Lower South Platte Surface Water Model
Status and Recommendations
August 22, 2012, revised December 26, 2012

Introduction

The following is a status update on the development of the Lower South Platte StateMod model component of the South Platte Decision Support System. The Lower South Platte model represents the physical, legal, and administrative conditions in Water Districts 1 and 64, and will serve as the template for models developed in the upper South Platte River basins. Work on this model first began at the State Engineer's Office; additional refinement and calibration efforts took place under Lower South Platte Amendment 7 Scope of Work.

Understanding and correctly modeling the historical conditions is the most important step in the modeling process. This historical calibration model demonstrates the ability to duplicate existing administration and operation; and the baseline model used to simulate changes in basin demands, supplies, and operations builds on this initial model.

Many of the surface water modeling calibration techniques applied during the CRDSS development of the Western Slope models are not applicable to the more complex administrative and operational practices in the Lower South Platte. Numerous off-channel reservoir systems; augmentation and recharge operations; reservoir seepage; and the surface water and ground water interaction in the basin are complex elements that have not been modeled in other CDSS surface water models. Modeling these complex elements has proven to be challenging, and most of the calibration effort to date has concentrated on operations unique to the South Platte basin. New modeling techniques were used to correctly represent these elements in the model, such as the use of canal and recharge area plan structures to account for recharge supplies. New calibration techniques were used to look at how these elements are simulated in the model, including adjusting reservoir seepage factors based on the comparison of both simulated and measured reservoir contents and total headgate diversions.

The StateMod refinement portion consumed the majority of the budget for the project and the remaining was used to develop the historical model with limited calibration efforts. In its current state, the model represents historical and recent basin operations and can be used for several purposes, including assessing the impact of the Compact on users in Water District 64; providing an estimate of reservoir seepage; and providing anecdotal and physical information for comparison and calibration of the ground water model.

Summarized below is the status of efforts to date and recommendations for refinement of the Lower South Platte StateMod model.

Amendment 7 Task Status

Task 1 – StateMod Refinements

During the initial efforts to develop a Lower South Platte StateMod model, several StateMod code reporting issues and operating rule enhancements necessary for the correct representation of administrative conditions were identified and documented in a memorandum titled *StateMod Testing Results - May 4, 2010*. Several of these enhancements were completed during Amendment 6 efforts. Additional operational issues were identified during testing of these original enhancements through work on the Colorado River Water Availability Study, and by other consultants. The operations not completed during Amendment 6 plus the additionally identified StateMod enhancements were completed in Amendment 7. These include the following:

- Plan Reoperation
- Plan Spill Check
- Plan File Reporting
- Plan to Instream Flow Reach Operations
- South Platte Compact Operation
- Check File Enhancement
- Linker File Enhancement

Status:

The StateMod enhancements and operational issues identified in Amendment 7 were addressed and corrected in StateMod Version 13.00.00. Additional issues identified with the La Plata Compact, Type 4, and Type 28 operating rules were also corrected in StateMod Version 13.00.01. The Check File Enhancements were implemented in StateMod File Checker (SMFC) Version 3.2. The Linker File Enhancements were implemented in StateMod Linker (SMLink) Version 3.1, although thorough testing of this functionality was not possible due to the limited models currently complex enough to link. Future testing, and possible enhancement, is necessary when the South Platte River model is completed and linked with the Western Slope models.

Task 2 – Completion of the Lower South Platte Model

The intent of Amendment 7 was the completion of the Lower South Platte model that included finalization of the historical model representation and calibration; refinement of the calculated dataset comparison; finalization of the baseline dataset; and finalization of model documentation. Under CDSS, the calculated demand represents the amount of diversions (surface and/or ground water) required to meet full crop irrigation requirement. Therefore, in the Lower South Platte model, the calculated dataset needs to reflect the full crop demands that can be met by a combination of surface and ground water as a single demand by modeled structure. Modeling techniques used to represent this single demand approach were to be investigated during the development of the Rio Grande surface water model, however that modeling effort was not completed and the new techniques were not fully implemented. Amendment 7 had established a task that would investigate this single demand technique. However, in order to complete the tasks in Amendment 7, it was also necessary to develop modeling techniques that could be used to represent other complex administrative and operational realities, including augmentation plans, recharge supplies from canal leakage and recharge areas, and off-channel reservoir systems, within the CDSS StateMod framework.

Status:

Under Amendment 7 several steps were taken to further develop the Lower South Platte model that was not originally anticipated, as follows:

- Investigation of modeling techniques and preliminary calibration efforts uncovered data inconsistencies between reservoir contents and diversions to storage. These inconsistencies were identified and corrected. In the Lower South Platte Model, the reservoirs and the irrigation demands they serve are represented with off-channel reservoir systems. When diversions to storage and change in reservoir storage are inconsistent in a reservoir system, the model accounts for this inconsistency by creating natural flow from the reservoir system. Correcting these instances where the inconsistencies were large provided for more reasonable estimates of natural flow throughout the model.
- StateDMI is not currently capable of creating the StateMod input file that tells the model which wells are associated with augmentation plans, therefore an approach using an external database was created to develop this file. This database created a reproducible platform to integrate the information from the well file with the plan file, and correctly account augmentation demands.
- Three meetings were held with Division 1 staff regarding the South Platte Compact; major augmentation plans in the basin; general recharge operations associated with those plans; reservoir operations including winter storage targets; irrigation deliveries; and general characteristics of the river. Many input parameters were revised based on these discussions including the list of augmentation plans to include, reservoir targets, and operating rules used to divert irrigation and recharge.

These unforeseen refinement efforts were necessary for the Lower South Platte model to reflect the operation, management, and administration of the lower South

Platte River. These were completed using funding allocated under Amendment 7. These refinements have helped achieve better calibration of the historical model, as assessed by comparing simulated streamflow, diversions and reservoir contents to measured values. It is recommended that additional funding be allocated to complete historical calibration, fully implement augmentation plans, create the Baseline dataset, and finalize documentation.

Historical Calibration

The historical calibration of the model was performed in two steps (termed H1 and H2 model scenarios), to be consistent with other basins where CDSS surface water modeling has been implemented. In the first step (H1), the model was simulated to meet historical surface water diversions, well demands were set to StateCU-estimated ground water diversions, and reservoir storage target and release criteria were based on historical contents. The historical diversions included diversions to irrigation, storage, and recharge. During historical model simulation, recharge operations were not explicitly simulated, however the portion of the diversions that went to recharge were diverted and "applied" to irrigated land. When there was not an irrigation demand, the recharge water accrued back to the river according to the same recharge patterns assigned to the irrigated land based on Glover analyses using required parameters estimated at the centroid of the irrigated land for each structure (ditch and/or aggregated ground water only lands). This general approach adequately represents recharge and depletion patterns for basin-level modeling and, as with all CDSS modeling efforts, can be further enhanced with specific decreed operations by users interested in more detail at a local level. With this approach, the recharge water is simulated in sufficient enough detail without adding the complexity of representing individual recharge sites and operations in the historical calibration efforts.

In the second step (H2, termed the historical calibration model), the model was simulated to meet historical surface water diversions and well demands were set to StateCU-estimated ground water diversions, however the reservoirs were allowed to fill to capacity and release as needed to meet irrigation demands. Recharge operations were not explicitly simulated in the H2 scenario, and were accounted for the same as the H1 scenario. In this step, calibration included revisions to reservoir capacities and winter targets, canal capacities, and reservoir operating rules. The following figures and tables illustrate the results of the H2 calibration scenario compared to recorded measurements, with discussion regarding specific issues and areas where additional calibration efforts may result in a better historical representation.

Table 1 summarizes the annual average streamflow for calendar years 1975 through 2006 (see SPDSS Task Memorandum 1 for recommended use of calendar year format), as estimated in the H2 historical calibration model simulation and the average annual values of actual gage records for comparison. Figures 1 through 8 below graphically present monthly streamflow estimated by the H2 model compared to historical observations at the four streamflow gages, in both time-series format and as scatter graphs. When only one line appears on the time-series graph, it indicates that the simulated and historical results are the same at the scale presented. The “goodness of fit” is indicated by the R^2 value shown on each scatter graph.

Calibration based on simulated streamflow is generally good in terms of both annual volume and monthly pattern. In terms of average annual volume, the simulated streamflow at the four gaged locations is very close to the historical average. Review of the monthly data however indicates months where the model is over or under simulating streamflow, resulting in greater deviation from the historical data. Monthly deviations can be caused by the timing of depletions or return flows, as well as operational practices. Overall, the largest differences are seen during periods of low streamflow, and during the winter months when diversions to storage are taking place. The monthly pattern issues are compounded from upstream to downstream, resulting in the largest differences at the Julesburg gage. It is anticipated that additional calibration of the reservoirs will yield better calibration of the streamflow gages in the winter months, improving the overall calibration of the model.

Table 1: Average Annual Streamflow Gage Comparison (H2 Calibration Scenario)

Gage ID	Historical	Simulated	Historical - Simulated		Gage Name
			Volume	Percent	
6754000	813,464	811,385	2,079	0%	South Platte River near Kersey, CO
6758500	577,758	564,182	13,576	2%	South Platte River near Weldona, CO
6759910	508,204	503,084	5,121	1%	South Platte River near Balzac, CO (at Cooper Bridge)
6764000	483,711	490,250	-6,539	-1%	South Platte River at Julesburg, CO

Figure 1: Kersey Gage Monthly Time Series Comparison (1975 – 2006)

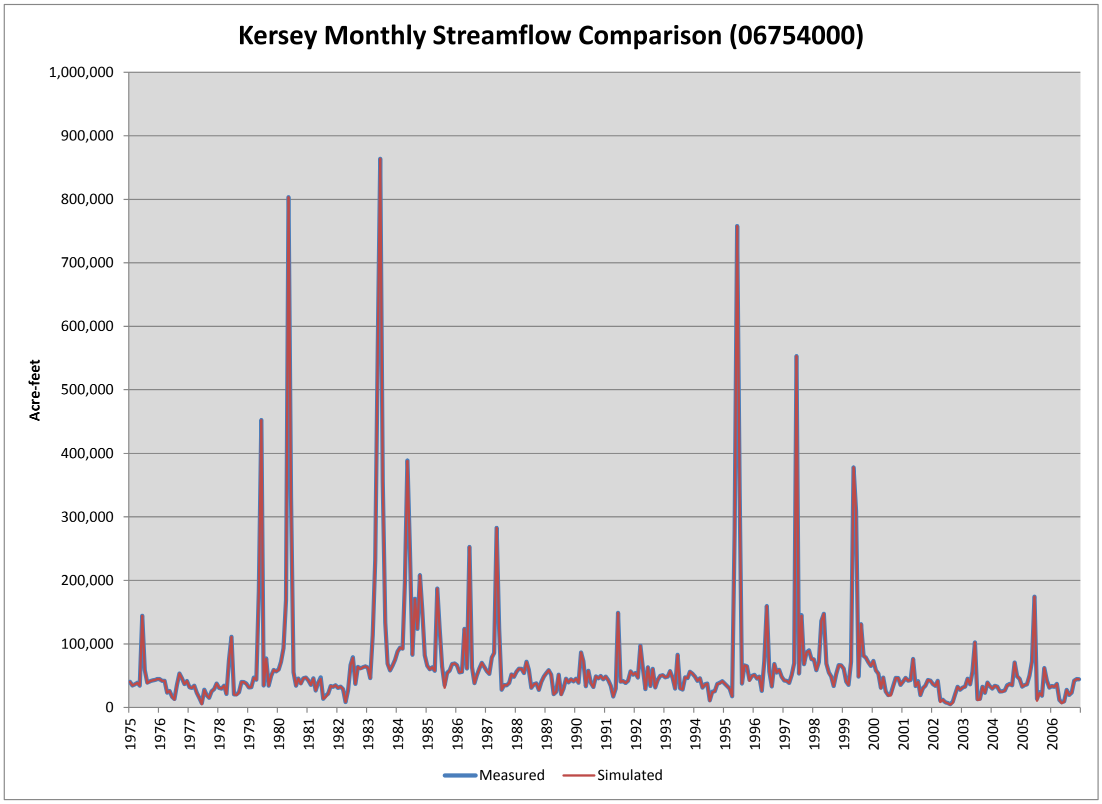


Figure 2: Kersey Gage Scatter Plot Comparison (1975 – 2006)

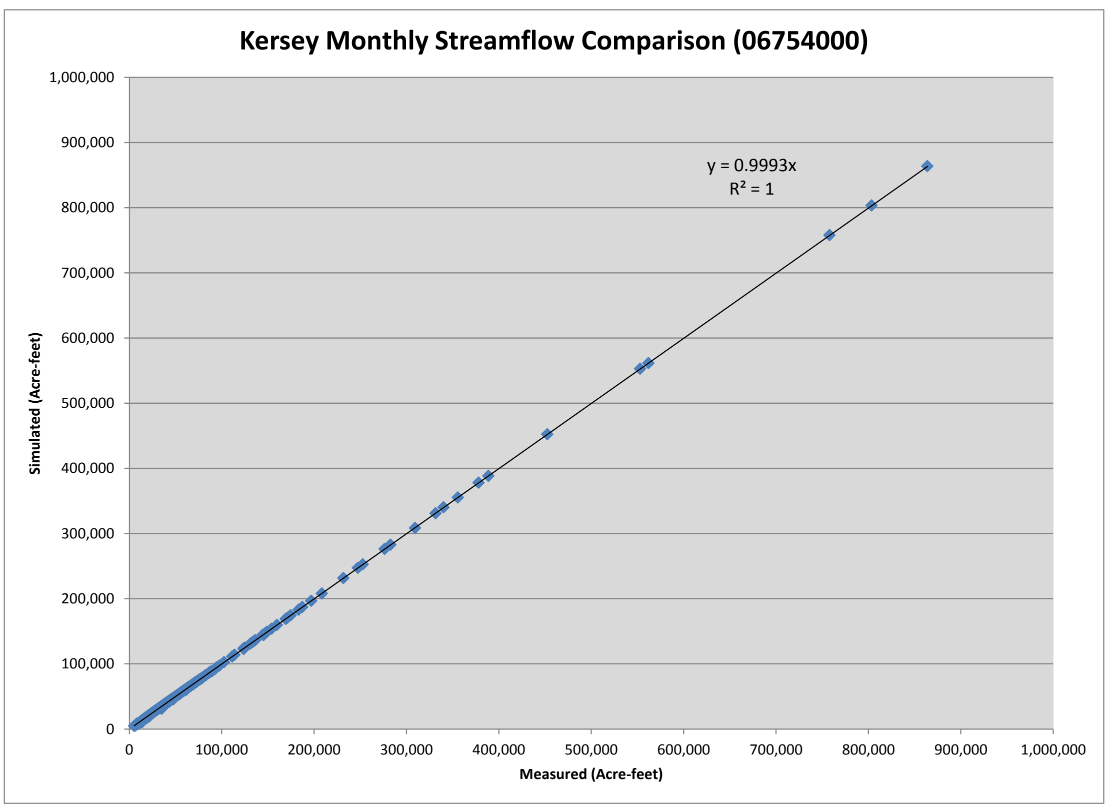


Figure 3: Weldona Gage Monthly Time Series Comparison (1975 – 2006)

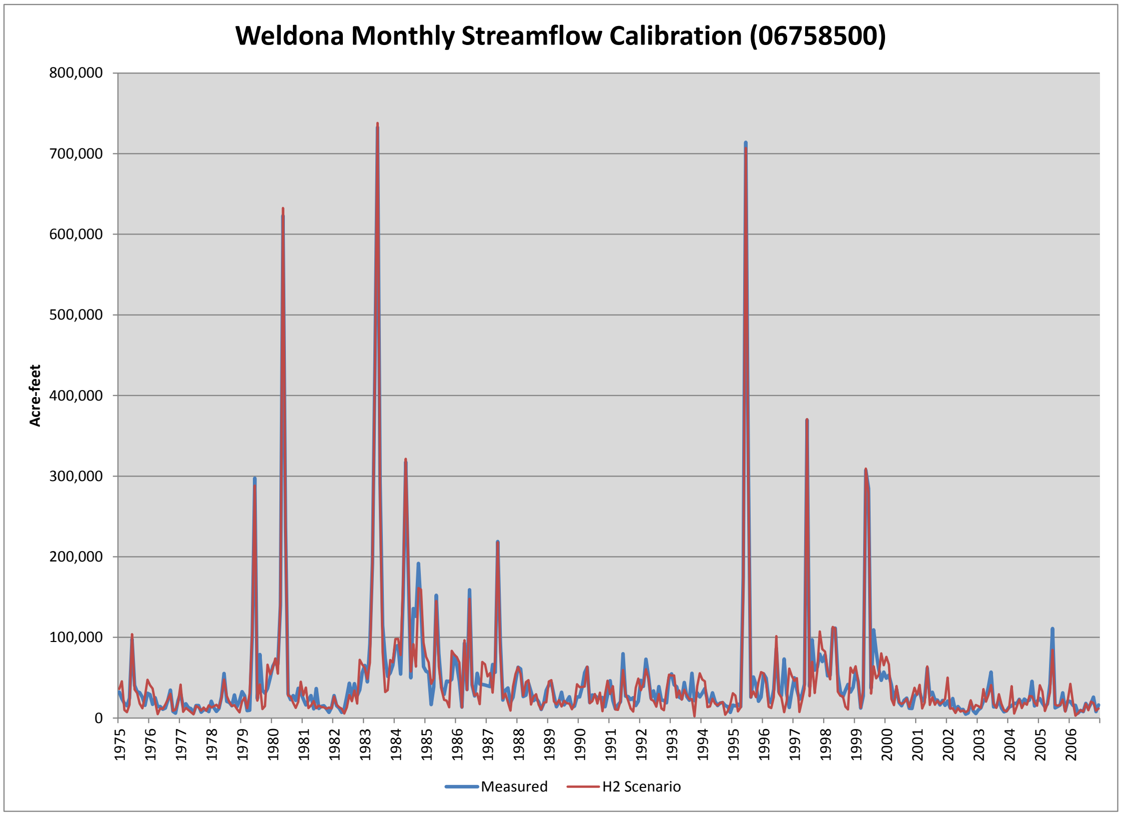


Figure 4: Weldona Gage Scatter Plot Comparison (1975 – 2006)

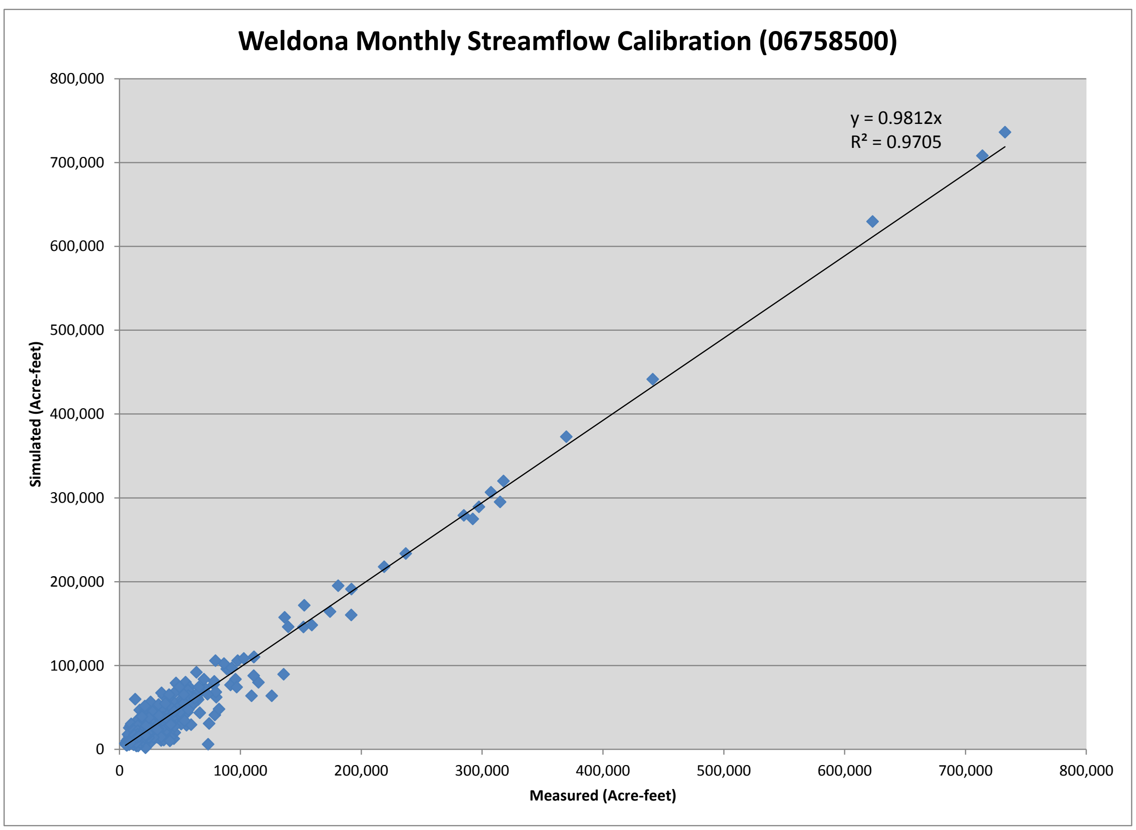


Figure 5: Balzac Gage Monthly Time Series Comparison (1975 – 2006)

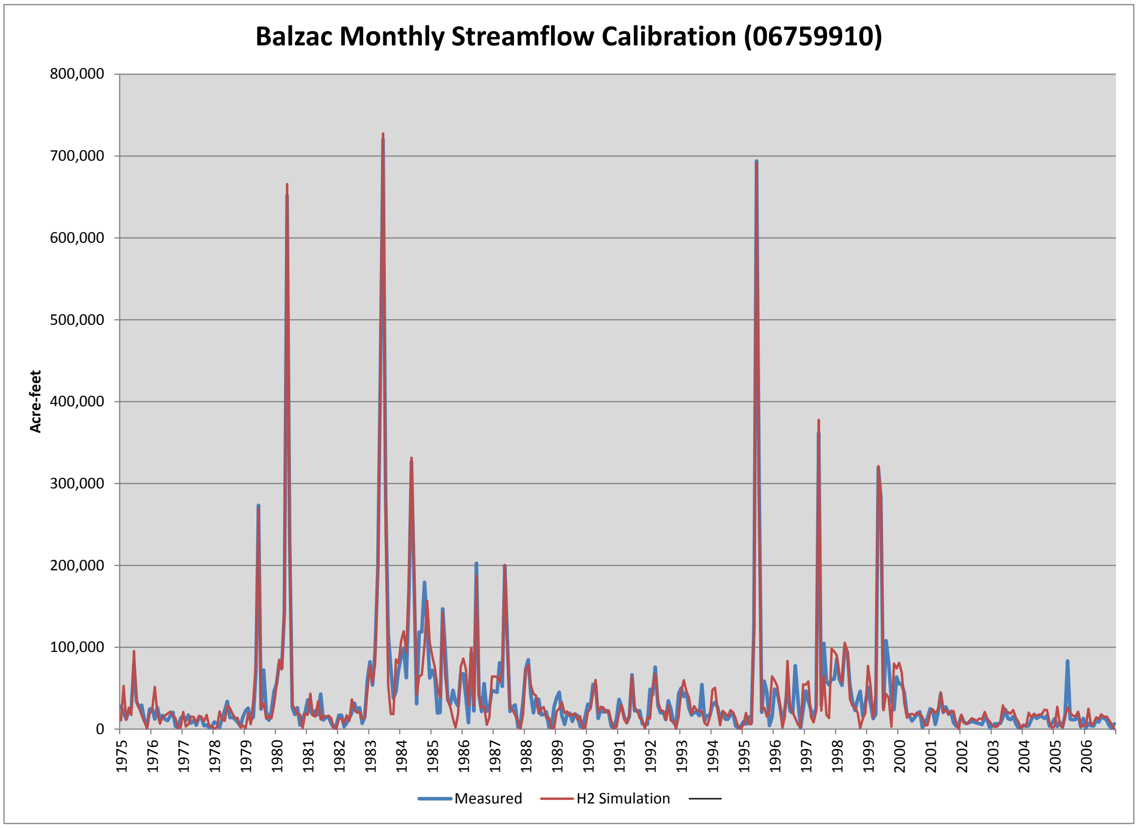


Figure 6: Balzac Gage Scatter Plot Comparison (1975 – 2006)

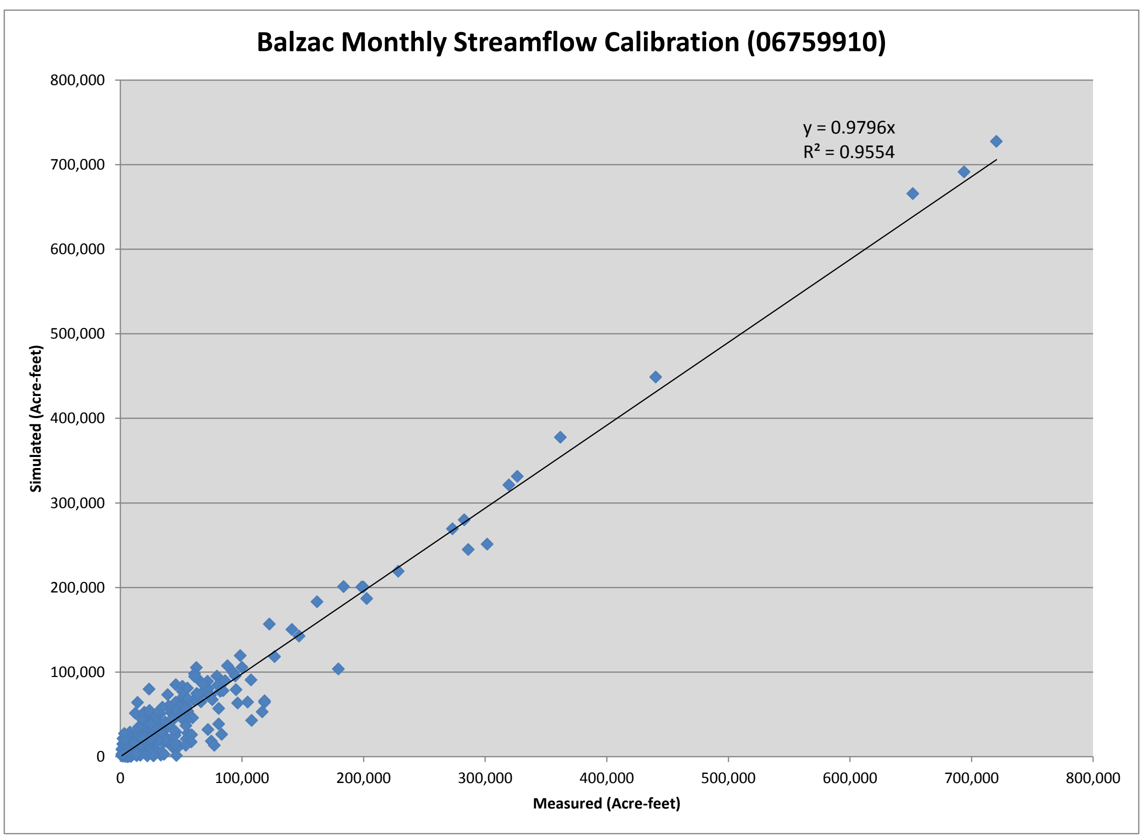


Figure 7: Julesburg Gage Monthly Time Series Comparison (1975 – 2006)

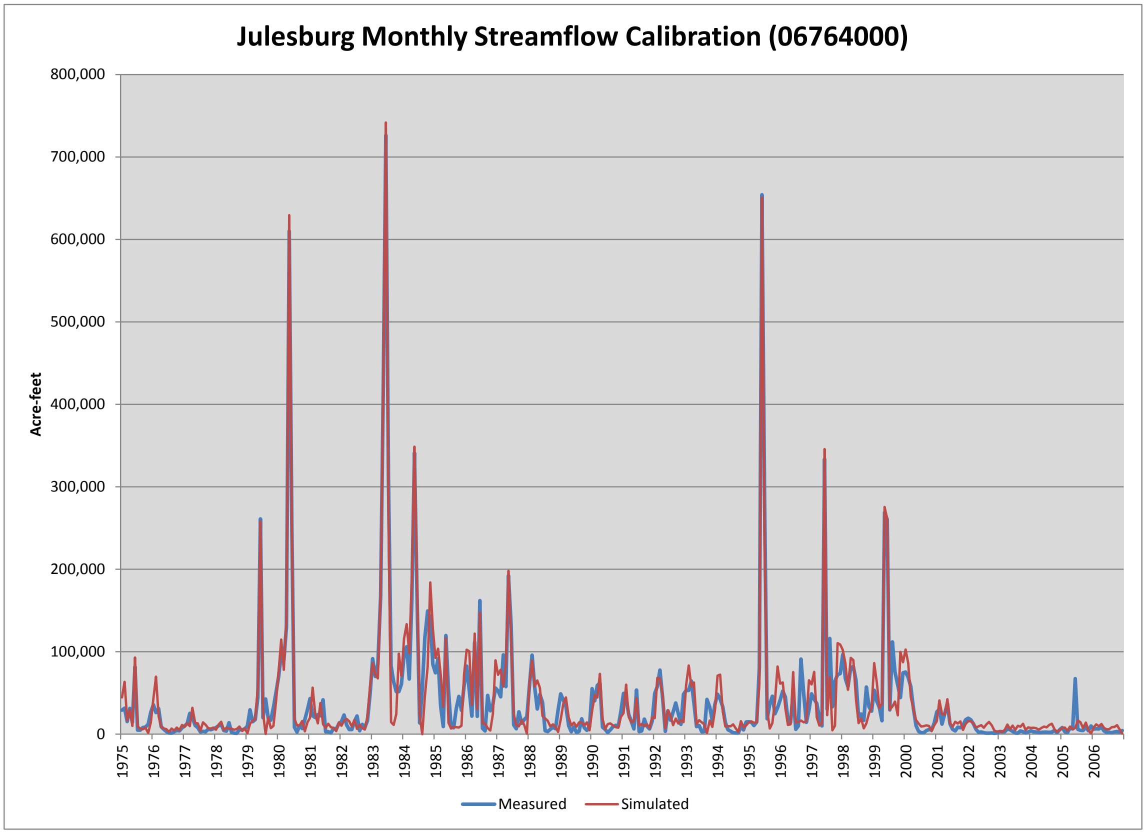
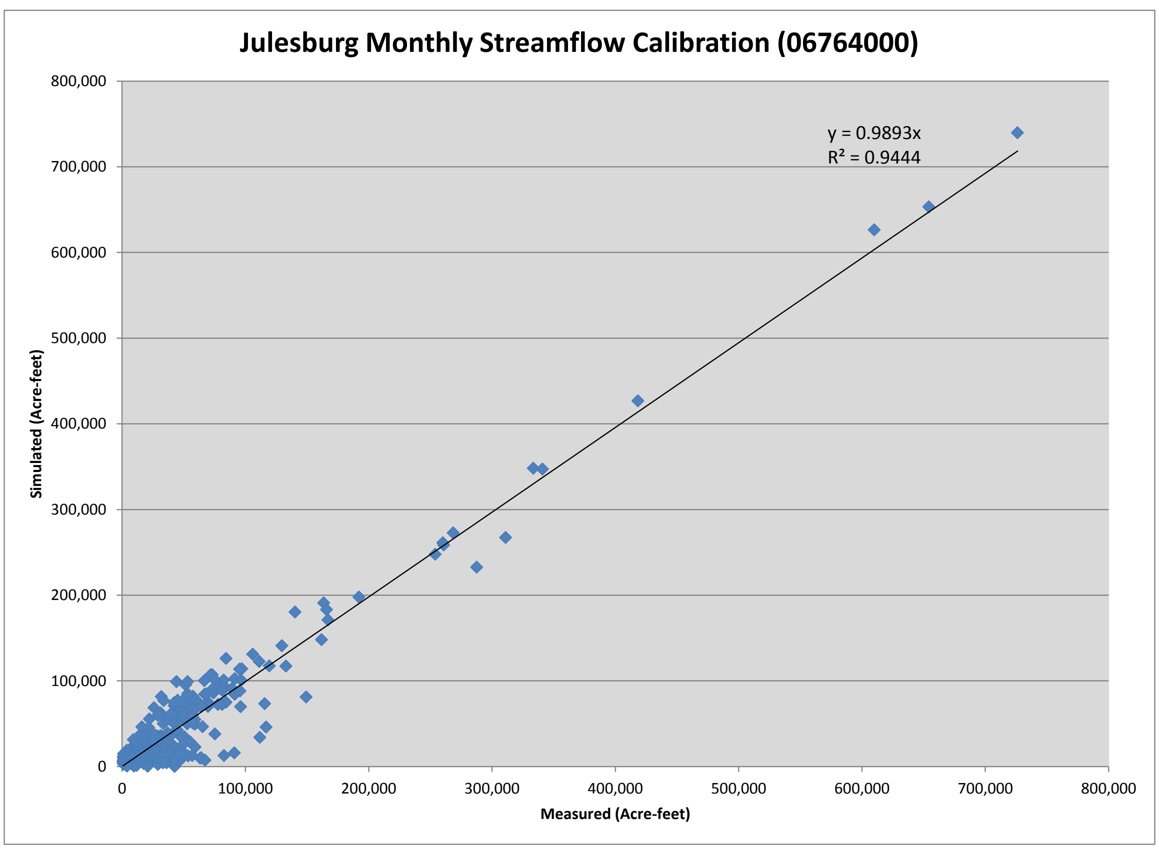


Figure 8: Julesburg Gage Scatter Plot Comparison (1975 – 2006)



Calibration based on simulated diversions is considered very good for structures that divert for irrigation use. Structures that divert for both direct irrigation and storage, however, experience more variation and deviation from the historical records. Calibration for structures that divert for storage are dependent on the calibration of reservoir operations; and the interdependency of diversions, reservoir contents, and irrigation demand influences calibration of both the diversion structure and reservoir. For example, reservoir seepage occurs in many, if not all, of the Lower South Platte reservoirs. However the amount of seepage is generally not known or quantified. When estimating seepage for a reservoir, both the diversions to storage (i.e. additional diversions to "make up" for seepage losses) and reservoir contents are reviewed to calibrate the seepage parameter for the reservoir.

Table 2 summarizes the annual average diversions for water years 1975 through 2006, as estimated in the H2 calibration run compare to the average annual values of actual diversions records. The table is categorized by the type of diversion structure (e.g. diversions to irrigation/storage). Note that there are structures in the Lower South Platte that have decreed alternate points to wells as denoted in Table 2, and therefore their historical surface water diversions from 1975 on are low or zero and their historical use is included in pumping estimates. Figures 9 through 15 below graphically present monthly diversions estimated by the model compared to historical observations for select diversion structures.

Table 2: Average Annual Diversion Comparison

Structure WDID	Historical	Simulated	Historical - Simulated		Gage Name
			Volume	Percent	
Diversions to Storage and/or Irrigation					
0100501	79,887	77,947	1,940	2%	Empire Canal
0100503_D	145,490	151,423	-5,933	-4%	Riverside Div System
0100507_D	59,494	93,910	-34,416	-58%	Bijou Div System 1)
0100513	37,618	31,521	6,097	16%	Jackson Lake Inlet
0100687	113,005	116,507	-3,502	-3%	N Sterling Div System
0100829	38,455	37,362	1,093	3%	Prewitt Res Inlet
6400511_D	53,343	62,335	-8,992	-17%	Harmony Div System
0200834	39,731	41,794	-2,062	-5%	Lower Latham Ditch
Diversions to Irrigation					
0100503_I	102,466	101,069	1,397	1%	Riverside Irrigation
0100507_I	83,855	82,359	1,496	2%	Bijou Irrigation
0100511	40,130	39,785	345	1%	Weldon Valley Ditch
0100514	60,753	60,461	292	-	Ft Morgan Canal
0100515	33,125	32,730	396	1%	Upper Platte and Beaver Canal
0100517	4,830	4,830	-	-	Deuel and Snyder Ditch

Structure WDID	Historical	Simulated	Historical - Simulated		Gage Name
			Volume	Percent	
0100518	28,724	28,324	400	1%	Lower Platte and Beaver Canal
0100519_D	13,820	13,524	296	2%	Tremont Div System
0100520	-	-	-	-	Gill Stevens Ditch[2)]
0100524	-	-	-	-	Trowell Ditch[2)]
0100525	5,283	5,283	-	-	Tetsel Ditch
0100526	3,123	3,121	2	-	Johnson Edwards Ditch
0100565	-	-	-	-	Maguire Ditch
0100570	-	-	-	-	East Gulch Ditch
0100620	-	-	-	-	Consolidated Larson Ditch
0100687_I	84,813	83,008	1,806	2%	N Sterling Irrigation
0100688	1,415	1,379	36	3%	Union Ditch
0103817_I	198	198	-	-	Jackson Irrigation
01_ADP037	-	-	-	-	Lower South Platte SW Aggregate 37
0200834_I	36,778	36,778	-	-	Lower Latham Irrigation
0200837	3,987	3,987	-	-	Highland Ditch
6400501	-	-	-	-	Carlson Ditch[2)]
6400502	1,911	1,832	79	4%	Liddle Ditch
6400503	3,488	3,463	24	1%	S. Reservation Ditch
6400504	10,810	10,789	22	-	Peterson Ditch
6400506	240	240	-	-	Red Lion Supply Ditch
6400507	-	-	-	-	Long Island Ditch[2)]
6400508	2,809	2,809	-	-	Settlers Ditch[2)]
6400511_I	40,225	40,225	-	-	Harmony Irrigation
6400513	1,062	1,055	7	1%	Chambers Ditc[2)]h
6400514	854	854	-	-	Ramsey Ditch
6400516	4,777	4,777	-	-	Powell Blair Ditch
6400518	1,479	1,477	2	-	Lone Tree Ditch[2)]
6400519	-	-	-	-	Jud Brush Ditch[2)]
6400520	22,855	22,557	298	1%	Iliff Platte Valley Ditch
6400522_D	7,657	7,383	275	4%	Bravo Div System
6400524	6,792	6,764	28	-	Lowline Ditch
6400525	2,449	2,444	5	-	Henderson Smith Ditch
6400526	1,107	1,100	8	1%	Sterling Irrigation Co. Ditch 2[2)]
6400528	23,977	23,697	281	1%	Sterling Irrigation Co. Ditch 1
6400530	8,341	8,300	41	-	Springdale Ditch
6400531	9,154	9,154	-	-	Schneider Ditch
6400532	1,775	1,775	-	-	Davis Bros. Ditch[2)]
6400533	28,790	28,790	-	-	Pawnee Ditch
6400535	13,352	13,329	23	-	South Platte Ditch

Structure WDID	Historical	Simulated	Historical - Simulated		Gage Name
			Volume	Percent	
6400542	-	-	-	-	McWilliams Ditch
6400584	-	-	-	-	I.O. Jones Ditch
6400599	-	-	-	-	Rice Ditch

[1] See additional comment about Bijou calibration below

[1] Structures with alternate points to wells

Figure 9: Fort Morgan Canal Monthly Time Series Comparison (1975 – 2006)

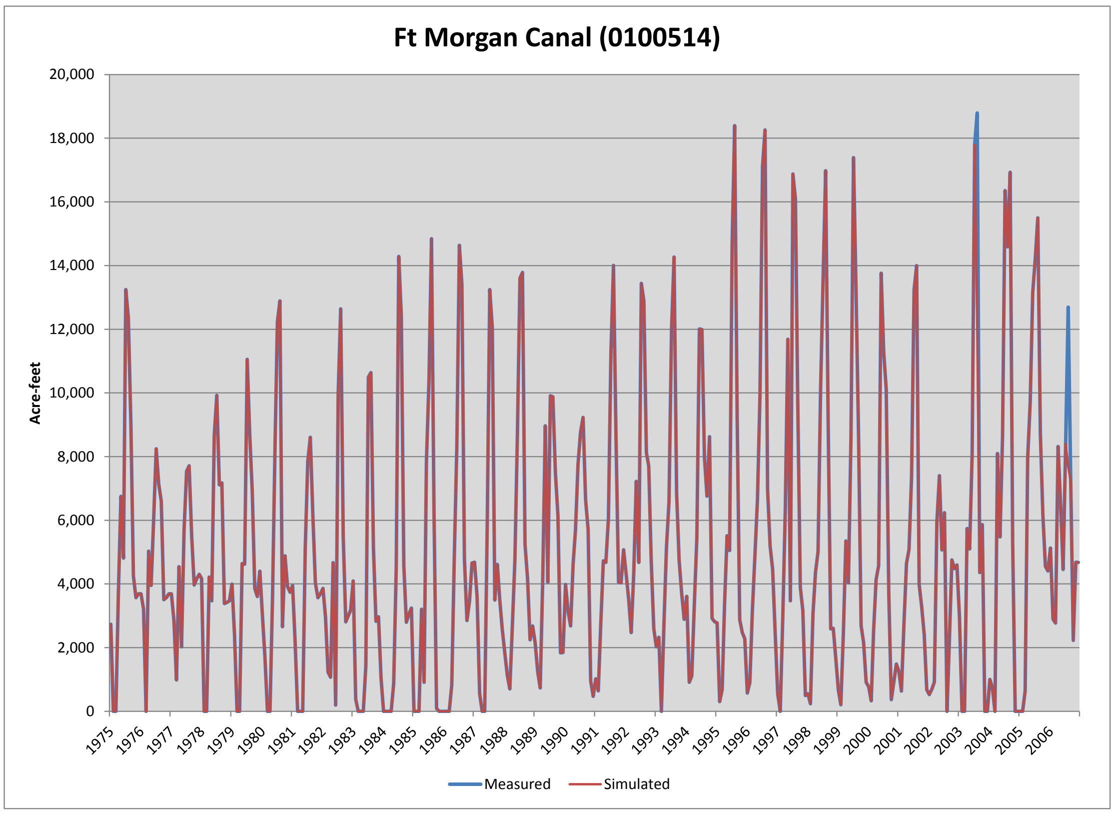


Figure 10: Lower Platte and Beaver Canal Monthly Time Series Comparison (1975 – 2006)

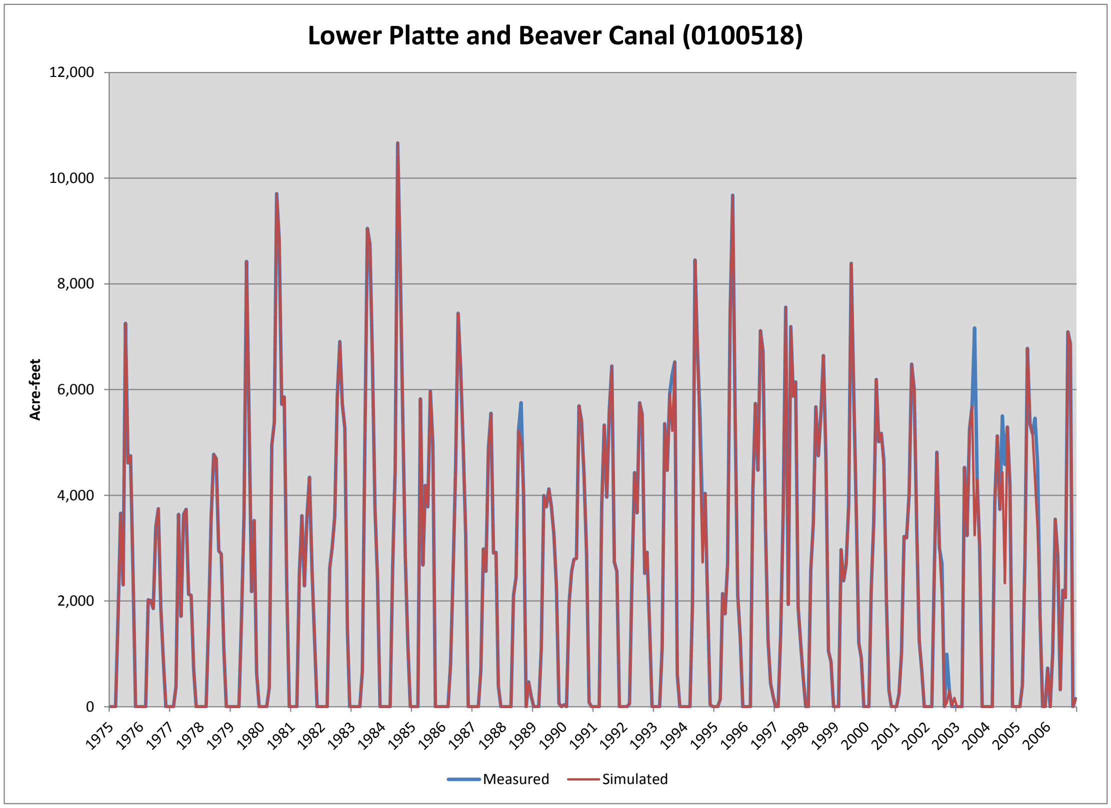


Figure 11: Peterson Ditch Monthly Time Series Comparison (1975 – 2006)

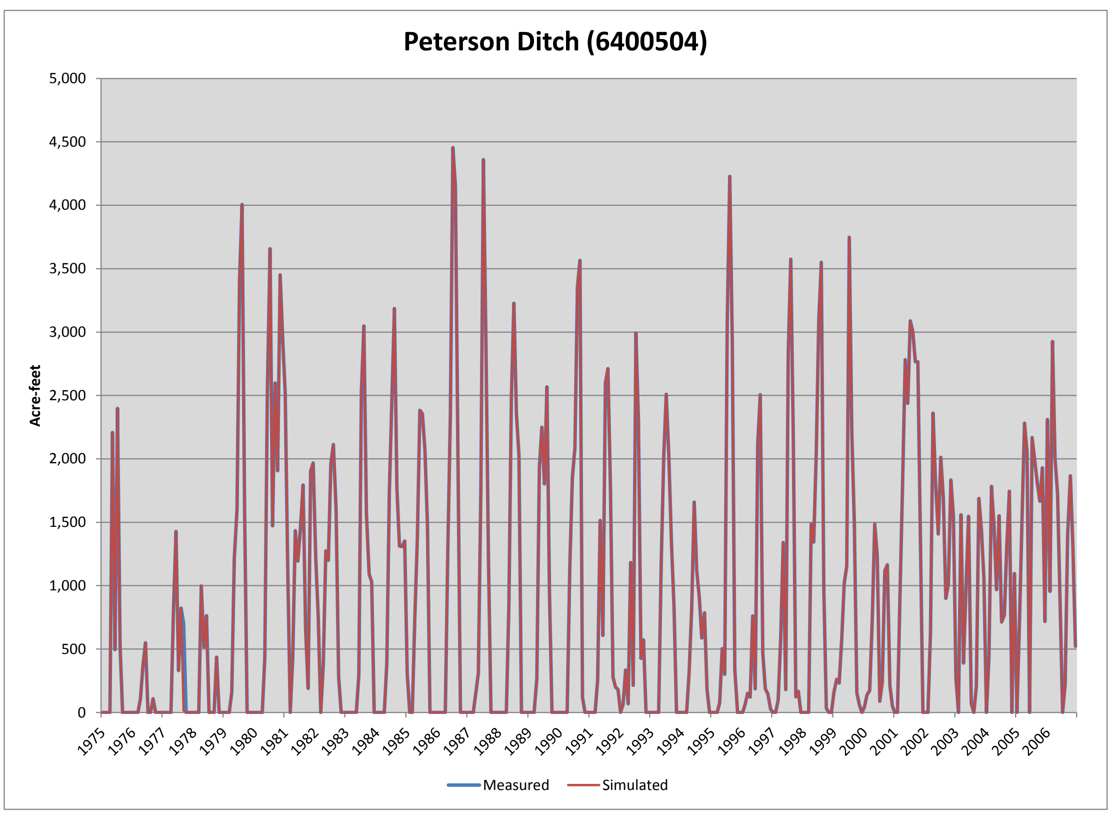


Figure 12: Riverside Diversion System Monthly Time Series Comparison (1975 – 2006)

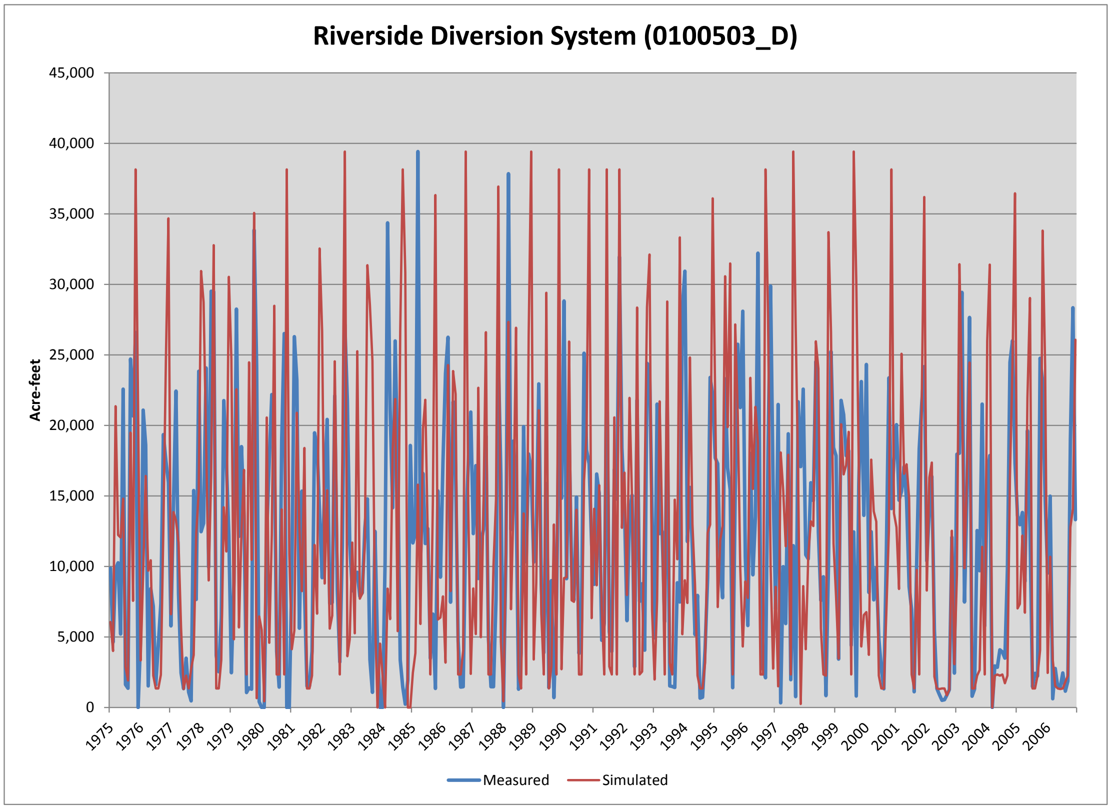


Figure 13: Riverside Irrigation System Monthly Time Series Comparison (1975 – 2006)

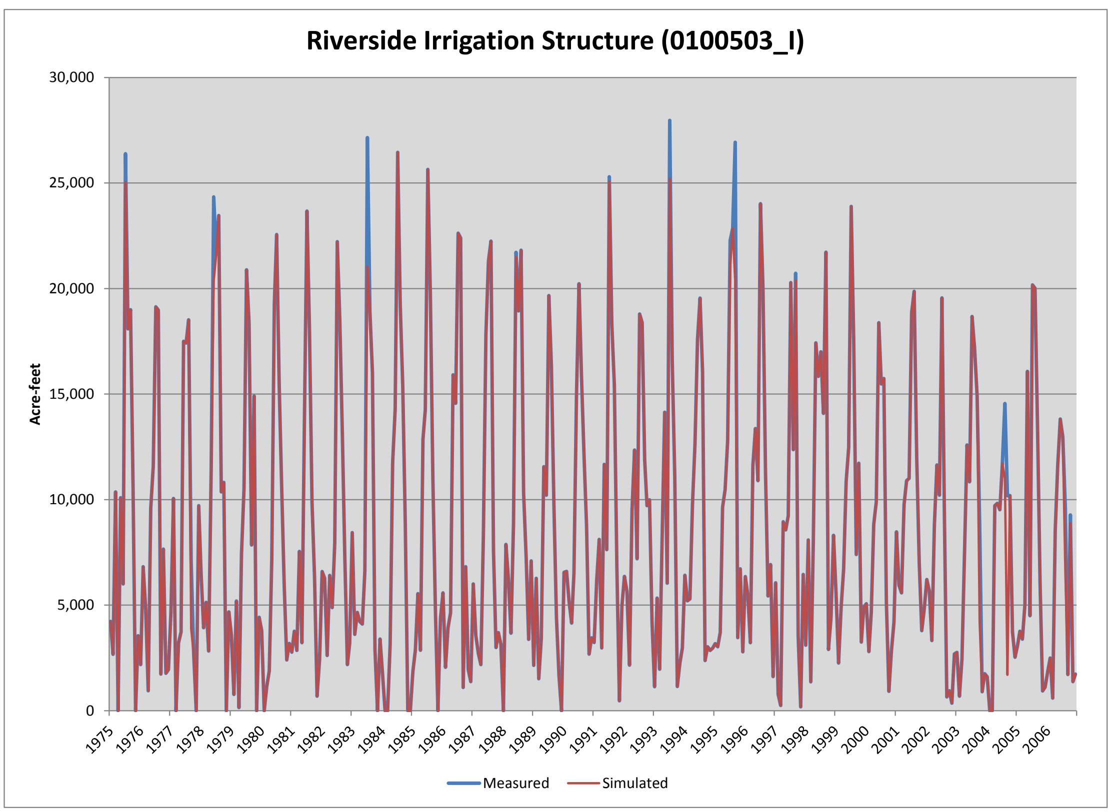


Figure 14: North Sterling Canal Monthly Time Series Comparison (1975 – 2006)

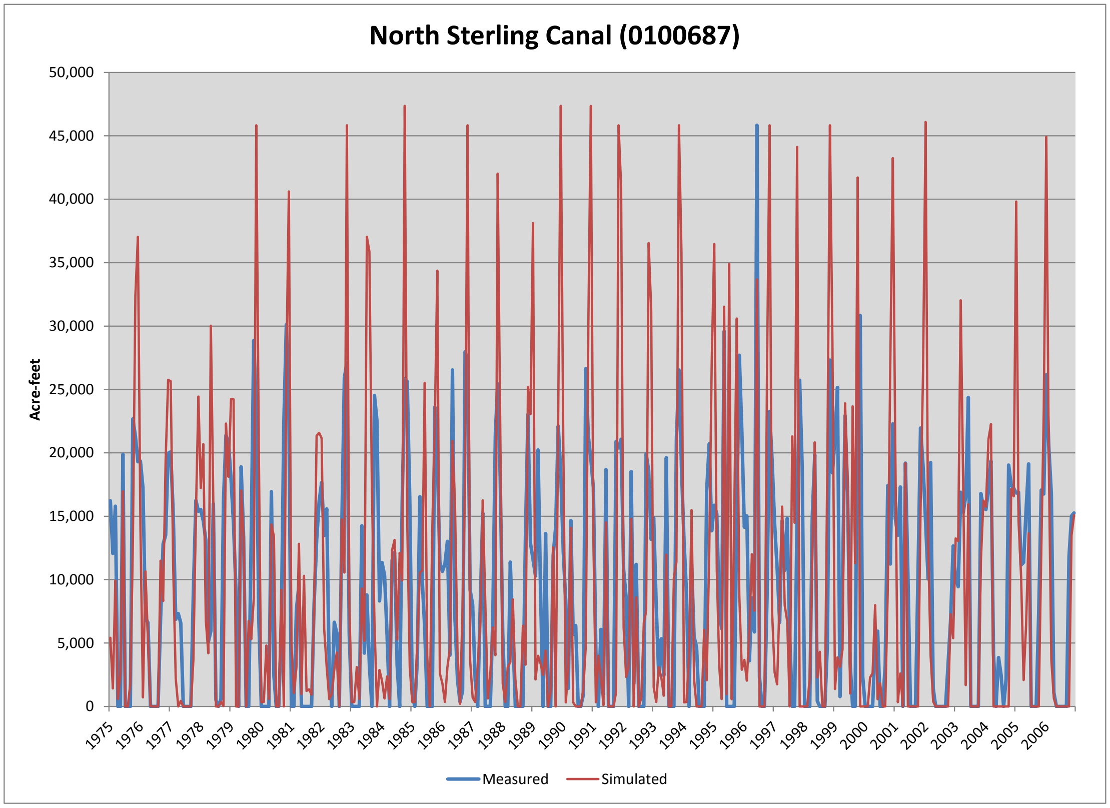
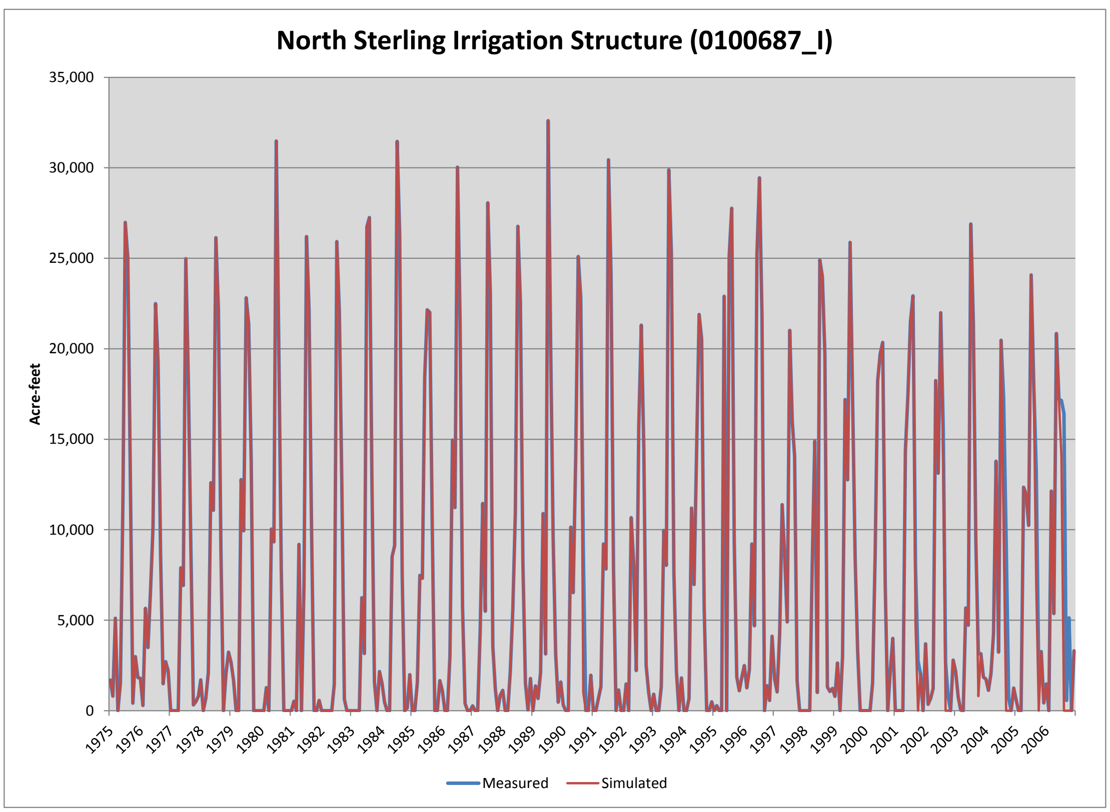


Figure 15: North Sterling Irrigation System Monthly Time Series Comparison (1975 – 2006)



Calibration (H2) based on simulated reservoir contents is generally good for irrigation reservoirs; calibration issues remain with reservoirs used for augmentation. The current historical scenario does not fully simulate augmentation plan operations, therefore the reservoirs that are used in whole or in part to meet augmentation requirements will need additional calibration once these operations are included in the model.

Specifically, the operations and seepage associated with Bijou Reservoir No. 2 will have to be addressed. Bijou Reservoir No. 2 was historically used for irrigation; however due to large seepage losses, it was eventually operated for recharge. This change in usage, seepage loss, and the recharge operations will need to be addressed before the reservoir will be calibrated. The filling “targets” for Bijou Reservoir No. 2 were not relaxed to be full capacity in the H2 scenario; they remain set to historical end-of-month contents. It is anticipated that the filling “targets” will be relaxed to full capacity once augmentation operations are incorporated into the final historical (H3) scenario. Additional calibration of the Bijou system is also expected to address the over-simulation of diversions through the Bijou diversion system shown in Table 2.

The diversion carrier to store water in Lower Latham Reservoir and the reservoir itself are located in Water District 2 and were included in the Lower South Platte model because irrigation return flows and well depletions impact the river in Water District 1. It is anticipated that further review of Lower Latham Reservoir will take place under the Upper South Platte modeling efforts and calibration of the reservoir will take place when the Upper and Lower South Platte models are combined.

As discussed above, any calibration efforts for the reservoirs must include consideration of diversions to storage and diversions to meet irrigation demand. Figures 16 through 23 graphically present reservoir end-of-month contents estimated by the model compared to historical observations for select diversion structures.

Figure 16: Prewitt Reservoir Comparison of Reservoir Contents (1975 – 2006)

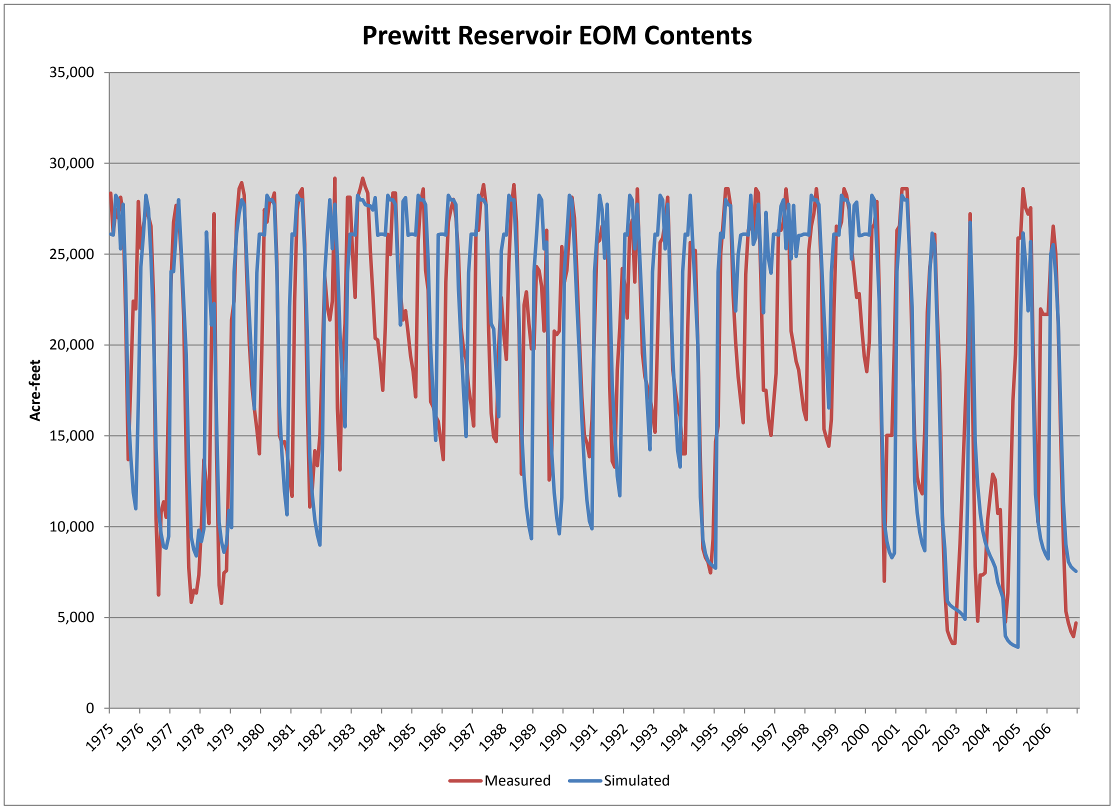


Figure 17: North Sterling Reservoir Comparison of Reservoir Contents (1975 – 2006)

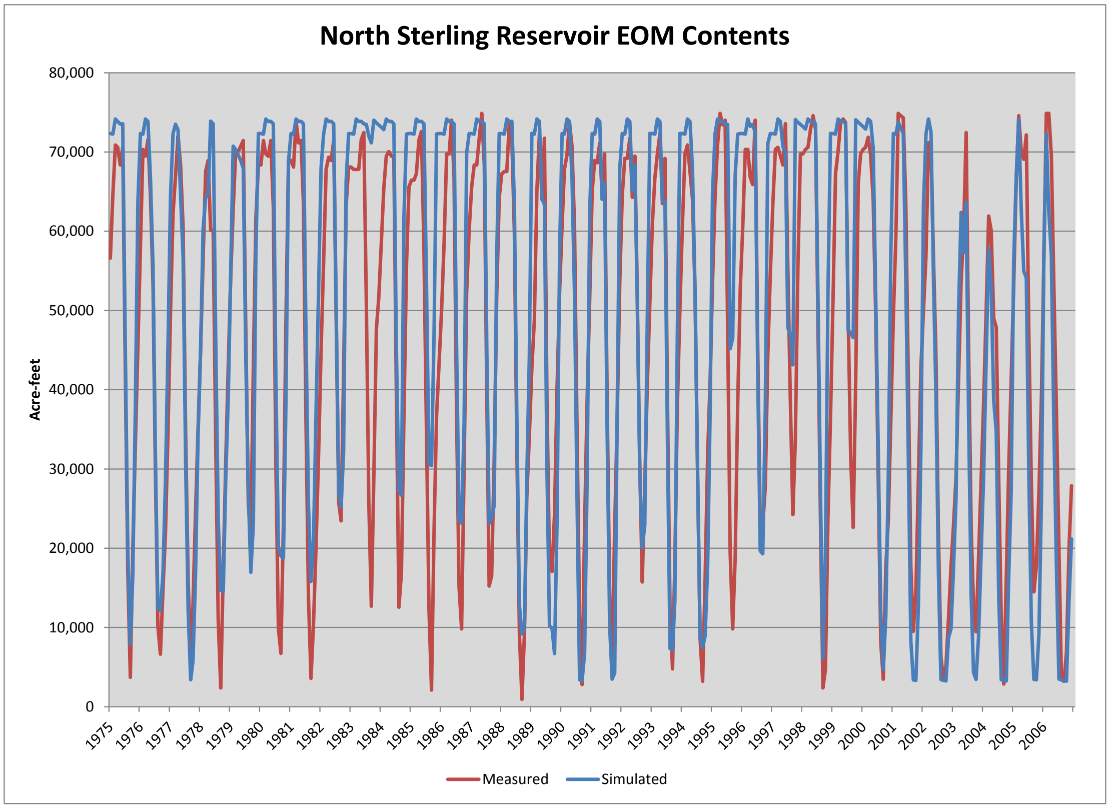


Figure 18: Julesburg Reservoir Comparison of Reservoir Contents (1975 – 2006)

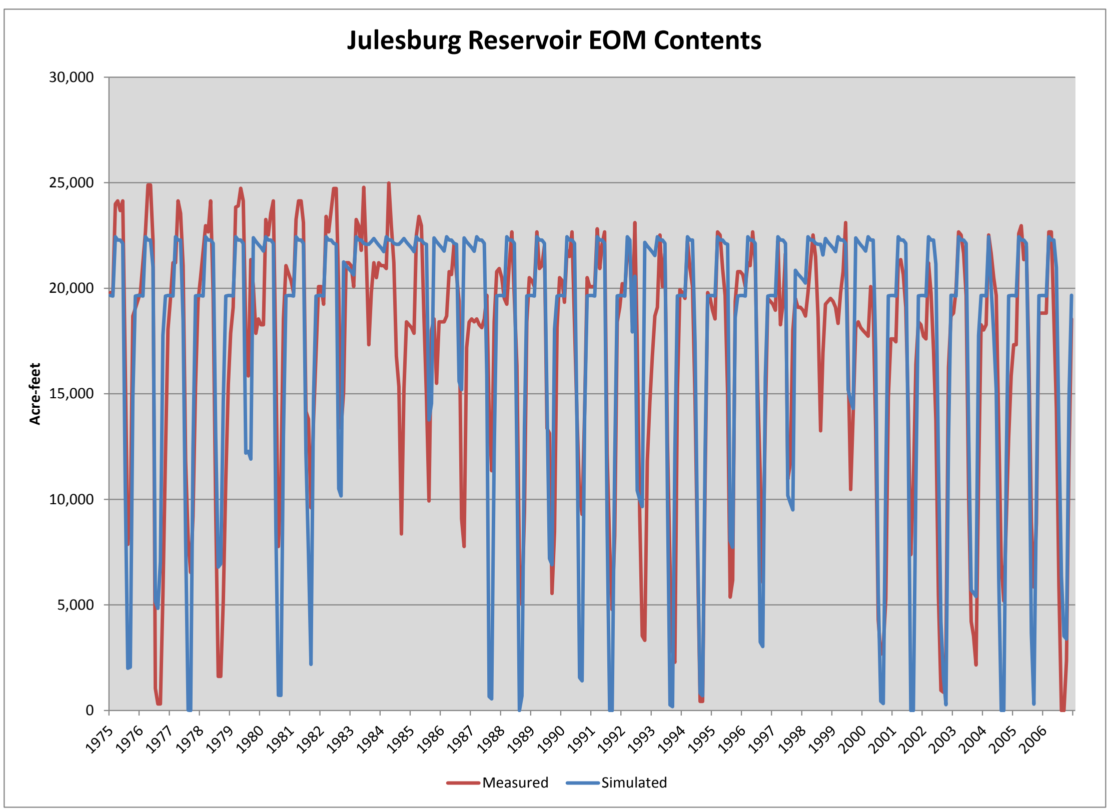


Figure 19: Lower Latham Reservoir Comparison of Reservoir Contents (1975 – 2006)

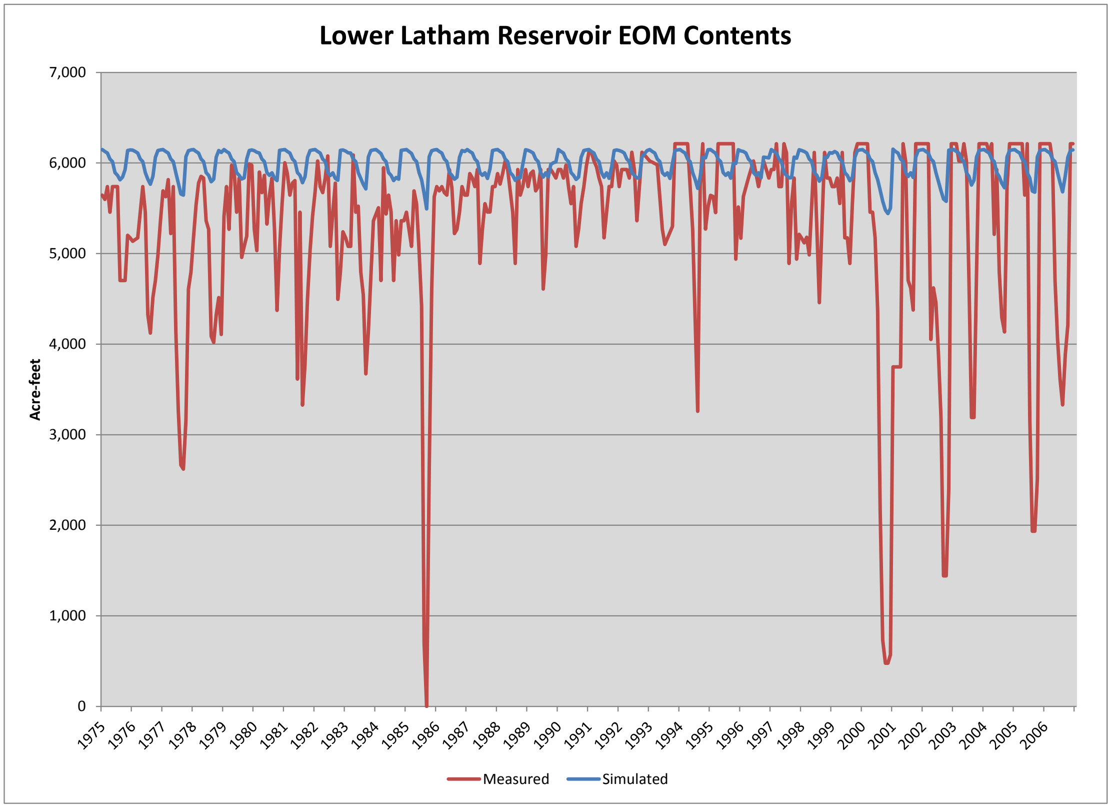


Figure 20: Riverside Reservoir Comparison of Reservoir Contents (1975 – 2006)

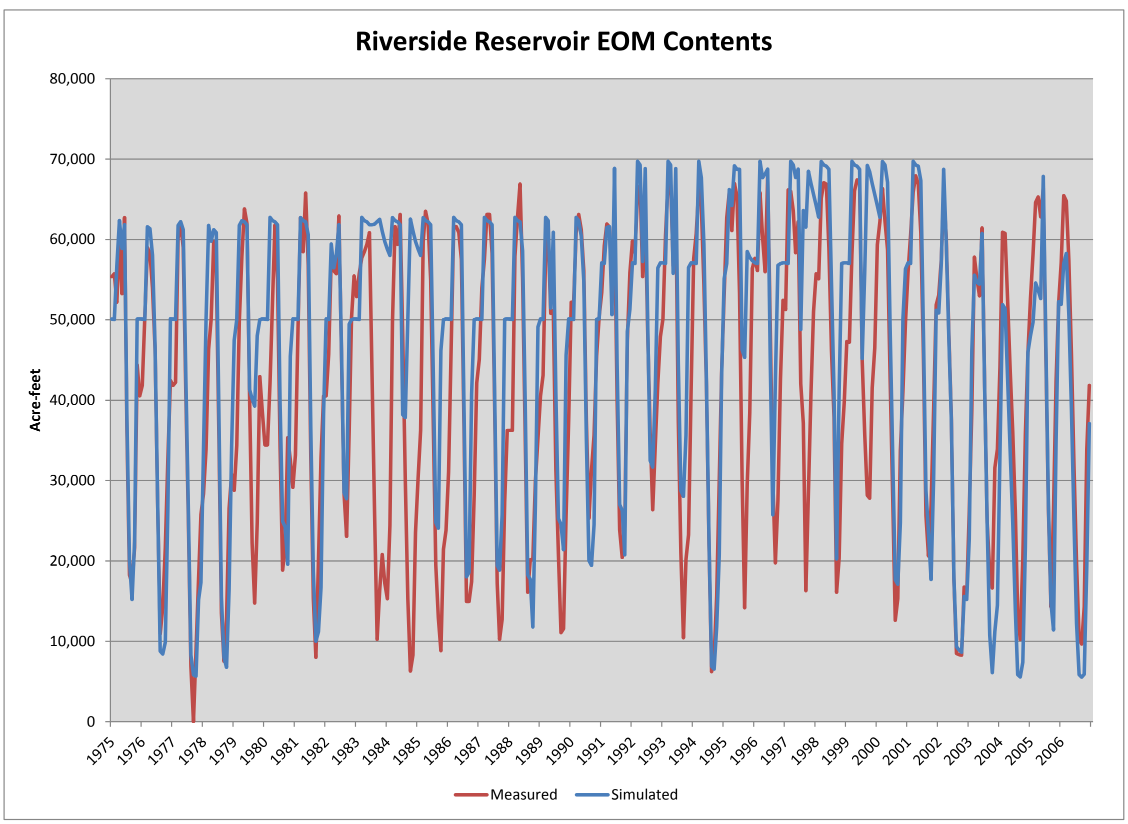


Figure 21: Bijou No. 2 Reservoir Comparison of Reservoir Contents (1975 – 2006)

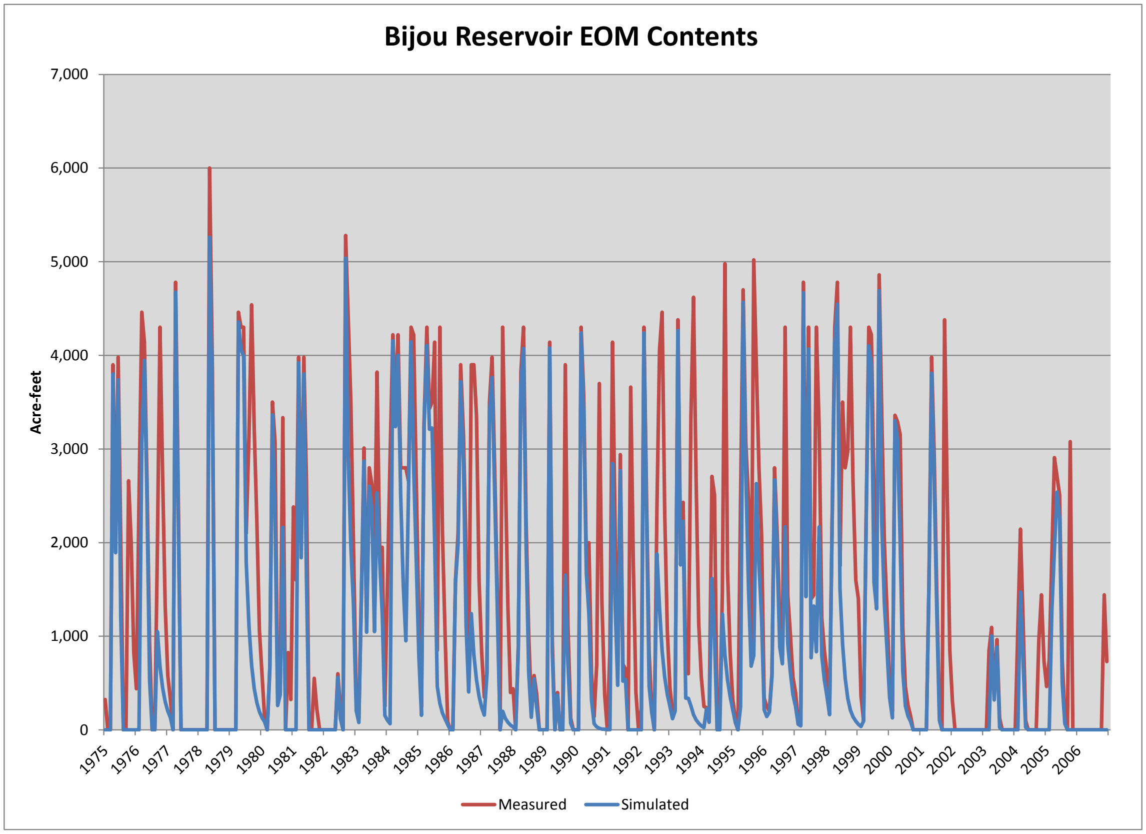


Figure 22: Empire Reservoir Comparison of Reservoir Contents (1975 – 2006)

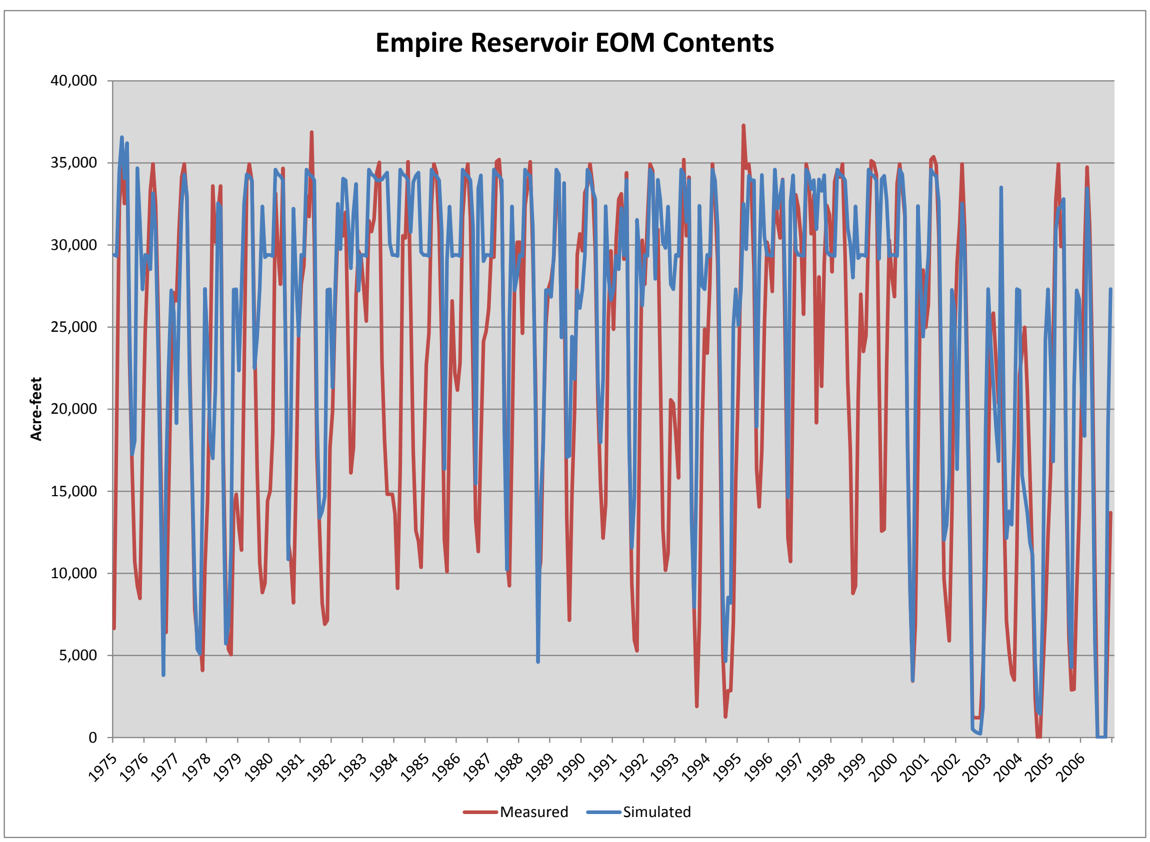
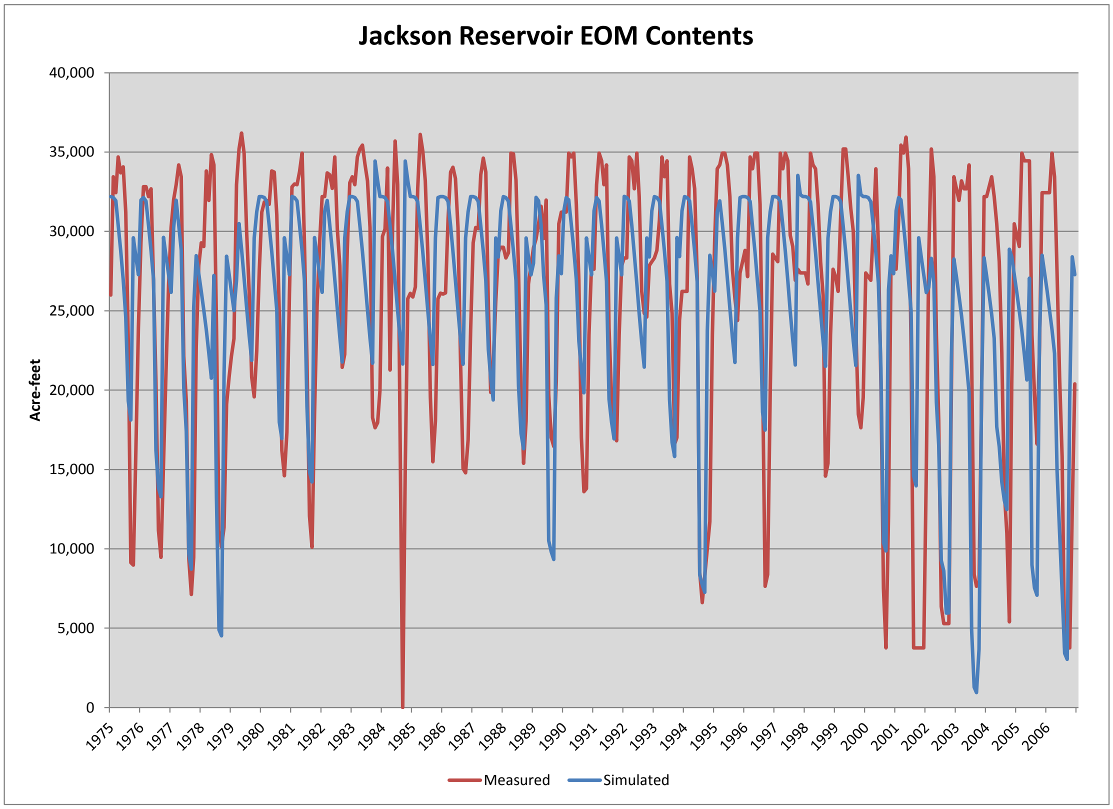


Figure 23: Jackson Reservoir Comparison of Reservoir Contents (1975 – 2006)



Task 3 – Project Management and Coordination

Coordination with the StateMod programmer and the Division 1 staff continued throughout the project.

Status:

This task was completed in conjunction with the Task 1 and 2 efforts. Meetings with Division 1 served as a forum to specifically discuss the modeling techniques used to represent the Compact, as well as to discuss the Lower South Platte model as a whole, specific modeling techniques used to represent the complex augmentation and recharge operations, and gain “buy-in” from the administrators regarding the modeling efforts.

Recommendations for Lower South Platte Model

As discussed above, there are complex administrative and operational practices in the Lower South Platte that are not present, and hence not been modeled in other CDSS basins. Many of the efforts in developing the historical calibration runs (H1 and H2), involved addressing modeling issues associated with the South Platte Compact; off-channel reservoir systems; augmentation and recharge operations; and surface water and ground water interaction. Progress was made in the historical runs in terms of the representation of augmentation plan structures in the model, data consistency issues, reservoir targets, and natural flow estimates.

The current H2 model well represents current irrigation, reservoir use, and operation practices in the basin. This model can be used to better analyze the surface and ground water interaction in the basin, to consider changes to reservoir operations, to understand Compact implications, and to inform the ground water model with pumping and/or recharge information.

Full implementation of augmentation operations in the final historical scenario (H3) is recommended. Once implemented, this model can be used to answer planning questions regarding augmentation and recharge operations. Additional calibration, as well as the development of the calculated and baseline model datasets, is important for expanding the use of the Lower South Platte model to represent changes in current operations and water uses. The following discusses recommended steps to move towards that goal.

1. Additional Historical Calibration

The comparison of simulated results to historical diversion and streamflow records illustrates the location and magnitude of the remaining issues that need to be addressed. The monthly variability need to be analyzed, and it is anticipated that additional review and adjustment of return flow timing, reservoir seepage, and depletions will result in better calibration. In addition, the amount of irrigation demand that is met from surface water diversions versus storage should be analyzed. Overall, it is anticipated that minor calibration efforts to irrigation reservoirs and more extensive calibration efforts for recharge reservoirs is needed.

Bijou Reservoir No. 2 in particular is difficult to model due to its history as both an operational irrigation reservoir and as a recharge reservoir with large seepage losses. Fully implementing augmentation demands in the H3 scenario, as discussed below, will assist in the overall representation and operation of this reservoir. Note that although the comparison of Lower Latham Reservoir did not show good correlation in terms of reservoir contents, this reservoir may not be further calibrated in this modeling effort. It is expected that Lower Latham Reservoir, located in Water District 2, will be analyzed and calibrated in the Upper South Platte Modeling efforts and during the overall model calibration when the Upper and Lower South Platte models are combined.

In addition to reservoir operations, overall administrative and operational information gleaned during meetings with the Division 1 staff needs to be fully incorporated. A portion of this information was incorporated in the H2 scenario calibration efforts. The remaining information, including return flow locations, general reservoir operations, and augmentation plan operations, still needs to be incorporated into the H2 scenario.

The development of an H3 scenario, which would reflect full implementation of augmentation operations and additional calibration efforts associated with that implementation, is recommended. This may include revision to augmentation/recharge reservoir locations, water rights used for augmentation, and the development of recharge area “demands”.

2. Develop Calculated Scenario

The calculated scenario is similar to the historical scenarios in that the historical operations are represented, however the irrigation demand is based on the irrigation water requirement and historical efficiencies instead of historical diversions. Unlike the historical models, calculated irrigated demand represents the full crop demand that can be met from both surface water and ground water sources. The demand used in the historical model includes both irrigation diversions and demand to fill recharge ponds. In the calculated scenario, it will be necessary to break apart those uses and provide separate demands. The following are anticipated steps to develop the calculated dataset:

- Develop the calculated irrigation demand based on StateCU irrigation water requirement and average monthly efficiencies. Using control options, let the model allocate surface water based on priority to meet the irrigation demand, then simulate pumping to meet the unmet irrigation water requirement on lands with ground water sources. For wells under many augmentation plans, this assumes that irrigated parcels get a full supply. For some augmentation plans, most notably Central Colorado Water Conservancy District GMS and WAS augmentation plans, ground water pumping estimates based on irrigation water requirement were reduced based on augmentation plan quotas.

- Develop a representative recharge demand; potentially based on historical diversion class records, water rights, augmentation requirement, recharge capacity, anecdotal information from the Division 1 office, and/or a combination of this information. Fully implement operating rules associated with augmentation operations, including carrying water rights for augmentation to aggregated recharge areas, accounting for in- and out-of priority depletions, and applying canal seepage and recharge to meet the augmentation demand. Note that these operating rules have been previously developed, however could not be fully implemented until a representative recharge demand was developed.
- Simulate the calculated scenario and review results to determine if additional calibration is needed.
- Provide a comparison to the amount of historical pumping from StateCU to the amount of pumping simulated in the calculated scenario and the revised pumping estimates required to calibrate the ground water model. Depending on the results of these comparisons, calibrate operations to better correlate to estimates of pumping.

3. Develop Baseline Scenario

The baseline scenario provides a basis against which to compare future scenarios, and serves as the starting point for using the model to analyze specific water resources management issues. The baseline scenario reflects the river system as it is currently, with all operations as they exist now included over the entire study period. The following are anticipated steps needed to develop the baseline dataset:

- In the historical model, operating rules associated with each augmentation plan are “turned on” using “on/off” dates as they were decreed over time. In the baseline scenario, the augmentation plan “on/off” dates will be adjusted to be turned on for the entire period.
- As with the augmentation plans, adjust appropriate reservoir files so that all reservoirs are online for the entire period.
- Develop a representative baseline recharge demand. As discussed above, many pieces of information will be involved with determining a baseline recharge demand for each augmentation plan.

4. Finalize Documentation

The Lower South Platte River Basin Water Resources Planning Model User's Manual will document the model input files; describe the complex operations in the basin; and summarize calibration process and results. The framework for this documentation has been developed based on previous CDSS modeling efforts; details associated with the final model files, calibration results, and baseline scenario will need to be added for the final deliverable.

Recommendations for Upper South Platte and Tributary Modeling Efforts

Due to the complexities associated with water use in the South Platte Basin, including augmentation plans, municipal use of changed water rights, reusable supplies, and surface and ground water interaction, it was determined that developing models representing individual tributaries and water districts in lieu of a full South Platte model was prudent. These individual models would then be combined to create a full basin model that can be used for future "what-if" scenarios.

It is recommended that the Upper South Platte and Tributary model developers focus on understanding and representing historical operations, quantifying non-irrigation demands, and reconciling data issues to develop the historical scenarios (H1, H2, and H3). The model developers can rely on information developed during previous SPDSS efforts, including operational memoranda of reservoir and irrigation systems. Based on the development of the Lower South Platte model, it is likely they will also need to work with water users and water commissioners to understand specific calibration issues.

Once the historical models are developed, they can be integrated to represent the entire South Platte, and the model can be calibrated as a whole. Many operations carry through multiple water districts, including trans-tributary diversions, municipal supplies and diversions to storage. Reconciliation of these inter-basin operations will take place during the combination of the models, thus reducing duplicate calibration efforts.

Model representation of key operations in each basin should be documented during each tributary development; however it is recommended that full documentation be developed only for the combined model. Comprehensive model documentation can be created for the entire South Platte model using the key operational information from each individual model. In general, the following are steps to create the historical models for the Upper South Platte and Tributary models.

1) Using information developed in the SPDSS task memos, create the historical model input files and river network for each Upper South Platte and Tributary model. For the historical scenarios, separate historical surface water demands for each use (e.g. irrigation, storage, recharge, and municipal) should be understood and represented. In addition, the model developer should have a

good understanding of the water rights used to meet specific demands. As with the Lower South Platte model, it is recommended that the ground water demand be kept separate in the tributary models until the development of the calculated scenario for the entire South Platte basin.

2) Develop the reservoir account, operating rules, and calibration sections for the final document, using the format developed for CRDSS model documentation. These sections can then be included in the overall South Platte basin model documentation.
3) Integrate the Upper South Platte and Tributary models with the Lower South Platte model to create the entire South Platte model. It is recommended that the models not be "linked", rather the DMI commands used to generate the input files be combined and rerun to create the input files for the combined model. Likewise, it is recommended that the individual river networks be merged to create a network for the combined model. Model developers should be required to use the CDSS DMI-standard procedures for developing input files. If significant changes to canal efficiency were required for the calibration of the individual tributary models, it may be necessary to revise and rerun the StateCU analysis.
4) Recalibrate the combined South Platte model concentrating on inter-basin operations. Inter-basin operations may include shared demands, return flows, reservoir storage or releases, or transbasin delivery. A smaller-scale example is Lower Latham Reservoir which diverts for storage in Water District 2 and releases to lands in Water District 1. On a much larger-scale, Colorado-Big Thompson Project water can be used across many districts. Note that revisions to demands, operations or return flows will change natural flow estimates, which may require additional natural flow calibration.
5) Create combined South Platte model calculated and baseline scenarios based on procedures from Lower South Platte model. As discussed above, the implementation of a single demand for the calculated dataset that can be satisfied by both surface and ground water supplies has not been fully implemented in the Lower South Platte Model. Once the calculated dataset has been developed in the Lower South Platte model, the procedure can be used for the combined model.
6) Using the individual tributary modeling sections, create the combined South Platte model documentation. The general CDSS documentation framework will be used for the final documentation and supplemented in areas with new procedures and input files.

Comments and Concerns

As discussed above, many of the calibration techniques applied during the CRDSS development of the Western Slope models are not applicable to the more complex administrative and operational practices in the Lower South Platte. Numerous off-channel reservoir systems; augmentation and recharge operations; reservoir seepage;

and the surface water and ground water interaction in the basin are complex elements that have not been modeled in other CDSS models. Modeling these complex elements has proven to be challenging, and most of the calibration effort to date has concentrated on operations unique to the South Platte basin.

The Lower South Platte StateMod model is intended to be used as a "template" for the development of models for the remaining South Platte main stem and major tributaries and for the combined South Platte model. Therefore, it is critical that the Lower South Platte model be fully developed, defensible, and vetted with State planners and administrators. It is recommended that additional funds be allocated to finalize the model prior to developing models representing other areas of the basin.