluated, $CRPS_{forecast}$, and the climatological distribution $CRPS_{climat}$.

$$CRPSS\ = 1 - \frac{CRPS_{forecast}}{CRPS_{climat}}$$

Brier Score (BS) is defined as the mean difference between forecast probability and occurrence of an event, namely,

$$BS\ (F, x) = \frac{1}{N} \sum_{i=1}^{N} (F(y) - I(y - x))^2$$

Brier Skill Score is defined to gauge the skills of an ensemble forecast suite relative to a reference forecast suite, e.g., climatology, i.e.:

$$BSS\ = 1 - \frac{BS_{control}}{BS_{reference}}$$

Where $BS_{control}$ is and $BS_{reference}$ are Brier Score for the control and reference forecast suites. A reliability diagram is a plot of frequency of observations above a given threshold within a subsample, for which the forecast probability exceeding (or below) the threshold equals a prescribed value. It characterizes under or overconfidence in the forecast.

Receiver Operating Characteristic (ROC) is a plot of true positive rate (TPR) against false alarm rate (FAR) for a prescribed threshold. It characterizes discrimination skills of forecasts. Originally developed for deterministic forecasts, it can be adapted to ensemble forecasts by averaging the TPR and FAR for each ensemble member. Just like BSS, a ROC score can be defined for a control forecast suite against a reference forecast:

$$ROC\ score = 1 - \frac{ROC_{control}}{ROC_{reference}}$$

Fig. 5-2 presents the comparisons of CRPSS computed for the GEFS raw forecasts and for postprocessed PQPFs based on the default parameter estimation scheme of MMGD and CBPR. Among the three forecast suites, the raw GEFSv12 forecasts feature the lowest CRPSS, which is above zero for lead time of day 1-4. MMGD performs the best and is followed by CBPR.

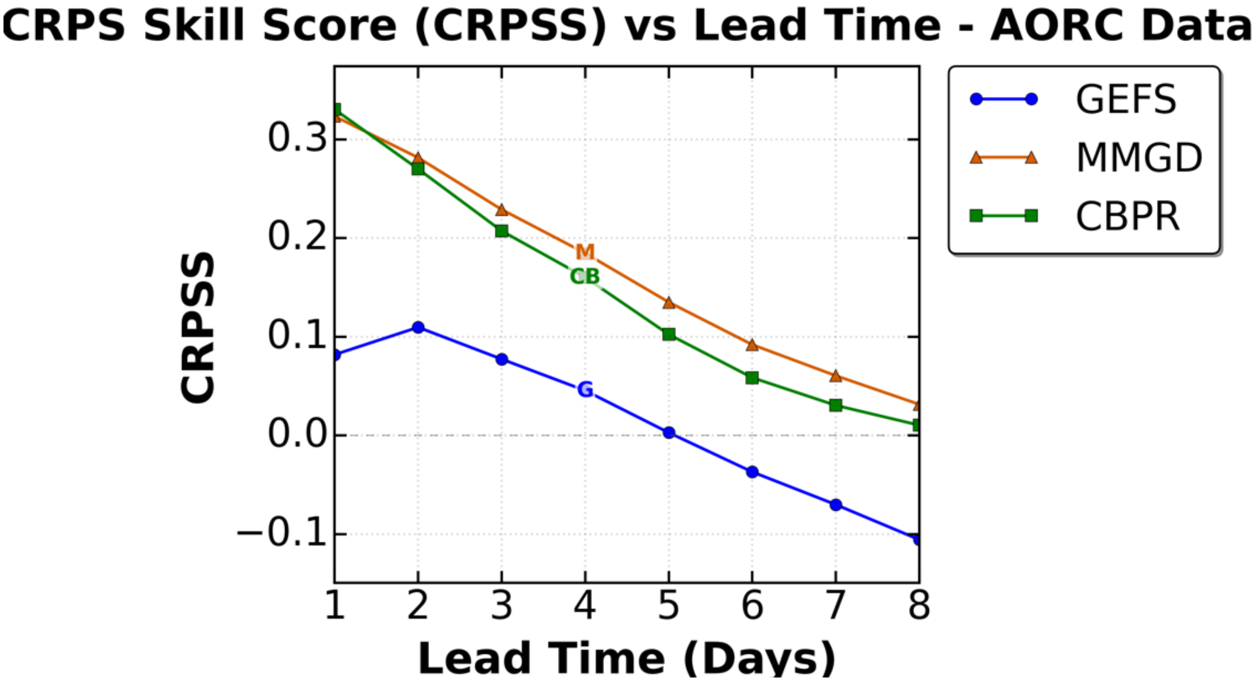

Figure 5-2: CPRSS of ensemble QPFs/PQPFs against lead time. Shown are CPRSS values computed for GEFS raw forecasts, and those for postprocessed PQPFs based on the default MMGD parameter estimation scheme and CBPR. The reference forecast is climatology.

Figs. 5-3 and 5-4 show the BSS for the three forecast suites computed using 25mm/day (moderate) and 90mm/day (heavy) thresholds. The results are largely consistent with those for CRPSS. Notable observations include the following:

- Postprocessed PQPFs using the default parameter estimation scheme and CBPR both widely outperform raw GEFSv12.
- CBPR slightly outperforms default MMGD for the first two days, but tends to underperform at longer lead times.
- Forecast skills decline with increases in precipitation thresholds. At the 25mm/day threshold, GEFSv12 raw forecasts are more skillful than climatology to day 5, whereas at 90mm/day threshold, the forecast skills diminish at day-3 lead and beyond.

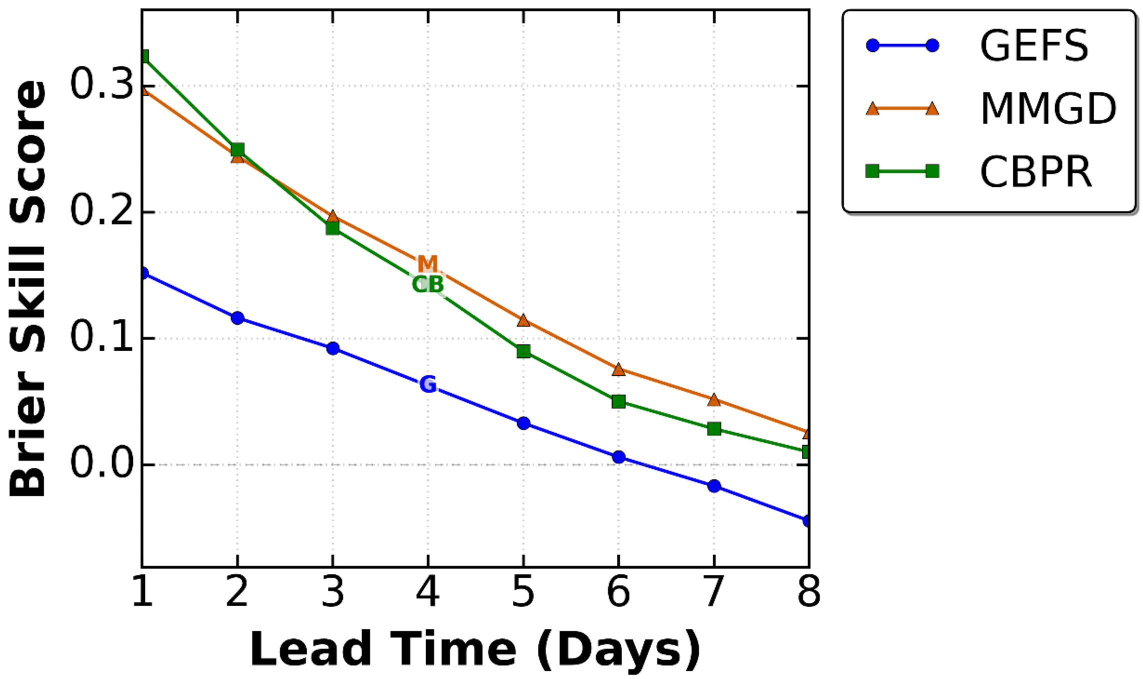

Figure 5-3: BSS of ensemble QPFs/PQPFs against lead time. Shown are BSS values computed using 25mm/day threshold for GEFS raw forecasts, and those for postprocessed PQPFs based on the default MMGD parameter estimation scheme and CBPR. The reference forecast is climatology.

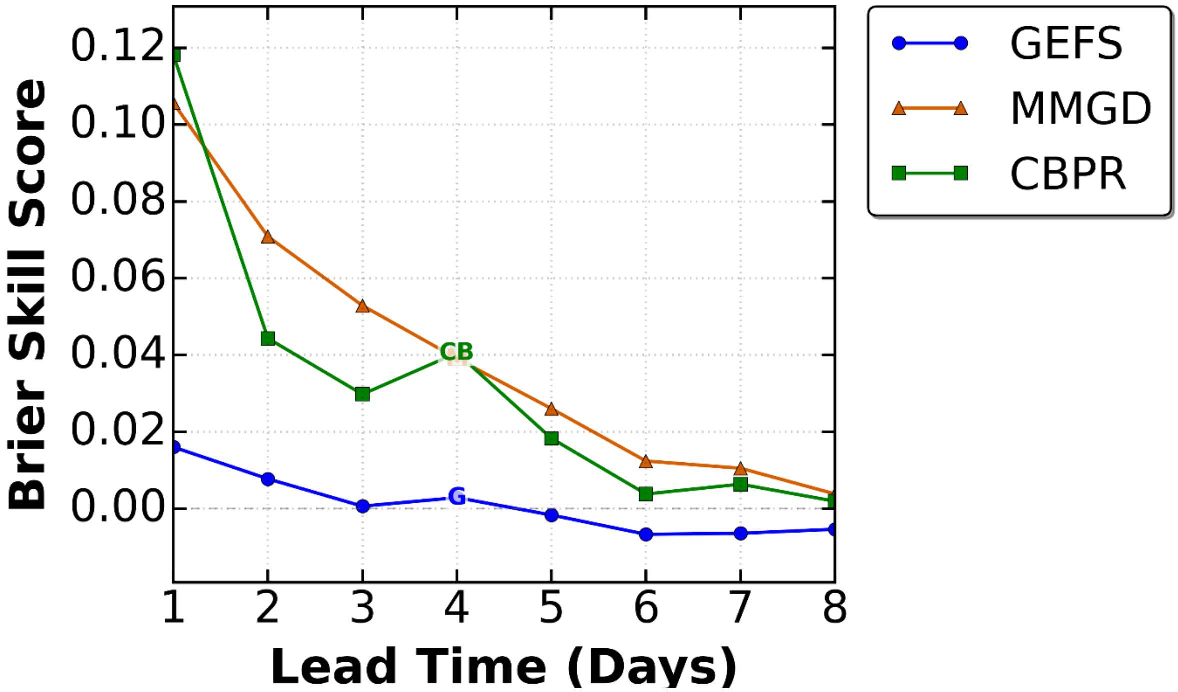

Figure 5-4: As Fig. 5-3, except at threshold of 90mm/day.

Figs. 5-5 and 5-6 show the ROC curves at day-1 and day-3 leads. Table 5-1 summarizes the area under the ROC curve for each forecast suite at day 1, 3 and 5 leads.
The following observations are evident:

- Raw GEFSv12 forecasts feature discernible discrimination skills at the lower threshold 25mm/day) for both day-1 and day-3 leads, but at the higher threshold (90mm/day), the discrimination skills become marginal (close to 0.5).
- Postprocessed PQPFs produced using MMGD based on the default scheme and CBPR both outperform GEFS in discrimination skills. The two schemes perform largely comparably, though it appears that CBPR slightly underperforms the default scheme at day-3 and day-5 leads.
- CBPR only outperforms MMGD at day-1 lead and above the 90 mm/day threshold.

Table 5-1: Area under the ROC curves for raw GEFS QPFs and postprocessed PQPFs.

Lead Time [day]	**Threshold [mm]**	**Area Under Curve**			**Best**
		GEFS	**CBPR**	**MMGD**	
1	25	0.664	0.937	0.937	MMGD/CBPR
1	60	0.547	0.952	0.952	MMGD/CBPR
1	90	0.522	0.965	0.964	CBPR
3	25	0.647	0.918	0.922	MMGD
3	60	0.54	0.927	0.932	MMGD
3	90	0.513	0.937	0.941	MMGD
5	25	0.617	0.866	0.874	MMGD
5	60	0.531	0.874	0.886	MMGD
5	90	0.511	0.884	0.897	MMGD

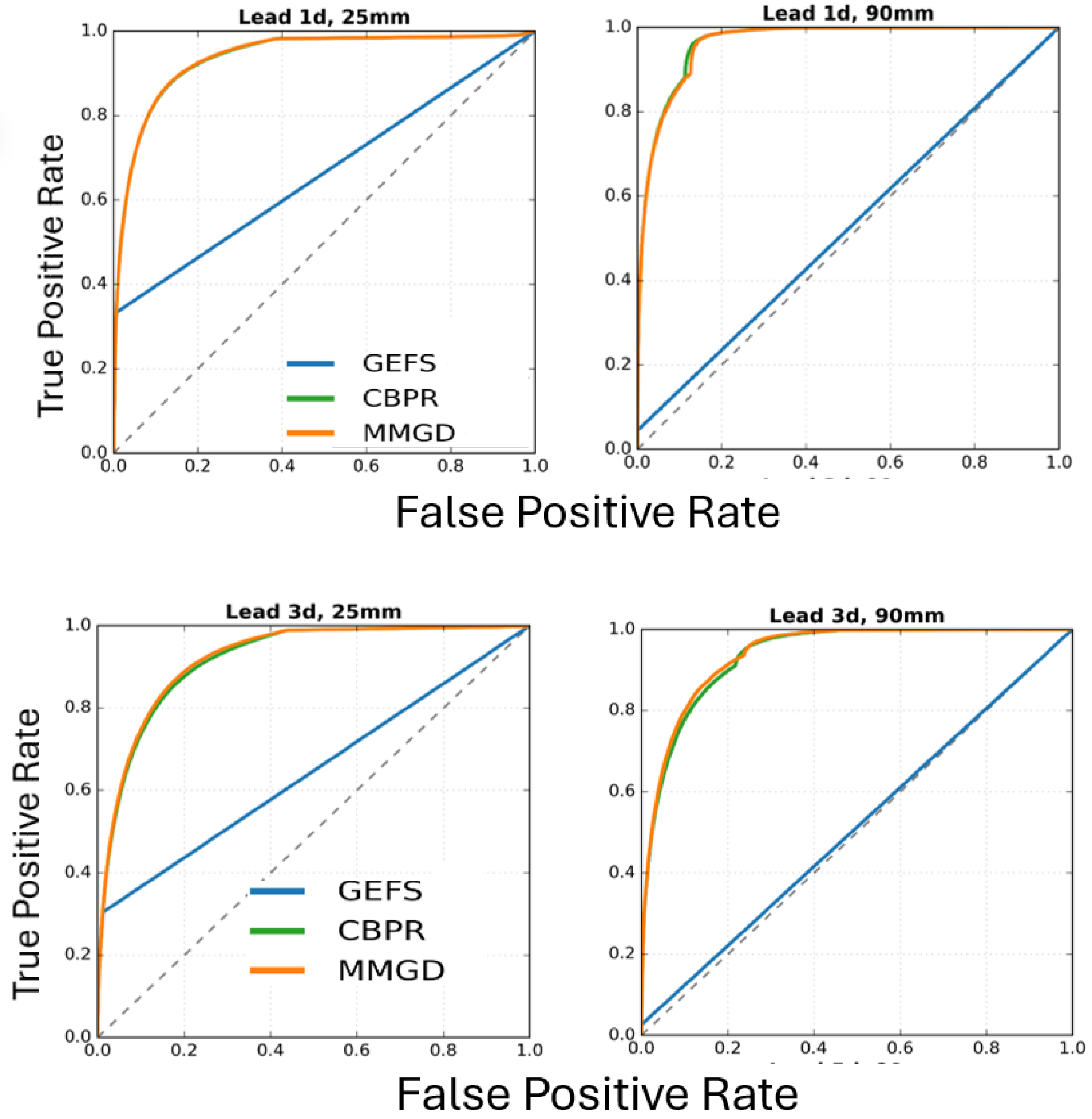

Figure 5-5: ROC computed for GEFSv12 raw forecasts, and postprocessed PQPFs based on default parameter estimation scheme and CBPR, at 1-day lead and 25mm/day threshold (top left); 1-day lead and 90mm/day threshold (top right); 3-day lead and 25mm/day threshold (bottom left) and 3-day lead and 90mm/day threshold (bottom right).

Fig. 5-6 shows the reliability diagrams for PQPFs based on MMGD and CBPR at day-1 and day-3 leads above 25 mm/day and 90 mm/day thresholds. The following observations are evident.

- Broadly speaking, MMGD PQPFs based on the default scheme tend to underforecast at both the low and high thresholds and across lead times, whereas those based on the CBPR tend to overforecast, and more so at the longer lead.
- Between the two product suites, MMGD and CBPR-based forecasts tend to be comparable in reliability to the 25mm/day threshold, with CBPR underperforming at day-3 due to the severe overforecast.
- MMGD fails to produce high confidence forecasts at day-3 and above 90mm/day threshold, as evidenced by a sharp drop-off in probability above 0.4.

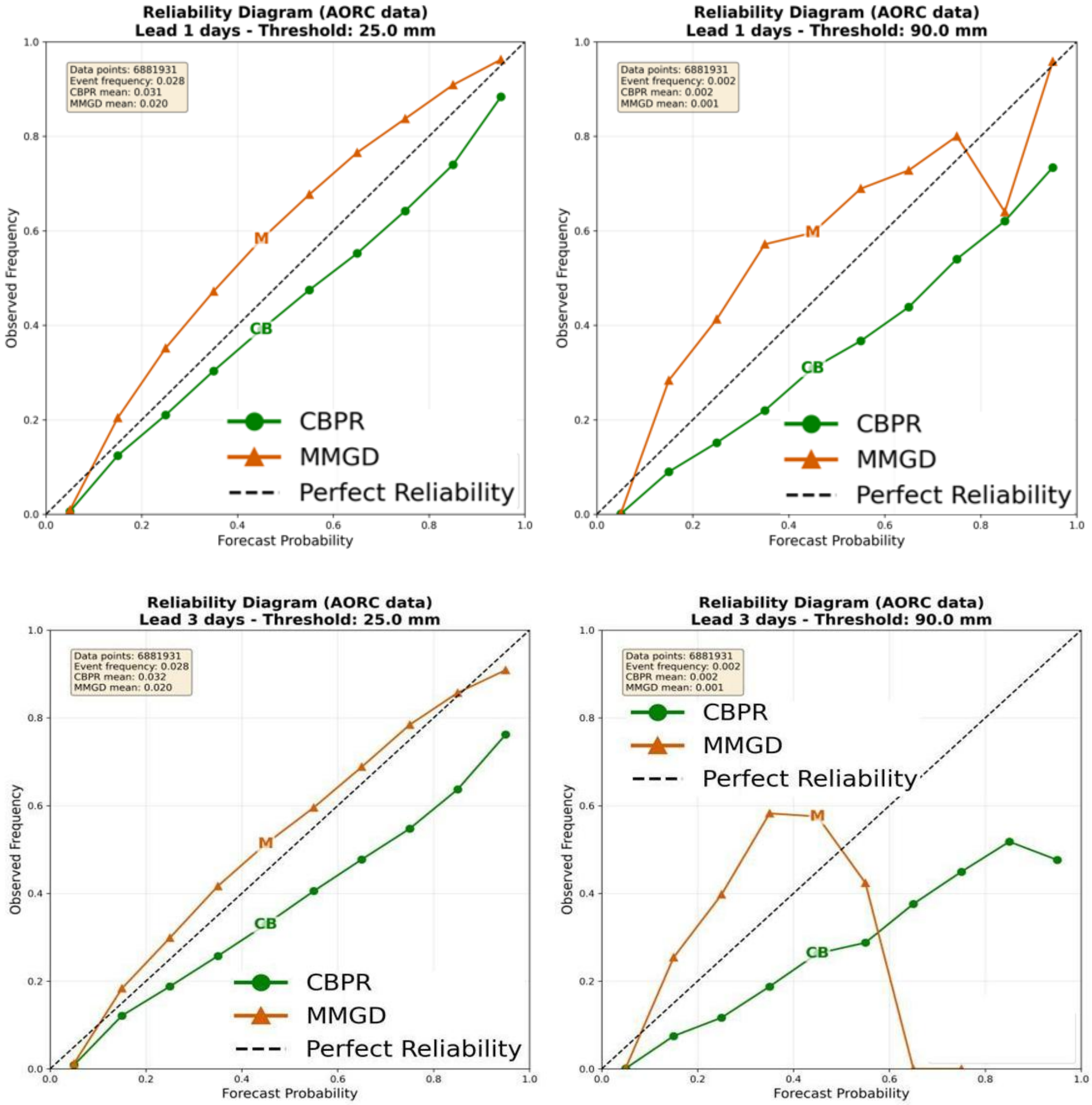

Figure 5-6: Reliability diagram for GEFSv12 raw forecasts, and postprocessed PQPFs based on default parameter estimation scheme and CBPR, at 1-day lead and 25mm/day threshold (top left); 1-day lead and 90mm/day threshold (top right); 3-day lead and 25mm/day threshold (bottom left) and 3-day lead and 90mm/day threshold (bottom right).

6. Summary and Recommendations

This project was launched as a part of the broader Texas FIRO initiative with a focus on improving HEFS forecasts in the central Brazos FIRO Pilot. An earlier investigation revealed that the HEFS forecasts exhibit severe negative bias for major inflow events. This bias is attributed to a) a tendency of the hydrologic model employed in HEFS, namely SAC-SMA, to under-predict peaks in major flood events, and b) underforecast of precipitation amounts in HEFS postprocessed ensemble precipitation forecasts. In addition, the investigation found that the joint reservoir model in the NWS CHPS, namely, RES-J, did not account for withdrawal, and this contributed to the inability of the model to reproduce severe drawdowns through drought episodes.

The present project marks an initial attempt to improve the operational HEFS and reservoir modeling system to facilitate FIRO investigations. It features three thrusts: 1) re-calibrating the SAC-SMA to improve the bias in the HEFS forecasts; 2) activating and calibrating the withdrawal in the reservoir model to better match the historical reservoir levels; and 3) experimenting with alternative, gridded ensemble precipitation postprocessing scheme to address the bias and skill deficiencies in the ensemble precipitation forecasts. Key findings include the following.

1. Generally speaking, the latest re-calibration of SAC-SMA slightly improved the bias in the simulations of major flood events at key forecast points, including the four reservoir inlets and three gauged sites upstream of Belton Lake and Lake Stillhouse Hollow. The improvements were also reflected in the ensemble hindcasts for these major events. However, it should be noted that the impacts are unevenly felt at different forecast points, and bias remains negative for a majority of forecast points for high flows in general and over major events in particular.

2. At a few sites, recalibration slightly degraded the model performance. Specifically, the hindcasts of inflow series to all four reservoirs remain severely biased over the two major flood events in June 2007 and October 2018. Recalibration yielded more pronounced improvements to hindcast biases for the latter event, most likely due to its inclusion in the calibration window (2010-2019). For the former event, the bias remains negative, and the improvements from the recalibration are marginal. At Lake Georgetown, where the June 2007 flood produced near-record monthly inflow, the ensemble mean and spread series both experienced small increases after the latest calibration that were unable to close the gap between forecasts and observations.

3. Large phase discrepancies were found between model simulations of reservoir inflows and estimates from the USACE at Belton Lake. Though the timing of simulations was likely subject to errors; errors in USACE estimates, which were based on reservoir water budget, cannot be ruled out.

4. Activating lakeside withdrawal resulted in much improved representation of drawdowns at Belton Lake, Georgetown Lake, and Granger Lake. However, the impacts were negligible at Lake Stillhouse Hollow, and the depth of drawdowns for the most severe drought events, e.g., the drought of 2011, remains underrepresented at the former three

reservoirs. The project team has not been able to determine the exact cause of the muted impacts at Lake Stillhouse Hollow.

5. Gridded PQPFs produced using MMGD (i.e., with the default formulation) and CBPR were broadly more skillful than the raw ensemble forecasts from GEFSv12 reforecasts for day 1-8. These were reflected in higher CPRS and BSS. In addition, both products exhibited higher discrimination skills as seen in the comparisons of ROC curves. Between MMGD and CBPR, the latter tends to outperform at shorter lead times (day 1-2) but underperforms at longer leads in terms of both BSS and ROC. Comparison of reliability diagrams of the two PQPF suites revealed that CBPR exhibits a consistent tendency to overforecast, where MMGD product is broadly more reliable at shorter leads and lower thresholds. However, at day 3 and above the 90mm/day threshold, MMGD was unable to produce meaningful probabilities whereas CBPR product tends to be more reliable. These observations are consistent with the design of CBPR that is to reduce Type-2 conditional bias at the upper tail at the expense of inflating amounts for small-moderate amounts.

The following recommendations are made by the project team based on the findings:

1. The modest improvements through the latest round of calibration behooves us to improve the calibration process to more thoroughly explore potential parameter combinations that would further improve in the WGRFC model simulations particularly for major flood events when negative biases persisted. At present, WGRFC staff either calibrate the models manually, or rely on external contractors to perform this task for designated locations. A more automated, streamlined calibration workflow that can expeditiously search parameter values within physically realistic bounds will greatly facilitate more frequent calibration that would meet the operational requirements.

2. The potential inaccuracy in reservoir inflow estimates based on the reservoir water balance approach requires further investigations. It is recommended that a systematic strategy is formulated to quality assure daily reservoir inflow estimates and identify situations where such estimates are deemed suspicious due to violation of assumptions of the reservoir water balance approach used in deriving the estimates. These include high wind conditions, backwater effects, and hysteresis in reservoir stage-inflow relationship. In addition, the scarcity of stream gauges surrounding the reservoirs limited the ability of WGRFC and partners to calibrate or validate model output. It is therefore recommended that additional gauges and related sensors be installed near reservoir inlets and around reservoirs to provide more specific flow information.

3. The remaining biases in RES-J after the current calibration effort warrant further investigations. It is recommended that the fidelity of lake evaporation estimates used in WGRFC operation be reviewed; such estimates are currently supplied by a proxy calculated by adjusting potential evapotranspiration with evapotranspiration demand that is typically employed in runoff simulations. In addition, confirming the realism of withdrawal amounts using archives at USACE-SWF and BRA will be necessary.

4. For FIRO analysis, the project team and WGRFC need to determine the operational scenarios where it is advantageous to deploy the alternative RES-J parameter table that enables the seasonal guide curve, e.g., over the summer or during a drought event where inflow diminishes. It is also important to assess the impacts of integrating the alternative RES-J parameter table on prediction of high flow episodes to reduce potential degradations to operation.

5. The gridded CBPR implemented by the project team was employed to produce PQPFs, which underwent evaluations against those produced by a gridded MMGD. These schemes have not been used to produce ensemble precipitation or streamflow forecasts, as doing so requires the implementation of a sampling algorithm and a gridded version of Schaake Shuffle, which was out of the scope of this project. As these algorithms are being implemented in a parallel effort, it is recommended that both gridded MMGD and CBPR be further assessed against the operational, basin-based schemes to determine the skills in the ensemble precipitation and streamflow forecasts. In addition, alternative contemporary schemes such as Censored Shift Gamma Distribution (Scheuerer and Hamill 2015; Zhang et al., 2017) and variants (Ghazvinian et al., 2021, 2022) should be included in future evaluation for skills in resolving heavy to extreme precipitation. It is worth noting that the basin-based CBPR has been implemented within HEFS and undergone initial assessments at OWP. A four-way comparison among gridded and basin-based MMGD and CBPR schemes is therefore warranted, and the emphasis should be placed on heavy precipitation events with large spatial displacement errors. Due to the clear tendency of CBPR to overforecast, it is key to incorporate events foreseen by GEFS forecasts rather than those that did occur in the evaluation to determine the concept of operation for the alternative schemes.

Acknowledgement

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References

Burnash, R.J., 1973. *A generalized streamflow simulation system: Conceptual modeling for digital computers*. US Department of Commerce, National Weather Service, and State of California, Department of Water Resources.

Clark, M., Gangopadhyay, S., Hay, L., Rajagopalan, B. and Wilby, R., 2004. The Schaake shuffle: A method for reconstructing space–time variability in forecasted precipitation and temperature fields. *Journal of Hydrometeorology*, *5*(1), pp.243-262.

Demargne, J., Wu, L., Regonda, S.K., Brown, J.D., Lee, H., He, M., Seo, D.J., Hartman, R., Herr, H.D., Fresch, M. and Schaake, J., 2014. The science of NOAA's operational hydrologic ensemble forecast service. BAMS , 95(1), pp.79-98.

Ghazvinian, M., Zhang, Y., Seo, D.J., He, M. and Fernando, N., 2021. A Novel Hybrid Artificial Neural Network-Parametric Scheme for Postprocessing Medium-Range Precipitation Forecasts. Advances in Water Resources, p.103907.

Ghazvinian, M., Zhang, Y., Hamill, T.M., Seo, D.J. and Fernando, N., 2022. Improving probabilistic quantitative precipitation forecasts using short training data through artificial neural networks. *Journal of Hydrometeorology*, *23*(9), pp.1365-1382.

Gupta, H.V. and Kling, H., 2011. On typical range, sensitivity, and normalization of Mean Squared Error and Nash-Sutcliffe Efficiency type metrics. Water Resources Research, 47(10).

Jozaghi, A., Shen, H. and Seo, D.J., 2024. Adaptive conditional bias-penalized kriging for improved spatial estimation of extremes. Stochastic Environmental Research and Risk Assessment, 38(1), pp.193-209.

Kim, S., H. Sadeghi, R. A. Limon, D.-J. Seo, A. Philpott, F. Bell, J. Brown, K. He, 2018. Ensemble streamflow forecasting using short- and medium-range precipitation forecasts for the Upper Trinity River Basin in North Texas via the Hydrologic Ensemble Forecast Service (HEFS). J. of Hydromet. 19(9), pp.1467-1483.

Kim, S. and Seo, D.J., 2025. Improving Ensemble Precipitation and Streamflow Forecasts for Large Events with the Conditional Bias-Penalized Regression-Aided Meteorological Ensemble Forecast Processor. Weather and Forecasting, 40(6), pp.959-975.

Kitzmiller, D.H., Wu, W., Zhang, Z., Patrick, N. and Tan, X., 2018, December. The analysis of record for calibration: A high-resolution precipitation and surface weather dataset for the United States. In AGU fall meeting abstracts (Vol. 2018, pp. H41H-06).

Lynker 2022. NOAA National Weather Service Hydrologic Modeling Calibrations. Available at https://www.twdb.texas.gov/publications/reports/contracted_reports/doc/2100012514.pdf.

Nash, J.E. and Sutcliffe, J.V., 1970. River flow forecasting through conceptual models part I—A discussion of principles. *Journal of hydrology*, *10*(3), pp.282-290.

Regonda, S., and Seo, D.-J. 2008. Statistical post processing streamflow ensembles to improve reliability over a wide range of time scales. 2nd CPPA PIs Meeting, Silver Spring, MD, NOAA, http://vintage.joss.ucar.edu/joss_psg/meetings/Meetings_2008/CPPA/poster/RegondaPoster.pdf.

Scheuerer, M. and Hamill, T.M., 2015. Statistical postprocessing of ensemble precipitation forecasts by fitting censored, shifted gamma distributions. *Monthly Weather Review*, *143*(11), pp.4578-4596.

TWDB 2020. Forecast-informed Reservoir Operations (FIRO) and Water Resources Management in Texas and Oklahoma. Available at https://www.twdb.texas.gov/publications/reports/other_reports/doc/TWDB_UTA_NIDIS_forecasts_workshop_report.pdf

Wu, L., Seo, D.J., Demargne, J., Brown, J.D., Cong, S. and Schaake, J., 2011. Generation of ensemble precipitation forecast from single-valued quantitative precipitation forecast for hydrologic ensemble prediction. *Journal of hydrology*, *399*(3-4), pp.281-298.

Wu, L., Zhang, Y., Adams, T., Lee, H., Liu, Y. and Schaake, J., 2018. Comparative evaluation of three Schaake shuffle schemes in postprocessing GEFS precipitation ensemble forecasts. *Journal of Hydrometeorology*, *19*(3), pp.575-598.

Zhang, Y., Wu, L., Scheuerer, M., Schaake, J. and Kongoli, C., 2017. Comparison of probabilistic quantitative precipitation forecasts from two postprocessing mechanisms. *Journal of Hydrometeorology*, *18*(11), pp.2873-2891.

Appendix A: Calibrated SAC-SMA Parameter Values

The SAC-SMA parameter values from the earlier (2022) and present (2025) calibration efforts for each forecast points are shown in Tables A-1 – A-11.

Table A-1: CPKT2

Year	UZTWM	UZFWM	UZK	ZPERC	REXP	LZTWM	LZFSM	LZFPM	LZSK	LZPK	PFREE
2022	110	25	0.65	250	2.5	190	20	30	0.1	0.004	0.04
2025	112	21	0.61	237	2.3	169	23	48	0.1	0.0	0.05

Table A-2: DSBT2

Year	UZTWM	UZFWM	UZK	ZPERC	REXP	LZTWM	LZFSM	LZFPM	LZSK	LZPK	PFREE
2022	75	40	0.65	200	2.4	195	12	30	0.33	0.005	0.04
2025	78	44	0.62	194	2.5	199	7	74	0.33	0.01	0

Table A-3: HMLT2

Year	UZTWM	UZFWM	UZK	ZPERC	REXP	LZTWM	LZFSM	LZFPM	LZSK	LZPK	PFREE
2022	55	50	0.2	194	2.67	250	16	30	0.11	0.004	0.04
2025	141	66	0.8	101	2.1	302	166	99	0.28	0.15	0.74

Table A-4: GAST2

Year	UZTWM	UZFWM	UZK	ZPERC	REXP	LZTWM	LZFSM	LZFPM	LZSK	LZPK	PFREE
2022	50	75	0.35	130	1.8	140	35	25	0.12	0.01	0.1
2025	121	98	0.59	52	3.2	187	232	685	0.06	0.13	0.14

Table A-5: PICT2

Year	UZTWM	UZFWM	UZK	ZPERC	REXP	LZTWM	LZFSM	LZFPM	LZSK	LZPK	PFREE
2022	80	60	0.37	180	1.4	160	8	90	0.05	0.01	0.25
2025	71	64	0.38	177	1.4	136	22	139	0.06	0	0.26

Table A-7: KEMT2

Year	UZTWM	UZFWM	UZK	ZPERC	REXP	LZTWM	LZFSM	LZFPM	LZSK	LZPK	PFREE
2022	85	70	0.3	110	1.4	180	20	400	0.05	0.002	0.18
2025	99	70	0.3	98	1.6	193	34	409	0.03	0	0.18

Table A-8: BLNT2

Year	UZTWM	UZFWM	UZK	ZPERC	REXP	LZTWM	LZFSM	LZFPM	LZSK	LZPK	PFREE
2022	25	22	0.1	120	2.0	135	75	80	0.05	0.007	0.04
2025	40	43	0.17	194	2.67	191	13	23	0.11	0.05	0.04

Table A-8: STIT2

Year	UZTWM	UZFWM	UZK	ZPERC	REXP	LZTWM	LZFSM	LZFPM	LZSK	LZPK	PFREE
2022	40	43	0.17	194	2.67	191	13	23	0.11	0.05	0.04
2025	35	43	0.18	194	2.67	210	7	13	0.11	0.05	0.04

Table A-9: GGLT2

Year	UZTWM	UZFWM	UZK	ZPERC	REXP	LZTWM	LZFSM	LZFPM	LZSK	LZPK	PFREE
2022	40	43	0.17	194	2.67	191	13	23	0.11	0.05	0.04
2025	70	43	0.18	150	2.67	100	7	23	0.11	0.05	0.04

Table A-10: GNGT2

Year	UZTWM	UZFWM	UZK	ZPERC	REXP	LZTWM	LZFSM	LZFPM	LZSK	LZPK	PFREE
2022	40	43	0.17	194	2.67	191	13	23	0.11	0.05	0.04
2025	70	43	0.18	150	2.67	100	7	23	0.11	0.05	0.04

Table A-11: GETT2

Year	UZTWM	UZFWM	UZK	ZPERC	REXP	LZTWM	LZFSM	LZFPM	LZSK	LZPK	PFREE
2022	40	15	0.25	150	3.5	191	25	60	0.14	0.01	0.04
2025	21	10	0.01	12	0.5	25	12	27	0.01	0.01	0.02

Appendix B: RES-J Parameter Table

The revised RES-J parameter table with withdrawal enabled is attached below.

```
----------------------------------------------------------------------------------------------------------
<?xml version="1.0" encoding="utf-8"?>
<parameters version="1.5" xsi:schemaLocation="http://www.wldelft.nl/fews/PI
pi_modelparameters.xsd" xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xmlns="http://www.wldelft.nl/fews/PI">
  <group id="default">
    <parameter id="OPERATION_CONTENTS">
      <stringValue> #
 # This RES operation has 5 reservoirs, each with several corresponding nodes.
 # The [AAA]_FSTORAGE node calculates the current flood storage at each reservoi
 # The bottom of the flood pool is zero, and the storage above that is calculate
 # using the elev-storage curve with the results in ac-ft.
 # The [AAA]_PERCENTF node calculates the current percent full for each reservoi
 # The bottom of the flood pool is zero, the top is 100.
 # The [AAA]T2 nodes bring in the local flow for each relevant local area.
 # The HMLT2 flow is lagged/attenuated and then combined with GAST2 to get the
 # total local flow for HMLT2/GAST2.
 # The LRIT2_CAPAC node determines the channel capacity at LRIT2 based on the
 # pool elevation at Belton Reservoir (BLN).  The capacity is variable with pool
 # and is modified to stay high for a little longer than the rules strictly indi
 # The LRIT2_AVAIL node uses the previously calculated channel capacity and the
 # flow to determine the available flow for reservoir releases (BLN and STI).
 # The SYS_PERCENTF node determines the overall system percent full by adding up
 # all of the storages at the 5 reservoirs and dividing them by the total flood
 # capacity.
 # The [AAA]_INDEX nodes determine a "fullness index" that gives an idea of how
 # an individual reservoir is compared to the overall average fullness.  This in
 # is calculated as the difference between the individual percent full and the
 # system percent full, plus 100.  This results in a number between 0 and 200
 # where 0 means the individual reservoir is far emptier than the average,
 # 100 means that the reservoir fullness is equal to the average, and 200 means
 # that the reservoir is much fuller than the average. Typically the values are
 # between 50 and 150.
 # BLN and STI have [AAA]_INDEX_2 nodes, which are similar to the regular index
 # nodes, except that they use the average storage just between BLN and STI
 # instead of the average of all 5 reservoirs.  These second indexes are used
 # to allocate channel capacity at LRIT2 between the BLN and STI releases.
 #
 ##########################################################################
 #TIMESERIES                                   #{
 TIMESERIES
```

```
 TIMESTEP   6
 ###### ######## #### ## ############
 #
 #---------------------------------- Proctor time series
 #
 INPUT  PCTT2   PELV  6 PCT_POOL     #OBSERVED POOL ELEVATION
 INPUT  PCTT2    RQOT  6 PCT_RELEASE  #OBSERVED RELEASES
 INPUT  PCTT2INF RQIN  6 PCT_INFLOW   #COMPUTED POSITIVE INFLOWS
 INPUT  HMLT2LCL SQIN  6 HMLT2_LOCAL  #Local HMLT2 flow
 INPUT  GAST2LCL SQIN  6 GAST2_LOCAL  #Local GAST2 flow
 INPUT  PCTT2    MAP   6  PCT_RAIN
 INPUT  PCTT2    MAPE 24  PCT_EVAP
 INPUT  BLNT2    MAP   6  BLN_RAIN
 INPUT  BLNT2    MAPE 24  BLN_EVAP
 INPUT  STIT2    MAP   6  STI_RAIN
 INPUT  STIT2    MAPE 24  STI_EVAP
 INPUT  GGLT2    MAP   6  GGL_RAIN
 INPUT  GGLT2    MAPE 24  GGL_EVAP
 INPUT  GNGT2    MAP   6  GNG_RAIN
 INPUT  GNGT2    MAPE 24  GNG_EVAP
 OUTPUT PCTSIMRL SQIN  6 PCT_SIMREL   #SIMULATED RELEASES
 OUTPUT PCTSIMEL PELE  6 PCT_SIMPOOL  #SIMULATED POOL ELEVATION
 OUTPUT PCT_PF   SQIN  6 PCT_PERCENTF #Percent full for PCT
 OUTPUT PCT_STOR SRSO  6 PCT_FSTORAGE #Simulated reservoir storage for PCT
 OUTPUT PCT_INDX SQIN  6 PCT_INDEX    #Index value for PCT%/SYS%
 #
 #---------------------------------- Belton time series
 #
 INPUT  BLNT2   PELV  6 BLN_POOL     #OBSERVED POOL ELEVATION
 INPUT  BLNT2    RQOT  6 BLN_RELEASE  #OBSERVED RELEASES
 INPUT  BLNT2INF RQIN  6 BLN_CPINFL   #COMPUTED POSITIVE INFLOWS
 INPUT  BLNT2LCL SQIN  6 BLN_LOCAL    #COMPUTED LOCAL INFLOWS
 INPUT  PICT2    QINE  6 PICT2_TOTAL  #OBSERVED TOTAL FLOWS AT PIC
 OUTPUT BLNT2INF SQIN  6 BLN_TOTIN    #SIMULATED TOTAL INFLOW
 OUTPUT BLNSIMRL SQIN  6 BLN_SIMREL   #SIMULATED RELEASES
 OUTPUT BLNSIMEL PELE  6 BLN_SIMPOOL  #SIMULATED POOL ELEVATION
 OUTPUT BLN_PF   SQIN  6 BLN_PERCENTF #Percent full for BLN
 OUTPUT BLN_STOR SRSO  6 BLN_FSTORAGE #Simulated reservoir storage for BLN
 OUTPUT BLN_INDX SQIN  6 BLN_INDEX    #Index value for BLN%/SYS%
 OUTPUT BLN_IDX2 SQIN  6 BLN_INDEX_2  #Index value for BLN%/LRI%
 OUTPUT BLN_IDX3 SQIN  6 BLN_INDEX_3  #Index value for BLN%/CMN%
#   OUTPUT BLN_NORM SQIN  6 BLN_NORMAL_T #Displays the result of the "NORMAL"
ta
#   OUTPUT BLN_LRIC SQIN  6 BLN_LRI_CA_T #Displays the result of the "LRI_CAPACI
#   OUTPUT BLN_CMNC SQIN  6 BLN_CMN_CA_T #Displays the result of the
"CMN_CAPACI
```

```
#   OUTPUT BLN_TOTC SQIN  6 BLN_TOT_CA_T #Displays the result of the
"TOT_CAPACI
 #
 #----------------------------------- Stillhouse time series
 #
 INPUT  STIT2   PELV  6 STI_POOL     #OBSERVED POOL ELEVATION
 INPUT  STIT2    RQOT  6 STI_RELEASE  #OBSERVED RELEASES
 INPUT  STIT2INF RQIN  6 STI_INFLOW   #COMPUTED POSITIVE INFLOWS
 INPUT  LRIT2LCL SQIN  6 LRIT2_LOCAL  #Local LRIT2 flow
 OUTPUT STISIMRL SQIN  6 STI_SIMREL   #SIMULATED RELEASES
 OUTPUT STISIMEL PELE  6 STI_SIMPOOL  #SIMULATED POOL ELEVATION
 OUTPUT STI_PF   SQIN  6 STI_PERCENTF #Percent full for STI
 OUTPUT STI_STOR SRSO  6 STI_FSTORAGE #Simulated reservoir storage for STI
 OUTPUT STI_INDX SQIN  6 STI_INDEX    #Index value for STI%/SYS%
 OUTPUT STI_IDX2 SQIN  6 STI_INDEX_2  #Index value for STI%/LRI%
 OUTPUT STI_IDX3 SQIN  6 STI_INDEX_3  #Index value for STI%/CMN%.
#   OUTPUT STI_NORM SQIN  6 STI_NORMAL_T #Displays the result of the "NORMAL" ta
#   OUTPUT STI_LRIC SQIN  6 STI_LRI_CA_T #Displays the result of the "LRI_CAPACI
#   OUTPUT STI_CMNC SQIN  6 STI_CMN_CA_T #Displays the result of the
"CMN_CAPACI
#   OUTPUT STI_TOTC SQIN  6 STI_TOT_CA_T #Displays the result of the "TOT_CAPACI
 #
 #----------------------------------- Georgetown time series
 #
 INPUT  GGLT2   PELV  6 GGL_POOL     #OBSERVED POOL ELEVATION
 INPUT  GGLT2    RQOT  6 GGL_RELEASE  #OBSERVED RELEASES
 INPUT  GGLT2INF RQIN  6 GGL_INFLOW   #COMPUTED POSITIVE INFLOWS
 INPUT  GGL_W    SQIN  6 GGL_DIVERSN  #DIVERSION
 OUTPUT GGLSIMRL SQIN  6 GGL_SIMREL   #SIMULATED RELEASES
 OUTPUT GGLSIMEL PELE  6 GGL_SIMPOOL  #SIMULATED POOL ELEVATION
 OUTPUT GGL_PF   SQIN  6 GGL_PERCENTF #Percent full for GGL
 OUTPUT GGL_STOR SRSO  6 GGL_FSTORAGE #Simulated reservoir storage for GGL
 OUTPUT GGL_INDX SQIN  6 GGL_INDEX    #Index value for GGL%/SYS%
 #
 #----------------------------------- Granger time series
 #
 INPUT  GNGT2   PELV  6 GNG_POOL     #OBSERVED POOL ELEVATION
 INPUT  GNGT2    RQOT  6 GNG_RELEASE  #OBSERVED RELEASES
 INPUT  GNGT2INF RQIN  6 GNG_CPINFL   #COMPUTED POSITIVE INFLOWS
 INPUT  GNGT2LCL SQIN  6 GNG_LOCAL    #COMPUTED LOCAL INFLOWS
 INPUT  GNG_W    SQIN  6 GNG_DIVERSN  #DIVERSION
 INPUT  RSAT2LCL SQIN  6 RSAT2_LOCAL  #Local RSAT2 flow
 INPUT  CMNT2LCL SQIN  6 CMNT2_LOCAL  #Local CMNT2 flow
 INPUT  GETT2    QINE  6 GETT2_TOTAL  #OBSERVED TOTAL FLOWS AT GET
 OUTPUT GNGT2INF SQIN  6 GNG_TOTIN    #SIMULATED TOTAL INFLOW
 OUTPUT GNGSIMRL SQIN  6 GNG_SIMREL   #SIMULATED RELEASES
```

```
 OUTPUT GNGSIMEL PELE  6 GNG_SIMPOOL  #SIMULATED POOL ELEVATION
 OUTPUT GNG_PF   SQIN  6 GNG_PERCENTF #Percent full for GNG
#  OUTPUT GNG_W    SDQI  6 GNG_SIMWITH  #SIMULATED WITHDRAWALS (NEGS,
EVAP, DIV)
 OUTPUT GNG_STOR RSTO  6 GNG_STOR
 OUTPUT GNG_STOR SRSO  6 GNG_FSTORAGE #Simulated reservoir storage for GNG
 OUTPUT GNG_INDX SQIN  6 GNG_INDEX    #Index value for GNG%/SYS%
 OUTPUT GNG_IDX3 SQIN  6 GNG_INDEX_3  #Index value for GNG%/CMN%
 #
 #---------------------------------- Misc. time series
 #
 OUTPUT LRI_CAPM SQIN  6 LRI_CAPACMOD #Modified capacity at LRIT2
 INPUT  ZEROS    SQIN  6 ZEROS        #Blank time series
 OUTPUT SYS_PF   SQIN  6 SYS_PERCENTF #Total system percent full
 OUTPUT SHUTOFF  SQIN  6 SHUT_OFF
 INPUT  TOTALLOC SQIN  6 TOTAL_LOCAL
 INPUT  CLR_TLOC SQIN  6 CMNLRIRMA
ENDTIMESERIES
################################################################}
################################################################
TOPOLOGY                                              #{
 ############ ############ ##### ############ ##### ############
 NODE         SHUT_OFF
 RESERVOIR    PCT
 REACH        PCT_TO_HML   BELOW PCT
   # PCT_TO_HML has no TSINPUT.
   # All inflows will be automatically connected to releases from
   #  PCT.
   # In the segment punch, an HSLT2 segment exists downstream of
   #  PCT.  It has STAGE-Q and ADJUST-Q operations.  Nothing that
   #  we need to include herein.  The HSLT2 goes into HMLT2.
 REACH        HML_TO_GAS   BELOW PCT_TO_HML
   # HML_TO_GAS has TSINPUT INFLOWS HMLT2_LOCAL.
   # Also inflows will be automatically connected to releases
   #  from PCT_TO_HML.
 REACH        GAS_TO_BLN   BELOW HML_TO_GAS
   # GAS_TO_BLN has TSINPUT as local runoff from GAST2.  Outflows from HML_TO_G
 REACH        PIC_TO_BLN
   # PIC_TO_BLN has TSINPUT INFLOWS PICT2 QINE.  Nothing is upstream.
 NODE         BLN_INFLOW   BELOW PIC_TO_BLN   BELOW GAS_TO_BLN
 # Isolate reservoir from rest of topology to force with observed inflow
 #RESERVOIR    BLN          BELOW BLN_INFLOW
 RESERVOIR    BLN
 NODE         PCT_FSTORAGE
 NODE         PCT_PERCENTF
 NODE         BLN_FSTORAGE
```

```
 NODE        BLN_PERCENTF
 RESERVOIR   STI
 NODE        STI_FSTORAGE
 NODE        STI_PERCENTF
 NODE        LRIT2_LOC
  # We changed this from LRIT2 to LRIT2_LOC because we don't wish to suggest t
 NODE        LRIT2_CAPAC
 RESERVOIR   GGL
  # In the segment punch, a GERT2 segment exists downstream of
  #  GGL.  It has STAGE-Q and ADJUST-Q operations.  Nothing that
  #  we need to include herein; no routing, no additional flow.
  # Flows from GERT2 go into GEOT2.
  # In the segment punch, the GEOT2 segment exists downstream of
  #  GERT2, where it receives flow from GERT2 and GETT2.  These flows
  #  are not routed in any fashion.  The segment also has
  #  STAGE-Q and ADJUST-Q operations.  We will need to add GETT2
  #  somewhere here.
  # Flows from GEOT2 go into the GNGT2 where they are routed.
  # All of this action, including the routing, we'll do in a
  #  reach we'll call GGL_TO_GNG
 REACH        GGL_TO_GNG   BELOW GGL
 NODE        GNG_INFLOW   BELOW GGL_TO_GNG
 # Isolate reservoir from rest of topology to force with observed inflow
 #RESERVOIR   GNG          BELOW GNG_INFLOW
 RESERVOIR   GNG
 NODE        GGL_FSTORAGE
 NODE        GGL_PERCENTF
 NODE        GNG_FSTORAGE
 NODE        GNG_PERCENTF
 NODE        SYS_PERCENTF
 NODE        PCT_INDEX
 NODE        BLN_INDEX
 NODE        BLN_INDEX_2
 NODE        BLN_INDEX_3
 NODE        STI_INDEX
 NODE        STI_INDEX_2
 NODE        STI_INDEX_3
 NODE        GGL_INDEX
# NODE        GGL_DELAY
 NODE        GNG_INDEX
 NODE        GNG_INDEX_3
 NODE        ROOT         BELOW SHUT_OFF     \
                  BELOW BLN_INFLOW   \
                  BELOW BLN          \
                  BELOW PCT_FSTORAGE \
                  BELOW PCT_PERCENTF \
```

```
                  BELOW BLN_FSTORAGE \
                  BELOW BLN_PERCENTF \
                  BELOW STI          \
                  BELOW STI_FSTORAGE \
                  BELOW STI_PERCENTF \
                  BELOW LRIT2_LOC    \
                  BELOW LRIT2_CAPAC  \
                  BELOW GNG_INFLOW   \
                  BELOW GNG          \
                  BELOW GGL_FSTORAGE \
                  BELOW GGL_PERCENTF \
                  BELOW GNG_FSTORAGE \
                  BELOW GNG_PERCENTF \
                  BELOW SYS_PERCENTF \
                  BELOW PCT_INDEX    \
                  BELOW BLN_INDEX    \
                  BELOW BLN_INDEX_2  \
                  BELOW BLN_INDEX_3  \
                  BELOW STI_INDEX    \
                  BELOW STI_INDEX_2  \
                  BELOW STI_INDEX_3  \
                  BELOW GGL_INDEX    \
                  BELOW GNG_INDEX    \
                  BELOW GNG_INDEX_3
ENDTOPOLOGY
######################################################################}
######################################################################{
PARAMETERS
 UNITS   ENGLISH
 ### Begin NODE SHUT_OFF ###{
 ############ ############{
 # The SHUT_OFF node provides a means of turning off an existing
 #     recovery release based on a sum of un-regulated local
 #     flows.
 # The trigger is set up to activate when the local flows exceed
 #     50000 cfs and will de-activate after the local flows drop
 #     below 20000 cfs.  There may be a delay in de-activation.
 NODE         SHUT_OFF
  ######## ######## ############
  TSINPUT  INFLOW   ZEROS
  TSOUTPUT OUTFLOW  SHUT_OFF
  PREVIOUSDISCHARGE 0.000000
  DISCHARGE 0.000000
  INITIALINFLOW 0.000000
  PREVIOUSINFLOW 0.000000
  INITIALDIVERSION -0.000000
```

```
 PREVIOUSDIVERSION -0.000000
ENDNODE
############ ############}
############ ############ ############{
LOOKUP3      SHUT_OFF     TRACKTREND
 COLUMNVAR SHUT_OFF.STARTINGDISCHARGE
 TSINDEX ROWS    TOTAL_LOCAL
 ROWVAR    INPUT_TS CFS
 TABLEVAR AUGMENTATION
 VALUES
            0  10  905   920   1000
  00000     0   0    0   910    990
  20000     0   0    0   920.1  990
  50000  1000   0    0  1000   1000
 ENDVALUES
 INTERPOLATE COLUMNS
ENDLOOKUP3
# NOTE: PE is also used to determine when to allow a "Back On".
############ ############ ############}
### End NODE SHUT_OFF ###}
### Begin RESERVOIR PCT ###{
############ ############
RESERVOIR    PCT         #{
 ######## ######## ############
 TSINPUT  INFLOW   PCT_INFLOW
 TSOUTPUT RELEASE  PCT_SIMREL
 TSOUTPUT POOL     PCT_SIMPOOL
 TABLE   ELEV_STOR
  1133.5       0.0
  1134.0       2.0
  1135.0      35.0
  1136.0     234.0
  1137.0     663.0
  1138.0    1251.0
  1139.0    1932.0
  1140.0    2699.0
  1141.0    3589.0
  1142.0    4592.0
  1143.0    5683.0
  1144.0    6853.0
  1145.0    8185.0
  1146.0    9654.0
  1147.0   11268.0
  1148.0   12987.0
  1149.0   14813.0
  1150.0   16745.0
```

1151.0	18836.0
1152.0	21057.0
1153.0	23391.0
1154.0	25827.0
1155.0	28378.0
1156.0	31080.0
1157.0	34162.0
1158.0	37790.0
1159.0	41687.0
1160.0	45852.0
1161.0	50234.0
1162.0	54762.0
1163.0	59480.0
1164.0	64430.0
1165.0	69620.0
1166.0	75030.0
1167.0	80670.0
1168.0	86540.0
1169.0	92640.0
1170.0	98960.0
1171.0	105500.0
1172.0	112300.0
1173.0	119300.0
1174.0	126600.0
1175.0	134100.0
1176.0	141800.0
1177.0	149800.0
1178.0	158100.0
1179.0	166700.0
1180.0	175500.0
1181.0	184600.0
1182.0	193900.0
1183.0	203600.0
1184.0	213500.0
1185.0	223700.0
1186.0	234300.0
1187.0	245100.0
1188.0	256200.0
1189.0	267600.0
1190.0	279200.0
1191.0	291200.0
1192.0	303500.0
1193.0	316100.0
1194.0	329000.0
1195.0	342200.0
1196.0	355700.0

```
   1197.0  369500.0
   1198.0  383700.0
   1199.0  398200.0
   1200.0  413100.0
   1201.0  428400.0
   1202.0  444000.0
   1203.0  459900.0
   1204.0  476300.0
   1205.0  493100.0
   1206.0  510300.0
   1207.0  527900.0
   1208.0  545800.0
   1209.0  564300.0
   1210.0  583100.0
  ENDTABLE
INITIALPOOL  1156.209974
PREVIOUSPOOL  1156.209974
INITIALRELEASE  9.760674
PREVIOUSRELEASE  9.763287
  MINPOOL       1133.5
  MINRELEASE       0.0
INITIALWITHDRAW  16.673977
INITIALINFLOW  0.001448
PREVIOUSWITHDRAW  16.685842
PREVIOUSINFLOW  0.004344
 ENDRESERVOIR
 ############ ############}
 ############ ############ ############
 SETWITHDRAW  PCT         WITHDRAWAL  #{
#   TSINPUT   OBSERVEDWITHDRAW  PCT_WITHDRAW
  VALUES
   ELEV    1128.0  1162.0    ENDELEV
   01/01    9.17    9.17
   02/01    8.68    8.68
   03/01   11.90   11.90
   04/01   14.33   14.33
   05/01   15.33   15.33
   06/01   25.29   25.29
   07/01   38.96   38.96
   08/01   40.66   40.66
   09/01   27.91   27.91
   10/01   23.26   23.26
   11/01   15.33   15.33
   12/01   12.08   12.08
  ENDVALUES
  #BLEND           0
```

```
 #BLENDTS          0
 INTERPOLATE     ALL
 INITIALTRANSFER 9.170004
ENDSETWITHDRAW
############ ############ ############}
############ ############ ############{
LOOKUP3      PCT          EVAP
 ROWVAR       PCT.STARTINGPOOL
 COLUMNVAR    DATE
 TABLEVAR     WITHDRAWL
 VALUES
        1/15   2/15   3/15   4/15   5/15   6/15   7/15   8/15   9/15 \
       10/15  11/15  12/15
  1133    0.0    0.0    0.1    0.1    0.1    0.1    0.1    0.1    0.1 \
          0.1    0.0    0.0
  1134    0.4    0.5    0.7    0.9    0.9    1.2    1.4    1.3    1.0 \
          0.8    0.6    0.4
  1135    1.0    1.3    1.9    2.3    2.3    3.2    3.6    3.4    2.7 \
          2.1    1.5    1.1
  1136    1.5    1.9    2.8    3.5    3.4    4.8    5.5    5.0    4.0 \
          3.1    2.2    1.6
  1137    1.9    2.4    3.5    4.4    4.3    5.9    6.8    6.3    5.0 \
          3.9    2.8    2.0
  1138    2.1    2.6    3.9    4.9    4.7    6.6    7.6    7.0    5.5 \
          4.4    3.1    2.3
  1139    2.4    3.0    4.5    5.6    5.5    7.6    8.7    8.0    6.3 \
          5.0    3.6    2.6
  1140    2.8    3.5    5.1    6.4    6.3    8.7   10.0    9.2    7.3 \
          5.8    4.1    3.0
  1141    3.1    3.9    5.7    7.1    7.0    9.7   11.1   10.2    8.1 \
          6.4    4.5    3.3
  1142    3.3    4.2    6.2    7.7    7.5   10.4   12.0   11.1    8.8 \
          6.9    4.9    3.6
  1143    3.7    4.7    6.9    8.6    8.4   11.6   13.4   12.3    9.8 \
          7.7    5.5    4.0
  1144    4.1    5.2    7.7    9.7    9.5   13.1   15.1   13.9   11.0 \
          8.7    6.2    4.5
  1145    4.5    5.7    8.4   10.5   10.2   14.2   16.3   15.0   11.9 \
          9.4    6.7    4.9
  1146    4.8    6.1    9.0   11.2   11.0   15.2   17.4   16.1   12.7 \
         10.1    7.1    5.2
  1147    5.2    6.5    9.6   12.1   11.8   16.3   18.8   17.3   13.7 \
         10.8    7.7    5.6
  1148    5.5    6.9   10.2   12.8   12.5   17.3   19.9   18.3   14.5 \
         11.4    8.1    6.0
  1149    5.8    7.4   10.9   13.6   13.3   18.4   21.2   19.5   15.5 \
```

```
     12.2   8.7   6.4
1150    6.3   7.9  11.7  14.6  14.3  19.8  22.8  21.0  16.6 \
     13.1   9.3   6.8
1151    6.6   8.3  12.3  15.3  15.0  20.8  23.9  22.0  17.4 \
     13.8   9.8   7.2
1152    6.9   8.7  12.8  16.0  15.7  21.7  25.0  23.0  18.2 \
     14.4  10.2   7.5
1153    7.2   9.1  13.4  16.7  16.4  22.7  26.1  24.0  19.0 \
     15.0  10.7   7.8
1154    7.5   9.5  14.0  17.5  17.1  23.7  27.3  25.1  19.9 \
     15.7  11.2   8.2
1155    8.0  10.1  14.8  18.6  18.1  25.1  28.9  26.6  21.1 \
     16.7  11.8   8.7
1156    9.7  12.2  18.0  22.5  22.0  30.6  35.1  32.3  25.6 \
     20.2  14.4  10.5
1157   10.9  13.8  20.3  25.4  24.8  34.4  39.5  36.4  28.8 \
     22.8  16.2  11.9
1158   11.7  14.8  21.9  27.4  26.8  37.1  42.6  39.3  31.1 \
     24.6  17.4  12.8
1159   12.4  15.7  23.2  29.1  28.4  39.4  45.2  41.7  33.0 \
     26.1  18.5  13.6
1160   13.0  16.5  24.3  30.4  29.7  41.2  47.3  43.6  34.5 \
     27.3  19.3  14.2
1161   13.6  17.2  25.3  31.7  31.0  42.9  49.3  45.4  36.0 \
     28.4  20.2  14.8
1162   14.1  17.9  26.3  33.0  32.2  44.7  51.3  47.3  37.5 \
     29.6  21.0  15.4
1165   16.0  20.3  29.9  37.5  36.6  50.8  58.3  53.7  42.6 \
     33.6  23.8  17.5
1170   19.7  24.9  36.7  45.9  44.9  62.2  71.4  65.8  52.1 \
     41.2  29.2  21.5
1175   23.5  29.8  43.9  54.9  53.7  74.5  85.6  78.8  62.5 \
     49.3  35.0  25.7
1180   27.7  35.1  51.7  64.7  63.3  87.7 100.7  92.8  73.5 \
     58.1  41.2  30.3
1182   29.5  37.3  55.0  68.8  67.3  93.2 107.1  98.6  78.2 \
     61.7  43.8  32.2
1184   31.3  39.5  58.3  73.0  71.3  98.9 113.6 104.6  82.9 \
     65.5  46.5  34.1
1186   33.1  41.9  61.7  77.3  75.5 104.7 120.3 110.8  87.8 \
     69.3  49.2  36.1
1188   35.0  44.2  65.3  81.7  79.9 110.6 127.1 117.1  92.8 \
     73.3  52.0  38.2
1190   36.9  46.7  68.9  86.2  84.3 116.8 134.1 123.6  97.9 \
     77.3  54.9  40.3
1192   38.9  49.2  72.6  90.8  88.8 123.0 141.3 130.2 103.2 \
```

```
        81.5   57.8   42.4
  1194    40.9   51.7   76.3   95.5   93.4  129.4  148.7  136.9  108.5 \
        85.7   60.8   44.7
  1196    43.0   54.4   80.2  100.3   98.1  135.9  156.2  143.8  114.0 \
        90.0   63.9   46.9
  1198    45.1   57.0   84.1  105.2  102.9  142.6  163.9  150.9  119.6 \
        94.4   67.0   49.2
  1200    47.2   59.8   88.1  110.3  107.8  149.4  171.7  158.1  125.3 \
        99.0   70.2   51.6
  1202    49.4   62.5   92.3  115.4  112.9  156.4  179.7  165.5  131.2 \
       103.6   73.5   54.0
  1204    51.7   65.4   96.4  120.7  118.0  163.5  187.9  173.0  137.1 \
       108.3   76.8   56.4
  1206    54.0   68.3  100.7  126.0  123.2  170.8  196.2  180.7  143.2 \
       113.1   80.2   58.9
  1208    56.3   71.2  105.1  131.5  128.6  178.2  204.7  188.5  149.4 \
       118.0   83.7   61.5
  1210    58.7   74.3  109.5  137.0  134.0  185.7  213.4  196.5  155.8 \
       123.0   87.2   64.1
 ENDVALUES
 INTERPOLATE ALL
ENDLOOKUP3
############ ############ ############}
############ ############ ############{
SETSUM       PCT          NEGINFW_EVAP
 SETWITHDRAW  PCT          WITHDRAWAL
 #LOOKUP3     PCT          EVAP
ENDSETSUM
############ ############ ############}
############ ############ ############{
LOOKUP3      PCT          NORMAL
 ROWVAR PCT.STARTINGPOOL
 COLUMNVAR PCT_INDEX.STARTINGDISCHARGE
 TABLEVAR RELEASE
 VALUES
          75    86    90   100   105   110   150
  1132.0     5     5     5     5     5     5     5
  1155.0    10    10    10    10    10    10    10
  1162.0    20    20    20    20    25    30    50
  1163.0   300   325   330   350   450   800  1200
  1168.0   400   450   460   500   700  1500  2000
  1174.0   600   700  2000  2000  2000  2000  2000
  1186.0   700   800  2000  2000  2000  2000  2000
  1190.0   800  1500  2500  3200  3200  3300  3500
  1196.0  2500  3000  3200  4000  4000  4100  4300
 ENDVALUES
```

```
   INTERPOLATE ALL
  ENDLOOKUP3
  ############ ############ ############}
  ############ ############ ############{
  LOOKUP3      PCT          CAPACITY
   TSINDEX COLUMNS GAST2_LOCAL
   COLUMNVAR INPUT_TS CFS
   ROWVAR PCT.STARTINGPOOL
   TABLEVAR RELEASE
   VALUES
            0  5000
    1162.0 5000     0
    1180.0 5000     0
    1182.0 5000   660
    1196.0 5000  2000
   ENDVALUES
   INTERPOLATE ALL
  ENDLOOKUP3
  ############ ############ ############}
  ############ ############ ############{
  SETMIN       PCT          CAPACITIESA
   LOOKUP3      PCT          NORMAL
   LOOKUP3      PCT          CAPACITY
  ENDSETMIN
  ############ ############ ############}
  ############ ############ ############{
  SPILLWAY     PCT          SPILL
   TABLE       ELEV_SPILL
    1196.0  0
    1197.0  7500
    1198.0  70000
    1210.0  100000
   ENDTABLE
   INTERVALS   12
INITIALSPILL  0.000000
  ENDSPILLWAY
  ############ ############ ############}
  ############ ############ ############{
  SETMAX       PCT          FINAL
   SETMIN       PCT          CAPACITIESA
   SPILLWAY     PCT          SPILL
  ENDSETMAX
  ############ ############ ############}
  ############ ############ ############{
  ADJUST       PCT          SET_TO_OBS
#   TSINPUT OBSERVEDRELEASE PCT_RELEASE
```

```
  TSINPUT OBSERVEDPOOL    PCT_POOL
  ADJSIM  OFF
 ENDADJUST
 ############ ############ ############}
 ### End RESERVOIR PCT ###}
 ### Begin NODE PCT_FSTORAGE ###{
 ############ ############{
 NODE         PCT_FSTORAGE
  TSINPUT  INFLOW   ZEROS
  TSOUTPUT OUTFLOW PCT_FSTORAGE
  PREVIOUSDISCHARGE 0.000000
  DISCHARGE 0.000000
  INITIALINFLOW 0.000000
  PREVIOUSINFLOW 0.000000
  INITIALDIVERSION -0.000000
  PREVIOUSDIVERSION -0.000000
 ENDNODE
 ############ ############}
 ############ ############ ############{
 LOOKUP3      PCT_FSTORAGE FLOOD_STORAG
  # Total flood storage between 1162 and 1197 is 314985.5 ac-ft
  ROWVAR PCT.ENDINGPOOL
#    TSINDEX ROWS PCT_POOL
#    ROWVAR INPUT_TS FT
  COLUMNVAR 1
  TABLEVAR AUGMENTATION
  VALUES
             0
   1162      0.00
   1165  14903.00
   1170  44243.00
   1175  79363.00
   1180 120758.00
   1182 139203.00
   1184 158798.00
   1186 179558.00
   1188 201463.00
   1190 224533.00
   1192 248803.00
   1194 274243.00
   1196 300968.00
   1198 329003.00
   1200 358408.00
   1202 389243.00
   1204 421608.00
   1206 455553.00
```

```
   1208 491133.00
   1210 528353.00
  ENDVALUES
  INTERPOLATE ALL
 ENDLOOKUP3
 ############ ############ ############}
 ### End NODE PCT_FSTORAGE ###}
 ### Begin NODE PCT_PERCENTF ###{
 ############ ############{
 NODE         PCT_PERCENTF
  TSINPUT  INFLOW   ZEROS
  TSOUTPUT OUTFLOW PCT_PERCENTF
  PREVIOUSDISCHARGE 0.000000
  DISCHARGE 0.000000
  INITIALINFLOW 0.000000
  PREVIOUSINFLOW 0.000000
  INITIALDIVERSION -0.000000
  PREVIOUSDIVERSION -0.000000
 ENDNODE
 ############ ############}
 ############ ############ ############{
 LOOKUP3      PCT_PERCENTF PERCENT_FULL
  # Total flood storage between 1162 and 1197 is 314985.5 ac-ft
  ROWVAR PCT.ENDINGPOOL
#    TSINDEX ROWS PCT_POOL
#    ROWVAR INPUT_TS FT
  COLUMNVAR 1
  TABLEVAR AUGMENTATION
  VALUES
           0
   1162   0.00
   1165   4.73
   1170  14.05
   1175  25.20
   1180  38.34
   1182  44.19
   1184  50.41
   1186  57.01
   1188  63.96
   1190  71.28
   1192  78.99
   1194  87.07
   1196  95.55
   1198 104.45
  ENDVALUES
  INTERPOLATE ALL
```

```
  ENDLOOKUP3
  ############ ############ ############}
  ### End NODE PCT_PERCENTF ###}
  ### Begin REACH PCT_TO_HML ###{
  ############ ############ {
  REACH       PCT_TO_HML
  ENDREACH
  ############ ############ }
  ############ ############ ############{
  LAGK        PCT_TO_HML   HMLT2_LAGK
   LAG
    TABLE INFLOW_LAG
           1.000 24.000
        4000.048 30.000
        8000.097 36.000
       50000.605 30.000
      150001.797 24.000
     1000011.00  18.000
    ENDTABLE
   ENDLAG
   K
    TABLE OUTFLOW_K
           0.000  24.000
        3000.035  24.000
       10000.111  12.000
     1000011.000  12.000
    ENDTABLE
   ENDK
   COINFLOW
    VALUES
9.775965
9.773458
9.770950
9.768443
9.765865
9.763287
9.760674
    ENDVALUES
   ENDCOINFLOW
INITIALOUTFLOW  9.780944
INITIALSTORAGE  234.742663
INITIALLAGGEDINFLOW  9.770950
  ENDLAGK
  ############ ############ ############}
  ### End REACH PCT_TO_HML ###}
  ### Begin REACH HML_TO_GAS ###{
```

```
  ############ ############ {
  REACH        HML_TO_GAS
   TSINPUT  INFLOW HMLT2_LOCAL
  ENDREACH
  ############ ############ }
  ############ ############ ############{
  LAGK         HML_TO_GAS   GAST2_LAGK
   LAG
    TABLE INFLOW_LAG
          1.000 36.000
       5000.059 42.000
       9000.104 48.000
      11000.133 54.000
      12000.145 60.000
      15000.180 66.000
      50000.605 60.000
     150001.797 54.000
    1000011.000 48.000
    ENDTABLE
   ENDLAG
   K
    TABLE OUTFLOW_K
          0.000  30.000
    1000011.000  24.000
    ENDTABLE
   ENDK
   COINFLOW
    VALUES
9.808913
9.806547
9.804040
9.801427
9.798743
9.796059
9.793446
9.790903
9.788396
9.785924
9.783452
9.780944
    ENDVALUES
   ENDCOINFLOW
INITIALOUTFLOW  0.000000
INITIALSTORAGE  0.000000
INITIALLAGGEDINFLOW  0.000000
  ENDLAGK
```

```
 ############ ############ ############}
 ### End REACH HML_TO_GAS ###}
 ### Begin REACH GAS_TO_BLN ###{
 ############ ############ {
 REACH        GAS_TO_BLN
  TSINPUT  INFLOW GAST2_LOCAL
 ENDREACH
 ############ ############ }
 ############ ############ ############{
 LAGK         GAS_TO_BLN   BLNT2_LAGK
  LAG
   TABLE INFLOW_LAG
         1.000 30.000
      5000.059 36.000
      9000.104 42.000
     11000.133 48.000
     13000.155 54.000
     15000.180 60.000
     50000.605 54.000
    150001.797 48.000
   1000011.000 42.000
   ENDTABLE
  ENDLAG
  # NO K
  COINFLOW
   VALUES
9.828654
9.826782
9.824911
9.823004
9.821026
9.819013
9.816965
9.814846
9.812621
9.810326
9.807960
   ENDVALUES
  ENDCOINFLOW
INITIALOUTFLOW  0.000000
INITIALSTORAGE  0.000000
INITIALLAGGEDINFLOW  0.000000
 ENDLAGK
 ############ ############ ############}
 ### End REACH GAS_TO_BLN ###}
 ### Begin REACH PIC_TO_BLN ###{
```

```
 ############ ############ {
 REACH        PIC_TO_BLN
  TSINPUT  INFLOW PICT2_TOTAL
 ENDREACH
 ############ ############ }
 ############ ############ ############{
 LAGK         PIC_TO_BLN   BLNT2_LAGK
  LAG
   TABLE INFLOW_LAG
         1.000 24.000
     10000.110 30.000
     40000.477 36.000
    150001.797 42.000
    300003.594 48.000
    500005.969 36.000
   1000011.000 24.000
   ENDTABLE
  ENDLAG
  # NO K
  COINFLOW
   VALUES
2.720451
3.164919
2.999965
2.857789
2.720451
2.999965
2.999965
2.720451
2.720451
   ENDVALUES
  ENDCOINFLOW
INITIALOUTFLOW  0.000000
INITIALSTORAGE  0.000000
INITIALLAGGEDINFLOW  0.000000
 ENDLAGK
 ############ ############ ############}
 ### End REACH PIC_TO_BLN ###}
 ### Begin NODE BLN_INFLOW ###{
 ############ ############{
 NODE         BLN_INFLOW
  TSINPUT  INFLOW   BLN_LOCAL
  TSOUTPUT OUTFLOW BLN_TOTIN
  PREVIOUSDISCHARGE 12.678850
  DISCHARGE 12.539499
  INITIALINFLOW 12.539499
```

```
   PREVIOUSINFLOW 12.678850
   INITIALDIVERSION 0.000000
   PREVIOUSDIVERSION 0.000000
  ENDNODE
  ############ ############}
  ### End NODE BLN_INFLOW ###}
  ### Begin RESERVOIR BLN ###{
  ############ ############
  RESERVOIR    BLN        #{
   ######## ######## ############
#   TSINPUT  INFLOW   BLN_LOCAL
#   TSINPUT  INFLOW   BLN_INFLOW
   TSINPUT  INFLOW   BLN_CPINFL
   TSOUTPUT RELEASE  BLN_SIMREL
   TSOUTPUT POOL     BLN_SIMPOOL
   TABLE   ELEV_STOR
    #482.00      0.0
    #483.00      0.0
    #484.00      0.0
    485.00      0.0
    486.00      1.0
    487.00      3.0
    488.00      6.0
    489.00     12.0
    490.00     21.0
    491.00     36.0
    492.00     55.0
    493.00     82.0
    494.00    118.0
    495.00    168.0
    496.00    235.0
    497.00    323.0
    498.00    432.0
    499.00    562.0
    500.00    714.0
    501.00    891.0
    502.00   1099.0
    503.00   1344.0
    504.00   1637.0
    505.00   1970.0
    506.00   2339.0
    507.00   2742.0
    508.00   3179.0
    509.00   3652.0
    510.00   4165.0
    511.00   4714.0
```

512.00	5305.0
513.00	5941.0
514.00	6627.0
515.00	7366.0
516.00	8171.0
517.00	9061.0
518.00	10049.0
519.00	11131.0
520.00	12297.0
521.00	13538.0
522.00	14856.0
523.00	16246.0
524.00	17709.0
525.00	19253.0
526.00	20884.0
527.00	22590.0
528.00	24367.0
529.00	26217.0
530.00	28140.0
531.00	30141.0
532.00	32226.0
533.00	34401.0
534.00	36672.0
535.00	39050.0
536.00	41542.0
537.00	44152.0
538.00	46869.0
539.00	49689.0
540.00	52618.0
541.00	55661.0
542.00	58823.0
543.00	62109.0
544.00	65511.0
545.00	69023.0
546.00	72665.0
547.00	76448.0
548.00	80379.0
549.00	84464.0
550.00	88698.0
551.00	93075.0
552.00	97589.0
553.00	102239.0
554.00	107007.0
555.00	111883.0
556.00	116869.0
557.00	121961.0

558.00	127161.0
559.00	132484.0
560.00	137929.0
561.00	143508.0
562.00	149238.0
563.00	155124.0
564.00	161187.0
565.00	167391.0
566.00	173722.0
567.00	180200.0
568.00	186874.0
569.00	193772.0
570.00	200925.0
571.00	208330.0
572.00	215968.0
573.00	223819.0
574.00	231868.0
575.00	240110.0
576.00	248520.0
577.00	257139.0
578.00	266007.0
579.00	275107.0
580.00	284429.0
581.00	293947.0
582.00	303671.0
583.00	313577.0
584.00	323665.0
585.00	333939.0
586.00	344401.0
587.00	355052.0
588.00	365898.0
589.00	376960.0
590.00	388218.0
591.00	399670.0
592.00	411322.0
593.00	423181.0
594.00	435225.0
595.00	448565.0
600.00	514525.0
605.00	585136.0
610.00	663263.0
615.00	748940.0
620.00	842579.0
625.00	944028.0
630.00	1056799.0
635.00	1178235.0

```
   640.00 1311095.0
   645.00 1456835.0
   650.00 1615925.0
   655.00 1789445.0
   660.00 1977955.0
   662.00 2057595.0
  ENDTABLE
INITIALPOOL  590.419948
PREVIOUSPOOL  590.419948
INITIALRELEASE  47.967511
PREVIOUSRELEASE  47.970901
  MINPOOL        485.0
  MINRELEASE       0.0
INITIALWITHDRAW  30.470459
INITIALINFLOW  12.539499
PREVIOUSWITHDRAW  30.505527
PREVIOUSINFLOW  12.678850
 ENDRESERVOIR
 ############ ############}
 ############ ############ ############{
 SETWITHDRAW  BLN         WITHDRAWAL
#  TSINPUT   OBSERVEDWITHDRAW  BLN_WITHDRAW
  VALUES
   ELEV    483.0   581.0   587.0   594.0     ENDELEV
   01/01   136     116     102      68
   02/01   128     108      96     64
   03/01   142     121     107      71
   04/01   157     133     118      78
   05/01   178     151     133      89
   06/01   203     172     152     101
   07/01   236     200     177     118
   08/01   257     218     192     128
   09/01   216     184     162     108
   10/01   190     161     142      95
   11/01   153     130     115      77
   12/01   145     123     108      72
  ENDVALUES
  INTERPOLATE    ALL
  INITIALTRANSFER 0.000000
 ENDSETWITHDRAW
 ############ ############ ############}
 ############ ############ ############{
 LOOKUP3      BLN          EVAP
  ROWVAR       BLN.STARTINGPOOL
  COLUMNVAR    DATE
  TABLEVAR     WITHDRAWL
```

```
VALUES
      1/15   2/15   3/15   4/15   5/15   6/15   7/15   8/15   9/15 \
      10/15  11/15  12/15
 486    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0 \
        0.0    0.0    0.0
 487    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0 \
        0.0    0.0    0.0
 488    0.0    0.0    0.0    0.0    0.0    0.0    0.1    0.1    0.0 \
        0.0    0.0    0.0
 489    0.0    0.0    0.0    0.0    0.0    0.1    0.1    0.1    0.1 \
        0.0    0.0    0.0
 490    0.0    0.0    0.1    0.1    0.1    0.1    0.1    0.1    0.1 \
        0.1    0.1    0.0
 491    0.0    0.1    0.1    0.1    0.1    0.2    0.2    0.2    0.1 \
        0.1    0.1    0.1
 492    0.1    0.1    0.1    0.1    0.1    0.2    0.3    0.2    0.2 \
        0.1    0.1    0.1
 493    0.1    0.1    0.2    0.2    0.2    0.3    0.3    0.3    0.3 \
        0.2    0.1    0.1
 494    0.1    0.1    0.2    0.3    0.3    0.4    0.4    0.4    0.3 \
        0.3    0.2    0.1
 495    0.2    0.2    0.3    0.4    0.4    0.5    0.6    0.6    0.5 \
        0.4    0.3    0.2
 496    0.2    0.3    0.4    0.5    0.5    0.7    0.8    0.8    0.6 \
        0.5    0.3    0.2
 497    0.3    0.4    0.5    0.6    0.6    0.9    1.1    1.0    0.8 \
        0.6    0.4    0.3
 498    0.3    0.4    0.6    0.8    0.8    1.1    1.3    1.2    1.0 \
        0.7    0.5    0.4
 499    0.4    0.5    0.7    0.9    0.9    1.3    1.5    1.4    1.1 \
        0.9    0.6    0.4
 500    0.4    0.6    0.8    1.1    1.1    1.5    1.8    1.7    1.3 \
        1.0    0.7    0.5
 501    0.5    0.7    1.0    1.2    1.2    1.8    2.1    2.0    1.5 \
        1.2    0.8    0.6
 502    0.6    0.8    1.2    1.4    1.5    2.1    2.4    2.3    1.8 \
        1.4    1.0    0.7
 503    0.7    1.0    1.4    1.7    1.7    2.4    2.9    2.7    2.2 \
        1.6    1.2    0.8
 504    0.9    1.1    1.6    2.0    2.0    2.9    3.4    3.2    2.5 \
        1.9    1.4    0.9
 505    1.0    1.3    1.8    2.2    2.3    3.2    3.8    3.6    2.8 \
        2.2    1.5    1.0
 506    1.1    1.4    2.0    2.5    2.5    3.5    4.2    4.0    3.1 \
        2.4    1.7    1.1
 507    1.1    1.5    2.2    2.7    2.7    3.8    4.6    4.3    3.4 \
```

```
     2.6   1.8   1.2
508    1.2   1.6   2.3   2.9   2.9   4.1   4.9   4.7   3.7 \
     2.8   2.0   1.3
509    1.3   1.8   2.6   3.2   3.2   4.5   5.4   5.1   4.0 \
     3.0   2.1   1.5
510    1.4   1.9   2.7   3.4   3.4   4.8   5.8   5.4   4.3 \
     3.3   2.3   1.6
511    1.6   2.0   2.9   3.6   3.7   5.2   6.2   5.8   4.6 \
     3.5   2.5   1.7
512    1.7   2.2   3.2   3.9   4.0   5.6   6.7   6.3   4.9 \
     3.8   2.7   1.8
513    1.8   2.4   3.4   4.2   4.3   6.0   7.2   6.8   5.3 \
     4.1   2.9   1.9
514    1.9   2.5   3.7   4.6   4.6   6.5   7.7   7.3   5.7 \
     4.4   3.1   2.1
515    2.1   2.7   4.0   4.9   5.0   7.0   8.4   7.9   6.2 \
     4.7   3.3   2.3
516    2.3   3.0   4.4   5.4   5.5   7.7   9.2   8.6   6.8 \
     5.2   3.7   2.5
517    2.6   3.3   4.9   6.0   6.1   8.6  10.2   9.6   7.6 \
     5.8   4.1   2.8
518    2.8   3.7   5.4   6.6   6.7   9.4  11.3  10.6   8.4 \
     6.4   4.5   3.1
519    3.1   4.0   5.8   7.2   7.3  10.3  12.3  11.5   9.1 \
     6.9   4.9   3.3
520    3.3   4.3   6.2   7.7   7.8  11.0  13.1  12.3   9.7 \
     7.4   5.2   3.6
521    3.5   4.6   6.6   8.2   8.3  11.7  13.9  13.1  10.3 \
     7.9   5.5   3.8
522    3.7   4.8   7.0   8.7   8.8  12.4  14.8  13.9  10.9 \
     8.4   5.9   4.0
523    3.9   5.1   7.4   9.1   9.2  13.0  15.5  14.6  11.5 \
     8.8   6.2   4.2
524    4.1   5.3   7.8   9.6   9.7  13.7  16.3  15.4  12.1 \
     9.3   6.5   4.4
525    4.3   5.7   8.2  10.2  10.3  14.5  17.3  16.3  12.8 \
     9.8   6.9   4.7
526    4.6   5.9   8.6  10.7  10.8  15.2  18.2  17.1  13.5 \
    10.3   7.2   4.9
527    4.8   6.2   9.0  11.2  11.3  15.9  19.0  17.9  14.1 \
    10.8   7.6   5.1
528    5.0   6.5   9.4  11.6  11.7  16.5  19.8  18.6  14.6 \
    11.2   7.9   5.4
529    5.1   6.7   9.7  12.1  12.2  17.2  20.5  19.3  15.2 \
    11.6   8.2   5.6
530    5.4   7.0  10.1  12.6  12.7  17.9  21.4  20.1  15.8 \
```

```
        12.1   8.5   5.8
531    5.6   7.3  10.6  13.1  13.2  18.6  22.2  20.9  16.5 \
        12.6   8.9   6.0
532    5.8   7.6  11.0  13.6  13.8  19.4  23.2  21.8  17.2 \
        13.1   9.2   6.3
533    6.1   7.9  11.5  14.2  14.4  20.3  24.2  22.8  17.9 \
        13.7   9.6   6.6
534    6.3   8.3  12.0  14.9  15.0  21.2  25.3  23.8  18.7 \
        14.3  10.1   6.9
535    6.6   8.7  12.6  15.6  15.8  22.2  26.5  24.9  19.6 \
        15.0  10.5   7.2
536    7.0   9.1  13.2  16.3  16.5  23.3  27.8  26.2  20.6 \
        15.7  11.1   7.5
537    7.3   9.5  13.8  17.1  17.3  24.3  29.0  27.3  21.5 \
        16.4  11.6   7.9
538    7.6   9.9  14.3  17.7  17.9  25.2  30.1  28.4  22.3 \
        17.1  12.0   8.2
539    7.8  10.2  14.9  18.4  18.6  26.2  31.3  29.4  23.2 \
        17.7  12.5   8.5
540    8.2  10.6  15.4  19.1  19.3  27.2  32.5  30.6  24.1 \
        18.4  12.9   8.8
541    8.5  11.0  16.0  19.9  20.1  28.3  33.8  31.8  25.0 \
        19.1  13.4   9.2
542    8.8  11.5  16.7  20.6  20.9  29.4  35.1  33.0  26.0 \
        19.9  14.0   9.5
543    9.1  11.9  17.3  21.4  21.7  30.5  36.5  34.3  27.0 \
        20.7  14.5   9.9
544    9.4  12.3  17.9  22.1  22.4  31.5  37.6  35.4  27.9 \
        21.3  15.0  10.2
545    9.8  12.7  18.5  22.9  23.1  32.6  38.9  36.6  28.8 \
        22.0  15.5  10.6
546   10.1  13.2  19.2  23.8  24.0  33.8  40.4  38.0  29.9 \
        22.9  16.1  11.0
547   10.5  13.7  19.9  24.7  25.0  35.2  42.0  39.5  31.1 \
        23.8  16.7  11.4
548   10.9  14.3  20.7  25.7  25.9  36.5  43.6  41.1  32.3 \
        24.7  17.4  11.8
549   11.4  14.8  21.5  26.7  26.9  37.9  45.3  42.6  33.6 \
        25.7  18.0  12.3
550   11.8  15.3  22.3  27.6  27.9  39.3  46.9  44.1  34.7 \
        26.6  18.7  12.7
551   12.1  15.8  23.0  28.5  28.8  40.5  48.4  45.6  35.9 \
        27.4  19.3  13.1
552   12.5  16.3  23.7  29.4  29.7  41.8  49.9  47.0  37.0 \
        28.3  19.9  13.5
553   12.9  16.8  24.4  30.2  30.5  42.9  51.3  48.3  38.0 \
```

```
      29.1  20.4  13.9
554    13.2  17.2  24.9  30.9  31.2  44.0  52.5  49.4  38.9 \
      29.8  20.9  14.2
555    13.5  17.6  25.5  31.6  31.9  45.0  53.7  50.5  39.8 \
      30.4  21.4  14.6
556    13.8  18.0  26.1  32.3  32.6  46.0  54.9  51.6  40.7 \
      31.1  21.8  14.9
557    14.0  18.3  26.6  32.9  33.3  46.9  56.0  52.7  41.5 \
      31.7  22.3  15.2
558    14.4  18.8  27.2  33.7  34.1  48.0  57.3  54.0  42.5 \
      32.5  22.8  15.5
559    14.7  19.2  27.8  34.5  34.9  49.1  58.6  55.2  43.4 \
      33.2  23.3  15.9
560    15.0  19.6  28.5  35.3  35.7  50.2  60.0  56.5  44.4 \
      34.0  23.9  16.3
561    15.4  20.1  29.2  36.2  36.6  51.6  61.6  57.9  45.6 \
      34.9  24.5  16.7
562    15.9  20.7  30.0  37.2  37.6  52.9  63.2  59.5  46.8 \
      35.8  25.2  17.1
563    16.3  21.3  30.9  38.3  38.7  54.5  65.1  61.2  48.2 \
      36.9  25.9  17.6
564    16.8  21.9  31.7  39.3  39.8  56.0  66.8  62.9  49.5 \
      37.9  26.6  18.1
565    17.1  22.3  32.4  40.1  40.6  57.1  68.2  64.2  50.6 \
      38.7  27.2  18.5
566    17.5  22.8  33.1  41.0  41.4  58.3  69.7  65.6  51.6 \
      39.5  27.7  18.9
567    18.0  23.4  34.0  42.1  42.6  59.9  71.5  67.3  53.0 \
      40.5  28.5  19.4
568    18.5  24.2  35.1  43.5  44.0  61.9  73.9  69.6  54.8 \
      41.9  29.4  20.0
569    19.2  25.0  36.3  44.9  45.4  64.0  76.4  71.9  56.6 \
      43.3  30.4  20.7
570    19.9  26.0  37.7  46.7  47.2  66.4  79.3  74.7  58.8 \
      44.9  31.6  21.5
571    20.5  26.8  38.9  48.2  48.7  68.6  81.9  77.1  60.7 \
      46.4  32.6  22.2
572    21.2  27.6  40.1  49.6  50.2  70.6  84.3  79.4  62.5 \
      47.8  33.6  22.9
573    21.7  28.3  41.1  50.9  51.5  72.5  86.5  81.5  64.1 \
      49.0  34.5  23.5
574    22.3  29.0  42.1  52.2  52.8  74.3  88.7  83.5  65.8 \
      50.3  35.3  24.1
575    22.7  29.7  43.1  53.3  53.9  75.9  90.7  85.3  67.2 \
      51.4  36.1  24.6
576    23.2  30.3  44.0  54.5  55.1  77.5  92.6  87.1  68.6 \
```

```
     52.4  36.9  25.1
577   23.9  31.1  45.2  56.0  56.6  79.7  95.2  89.6  70.5 \
     53.9  37.9  25.8
578   24.6  32.0  46.5  57.6  58.2  82.0  97.9  92.1  72.5 \
     55.4  39.0  26.5
579   25.2  32.8  47.6  59.0  59.7  84.0 100.3  94.4  74.3 \
     56.8  39.9  27.2
580   25.7  33.6  48.7  60.3  61.0  85.9 102.6  96.5  76.0 \
     58.1  40.8  27.8
581   26.3  34.3  49.8  61.7  62.3  87.8 104.8  98.6  77.7 \
     59.4  41.7  28.4
582   26.8  35.0  50.8  62.9  63.6  89.5 106.9 100.6  79.2 \
     60.5  42.5  29.0
583   27.3  35.6  51.7  64.1  64.7  91.2 108.9 102.5  80.7 \
     61.7  43.3  29.5
584   27.8  36.3  52.6  65.2  65.9  92.8 110.8 104.3  82.1 \
     62.8  44.1  30.0
585   28.3  37.0  53.6  66.4  67.2  94.6 112.9 106.3  83.7 \
     64.0  44.9  30.6
586   28.8  37.6  54.6  67.6  68.3  96.2 114.9 108.1  85.1 \
     65.1  45.7  31.2
587   29.4  38.3  55.6  68.8  69.6  98.0 117.0 110.1  86.7 \
     66.3  46.6  31.7
588   29.9  39.0  56.6  70.2  70.9  99.9 119.2 112.2  88.4 \
     67.6  47.5  32.3
589   30.5  39.8  57.7  71.5  72.3 101.8 121.5 114.4  90.1 \
     68.9  48.4  33.0
590   31.0  40.5  58.7  72.7  73.5 103.5 123.6 116.4  91.6 \
     70.0  49.2  33.5
591   31.5  41.1  59.7  74.0  74.8 105.3 125.7 118.3  93.1 \
     71.2  50.0  34.1
592   32.1  41.9  60.8  75.4  76.2 107.3 128.1 120.6  94.9 \
     72.6  51.0  34.7
593   32.7  42.6  61.8  76.6  77.4 109.0 130.1 122.5  96.4 \
     73.7  51.8  35.3
594   33.2  43.2  62.8  77.7  78.6 110.7 132.1 124.4  97.9 \
     74.9  52.6  35.8
595   35.1  45.8  66.5  82.4  83.3 117.3 140.1 131.8 103.8 \
     79.4  55.8  38.0
600   38.8  50.6  73.4  90.9  91.9 129.4 154.5 145.4 114.5 \
     87.5  61.5  41.9
605   42.6  55.5  80.6  99.9 100.9 142.1 169.7 159.7 125.7 \
     96.1  67.6  46.0
610   46.6  60.7  88.2 109.2 110.4 155.5 185.6 174.7 137.5 \
    105.2  73.9  50.3
615   50.8  66.2  96.1 119.0 120.3 169.4 202.3 190.4 149.9 \
```

```
       114.6   80.5   54.8
  620    55.1   71.9  104.3  129.3  130.7  184.0  219.7  206.8  162.8 \
       124.5   87.5   59.6
  625    59.7   77.8  112.9  139.9  141.4  199.2  237.8  223.8  176.2 \
       134.7   94.7   64.5
  630    64.4   84.0  121.9  151.0  152.7  215.0  256.7  241.6  190.2 \
       145.4  102.2   69.6
  635    69.3   90.4  131.2  162.6  164.3  231.4  276.3  260.0  204.7 \
       156.5  110.0   74.9
  640    74.4   97.1  140.9  174.5  176.4  248.4  296.6  279.2  219.8 \
       168.0  118.1   80.4
  645    79.7  104.0  150.9  186.9  189.0  266.0  317.7  299.0  235.4 \
       180.0  126.5   86.1
  650    85.2  111.1  161.2  199.7  201.9  284.3  339.5  319.5  251.5 \
       192.3  135.1   92.0
  655    90.8  118.5  171.9  213.0  215.3  303.2  362.0  340.7  268.2 \
       205.1  144.1   98.2
  660    96.7  126.1  183.0  226.7  229.2  322.7  385.3  362.6  285.5 \
       218.3  153.4  104.5
  662    99.1  129.2  187.5  232.3  234.8  330.6  394.8  371.6  292.5 \
       223.7  157.2  107.0
 ENDVALUES
 INTERPOLATE ALL
ENDLOOKUP3
############ ############ ############}
############ ############ ############{
SETSUM       BLN         NEGINFW_EVAP
 SETWITHDRAW  BLN          WITHDRAWAL
 #LOOKUP3      BLN          EVAP
ENDSETSUM
############ ############ ############}
############ ############ ############{
LOOKUP3      BLN          NORMAL
 ROWVAR BLN.STARTINGPOOL
 COLUMNVAR BLN_INDEX.STARTINGDISCHARGE
 TABLEVAR RELEASE
 VALUES
         75   100   115
  485.0    10    10    10
  594.3    50    50   200
  598.0  1500  2500  3500
  600.0  3500  5000  5500
  605.0  4000  5500  6500
  610.0  4500  6000  7000
  631.0  6000  7000  8000
  632.5     0     0     0
```

```
  ENDVALUES
  INTERPOLATE ALL
 ENDLOOKUP3
 ############ ############ ############}
 ############ ############ ############{
 LOOKUP3      BLN          LRI_CAPACITY
  # Belton has 62.1% of the storage space that contributes to LRIT2 gage
  # Stillhouse has the other 37.9%.  This method allocates channel capacity acc
  ROWVAR BLN_INDEX_2.STARTINGDISCHARGE
  COLUMNVAR LRIT2_CAPAC.STARTINGDISCHARGE -
LRIT2_LOC.STARTINGDISCHARGE
  TABLEVAR RELEASE
  VALUES
          0 10000
    85.0     0  2000
    90.0     0  3000
   100.0     0  6500
   110.0     0  9000
  ENDVALUES
  INTERPOLATE ALL
 ENDLOOKUP3
 ############ ############ ############}
 ############ ############ ############{
 LOOKUP3      BLN          CMN_CAPACITY
  # Belton has 52.9% of the storage space that contributes to CMNT2 gage
  # Stillhouse has 32.3%, Granger has 14.8%. This method allocates channel capa
  TSINDEX COLUMNS CMNLRIRMA
  COLUMNVAR INPUT_TS CFS
  ROWVAR BLN_INDEX_3.STARTINGDISCHARGE
  TABLEVAR RELEASE
  VALUES
          0 10000
    95.0  3000     0
   100.0  5290     0
   110.0  7500     0
   115.0  8000     0
  ENDVALUES
  INTERPOLATE ALL
 ENDLOOKUP3
 ############ ############ ############}
 ############ ############ ############{
 LOOKUP3      BLN          TOT_CAPACITY
  # Look at the summed local flows plus Somerville
  ROWVAR BLN.STARTINGPOOL
  COLUMNVAR SHUT_OFF.STARTINGDISCHARGE
  TABLEVAR RELEASE
```

```
   VALUES
            0   920  1000 # 920.0  1000
    594.0 99999  1500     0
    600.0 99999  2000     0
    631.0 99999  2500     0
   ENDVALUES
   INTERPOLATE ALL
  ENDLOOKUP3
  ############ ############ ############}
  ############ ############ ############{
  SETMIN       BLN          CAPACITIESB
   LOOKUP3      BLN          NORMAL
   LOOKUP3      BLN          LRI_CAPACITY
   LOOKUP3      BLN          CMN_CAPACITY
   LOOKUP3      BLN          TOT_CAPACITY
  ENDSETMIN
  ############ ############ ############}
  ############ ########### #############{
  SPILLWAY     BLN          SPILL
   TABLE       ELEV_SPILL
   631.0     0
   632.0     4000
   633.0     4500
   634.0     6500
   635.0     12500
   662.0     100000
   ENDTABLE
   INTERVALS   12
INITIALSPILL  0.000000
  ENDSPILLWAY
  ############ ############ ############}
  ############ ############ ############{
  SETMAX       BLN          FINAL
   SETMIN       BLN          CAPACITIESB
   SPILLWAY     BLN          SPILL
  ENDSETMAX
  ############ ############ ############}
  ############ ########### #############{
  ADJUST       BLN          SET_TO_OBS
#   TSINPUT OBSERVEDRELEASE BLN_RELEASE
   TSINPUT OBSERVEDPOOL    BLN_POOL
   ADJSIM  OFF
  ENDADJUST
  ############ ############ ############}
  ### End RESERVOIR BLN ###}
  ### Begin NODE BLN_FSTORAGE ###{
```

```
  ############ ############{
  NODE         BLN_FSTORAGE
   TSINPUT  INFLOW   ZEROS
   TSOUTPUT OUTFLOW BLN_FSTORAGE
   PREVIOUSDISCHARGE 0.000000
   DISCHARGE 0.000000
   INITIALINFLOW 0.000000
   PREVIOUSINFLOW 0.000000
   INITIALDIVERSION -0.000000
   PREVIOUSDIVERSION -0.000000
  ENDNODE
  ############ ############}
  ############ ############ ############{
  LOOKUP3      BLN_FSTORAGE FLOOD_STORAG
   # Total flood storage between 594 and 631 is 645861.2 ac-ft
   ROWVAR BLN.ENDINGPOOL
#    TSINDEX ROWS BLN_POOL
#    ROWVAR INPUT_TS FT
   COLUMNVAR 1
   TABLEVAR AUGMENTATION
   VALUES
           0
    594       0
    595   13340
    600   79300
    605  149911
    610  228038
    615  313715
    620  407354
    625  508803
    630  621574
    635  743010
    640  875870
    645 1021610
    650 1180700
    655 1354220
    660 1542730
    662 1622370
   ENDVALUES
   INTERPOLATE ALL
  ENDLOOKUP3
  ############ ############ ############}
  ### End NODE BLN_FSTORAGE ###}
  ### Begin NODE BLN_PERCENTF ###{
  ############ ############{
  NODE         BLN_PERCENTF
```

```
   TSINPUT  INFLOW   ZEROS
   TSOUTPUT OUTFLOW BLN_PERCENTF
   PREVIOUSDISCHARGE 0.000000
   DISCHARGE 0.000000
   INITIALINFLOW 0.000000
   PREVIOUSINFLOW 0.000000
   INITIALDIVERSION -0.000000
   PREVIOUSDIVERSION -0.000000
  ENDNODE
  ############ ############}
  ############ ############ ############{
  LOOKUP3      BLN_PERCENTF PERCENT_FULL
   # Total flood storage between 594 and 631 is 645861.2 ac-ft
   ROWVAR BLN.ENDINGPOOL
#    TSINDEX ROWS BLN_POOL
#    ROWVAR INPUT_TS FT
   COLUMNVAR 1
   TABLEVAR AUGMENTATION
   VALUES
            0
    594   0.00
    595   2.07
    600  12.28
    605  23.21
    610  35.31
    615  48.57
    620  63.07
    625  78.78
    630  96.24
    635 115.04
   ENDVALUES
   INTERPOLATE ALL
  ENDLOOKUP3
  ############ ############ ############}
  ### End NODE BLN_PERCENTF ###}
  ### Begin RESERVOIR STI ###{
  ############ ############
  RESERVOIR    STI        #{
   ######## ######## ############
   TSINPUT  INFLOW   STI_INFLOW
   TSOUTPUT RELEASE  STI_SIMREL
   TSOUTPUT POOL     STI_SIMPOOL
   TABLE   ELEV_STOR
    #504.00      0.0
    505.00      0.0
    506.00      1.0
```

```
507.00      1.01 #Adjusted
508.00      3.0
509.00      5.0
510.00      7.0
511.00     11.0
512.00     17.0
513.00     26.0
514.00     38.0
515.00     54.0
516.00     75.0
517.00    109.0
518.00    166.0
519.00    249.0
520.00    354.0
521.00    479.0
522.00    629.0
523.00    814.0
524.00   1035.0
525.00   1282.0
526.00   1550.0
527.00   1838.0
528.00   2146.0
529.00   2472.0
530.00   2817.0
531.00   3185.0
532.00   3574.0
533.00   3986.0
534.00   4420.0
535.00   4876.0
536.00   5350.0
537.00   5841.0
538.00   6351.0
539.00   6879.0
540.00   7426.0
541.00   7993.0
542.00   8582.0
543.00   9198.0
544.00   9841.0
545.00  10514.0
546.00  11219.0
547.00  11956.0
548.00  12724.0
549.00  13527.0
550.00  14364.0
551.00  15236.0
552.00  16144.0
```

553.00	17088.0
554.00	18069.0
555.00	19090.0
556.00	20153.0
557.00	21257.0
558.00	22404.0
559.00	23594.0
560.00	24825.0
561.00	26094.0
562.00	27405.0
563.00	28762.0
564.00	30166.0
565.00	31624.0
566.00	33136.0
567.00	34703.0
568.00	36321.0
569.00	37991.0
570.00	39715.0
571.00	41489.0
572.00	43313.0
573.00	45187.0
574.00	47113.0
575.00	49090.0
576.00	51120.0
577.00	53206.0
578.00	55350.0
579.00	57557.0
580.00	59829.0
581.00	62163.0
582.00	64557.0
583.00	67012.0
584.00	69533.0
585.00	72120.0
586.00	74775.0
587.00	77494.0
588.00	80277.0
589.00	83129.0
590.00	86050.0
591.00	89040.0
592.00	92099.0
593.00	95233.0
594.00	98449.0
595.00	101751.0
596.00	105128.0
597.00	108581.0
598.00	112108.0

```
    599.00  115710.0
    600.00  119387.0
    601.00  123144.0
    602.00  126982.0
    603.00  130904.0
    604.00  134913.0
    605.00  139013.0
    606.00  143213.0
    607.00  147520.0
    608.00  151943.0
    609.00  156477.0
    610.00  161119.0
    611.00  165878.0
    612.00  170762.0
    613.00  175778.0
    614.00  180935.0
    615.00  186239.0
    616.00  191685.0
    617.00  197278.0
    618.00  203058.0
    619.00  209055.0
    620.00  215185.0
    621.00  221441.0
    622.00  227825.0
    625.00  247630.0
    630.00  282955.0
    635.00  321104.0
    640.00  362046.0
    645.00  405783.0
    650.00  452353.0
    655.00  501783.0
    660.00  554369.0
    665.00  610734.0
    670.00  671194.0
    675.00  735784.0
    680.00  804405.0
    685.00  877126.0
    690.00  953970.0
    692.00  985933.0
    694.00 1018588.0
    698.00 1084272.0
   ENDTABLE
INITIALPOOL  621.689961
PREVIOUSPOOL  621.689961
INITIALRELEASE  9.913691
PREVIOUSRELEASE  9.913903
```

```
  MINPOOL        505.0
  MINRELEASE       0.0
INITIALWITHDRAW  17.701487
INITIALINFLOW  74.249356
PREVIOUSWITHDRAW  17.714659
PREVIOUSINFLOW  72.886076
 ENDRESERVOIR
 ############ ############}
 ############ ############ ############{
 SETWITHDRAW  STI        WITHDRAWAL
# TSINPUT   OBSERVEDWITHDRAW  STI_WITHDRAW
  VALUES
   ELEV   515.0   605.0   615.0   622.0    ENDELEV
   01/01   28     28     24      9
   02/01   26     26     22      9
   03/01   29     29     24     10
   04/01   31     31     26     10
   05/01   34     34     28     11
   06/01   41     41     34     14
   07/01   46     46     38     15
   08/01   47     47     39     16
   09/01   41     41     34     14
   10/01   36     36     30     12
   11/01   30     30     25     10
   12/01   29     29     25     10
  ENDVALUES
  #BLEND          0
  #BLENDTS         0
  INTERPOLATE    ALL
  INITIALTRANSFER 0.000000
 ENDSETWITHDRAW
 ############ ############ ############}
 ############ ############ ############{
 SETWITHDRAW  STI        DIVERSION
  #TSINPUT   OBSERVEDWITHDRAW  STI_DIVERSN
  VALUES
   ELEV   515.0   622.0    ENDELEV
   01/01   34.4   34.4
   02/01   22.2   22.2
   03/01   16.4   16.4
   04/01   21.2   21.2
   05/01   21.9   21.9
   06/01   18.6   18.6
   07/01   23.8   23.8
   08/01   27.4   27.4
   09/01   28.3   28.3
```

```
 10/01    33.4    33.4
 11/01    35.7    35.7
 12/01    36.9    36.9
 ENDVALUES
 INITIALTRANSFER 0.0
ENDSETWITHDRAW
############ ############ ############}
############ ############ ############{
LOOKUP3      STI          EVAP
 ROWVAR       STI.STARTINGPOOL
 COLUMNVAR    DATE
 TABLEVAR     WITHDRAWL
 VALUES
       1/15   2/15   3/15   4/15   5/15   6/15   7/15   8/15   9/15 \
       10/15  11/15  12/15
  506     0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0 \
          0.0    0.0    0.0
  507     0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0 \
          0.0    0.0    0.0
  508     0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0 \
          0.0    0.0    0.0
  509     0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0 \
          0.0    0.0    0.0
  510     0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0 \
          0.0    0.0    0.0
  511     0.0    0.0    0.0    0.0    0.0    0.0    0.1    0.0    0.0 \
          0.0    0.0    0.0
  512     0.0    0.0    0.0    0.0    0.0    0.1    0.1    0.1    0.1 \
          0.0    0.0    0.0
  513     0.0    0.0    0.0    0.1    0.1    0.1    0.1    0.1    0.1 \
          0.1    0.0    0.0
  514     0.0    0.1    0.1    0.1    0.1    0.1    0.1    0.1    0.1 \
          0.1    0.1    0.0
  515     0.1    0.1    0.1    0.1    0.1    0.2    0.2    0.2    0.1 \
          0.1    0.1    0.1
  516     0.1    0.1    0.1    0.2    0.2    0.2    0.3    0.2    0.2 \
          0.2    0.1    0.1
  517     0.1    0.2    0.2    0.3    0.3    0.4    0.4    0.4    0.3 \
          0.3    0.2    0.1
  518     0.2    0.3    0.4    0.4    0.4    0.6    0.7    0.7    0.5 \
          0.4    0.3    0.2
  519     0.3    0.3    0.5    0.6    0.6    0.8    1.0    0.9    0.7 \
          0.6    0.4    0.3
  520     0.3    0.4    0.6    0.7    0.7    1.0    1.2    1.1    0.8 \
          0.7    0.5    0.3
  521     0.4    0.5    0.7    0.8    0.8    1.2    1.4    1.3    1.0 \
```

```
      0.8   0.6   0.4
522    0.5   0.6   0.8   1.0   1.0   1.4   1.7   1.6   1.2 \
      1.0   0.7   0.5
523    0.6   0.7   1.0   1.2   1.3   1.7   2.1   1.9   1.5 \
      1.2   0.8   0.6
524    0.7   0.9   1.2   1.4   1.5   2.0   2.4   2.2   1.8 \
      1.4   1.0   0.7
525    0.7   0.9   1.3   1.6   1.6   2.2   2.6   2.4   1.9 \
      1.5   1.1   0.8
526    0.8   1.0   1.4   1.7   1.7   2.4   2.8   2.6   2.1 \
      1.6   1.1   0.8
527    0.8   1.1   1.5   1.8   1.8   2.5   3.0   2.8   2.2 \
      1.8   1.2   0.9
528    0.9   1.1   1.6   1.9   2.0   2.7   3.2   3.0   2.4 \
      1.9   1.3   0.9
529    0.9   1.2   1.7   2.0   2.1   2.8   3.4   3.1   2.5 \
      2.0   1.4   1.0
530    1.0   1.3   1.8   2.2   2.2   3.0   3.6   3.3   2.6 \
      2.1   1.5   1.1
531    1.1   1.4   1.9   2.3   2.3   3.2   3.8   3.5   2.8 \
      2.2   1.6   1.1
532    1.1   1.4   2.0   2.4   2.5   3.4   4.0   3.8   3.0 \
      2.4   1.7   1.2
533    1.2   1.5   2.1   2.6   2.6   3.6   4.3   4.0   3.1 \
      2.5   1.7   1.3
534    1.2   1.6   2.2   2.7   2.8   3.8   4.5   4.2   3.3 \
      2.6   1.8   1.3
535    1.3   1.7   2.3   2.8   2.9   3.9   4.7   4.4   3.5 \
      2.7   1.9   1.4
536    1.3   1.7   2.4   2.9   3.0   4.1   4.9   4.5   3.6 \
      2.8   2.0   1.4
537    1.4   1.8   2.5   3.0   3.1   4.2   5.1   4.7   3.7 \
      3.0   2.1   1.5
538    1.5   1.9   2.6   3.2   3.2   4.4   5.2   4.9   3.9 \
      3.1   2.1   1.5
539    1.5   1.9   2.7   3.3   3.3   4.5   5.4   5.0   4.0 \
      3.2   2.2   1.6
540    1.6   2.0   2.8   3.4   3.5   4.7   5.6   5.2   4.1 \
      3.3   2.3   1.6
541    1.6   2.1   2.9   3.5   3.6   4.9   5.8   5.4   4.3 \
      3.4   2.4   1.7
542    1.7   2.2   3.0   3.7   3.7   5.1   6.1   5.6   4.5 \
      3.6   2.5   1.8
543    1.8   2.3   3.1   3.8   3.9   5.3   6.3   5.9   4.7 \
      3.7   2.6   1.9
544    1.8   2.4   3.3   4.0   4.1   5.6   6.6   6.2   4.9 \
```

```
      3.9   2.7   2.0
545    1.9   2.5   3.4   4.2   4.3   5.8   6.9   6.4   5.1 \
      4.1   2.8   2.0
546    2.0   2.6   3.6   4.4   4.5   6.1   7.3   6.7   5.4 \
      4.3   3.0   2.1
547    2.1   2.7   3.7   4.6   4.7   6.4   7.6   7.0   5.6 \
      4.5   3.1   2.2
548    2.2   2.8   3.9   4.8   4.9   6.7   7.9   7.4   5.8 \
      4.6   3.2   2.3
549    2.3   3.0   4.1   5.0   5.1   6.9   8.3   7.7   6.1 \
      4.8   3.4   2.4
550    2.4   3.1   4.2   5.2   5.3   7.2   8.6   8.0   6.4 \
      5.0   3.5   2.5
551    2.5   3.2   4.4   5.4   5.5   7.5   9.0   8.3   6.6 \
      5.3   3.7   2.6
552    2.6   3.3   4.6   5.6   5.8   7.8   9.4   8.7   6.9 \
      5.5   3.8   2.7
553    2.7   3.5   4.8   5.9   6.0   8.1   9.7   9.0   7.2 \
      5.7   4.0   2.9
554    2.8   3.6   5.0   6.1   6.2   8.5  10.1   9.4   7.4 \
      5.9   4.1   3.0
555    2.9   3.8   5.2   6.3   6.5   8.8  10.5   9.7   7.8 \
      6.2   4.3   3.1
556    3.0   3.9   5.4   6.6   6.7   9.2  10.9  10.1   8.1 \
      6.4   4.5   3.2
557    3.1   4.1   5.6   6.8   7.0   9.5  11.3  10.5   8.4 \
      6.7   4.6   3.3
558    3.3   4.2   5.8   7.1   7.3   9.9  11.8  10.9   8.7 \
      6.9   4.8   3.5
559    3.4   4.4   6.0   7.4   7.5  10.3  12.2  11.3   9.0 \
      7.2   5.0   3.6
560    3.5   4.5   6.2   7.6   7.8  10.6  12.6  11.7   9.3 \
      7.4   5.2   3.7
561    3.6   4.7   6.4   7.8   8.0  10.9  13.0  12.1   9.6 \
      7.6   5.3   3.8
562    3.7   4.8   6.6   8.1   8.3  11.3  13.4  12.5   9.9 \
      7.9   5.5   4.0
563    3.9   5.0   6.9   8.4   8.6  11.7  13.9  12.9  10.3 \
      8.2   5.7   4.1
564    4.0   5.2   7.1   8.7   8.9  12.1  14.4  13.4  10.6 \
      8.5   5.9   4.2
565    4.2   5.4   7.4   9.0   9.2  12.6  15.0  13.9  11.1 \
      8.8   6.1   4.4
566    4.3   5.6   7.7   9.4   9.6  13.0  15.5  14.4  11.5 \
      9.1   6.4   4.6
567    4.5   5.7   7.9   9.7   9.9  13.5  16.1  14.9  11.9 \
```

```
     9.4   6.6   4.7
568    4.6   5.9   8.2  10.0  10.2  13.9  16.6  15.4  12.2 \
     9.7   6.8   4.9
569    4.7   6.1   8.4  10.3  10.5  14.4  17.1  15.9  12.6 \
    10.0   7.0   5.0
570    4.9   6.3   8.7  10.6  10.9  14.8  17.7  16.4  13.0 \
    10.3   7.2   5.2
571    5.0   6.5   8.9  10.9  11.2  15.2  18.1  16.8  13.4 \
    10.6   7.4   5.3
572    5.2   6.7   9.2  11.2  11.5  15.6  18.6  17.3  13.8 \
    10.9   7.6   5.5
573    5.3   6.9   9.5  11.6  11.8  16.1  19.2  17.8  14.1 \
    11.2   7.9   5.6
574    5.5   7.0   9.7  11.9  12.1  16.5  19.7  18.2  14.5 \
    11.5   8.1   5.8
575    5.6   7.2  10.0  12.2  12.4  17.0  20.2  18.8  14.9 \
    11.8   8.3   5.9
576    5.8   7.4  10.2  12.5  12.8  17.4  20.8  19.3  15.3 \
    12.2   8.5   6.1
577    5.9   7.6  10.5  12.9  13.1  17.9  21.3  19.8  15.7 \
    12.5   8.7   6.3
578    6.1   7.8  10.8  13.2  13.5  18.4  21.9  20.4  16.2 \
    12.9   9.0   6.4
579    6.3   8.1  11.1  13.6  13.9  19.0  22.6  20.9  16.7 \
    13.2   9.3   6.6
580    6.4   8.3  11.5  14.0  14.3  19.5  23.2  21.6  17.1 \
    13.6   9.5   6.8
581    6.6   8.5  11.8  14.4  14.7  20.0  23.8  22.1  17.6 \
    14.0   9.8   7.0
582    6.8   8.7  12.1  14.8  15.0  20.5  24.5  22.7  18.0 \
    14.3  10.0   7.2
583    7.0   9.0  12.4  15.1  15.4  21.1  25.1  23.3  18.5 \
    14.7  10.3   7.4
584    7.1   9.2  12.7  15.5  15.9  21.6  25.8  23.9  19.0 \
    15.1  10.6   7.6
585    7.3   9.4  13.0  15.9  16.3  22.2  26.4  24.5  19.5 \
    15.5  10.8   7.8
586    7.5   9.7  13.4  16.4  16.7  22.8  27.1  25.2  20.0 \
    15.9  11.1   8.0
587    7.7   9.9  13.7  16.7  17.1  23.3  27.7  25.7  20.5 \
    16.3  11.4   8.2
588    7.9  10.2  14.0  17.1  17.5  23.9  28.4  26.4  21.0 \
    16.7  11.6   8.4
589    8.1  10.4  14.4  17.6  17.9  24.4  29.1  27.0  21.5 \
    17.1  11.9   8.6
590    8.3  10.7  14.7  18.0  18.3  25.0  29.8  27.7  22.0 \
```

```
     17.5  12.2   8.8
591    8.5  10.9  15.0  18.4  18.8  25.6  30.5  28.3  22.5 \
     17.9  12.5   9.0
592    8.7  11.2  15.4  18.8  19.2  26.2  31.2  29.0  23.0 \
     18.3  12.8   9.2
593    8.9  11.4  15.8  19.3  19.7  26.9  32.0  29.7  23.6 \
     18.8  13.1   9.4
594    9.1  11.8  16.2  19.8  20.2  27.6  32.9  30.5  24.3 \
     19.3  13.5   9.7
595    9.3  12.0  16.6  20.3  20.7  28.3  33.7  31.3  24.9 \
     19.7  13.8   9.9
596    9.6  12.3  17.0  20.8  21.2  28.9  34.5  32.0  25.4 \
     20.2  14.1  10.1
597    9.8  12.6  17.4  21.2  21.7  29.5  35.2  32.7  26.0 \
     20.6  14.4  10.3
598   10.0  12.8  17.7  21.7  22.1  30.2  36.0  33.3  26.5 \
     21.1  14.7  10.6
599   10.2  13.1  18.1  22.1  22.6  30.8  36.7  34.0  27.1 \
     21.5  15.0  10.8
600   10.4  13.4  18.5  22.6  23.1  31.5  37.5  34.8  27.7 \
     22.0  15.4  11.0
601   10.6  13.7  18.9  23.1  23.6  32.2  38.3  35.5  28.3 \
     22.5  15.7  11.3
602   10.8  14.0  19.3  23.6  24.1  32.8  39.1  36.3  28.9 \
     22.9  16.0  11.5
603   11.1  14.3  19.7  24.1  24.6  33.6  40.0  37.1  29.5 \
     23.4  16.4  11.8
604   11.3  14.6  20.2  24.7  25.1  34.3  40.9  37.9  30.2 \
     24.0  16.7  12.0
605   11.6  15.0  20.6  25.3  25.8  35.1  41.9  38.8  30.9 \
     24.5  17.2  12.3
606   11.9  15.3  21.1  25.9  26.4  36.0  42.9  39.8  31.6 \
     25.1  17.6  12.6
607   12.2  15.7  21.7  26.6  27.1  37.0  44.0  40.8  32.5 \
     25.8  18.0  12.9
608   12.5  16.2  22.3  27.3  27.8  37.9  45.2  41.9  33.3 \
     26.5  18.5  13.3
609   12.8  16.5  22.8  27.9  28.5  38.8  46.3  42.9  34.1 \
     27.1  19.0  13.6
610   13.1  16.9  23.4  28.6  29.2  39.8  47.4  44.0  35.0 \
     27.8  19.4  13.9
611   13.5  17.4  24.0  29.3  29.9  40.8  48.6  45.1  35.9 \
     28.5  19.9  14.3
612   13.8  17.8  24.6  30.1  30.7  41.9  49.9  46.3  36.8 \
     29.3  20.5  14.7
613   14.2  18.3  25.3  30.9  31.5  43.0  51.3  47.6  37.8 \
```

```
     30.1  21.0  15.1
614   14.6  18.9  26.0  31.8  32.5  44.3  52.8  48.9  38.9 \
     30.9  21.6  15.5
615   15.0  19.4  26.7  32.7  33.3  45.5  54.2  50.3  40.0 \
     31.8  22.2  15.9
616   15.4  19.9  27.4  33.6  34.2  46.7  55.7  51.6  41.1 \
     32.6  22.8  16.4
617   15.9  20.5  28.2  34.5  35.2  48.1  57.3  53.1  42.2 \
     33.6  23.5  16.8
618   16.5  21.3  29.4  35.9  36.6  50.0  59.5  55.2  43.9 \
     34.9  24.4  17.5
619   17.0  21.9  30.2  36.9  37.7  51.4  61.2  56.8  45.2 \
     35.9  25.1  18.0
620   17.3  22.3  30.8  37.7  38.4  52.4  62.5  57.9  46.1 \
     36.6  25.6  18.4
621   17.7  22.8  31.4  38.5  39.2  53.5  63.8  59.1  47.0 \
     37.4  26.1  18.7
622   18.1  23.4  32.3  39.5  40.2  54.9  65.4  60.7  48.3 \
     38.3  26.8  19.2
625   18.0  23.2  32.0  39.1  39.9  54.4  64.8  60.1  47.8 \
     38.0  26.6  19.0
630   19.6  25.3  34.9  42.6  43.5  59.3  70.7  65.6  52.2 \
     41.4  29.0  20.8
635   21.3  27.5  37.9  46.4  47.3  64.5  76.9  71.3  56.7 \
     45.0  31.5  22.6
640   23.1  29.8  41.1  50.2  51.2  69.9  83.3  77.2  61.4 \
     48.8  34.1  24.5
645   24.9  32.1  44.3  54.3  55.3  75.5  89.9  83.4  66.4 \
     52.7  36.8  26.4
650   26.9  34.6  47.8  58.4  59.6  81.3  96.9  89.9  71.5 \
     56.8  39.7  28.5
655   28.9  37.2  51.3  62.8  64.0  87.4 104.1  96.5  76.8 \
     61.0  42.6  30.6
660   30.9  39.9  55.0  67.3  68.6  93.6 111.6 103.5  82.3 \
     65.4  45.7  32.8
665   33.1  42.6  58.8  72.0  73.4 100.1 119.3 110.6  88.0 \
     69.9  48.9  35.1
670   35.3  45.5  62.8  76.8  78.3 106.8 127.3 118.1  93.9 \
     74.6  52.1  37.4
675   37.6  48.4  66.8  81.8  83.4 113.8 135.5 125.7 100.0 \
     79.4  55.5  39.8
680   39.9  51.5  71.0  86.9  88.6 120.9 144.1 133.6 106.3 \
     84.4  59.0  42.3
685   42.4  54.6  75.4  92.2  94.0 128.3 152.9 141.8 112.7 \
     89.6  62.6  44.9
690   44.9  57.9  79.8  97.7  99.6 135.9 161.9 150.2 119.4 \
```

```
        94.9   66.3   47.6
  692    45.9   59.2   81.6   99.9  101.9  139.0  165.6  153.6  122.1 \
        97.0   67.8   48.7
  694    46.9   60.5   83.5  102.1  104.2  142.1  169.3  157.0  124.9 \
        99.2   69.4   49.8
  698    49.1   63.2   87.2  106.7  108.8  148.5  176.9  164.1  130.5 \
       103.7   72.5   52.0
 ENDVALUES
 INTERPOLATE ALL
ENDLOOKUP3
############ ############ ############}
############ ############ ############{
SETSUM       STI          NEGINFW_EVAP
 SETWITHDRAW  STI          WITHDRAWAL
 SETWITHDRAW  STI          DIVERSION
 #LOOKUP3     STI          EVAP
ENDSETSUM
############ ############ ############}
############ ############ ############{
LOOKUP3      STI          NORMAL
 ROWVAR STI.STARTINGPOOL
 COLUMNVAR STI_INDEX.STARTINGDISCHARGE
 TABLEVAR RELEASE
 VALUES
         85    95   100   110   125
  505.0     1     1     1     1     1
  622.0     1     1    10    30   100
  625.0   200   700  1400  2000  2200
  635.0   500  1000  1500  2500  3000
  640.0   700  1100  2000  3500  4000
  655.0   800  1200  2200  3500  5000
  666.0  1500  2500  3500  3900  5000
  667.0    25    50   100   100   110
  675.0     0     0     0     0     0
 ENDVALUES
 INTERPOLATE ALL
ENDLOOKUP3
############ ############ ############}
############ ############ ############{
LOOKUP3      STI          LRI_CAPACITY
 # Belton has 62.1% of the storage space that contributes to LRIT2 gage
 # Stillhouse has the other 37.9%.  This method allocates channel capacity acc
 ROWVAR STI_INDEX_2.STARTINGDISCHARGE
 COLUMNVAR LRIT2_CAPAC.STARTINGDISCHARGE -
LRIT2_LOC.STARTINGDISCHARGE
 TABLEVAR RELEASE
```

```
 VALUES
          0 10000
   90.0     0  3000
  100.0     0  3790
  110.0     0  6000
  115.0     0  8000
 ENDVALUES
 INTERPOLATE ALL
ENDLOOKUP3
############ ############ ############}
############ ############ ############{
LOOKUP3      STI          CMN_CAPACITY
 # Belton has 52.9% of the storage space that contributes to CMNT2 gage
 # Stillhouse has 32.3%, Granger has 14.8%. This method allocates channel capa
 TSINDEX COLUMNS CMNLRIRMA
 COLUMNVAR INPUT_TS CFS
 ROWVAR STI_INDEX_3.STARTINGDISCHARGE
 TABLEVAR RELEASE
 VALUES
          0 10000
   90.0  1500     0
   95.0  3200     0
  100.0  3230     0
  105.0  4115     0
  110.0  5000     0
  115.0  7000     0
 ENDVALUES
 INTERPOLATE ALL
ENDLOOKUP3
############ ############ ############}
############ ############ ############{
LOOKUP3      STI          TOT_CAPACITY
 # Look at the summed local flows plus Somerville
 ROWVAR STI.STARTINGPOOL
 COLUMNVAR SHUT_OFF.STARTINGDISCHARGE
 TABLEVAR RELEASE
 VALUES
          #0 920.0  1000
          0   920  1000 # 920.0  1000
  622.0 99999  1000     0
  644.0 99999  2000     0
  666.0 99999  2000     0
 ENDVALUES
 INTERPOLATE ALL
ENDLOOKUP3
############ ############ ############}
```

```
  ############ ############ ############{
  SETMIN      STI        CAPACITIESC
   LOOKUP3     STI        LRI_CAPACITY
   LOOKUP3     STI        CMN_CAPACITY
   LOOKUP3     STI        TOT_CAPACITY
   LOOKUP3     STI        NORMAL
  ENDSETMIN
  ############ ############ ############}
  ############ ########### #############{
  SPILLWAY    STI        SPILL
   TABLE      ELEV_SPILL
   666.0  0
   666.5  1500
   667.0  2500
   670.0  30000
   675.0  50000
   698.0  100000
   ENDTABLE
   INTERVALS   12
 INITIALSPILL  0.000000
  ENDSPILLWAY
  ############ ############ ############}
  ############ ############ ############{
  SETMAX      STI        FINAL
   SETMIN      STI        CAPACITIESC
   SPILLWAY    STI        SPILL
  ENDSETMAX
  ############ ############ ############}
  ############ ########### #############{
  ADJUST      STI        SET_TO_OBS
#    TSINPUT OBSERVEDRELEASE STI_RELEASE
   TSINPUT OBSERVEDPOOL    STI_POOL
   ADJSIM  OFF
  ENDADJUST
  ############ ############ ############}
  ### End RESERVOIR STI ###}
  ### Begin NODE STI_FSTORAGE ###{
  ############ ############{
  NODE        STI_FSTORAGE
   TSINPUT  INFLOW   ZEROS
   TSOUTPUT OUTFLOW STI_FSTORAGE
   PREVIOUSDISCHARGE 0.000000
   DISCHARGE 0.000000
   INITIALINFLOW 0.000000
   PREVIOUSINFLOW 0.000000
   INITIALDIVERSION -0.000000
```

```
  PREVIOUSDIVERSION -0.000000
 ENDNODE
 ############ ############}
 ############ ############ ############{
 LOOKUP3      STI_FSTORAGE FLOOD_STORAG
  # Total flood storage between 622 and 666 is 395001.0 ac-ft
  ROWVAR STI.ENDINGPOOL
#    TSINDEX ROWS STI_POOL
#    ROWVAR INPUT_TS FT
  COLUMNVAR 1
  TABLEVAR AUGMENTATION
  VALUES
           0
   622      0
   625  19805
   630  55130
   635  93279
   640 134221
   645 177958
   650 224528
   655 273958
   660 326544
   665 382909
   670 443369
   675 507959
   680 576580
   685 649301
   690 726145
   692 758108
   694 790763
   698 856447
  ENDVALUES
  INTERPOLATE ALL
 ENDLOOKUP3
 ############ ############ ############}
 ### End NODE STI_FSTORAGE ###}
 ### Begin NODE STI_PERCENTF ###{
 ############ ############{
 NODE         STI_PERCENTF
  TSINPUT  INFLOW   ZEROS
  TSOUTPUT OUTFLOW STI_PERCENTF
  PREVIOUSDISCHARGE 0.000000
  DISCHARGE 0.000000
  INITIALINFLOW 0.000000
  PREVIOUSINFLOW 0.000000
  INITIALDIVERSION -0.000000
```

```
   PREVIOUSDIVERSION -0.000000
  ENDNODE
  ############ ############}
  ############ ############ ############{
  LOOKUP3      STI_PERCENTF PERCENT_FULL
   # Total flood storage between 622 and 666 is 395001.0 ac-ft
   ROWVAR STI.ENDINGPOOL
#    TSINDEX ROWS STI_POOL
#    ROWVAR INPUT_TS FT
   COLUMNVAR 1
   TABLEVAR AUGMENTATION
   VALUES
           0
    622   0.00
    625   5.01
    630  13.96
    635  23.61
    640  33.98
    645  45.05
    650  56.84
    655  69.36
    660  82.67
    665  96.94
    670 112.25
   ENDVALUES
   INTERPOLATE ALL
  ENDLOOKUP3
  ############ ############ ############}
  ### Begin NODE LRIT2_LOC ###{
  ############ ############
  NODE         LRIT2_LOC
   TSINPUT  INFLOW LRIT2_LOCAL
   DISCHARGE 0.000000
   PREVIOUSDISCHARGE 0.000000
   INITIALINFLOW 0.000000
   PREVIOUSINFLOW 0.000000
   INITIALDIVERSION 0.000000
   PREVIOUSDIVERSION 0.000000
  ENDNODE
  ############ ############
  ### End NODE LRIT2_LOC ###}
  ### Begin NODE LRIT2_CAPAC ###{
  ############ ############
  NODE         LRIT2_CAPAC
   TSINPUT  INFLOW   ZEROS
   TSOUTPUT OUTFLOW LRI_CAPACMOD
```

```
 DISCHARGE 3000.000000
 PREVIOUSDISCHARGE 3000.000000
 INITIALINFLOW 0.000000
 PREVIOUSINFLOW 0.000000
 INITIALDIVERSION -3000.000000
 PREVIOUSDIVERSION -3000.000000
ENDNODE
############ ############
############ ############ ############{
LOOKUP3      LRIT2_CAPAC  HOLD_CAPAC_B
 COLUMNVAR LRIT2_CAPAC.STARTINGDISCHARGE
 ROWVAR BLN.STARTINGPOOL
 TABLEVAR AUGMENTATION
 VALUES
          0  2999  5999  9999
  594.0  3000  3000  3000  3000
  596.0  3000  3000  6000  6000
  596.5  6000  6000  6000  6000
  605.0  6000  6000  6000 10000
  610.0 10000 10000 10000 10000
 ENDVALUES
ENDLOOKUP3
############ ############ ############}
############ ############ ############{
LOOKUP3      LRIT2_CAPAC  HOLD_CAPAC_S
 COLUMNVAR LRIT2_CAPAC.STARTINGDISCHARGE
 ROWVAR STI.STARTINGPOOL
 TABLEVAR AUGMENTATION
 VALUES
          0  2999  5999  9999
  622.0  3000  3000  3000  3000
  624.0  3000  3000  6000  6000
  625.0  6000  6000  6000  6000
  635.0  6000  6000  6000 10000
  640.0 10000 10000 10000 10000
 ENDVALUES
ENDLOOKUP3
############ ############ ############}
############ ############ ############{
# This method takes the minimum of two augmentations
# This is equivalent to taking the maximum of the two values
# because augmentations are negative diversions.
# This method should be thought of as taking the max, not the min
SETMIN       LRIT2_CAPAC  TAKE_LARGEST
 LOOKUP3      LRIT2_CAPAC  HOLD_CAPAC_B
 LOOKUP3      LRIT2_CAPAC  HOLD_CAPAC_S
```

```
ENDSETMIN
############ ############ ############}
### End NODE LRIT2_CAPAC ###}
### Begin RESERVOIR GGL ###{
############ ############{
RESERVOIR    GGL
 ######## ######## ############
 TSINPUT  INFLOW   GGL_INFLOW
 TSOUTPUT RELEASE  GGL_SIMREL
 TSOUTPUT POOL     GGL_SIMPOOL
 TABLE   ELEV_STOR
  708       0
  709       1
  710       3
  711       5
  712       8
  713      12
  714      17
  715      24
  716      31
  717      41
  718      52
  719      66
  720      81
  721      98
  722     118
  723     141
  724     166
  725     197
  726     239
  727     291
  728     353
  729     427
  730     516
  731     617
  732     728
  733     850
  734     982
  735    1123
  736    1277
  737    1441
  738    1619
  739    1811
  740    2020
  741    2243
  742    2479
```

743	2730
744	2994
745	3273
746	3569
747	3880
748	4206
749	4547
750	4904
751	5276
752	5663
753	6064
754	6478
755	6905
756	7346
757	7805
758	8282
759	8779
760	9293
761	9828
762	10382
763	10957
764	11552
765	12169
766	12809
767	13471
768	14159
769	14871
770	15609
771	16373
772	17161
773	17972
774	18806
775	19665
776	20546
777	21450
778	22380
779	23334
780	24314
781	25322
782	26356
783	27416
784	28506
785	29625
786	30775
787	31951
788	33154

```
    789   34382
    790   35632
    791   36904
    795   42412
    800   50162
    805   58897
    810   68527
    815   79177
    820   90937
    825  103897
    830  118207
    835  133897
    840  151057
    845  170122
    850  191362
    855  214962
    860  241062
    865  269677
    870  300867
    872  314072
    874  327697
    876  341757
    878  356267
    879  363682
   ENDTABLE
INITIALPOOL  789.750000
PREVIOUSPOOL  789.759843
INITIALRELEASE  3.653035
PREVIOUSRELEASE  3.654766
   MINPOOL        708.0
   MINRELEASE       0.0
INITIALWITHDRAW  37.954338
INITIALINFLOW  0.000000
PREVIOUSWITHDRAW  37.969382
PREVIOUSINFLOW  0.000000
  ENDRESERVOIR
  ############ ############}
  ############ ############ ############{
  SETWITHDRAW  GGL         WITHDRAWAL
#   TSINPUT   OBSERVEDWITHDRAW  GGL_WITHDRAW
   VALUES
    ELEV   720.0  766.0  791.0    ENDELEV
    01/01   11     16     33
    02/01   10     16     31
    03/01   13     19     38
    04/01   15     22     45
```

```
  05/01    17      26      51
  06/01    20      30      60
  07/01    24      36      73
  08/01    26      39      79
  09/01    22      33      66
  10/01    18      28      55
  11/01    14      21      42
  12/01    12      19      37
 ENDVALUES
 INTERPOLATE     ALL
 INITIALTRANSFER 0.000000
ENDSETWITHDRAW
############ ############ ############}
############ ############ ############{
SETWITHDRAW  GGL         DIVERSION
 #TSINPUT   OBSERVEDWITHDRAW  GGL_DIVERSN
 VALUES
  ELEV    720.0   791.0     ENDELEV
  01/01   -34.4   -34.4
  02/01   -22.2   -22.2
  03/01   -16.4   -16.4
  04/01   -21.2   -21.2
  05/01   -21.9   -21.9
  06/01   -18.6   -18.6
  07/01   -23.8   -23.8
  08/01   -27.4   -27.4
  09/01   -28.3   -28.3
  10/01   -33.4   -33.4
  11/01   -35.7   -35.7
  12/01   -36.9   -36.9
 ENDVALUES
 INITIALTRANSFER 0.0
ENDSETWITHDRAW
############ ############ ############}
############ ############ ############{
LOOKUP3      GGL          EVAP
 COLUMNVAR    DATE
 ROWVAR       GGL.STARTINGPOOL
 TABLEVAR     WITHDRAWAL
 VALUES
       01/15  02/15  03/15  04/15  05/15  06/15  07/15  08/15  09/15 \
        10/15  11/15  12/15
  706   0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000 \
        0.000  0.000  0.000
  707   0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000 \
        0.000  0.000  0.000
```

```
708  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000 \
    0.000  0.000  0.000
709  0.003  0.003  0.005  0.007  0.007  0.009  0.010  0.010  0.008 \
    0.006  0.004  0.003
710  0.005  0.007  0.011  0.013  0.014  0.017  0.020  0.020  0.016 \
    0.012  0.008  0.006
711  0.008  0.010  0.016  0.020  0.021  0.026  0.030  0.031  0.024 \
    0.018  0.012  0.008
712  0.008  0.010  0.016  0.020  0.021  0.026  0.030  0.031  0.024 \
    0.018  0.012  0.008
713  0.013  0.017  0.027  0.033  0.036  0.044  0.049  0.051  0.040 \
    0.030  0.020  0.014
714  0.016  0.021  0.032  0.039  0.043  0.052  0.059  0.061  0.048 \
    0.036  0.025  0.017
715  0.018  0.024  0.038  0.046  0.050  0.061  0.069  0.071  0.056 \
    0.042  0.029  0.020
716  0.024  0.031  0.048  0.059  0.064  0.078  0.089  0.092  0.071 \
    0.054  0.037  0.025
717  0.026  0.035  0.054  0.065  0.072  0.087  0.099  0.102  0.079 \
    0.059  0.041  0.028
718  0.034  0.045  0.070  0.085  0.093  0.113  0.128  0.132  0.103 \
    0.077  0.053  0.037
719  0.037  0.049  0.075  0.092  0.100  0.122  0.138  0.143  0.111 \
    0.083  0.057  0.040
720  0.042  0.055  0.086  0.105  0.114  0.139  0.158  0.163  0.127 \
    0.095  0.065  0.045
721  0.047  0.062  0.097  0.118  0.129  0.157  0.178  0.183  0.143 \
    0.107  0.074  0.051
722  0.055  0.073  0.113  0.137  0.150  0.183  0.207  0.214  0.167 \
    0.125  0.086  0.059
723  0.063  0.083  0.129  0.157  0.172  0.209  0.237  0.245  0.191 \
    0.143  0.098  0.068
724  0.071  0.094  0.145  0.177  0.193  0.235  0.267  0.275  0.214 \
    0.161  0.110  0.076
725  0.092  0.121  0.188  0.229  0.250  0.305  0.346  0.357  0.278 \
    0.208  0.143  0.099
726  0.126  0.166  0.258  0.314  0.343  0.418  0.474  0.489  0.381 \
    0.286  0.196  0.136
727  0.150  0.198  0.306  0.373  0.408  0.496  0.563  0.581  0.453 \
    0.339  0.233  0.161
728  0.176  0.232  0.360  0.438  0.479  0.583  0.662  0.683  0.532 \
    0.399  0.274  0.190
729  0.216  0.284  0.440  0.536  0.587  0.713  0.810  0.836  0.651 \
    0.488  0.335  0.232
730  0.252  0.333  0.515  0.628  0.687  0.835  0.948  0.978  0.762 \
    0.571  0.393  0.272
```

```
731  0.279 0.367 0.569 0.693 0.759 0.922 1.047 1.080 0.842 \
     0.631 0.433 0.300
732  0.308 0.405 0.628 0.765 0.837 1.018 1.156 1.192 0.929 \
     0.696 0.478 0.331
733  0.334 0.440 0.682 0.831 0.909 1.105 1.255 1.294 1.008 \
     0.756 0.519 0.360
734  0.360 0.475 0.735 0.896 0.980 1.192 1.354 1.396 1.088 \
     0.815 0.560 0.388
735  0.387 0.509 0.789 0.961 1.052 1.279 1.452 1.498 1.167 \
     0.875 0.601 0.416
736  0.418 0.551 0.853 1.040 1.138 1.383 1.571 1.620 1.263 \
     0.946 0.650 0.450
737  0.450 0.593 0.918 1.118 1.224 1.488 1.689 1.743 1.358 \
     1.017 0.699 0.484
738  0.486 0.641 0.993 1.210 1.324 1.610 1.828 1.885 1.469 \
     1.101 0.757 0.524
739  0.528 0.697 1.079 1.315 1.438 1.749 1.986 2.049 1.596 \
     1.196 0.822 0.569
740  0.565 0.745 1.154 1.406 1.539 1.871 2.124 2.191 1.707 \
     1.279 0.879 0.609
741  0.605 0.797 1.234 1.504 1.646 2.001 2.272 2.344 1.826 \
     1.368 0.941 0.651
742  0.642 0.846 1.310 1.596 1.746 2.123 2.411 2.487 1.938 \
     1.452 0.998 0.691
743  0.678 0.894 1.385 1.687 1.846 2.245 2.549 2.629 2.049 \
     1.535 1.055 0.731
744  0.713 0.939 1.454 1.772 1.939 2.358 2.677 2.762 2.152 \
     1.612 1.108 0.768
745  0.755 0.995 1.540 1.877 2.054 2.497 2.836 2.925 2.279 \
     1.708 1.174 0.813
746  0.799 1.053 1.632 1.988 2.175 2.645 3.004 3.098 2.414 \
     1.809 1.243 0.861
747  0.839 1.105 1.712 2.086 2.283 2.776 3.152 3.251 2.533 \
     1.898 1.305 0.904
748  0.878 1.157 1.793 2.184 2.390 2.906 3.300 3.404 2.652 \
     1.987 1.366 0.946
749  0.918 1.209 1.873 2.283 2.497 3.037 3.448 3.557 2.771 \
     2.076 1.427 0.989
750  0.957 1.261 1.954 2.381 2.605 3.167 3.596 3.710 2.890 \
     2.166 1.489 1.031
751  0.999 1.317 2.039 2.485 2.719 3.306 3.754 3.873 3.017 \
     2.261 1.554 1.076
752  1.039 1.369 2.120 2.583 2.827 3.437 3.903 4.026 3.137 \
     2.350 1.615 1.119
753  1.070 1.410 2.184 2.662 2.912 3.541 4.021 4.148 3.232 \
     2.422 1.664 1.153
```

```
754  1.104  1.455  2.254  2.747  3.005  3.654  4.150  4.281  3.335 \
     2.499  1.718  1.190
755  1.141  1.504  2.329  2.838  3.106  3.776  4.288  4.423  3.446 \
     2.582  1.775  1.229
756  1.183  1.559  2.415  2.943  3.220  3.915  4.446  4.586  3.573 \
     2.677  1.840  1.275
757  1.230  1.622  2.512  3.061  3.349  4.072  4.624  4.770  3.716 \
     2.784  1.914  1.326
758  1.280  1.688  2.614  3.185  3.485  4.237  4.812  4.963  3.867 \
     2.898  1.992  1.379
759  1.328  1.750  2.710  3.303  3.614  4.394  4.989  5.147  4.010 \
     3.005  2.065  1.430
760  1.380  1.819  2.818  3.434  3.757  4.568  5.187  5.351  4.169 \
     3.124  2.147  1.487
761  1.433  1.889  2.925  3.564  3.900  4.742  5.385  5.555  4.328 \
     3.243  2.229  1.544
762  1.483  1.954  3.027  3.689  4.036  4.907  5.572  5.748  4.479 \
     3.356  2.306  1.598
763  1.538  2.027  3.140  3.826  4.186  5.090  5.780  5.962  4.645 \
     3.481  2.392  1.657
764  1.591  2.096  3.247  3.957  4.329  5.264  5.977  6.166  4.804 \
     3.600  2.474  1.714
765  1.651  2.176  3.370  4.107  4.494  5.464  6.205  6.400  4.987 \
     3.736  2.568  1.779
766  1.712  2.256  3.494  4.258  4.659  5.664  6.432  6.635  5.169 \
     3.873  2.662  1.844
767  1.775  2.339  3.623  4.415  4.830  5.873  6.669  6.879  5.360 \
     4.016  2.760  1.912
768  1.840  2.426  3.757  4.578  5.009  6.091  6.916  7.134  5.558 \
     4.165  2.863  1.983
769  1.906  2.512  3.891  4.742  5.188  6.308  7.163  7.389  5.757 \
     4.314  2.965  2.054
770  1.975  2.602  4.031  4.912  5.374  6.534  7.420  7.654  5.963 \
     4.468  3.071  2.127
771  2.040  2.689  4.165  5.075  5.553  6.752  7.667  7.909  6.162 \
     4.617  3.173  2.198
772  2.106  2.776  4.299  5.239  5.732  6.969  7.914  8.164  6.360 \
     4.766  3.276  2.269
773  2.161  2.848  4.412  5.376  5.882  7.152  8.121  8.378  6.527 \
     4.891  3.361  2.328
774  2.227  2.935  4.546  5.540  6.061  7.370  8.368  8.632  6.726 \
     5.039  3.464  2.399
775  2.287  3.015  4.669  5.690  6.226  7.570  8.596  8.867  6.908 \
     5.176  3.558  2.464
776  2.348  3.094  4.793  5.840  6.390  7.770  8.823  9.101  7.091 \
     5.313  3.652  2.529
```

```
777  2.411  3.178  4.921  5.997  6.562  7.979  9.060  9.346  7.282 \
     5.456  3.750  2.597
778  2.477  3.264  5.056  6.161  6.741  8.196  9.307  9.601  7.480 \
     5.605  3.852  2.668
779  2.542  3.351  5.190  6.324  6.920  8.414  9.554  9.855  7.679 \
     5.753  3.954  2.739
780  2.611  3.441  5.329  6.494  7.106  8.640  9.811 10.120  7.885 \
     5.908  4.061  2.813
781  2.684  3.538  5.480  6.678  7.306  8.884 10.088 10.406  8.107 \
     6.075  4.175  2.892
782  2.753  3.628  5.619  6.848  7.492  9.110 10.344 10.671  8.314 \
     6.229  4.282  2.966
783  2.826  3.725  5.769  7.031  7.693  9.354 10.621 10.956  8.536 \
     6.396  4.396  3.045
784  2.905  3.829  5.930  7.227  7.907  9.615 10.917 11.262  8.774 \
     6.574  4.519  3.130
785  2.984  3.933  6.091  7.423  8.122  9.876 11.214 11.568  9.013 \
     6.753  4.641  3.215
786  3.058  4.030  6.242  7.606  8.322 10.119 11.490 11.853  9.235 \
     6.920  4.756  3.294
787  3.129  4.124  6.387  7.783  8.516 10.354 11.757 12.128  9.449 \
     7.080  4.866  3.371
788  3.197  4.214  6.526  7.953  8.702 10.580 12.014 12.393  9.656 \
     7.235  4.973  3.444
789  3.260  4.297  6.655  8.110  8.873 10.789 12.251 12.638  9.846 \
     7.378  5.071  3.512
790  3.315  4.370  6.768  8.247  9.024 10.972 12.459 12.852 10.013 \
     7.503  5.157  3.572
791  3.384  4.460  6.907  8.417  9.210 11.198 12.716 13.117 10.220 \
     7.657  5.263  3.645
795  3.714  4.895  7.582  9.239 10.109 12.291 13.957 14.397 11.217 \
     8.405  5.777  4.001
800  4.185  5.516  8.543 10.411 11.391 13.851 15.728 16.224 12.640 \
     9.471  6.510  4.509
805  4.701  6.196  9.597 11.694 12.795 15.558 17.666 18.224 14.199 \
    10.639  7.312  5.065
810  5.265  6.939 10.747 13.097 14.330 17.424 19.785 20.409 15.901 \
    11.914  8.189  5.672
815  5.879  7.749 12.001 14.625 16.002 19.457 22.094 22.791 17.757 \
    13.305  9.145  6.334
820  6.548  8.629 13.365 16.287 17.820 21.668 24.604 25.381 19.775 \
    14.817 10.184  7.054
825  7.273  9.585 14.845 18.090 19.793 24.067 27.328 28.190 21.964 \
    16.457 11.311  7.835
830  8.057 10.619 16.446 20.042 21.929 26.663 30.277 31.232 24.333 \
    18.232 12.531  8.680
```

```
  835   8.904 11.736 18.176 22.149 24.235 29.467 33.460 34.516 26.892 \
       20.150 13.849  9.593
  840   9.817 12.939 20.040 24.420 26.719 32.488 36.891 38.055 29.649 \
       22.216 15.269 10.576
  845  10.799 14.232 22.043 26.862 29.391 35.737 40.580 41.860 32.614 \
       24.437 16.796 11.634
  850  11.852 15.621 24.193 29.482 32.258 39.222 44.538 45.943 35.795 \
       26.820 18.434 12.769
  855  12.980 17.107 26.496 32.288 35.327 42.955 48.776 50.315 39.201 \
       29.373 20.188 13.984
  860  14.186 18.696 28.956 35.286 38.609 46.945 53.306 54.988 42.842 \
       32.101 22.063 15.283
  865  15.472 20.391 31.582 38.486 42.109 51.201 58.139 59.974 46.727 \
       35.011 24.064 16.668
  870  16.842 22.196 34.378 41.893 45.837 55.734 63.287 65.283 50.864 \
       38.111 26.194 18.144
  872  17.414 22.950 35.546 43.316 47.394 57.627 65.436 67.501 52.591 \
       39.405 27.084 18.760
  874  18.000 23.723 36.742 44.774 48.989 59.566 67.638 69.772 54.361 \
       40.731 27.996 19.392
  876  18.600 24.514 37.967 46.267 50.623 61.553 69.894 72.099 56.174 \
       42.090 28.929 20.038
  878  19.215 25.324 39.222 47.796 52.296 63.587 72.204 74.482 58.031 \
       43.481 29.885 20.700
  879  19.528 25.736 39.861 48.574 53.147 64.622 73.380 75.695 58.975 \
       44.189 30.372 21.037
 ENDVALUES
 INTERPOLATE ALL
ENDLOOKUP3
############ ############ ############}
############ ############ ############{
SETSUM      GGL        NEG_N_EVAP
 SETWITHDRAW  GGL         WITHDRAWAL
 SETWITHDRAW  GGL         DIVERSION
 #LOOKUP3     GGL         EVAP
ENDSETSUM
############ ############ ############}
############ ############ ############{
LOOKUP3     GGL         SLOW_UP
 COLUMNVAR GGL.STARTINGRELEASE
 ROWVAR GGL.STARTINGPOOL
 TABLEVAR RELEASE
 VALUES
          0  170 350  650 1000 1200 1500 2000 2500
  779      4   4  4    4    4    4    4    4    4
  791.99  170  350 650 1000 1200 1500 2000 2500 9999
```

```
 ENDVALUES
 INTERPOLATE COLUMNS
ENDLOOKUP3
############ ############ ############}
############ ############ ############{
LOOKUP3      GGL          FIRST_GO
 COLUMNVAR GGL_INDEX.STARTINGDISCHARGE
 ROWVAR GGL.STARTINGPOOL
 TABLEVAR RELEASE
 VALUES
          85  100  115
  700       0    0    0
  765       2    2    2
  777       3    3    3
  779       4    4    4
  791.49  170  170  170
  793.49  170  250  650
  795     170  400  650
  800     250  650  800
  820     650  800 1300
 ENDVALUES
 INTERPOLATE COLUMNS
ENDLOOKUP3
############ ############ ############}
############ ############ ############{
SETMIN       GGL          SLOW_UP
 LOOKUP3      GGL          SLOW_UP
 LOOKUP3      GGL          FIRST_GO
ENDSETMIN
############ ############ ############}
############ ############ ############{
LOOKUP3      GGL          KEEP_IT_UP
 COLUMNVAR GGL.STARTINGRELEASE
 ROWVAR GGL.STARTINGPOOL
 TABLEVAR RELEASE
 VALUES
           0  170  250  650  800 1300 2000
  779        4    4    4    4    4    4    4
  791.99     0  170  250  250  650  800  800
  795        0  170  250  650  650  800  800
  800        0  170  250  650  650  800 1300
  820        0  170  250  650  800 1300 2000
 ENDVALUES
 INTERPOLATE COLUMNS
ENDLOOKUP3
############ ############ ############}
```

```
  ############ ############ ############{
  SETMAX      GGL         RECOVER
   SETMIN      GGL         SLOW_UP
    #LOOKUP3     GGL         SLOW_UP
    #LOOKUP3     GGL         FIRST_GO
#   LOOKUP3     GGL         KEEP_IT_UP
  ENDSETMAX
  ############ ############ ############}
  ############ ############ ############{
  LOOKUP3     GGL         MORETHANINFL
   COLUMNVAR GGL.PREVIOUSINFLOW + GGL.STARTINGINFLOW +
GGL.ENDINGINFLOW
   ROWVAR GGL.STARTINGRELEASE
   TABLEVAR RELEASE
   VALUES
           0  3000 9000
     0      4     4    4
    50     50    50   50
   1000   1000  1100 3300
   ENDVALUES
   INTERPOLATE ALL
  ENDLOOKUP3
  ############ ############ ############}
  ############ ############ ############{
  SETMAX      GGL         RECOVER_B
   SETMIN      GGL         SLOW_UP
    #LOOKUP3     GGL         SLOW_UP
    #LOOKUP3     GGL         FIRST_GO
   LOOKUP3     GGL         KEEP_IT_UP
   LOOKUP3     GGL         MORETHANINFL
  ENDSETMAX
  ############ ############ ############}
  ############ ############ ############{
  LOOKUP3     GGL         NORMAL
   COLUMNVAR GGL_INDEX.STARTINGDISCHARGE -
GNG_INDEX.STARTINGDISCHARGE
   ROWVAR GGL.STARTINGPOOL
   TABLEVAR RELEASE
   VALUES
         -15    0    5   15
    700      0    0    0    0
    765      2    2    2    2
    777      3    3    3    3
    791.0    4    4    4    4
    791.5   30   40   45   50
    793.5  170  250  300  350
```

```
  795     250  300  400  550
  800     250  650  750  800
  810     275  675  800 1100
  820     300  700  950 1300
  833.1   350  800 1050 1300
  835.0     0    0    0    0
 ENDVALUES
 INTERPOLATE ALL
ENDLOOKUP3
############ ############ ############}
########### ############ ############{
LOOKUP3     GGL          TOT_CAPACITY
 # Look at the summed local flows plus Somerville
 ROWVAR GGL.STARTINGPOOL
 COLUMNVAR SHUT_OFF.STARTINGDISCHARGE
 TABLEVAR RELEASE
 VALUES
          0   910  1000 # 920.0  1000
  780.0 99999     4     4
  791.0 99999   500     0
  815.0 99999   800     0
  834.0 99999  1300     0
 ENDVALUES
 INTERPOLATE ALL
ENDLOOKUP3
############ ############ ############}
############ ############ ############{
LOOKUP3      GGL          GNG_NORMAL
 ROWVAR GNG.STARTINGPOOL
 COLUMNVAR GNG_INDEX.STARTINGDISCHARGE
 TABLEVAR RELEASE
 VALUES
         85    95   100   110   125
  504.0     4     4     4     4     4
  505.0   350   700   750  1500  2000
  505.5  1000  1000  1000  2000  2500
  508.0  2000  2000  2500  3000  3000
  515.0  2500  3000  3500  3500  3500
  527.5  3500  4000  4000  4000  4000
  528.7     0     0     0     0     0
 ENDVALUES
 INTERPOLATE ALL
ENDLOOKUP3
############ ############ ############}
############ ############ ############{
LOOKUP3      GGL          GNG_CMN_CAP
```

```
 # Belton has 52.9% of the storage space that contributes to CMNT2 gage
 # Stillhouse has 32.3%, Granger has 14.8%. This method allocates channel capa
 TSINDEX COLUMNS CMNLRIRMA
 COLUMNVAR INPUT_TS CFS
 ROWVAR GNG_INDEX_3.STARTINGDISCHARGE
 TABLEVAR RELEASE
 VALUES
         0 10000
   75.0  2000    0
   95.0  2000    0
  100.0  2500    0
  110.0  3000    0
 ENDVALUES
 INTERPOLATE ALL
ENDLOOKUP3
############ ############ ############}
############ ############ ############{
LOOKUP3      GGL          GNG_TOT_CAP
 # Look at the summed local flows plus Somerville
 ROWVAR GNG.STARTINGPOOL
 COLUMNVAR SHUT_OFF.STARTINGDISCHARGE
 TABLEVAR RELEASE
 VALUES
         #0 920.0  1000
         0   920  1000 # 920.0  1000
  504.0 99999  1000    0
  515.0 99999  2000    0
  528.0 99999  2000    0
 ENDVALUES
 INTERPOLATE ALL
ENDLOOKUP3
############ ############ ############}
############ ############ ############{
SETMIN      GGL         CAPACITIES
 LOOKUP3     GGL         NORMAL
 LOOKUP3     GGL         TOT_CAPACITY
 LOOKUP3     GGL         GNG_NORMAL
 LOOKUP3     GGL         GNG_CMN_CAP
 LOOKUP3     GGL         GNG_TOT_CAP
ENDSETMIN
############ ############ ############}
############ ########### #############{
SPILLWAY     GGL         SPILL
 TABLE       ELEV_SPILL
 834.0     0
 834.5     1600
```

```
  835.0    3800
  879.0    25000
  ENDTABLE
  INTERVALS   12
INITIALSPILL  0.000000
 ENDSPILLWAY
 ############ ############ ############}
 ############ ############ ############{
 SETMAX      GGL         FINAL
  SETMIN      GGL         CAPACITIES
  SPILLWAY     GGL         SPILL
 ENDSETMAX
 ############ ############ ############}
 ############ ########### #############{
 ADJUST       GGL         SET_TO_OBS
  #TSINPUT OBSERVEDRELEASE GGL_RELEASE
  TSINPUT OBSERVEDPOOL    GGL_POOL
  ADJSIM  OFF
 ENDADJUST
 ############ ############ ############}
 ### End RESERVOIR GGL ###}
 ### Begin NODE GGL_FSTORAGE ###{
 ############ ############{
 NODE        GGL_FSTORAGE
  TSINPUT  INFLOW   ZEROS
  TSOUTPUT OUTFLOW GGL_FSTORAGE
  PREVIOUSDISCHARGE 0.000000
  DISCHARGE 0.000000
  INITIALINFLOW 0.000000
  PREVIOUSINFLOW 0.000000
  INITIALDIVERSION -0.000000
  PREVIOUSDIVERSION -0.000000
 ENDNODE
 ############ ############}
 ############ ############ ############{
 LOOKUP3      GGL_FSTORAGE FLOOD_STORAG
  # Total flood storage between 791 and 834 is 93855.0 ac-ft
  ROWVAR GGL.ENDINGPOOL
#    TSINDEX ROWS GGL_POOL
#    ROWVAR INPUT_TS FT
  COLUMNVAR 1
  TABLEVAR AUGMENTATION
  VALUES
         0
   791     0
   795   5508
```

```
   800  13258
   805  21993
   810  31623
   815  42273
   820  54033
   825  66993
   830  81303
   835  96993
   840 114153
   845 133218
   850 154458
   855 178058
   860 204158
   865 232773
   870 263963
   872 277168
   874 290793
   876 304853
   878 319363
   879 326778
  ENDVALUES
  INTERPOLATE ALL
 ENDLOOKUP3
 ############ ############ ############}
 ### End NODE GGL_FSTORAGE ###}
 ### Begin NODE GGL_PERCENTF ###{
 ############ ############{
 NODE         GGL_PERCENTF
  TSINPUT  INFLOW   ZEROS
  TSOUTPUT OUTFLOW GGL_PERCENTF
  PREVIOUSDISCHARGE 0.000000
  DISCHARGE 0.000000
  INITIALINFLOW 0.000000
  PREVIOUSINFLOW 0.000000
  INITIALDIVERSION -0.000000
  PREVIOUSDIVERSION -0.000000
 ENDNODE
 ############ ############}
 ############ ############ ############{
 LOOKUP3      GGL_PERCENTF PERCENT_FULL
  # Total flood storage between 791 and 834 is 93855.0 ac-ft
  ROWVAR GGL.ENDINGPOOL
#    TSINDEX ROWS GGL_POOL
#    ROWVAR INPUT_TS FT
  COLUMNVAR 1
  TABLEVAR AUGMENTATION
```

```
  VALUES
         0
   791   0.00
   795   5.87
   800  14.13
   805  23.43
   810  33.69
   815  45.04
   820  57.57
   825  71.38
   830  86.63
   835 103.34
  ENDVALUES
  INTERPOLATE ALL
 ENDLOOKUP3
 ############ ############ ############}
 ### End NODE GGL_PERCENTF ###}
 ### Begin REACH GGL_TO_GNG ###{
 ############ ############ {
 REACH        GGL_TO_GNG
  TSINPUT  INFLOW GETT2_TOTAL
 ENDREACH
 ############ ############ }
 ############ ############ ############{
 LAGK         GGL_TO_GNG   GNGT2_LAGK
  LAG
   TABLE INFLOW_LAG
        1.000 12.000
     20000.229  6.000
   ENDTABLE
  ENDLAG
  K
   TABLE OUTFLOW_K
        0.000   6.000
    1000011.000  12.000
   ENDTABLE
  ENDK
  COINFLOW
   VALUES
10.241057
9.954656
11.475262
   ENDVALUES
  ENDCOINFLOW
INITIALOUTFLOW  0.000000
INITIALSTORAGE  0.000000
```

```
INITIALLAGGEDINFLOW  0.000000
 ENDLAGK
 ############ ############ ############}
 ### End REACH GGL_TO_GNG ###}
 ### Begin NODE GNG_INFLOW ###{
 ############ ############{
 NODE         GNG_INFLOW
  TSINPUT  INFLOW   GNG_LOCAL
  TSOUTPUT OUTFLOW GNG_TOTIN
  PREVIOUSDISCHARGE 10.860084
  DISCHARGE 10.753858
  INITIALINFLOW 10.753858
  PREVIOUSINFLOW 10.860084
  INITIALDIVERSION 0.000000
  PREVIOUSDIVERSION 0.000000
 ENDNODE
 ############ ############}
 ### End NODE GNG_INFLOW ###}
 ### Begin RESERVOIR GNG ###{
 ############ ############{
 RESERVOIR    GNG
  ######## ######## ############
#   TSINPUT  INFLOW   GNG_LOCAL
#   TSINPUT  INFLOW   GNG_INFLOW
  TSINPUT  INFLOW   GNG_CPINFL
  TSOUTPUT RELEASE  GNG_SIMREL
  TSOUTPUT POOL     GNG_SIMPOOL
#   TSOUTPUT WITHDRAW GNG_SIMWITH
  TSOUTPUT STORAGE  GNG_STOR
  TABLE   ELEV_STOR
   466.00       0.0
   467.00       1.0
   468.00      14.0
   469.00      48.0
   470.00     106.0
   471.00     191.0
   472.00     305.0
   473.00     448.0
   474.00     617.0
   475.00     820.0
   476.00    1061.0
   477.00    1355.0
   478.00    1731.0
   479.00    2205.0
   480.00    2786.0
   481.00    3475.0
```

```
    482.00    4257.0
    483.00    5119.0
    484.00    6064.0
    485.00    7107.0
    486.00    8261.0
    487.00    9532.0
    488.00   10906.0
    489.00   12384.0
    490.00   13968.0
    491.00   15665.0
    492.00   17486.0
    493.00   19441.0
    494.00   21537.0
    495.00   23791.0
    496.00   26215.0
    497.00   28830.0
    498.00   31640.0
    499.00   34625.0
    500.00   37798.0
    501.00   41172.0
    502.00   44749.0
    503.00   48543.0
    504.00   52525.0
    505.00   57808.0
    510.00   83513.0
    515.00  115377.0
    520.00  154124.0
    525.00  200405.0
    530.00  254775.0
    535.00  317619.0
    540.00  389762.0
    545.00  471255.0
    550.00  562105.0
    552.00  601105.0
    554.00  641555.0
    556.00  683505.0
    558.00  726855.0
    560.00  771505.0
    562.00  817655.0
    564.00  865255.0
    566.00  914255.0
    568.00  964655.0
    570.00 1016655.0
   ENDTABLE
INITIALPOOL  502.399934
PREVIOUSPOOL  502.399934
```

```
INITIALRELEASE  4.000000
PREVIOUSRELEASE  4.000000
  MINPOOL        466.0
  MINRELEASE       0.0
INITIALWITHDRAW  30.584631
INITIALINFLOW  10.753858
PREVIOUSWITHDRAW  30.601194
PREVIOUSINFLOW  10.860084
 ENDRESERVOIR
 ############ ############}
 ############ ############ ############{
 SETWITHDRAW  GNG        WITHDRAWAL
#   TSINPUT   OBSERVEDWITHDRAW  GNG_WITHDRAW
  VALUES
   ELEV    457.0   498.0   502.0   504.0    ENDELEV
   01/01    16      16      12      4
   02/01    16      16      12      4
   03/01    20      20      15      5
   04/01    20      20      15      5
   05/01    20      20      15      5
   06/01    24      24      18      6
   07/01    28      28      21      7
   08/01    32      32      24      8
   09/01    28      28      21      7
   10/01    24      24      18      6
   11/01    20      20      15      5
   12/01    20      20      15      5
  ENDVALUES
  INTERPOLATE    ALL
  INITIALTRANSFER 0.000000
 ENDSETWITHDRAW
 ############ ############ ############}
 ############ ############ ############{
 SETWITHDRAW  GNG        DIVERSION
  TSINPUT   OBSERVEDWITHDRAW  GNG_DIVERSN
  VALUES
   ELEV    445.0     570.0    ENDELEV
   01/01     0.0       0.0
  ENDVALUES
  INITIALTRANSFER 21.815235
 ENDSETWITHDRAW
 ############ ############ ############}
 ############ ############ ############{
 LOOKUP3     GNG        EVAP
  ROWVAR      GNG.STARTINGPOOL
  COLUMNVAR    DATE
```

```
TABLEVAR    WITHDRAWAL
VALUES
     01/15  02/15  03/15  04/15  05/15  06/15  07/15  08/15  09/15 \
      10/15  11/15  12/15
 466     0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0 \
         0.0    0.0    0.0
 467     0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0 \
         0.0    0.0    0.0
 468     0.1    0.1    0.1    0.2    0.2    0.2    0.2    0.2    0.2 \
         0.1    0.1    0.1
 469     0.1    0.2    0.2    0.3    0.3    0.4    0.4    0.5    0.4 \
         0.3    0.2    0.1
 470     0.2    0.2    0.4    0.5    0.5    0.6    0.7    0.7    0.6 \
         0.4    0.3    0.2
 471     0.3    0.3    0.5    0.6    0.7    0.9    1.0    1.0    0.8 \
         0.6    0.4    0.3
 472     0.3    0.4    0.7    0.8    0.9    1.1    1.3    1.3    1.0 \
         0.8    0.5    0.4
 473     0.4    0.5    0.8    1.0    1.1    1.4    1.5    1.6    1.2 \
         0.9    0.6    0.4
 474     0.5    0.6    1.0    1.2    1.3    1.6    1.8    1.9    1.4 \
         1.1    0.7    0.5
 475     0.6    0.8    1.2    1.5    1.6    1.9    2.2    2.3    1.8 \
         1.3    0.9    0.6
 476     0.7    0.9    1.4    1.7    1.9    2.3    2.6    2.7    2.1 \
         1.6    1.1    0.7
 477     0.9    1.2    1.8    2.2    2.4    2.9    3.3    3.4    2.6 \
         2.0    1.4    0.9
 478     1.1    1.5    2.3    2.8    3.0    3.7    4.2    4.3    3.4 \
         2.5    1.7    1.2
 479     1.4    1.8    2.8    3.4    3.8    4.6    5.2    5.4    4.2 \
         3.1    2.1    1.5
 480     1.7    2.2    3.4    4.2    4.6    5.5    6.3    6.5    5.1 \
         3.8    2.6    1.8
 481     1.9    2.6    4.0    4.8    5.3    6.4    7.3    7.5    5.9 \
         4.4    3.0    2.1
 482     2.2    2.8    4.4    5.4    5.9    7.2    8.1    8.4    6.5 \
         4.9    3.4    2.3
 483     2.4    3.1    4.8    5.9    6.4    7.8    8.9    9.2    7.1 \
         5.4    3.7    2.5
 484     2.6    3.4    5.3    6.5    7.1    8.6    9.8   10.1    7.9 \
         5.9    4.1    2.8
 485     2.9    3.8    5.9    7.2    7.8    9.5   10.8   11.2    8.7 \
         6.5    4.5    3.1
 486     3.2    4.2    6.5    7.9    8.7   10.6   12.0   12.4    9.6 \
         7.2    5.0    3.4
```

```
487    3.5   4.6   7.1   8.7   9.5  11.5  13.1  13.5  10.5 \
     7.9   5.4   3.8
488    3.7   4.9   7.6   9.3  10.2  12.4  14.1  14.5  11.3 \
     8.5   5.8   4.0
489    4.0   5.3   8.2  10.0  11.0  13.3  15.1  15.6  12.2 \
     9.1   6.3   4.3
490    4.3   5.7   8.8  10.7  11.7  14.3  16.2  16.7  13.0 \
     9.8   6.7   4.6
491    4.6   6.1   9.4  11.5  12.6  15.3  17.4  17.9  14.0 \
    10.5   7.2   5.0
492    5.0   6.5  10.1  12.3  13.5  16.4  18.6  19.2  15.0 \
    11.2   7.7   5.3
493    5.3   7.0  10.9  13.2  14.5  17.6  20.0  20.6  16.1 \
    12.0   8.3   5.7
494    5.7   7.5  11.7  14.2  15.5  18.9  21.5  22.1  17.3 \
    12.9   8.9   6.2
495    6.1   8.1  12.5  15.3  16.7  20.3  23.1  23.8  18.5 \
    13.9   9.6   6.6
496    6.6   8.7  13.5  16.4  18.0  21.9  24.8  25.6  20.0 \
    15.0  10.3   7.1
497    7.1   9.4  14.6  17.8  19.4  23.6  26.8  27.7  21.6 \
    16.2  11.1   7.7
498    7.6  10.0  15.6  19.0  20.7  25.2  28.6  29.5  23.0 \
    17.2  11.9   8.2
499    8.1  10.7  16.5  20.1  22.0  26.8  30.4  31.4  24.4 \
    18.3  12.6   8.7
500    8.6  11.3  17.6  21.4  23.4  28.5  32.3  33.3  26.0 \
    19.5  13.4   9.3
501    9.1  12.0  18.7  22.7  24.9  30.3  34.4  35.4  27.6 \
    20.7  14.2   9.8
502    9.7  12.7  19.7  24.0  26.3  32.0  36.3  37.5  29.2 \
    21.9  15.0  10.4
503   10.3  13.5  20.9  25.5  27.9  33.9  38.5  39.7  31.0 \
    23.2  15.9  11.0
504   10.7  14.1  21.8  26.6  29.1  35.4  40.2  41.4  32.3 \
    24.2  16.6  11.5
505   11.1  14.6  22.6  27.6  30.2  36.7  41.7  43.0  33.5 \
    25.1  17.2  11.9
510   14.0  18.4  28.6  34.8  38.1  46.3  52.6  54.3  42.3 \
    31.7  21.8  15.1
515   17.2  22.7  35.2  42.9  46.9  57.1  64.8  66.9  52.1 \
    39.0  26.8  18.6
520   20.8  27.5  42.5  51.8  56.7  69.0  78.3  80.8  62.9 \
    47.2  32.4  22.4
525   24.8  32.6  50.5  61.6  67.4  81.9  93.1  96.0  74.8 \
    56.0  38.5  26.7
```

```
  530   29.0   38.3   59.2   72.2   79.0   96.1  109.1  112.5   87.7 \
        65.7   45.1   31.3
  535   33.6   44.3   68.6   83.6   91.5  111.3  126.4  130.3  101.6 \
        76.1   52.3   36.2
  540   38.6   50.8   78.7   95.9  105.0  127.6  144.9  149.5  116.5 \
        87.3   60.0   41.5
  545   43.8   57.8   89.5  109.1  119.3  145.1  164.7  169.9  132.4 \
        99.2   68.2   47.2
  550   49.5   65.2  100.9  123.0  134.6  163.7  185.8  191.7  149.4 \
       111.9   76.9   53.3
  552   51.8   68.3  105.7  128.8  141.0  171.4  194.6  200.8  156.4 \
       117.2   80.6   55.8
  554   54.2   71.4  110.6  134.8  147.5  179.3  203.6  210.0  163.7 \
       122.6   84.3   58.4
  556   56.6   74.6  115.6  140.9  154.1  187.4  212.8  219.5  171.0 \
       128.2   88.1   61.0
  558   59.1   77.9  120.7  147.1  161.0  195.7  222.2  229.2  178.6 \
       133.8   92.0   63.7
  560   61.7   81.3  125.9  153.5  167.9  204.2  231.8  239.1  186.3 \
       139.6   96.0   66.5
  562   64.3   84.7  131.3  160.0  175.0  212.8  241.6  249.3  194.2 \
       145.5  100.0   69.3
  564   67.0   88.3  136.7  166.6  182.3  221.6  251.6  259.6  202.2 \
       151.5  104.2   72.1
  566   69.7   91.8  142.2  173.3  189.7  230.6  261.9  270.1  210.5 \
       157.7  108.4   75.1
  568   72.5   95.5  147.9  180.2  197.2  239.8  272.3  280.9  218.8 \
       164.0  112.7   78.1
  570   75.3   99.2  153.7  187.3  204.9  249.1  282.9  291.8  227.4 \
       170.4  117.1   81.1
 ENDVALUES
 INTERPOLATE ALL
ENDLOOKUP3
############ ############ ############}
############ ############ ############{
SETSUM       GNG          NEG_N_EVAP
 SETWITHDRAW  GNG          WITHDRAWAL
 #SETWITHDRAW  GNG          DIVERSION
 #LOOKUP3     GNG          EVAP
ENDSETSUM
############ ############ ############}
############ ############ ############{
LOOKUP3      GNG          NORMAL
 ROWVAR GNG.STARTINGPOOL
 COLUMNVAR GNG_INDEX.STARTINGDISCHARGE
 TABLEVAR RELEASE
```

```
 VALUES
        85    95   100   110   125
  504.0     4     4     4     4     4
  505.0   350   700   750  1500  2000
  505.5  1000  1000  1000  2000  2500
  508.0  2000  2000  2500  3000  3000
  515.0  2500  3000  3500  3500  3500
  527.5  3500  4000  4000  4000  4000
  528.7     0     0     0     0     0
 ENDVALUES
 INTERPOLATE ALL
ENDLOOKUP3
############ ############ ############}
############ ############ ############{
LOOKUP3      GNG          CMN_CAPACITY
 # Belton has 52.9% of the storage space that contributes to CMNT2 gage
 # Stillhouse has 32.3%, Granger has 14.8%. This method allocates channel capa
 TSINDEX COLUMNS CMNLRIRMA
 COLUMNVAR INPUT_TS CFS
 ROWVAR GNG_INDEX_3.STARTINGDISCHARGE
 TABLEVAR RELEASE
 VALUES
          0 5000 10000
   75.0  2000 1000     0
   95.0  2000 1000     0
  100.0  2500 1250     0
  110.0  6000 3500     0
  #110.0  5000 2000     0
 ENDVALUES
 INTERPOLATE ALL
ENDLOOKUP3
############ ############ ############}
############ ############ ############{
LOOKUP3      GNG          REL_AND_REAL
 COLUMNVAR GNG_INDEX_3.STARTINGDISCHARGE
 ROWVAR    GNG.STARTINGPOOL
 TABLEVAR RELEASE
 VALUES
        75   95  100  110
   504  2000 2000 2000 2000
   510  2000 2000 2000 2500 #maybe this last value down
   515  2000 2000 3500 4500
   520  2000 2500 4500 5500
 ENDVALUES
 INTERPOLATE ALL
ENDLOOKUP3
```

```
############ ############ ############}
############ ############ ############{
LOOKUP3      GNG          TOT_CAPACITY
 # Look at the summed local flows plus Somerville
 ROWVAR GNG.STARTINGPOOL
 COLUMNVAR SHUT_OFF.STARTINGDISCHARGE
 TABLEVAR RELEASE
 VALUES
           0   920  1000
  504.0 99999  1000     0
  515.0 99999  2000     0
  528.0 99999  2000     0
 ENDVALUES
 INTERPOLATE ALL
ENDLOOKUP3
############ ############ ############}
############ ############ ############{
LOOKUP3      GNG          START_UP
 COLUMNVAR INPUT_TS CFS
 TSINDEX COLUMNS TOTAL_LOCAL
 ROWVAR GNG.STARTINGPOOL
 TABLEVAR RELEASE
 VALUES
          0  30000
  504.0 9999      0
  504.5 9999      0
  505.0 9999      0
 ENDVALUES
ENDLOOKUP3
############ ############ ############}
############ ############ ############{
SETMIN       GNG          CAPACITIES
 LOOKUP3      GNG          START_UP
 LOOKUP3      GNG          NORMAL
 LOOKUP3      GNG          CMN_CAPACITY
 LOOKUP3      GNG          TOT_CAPACITY
 LOOKUP3      GNG          REL_AND_REAL
ENDSETMIN
############ ############ ############}
############ ########### #############{
SPILLWAY     GNG          SPILL
 TABLE       ELEV_SPILL
  527.5         0
  528.0       100
  528.5       800
  529.0      1500
```

```
   529.5      2500
   530.0      7000
   570.0     25000
  ENDTABLE
  INTERVALS    12
INITIALSPILL  0.000000
 ENDSPILLWAY
 ############ ############ ############}
 ############ ############ ############{
 SETMAX       GNG          FINAL
  SETMIN       GNG          CAPACITIES
  SPILLWAY     GNG          SPILL
 ENDSETMAX
 ############ ############ ############}
 ############ ########### #############{
 ADJUST       GNG          SET_TO_OBS
  #TSINPUT OBSERVEDRELEASE GNG_RELEASE
  TSINPUT OBSERVEDPOOL    GNG_POOL
  ADJSIM  OFF
 ENDADJUST
 ############ ############ ############}
 ### End RESERVOIR GNG ###}
 ### Begin NODE GNG_FSTORAGE ###{
 ############ ############{
 NODE         GNG_FSTORAGE
  TSINPUT  INFLOW   ZEROS
  TSOUTPUT OUTFLOW GNG_FSTORAGE
  PREVIOUSDISCHARGE 0.000000
  DISCHARGE 0.000000
  INITIALINFLOW 0.000000
  PREVIOUSINFLOW 0.000000
  INITIALDIVERSION -0.000000
  PREVIOUSDIVERSION -0.000000
 ENDNODE
 ############ ############}
 ############ ############ ############{
 LOOKUP3      GNG_FSTORAGE FLOOD_STORAG
  # Total flood storage between 504 and 528 is 180502.0 ac-ft
  ROWVAR GNG.ENDINGPOOL
  COLUMNVAR 1
  TABLEVAR AUGMENTATION
  VALUES
          0
   504     0
   505   5283
   510  30988
```

```
  515  62852
  520 101599
  525 147880
  530 202250
  535 265094
  540 337237
  545 418730
  550 509580
  552 548580
  554 589030
  556 630980
  558 674330
  560 718980
  562 765130
  564 812730
  566 861730
  568 912130
  570 964130
 ENDVALUES
 INTERPOLATE ALL
ENDLOOKUP3
############ ############ ############}
### End NODE GNG_FSTORAGE ###}
### Begin NODE GNG_PERCENTF ###{
############ ############{
NODE         GNG_PERCENTF
 TSINPUT  INFLOW   ZEROS
 TSOUTPUT OUTFLOW GNG_PERCENTF
 PREVIOUSDISCHARGE 0.000000
 DISCHARGE 0.000000
 INITIALINFLOW 0.000000
 PREVIOUSINFLOW 0.000000
 INITIALDIVERSION -0.000000
 PREVIOUSDIVERSION -0.000000
ENDNODE
############ ############}
############ ############ ############{
LOOKUP3      GNG_PERCENTF PERCENT_FULL
 # Total flood storage between 504 and 528 is 180502.0 ac-ft
 ROWVAR GNG.ENDINGPOOL
 COLUMNVAR 1
 TABLEVAR AUGMENTATION
 VALUES
          0
  504   0.00
  505   2.93
```

```
   510  17.17
   515  34.82
   520  56.29
   525  81.93
   530 112.05
  ENDVALUES
  INTERPOLATE ALL
 ENDLOOKUP3
 ############ ############ ############}
 ### End NODE GNG_PERCENTF ###}
 ### Begin NODE SYS_PERCENTF ###{
 ############ ############{
 NODE         SYS_PERCENTF
  TSINPUT  INFLOW   ZEROS
  TSOUTPUT OUTFLOW SYS_PERCENTF
  PREVIOUSDISCHARGE 0.000000
  DISCHARGE 0.000000
  INITIALINFLOW 0.000000
  PREVIOUSINFLOW 0.000000
  INITIALDIVERSION -0.000000
  PREVIOUSDIVERSION -0.000000
 ENDNODE
 ############ ############}
 ############ ############ ############{
 LOOKUP3      SYS_PERCENTF PERCENT_FULL
  # Total flood storage between for the system is 1630205 ac-ft
  ROWVAR PCT_FSTORAGE.ENDINGDISCHARGE +
BLN_FSTORAGE.ENDINGDISCHARGE \
    + STI_FSTORAGE.ENDINGDISCHARGE + GGL_FSTORAGE.ENDINGDISCHARGE + \
    GNG_FSTORAGE.ENDINGDISCHARGE
  COLUMNVAR 1
  TABLEVAR AUGMENTATION
  VALUES
          0
       0   0
   1630205 100
  ENDVALUES
  INTERPOLATE ALL
 ENDLOOKUP3
 ############ ############ ############}
 ### End NODE SYS_PERCENTF ###}
 ### Begin NODE PCT_INDEX ###{
 ############ ############{
 NODE         PCT_INDEX
  TSINPUT  INFLOW   ZEROS
  TSOUTPUT OUTFLOW PCT_INDEX
```

```
 PREVIOUSDISCHARGE 100.000000
 DISCHARGE 100.000000
 INITIALINFLOW 0.000000
 PREVIOUSINFLOW 0.000000
 INITIALDIVERSION -100.000000
 PREVIOUSDIVERSION -100.000000
ENDNODE
############ ############}
############ ############ ############{
LOOKUP3      PCT_INDEX    PCT_INDEX
 ROWVAR PCT_PERCENTF.ENDINGDISCHARGE
 COLUMNVAR SYS_PERCENTF.ENDINGDISCHARGE
 TABLEVAR AUGMENTATION
 VALUES
         0.0  100.0
   0.0 100.0    0.0
  100.0 200.0  100.0
 ENDVALUES
 INTERPOLATE ALL
ENDLOOKUP3
############ ############ ############}
### End NODE PCT_INDEX ###}
### Begin NODE BLN_INDEX ###{
############ ############{
NODE         BLN_INDEX
 TSINPUT INFLOW ZEROS
 TSOUTPUT OUTFLOW BLN_INDEX
 PREVIOUSDISCHARGE 100.000000
 DISCHARGE 100.000000
 INITIALINFLOW 0.000000
 PREVIOUSINFLOW 0.000000
 INITIALDIVERSION -100.000000
 PREVIOUSDIVERSION -100.000000
ENDNODE
############ ############}
############ ############ ############{
LOOKUP3      BLN_INDEX    BLN_INDEX
 ROWVAR BLN_PERCENTF.ENDINGDISCHARGE
 COLUMNVAR SYS_PERCENTF.ENDINGDISCHARGE
 TABLEVAR AUGMENTATION
 VALUES
         0.0  100.0
   0.0 100.0    0.0
  100.0 200.0  100.0
 ENDVALUES
 INTERPOLATE ALL
```

```
ENDLOOKUP3
############ ############ ############}
### End NODE BLN_INDEX ###}
### Begin NODE BLN_INDEX_2 ###{
############ ############{
NODE        BLN_INDEX_2
 TSINPUT INFLOW ZEROS
 TSOUTPUT OUTFLOW BLN_INDEX_2
 PREVIOUSDISCHARGE 100.000000
 DISCHARGE 100.000000
 INITIALINFLOW 0.000000
 PREVIOUSINFLOW 0.000000
 INITIALDIVERSION -100.000000
 PREVIOUSDIVERSION -100.000000
ENDNODE
############ ############}
############ ############ ############{
LOOKUP3     BLN_INDEX_2  INDEX_AT_LRI
 # Total flood storage in BLN and STI is 1040862.2 ac-ft
 # These two reservoir releases combine at LRIT2
 ROWVAR BLN_PERCENTF.ENDINGDISCHARGE
 COLUMNVAR BLN_FSTORAGE.ENDINGDISCHARGE +
STI_FSTORAGE.ENDINGDISCHARGE
 TABLEVAR AUGMENTATION
 VALUES
         0.0 1040862.2
    0.0 100.0      0.0
  100.0 200.0    100.0
 ENDVALUES
 INTERPOLATE ALL
ENDLOOKUP3
############ ############ ############}
### End NODE BLN_INDEX_2 ###}
### Begin NODE BLN_INDEX_3 ###{
############ ############{
NODE        BLN_INDEX_3
 TSINPUT INFLOW ZEROS
 TSOUTPUT OUTFLOW BLN_INDEX_3
 PREVIOUSDISCHARGE 100.000000
 DISCHARGE 100.000000
 INITIALINFLOW 0.000000
 PREVIOUSINFLOW 0.000000
 INITIALDIVERSION -100.000000
 PREVIOUSDIVERSION -100.000000
ENDNODE
############ ############}
```

```
 ############ ############ ############{
 LOOKUP3      BLN_INDEX_3  INDEX_AT_CMN
  # Total flood storage in BLN, STI and GNG is 1221364.2 ac-ft
  # These three reservoir releases combine at CMNT2,
  #  with LRIT2 and RSAT2
  ROWVAR BLN_PERCENTF.ENDINGDISCHARGE
  COLUMNVAR BLN_FSTORAGE.ENDINGDISCHARGE +
STI_FSTORAGE.ENDINGDISCHARGE + \
           GNG_FSTORAGE.ENDINGDISCHARGE
  TABLEVAR AUGMENTATION
  VALUES
         0.0 1221364.2
    0.0 100.0       0.0
   100.0 200.0     100.0
  ENDVALUES
  INTERPOLATE ALL
 ENDLOOKUP3
 ############ ############ ############}
 ### End NODE BLN_INDEX_3 ###}
 ### Begin NODE STI_INDEX ###{
 ############ ############{
 NODE         STI_INDEX
  TSINPUT INFLOW ZEROS
  TSOUTPUT OUTFLOW STI_INDEX
  PREVIOUSDISCHARGE 100.000000
  DISCHARGE 100.000000
  INITIALINFLOW 0.000000
  PREVIOUSINFLOW 0.000000
  INITIALDIVERSION -100.000000
  PREVIOUSDIVERSION -100.000000
 ENDNODE
 ############ ############}
 ############ ############ ############{
 LOOKUP3      STI_INDEX    STI_INDEX
  ROWVAR STI_PERCENTF.ENDINGDISCHARGE
  COLUMNVAR SYS_PERCENTF.ENDINGDISCHARGE
  TABLEVAR AUGMENTATION
  VALUES
         0.0  100.0
    0.0 100.0    0.0
   100.0 200.0  100.0
  ENDVALUES
  INTERPOLATE ALL
 ENDLOOKUP3
 ############ ############ ############}
 ### End NODE STI_INDEX ###}
```

```
### Begin NODE STI_INDEX_2 ###{
############ ############{
NODE        STI_INDEX_2
 TSINPUT INFLOW ZEROS
 TSOUTPUT OUTFLOW STI_INDEX_2
 PREVIOUSDISCHARGE 100.000000
 DISCHARGE 100.000000
 INITIALINFLOW 0.000000
 PREVIOUSINFLOW 0.000000
 INITIALDIVERSION -100.000000
 PREVIOUSDIVERSION -100.000000
ENDNODE
############ ############}
############ ############ ############{
LOOKUP3     STI_INDEX_2  INDEX_AT_LRI
 # Total flood storage in BLN and STI is 1040862.2 ac-ft
 # These two reservoir releases combine at LRIT2
 ROWVAR STI_PERCENTF.ENDINGDISCHARGE
 COLUMNVAR BLN_FSTORAGE.ENDINGDISCHARGE +
STI_FSTORAGE.ENDINGDISCHARGE
 TABLEVAR AUGMENTATION
 VALUES
        0.0 1040862.2
   0.0 100.0      0.0
  100.0 200.0     100.0
 ENDVALUES
 INTERPOLATE ALL
ENDLOOKUP3
############ ############ ############}
### End NODE STI_INDEX_2 ###}
### Begin NODE STI_INDEX_3 ###{
############ ############{
NODE        STI_INDEX_3
 TSINPUT INFLOW ZEROS
 TSOUTPUT OUTFLOW STI_INDEX_3
 PREVIOUSDISCHARGE 100.000000
 DISCHARGE 100.000000
 INITIALINFLOW 0.000000
 PREVIOUSINFLOW 0.000000
 INITIALDIVERSION -100.000000
 PREVIOUSDIVERSION -100.000000
ENDNODE
############ ############}
############ ############ ############{
LOOKUP3     STI_INDEX_3  INDEX_AT_CMN
 # Total flood storage in BLN, STI and GNG is 1221364.2 ac-ft
```

```
  # These three reservoir releases combine at CMNT2,
  #  with LRIT2 and RSAT2
  ROWVAR STI_PERCENTF.ENDINGDISCHARGE
  COLUMNVAR BLN_FSTORAGE.ENDINGDISCHARGE +
STI_FSTORAGE.ENDINGDISCHARGE + \
          GNG_FSTORAGE.ENDINGDISCHARGE
  TABLEVAR AUGMENTATION
  VALUES
         0.0 1221364.2
    0.0 100.0       0.0
   100.0 200.0     100.0
  ENDVALUES
  INTERPOLATE ALL
 ENDLOOKUP3
 ############ ############ ############}
 ### End NODE STI_INDEX_3 ###}
 ### Begin NODE GGL_INDEX ###{
 ############ ############{
 NODE         GGL_INDEX
  TSINPUT INFLOW ZEROS
  TSOUTPUT OUTFLOW GGL_INDEX
  PREVIOUSDISCHARGE 100.000000
  DISCHARGE 100.000000
  INITIALINFLOW 0.000000
  PREVIOUSINFLOW 0.000000
  INITIALDIVERSION -100.000000
  PREVIOUSDIVERSION -100.000000
 ENDNODE
 ############ ############}
 ############ ############ ############{
 LOOKUP3      GGL_INDEX    GGL_INDEX
  ROWVAR GGL_PERCENTF.ENDINGDISCHARGE
  COLUMNVAR SYS_PERCENTF.ENDINGDISCHARGE
  TABLEVAR AUGMENTATION
  VALUES
         0.0  100.0
    0.0 100.0    0.0
   100.0 200.0  100.0
  ENDVALUES
  INTERPOLATE ALL
 ENDLOOKUP3
 ############ ############ ############}
 ### End NODE GGL_INDEX ###}
 ### Begin NODE GGL_DELAY ###{
 ############ ############{
# NODE         GGL_DELAY
```

```
# TSINPUT INFLOW GGL_RELEASE
# PREVIOUSDISCHARGE 100.000000
# DISCHARGE 100.000000
# INITIALINFLOW 100.000000
# PREVIOUSINFLOW 100.000000
# INITIALDIVERSION 0.000000
# PREVIOUSDIVERSION 0.000000
# ENDNODE
 ############ ############}
 ### End NODE GGL_DELAY ###}
 ### Begin NODE GNG_INDEX ###{
 ############ ############{
 NODE        GNG_INDEX
  TSINPUT INFLOW ZEROS
  TSOUTPUT OUTFLOW GNG_INDEX
  PREVIOUSDISCHARGE 100.000000
  DISCHARGE 100.000000
  INITIALINFLOW 0.000000
  PREVIOUSINFLOW 0.000000
  INITIALDIVERSION -100.000000
  PREVIOUSDIVERSION -100.000000
 ENDNODE
 ############ ############}
 ############ ############ ############{
 LOOKUP3     GNG_INDEX    GNG_INDEX
  ROWVAR GNG_PERCENTF.ENDINGDISCHARGE
  COLUMNVAR SYS_PERCENTF.ENDINGDISCHARGE
  TABLEVAR AUGMENTATION
  VALUES
         0.0  100.0
    0.0 100.0    0.0
  100.0 200.0  100.0
  ENDVALUES
  INTERPOLATE ALL
 ENDLOOKUP3
 ############ ############ ############}
 ### End NODE GNG_INDEX ###}
 ### Begin NODE GNG_INDEX_3 ###{
 ############ ############{
 NODE        GNG_INDEX_3
  TSINPUT INFLOW ZEROS
  TSOUTPUT OUTFLOW GNG_INDEX_3
  PREVIOUSDISCHARGE 100.000000
  DISCHARGE 100.000000
  INITIALINFLOW 0.000000
  PREVIOUSINFLOW 0.000000
```

```
  INITIALDIVERSION -100.000000
  PREVIOUSDIVERSION -100.000000
 ENDNODE
 ############ ############}
 ############ ############ ############{
 LOOKUP3      GNG_INDEX_3  INDEX_AT_CMN
  # Total flood storage in BLN, STI and GNG is 1221364.2 ac-ft
  # These three reservoir releases combine at CMNT2,
  #  with LRIT2 and RSAT2
  ROWVAR GNG_PERCENTF.ENDINGDISCHARGE
  COLUMNVAR BLN_FSTORAGE.ENDINGDISCHARGE +
STI_FSTORAGE.ENDINGDISCHARGE + \
          GNG_FSTORAGE.ENDINGDISCHARGE
  TABLEVAR AUGMENTATION
  VALUES
         0.0 1221364.2
    0.0 100.0       0.0
   100.0 200.0     100.0
  ENDVALUES
  INTERPOLATE ALL
 ENDLOOKUP3
 ############ ############ ############}
 ### End NODE GNG_INDEX_3 ###}
 ### Begin NODE ROOT ###{
 ############ ############
 NODE         ROOT
  DISCHARGE 4061.878024
  PREVIOUSDISCHARGE 4061.881555
  INITIALINFLOW 4061.878024
  PREVIOUSINFLOW 4061.881555
  INITIALDIVERSION 0.000000
  PREVIOUSDIVERSION 0.000000
 ENDNODE
 ############ ############
 ### End NODE ROOT ###}
   RAINEVAP     PCT      PCT_EVAP
    TSINPUT  OBSERVEDPRECIP  PCT_RAIN
    EVAP
    TSINPUT OBSERVEDEVAP    PCT_EVAP
    VALUES
    01/01  0
    12/31  0
    ENDVALUES
    ENDEVAP
   ENDRAINEVAP
   RAINEVAP     BLN      BLN_EVAP
```

```
    TSINPUT  OBSERVEDPRECIP  BLN_RAIN
    EVAP
    TSINPUT OBSERVEDEVAP    BLN_EVAP
    VALUES
    01/01  0
    12/31  0
    ENDVALUES
    ENDEVAP
   ENDRAINEVAP
   RAINEVAP     STI     STI_EVAP
    TSINPUT  OBSERVEDPRECIP  STI_RAIN
    EVAP
    TSINPUT OBSERVEDEVAP    STI_EVAP
    VALUES
    01/01  0
    12/31  0
    ENDVALUES
    ENDEVAP
   ENDRAINEVAP
   RAINEVAP     GGL     GGL_EVAP
    TSINPUT  OBSERVEDPRECIP  GGL_RAIN
    EVAP
    TSINPUT OBSERVEDEVAP    GGL_EVAP
    VALUES
    01/01  0
    12/31  0
    ENDVALUES
    ENDEVAP
   ENDRAINEVAP
   RAINEVAP     GNG     GNG_EVAP
    TSINPUT  OBSERVEDPRECIP  GNG_RAIN
    EVAP
    TSINPUT OBSERVEDEVAP    GNG_EVAP
    VALUES
    01/01  0
    12/31  0
    ENDVALUES
    ENDEVAP
   ENDRAINEVAP
ENDPARAMETERS
 ##################################################################}
 ##################################################################{
 RULES
  [TRUE]
   ::RAINEVAP     PCT         PCT_EVAP
   ::RAINEVAP     BLN         BLN_EVAP
```

```
 ::RAINEVAP    STI        STI_EVAP
 ::RAINEVAP    GGL        GGL_EVAP
 ::RAINEVAP    GNG        GNG_EVAP
[TRUE]
 ::LOOKUP3     SHUT_OFF    TRACKTREND
[TRUE]
 ::SETSUM      PCT        NEGINFW_EVAP
   #SETWITHDRAW  PCT        WITHDRAWAL
   #LOOKUP3     PCT        EVAP
[TRUE]
 ::SETMAX      PCT        FINAL
   #::SETMIN     PCT        CAPACITIESA
     #LOOKUP3     PCT        NORMAL
     #LOOKUP3     PCT        CAPACITY
   #::SPILLWAY    PCT        SPILL
[TRUE]
 ::ADJUST      PCT        SET_TO_OBS
[TRUE]
 ::LOOKUP3     PCT_FSTORAGE FLOOD_STORAG
 ::LOOKUP3     PCT_PERCENTF PERCENT_FULL
[TRUE]
 ::LAGK        PCT_TO_HML   HMLT2_LAGK
 ::LAGK        HML_TO_GAS   GAST2_LAGK
 ::LAGK        GAS_TO_BLN   BLNT2_LAGK
 ::LAGK        PIC_TO_BLN   BLNT2_LAGK
[TRUE]
 ::SETSUM      BLN        NEGINFW_EVAP
   #SETWITHDRAW  BLN        WITHDRAWAL
   #LOOKUP3     BLN        EVAP
[TRUE]
 ::SETMAX      BLN        FINAL
   #::SETMIN     BLN        CAPACITIESB
     #LOOKUP3     BLN        NORMAL
     #LOOKUP3     BLN        LRI_CAPACITY
     #LOOKUP3     BLN        CMN_CAPACITY
     #LOOKUP3     BLN        TOT_CAPACITY
   #::SPILLWAY    BLN        SPILL
[TRUE]
 ::ADJUST      BLN        SET_TO_OBS
[TRUE]
 ::LOOKUP3     BLN_FSTORAGE FLOOD_STORAG
 ::LOOKUP3     BLN_PERCENTF PERCENT_FULL
[TRUE]
 ::SETSUM      STI        NEGINFW_EVAP
   #SETWITHDRAW  STI        WITHDRAWAL
   #SETWITHDRAW  STI        DIVERSION
```

```
   #LOOKUP3     STI        EVAP
[TRUE]
  ::SETMAX      STI        FINAL
   #::SETMIN      STI        CAPACITIESC
      #LOOKUP3     STI        LRI_CAPACITY
      #LOOKUP3     STI        CMN_CAPACITY
      #LOOKUP3     STI        NORMAL
   #::SPILLWAY     STI        SPILL
[TRUE]
  ::ADJUST      STI        SET_TO_OBS
[TRUE]
  ::LOOKUP3     STI_FSTORAGE FLOOD_STORAG
  ::LOOKUP3     STI_PERCENTF PERCENT_FULL
[TRUE]
  ::SETMIN      LRIT2_CAPAC  TAKE_LARGEST
[TRUE]
  ::SETSUM      GGL        NEG_N_EVAP
   #SETWITHDRAW  GGL        WITHDRAWAL
   #SETWITHDRAW  GGL        DIVERSION
   #LOOKUP3     GGL        EVAP
[TRUE]
  ::SETMAX      GGL        FINAL
   #::SETMIN      GGL        CAPACITIES
      #LOOKUP3     GGL        NORMAL
      #LOOKUP3     GGL        TOT_CAPACITY
   #::SPILLWAY     GGL        SPILL
[TRUE]
  ::ADJUST      GGL        SET_TO_OBS
[TRUE]
  ::LOOKUP3     GGL_FSTORAGE FLOOD_STORAG
  ::LOOKUP3     GGL_PERCENTF PERCENT_FULL
[TRUE]
  ::LAGK        GGL_TO_GNG   GNGT2_LAGK
[TRUE]
  ::SETSUM      GNG        NEG_N_EVAP
    #SETWITHDRAW  GNG        WITHDRAWAL
    #SETWITHDRAW  GNG        DIVERSION
    #LOOKUP3     GNG        EVAP
[TRUE]
  ::SETMAX      GNG        FINAL
   #::SETMIN      GNG        CAPACITIES
      #LOOKUP3     GNG        START_UP
      #LOOKUP3     GNG        NORMAL
      #LOOKUP3     GNG        CMN_CAPACITY
      #LOOKUP3     GNG        TOT_CAPACITY
   #::SPILLWAY     GNG        SPILL
```

```
  [TRUE]
    ::ADJUST       GNG          SET_TO_OBS
  [TRUE]
    ::LOOKUP3      GNG_FSTORAGE FLOOD_STORAG
    ::LOOKUP3      GNG_PERCENTF PERCENT_FULL
  [TRUE]
    ::LOOKUP3      SYS_PERCENTF PERCENT_FULL
    ::LOOKUP3      PCT_INDEX    PCT_INDEX
    ::LOOKUP3      BLN_INDEX    BLN_INDEX
    ::LOOKUP3      BLN_INDEX_2  INDEX_AT_LRI
    ::LOOKUP3      BLN_INDEX_3  INDEX_AT_CMN
    ::LOOKUP3      STI_INDEX    STI_INDEX
    ::LOOKUP3      STI_INDEX_2  INDEX_AT_LRI
    ::LOOKUP3      STI_INDEX_3  INDEX_AT_CMN
    ::LOOKUP3      GGL_INDEX    GGL_INDEX
    ::LOOKUP3      GNG_INDEX    GNG_INDEX
    ::LOOKUP3      GNG_INDEX_3  INDEX_AT_CMN
 ENDRULES
 ################################################################}
ENDRES-J
</stringValue>
   </parameter>
  </group>
</parameters>
```

ATTACHMENT 1 - Draft Report Comments
Contract No. 2301792722 – University of Texas at Arlington

Report Title:

Improving the Hydrologic Ensemble Forecast Service model of the Little River Basin to facilitate assessment of Forecast-Informed Reservoir Operation

This report documents a project to improve the flood forecasting capabilities of the National Weather Service's West Gulf River Forecast Center. During the project, the contractor (the University of Texas at Arlington) re-calibrated model parameters for seven forecast points and updated model configurations for four reservoirs within the Little River Basin in Central Texas. They compared flood forecasts generated with the current and revised configurations of the model for the Little River Basin for historic flood events. The revised model was found to improve forecasts of both flood peak and volume. Examination of remaining forecasting errors identified that the current model did not account for withdrawals from water supply reservoirs. Including those withdrawals in the model led to improved forecasting performance for three of the four reservoirs. The project team identified inflow estimates to one of the reservoirs as a potential source of the remaining forecast error. This project also evaluated the utility of using a new method (Conditional Bias Penalizing Regression - CBPR) versus the current method (Mixed Meta-Gaussian Distribution) to produce precipitation forecasts. Results were promising but additional work will be required before a method based on CBPR is operational. Overall results of this project are of immediate interest to flood forecasting in the Little River Basin. More broadly, lessons learned during this project should prove useful to future efforts to improve flood forecasting in basins with one or more large reservoirs.

General comments:

Overall, the report is well-written and documents an effort that achieved the objectives of the Scope of Work.

Specific comments to be addressed:

1. Please recheck the document and correct typos such as the following (not exhaustive):
    a. Page 7, 4th paragraph, 1st sentence, "Corps of Engineers – Forth District" should be "Corps of Engineers – Fort Worth District."

    Corrected.

    b. Page 10, 1st paragraph, last sentence, "but are included in the calibration effort" should be "but are not included in the calibration effort."

    Corrected.

c. Page 11, Figure 1-2 title, "scalar multiplier apply to each" should be "scalar multipliers applied to each."

Corrected.

d. Page 12, 1st paragraph, 3rd bullet, "occurrence of these vents" should be "occurrence of these events."

Corrected.

e. Page 13, 2nd paragraph, 2nd sentence, "each forcing variables" should be "each forcing variable."

Corrected.

f. Page 13, 3rd paragraph, 3rd sentence, "the largest accumulatios" should be "the largest accumulations."

Corrected.

g. Page 15, 1st paragraph, last sentence, "against observations rather" should be "against observations."

Corrected.

h. Page 18, last paragraph, first sentence, "At nearly most" should be "At nearly all."

Corrected.

i. Page 21, 3rd paragraph, 2nd sentence, "January 2010 even" should be "January 2010 event."

Corrected.

j. Page 21, 6th paragraph, last sentence ("After the last calibration,") is incomplete.

Completed the sentence and added additional details.

k. Page 29, last paragraph, 5th sentence, "completed missed this episode" should be "completely missed this episode."

Corrected.

l. Page 33, 1st paragraph, 2nd paragraph, “it is unclear that” should be “it is clear that.”

Corrected.

m. Page 43, 1st paragraph, 3rd bullet, “preceding the latter by at about” should be “preceding the latter by about.”

Corrected.

2. Please define acronyms before they are used for the first time in the document. For example (not exhaustive): CHPS (on page 16) and OWP (also on page 16).

We have carefully reviewed the acronyms throughout the text and added the missing definitions in the text and the table preceding the text.

3. Please double check references within the document including the following (not exhaustive):
    a. Page 13, 1st paragraph, 1st sentence; page 43, last paragraph, 1st sentence; and page 44, 4th paragraph, 2nd sentence reference “Wu et al., 2010” but there is no corresponding reference on page 58.
    b. Page 13, 2nd paragraph, 4th sentence references Wu et al., 2017” but there is no corresponding reference on page 58.
    c. Page 43, last paragraph, 1st sentence references “Kim et al., 2025” but there is no corresponding reference on page 57.
    d. Page 45, 2nd paragraph, 3rd sentence, references “Scheurer and Hamill (2025)” but there is no corresponding reference on page 58.

We have carefully reviewed the references throughout the text, corrected any mistakes in the citations, and added any missing references to the list at the end of the document.

4. Please consider providing additional context for the project in the Executive Summary on Page 7. For example, the 2nd paragraph could be modified to the following to provide a brief description of previous flood model calibration work funded by the Texas Water Development Board:

    As a result of the findings, the team undertook a project sponsored by the Texas Water Development Board (TWDB) to improve the calibration of the

SAC-SMA for larger events, fill gaps in the earlier calibration, correct errors in the reservoir model used in the WGRFC operational system, and assess an enhanced postprocessing scheme for producing probabilistic precipitation forecasts. This project is in line with previous flood model calibration projects funded by the TWDB, including previous work in the Little River Basin (Lynker 2022). Results from this project will improve flood forecasting in the Little River Basin specifically and, more generally, provide insights for improving flood forecasting in basins with large reservoirs across the state.

Also recommend including the following reference:
Lynker 2022. NOAA National Weather Service Hydrologic Modeling Calibrations. Available at https://www.twdb.texas.gov/publications/reports/contracted_reports/doc/2100012514.pdf.

We have modified the second paragraph in the Executive Summary accordingly, and added the reference to the calibration project by Lynker.

5. Please amend the figure, figure title, and/or legend for Figure 1-2 on page 11, or provide additional description in the text, for clarity. The following aspects of the figure are difficult to interpret:
    a. The title states that "Forecast points with upstream watershed highlighted in red are not included in the calibration." Watersheds highlighted in red are described in the legend as "Difficult to calibrate." It is unclear if these areas were calibrated or not. Please clarify.

The watersheds upstream marked in deep red were not calibrated, whereas those downstream in purple and purple were. The legend and caption have both been modified to provide clarity on the status.

    b. The title states that "Watersheds in green are calibrated individually whereas those in red are calibrated as a group." It is unclear if the "red" mentioned in this portion of the title should be "pink." In the legend, the pink area is referred to as "Aggregated." Please clarify.

See the response to a) for the first question. The revised legend has "Aggregated-BLNT2" for the ungauged watersheds around Belton and "Aggregated-STIT2/GNGT2" for the watersheds around Stillhouse Hollow and Granger.

   c. The figure includes areas highlighted in purple that the legend describes as “Dual.” It is unclear how these areas differ from other areas in the figure. Please clarify.

See the response to b). The legend for the purple area is now “Aggregated-STIT2/GNGT2” to indicate the fact that these watersheds were lumped in a group and calibrated simultaneously with identical scalar multipliers.

   d. The title refers to “forecast points” while the legend refers to “forecast sites.” For clarity, please refer to them as one or the other in both the title and legend.

Changed.

   e. Two of the forecast “points/sites” in the upper portion of the figure are labeled as “DeLeon.” It is unclear if this is a typo.

The labels (meant for a city) have been removed.

   f. The label “Stillhouse Hollow Lake” may cause some confusion as it overlaps Belton Lake in the figure. Please reposition this label.

Changed.

6. Please provide descriptive axis titles in Figure 1-5 on Page 14.

Added.

7. Please use one acronym, either SAC-SMA or SACSMA, for the Sacramento Soil Moisture Accounting model throughout the document. Both acronyms are used, for example, in the second paragraph on page 18.

Corrected.