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Government of Alberta

Updates to the South Saskatchewan River Operational Model (SSROM) and the Underlying OASIS Platform – Final Report

Submitted by:
P. Kim Sturgess, C.M., P.Eng., FCAE
Chief Executive Officer
WaterSMART Solutions Ltd.
605, 839 5th Avenue SW
Calgary, Alberta T2P 3C8
kim.sturgess@watersmartsolutions.ca

Submitted to:
Anil Gupta
Alberta Environment and Parks
Anil.Gupta@gov.ab.ca

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Executive Summary

The South Saskatchewan River Operations Model (SSROM) is a comprehensive, daily, mass balance river model developed for the Bow River, Red Deer River, Oldman River, and South Saskatchewan River Basins. The various sub-basin models were constructed through several collaborative Working Groups between 2011 to 2015, which were then integrated, in 2015, to create the SSROM. The SSROM models the entirety of the South Saskatchewan River Basin (SSRB) and is built on the Operational Analysis and Simulation of Integrated Systems (OASIS) modelling platform.

Given the significant changes in the system since 2015 which include irrigation district expansions, construction of new infrastructure, and changes to the operation of the system, there was a recognized need to update the SSROM to reflect current operations. Collaborative Working Groups have provided updated information on the current base case, including updates to reservoir management, to reflect these current operations. Working Group members included irrigation districts and Government of Alberta (GoA) representatives, specifically members from key government departments such as Alberta Environment and Parks (AEP) and Agriculture Forestry and Rural Economic Development (AAFRED).

Key updates that are reflected in the new version of the SSROM included:

- Operational updates across key on-stream and off-stream reservoirs across all river basins.
- Updated irrigation demands, provided by AFRED from the Irrigation Demand Model Data (IDM), and updated irrigation acres, provided by irrigation districts, to improve accuracy of irrigation related modelling.
- Updated surface water demands, provided by AEP, to allow better reflection of non-irrigation licenses.
- Updated naturalized flows, provided by AEP, to allow improved analysis using historical flow data spanning 87 years (1929 – 2015).
- Updated municipal demand for the City of Calgary and the City of Lethbridge, to reflect the updated actual water use.

In addition to completing the primary objective, updating the model to reflect current basin operations, the following was also completed:

- Updated the OASIS modelling platform to OASIS Enterprise to allow more efficient modelling of complex scenarios, as well as a more user-friendly interface.
- The updated SSROM is available to any interested parties and stakeholders through the University of Lethbridge servers, and AEP has a copy for internal use. Stakeholder access to the model creates transparency and builds trust in model outputs, allowing for ongoing collaboration to build out “what if” scenarios using the SSROM base case. See Section 1.1 for project approach.

Working Group participants identified scenarios where the ‘what-if’ analysis offered by the SSROM would be beneficial for future assessment, including:

- Assisting in developing a drought management plan for the City of Calgary.
- Looking at different ways to optimize water management in the upper SSRB.

- Assessing various options for rural and economic development in a closed system.
- Evaluating ecosystem health within the context of new irrigation development.

Note that the descriptions of the system operations that are described in this report and integrated in the model are based on information provided by the regional irrigation district managers and AEP based on their best understanding at the time. Actual operation of the system could differ based on real-time conditions and changes to operations to address on the ground realities, which may differ from the theoretical rule curves and general results contained in this report.

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1.0 Introduction

The South Saskatchewan River Operations Model (SSROM) is a comprehensive, daily, mass balance river model developed for the Bow River, Red Deer River, Oldman River sub-basins and the South Saskatchewan River Basin including inflows from the major tributaries. The sub-basin models were developed in conjunction with several collaborative Working Groups from 2011 to 2015. In 2015 the sub-basin models were integrated to develop the SSROM. The SSROM models the whole South Saskatchewan River Basin (SSRB) and is built on the Operational Analysis and Simulation of Integrated Systems (OASIS) modelling platform.

In Alberta, the SSROM and the sub-basin models have been WaterSMART's primary tools used to build a collective understanding of the water management system in the SSRB and for collaborative exploration and assessment of opportunities to address water management challenges within and across the sub-basins. The models have been used to enable stakeholder Working Groups to examine and assess strategies for adapting to changes in water supply and demand and climate variability, including flood and drought, as well as the impacts the strategies could have across the full basin.

The SSROM was last fully updated in 2016 with the publication of the Roadmap for Sustainable Water Management in the SSRB (Alberta WaterSMART, 2016). Given the significant changes in the system over the last decade, and the increasing concerns over climate variability, there was a recognized need to update the SSROM to ensure that that it is representative of the SSRB as it operates today. The goal of the *Updates to the South Saskatchewan River Operational Model (SSROM) and Underlying OASIS Platform* project was to update the SSROM Base Case so that the model is reflective of the SSRB as it operates today and to update the underlying modelling platform from the original OASIS platform to the OASIS Enterprise platform. Furthermore, through this project the updated SSROM will be made available to the public so that it can continue to be employed as a tool in the collaborative watershed planning and management process.

The updates to the SSROM included extending the inflow dataset, originally from 1928 to 2009, to include 2010 to 2015, updating irrigation demands per updated data from Alberta Agriculture, Forestry and Rural Economic Development (AAFRED), updating surface water demands per updated information from Alberta Environment and Parks (AEP), and updating system operations based on knowledge from the Government of Alberta (GoA) and from irrigation district managers. This report lays out the approach taken to update the data in the SSROM, summarizes the model and the data within the model, compares the updated SSROM outputs to those from previous modelling efforts, and finally summarizes future modelling opportunities that can be supported by the SSROM's strengths.

1.1 Project Approach

The work on this project reflects the collaborative approach taken on previous projects involving the SSROM. In this project, collaboration was achieved via a Working Group comprised of two subgroups: GoA representatives and irrigation district representatives. The Working Group meetings were used to confirm data received from the GoA and the irrigation district representatives regarding the current operations of the SSRB.

A Working Group Kick-off Meeting was held to initiate the model updates. This meeting served to introduce project participants to one another and to provide a project overview. Following this meeting, a further three meetings were held. To ensure the efficient use of participants' time and the complete accounting of changes within the basin, the first two of these meetings were held as subgroup meetings where the GoA and irrigation district representatives met separately. This subgroup approach also helped to ensure that all perspectives were fully captured and allowed for more time to address participants' specific questions.

The subgroup meetings provided WaterSMART with information on the changes needed to update the SSROM, which was fully documented. The meeting feedback that WaterSMART documented was then used to update the SSROM Base Case. Working Group participants were asked to verify updates and note any other required changes prior to the third and final Working Group meeting. This final meeting brought the subgroups together and was used to present and validate the updated SSROM.

Following this meeting, participants were invited to SSROM User Training sessions. Two training sessions were delivered. The first session focused on basic OASIS (Operational Analysis and Simulation of Integrated Systems) functions, model logic, and how to make changes within the model (e.g., adding or removing elements, changing rule curves, etc.). The second session provided a deeper review of the OASIS platform including a demonstration of Operations Control Language (OCL) code, transitioning model logic to code, and user best practices. Slides from the training session are included in this report for reference, see Appendix I.

It should be noted that this report utilizes data from various sources, each with different reporting standards and nomenclature depending on the intended audience. As such, this report contains a mix of imperial and metric units depending on which is most commonly used to report on the parameter of interest. The conversion table below is provided for the reader to convert to the unit they feel most comfortable using.

Metric	Imperial
1 m^3/s or 1 cms	35.3 ft^3/s
1 dam^3 or 1 cdm	0.81 ac-ft
1 hectare	2.47 acre

2.0 Model Summary

This section summarizes the OASIS modelling platform, the SSROM, and the updates made to the SSROM throughout the *Updates to the SSROM and Underlying OASIS Platform* project. The SSROM is composed of three sub-basin models: the Red Deer River, the Bow River, and the Oldman sub-basins and the South Saskatchewan River Basin. Model data that is common to all three sub-basins is discussed prior to descriptions of each sub-basin; subsequently each sub-basin is discussed individually to highlight important operational aspects that differ per basin. This section focuses on high-level descriptions and on highlighting updates per basin; additional details regarding the sub-basin models can be found in previous reports, and specifics regarding all model updates can be seen in Appendix E.

2.1 The OASIS Modelling Platform

OASIS is flexible, transparent, data-driven, and effectively simulates water facility operations. It is a unique software program that evolved from Hazen and Sawyer's (Daniel P. Sheer, 1989) work in modelling water resource systems, allowing users to model virtually any water resources system quickly and accurately. OASIS is a mass balance model, meaning that water cannot be created or removed artificially. Because this model is water-resources specific, all continuity of flow equations is automatically written, saving significant time and reducing error compared to building river basin models using generic tools like spreadsheets.

Fundamentally, OASIS is driven by weights on variables; positive weights encourage actions, while negative weights discourage them. Further, the weights are ordinal. This means that a variable with a higher weight is given preference over one with a lower weight, regardless of the magnitude of the difference. Thus, in a very simple two-variable model (e.g., flow and storage), the solution will be the same whether the difference in the two weights is 0.1 or 100. Of course, as the model becomes more complex, it becomes increasingly complex to weight appropriately. A full list of all weights in the model (inclusive of reservoirs, arcs, demands, and OCL code) can be found using the "Special Output" button in OASIS and selecting "Weights.out."

To model more complex operations, OASIS uses OCL - a specially designed programming language intended for use by operators. More like a scripting or macro language than a formal programming language, this allows for easy description and implementation of complex operations. OCL allows users to define additional variables, targets, and constraints. OCL files written for this model can be found through the "setup" tab in OASIS Enterprise.

Once all weights, constraints, targets, and variables are defined and/or set, OASIS simulates the routing of water using a linear program. The model takes all user-set information, converts it to a mathematical equation, and solves it to maximize a "score" based on constraints and weights.

OASIS can be used in two primary modes: (1) a simulation mode to evaluate system performance for a given set of demands, operating policies, and facilities over the historic inflow record (this is what is used to conduct yield analyses); and (2) a position analysis mode for real-time management. In the latter mode, the model uses multiple ensemble inflow forecasts to provide a probabilistic assessment of conditions such as reservoir storage, typically up to one year in the future. Although it can be used for other purposes, this forecasting feature is particularly useful for drought management.

The detailed user manual for OASIS with OCL (300+ pages) is accessible from the model's Graphical User Interface under the Help Menu.

2.1.1 The SSROM

The SSROM is built on the OASIS platform. The SSROM is a compilation of twelve years of modelling efforts and countless hours of expert stakeholder engagement. The SSROM is composed of three sub-models – the Red Deer River Operational Model, the Bow River Operational Model, and the Oldman and South Saskatchewan River Operational Model. Throughout the sub-basins operations and priority water allocations differed, however the core of the mass balance model is the same. These sub-models are discussed in Sections 2.3.1 to 2.3.3. Figure 1 shows a schematic of the SSROM. Figure 1 should be read in conjunction with Figure 2, which indicates what the shapes and arrows within the SSROM schematic signify. The important water management and modelling components within the SSROM include reservoirs and lakes, demand nodes, instream demand nodes, junction nodes, inflows to the system, river or canal arcs, withdrawal arcs, and return arcs. Arcs connect nodes in the SSROM, allowing water to move from one location to the next.

A copy of the SSROM model is being made available for public access which will allow users to continue collaboration and build out various "what if" scenarios. Updates to the hosting will be provided via the WaterPortal (www.albertawaterportal.ca)

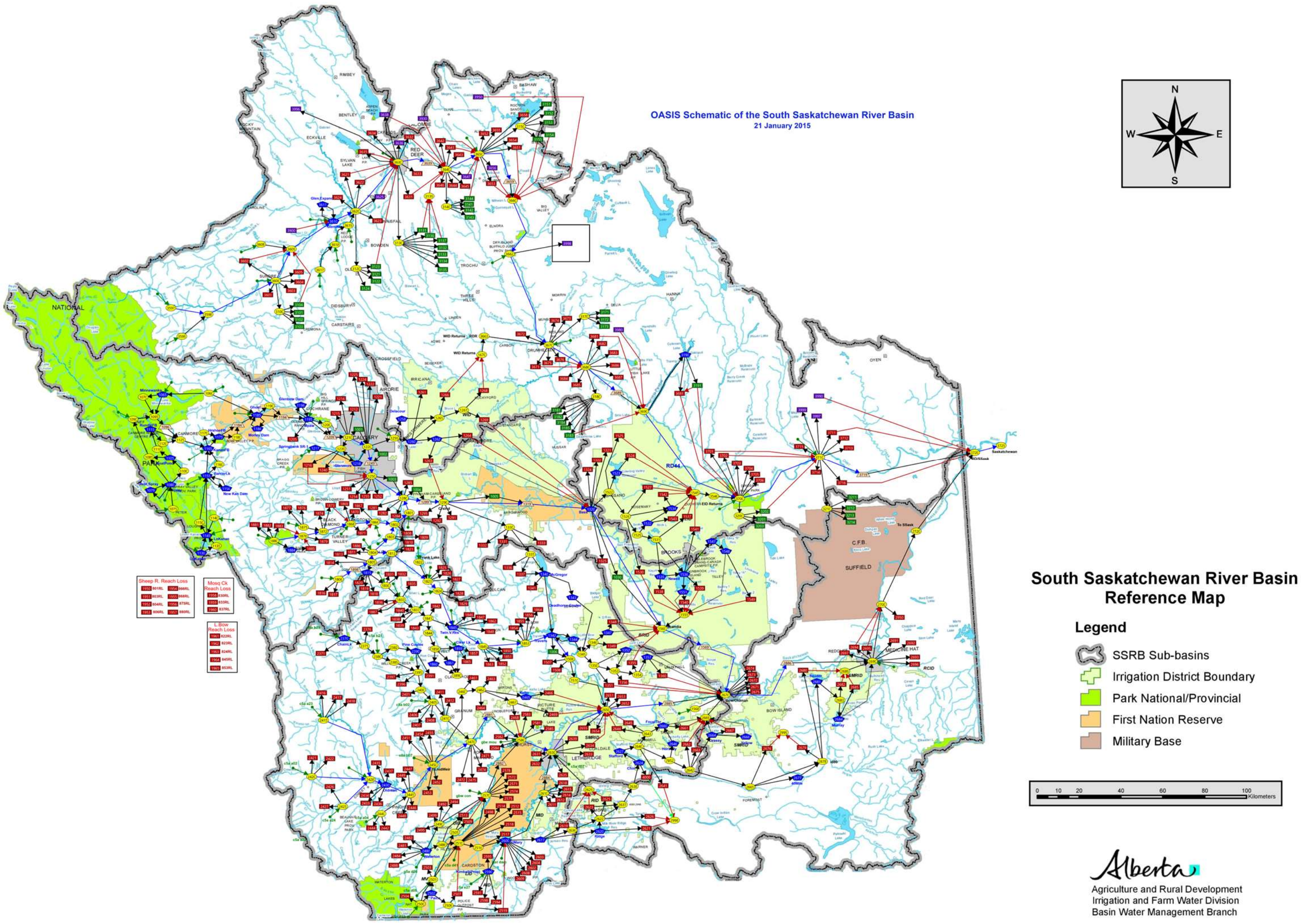


Figure 1. SSROM Schematic – including the Red Deer River, Bow River, and Oldman and South Saskatchewan River Basins.

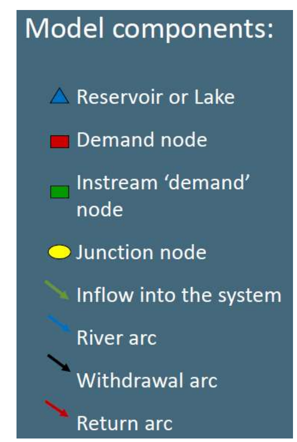


Figure 2. SSROM components.

Importantly, the SSROM attempts to represent the SSRB as it operates today; this is referred to as the modelling Base Case. Within the SSROM, and the Base Case, there are several important minimum flows that are representative of system operations. A summary of minimum flows is shown in Figure 3. Minimum flows for each sub-basin are discussed in more detail in the context of basin operations in Section 2.3.

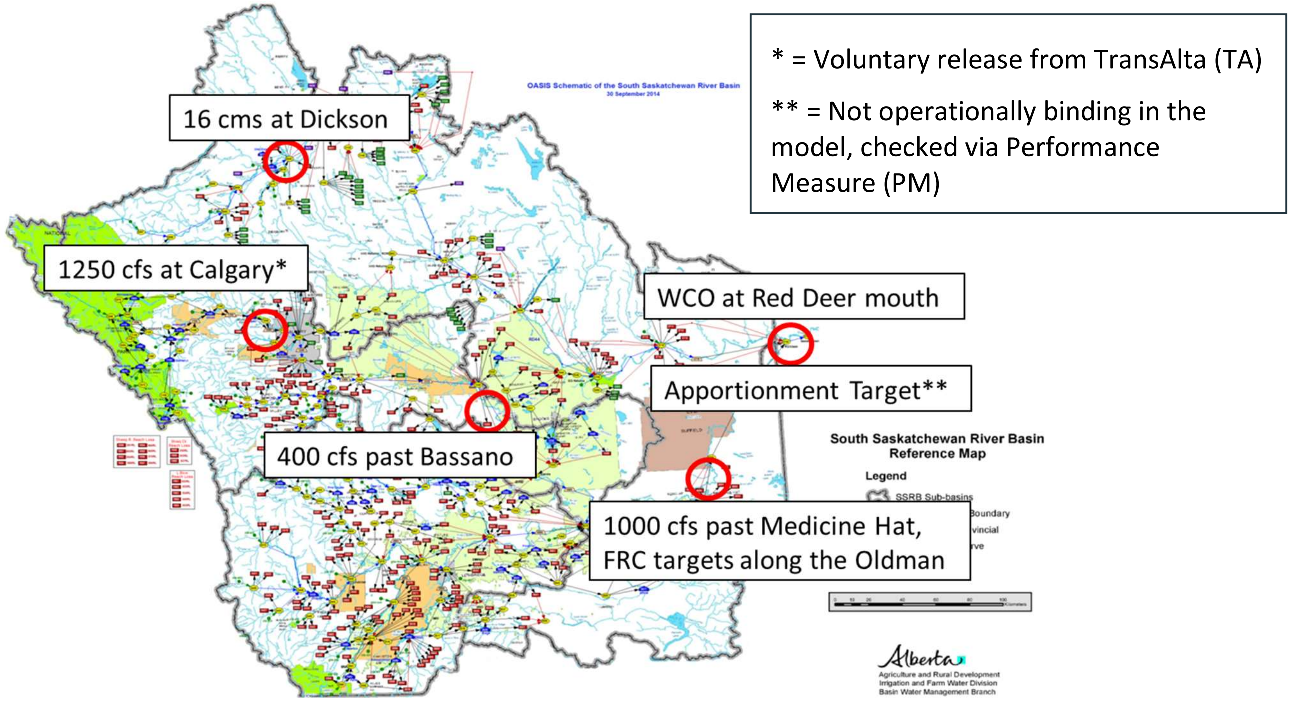


Figure 3. Summary of key minimum flows on main river stems of the SSRB built into the SSROM.

2.2 SSROM Data

The SSROM integrates several datasets that form the foundation of the model and allow accurate representation of the SSRB as it operates today. These datasets include naturalized flows, evaporation and precipitation[1], licensed allocation for the entire system or consumptive use (in some cases actual use numbers were provided by users), return flows, and physical data for diversions and reservoirs with associated operations. For discussion, these can be broadly categorized into water supply data, water demand data, and return flow data.

Obtaining the most recent supply, demand, and return data was a key goal of this project. Updated datasets were obtained from government departments and municipalities, including AEP, AAFRED, the

[1] Reservoir net evaporation records were not updated as part of this project, merely carried over from prior work. As such, refer to the South Saskatchewan River Basin Adaptation to Climate Variability Project Phase 1-3 reports for details on data and methodology.

City of Calgary, the City of Lethbridge, and the Alberta Energy Regulator (AER).

An updated naturalized flow dataset provided by AEP extends the historical inflow data, which previously included 1928 to 2009, to include 2010 to 2015. Integration of the naturalized flow dataset is discussed in more detail in Section 2.2.1.

Actual municipal use data was provided by the City of Calgary and the City of Lethbridge; these data reflect municipal growth and efficiency gains in municipal water infrastructure. AEP provided updates to surface water demands for the whole SSRB; the integration of these demands and return flows is discussed in Section 2.2.2.

AAFRED provided updated Irrigation Demand Model (IDM) data indicating irrigation demands based on infrastructure, crops, and irrigated acres in the 2018 irrigation year. This data captured improvements in irrigation district efficiencies and contained representative crop mixes for each irrigation district. Section 2.2.2.1 contains a discussion of IDM data and assumptions.

A comprehensive review of model demands and operations was achieved through the subgroup meetings with GoA and irrigation district representatives (Section 1.1). As a result of this review changes to demands, return flows, and operations were recorded, and the model was updated. The following operational updates were identified by participants and were not integrated into the model; these updates have been noted as potential future modelling opportunities:

- Update the City of Red Deer water demands with actual use data – most licences in the Red Deer Basin were modelled with full licence allocation. It was decided that the City of Red Deer would remain modelled at full allocation for consistency. Although this greatly overestimates actual use in the Red Deer system, stakeholders indicated to the project team that for the “base case” model in SSROM they would prefer to assume full use in all circumstances. This is in line with other assumptions in the Red Deer basin, where most users are assigned full license volume in their diversions.
- Update operations on the Sheerness and Deadfish diversions – Sheerness and Deadfish diversions were modeled based on the available data provided by AAFRED from the IDM (in the case of irrigation) or AEP from the WRMM (for non-irrigation use). Due to difficulties in disaggregating the IDM irrigation data from the WRMM blocks, some upstream users may also be lumped in with the diversion users. Without easy access to the required information, this was deemed sufficient for this effort as total river withdrawal volume is consistent with both WRMM (non-irrigation use) and IDM (irrigation volume). In SSROM the diversion capacity from the Red Deer is never binding. WaterSMART is continuing to follow up with AEP operations to further clarify Sheerness and Deadfish operations and this will need to be furthered on future updates.

Sections 2.2.1 and 2.2.2 describe data updates that have been applied across the SSROM in further detail; Sections 2.3.1 to 2.3.3 describe operational changes in the Red Deer, Bow and Oldman South Saskatchewan River Basins (including the southern tributaries). A full list of updates identified by the Working Group, including updates made under the scope of this project as well as potential future updates, is provided in Appendix E.

2.2.1 Water supply data – naturalized flow data

Naturalized streamflow data for the inflow nodes were obtained from AEP for the 2010 to 2015 period. The process for deriving inflow data from the naturalized dataset involved the following four steps (each of these steps is described in greater detail in the subsequent text).

1. Mapping the naturalized data gauges to the inflow nodes in the OASIS model (see Figure 4 to Figure 6).
2. Applying a spatial disaggregation factor to sites that did not map to a naturalized streamflow gauge (red circles in Figure 4 to Figure 6).
3. Calculating incremental flow.
4. Downscaling the weekly streamflow to daily time-step.

Naturalized gauges were mapped to the existing inflow nodes in the SSROM (Figure 4 to Figure 6); for sites without a naturalized gauge (shown in red), multipliers were derived to account for changes in watershed area relative to naturalized gauge locations. This approach allowed the naturalized hydrographs to be conserved from upstream to downstream. Watershed area multipliers were derived using the 1928 to 2009 inflow data from SSROM, where annual average inflows were used to reflect average runoff contribution as a function of watershed area. Time of travel and lags between major reaches were calculated within the SSROM and not the inflow data. The sum of inflows from nodes upstream of a given node were used to calculate total flow contribution to the farthest downstream node. The 1928 to 2009 average annual inflow to the downstream node was divided by the sum of upstream nodes to derive the multiplier for each node (Table 1). This allowed naturalized data to be synthesized for absent sites by portioning out a percentage of the reported natural flow to the new site.

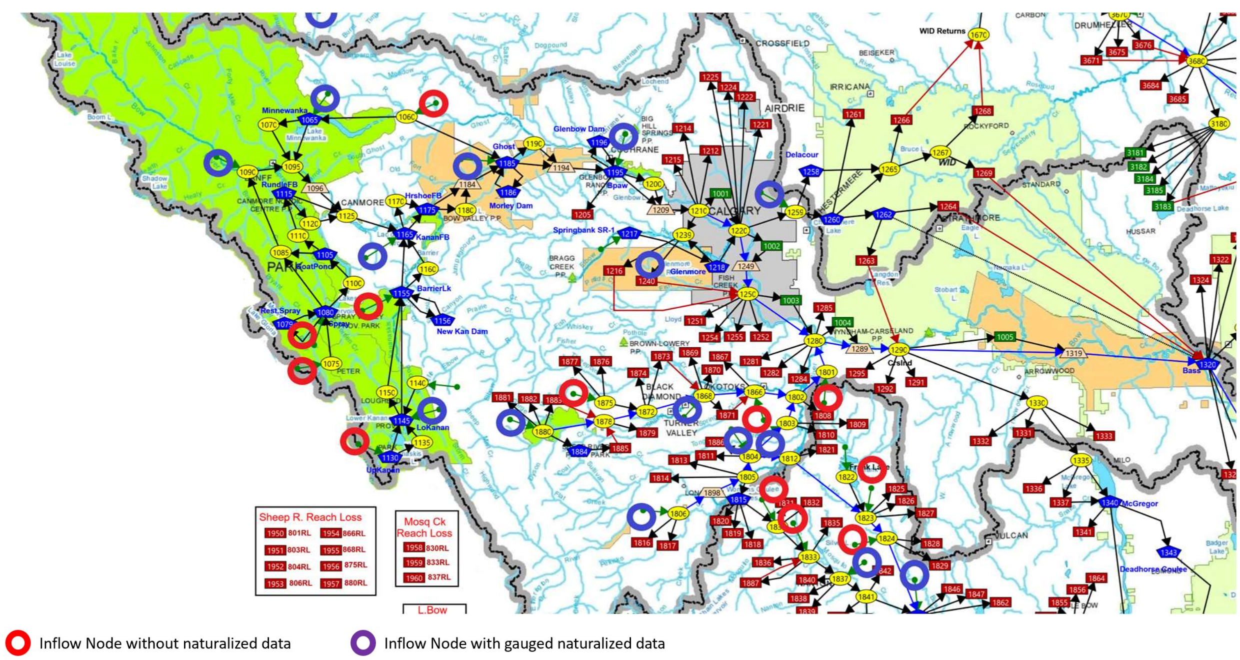
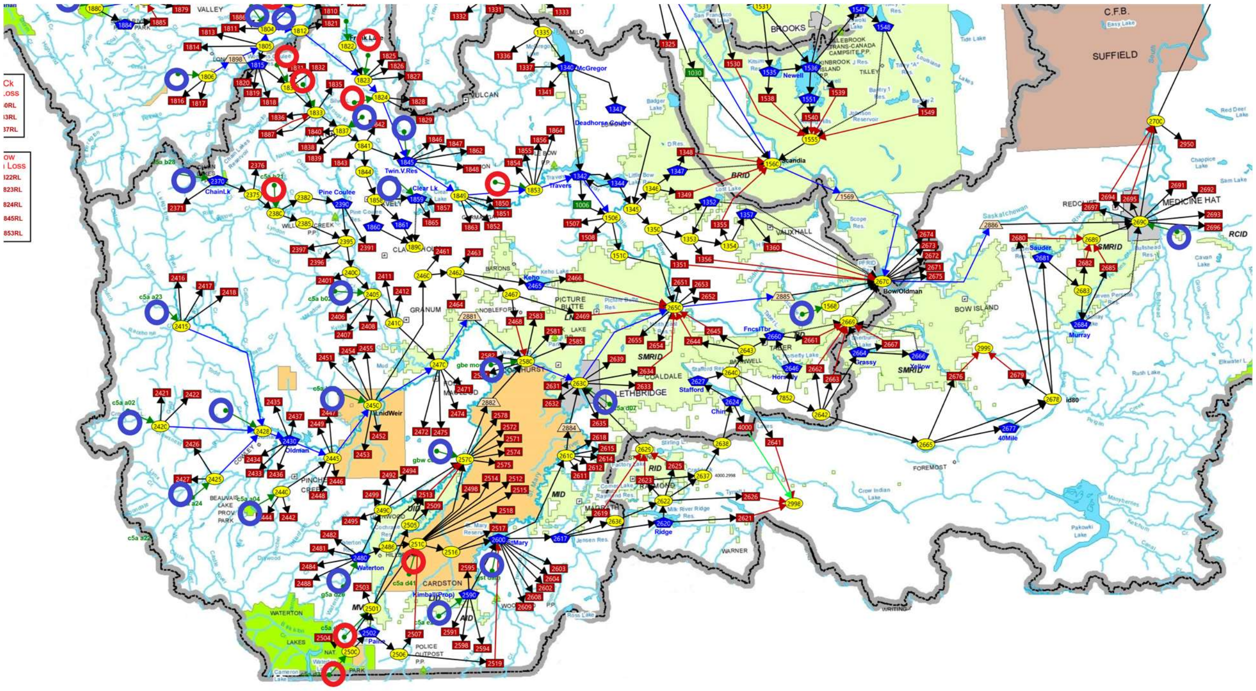
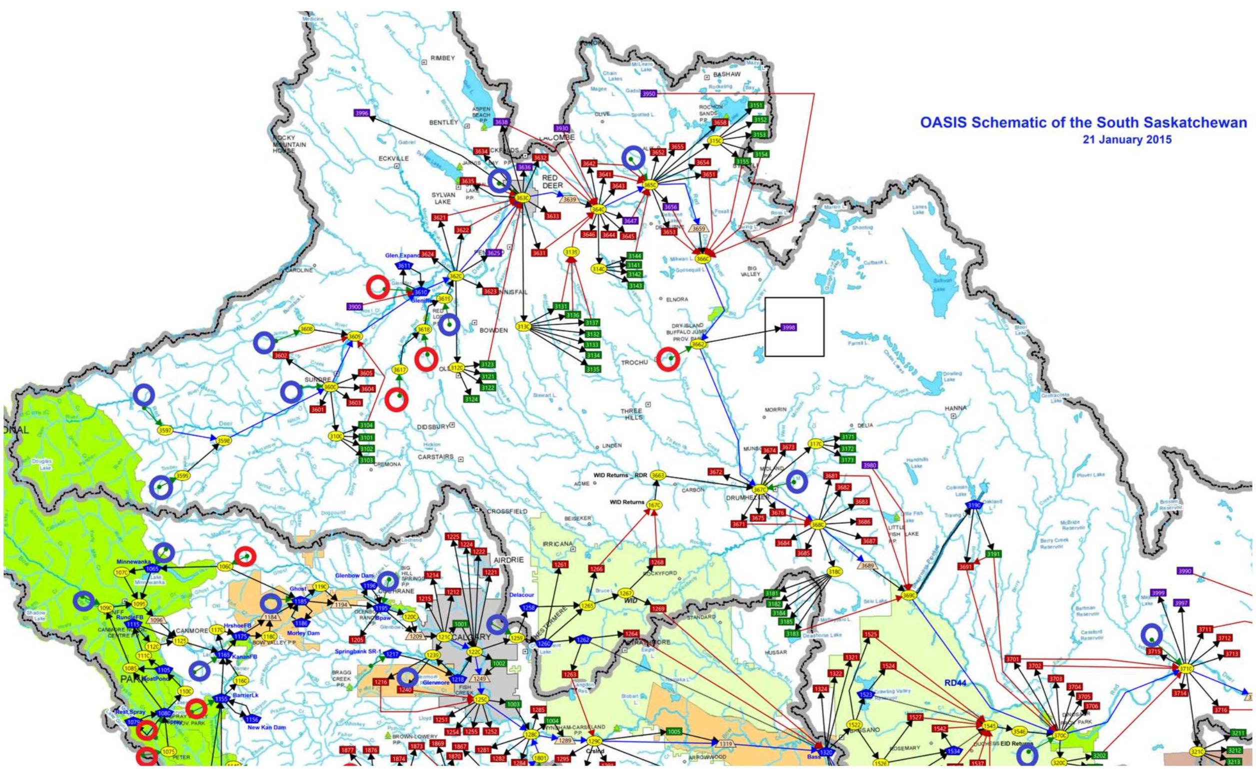


Figure 4. SSROM schematic with Bow River Basin naturalized gauged and ungauged sites.



Inflow Node without naturalized data   Inflow Node with gauged naturalized data

Figure 5. SSROM schematic with Oldman River Basin naturalized gauged and ungauged sites.



Inflow Node without naturalized data   Inflow Node with gauged naturalized data

Figure 6. Red Deer River Basin schematic with Bow Sub-basin naturalized gauged and ungauged sites.

Table 1. Spatial disaggregation multiplier summary.

Ungauged naturalized	OASIS Inflow Node Location Name	Naturalized data (gauged)	Applied multiplier	WSC ID/ ESRD ID
Red Deer River Basin				
3617	SalterCk	Little Red Deer River near the mouth	0.11	05CB001
3618	Harmattan	Little Red Deer River near the mouth	0.77	05CB001
3610	Glennifer	Red Deer River near Sundre	0.027	05CA001
3662	Id2	Red Deer River at Drumheller	0.143	05CE001
Oldman River Basin				
1830	Wom.Coulee.MosqCk	Mosquito Creek near the mouth	1.99	05AC031
1833	Mosq.Ck@Nanton	Mosquito Creek mouth near the mouth	0.4	05AC031
1822	Frank Lake	Little Bow River near the mouth	0.44	05AC023
1823	L.Bow	Little Bow River near the mouth	0.18	05AC023
1824	L.Bow1	Little Bow River near the mouth	0.39	05AC023
1853	LBow u/s Travers	Little Bow River near the mouth	0.86	05AC023

Ungauged naturalized	OASIS Inflow Node Location Name	Naturalized data (gauged)	Applied multiplier	WSC ID/ ESRD ID
2380	Div Pond	Willow Creek above Chain Lakes	2.52	05AB028
2500	Id40	Waterton River near Waterton National Park	0.3	05AD003
2501	Id41	Waterton River near Waterton National Park	0.27	05AD003
2510	Id42	Waterton River near Waterton National Park	0.058	05AD003
Bow River Basin				
1075	SDDiv	Bow River at Banff	0.036	05BB001
1080	Spray	Bow River at Banff	0.37	05BB001
1130	UpKanan	Kananaskis River above Pocaterra Creek	0.600	05BF003
1140	KentCrDiv	Bow River near Seebe	0.095	05BE004
1155	BarrierLk	Kananaskis River above Pocaterra Creek	0.7	05BF003
1060	GhostR	Ghost River near Cochrane	0.43	05BG001
1801	Inflow of C5BL24	Sheep River at the mouth	0.409	GSHMOU

Ungauged naturalized	OASIS Inflow Node Location Name	Naturalized data (gauged)	Applied multiplier	WSC ID/ ESRD ID
1866	Lic. Blw Otoktoks & Oktokes rtns	Sheep River at Okotoks	1.127	05BL012
1875	Threepoint Creek	Sheep River at the mouth	0.409	GSHMOU

Incremental inflow at each inflow node was calculated by subtracting its total flow from the sum of flows upstream, where headwater sites were the first increment. The incremental inflow data were temporally disaggregated to a daily time-step. A mean weekly-to-daily ratio was calculated using historical Water Survey of Canada (WSC) gauges (Table 2), where the average daily streamflow values were divided by the average weekly values for each WSC gauge. This same method was applied to the 1928 to 2009 data in the previous version of the SSROM. The WSC gauges were selected based on available data and spatial proximity to the naturalized gauges. In most cases, naturalized gauges were matched with WSC gauges. The final inflow time series from 2010 to 2015 was merged with the original 1928 to 2009 time series in the SSROM for a contiguous dataset from 1928 to 2015, inclusive. Previous methodologies used to simulate the daily flows for the 1928-2009 time series are provided in Red Deer River Basin, Bow River Basin and Oldman-South Saskatchewan (OSSK) River Basins reports (Alberta WaterSMART, 2015) (Alberta WaterSMART, 2010) (Alberta WaterSMART, 2014).

Table 2. WSC gauges used for temporal downscaling.

WSC station	SSROM node
Bow River near Seebe	1065
Cascade River near Banff	1075, 1080, 1090, 1155, 1130, 1145, 1165, 1060, 1185, 1065, 1140
Elbow River at Sarcee Bridge	1218
Bow River at Calgary	1259, 1195
Little Bow River at Carmangay	1822, 1830, 1833, 1823, 1824, 1837, 1845, 1853
Sheep River at Okotoks	1801, 1880, 1875, 1868, 1866, 1806, 1804, 1803
Waterton River near Waterton National Park	2480, 2510, 2500, 2501, 2570
St. Mary River at international boundary	2600, 2590
Willow Creek at Claresholm	2370, 2380, 2405

WSC station	SSROM node
Oldman River at Lethbridge	2415, 2420, 2428, 2450, 2580, 2630
Oldman River near Brocket	2440, 2425, 1568
Red Deer River at Red Deer	3597, 3599, 3600, 3597, 3667, 3608, 3630, 3650
Red Deer River near Bindloss	3662, 3670, 3700, 3710
Little Red Deer River near the mouth	3617, 3618, 3619

2.2.2 Water demand and return flow data

2.2.2.1 Irrigation demands and return flows

Irrigation demands in the SSROM are based on the IDM, which is managed by AAFRED. The IDM is a modeling application designed to simulate a complete irrigation project. The model calculates water required by on-farm demands and district demands given historical growing season weather conditions. On-farm demands include crop water needs and water losses due to on-farm systems, deep percolation, and runoff. District demands include base flow (return flow) and losses due to seepage and evaporation from canals and reservoirs. Note that in the IDM, irrigation water demands represent 90% of the ideal agricultural water supply.

AAFRED provided data from the 2018 IDM analysis; the data laid out irrigation water demands across the SSRB based on 2018 crop mixes, infrastructure, and irrigated acreages (2018 crop mixes and irrigated acreages are provided in Appendix C).

The IDM reports demand data in weekly time-steps for blocks of irrigated acres; Figure 7 shows an example of the IDM blocks within irrigation districts. To import these data into the SSROM, the IDM data were converted into daily data as a flat time-step conversion, the SSROM maintains the irrigation block system applied by the IDM.

The IDM calculates both consumptive use and return flows for the irrigation blocks. In the SSROM the returns are added to consumptive use to calculate desired diversion, return flows are routed back to the appropriate river at their approximate downstream location.

The IDM data also accounts for canal seepage and evaporative losses; these are therefore implicitly accounted for in the SSROM. IDM data integrated into the model can be found as timeseries, labeled by block as “Block###/irrigate” and “Block###/return.”

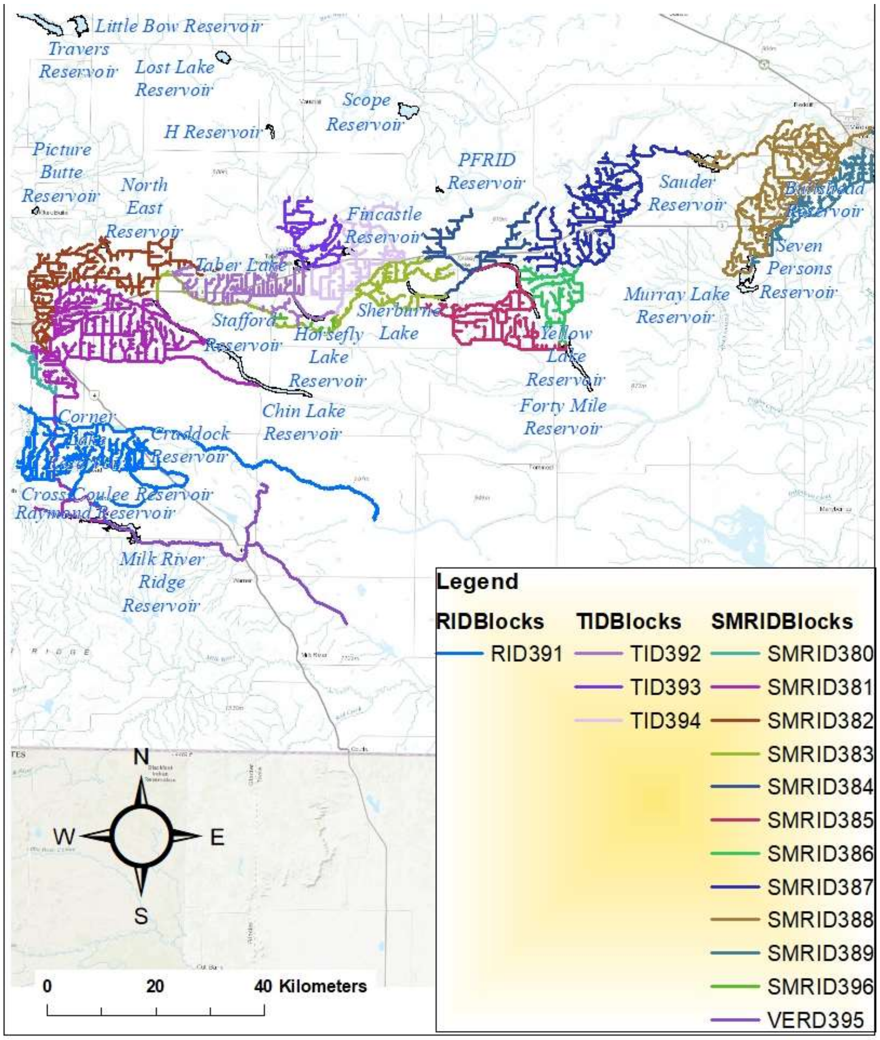


Figure 7. Example of the IDM blocks with irrigation districts – WRMM block area for Raymond Irrigation District (RID), St. Mary's River Irrigation District (SMRID), and Taber Irrigation District (TID). (Image provided by AAFRED, 2022)

2.2.2.2 Large municipal demands

To the extent possible, the SSROM attempts to model the SSRB as it is actually operated. It is well documented that the large municipalities in this system withdraw less than their full licence allocations on an annual basis. The difference between full allocated volume and actual use volume, even though it is technically "allocated," could serve other purposes within the SSRB, when available (e.g., environmental and recreational purposes). To allow for scenarios where these other purposes can be considered, large municipalities are represented as annual repeating patterns based on the most recent data made available by the municipalities. Return flows from these municipalities are similarly represented as monthly patterns of percent diversion returned to the system. Notably, the City of Red Deer is maintained at full licence capacity in the current Base Case.

Municipal demands and return flows for the City of Lethbridge as modelled in the SSROM are seen in Figure 8 and Figure 9. Demands are represented as a daily average over the past five years and include demands distributed regionally such as Coalhurst and Agropure. Return flows are represented as percentages of demands; note that not all regional distribution systems return water through the City of Lethbridge.

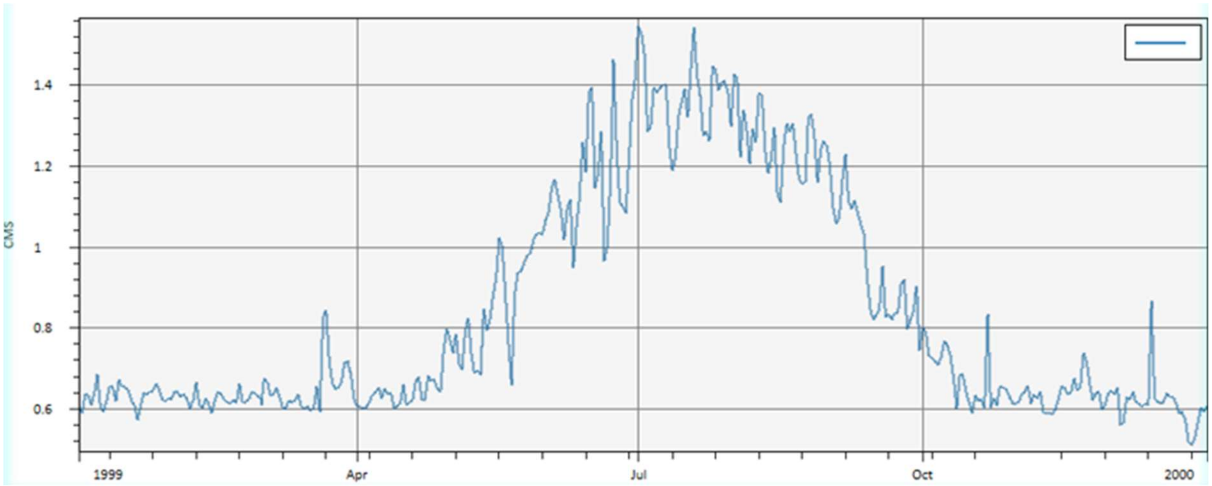


Figure 8. City of Lethbridge municipal demand.

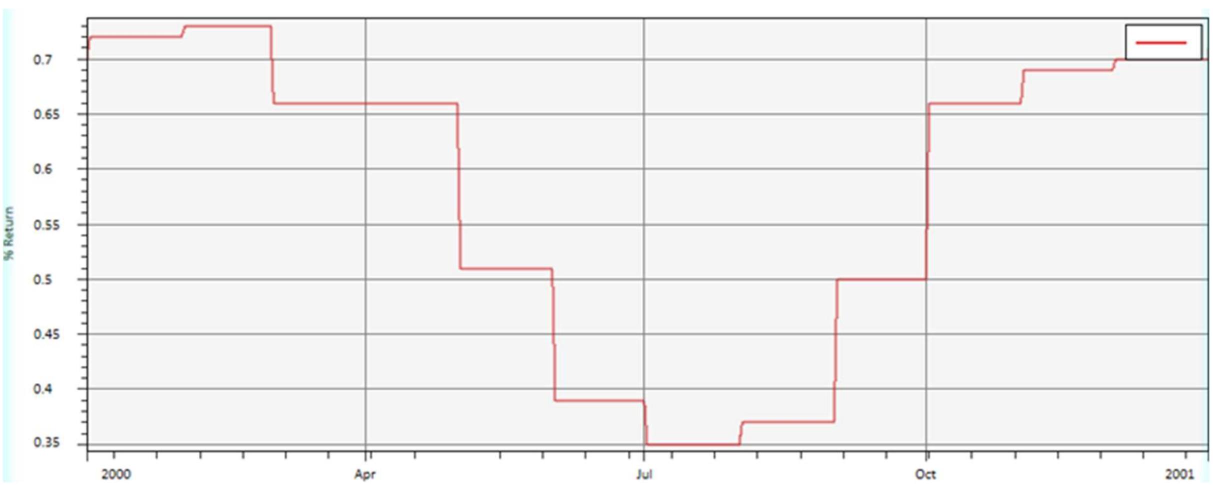


Figure 9. City of Lethbridge return flow.

The City of Calgary demand patterns for the Bearspaw and Glenmore water treatment plants as modelled in the SSROM can be seen in Figure 10 and Figure 11. In the SSROM the City of Calgary returns are fixed at 80% of demand.

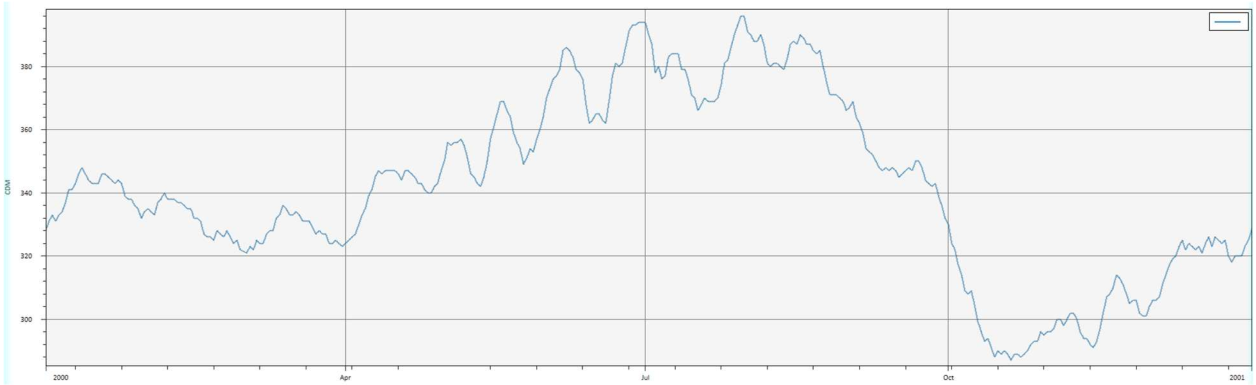


Figure 10. Calgary Bearspaw water treatment plant municipal demand

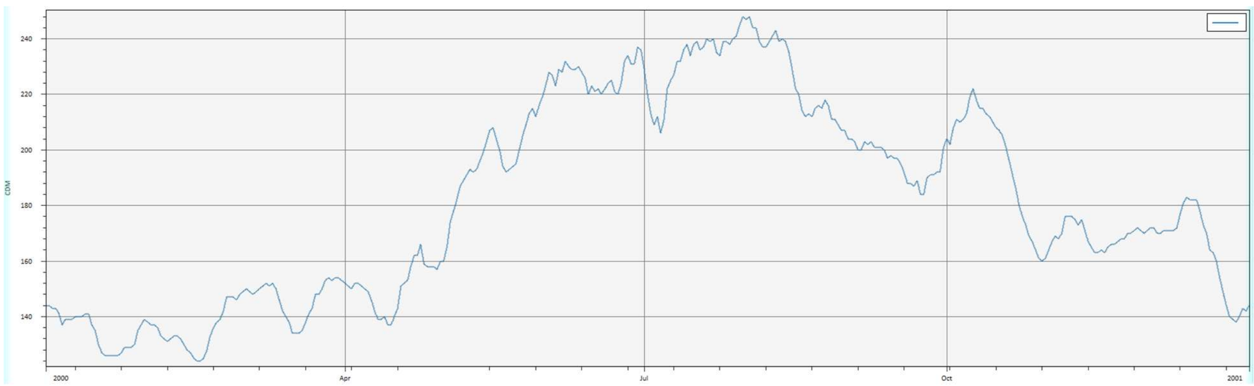


Figure 11. Calgary's Glenmore water treatment plant municipal demand

2.2.2.3 Remaining non-irrigation demands

The remaining non-irrigation demands in the SSRB are represented as repeating weekly patterns based on full licence allocation as provided by AEP; these demands have been fully updated in the SSROM to represent current demands. Licence groupings provided by AEP are shown in Appendix F. It should be noted that prior non-irrigation demands data may have been from before the Bow River and Oldman and South Saskatchewan River Basin closures; AEP is confident that the updated non-irrigation demand data is complete in respect to all known licences. The current data represents full licence allocation under an assumed pattern for these users.

The repeating patterns represent the demands of non-irrigation users and smaller municipalities as if they were at full licence allocation. Although this is a conservative estimate, the non-irrigation demands, and smaller municipalities demands represent a comparably small fraction of total use in the system. Each non-irrigation licence block is represented by a corresponding demand node in OASIS (except the large municipal users as described above, and any other exceptions referenced in Sections 2.3.1 to 2.3.3). Details regarding which licences are represented in each grouping block or demand group that can be found in Appendix F.

Non-irrigation data from the prior 2009 model relied on historical assumptions that were not well documented. In 2021 AEP began work on updating licence information and generously provided them for use in this project. As this new dataset is better documented, it has replaced the previous dataset in entirety (save for the Highwood system, where the datasets were additive per AEP's direction). A brief comparison of the differences between the two datasets is found below in Table 3.

2021 vs 2009 WRMM Datasets

Table 3. Difference in annual licensed volume by basin in between the 2021 and 2009 datasets. Results are relative to the 2009 original data. Due to the lack of knowledge of what assumptions and adjustments were made into the 2009 dataset, it is difficult to determine the accuracy of the values presented below. It is important to note that past non-irrigation demands data may have been from before the Bow River and Oldman and South Saskatchewan River Basin closures, that may influence the differences between the two datasets (see Section 2.2.2.3).

Basin	Dataset Differential (annual dam^3)	2009 Dataset (annual dam^3)	2021 Dataset (annual dam^3)
Bow	-13	63089.3	63076.6
Highwood	+12,037	91.8	12128.3
Red Deer	-8,599	29355.7	21527.0
Oldman	-8,994	38170.7	29176.7
Southern Tributaries	+15,776	9778.3	25554.5
South Saskatchewan	+6,622	33428.2	40050.1
(Oldman, STribs, & SSask)	+13,404	81377.2	94781.3
TOTAL	+16,829	176909.8	192157.9

2.3 System Operations

2.3.1 Red Deer River Basin

In the SSROM the Red Deer Basin covers the area beginning at Vam Creek and extends to the mouth and confluence with the Saskatchewan River. A few smaller streams are represented in the model, including Fallen Timber Creek and Little Red Deer River. The interactions between the Red Deer Basin and the Bow Basin are discussed in Section 2.3.4.

This section describes model operations within the SSROM specific to the Red Deer River Basin, laying out reservoir operations, shortage distribution, and target and minimum flows. The original Red Deer River Basin report (Alberta WaterSMART, 2015) can be referenced for full Red Deer River Basin operations.

2.3.1.1 Reservoirs

The Red Deer River has only one substantial source of available storage in the system: Gleniffer Reservoir, upstream of the City of Red Deer (note that Buffalo Lake is treated as a demand; details regarding Buffalo Lake are in the Red Deer River Basin report (Alberta WaterSMART, 2015)). The Gleniffer Reservoir is not operated for traditional water supply; storage in the Red Deer River Basin is primarily operated to maintain the Water Conservation Objectives (WCOs) in the system. This means that the Gleniffer Reservoir generally stores water in the spring, summer and fall, with the intention of releasing water over the winter and maintaining a WCO minimum release of 16 m^3/s (for additional detail regarding the WCO see Section 2.3.1.3). Figure 12 shows target releases from the Gleniffer Reservoir. Reservoir operations are also provided in Appendix D. The Sheerness Reservoir, added as part of the 2022 update, is modeled as simple "bathtub" containing 18,000 dam^3 of storage used to meet the licenses at that portion of the river.

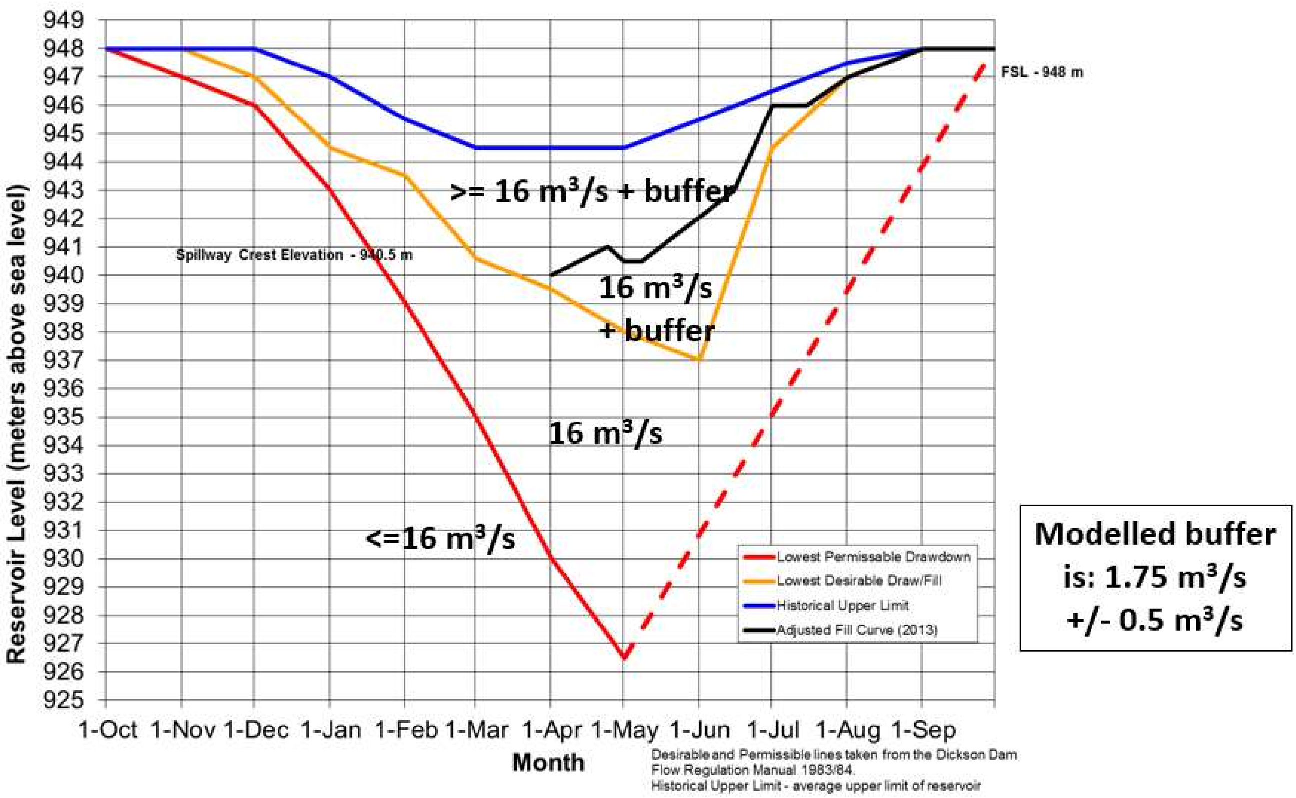


Figure 12. Targeted release from Dickson Dam based on storage condition.

2.3.1.2 Shortage distribution (licence priority)

As the Red Deer River Basin remains open to new allocations, use in this system is predicted by senior licence priority than the closed, southern basins. As there remains room in the Red Deer Basin for expansion, the informal agreements that take place in the closed, southern basins have not yet occurred in the Red Deer River Basin. As official senior licence priority is relied upon in the Red Deer Basin, approximately 72.5% of licences by volume were added directly to the SSROM (with use broken down by official licence dates). The remaining 27.5% of volume consisted of too many licences to remain in scope and were thus left in the rough demand groups that the original WRMM maintained. In past collaborative settings, stakeholders from the Red Deer Basin decided to generally consider operations in the context of full licence allocation. This context is maintained in the SSROM Base Case. Where these individual licenses were added, their volume was subtracted from their representative WRMM non-irrigation node to maintain an equivalent total system volume of demand.

In the SSROM water in the Red Deer Basin is provided as follows:

1. Senior Irrigators (identified by and remaining in WRMM blocks).
2. Major Demands (identified by and remaining in WRMM blocks).
3. Senior Licences (by licence date priority, pre- 17-Apr-1982).
4. Mid-Licence Irrigators (identified by and remaining in WRMM blocks).
5. Junior Licences (by licence date priority, post- 17-Apr-1982).
6. Junior Irrigators (identified by and remaining in WRMM blocks).
7. Minor Demands (identified by and remaining in WRMM blocks).
8. New licences (post-2009).
9. Temporary Diversion Licences (TDLs).

Details regarding the breakdown of licence priorities and the list of the licences modeled individually is available in Red Deer River Basin report (Alberta WaterSMART, 2015).

2.3.1.3 Target and minimum flows

The WCO in the Red Deer Basin, established in 2005 as part of the SSRB Water Management Plan, represents the major driver for minimum flows. From the Dickson Dam to the confluence with the Blindman River, the WCO is established as 45% of the natural flow rate or 16 m^3/s, whichever is greater at any point in time. From the Blindman River to the Saskatchewan border, the WCO is 45% of the natural flow rate or 16 m^3/s in the winter (November 1 to March 31) and 45% of the natural flow rate or 10 m^3/s in the summer (April 1 to October 31). Where licenses were retrofit, the summer WCO is applied year-round. These WCOs apply only to licences issued after May 1, 2005. For licences issued prior to May 1, 2005, the minimum flow applied is the older instream objective (IO) of 4.25 m^3/s for industrial demands or 8.5 m^3/s for non-industrial demands. Figure 13 shows minimum flows in the Red Deer River Basin.

Some tributary and in-stream objectives were not captured in the SSROM due to the increased modelling effort needed to pursue precise licence allocation of the Red Deer River basin. This could be provided in future work.

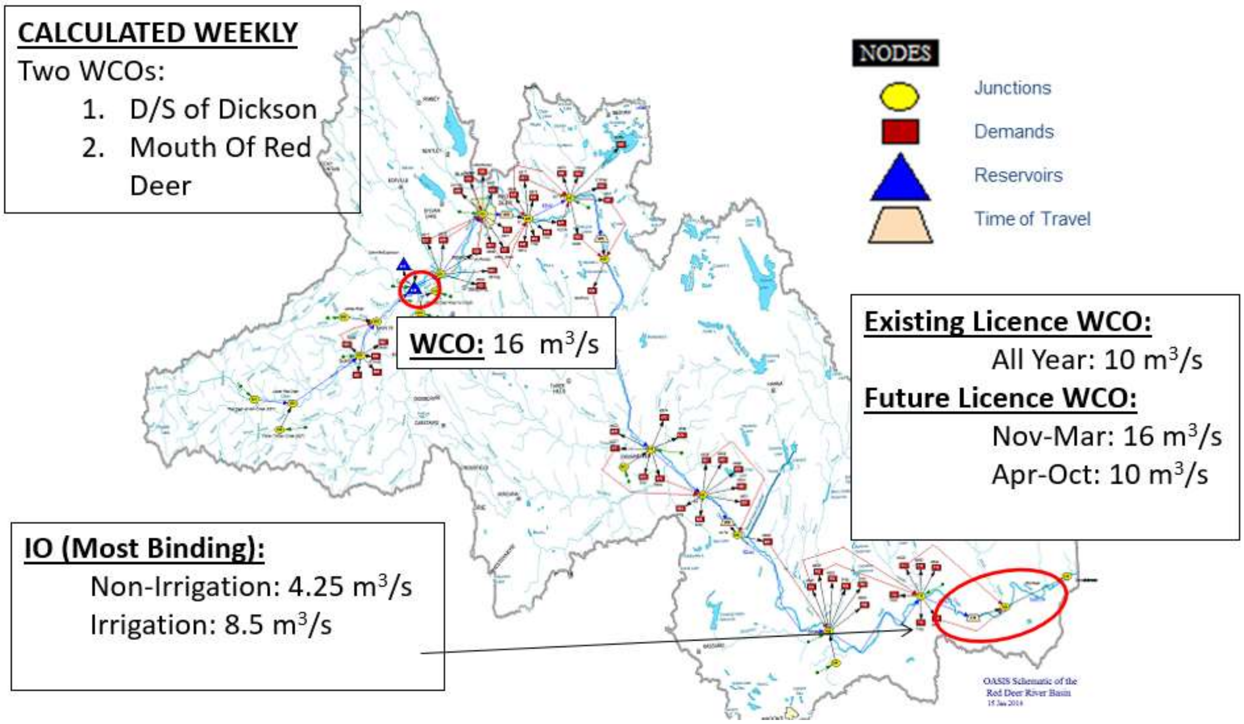


Figure 13. Minimum flow targets in the Red Deer River Basin.

2.3.1.4 Noteworthy water demand updates

As noted, the Red Deer River Basin is the only basin in the SSRB that is not closed to new applications for water licences; therefore, large licences that have been issued within the basin since the original Red Deer Model in 2015 have been updated in the SSROM. AEP provided updated non-irrigation licences with assumed demand pattern and AAFRED provided irrigation demands in the Red Deer River Basin, including historical annual TDLs. Based on this data the SSROM includes major recent licences added in the Red Deer River Basin, including the large Vesta Energy Ltd. licence of 5,120 dam^3/year. The assumptions for TDLs have also been updated based on data from 2017 to 2021; the TDLs above the City of Red Deer are estimated at 35.25 dam^3/day (12,865 dam^3/year) while TDLs below the City are estimated at 25.19 dam^3/day (9,913 dam^3/year). Based on stakeholder feedback, the Sheerness Reservoir (mentioned briefly in Section 2.3.1.1) has been added to the model and the demands reliant upon the diversion (which were formerly located at an on-stream node) have been shifted to reflect their ability to access reservoir storage in addition to diversion flows. This results in a slight over-estimation of demand on the Sheerness Reservoir as the river and reservoir demands were not easily separated at the time of this project. Additionally, note that the Deadfish diversion is rolled into the existing license blocks rather than being modeled independently because of the datasets available at the time of the update.

2.3.2 Bow River Basin

The Bow River Basin portion of the SSROM simulates current operations of facilities on, and withdrawals from, the Bow, Elbow, Highwood, and Sheep rivers from the headwaters to the confluence with the Oldman River, including major off-stream canals and storage reservoirs.

This section describes model operations within the SSROM specific to the Bow River Basin, laying out reservoir operations, shortage distribution, and target and minimum flows. The original Bow River Basin report (Alberta WaterSMART, 2010) can be referenced for full Bow River Basin operations.

2.3.2.1 Reservoirs

Most of the upstream storage in the Bow River is maintained within reservoirs operated by TransAlta, primarily for hydropower production. TransAlta has no legal requirement to utilize storage for purposes other than its own. Thus, when senior users call on their licences, they can at most call for natural inflows to pass through these reservoirs. TransAlta storage reservoirs are represented in the SSROM as following a normal pattern that represents average reservoir elevations over the 2012 to 2020 period in the case of Minnewanka, Spray, and Upper Kananaskis reservoirs or the 2015 to 2020 period in the case of Lower Kananaskis, Barrier, and Ghost reservoirs. The reservoirs represented using average elevations from 2015 to 2020 use the shorter period because the 2015 agreement (Government of Alberta, 2015) between TransAlta and the GoA led to a measurable re-shaping of their typical storage elevations. These normal patterns roughly replicate the operations of TransAlta reservoirs in terms of the estimated outflows above minimum. Figure 14 shows an example of the normal pattern for the Ghost Reservoir. In this figure, an operational shift can be seen starting January 1, 2015; the pattern after January 1, 2015, is what is reflected in the SSROM (seen in Figure 15). The full set of Normal Patterns are available in Appendix D (Figure 40 to Figure 51 and can also be found in the SSROM as "Pattern/[ReservoirName]_Normal."

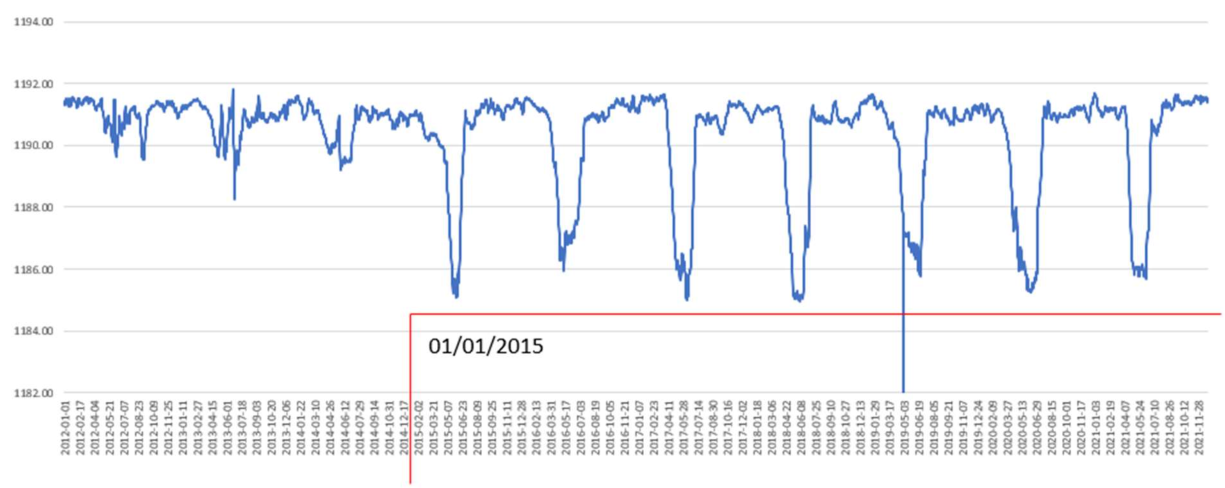


Figure 14. Example TransAlta reservoir normal pattern shown for Ghost Reservoir.

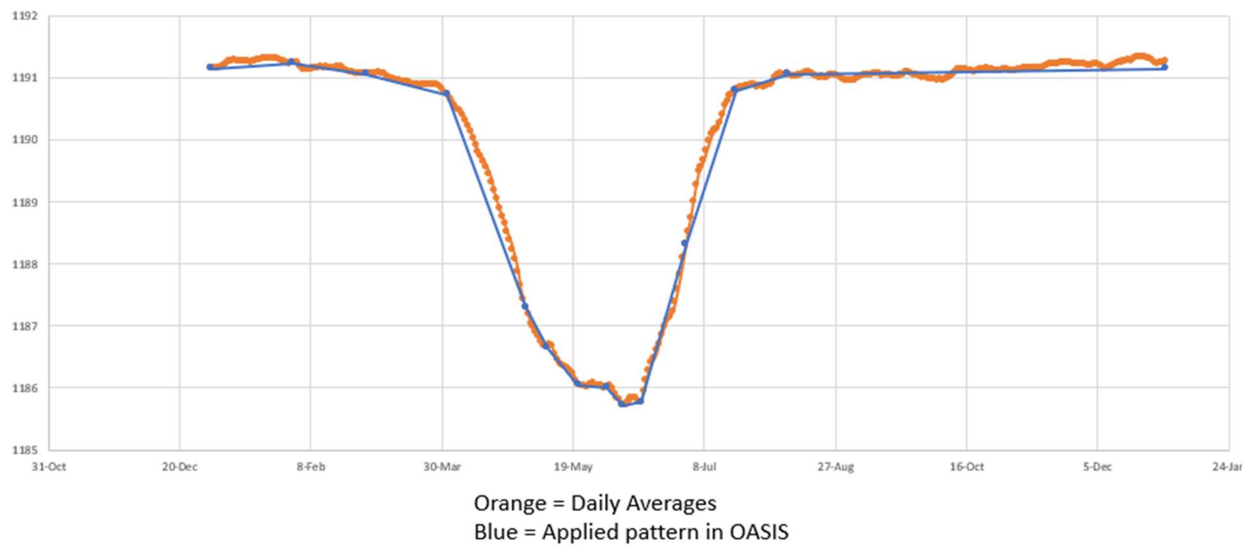


Figure 15. Ghost Reservoir daily historical average elevations and the resultant derived "normal pattern".

The Glenmore Reservoir is fed by the Elbow River, which enters the Bow River downstream of the City of Calgary; the Glenmore Reservoir supplies water for the City of Calgary. Glenmore Reservoir operations are shown in Figure 52 in Appendix D. The Springbank Reservoir (SR-1) dry dam will also soon be located on the Elbow River, which is being built to reduce flooding in Calgary. SR-1 will not operate for storage; instead, it will capture flows exceeding 160 m^3/s and release water after the peak at a rate of natural flow plus 28 m^3/s. Although this reservoir does not currently exist, it has been added to the SSROM Base Case as it is currently under construction.

Irrigation storage (including Chestermere, Langdon, McGregor, Travers, Newell reservoirs, and others) are modeled in the SSROM according to direction from irrigation district managers. An example irrigation reservoir storage can be seen in Figure 16, which is the Newell Reservoir. An example of irrigation reservoir elevations for the McGregor Reservoir can be seen in Figure 17. These reservoirs are filled by licensed diversions from the Bow River and generally have few operational rules for flood management beyond maintaining voids over the year. They generally fill in the spring and draw down over the late spring and summer as far as needed based on crop demand. Diversion limitations based on the Western Irrigation District (WID), Bow River Irrigation District (BRID), and Eastern Irrigation District (EID) licences are respected. There are two notable exceptions to this. The first is Chestermere Reservoir in the WID, which is presumed to be functionally unavailable for storage due to community development around the reservoir that has evolved over many decades. The second is McGregor Reservoir in the BRID. BRID has withdrawals from McGregor Reservoir that are limited by the elevation of their infrastructure. In SSROM, the BRID withdraws from the McGregor Reservoir below this level as needed in drought conditions. All reservoir operations, as represented in the SSROM, can be found in Appendix D.

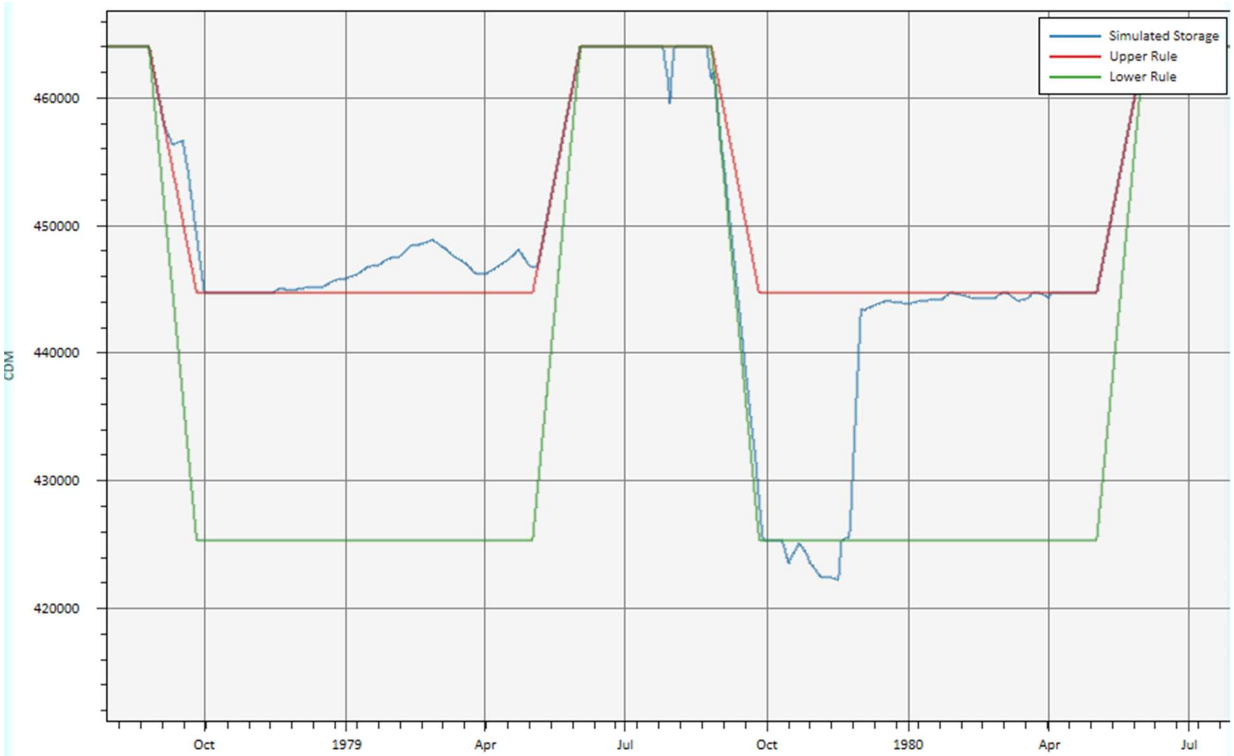


Figure 16. An example of irrigation storage in SSROM, Newell Reservoir storage. Reservoirs have an Upper and Lower Rule that they try to stay within but will withdraw as far as necessary to meet crop demand.

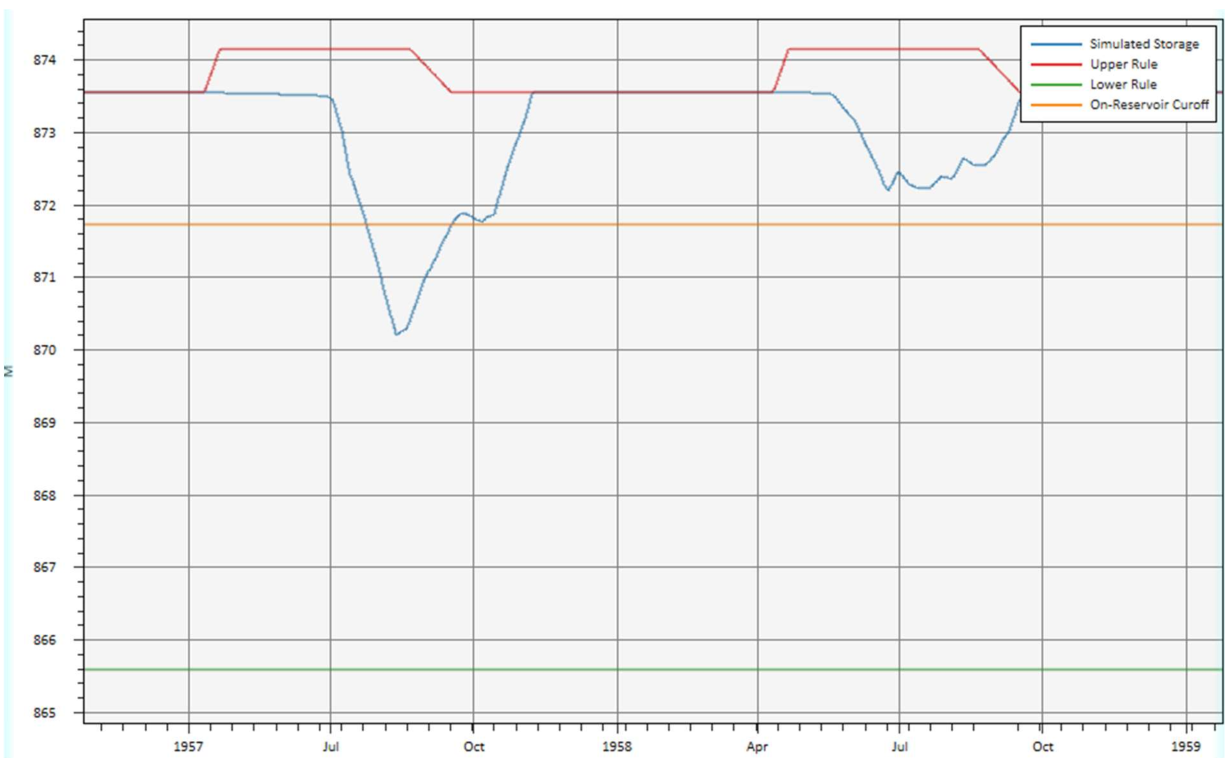


Figure 17. McGregor Reservoir key elevations, showing the on-reservoir cut-off level for irrigation and demonstrating that in SSROM the BRID will withdraw below that threshold if needed for downstream irrigation.

2.3.2.2 Shortage distribution (licence priority)

Based on conversations with the larger irrigation districts, it was determined that normally anthropocentric water uses are supplied first (that is, water would not be taken from municipal needs for crop watering in a severe circumstance) and that junior licences in the Bow River Basin are so small that it is not worth calling on them. For modelling purposes, this effectively re-orders licence priority in the Bow River Basin. To capture this, the SSROM delivers water as follows:

1. Junior licences (it was found that these licences are so small that the irrigation districts normally do not call on them).
2. Municipal demands (voluntary agreements already exist ensuring the primacy of anthropocentric use over agricultural).
3. Major irrigation districts (WID, BRID, EID– usually in that order).

Among the irrigation districts there is also a general recognition of the importance of demands that cannot be met by storage within their districts. Several EID demands, for example, are totally dependent on river flows with no access to storage. In the case that BRID has sufficient water for the headworks[2], it will allow extra water to flow to the EID and meet remaining BRID demands from storage. In the SSROM, under low flow circumstances, the irrigation districts divert the lesser of their licence or their river-dependent demands first. After these "protected demands" are met, the remaining river flow is divided up according to licence seniority; WID followed by BRID followed by EID that is dependent on senior of junior licences. Essentially, irrigation districts will not cause their neighbours to experience shortages while they preserve or refill storage.

Important to note is that the 2022 update assumes EID's use of its 1998 license conditions (Priority Number: 1998-07-13-002). It is understood that conditions under the 1998 licence are preferential to those of EID's previous licence (Priority Number: 1903-09-04-02) despite the previous licence's seniority. In general, the EID will call on their 1998 licence and will only call on their 1903 licence in drought conditions. If the EID does call on their 1903 licence, they must operate to the 1903 licence conditions for the remainder of the irrigation season. It is therefore understood that in normal operations EID will utilize their 1998 licence; the SSROM assumes this to always be the case. A switch to the 1903 licenses is considered an "exceptional operation" similar to a municipal drought response plan and is not considered part of the "base run" condition. Future work could explore possible implementation and implications of conditional triggers for licence switching, however.

Licence diversion permit conditions are determined by AEP according to the following logic:

- WID:
  - When river flow is equal to or below 155 m^3/s, the river is in LOW STAGE and the maximum diversion is 450 ft^3/s (12.743 m^3/s).

[2] The 300 ft^3/s carriage flows required to deliver water to the BRID headworks are considered to be part of that district's river-dependent demands.

  - When the river is between the above two values (i.e., between 155 and 300 m^3/s), the river is in HIGH STAGE and the maximum diversion is 600 ft^3/s (16.990 m^3/s).
  - When the river is equal to or above 300 m^3/s, it is termed to be in FLOOD STAGE and the maximum diversion is 750 ft^3/s (21.238 m^3/s).
- EID:
  - Divert up to 96.2 m^3/s (3,400 ft^3/s) from April 1 to May 31, inclusively, and July 26 to October 31, inclusively, in each year.
  - Divert up to 96.2 m^3/s (3,400 ft^3/s) from June 1 to July 25, inclusively, in each year, with a total diversion during the period of 679,000 acre-feet.
  - EID must maintain a minimum flow of 11.3m^3/s (400 ft^3/s) below the Bassano Dam at all times.
- BRID:
  - When the three-day average flow past Carseland is below 80 m^3/s (2825 ft^3/s) maximum diversion is 41.34 m^3/s (1,460 ft^3/s).[3]
  - At all other times maximum diversion is 51 m^3/s (1,800 ft^3/s).

2.3.2.3 Minimum Flows

Diversion limits notwithstanding, the primary minimum flows observed on the Bow River are at Bassano and Calgary. Per their licences, TransAlta is not required to release any water in excess of 350 ft^3/s continuous flow from the Ghost Reservoir and up to the natural flow at the Bearspaw Reservoir when and only when senior downstream licences are not being met. That said, TransAlta has historically maintained a minimum flow of approximately 1,250 ft^3/s from Bearspaw. As the SSROM attempts to model real-world operations rather than strictly legal obligations, the model assumes that TransAlta will continue to maintain 1,250 ft^3/s unless more is required per senior licences. The remaining minimum flow at Bassano of 400 ft^3/s is driven primarily by the limitations on withdrawal placed on EID.

Travers Reservoir in the BRID system is the sole remaining modeled minimum flow, with a required Little Bow release of at least 20 ft^3/s when incoming flows are below that threshold or the minimum of 12 ft^3/s or incoming flow at all other times.

2.3.3 Oldman South Saskatchewan River Basin

In the SSROM the Oldman and South Saskatchewan (OSSK) River Basins include all major tributaries, including the southern tributaries (the Belly, Waterton, and St. Mary rivers). This section describes model operations within the SSROM specific to the OSSK basins, laying out reservoir operations, shortage distribution, and target and minimum flows. The original OSSK River Basin report (Alberta WaterSMART, 2014) can be referenced for full OSSK operations.

[3] Although not technically a permit limit, this logic attempts to broadly capture the temperature limitations on the BRID licence. BRID's real-world license is limited to 1460 cfs when seven-day average temperature exceeds 18C or instantaneous temperature exceeds 22C.

One important intricacy in the OSSK basins is that this system is dependent on the cross-border flows from the United States on the St. Mary River. These flows are governed by international agreement and have historically been well above the minimum required pass-by flows. To aid in modeling possible future conditions, both a minimum entitlement and a historical inflow timeseries has been added to SSROM (these are found for nodes 2590 and 2600 as "timeseries/[node]/inflow-2022-Ent" and "timeseries/[node]/inflow-2022-Hist"). Entitlement flow is defined by the Boundary Water Treaty (1909) which establishes the terms and conditions under which Alberta and Montana share water. Alberta's water entitlement to the St. Mary River system was noted under this agreement and the subsequent 1921 International Joint Commission (IJC) Order. Alberta has historically received more water through the St. Mary River system than it was entitled to, because Montana lacks diversion and storage infrastructure to use their full entitlement. The base case assumes entitlement flows to ensure conservative estimates.

2.3.3.1 Reservoirs

In the Oldman River and the southern tributaries, there are two general classes of reservoirs: provincially managed water supply reservoirs and irrigation support reservoirs. The provincially managed water supply reservoirs include the Oldman, Waterton, and St. Mary reservoirs while the irrigation support reservoirs include those located within, and acting primarily in support of, irrigation districts. Although not called out individually, each of these reservoirs is operated to their upper rules to ensure proper flood protection is maintained in a given year. The SSROM models this by using a two-day perfect knowledge forecast (moderated by adding a 20% "noise" factor based on stakeholder agreement) that prevents the reservoirs from continuing to fill if flood risk exists.

Provincially Managed Water Supply Reservoirs

In the Oldman River Basin, the three largest reservoirs act to support all users in their respective areas. The St. Mary Reservoir primarily feeds the Magrath Irrigation District (MID), SMRID, TID (Taber Irrigation District), and RID (Raymond Irrigation District) irrigation diversion and other irrigation downstream to the mouth of the St. Mary River. It also maintains a minimum flow at the mouth to ensure compliance with the local Instream Objective (IO). Notably the St. Mary Reservoir's irrigation tunnel is substantially above the lowest outlet, leaving an additional 22,000 acre-feet for meeting the IO and downstream needs even if the diversion is no longer able to function. Figure 18 shows the St. Mary Reservoir elevation storage map. The simulated storage and rule curves implemented in SSROM are shown in Figure 75 in Appendix D. It is important to note that the St. Mary Reservoir does not consider conditions on the Oldman River when making a release.

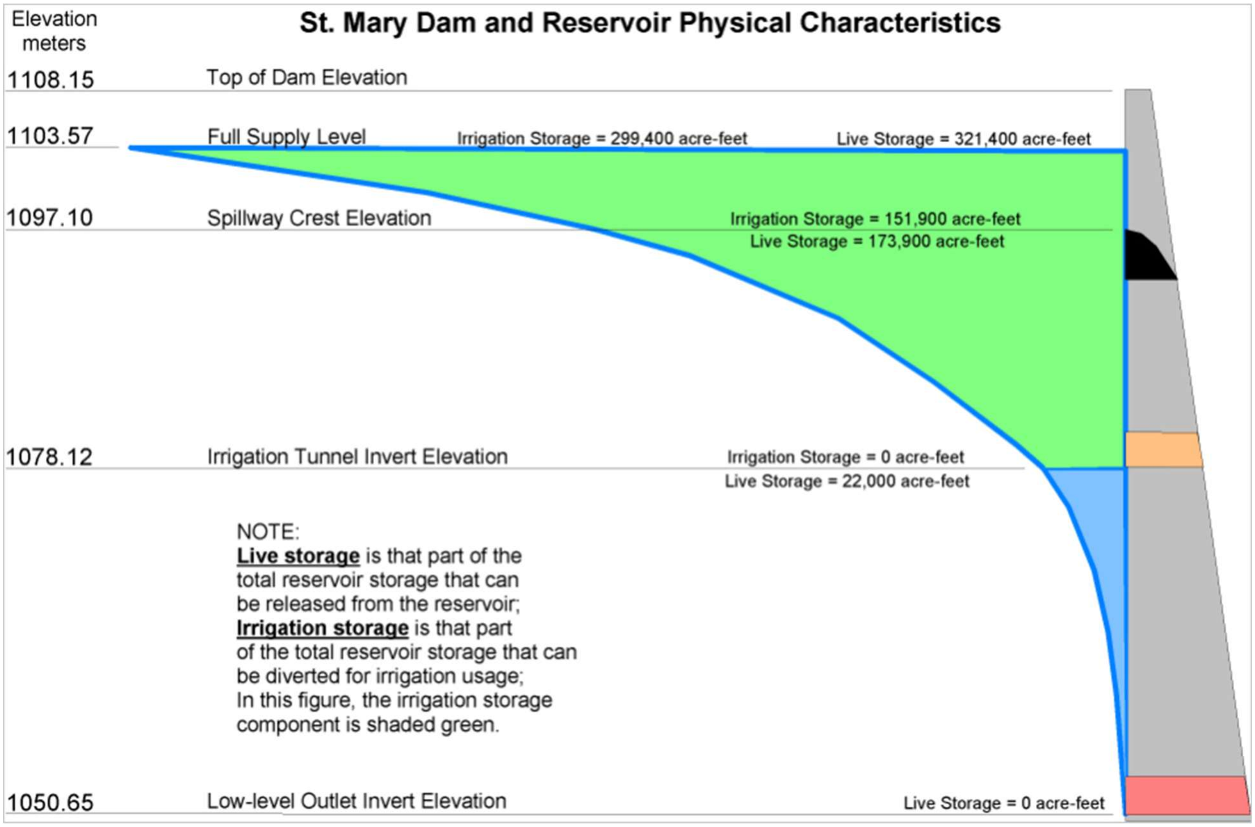


Figure 18. Approximate elevation-storage map of St. Mary Reservoir, noting important elevations. Figure courtesy of Alberta Environment and Parks, Water Infrastructure and Operations Branch – 2022.

The Waterton Reservoir functions similarly to the St. Mary Reservoir in that, through the connecting canals, it tries to support irrigation diversions to MID, SMRID, TID, and RID. The Waterton Reservoir preferentially passes water to the St. Mary Reservoir in anticipation of substantial drawdowns as long as the canal is available post-thaw and pre-freeze (modeled as April 15th to October 15th annually). The Waterton Reservoir also maintains IOs at the mouth of the Waterton and Belly rivers and supports local irrigation both off the Waterton River and, to some extent, those irrigators able to pull from the Waterton-St. Mary canal. Also, similar to the St. Mary Reservoir, the Waterton Reservoir has substantial storage available below the irrigation tunnel (approximately 47,500 acre-feet). Figure 19 shows the Waterton Reservoir elevation storage map. The simulated storage and rule curves implemented in SSROM for the Waterton Reservoir are shown in Figure 74 in Appendix D.

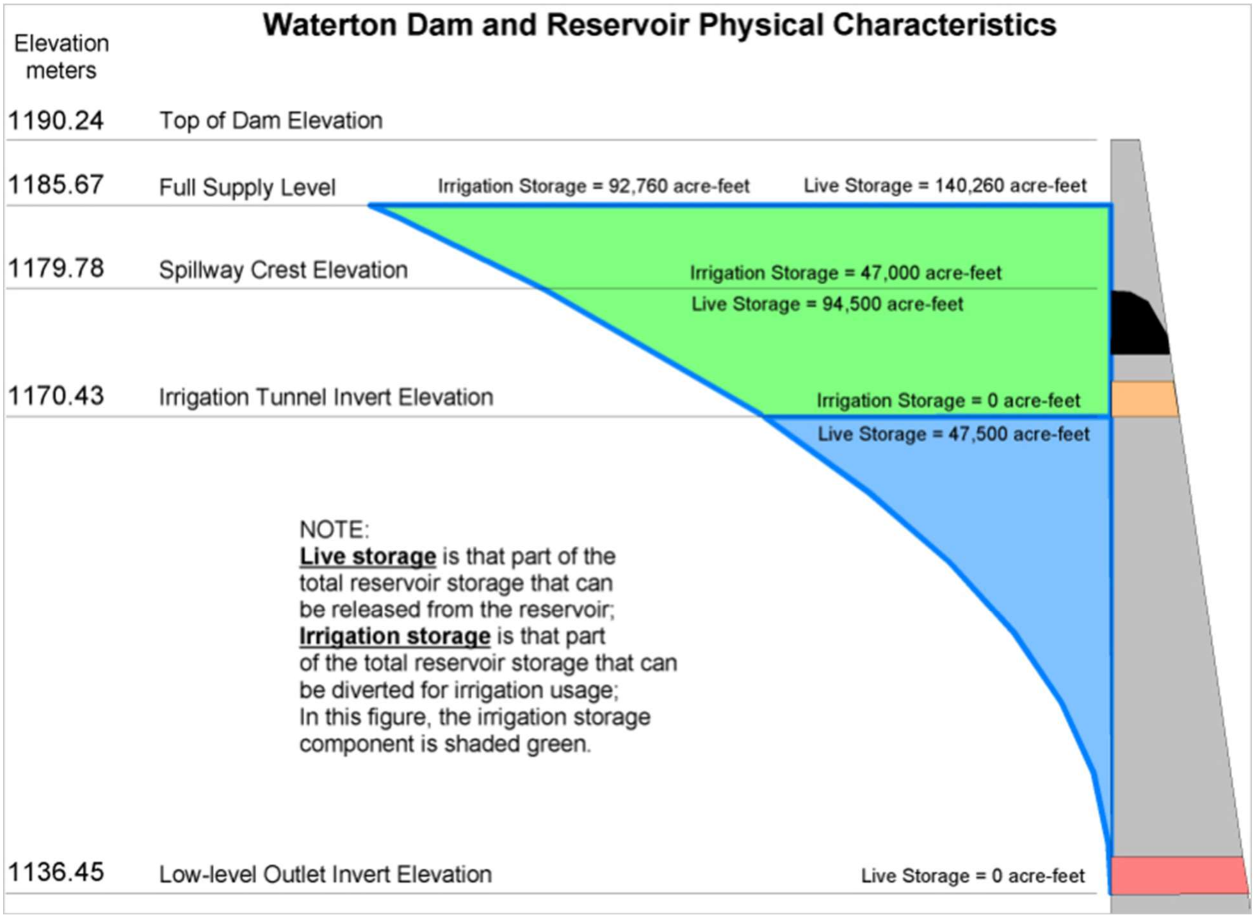


Figure 19. Approximate elevation-storage map of Waterton Reservoir, noting important elevations. Figure courtesy of Alberta Environment and Parks, Water Infrastructure and Operations Branch – 2022.

The other provincially managed water supply reservoir is the Oldman Reservoir; a sample of the Oldman Reservoir's rule curve can be seen in Figure 20. Figure 72 in Appendix D shows the simulated storage and rule curves for the Oldman Reservoir. The largest of the three reservoirs, the Oldman Reservoir attempts to forecast and release water for downstream irrigation, industry, municipalities, and the environment (as represented by the Fish Rule Curves and minimum flow at Medicine Hat, see Section 2.3.3.3). To forecast the necessary releases, the SSROM starts with the next three days' average downstream demands then subtracts expected incoming flow from small rivers, the Southern Tributaries, and the Bow River as appropriate. These inflows are estimated based on the last three days' flow. Note that this does not represent a multi-period optimization, but rather an attempt to replicate the external information operators will use on a given day when deciding release. The calculation can be seen below:

$$\textbf{Oldman release} = \textbf{Downstream Demand}_{(3\text{ day avg forward})} - \textbf{Downstream Inflows}_{(3\text{ day avg backward})}$$

The Oldman Reservoir does not coordinate with the St. Mary or Waterton reservoirs in any meaningful way other than assuming IO flows will proceed through the mouth of the Belly and St. Mary rivers at minimum.

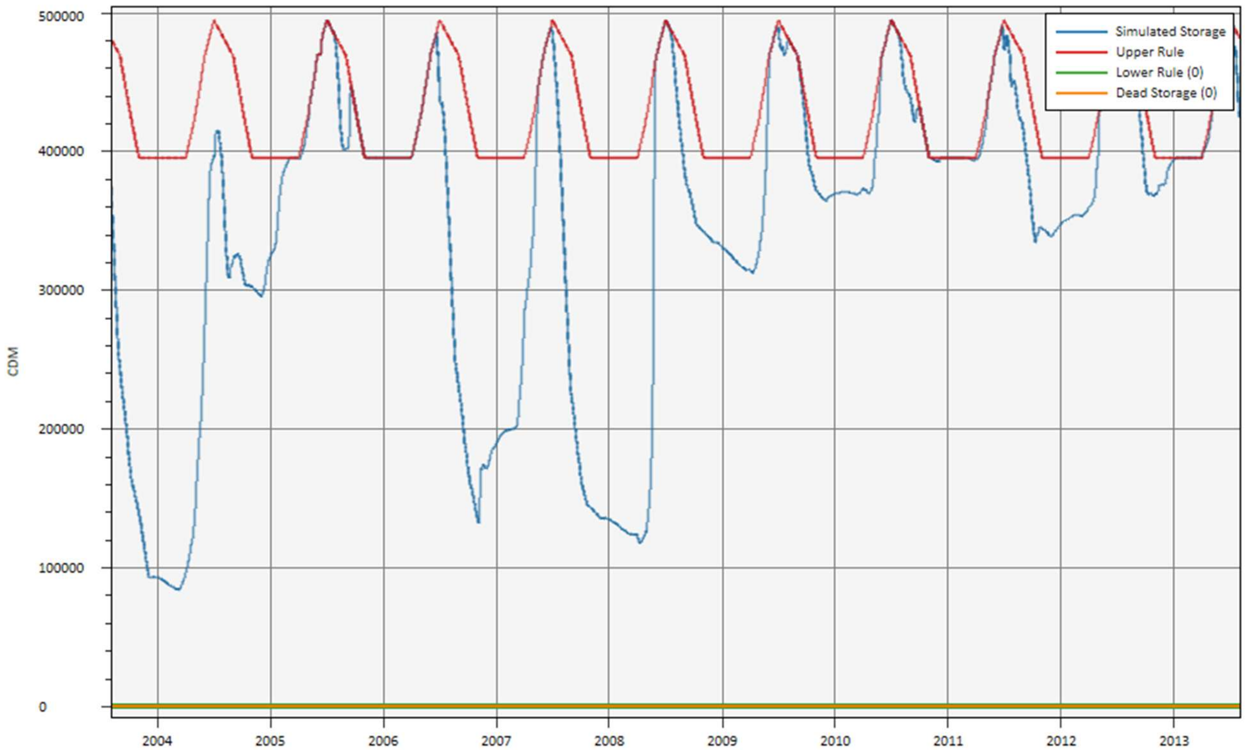


Figure 20. A sample of the Oldman Reservoir's rule curve and simulated storage. Note that Lower Rule and Dead Storage are 0. The SSROM models the Oldman Reservoir's nearly 500,000 CDM of storage as fully available for use.

Irrigation Reservoirs

Most of the irrigation reservoirs in the Oldman and southern tributaries are fed by the St. Mary Reservoir diversion. The exception to this is Keho Reservoir, which feeds the LNID (Lethbridge Northern Irrigation District). Keho Reservoir acts as a typical irrigation reservoir, filling per the LNID permit limitations and emptying as needed to meet crop demand (operations seen in Figure 21).

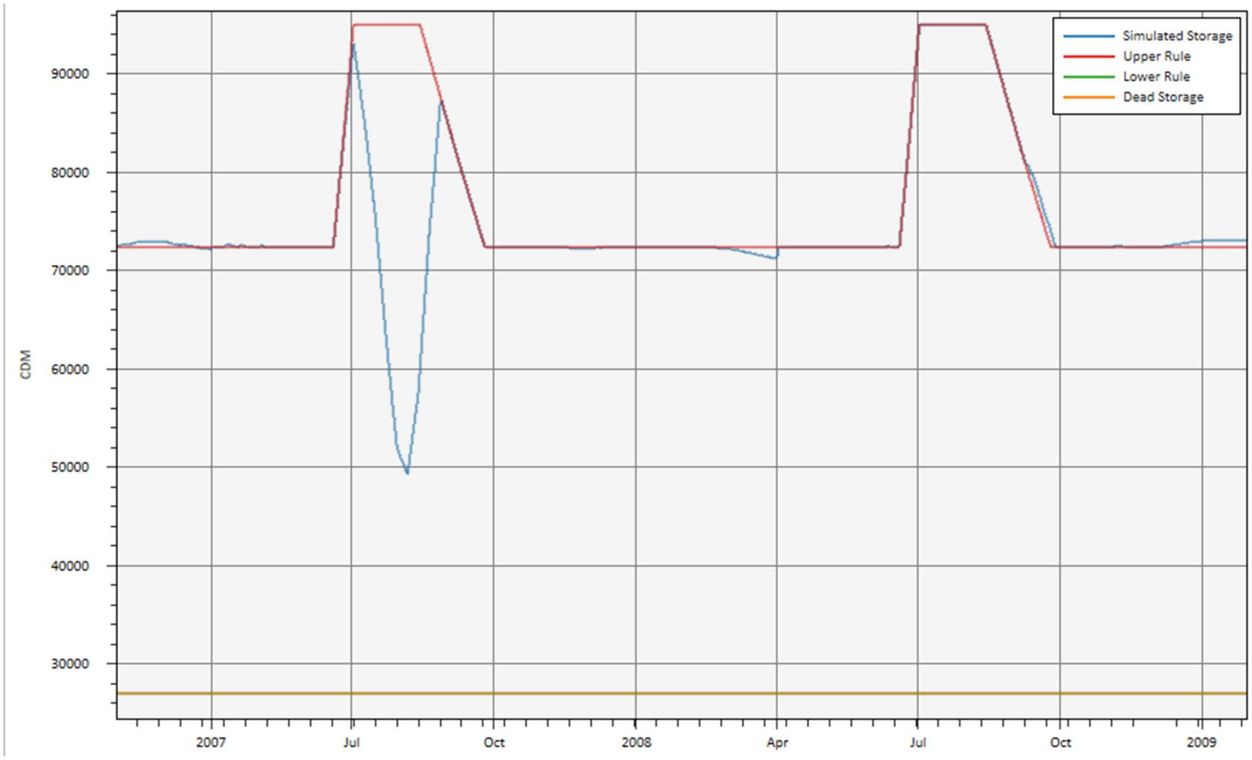


Figure 21. A sample of the Keho Reservoir's rule curve and simulated storage. Note that Lower Rule and Dead Storage are 0. The SSROM models the Keho Reservoir's nearly 95,000 CDM of storage as fully available for use.

In the area fed by the St. Mary Diversion, those demands that can be fed from storage have access to an extensive network of storage. In the real world these reservoirs operate in close consideration of each other's relative storage, but in SSROM this is simplified to an ordered drawdown. Each reservoir will draw down based on the ordered drawdown until they have all reached their lower rule curves (LRCs); if needed to meet crop demands, reservoirs withdraw below the LRCs in the same order. This order is of particular importance as Stafford Reservoir has substantial recreational value (and is thus drawn down last) and filling and withdrawing from 40 Mile Reservoir incurs pumping costs (and is drawn down second to last). Otherwise, the general drawdown order prioritizes withdrawals from Chin and Ridge reservoirs, and then utilizes local storage only if necessary. The full order for preference of use is (mapped in Figure 22):

1. Ridge
2. Chin
3. Murray
4. Sauder
5. Yellow
6. Grassy
7. Fincastle/Taber
8. Horsefly
9. 40 Mile
10. Stafford

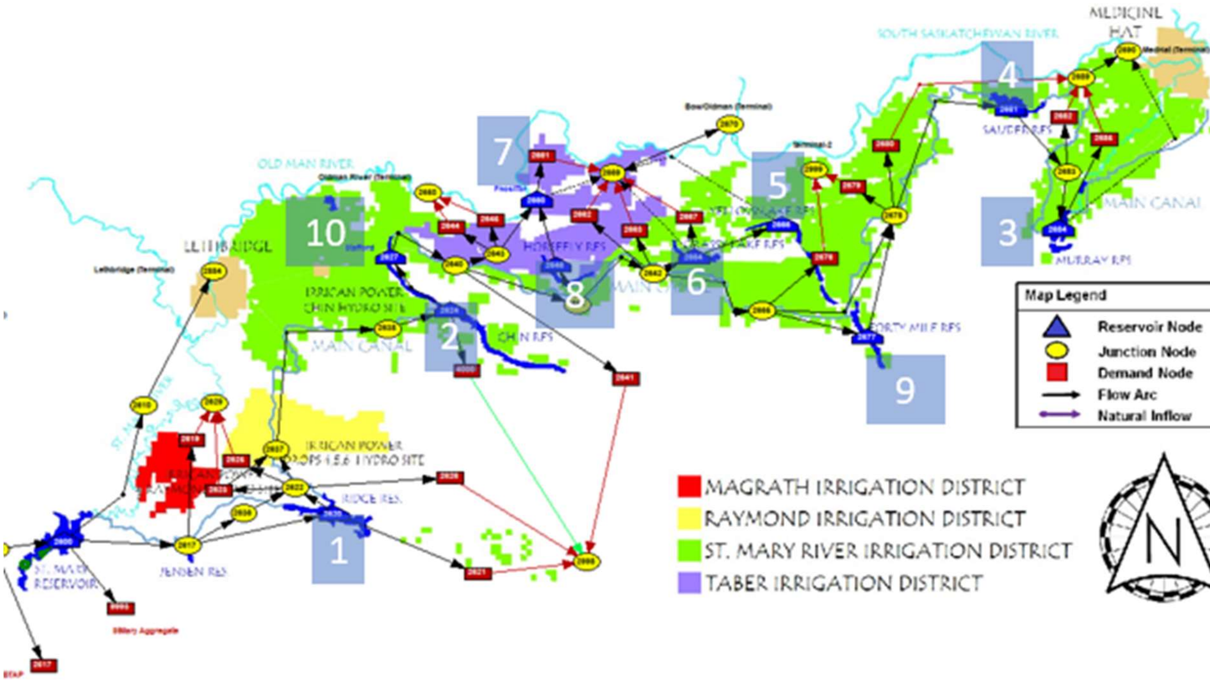


Figure 22. Order of reservoir drawdown preference in the St. Mary diversion system.

The SMRID system also generates incidental hydropower through drops 4, 5, and 6 and the Chin chute. The SSROM is able to roughly estimate power generation as a result of these operations. Although the irrigation districts explicitly operate primarily for crop demand (especially in drought periods), the SSROM does reflect the light preference in non-drought years to not pass more flow than the power generation turbines can pass. However, if reservoir levels fall and as the season proceeds the districts will not hesitate to pass flow around the turbines to ensure reliability of supply.

Ridge Reservoir also operates with two rule curves: wet and dry. The dry year rule curve is always followed in the fall (after July 1), with the wet applied as appropriate from April 1 to July 1. Ridge Reservoir further attempts to maintain a recession rate of no more than approximately 750 dam^3/day during wet years. Rule curves can be seen in Figure 23 and can be found as OCL patterns in the model, “Ridge_DryYear_RuleCurve” and “Ridge_WetYear_RuleCurve.”

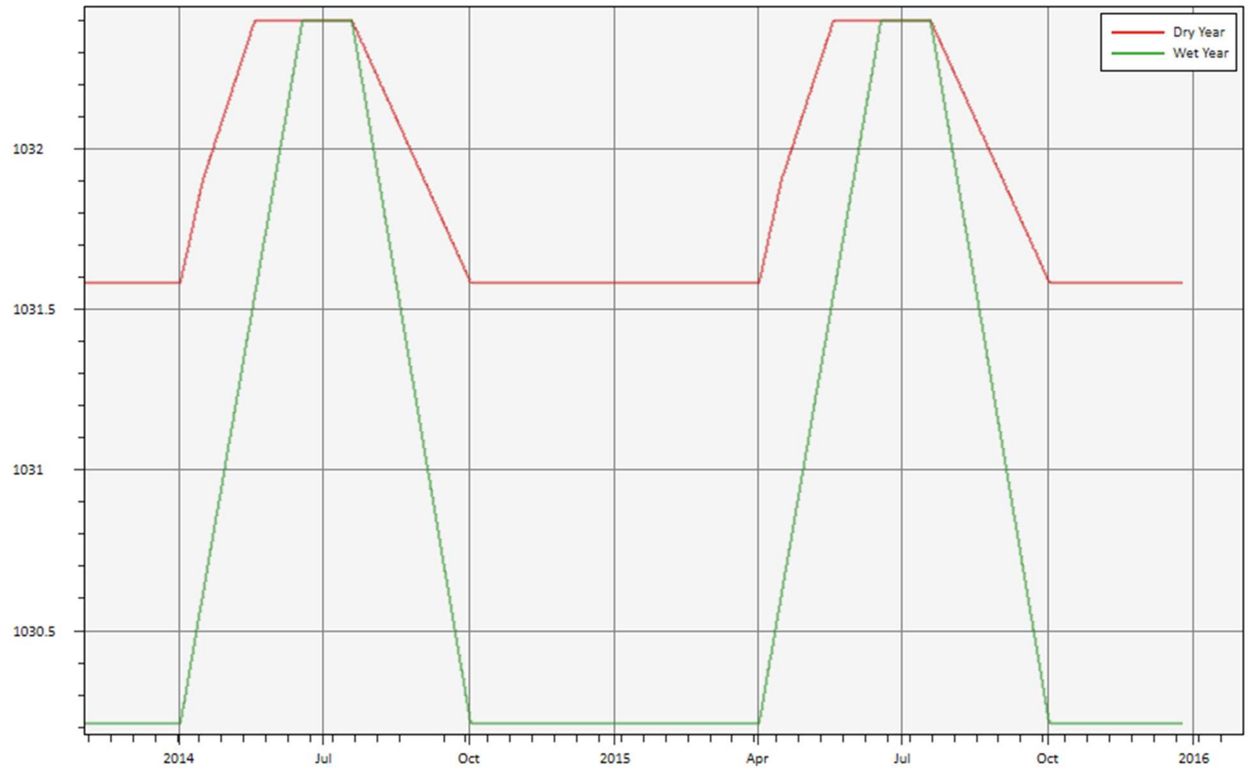


Figure 23. Ridge Reservoir operations as represented in the SSROM.

Additionally, the Jensen node in SSROM has been converted into a reservoir node with associated physical data but it does not operate; it simply fills and spills in SSROM in the Base Case. See Figure 76 in Appendix D for the simulated storage and rule curve integrated into SSROM.

Other reservoirs

The OSSK basins and southern tributaries portion of SSROM also includes a relatively simple model of Willow Creek. Willow Creek operates almost as a sub-model in that local inflows are always provided for local use within that system (i.e., Willow Creek will not short local uses to meet Oldman River Basin needs).

Within this system the Chain Lakes and Pine Coulee reservoirs operate as reservoirs that fill according to their rule curves and meet local demands while maintaining minimum outflows. Chain Lakes Reservoir has a non-gated spillway, and so releases are upper limited by the spillway curve, although the South Riparian Dam is able to make releases of up to 10 m^3/s even when the level is below the spillway. Chain Lakes Reservoir always releases a minimum flow based on time of year; see in Figure 24. See Figure 70 in Appendix D for Chain Lake Reservoir's simulated storage and curve.

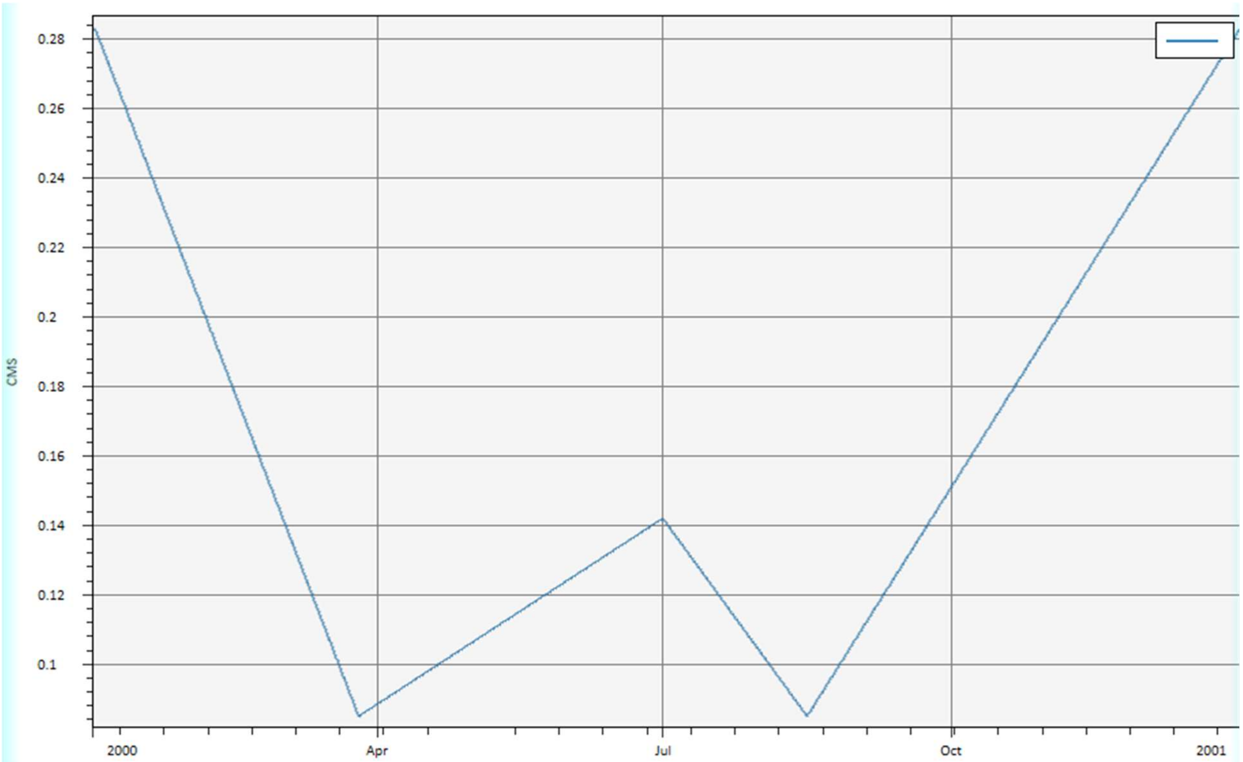


Figure 24. Chain Lakes Reservoir minimum release requirements.

Pine Coulee Reservoir operates similarly (minimum release requirements seen in Figure 25), but as it is filled by a diversion it is more limited in when it can fill. The reservoir abides by its fill limitations and minimum release requirements while also meeting the local demand. Pine Coulee Reservoir's simulated storage and rule curve is shown in Figure 71 of Appendix D.

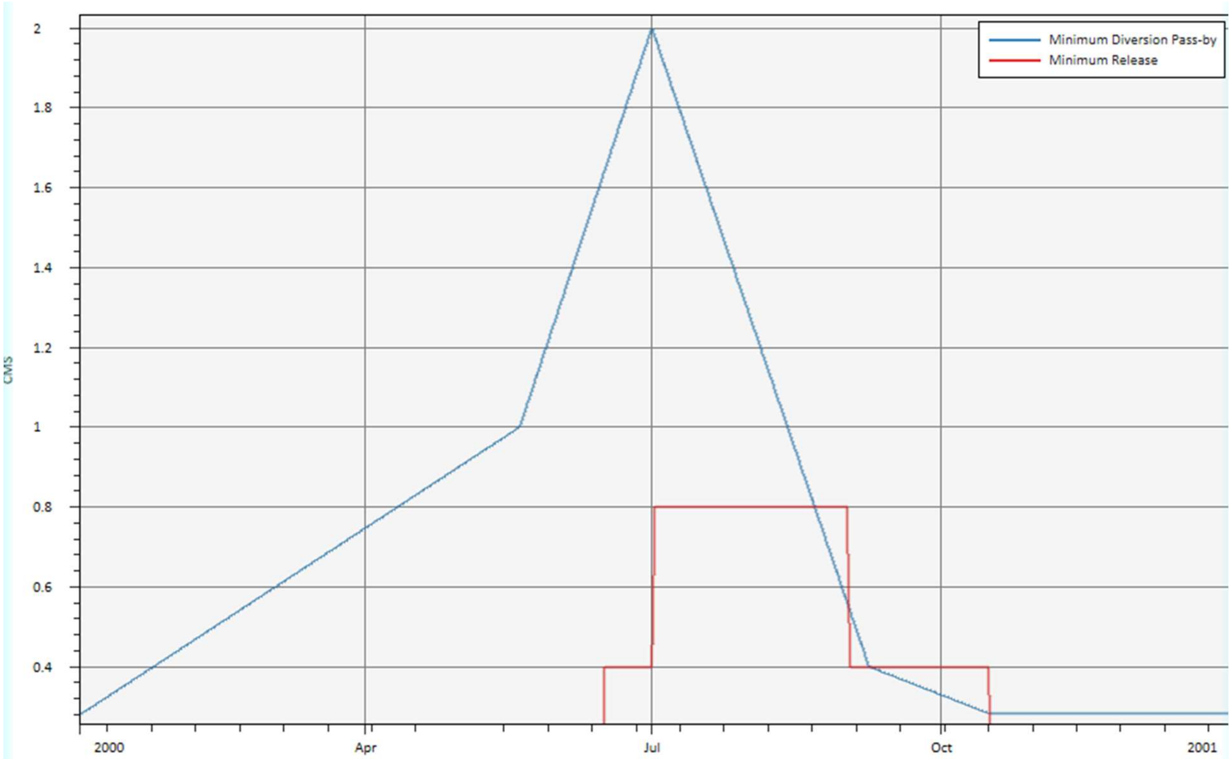


Figure 25. Minimum release requirements of Pine Coulee Reservoir.

2.3.3.2 Shortage distribution (licence priority)

Shortage distribution in the Oldman River Basin and southern tributaries follows a logic that falls between what is applied in the Bow River and the Red Deer River Basins. As with the Bow River Basin, the vast majority of small licences amount to a relatively small total volume; they are given an assumed priority based on a low likelihood of call. However, in the OSSK basins, there are many more irrigation districts with licences distributed across both seniority and geography. As such, licence allocation in the Oldman and southern tributaries follows the general order of:

1. Municipalities.
2. Small demands.
3. Irrigation lacking licence priority information.
4. Large irrigation districts.

Within the irrigation districts (SMRID, MID, RID, TID, LNID, MVID, LID, AID, UID, Blood Tribe, and Piikani Nation) volumes are assigned in licence priority order. Municipal licences are also assigned in order, but only relative to one another (Lethbridge, Taber, and Medicine Hat). Note that the licence priority does not imply diversion at full limit. Instead, simulated diversions based on historical use (municipal) or IDM data (irrigation) are distributed consistent with the priority and annual limits reflected in the licences.

Table 4. Table of individual licences applied in the OSSK sub-basins portion of the SSROM.

District	Extended Name	Priority	Volume (cdm)
SMRID	St. Mary River	1899020701	207,441
TID	Taber	1899020702	41,939
RID	Raymond	1899020703	15,098
MID	Magrath	1899020704	11,324
Medicine Hat	City of	1901	1,684.94
Lethbridge		1909	13,367
Medicine Hat	City of	1913	8,285.3
LNID	Lethbridge Northern	1917111601	185,025
MLVA	Mountain View	1923071003	9,251
MVLA	Leavitt	1939061701	9,560
MVLA	Aetna	1945063001	6,784
SMRID	St. Mary River	1950053107	409,309
MID	Magrath	1950053108	5,329
MID	Magrath	1950053109	16,652
MID	Magrath	1950053110	3,701
RID	Raymond	1950053114	15,431
RID	Raymond	1950053115	30,529
RID	Raymond	1950053116	6,784
TID	Taber	1950053117	41,322
TID	Taber	1950053118	83,261
TID	Taber	1950053119	18,503
LNID	Lethbridge Northern	1974110401	82,645
Taber	Town of	1975	2,837
Medicine Hat	City of	1977	64,038
Lethbridge	City of	1978	11,318
LNID	Lethbridge Northern	1982041501	61,675
Taber	Town of	1984	667.31
Medicine Hat	City of	1985	88,810.7
Lethbridge	City of	1987	6,171
UID	United	1991032401	62,909
MID	Magrath	1991082204	4,934
LNID	Lethbridge Northern	1991082301	61,675
RID	Raymond	1991082302	32,071
SMRID	St Mary River	1991082309	273,837
TID	Taber	1991082602	9,868
BTAP	Blood Tribe and Piikani	19911107001	49,672
MLVA	Mountain View	1991121702	617
MVLA	Aetna	1991122301	4,317

District	Extended Name	Priority	Volume (cdm)
MVLA	Leavitt	1991123004	5,242
UID	United	1993051701	20,970
Piikani Nation		20021206002	43,200

2.3.3.3 Target and minimum flows

The Oldman River and southern tributaries have numerous minimum and target flows, which are described below.

- Willow Creek: In addition to the minimum reservoir releases described above, there is a minimum flow at the mouth of 0.4 m^3/s year-round and 0.79 m^3/s from July 1 to August 31.
- Tributaries near the Oldman Reservoir: The upstream Oldman River has a minimum flow requirement between April 2 and October 29 that ranges from 4.33 to 18.35 m^3/s at peak, while the Crowsnest River minimum flow requirement ranges from 1.33 to 24.72 m^3/s and Castle River minimum flow requirement ranges from 2.75 to 5.92 m^3/s. Pincher Creek at the mouth, downstream of the dam, has minimum flow requirements that range from 0.17 m^3/s to 1.47 m^3/s. Annual minimum flow requirements for the tributaries near the Oldman Reservoir can be seen in Figure 26.

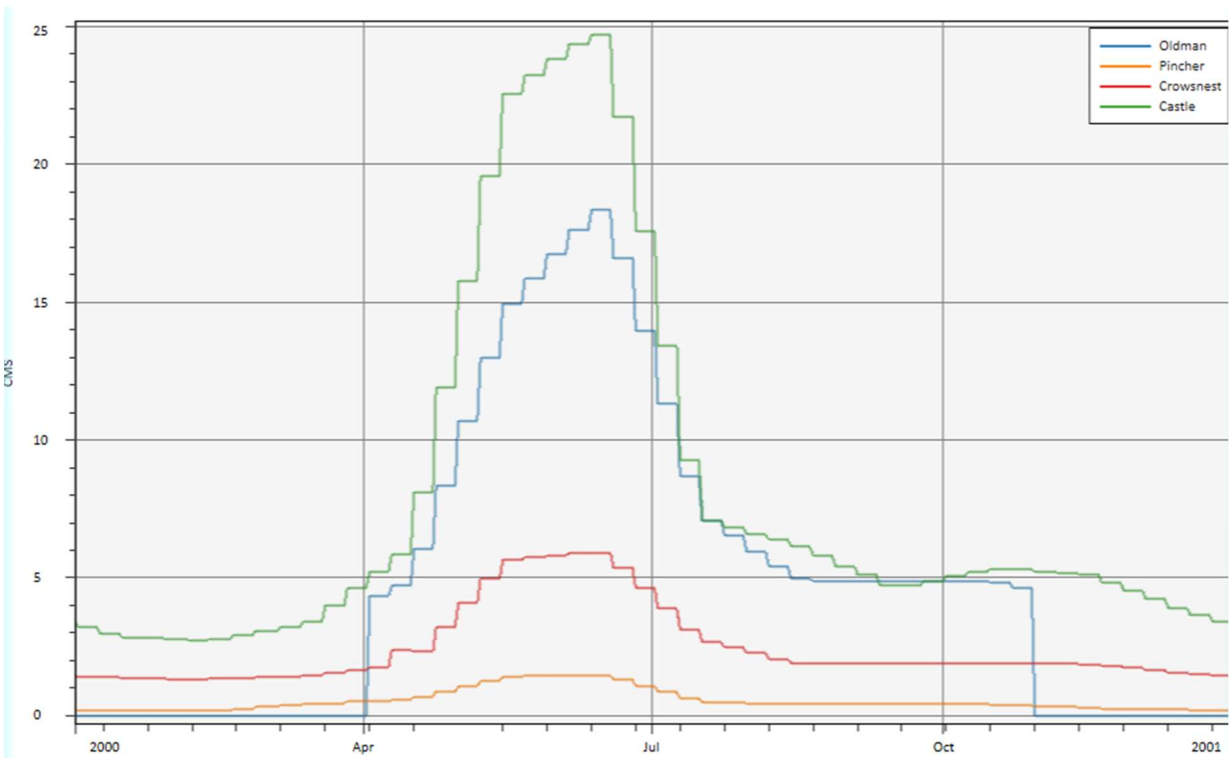


Figure 26. Oldman River, Crowsnest River, Castle River, and Pincher Creek minimum flow requirements.

- St. Mary and Waterton Rivers: As mentioned in the Section 2.3.3.1, St. Mary and Waterton reservoirs each release to meet IOs at the mouth of the St. Mary River and Waterton/Belly Rivers respectively. In each of these locations the IO is a fixed year-round value; IOs are 2.75 m^3/s for the St. Mary River and 2.27 m^3/s for the Waterton River. On the Belly River there is a flow requirement of 0.85 m^3/s from Payne Lake Reservoir, 0.93 m^3/s at the confluence with the Waterton River, and 0.93 m^3/s once again at the mouth. Within the St. Mary canal a minimum flow of 5.66 m^3/s is maintained throughout the irrigation season from April 1 to September 30, though in practice it is rarely binding as operations strongly prioritize substantial flows through the canal during irrigation season. Upstream of the St. Mary Reservoir the minimum flow ranges from 0.37 m^3/s to 2.29 m^3/s; minimum flows upstream of the St. Mary Reservoir can be seen in Figure 27.

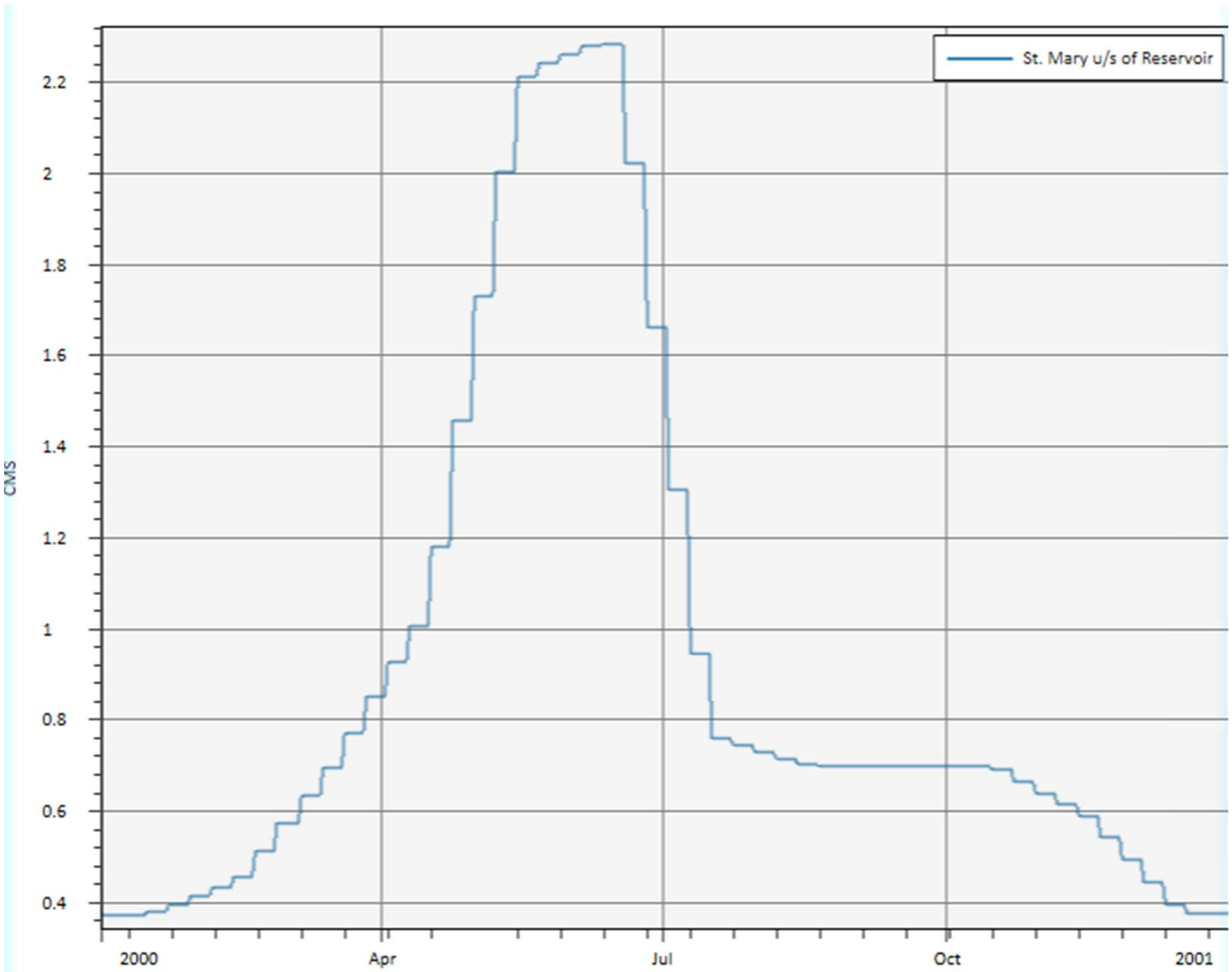


Figure 27. Annual minimum flow requirements upstream of the St. Mary Reservoir.

- Medicine Hat: Medicine Hat has a year-round minimum flow of 1,000 ft^3/s. Of note, this is applied after Medicine Hat's return flows to the river.
- 80% Fish Rule Curves (FRCs): the Oldman Reservoir attempts to make releases to ensure minimum flows for fish survival are maintained. Three locations are targeted for these releases: Reach 1 – downstream of Lethbridge; Reach 3 – Fort Macleod/Rocky Coulee confluence to the Belly River confluence; and Reach 4 – downstream of the LNID Weir. FRCs are calculated as follows:
  - Every day, the natural flow at these locations is calculated and compared against a reach- and month-specific table to determine the base 80% FRC target (see Figure 28). These

lookup tables can be found in the model as "Lookup/OrdFRC[Reach][Month]." Note that June is split in two.

- To address time of travel and smooth the response, the model then compares and averages this value across the prior two days and current day.
- This average stands in the case of Reach 4, but in Reaches 1 and 3 it is then compared against a minimum fish survival pattern for Lethbridge and Fort Macleod respectively. (i.e., the result of the Figure 28 lookup is compared against today's value from the pattern in Figure 29). The larger of the two is applied as the appropriate FRC target. These patterns can be found as "Pattern/Lethbridge_FishSurvivalMins_cms" and "Pattern/FortMacCleod_FishSurvivalMins_cms."
- Finally, a buffer of 0.5 to 2 m^3/s, dependent upon conditions and reach, is added to represent the real-world operations and how operators respond to uncertainty.
- These FRCs are then applied to the SSROM as a minimum flow target (see Figure 30 as an example).

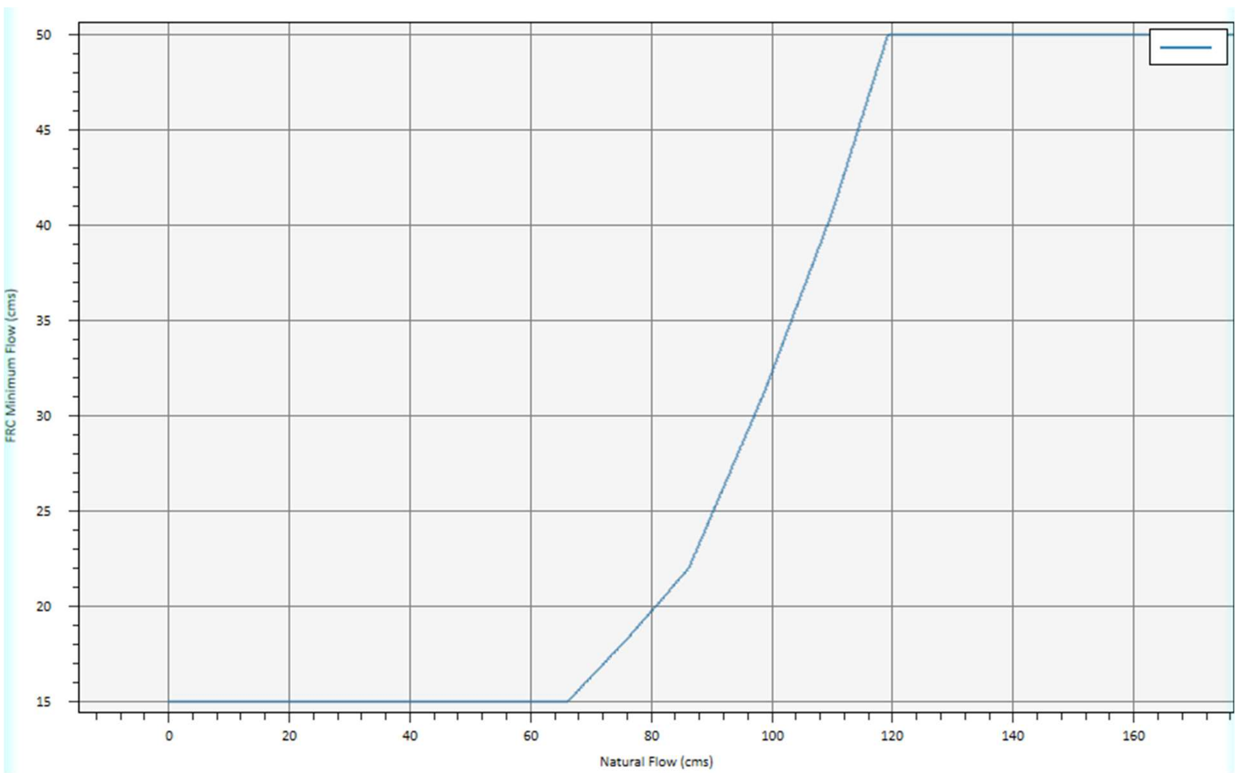


Figure 28. An example of a monthly 80% FRC lookup for Lethbridge, Natural Flow is fed in and the 80% FRC minimum reported out.

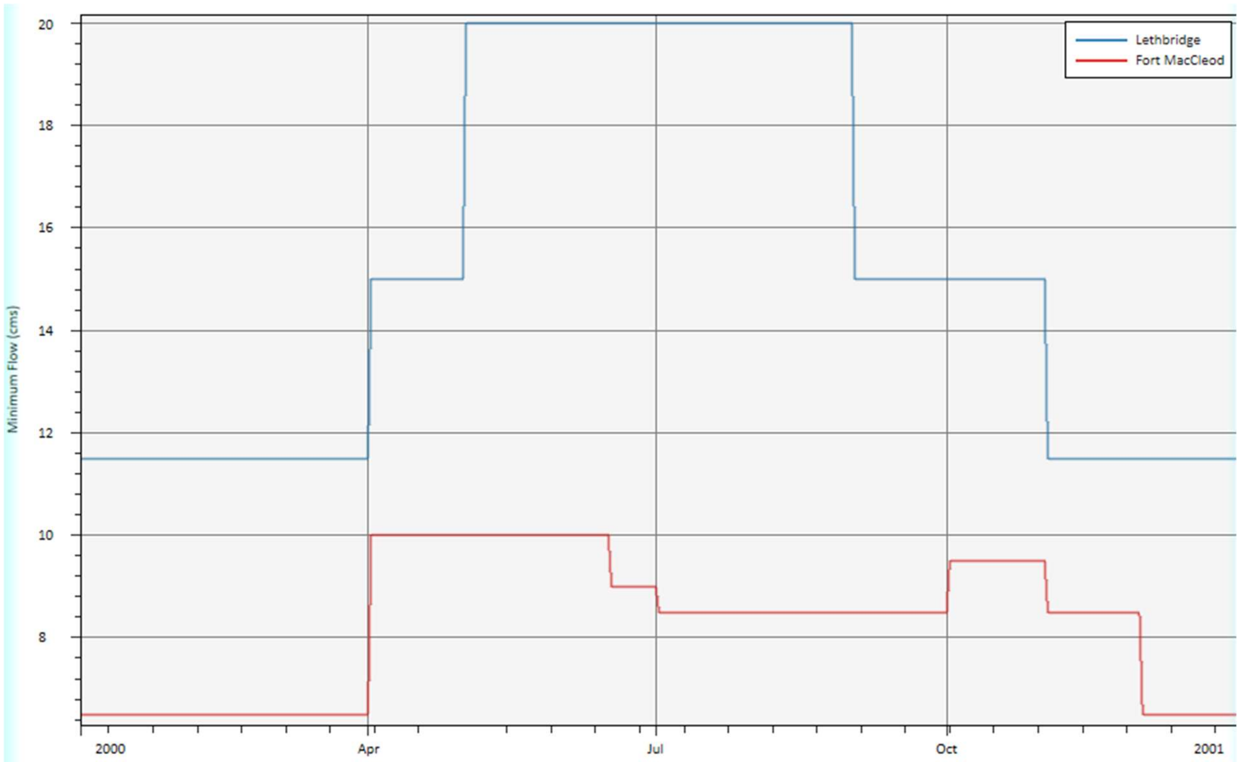


Figure 29. Minimum flow requirements for fish survival, per the monthly patterns. This is compared to the original 80% FRC requirement and the larger is taken.

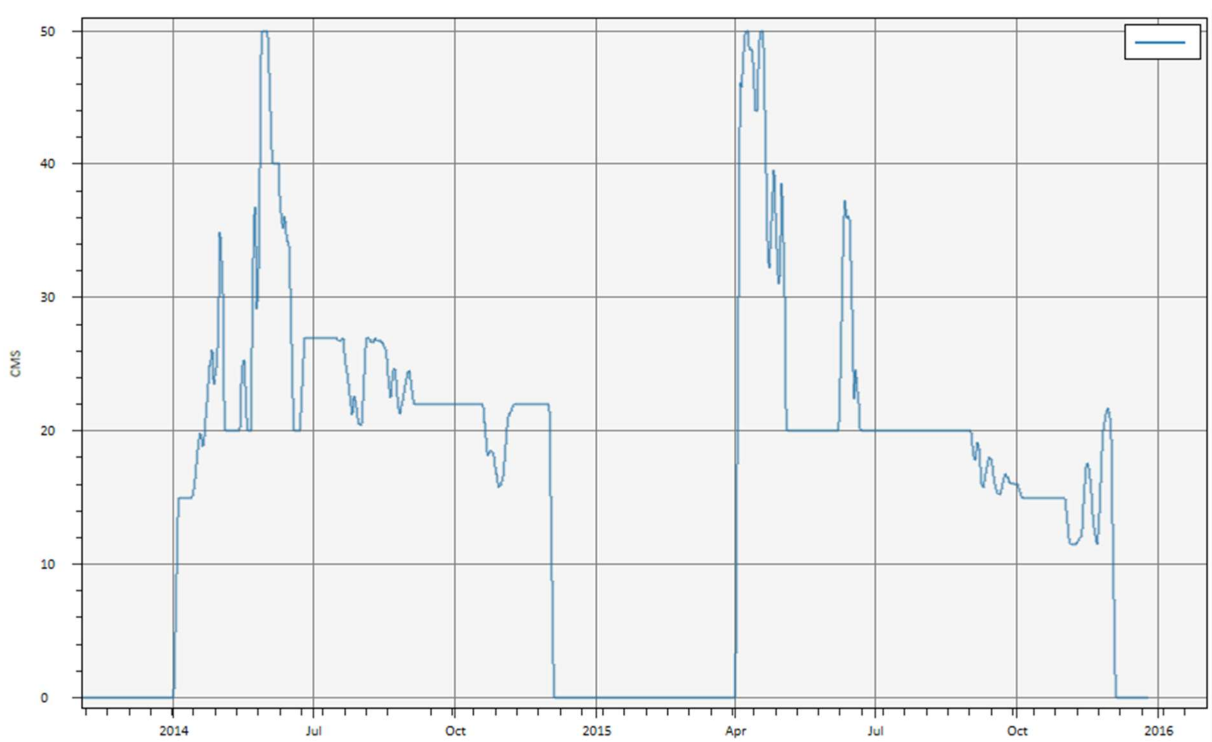


Figure 30. 80% FRC 1 at Lethbridge, final calculation across two years. Utilized in SSROM as the targeted minimum flow.

2.3.4 The South Saskatchewan River Basin

The full SSRB operates as three distinct basins that connect but do not cross-operate beyond five distinct locations of basin connectivity. As such, there are no additional operations that manage the system comprehensively. The SSROM, however, provides the opportunity to model and explore such operations in detail.

In the SSROM, the five major sites of basin connectivity are as follows (and as shown in Figure 31):

1. Red Deer River at the mouth.
2. Western Irrigation District (WID) returns at Drumheller.
3. Eastern Irrigation District (EID) returns at Dinosaur Park.
4. Flow into/through the Little Bow River south of Travers Reservoir.
5. The Bow/Oldman River confluence.

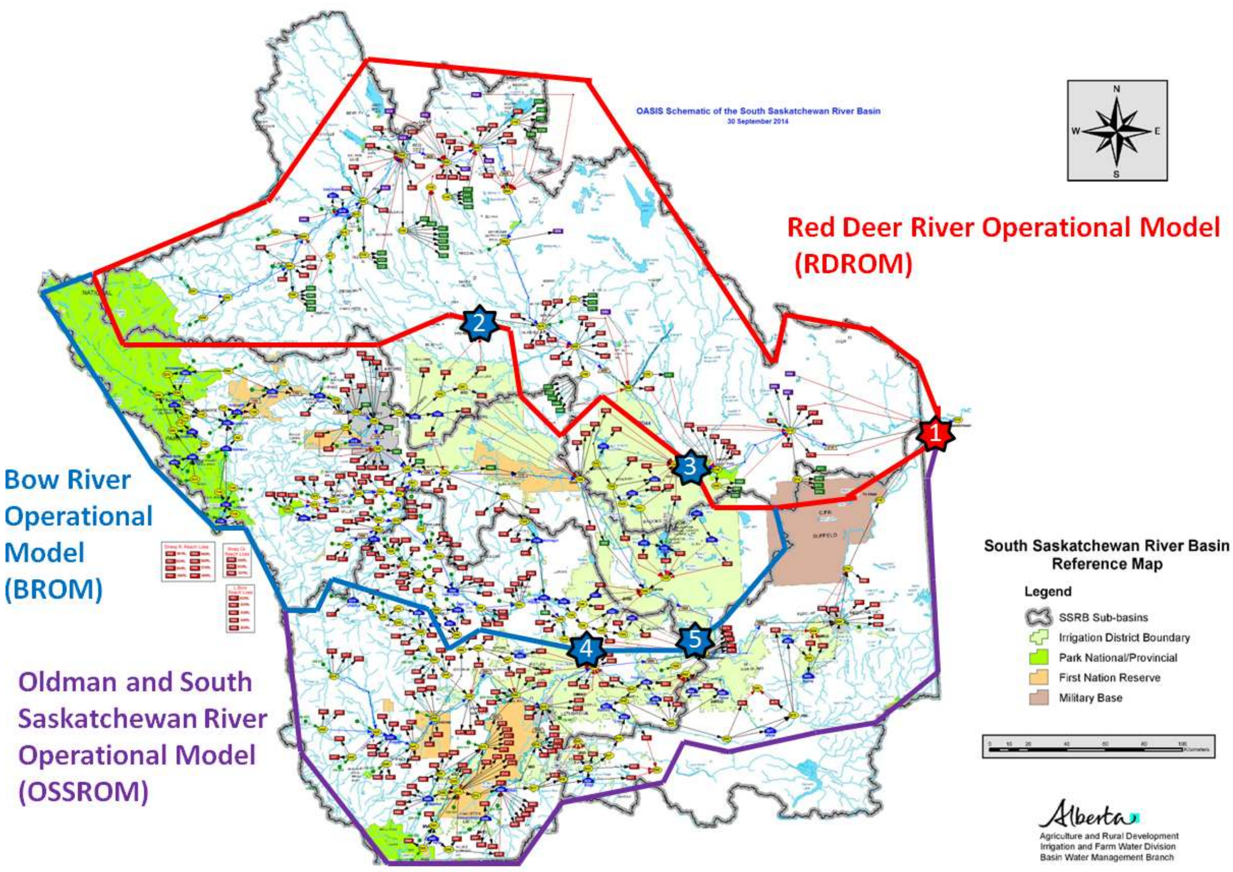


Figure 31. Major points of inter-basin connections in the South Saskatchewan River Basin.

2.3.5 Apportionment

Apportionment in the SSRB is not explicitly maintained by the SSROM beyond the Oldman Reservoir ensuring 1000 ft^3/s passes by Medicine Hat. Stakeholders completing additional "what if" scenarios utilizing the SSROM model should be aware that actual results could be impacted by apportionment conditions, however, if apportionment is not met during modelling it will show up against the apportionment performance measure. Operators on the Bow River and Red Deer River Basins did not enunciate any specific operations they undertake to meet apportionment obligations. In the SSROM, apportionment is instead evaluated separately as a performance measure (see Section 2.4) but merits some discussion here.

The Apportionment Agreement with Saskatchewan does not dictate a strict daily minimum flow; rather, the Prairie Provinces Water Board (PPWB) annual report indicates "Alberta is required to deliver 50% of the apportionable flow to Saskatchewan unless the total annual apportionable flow below the confluence is less than 5,180,000 dam^3, in which case Alberta is allowed a total net depletion of 2,590,000 dam^3 regardless of the percent delivery. However, Alberta cannot consume, divert, or store more than 50% of the apportionable flow if the effect reduces the flow below the confluence to less than 42.5 m^3/s at any time. As the apportionable flow for 2018 was 8,385,000 dam^3, and Alberta delivered greater than 50% of the apportionable flow, Alberta has met its obligations." (Prairies Provinces Water Board, 2019). Figure 32 shows Alberta's apportionment performance for the SSRB from 1970–2009.

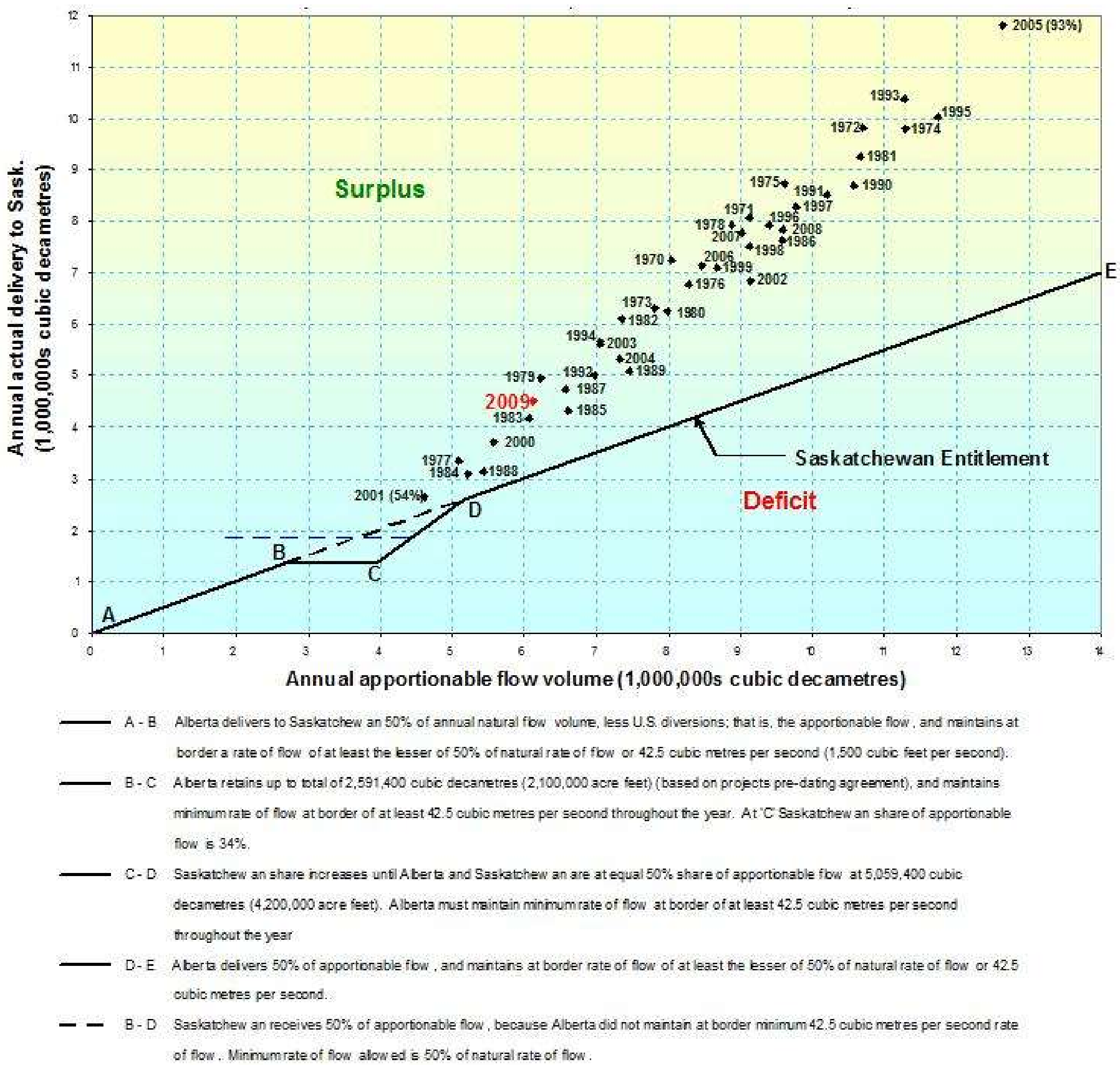


Figure 32. Alberta SSRB Apportionment Performance, 1970-2009. (AEP, 2003-2012)

Note: The horizontal dashed line illustrates what happens when the minimum flows of 42.5 m^3/s on the South Saskatchewan River and 16 m^3/s on the Red Deer River are maintained as minimums regardless of natural flow.

2.4 Performance Measures

Performance measures (PMs) are key assessment criteria and reflect an outcome of importance to model users. PMs are used to look at the relative difference, the direction and magnitude of change, given a particular assessment criterion between model runs.

As part of the SSROM updates, a dashboard of nine basin-wide and sub-basin PMs was created. The PMs included in this dashboard are shown in Table 5. The PMs included were selected from previous SSROM projects; these PMs are those commonly of importance or frequently requested by participants of historical Working Groups and were revalidated by the current Working Group.

Table 5. PMs in the SSROM Dashboard.

Basin	PM	Description
SSRB	Apportionment Contribution	Contribution to apportionment annually by sub-basin
SSRB	Minimum flows by year	Minimum flow at Bindloss, Calgary, Bassano, Lethbridge, and Medicine Hat
SSRB	Percentage of days meeting or exceeding 85% naturalized flow	Percentage of days meeting or exceeding 85% of naturalized flows (surrogate for IFN) during the open water season (April to October) and winter (November to March)
Red Deer	Weekly low flows	Annual WCO Flow Violations
Red Deer	Municipal and Industrial shortage volumes	Volume of industrial shortage
Bow	Shortage volumes	Volume of shortage for WID, EID, BRID, Calgary
Bow	Baseflow at Bassano	Percentage of days <400, 400-650, 651-800, 801-1000, 1001-1200 ft^3/s at Bassano
Oldman	Irrigation shortage volume	Shortage volume for irrigation districts
Oldman	FRC violations	Days with Fish Rule Curve violations

All these PMs are also available to users in the updated SSROM platform and can be viewed during scenario analysis; a more comprehensive list of PMs from past projects can be seen in Appendix G.

3.0 Comparison to previous work

3.1 Water diversion comparison

Comparisons between the 2009 and 2022 versions of the model show slight variances due to the change of multiple discrete elements (i.e., operations, irrigation data, other demands, etc.). As such, it is not always possible to clearly ascribe a cumulative effect to a single element. Nevertheless, it is important to consider and assess each variance as best as possible to confirm that prior results remain broadly valid relative to future work.

Even with all the model updates rolled together, it is still possible to compare net inputs to one another.

Changes in diversion volume near 1% are generally considered within the realm of modeling or mathematical error and are considered insubstantial in the overall context of the model. In the Red Deer River Basin, the 2022 data averages 11,100 dam^3 higher in diversion requests per year (about +4.29% relative to 2009) which is in line with expectations of increasing water use in the basin as it has remained open. In the Bow River Basin, the 2022 data averages 21,580 dam^3 lower demands per year (about -1.31% of 2009 data). However, this change borders on insubstantial from a modeling perspective, as changes near 1% are generally considered within the realm of modeling/mathematical error (due to rounding/truncation/estimation). In the Oldman, Southern Tributaries, and South Saskatchewan River Basins, the 2022 data averages 19,200 dam^3 higher per year (about +1.3% of 2009 data). Visual comparison of the diversion volume changes between model versions is available in Appendix H and shows the total basin requested diversions for each of the major SSROM basins (Red Deer, Bow, and Oldman/Southern Tributaries/South Saskatchewan River Basins).

3.2 Comparison of model impacts

In terms of major impacts to the system, the 2022 update has brought the SSROM modeling more in line with current understanding and expected results.

In terms of shortages, the Red Deer River Basin is unaffected by any modelling changes; there were no shortages to municipal, industrial, or irrigation use in either 2009 or 2022 models. Municipal uses across other river basins are similarly unaffected, as SSROM prioritizes anthropocentric use over irrigation.

Regarding irrigation in the Bow River Basin, however, there were a number of modelling changes that led to differences in shortages within irrigation districts across the historical timeseries when compared with the 2009 modeling (Figure 33 and Figure 35). In the WID, shortages saw a dramatic increase as the new WID license awarded in 2016 increases their diversion requests by roughly 35% relative to 2009 modeling. The WID has very limited storage capabilities (Langdon Reservoir is comparatively small to other irrigation reservoirs and Chestermere Reservoir is functionally unavailable for irrigation use in SSROM) so the increase in shortages are largely a result of demands in the WID being almost entirely dependent on river flow.

3.2.1 System shortages

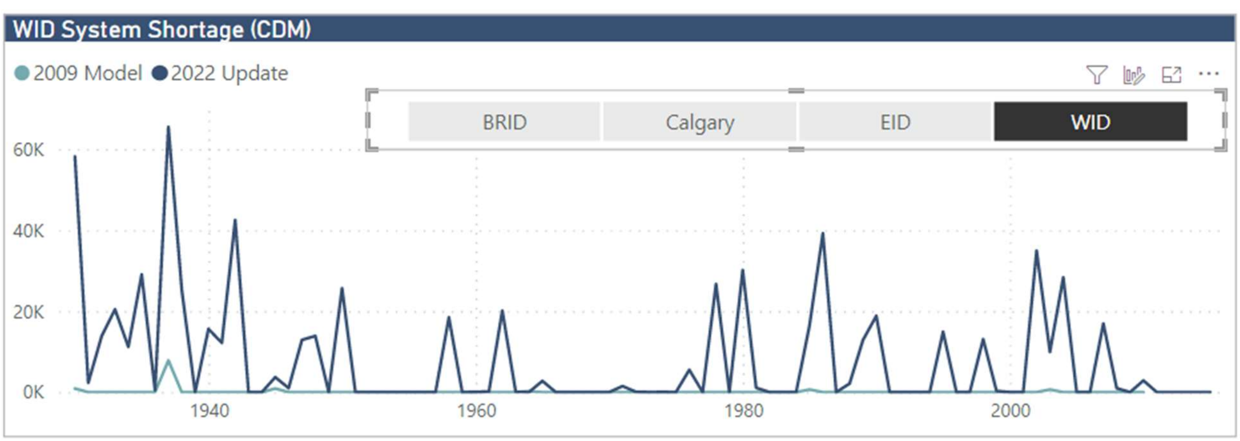


Figure 33. Shortage comparison between previous model data and updated data in the WID.

The BRID demands rose approximately 2% relative to the 2009 dataset, which resulted in only a minor increase in shortages. This is largely the result of the WID irrigation demand increases, which were offset slightly by the re-modeling of the EID diversion license. After implementing the EID 1998 license priority conditions the BRID has an increased seniority of diversion, though they still follow a "gentleman's agreement", described in Section 2.3.2.2, that maximizes yields in both systems.

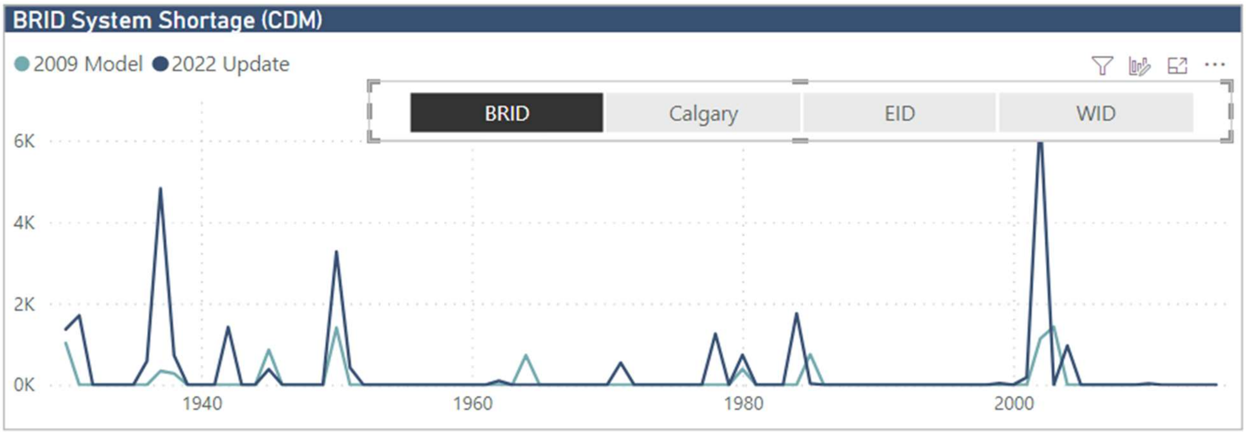


Figure 34. Shortage comparison between previous model data and updated data in the BRID.

The EID, despite the loss of priority from the 1998 license, saw a reduction in shortages due primarily to the reduction of diversion requests; diversion requests have decreased by approximately 20%, relative to 2009 modeling. Adjustment reflects the best available data at the time of this update.

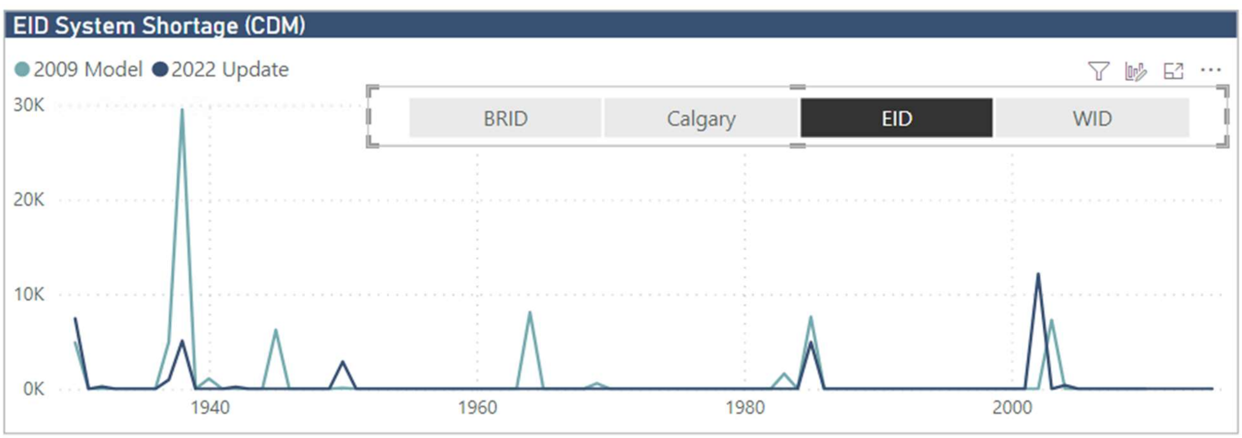


Figure 35. Shortage comparison between previous model data and updated data in the EID.

On the Oldman system there were substantially more changes in irrigation shortages. The implicit assumptions of the 2009 IDM dataset are not all known but given the clarity of the 2022 dataset, it is thought that the prior set utilized diversion estimates were too high relative to current conditions. Thus, most IDs saw their shortages decrease in the 2022 update. Conversations with representatives of these districts suggested that the 2022 results were better reflective of their experiences and expectations.

The UID shows variances over a number of periods, resulting in more difficultly understanding the data issues. However, the general consensus was that the 2022 results were more representative of known challenges in that system.

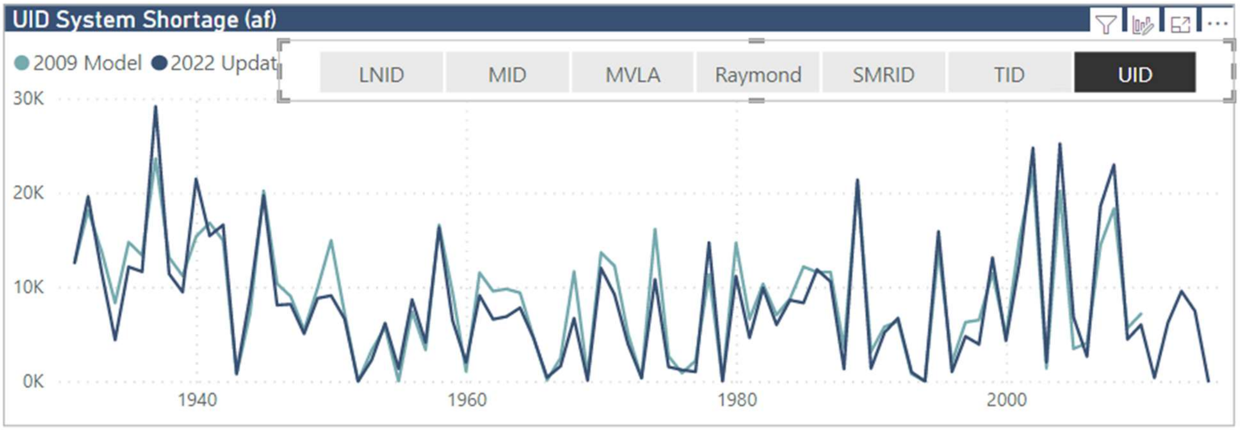


Figure 36 Shortage comparison between previous model data and updated data for United Irrigation District (UID)

Also notable in the Oldman system was the revision of Oldman/St. Mary/Waterton operations. As part of the 2022 update, the Oldman dam operations were modified to be more independent of St. Mary/Waterton conditions. This resulted in a substantial improvement to meeting the Fish Rule Curve targets (Figure 37) of the Oldman basin. The charts for all other irrigation districts in the Oldman basin are available in Appendix H.

3.2.2 Fish Rule Curves

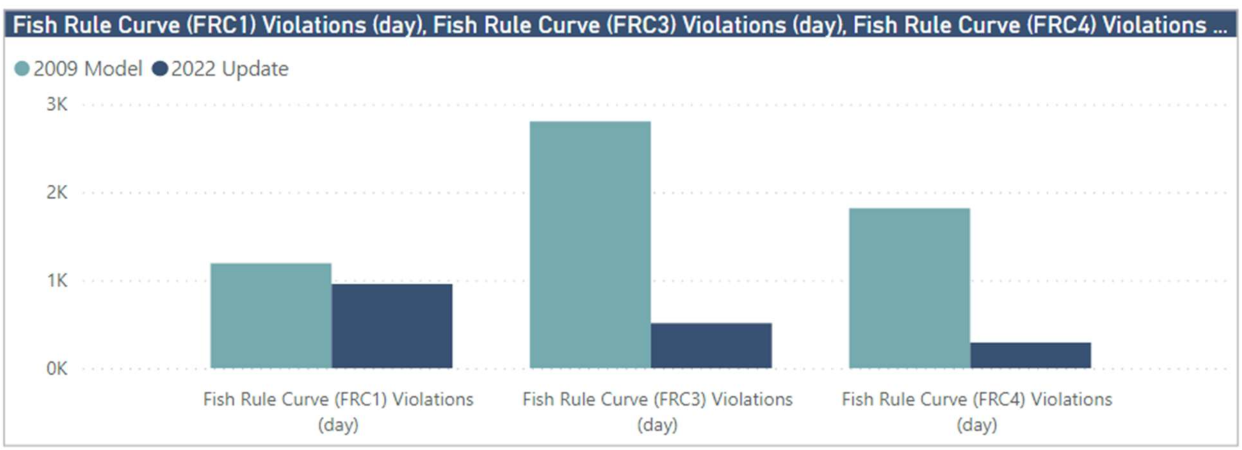


Figure 37 Comparison of Fish Rule Curve violations between previous model and updated model data in the Oldman basin.

At the whole basin level, the 2022 update provided interesting results relative to cross-border flows. As discussed, apportionment is not an operational component in SSROM, but it is a performance metric. In the 2009 work, the flows occasionally approached a point of concern but there were no identified apportionment failures (Figure 38). The 2022 results show a clear miss in 1937 and indicated concern in 1984, 1987 and 2001 (Figure 39), suggesting that apportionment is going to be more of an issue in future years.

3.2.3 Cross-border Flow Contributions

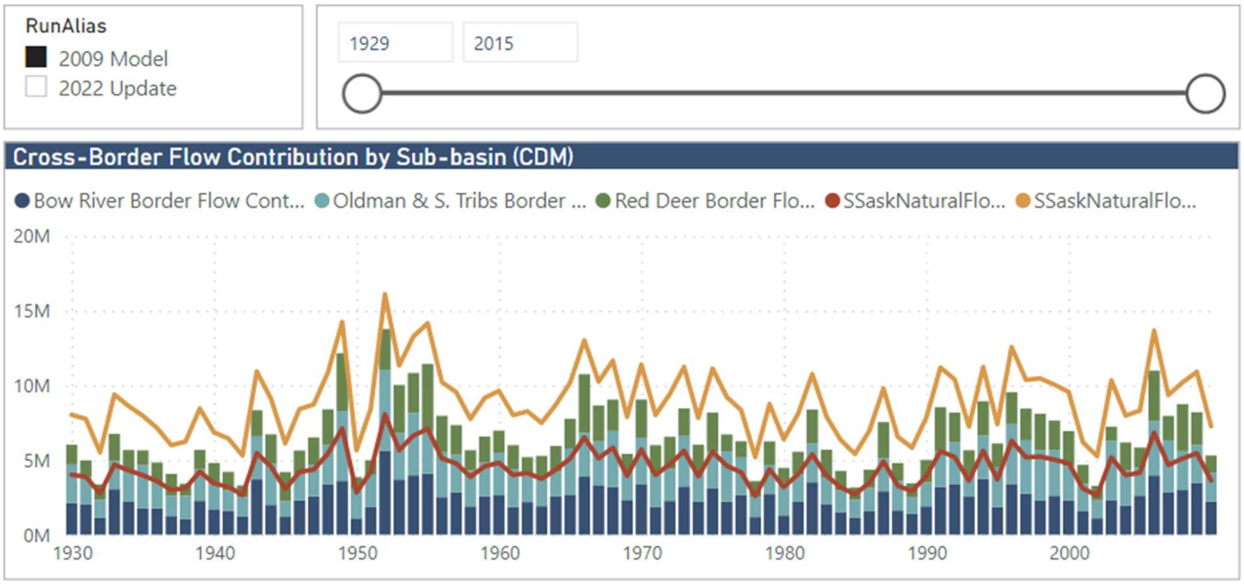


Figure 38 Cross border flow contribution by sub-basin across the historical timeseries using previous model data

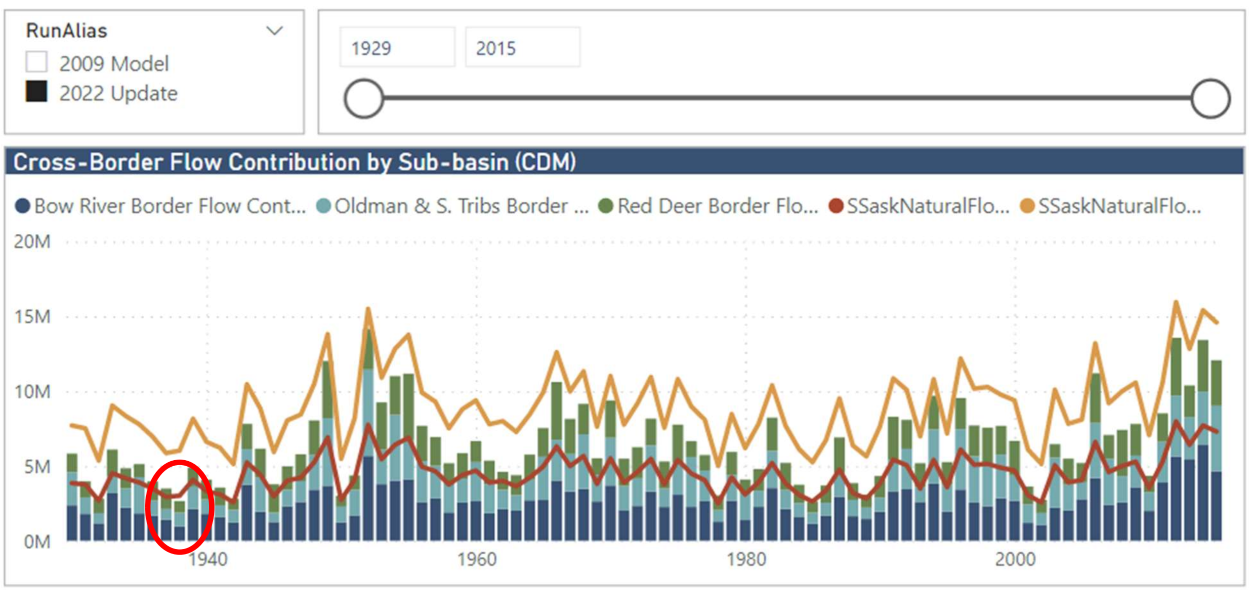


Figure 39 Cross border flow contribution by sub-basin across the historical timeseries using updated model data

In summary, the results of the models between 2009 and 2022 versions do not seem to indicate any changes substantial enough to invalidate prior work. Instead, this update appears to bring the SSROM into further alignment with today's conditions and stakeholder expectations. This work has resulted in a more thorough understanding of the implicit assumptions in the underlying datasets and clearer interpretations of operations in the system. The model is now ready for deployment and use in a wide variety of planning activities.

4.0 Recommendations and future modelling opportunities

Throughout the project, some recommendations for potential modeling opportunities were made that were out of scope. This section summarizes future modelling opportunities for collaborative work, as articulated during the Working Group meetings or individual meetings. These recommendations identify some new avenues that could be explored – avenues that offer insights into how the model could be used for better, more informed water management in the SSRB.

One of the strengths of the SSROM is that it can be employed as a tool for collaborative modelling. The SSROM can be used to quickly analyze various 'what-if' scenarios based on facts and to visually demonstrate results through PMs. These 'what-if' scenarios involve modelling changes to the SSROM Base Case to see what impact those changes would have within the SSRB. This could include the addition of a new reservoir or increasing the number of irrigated acres in a basin. Since the SSROM Base Case is a representation of the SSRB as it currently operates, the 'what if' scenarios can be used to analyze how the system may change in a low-risk (modelled) environment. Ultimately, the results from these scenario exercises should better inform water management and planning.

One of the scenarios suggested by the Working Group considers different ways to optimize water management in the upper SSRB. Barrier Dam, which is owned and operated by TransAlta on the upper Bow River Basin, currently has a spillway issue due to the damage that occurred from the 2013 flood (the spillway damage results in unintended releases of water from the reservoir). As a result, the reservoir is currently being operated at a lower average elevation as compared to before the flood. One of the assumptions in the model, based on the TransAlta Agreement, is to include the average elevations of the TransAlta reservoirs over the past five years due to changes in their operations since 2015, and assumes continued operations under those conditions going forward. Future work would be to include updated average elevations, supplied by TransAlta, that align with their current operations of the Barrier Dam. However, this is dependent on when TransAlta repairs the spillway.

Another recommendation suggested by the Working Group is to perform a historical data validation exercise, which is common when developing models. This would take historical hydrology (natural flows) and a sub-set of impairments (specifically withdrawals and returns) and then overlay the model's operation set. By comparing historical flows from a validation period (usually five to ten years of recent history) to the SSROM simulated flows for the same period, it is possible to statistically evaluate how well the model operations match to reality. Current datasets in SSROM are not appropriate for this effort, but future work could compile the necessary datasets and integrate them into the platform to perform this analysis. It is not known if appropriate datasets exist to conduct this validation exercise; datasets needed would include historical industrial, municipal and irrigation actual use demands over the historical period of interest, historical actual data from dam and reservoir operations, as well as corresponding irrigated acres and crop mixes of the time period.

Working Group participants identified other scenarios where 'what-if' analysis would be beneficial, which include:

- Assisting in developing a drought management plan for the City of Calgary.
- Looking at different ways to optimize water management in the upper SSRB.
- Assessing various options for rural and economic development in a closed system.
- Evaluating ecosystem health within the context of new irrigation development.

During the last Working Group meeting, participants were asked to suggest future modelling opportunities which would leverage the strengths of the SSROM. There were several recommendations for future modelling, including:

- Running more "what-if" scenarios in the SSROM to demonstrate that there is collaborative water management occurring, and that this collaboration is important in the SSRB. The SSROM could be leveraged to understand how future potential decisions made by the Canada Water Agency could impact operations of the SSRB. This could include impacts to water availability in the region, drought management planning or future expansion of irrigation.
- Showing how much small hydropower can be generated by leveraging hydropower generation on irrigation canals.
- Testing the impacts of policy changes in the SSRB, such as water reuse, changes in return flow provisions on water licences, changing WCOs, etc. to support updating the *Approved Water Management Plan for the SSRB*.
- Assessing the potential impact of climate change on the SSRB, including looking at earlier snow melt, increased precipitation as rain and decreased precipitation as snow, and potentially larger demands from the irrigation districts due to longer, warmer growing seasons and different cropping patterns.
- Assessing the potential to increase canal capacity from the Waterton Reservoir to the St. Mary Reservoir. Currently, it is understood that the canal capacity from the Waterton Reservoir to the St. Mary Reservoir is insufficient. The SSROM could be used to determine what size of canal would be appropriate to increase water transfers to the St. Mary system.

The newly updated SSROM provides various opportunities to implement 'what if' scenarios and to leverage PMs to visualize changes and impacts in the SSRB. The model provides a foundation to build on historic water management planning in the SSRB and to implement increased collaborative, well-informed water management planning in the SSRB.

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Appendix B Contact information

- GoA – Anil Gupta; anil.gupta@gov.ab.ca
- WaterSMART – Kim Sturgess; kim.sturgess@watersmartsolutions.ca

Appendix C 2018 crop mix and irrigated acres; 2020 assessed acres

The information in Table 6 reflects the change in irrigation acres across all irrigation districts between 2018 and 2020. Information from 2018 is from the Irrigation Demand Model (IDM) data provided by AAFRED. Unless otherwise indicated the 2020 acres represent all acres on the assessment roll as published by AAFRED in Table 4 of the 2020 Alberta Irrigation Information Report. The SSROM was updated using the 2020 assessment roll acres.

Table 6. 2018 acres from IDM and 2020 acres used to update the SSROM.

Irrigation District	2018 (IDM hectares)	2018 IDM acres	2020 assessment roll acres	Acre change	Acre change (%)
BRID	100,406.70	248,109.98	279,441.00	31,331.02	12.6
EID	122,940.70	303,792.62	307,588.00	3,795.38	1.2
WID	36,755.98	90,825.86	95,000.00*	4,174.14	4.6
AID	1,903.65	4,704.01	4,698.00	-6.01	-0.1
LID	2,035.83	5,030.63	5,365.00	334.37	6.6
LNID	75,717.98	187,102.91	195,063.00	7,960.09	4.3
MID	7,417.89	18,329.97	18,300.00	-29.97	-0.2
MVID	1,482.30	3,662.83	3,647.00	-15.83	-0.4
RCID	363.00	897.00	1,091.00	194.00	21.6
RID	18,356.66	45,360.22	48,095.00	2,734.78	6.0
SMRID	156,166.00	385,893.99	410,772.00	24,878.01	6.4
TID	32,934.13	81,381.88	90,347.00	8,965.12	11.0
UID	13,893.94	34,332.62	34,797.00	464.38	1.4

**Information provided by Western Irrigation District*

The SSROM was updated using the crop mixes noted in Table 7. This information was provided by AAFRED and reflects the crop mixes used in the IDM model runs.

Table 7. Crop mixes used in IDM data and integrated into the SSROM.

	Crop Type					
	Cereals	Forages	Others	Oil Seeds	Specialty Crops	TOTAL
BRID	40%	16%	0%	7%	36%	100%
EID	30%	41%	1%	10%	18%	100%
WID	29%	43%	1%	19%	8%	100%
AID	31%	64%	2%	2%	0%	100%
LID	5%	76%	19%	0%	0%	100%
LNID	22%	56%	1%	16%	4%	100%
MID	31%	47%	0%	17%	4%	100%
MVID	8%	85%	0%	4%	3%	100%
RCID	7%	93%	0%	0%	0%	100%
RID	30%	48%	0%	16%	5%	100%
SMRID	34%	25%	16%	1%	24%	100%
TID	33%	25%	0%	3%	39%	100%
UID	32%	42%	1%	20%	4%	100%

Appendix D Reservoir operations in the SSROM

Red Deer River Basin

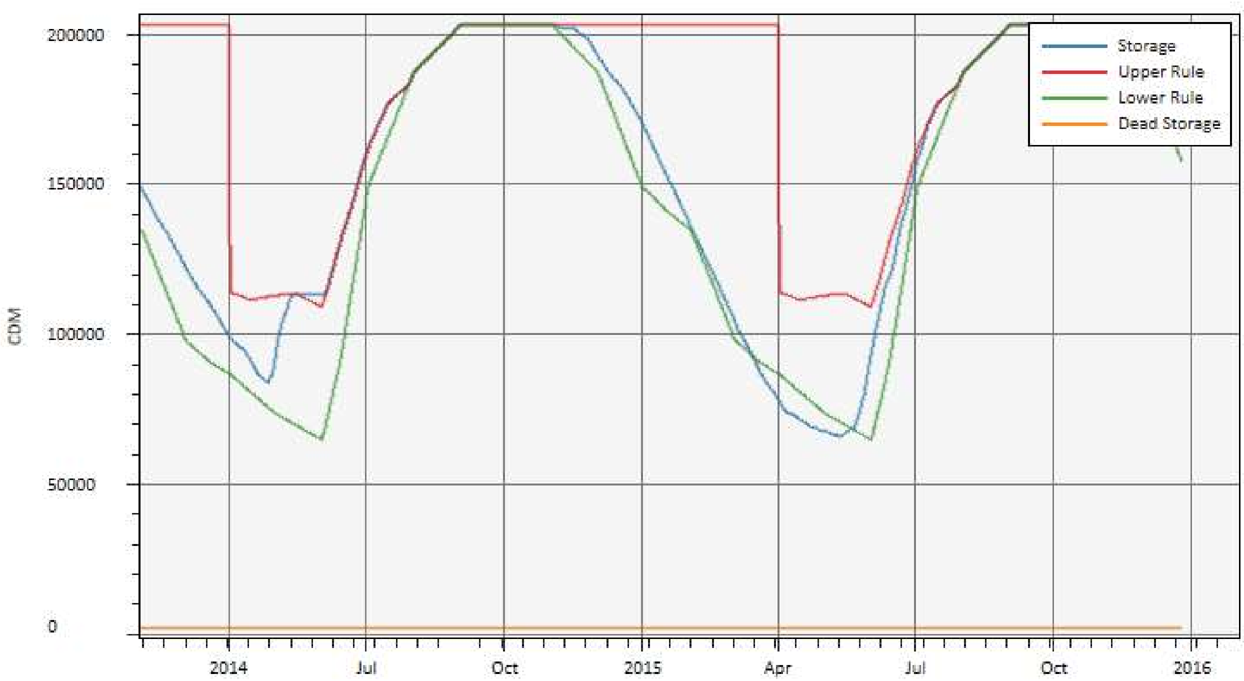

Figure 40. Simulated storage and rule curves implemented in the SSROM for Gleniffer Reservoir (model label: Gleniffer).

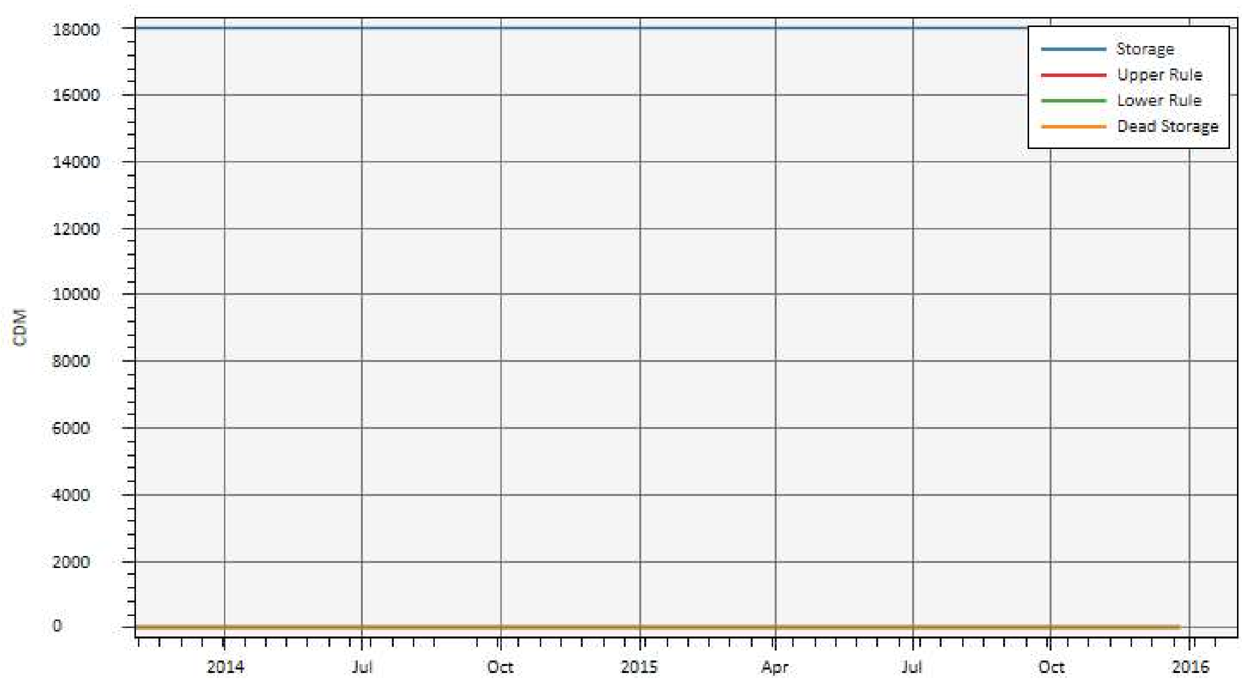

Figure 41. Simulated storage and rule curves implemented in the SSROM for Sheerness Reservoir (model label:

Sheerness Reservoir).

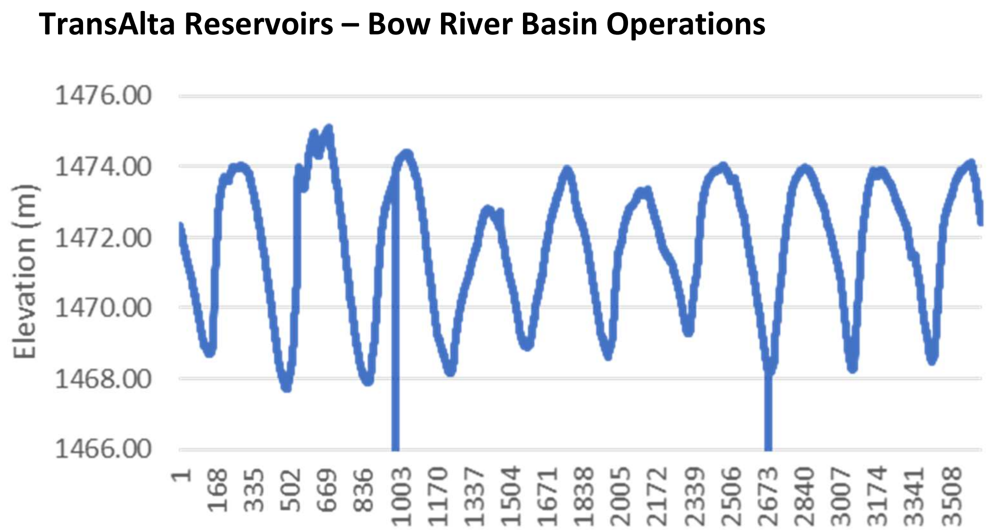

Figure 42. TransAlta normal patterns for Minnewanka Control Dam.

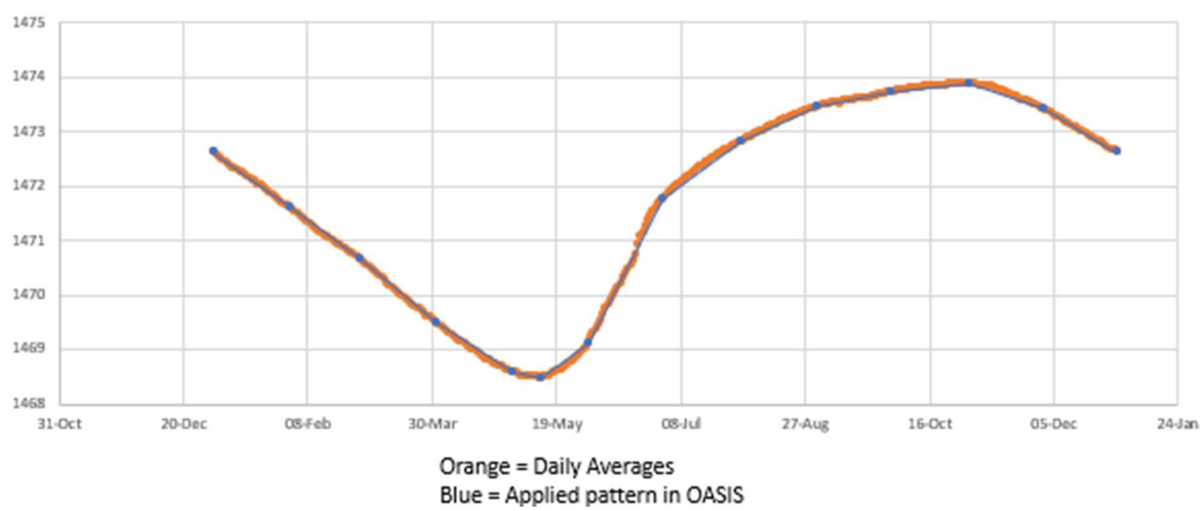

Figure 43. Minnewanka Control Dam 10-year average daily historical elevations (orange) and the resultant derived "normal pattern" (blue piecewise-linearized line with 14 fixed datapoints).

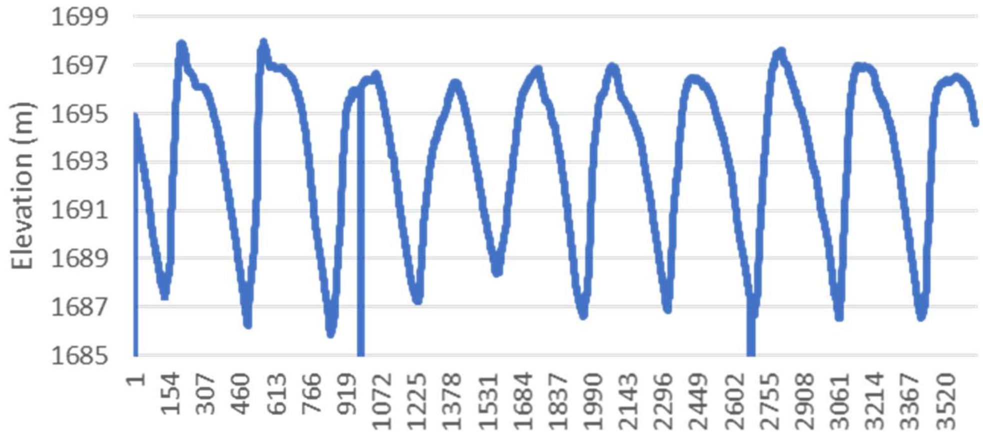

Figure 44. TransAlta normal patterns for Three Sisters (Spray) Reservoir.

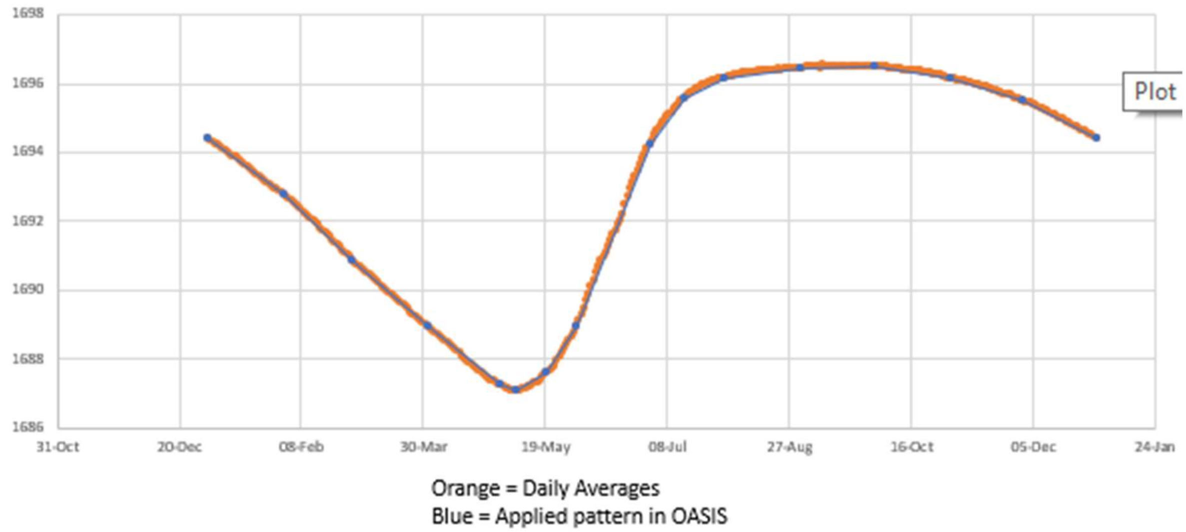

Figure 45. Three Sisters (Spray) historical elevations and the resultant derived "normal pattern".

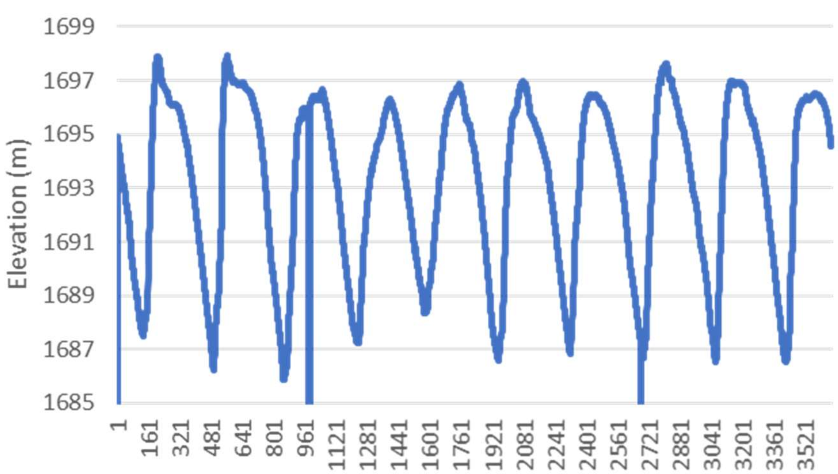

Figure 46. TransAlta normal patterns for Interlakes Reservoir.

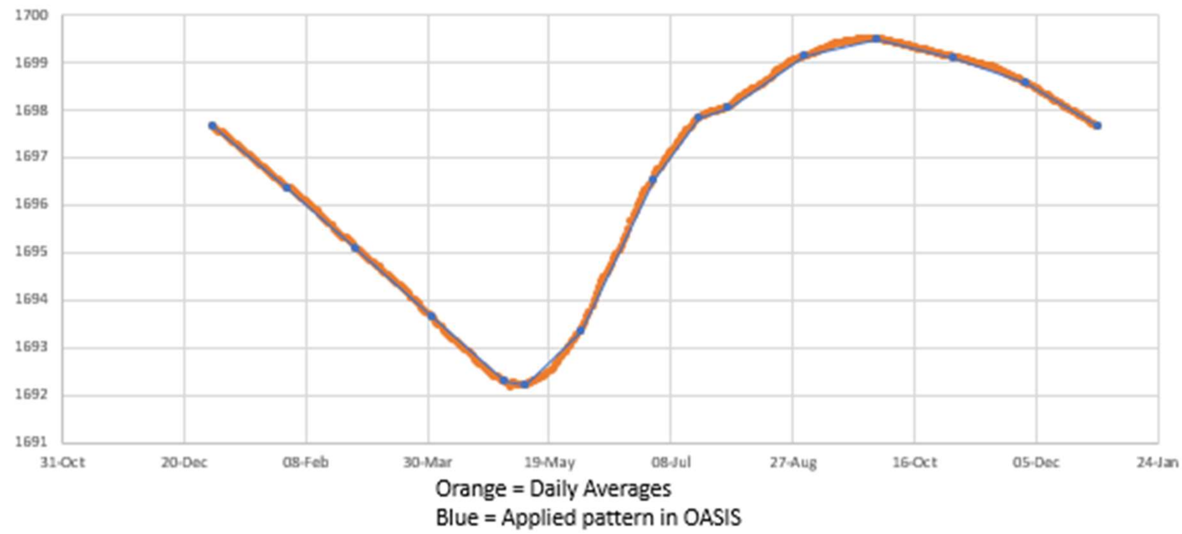

Figure 47. Interlakes Reservoir historical elevations and the resultant derived "normal pattern".

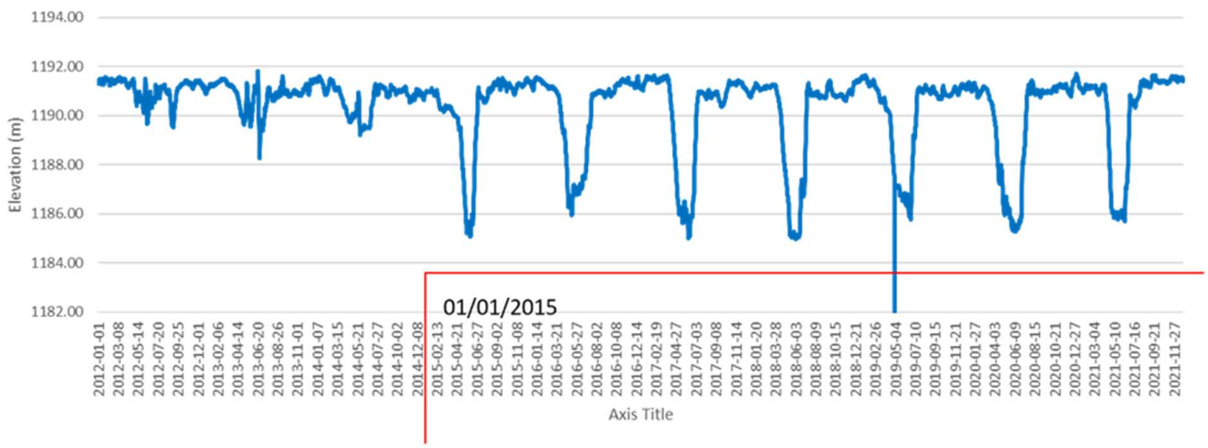

Figure 48. TransAlta normal patterns for Ghost Reservoir. Note the effect of the 2015 change in operations. For rule curve development, only this period post-2015 was considered.

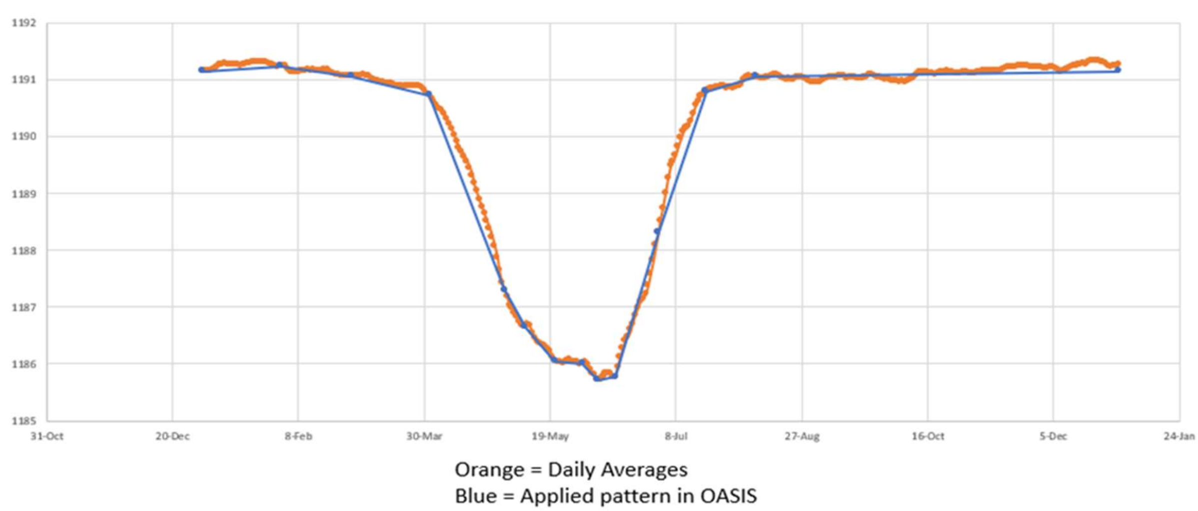

Figure 49. Ghost Reservoir historical elevations and the resultant derived "normal pattern".

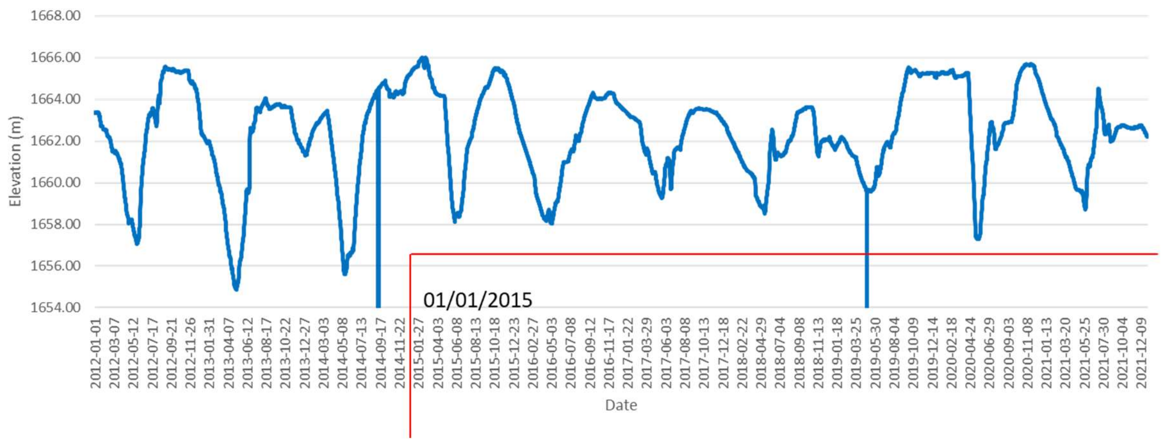

Figure 50. TransAlta normal patterns for Lower Kananaskis Reservoir. Note the effect of the 2015 change in operations. For rule curve development, only this period post-2015 was considered.

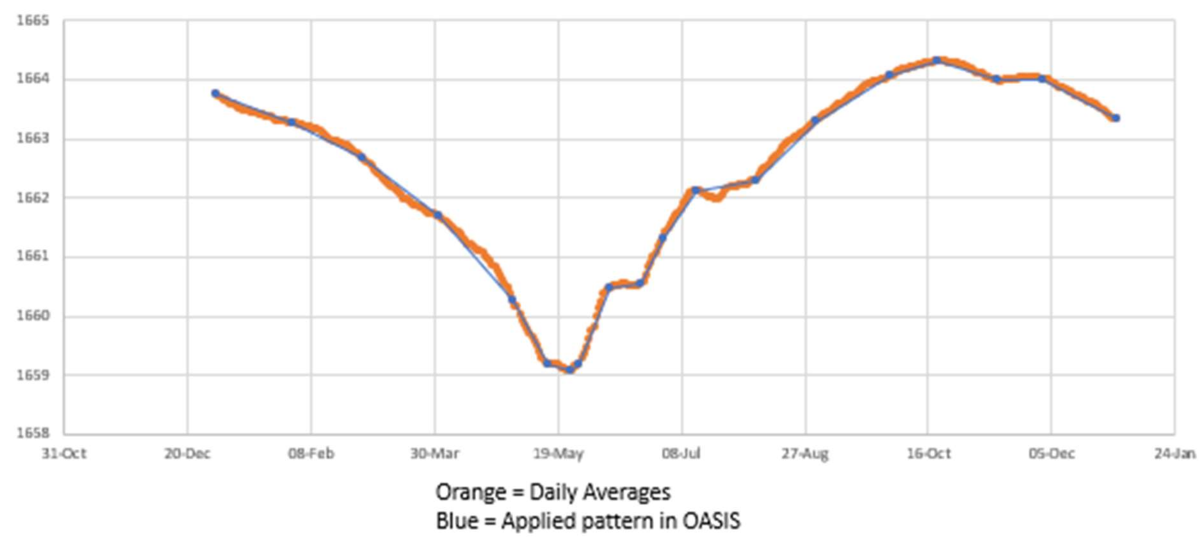

Figure 51. Pocaterra (Lower Kananaskis) historical elevations and the resultant derived "normal pattern".

Bow River Basin

Figure 52. Simulated storage and rule curves implemented in the SSROM for Glenmore Reservoir (model label: Glenmore).

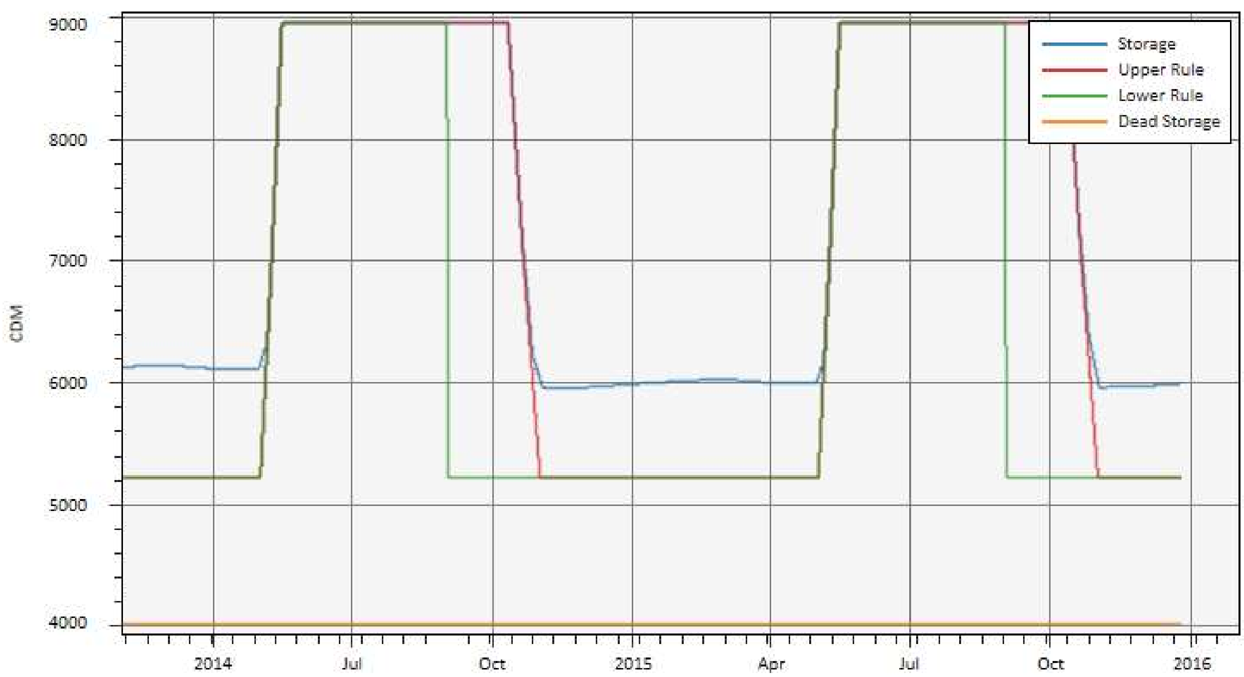

Figure 53. Simulated storage and rule curves implemented in the SSROM for Chestermere Reservoir (model label: Chestrmer).

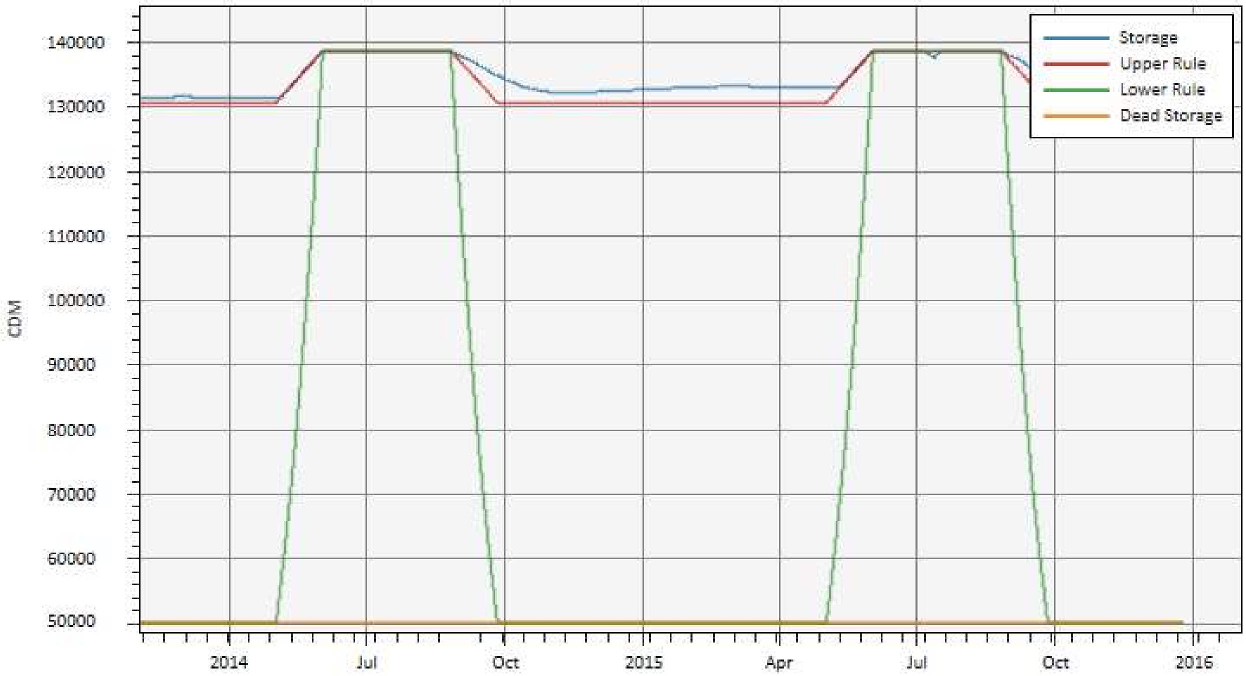

Figure 54. Simulated storage and rule curves implemented in the SSROM for Snake Reservoir (model label: Snake).

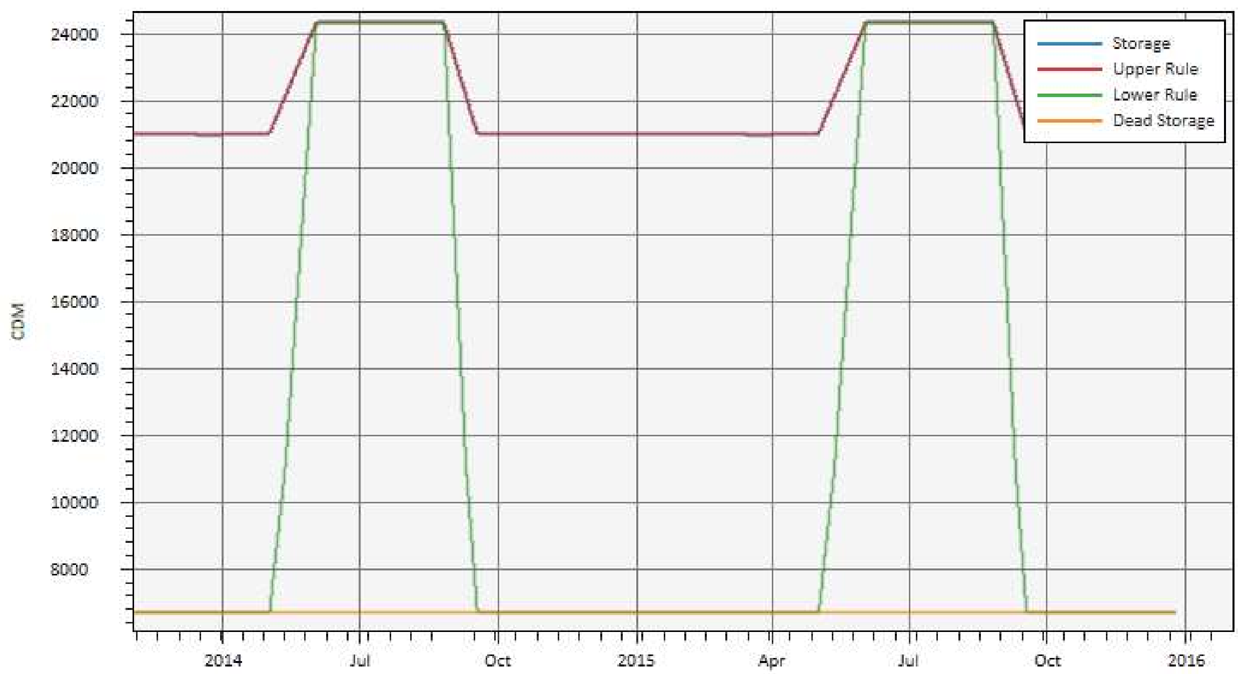

Figure 55. Simulated storage and rule curves implemented in the SSROM for Kitsim Reservoir (model label: Kitsim).

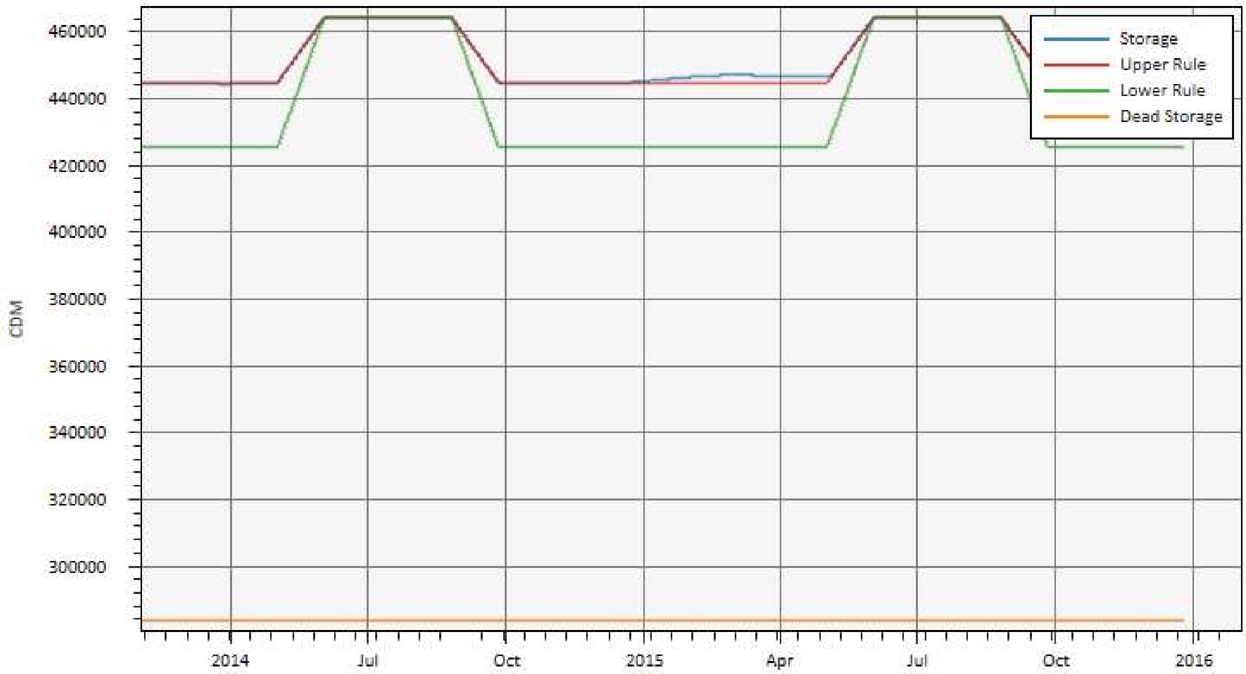

Figure 56. Simulated storage and rule curves implemented in the SSROM for Newell Reservoir (model label: Newell).

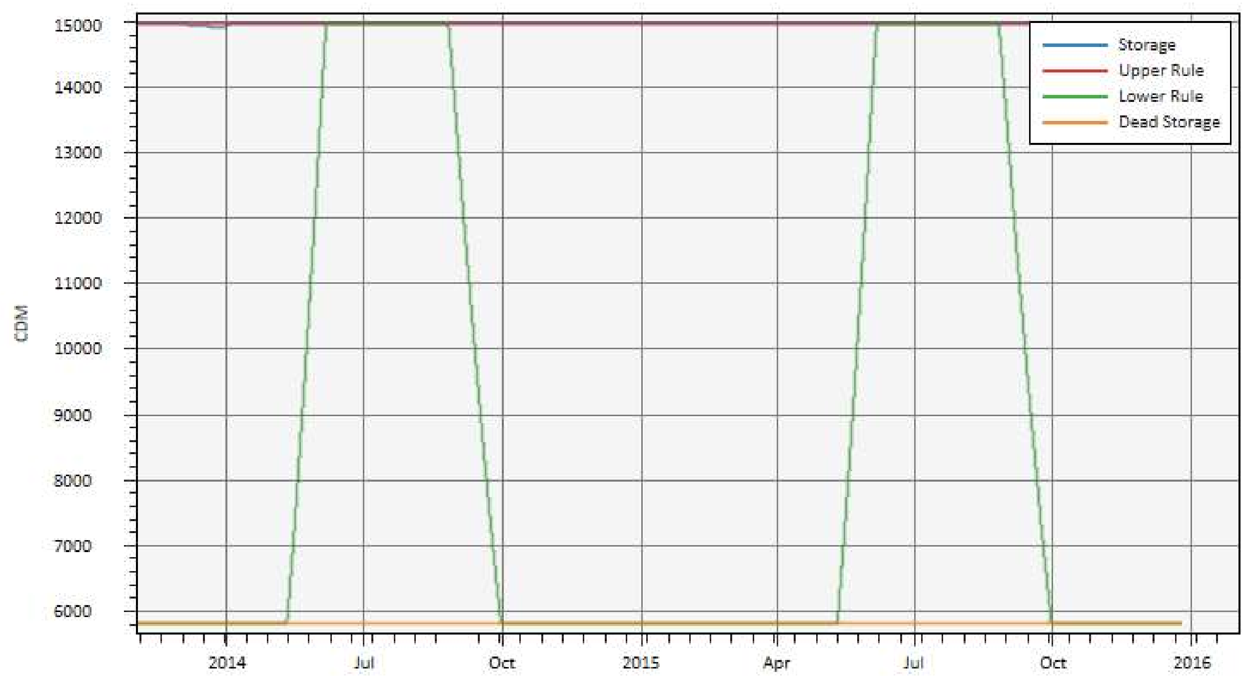

Figure 57. Simulated storage and rule curves implemented in the SSROM for Cowoki Reservoir (model label: Cowocki).

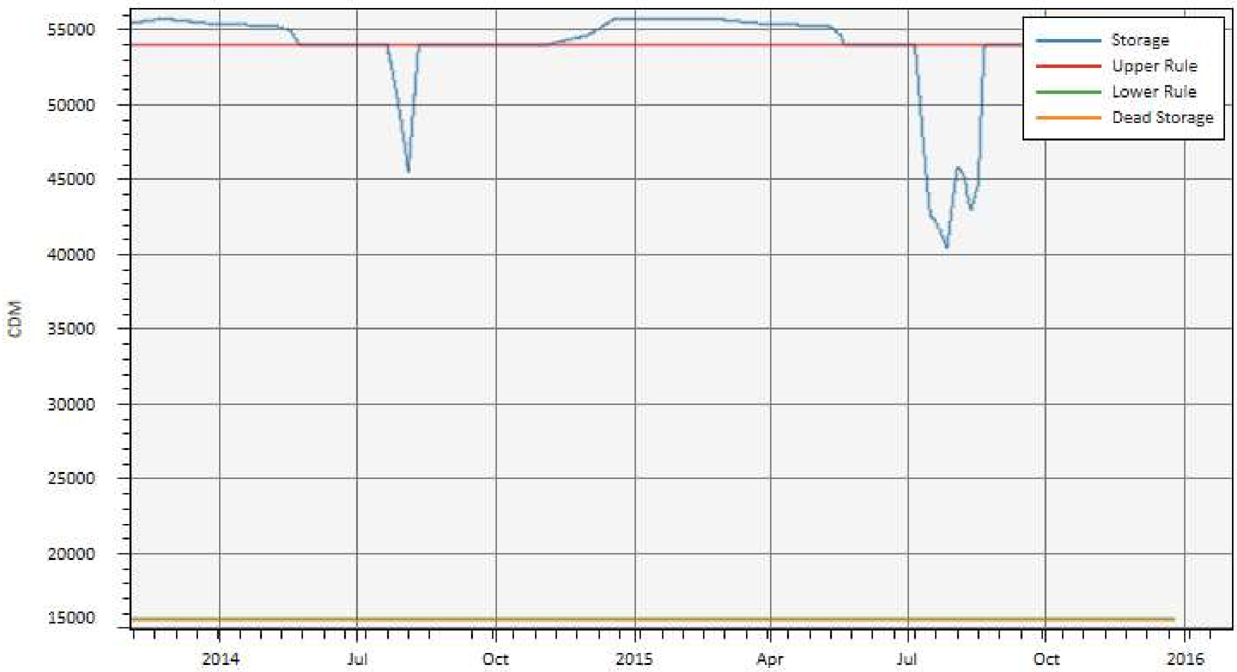

Figure 58. Simulated storage and rule curves implemented in the SSROM for Rolling Hills Reservoir (model label: Rolling Hills).

Oldman River Basin

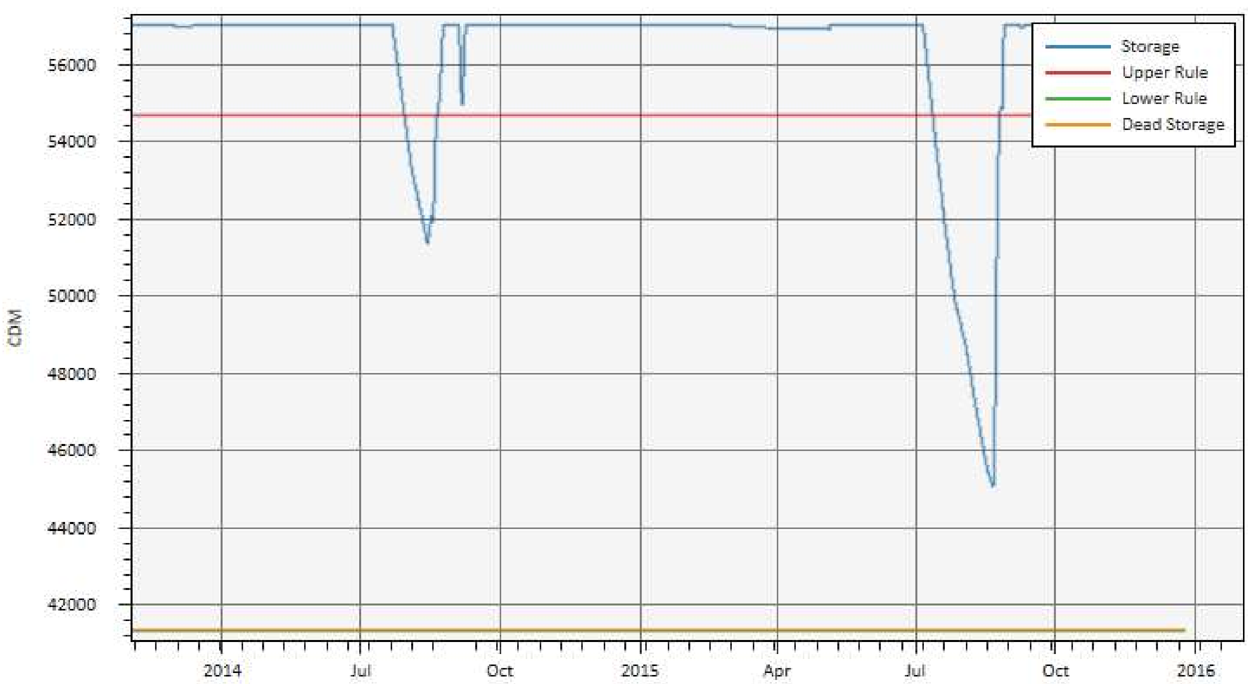

Figure 59. Simulated storage and rule curves implemented in the SSROM for Badger Reservoir (model label: Badger).

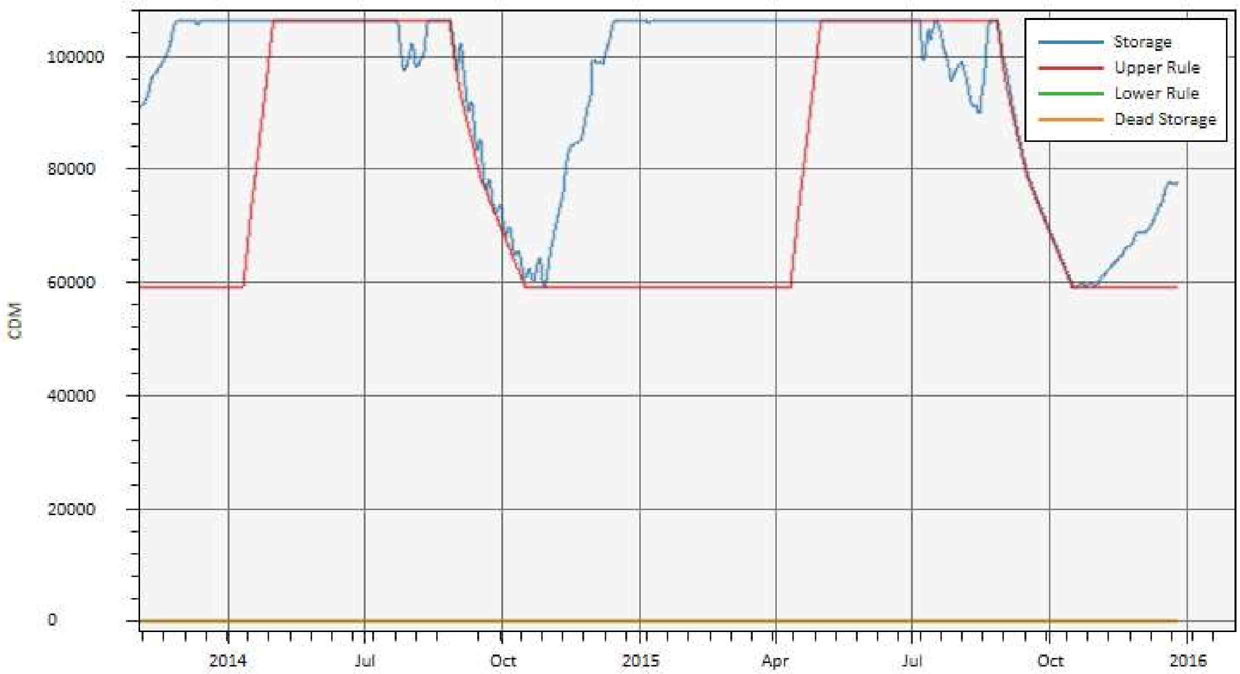

Figure 60. Simulated storage and rule curves implemented in the SSROM for Travers Reservoir (model label: Travers).

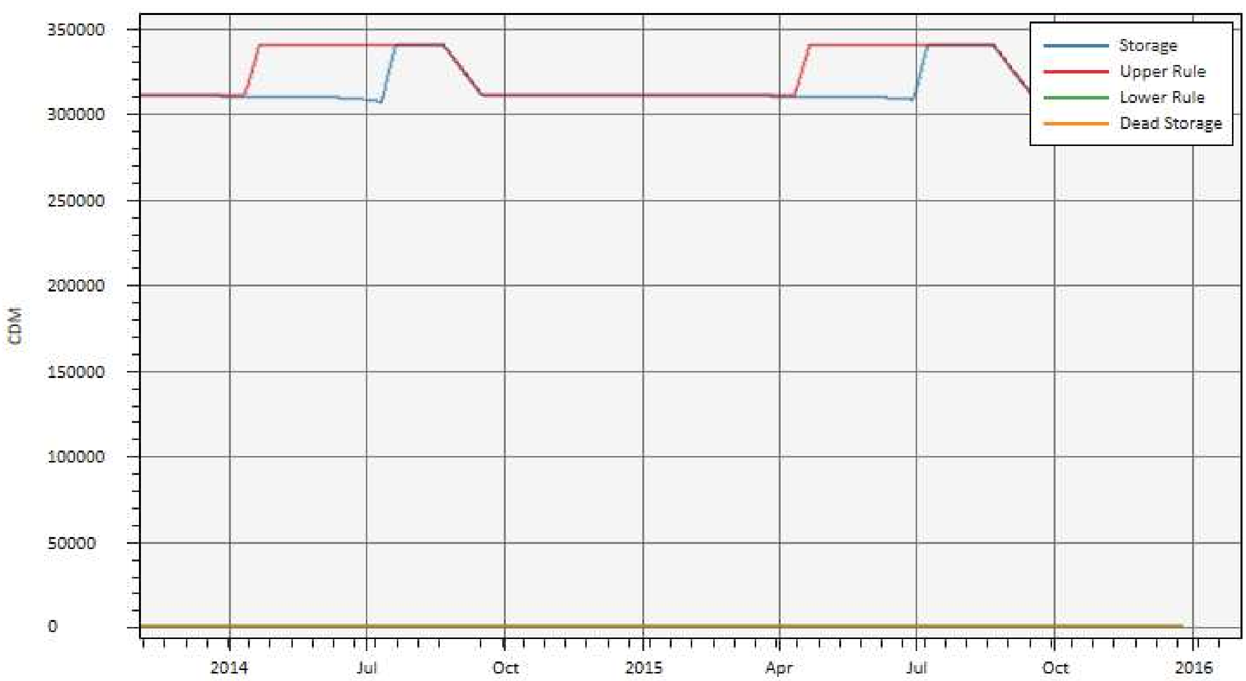

Figure 61. Simulated storage and rule curves implemented in the SSROM for McGregor Reservoir (model label: McGregor).

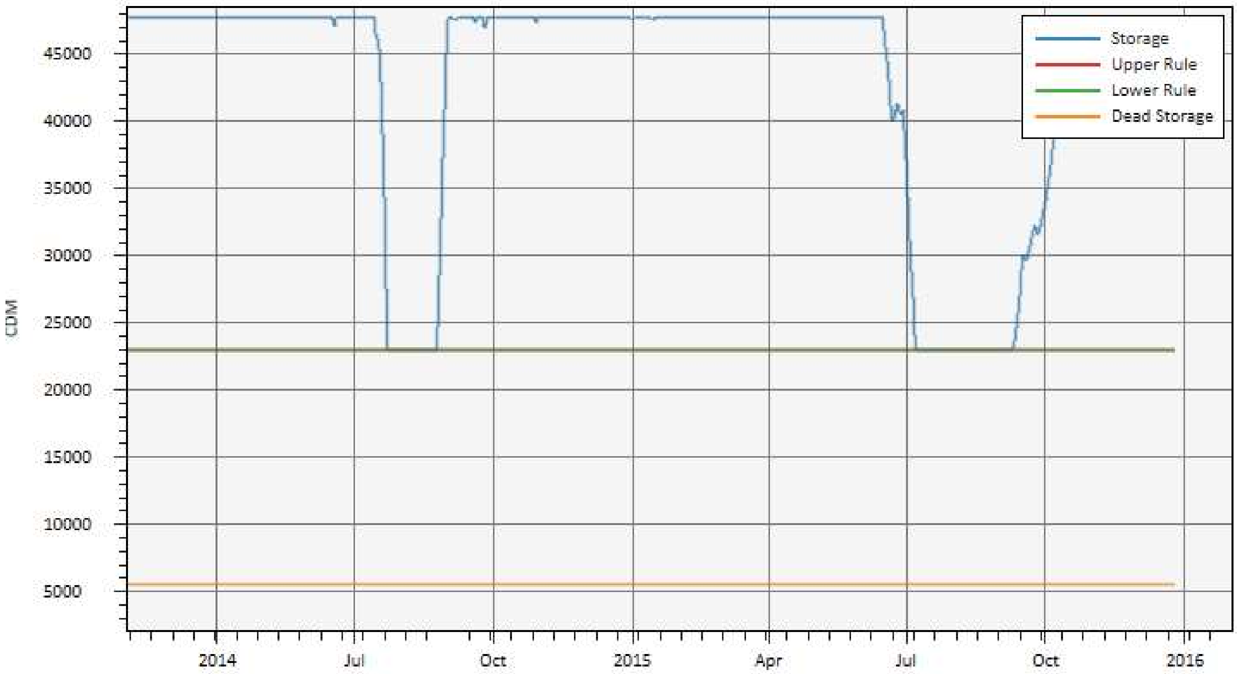

Figure 62. Simulated storage and rule curves implemented in the SSROM for Little Bow Reservoir (model label: LilBow).

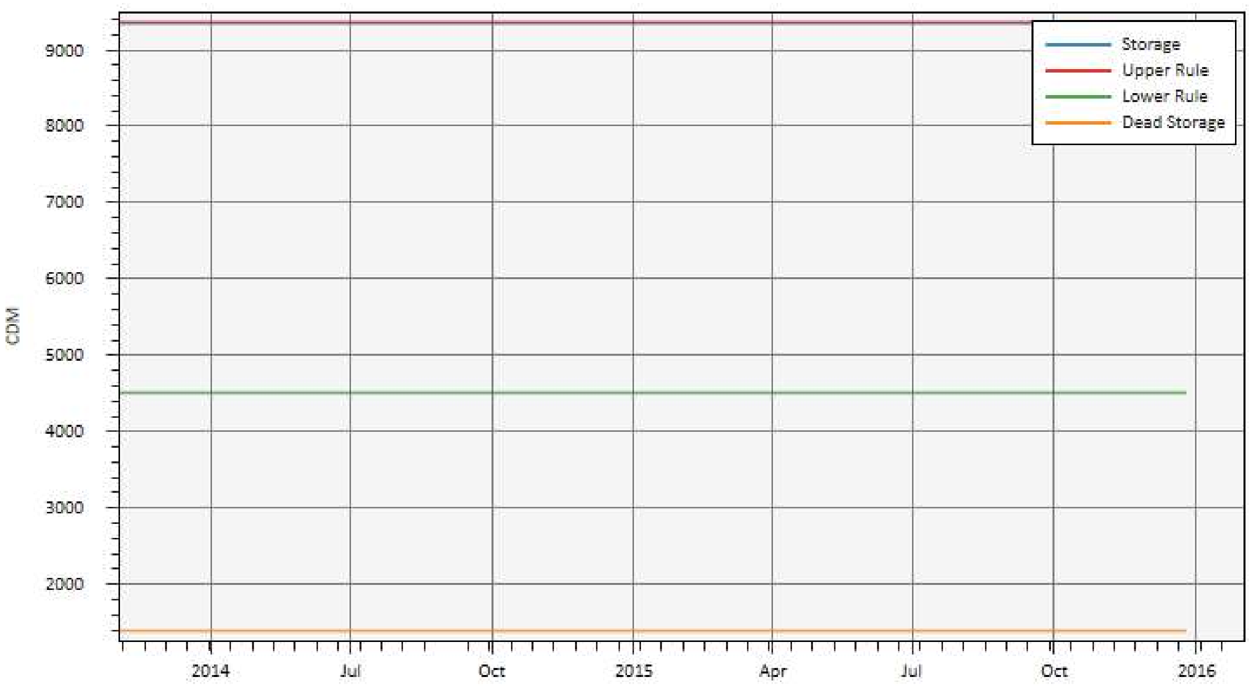

Figure 63. Simulated storage and rule curves implemented in the SSROM for Lost Lake Reservoir (model label: LostLk).

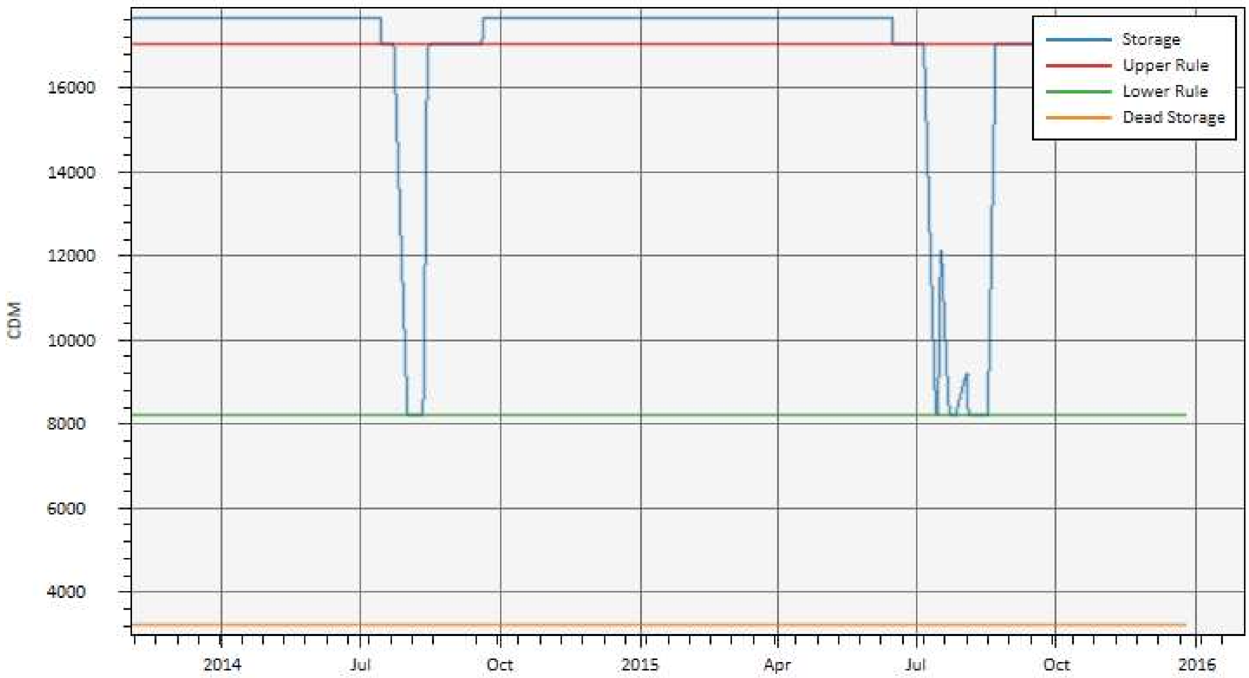

Figure 64. Simulated storage and rule curves implemented in the SSROM for Scope Reservoir (model label: Scope).

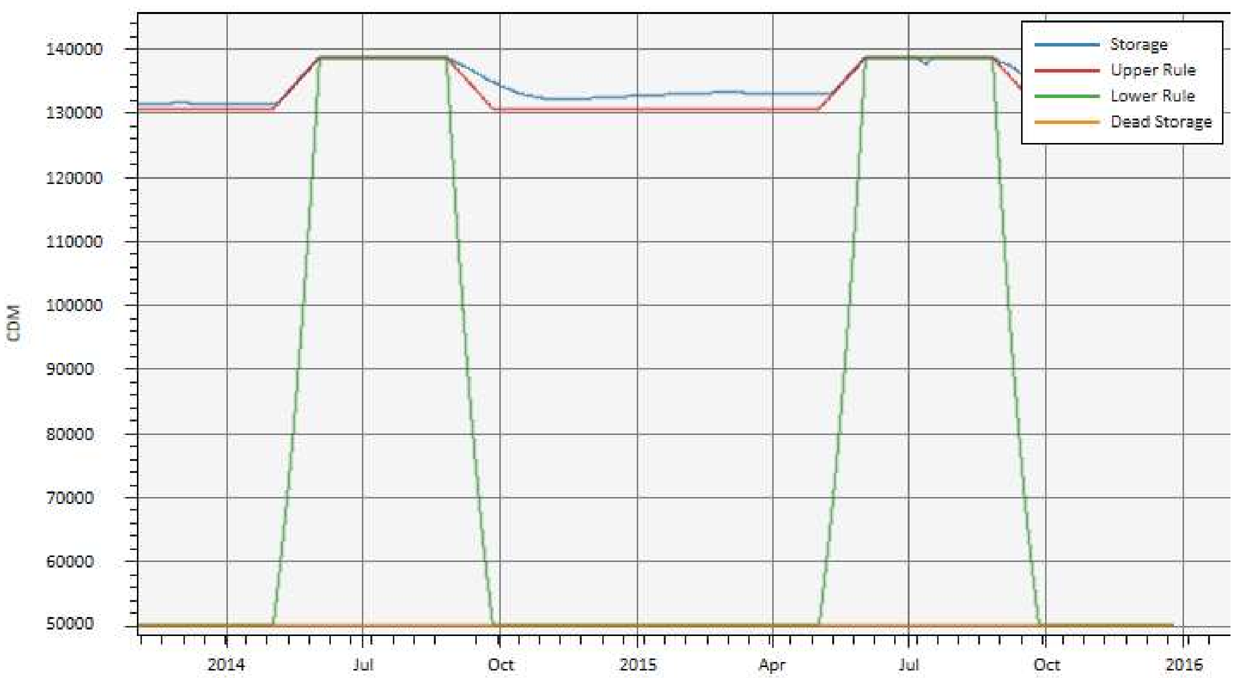

Figure 65. Simulated storage and rule curves implemented in the SSROM for Crawling Valley Reservoir (model label: CrawlV).

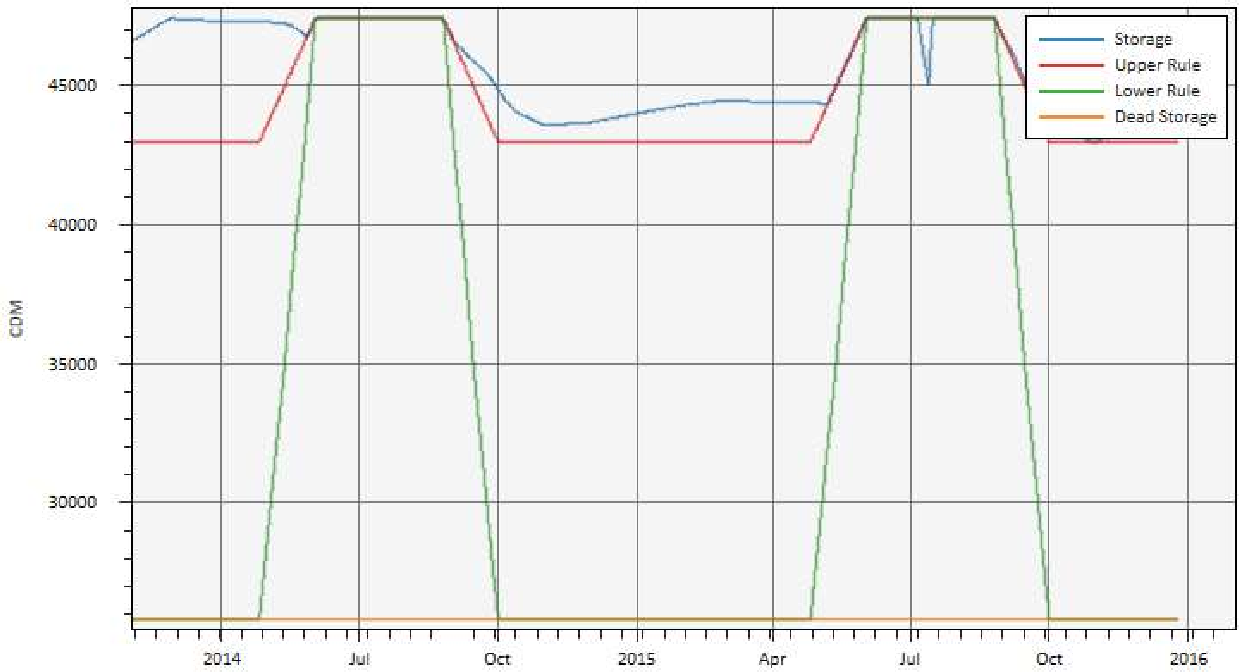

Figure 66. Simulated storage and rule curves implemented in the SSROM for Tilley B Reservoir (model label: Tilley B).

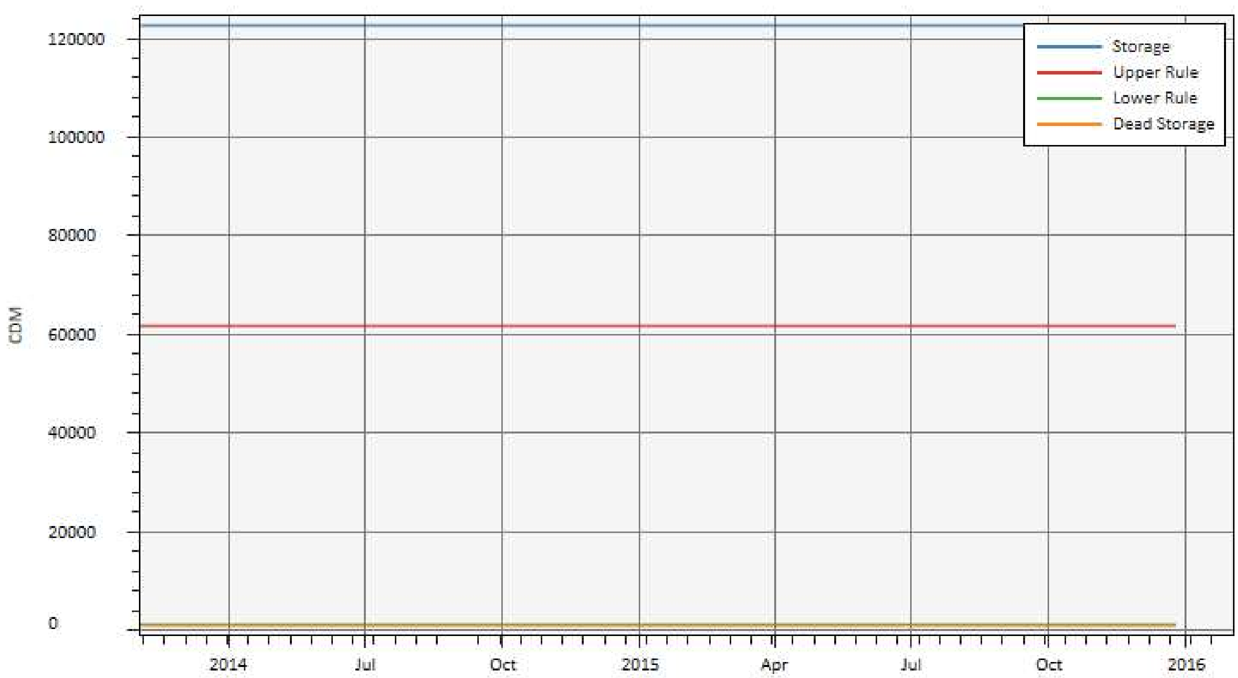

Figure 67. Simulated storage and rule curves implemented in the SSROM for Twin Valley Reservoir (model label: Twin.V.Res).

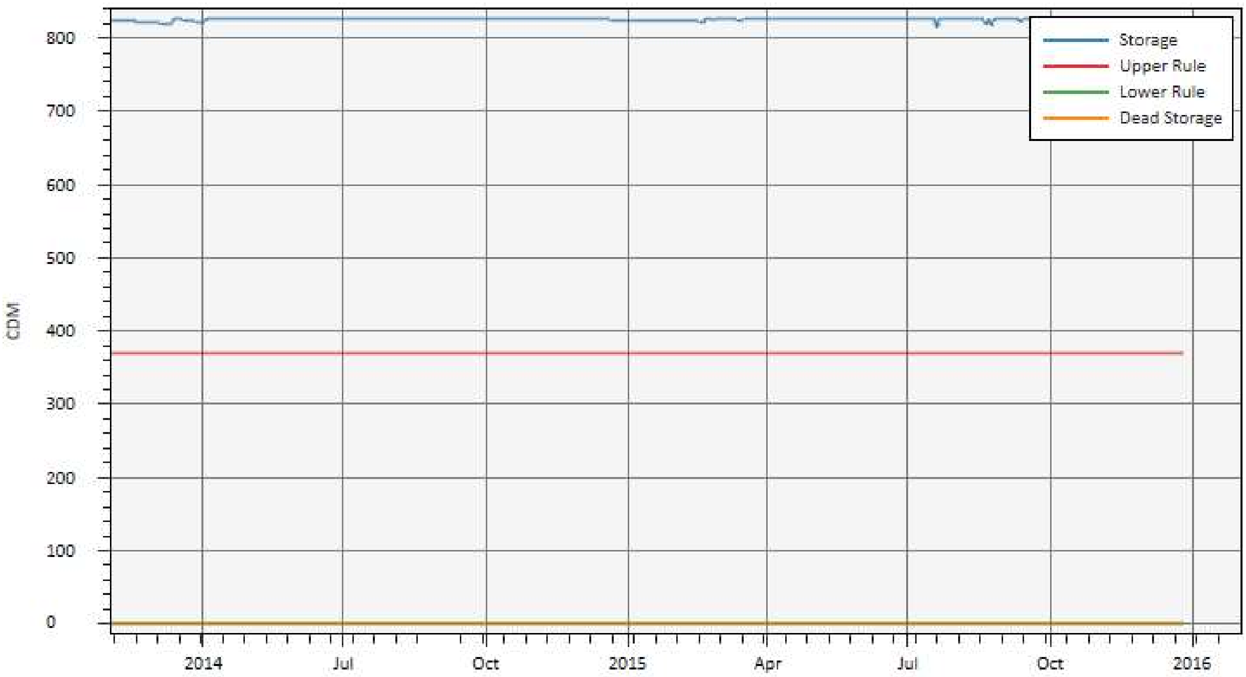

Figure 68. Simulated storage and rule curves implemented in the SSROM for Women's Coulee Reservoir (model label: Wom.Coulee).

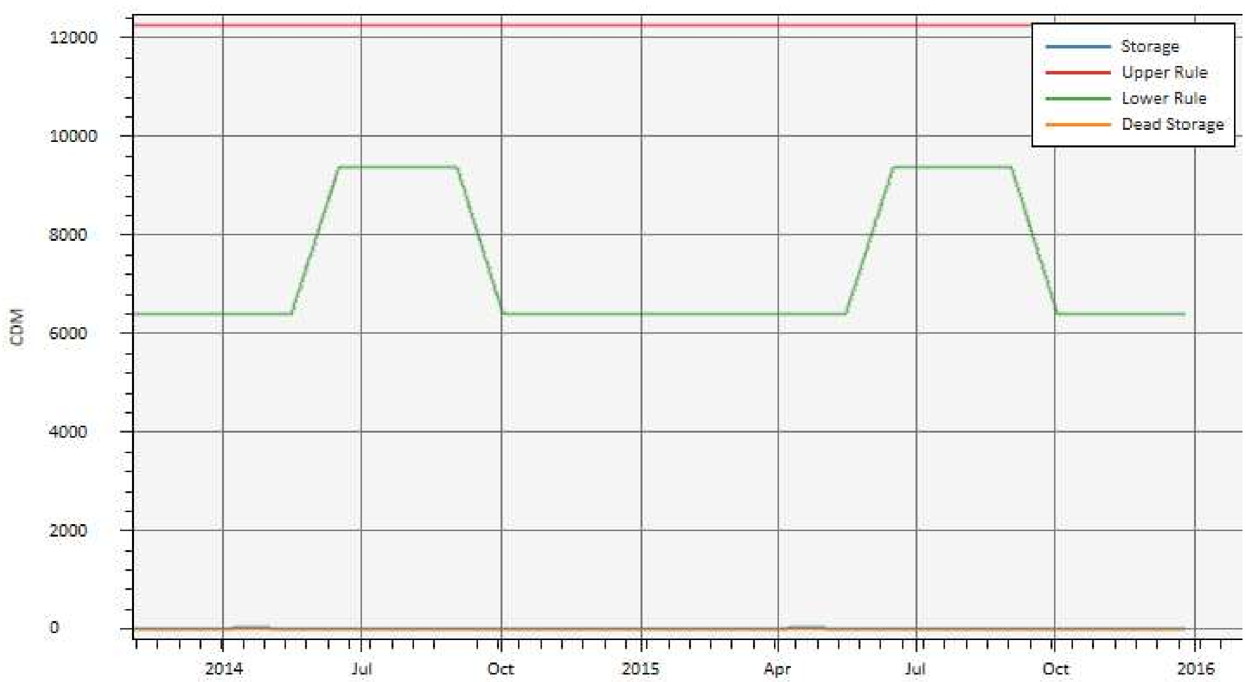

Figure 69. Simulated storage and rule curves implemented in the SSROM for Clear Lake Reservoir (model label: Clear Lk).

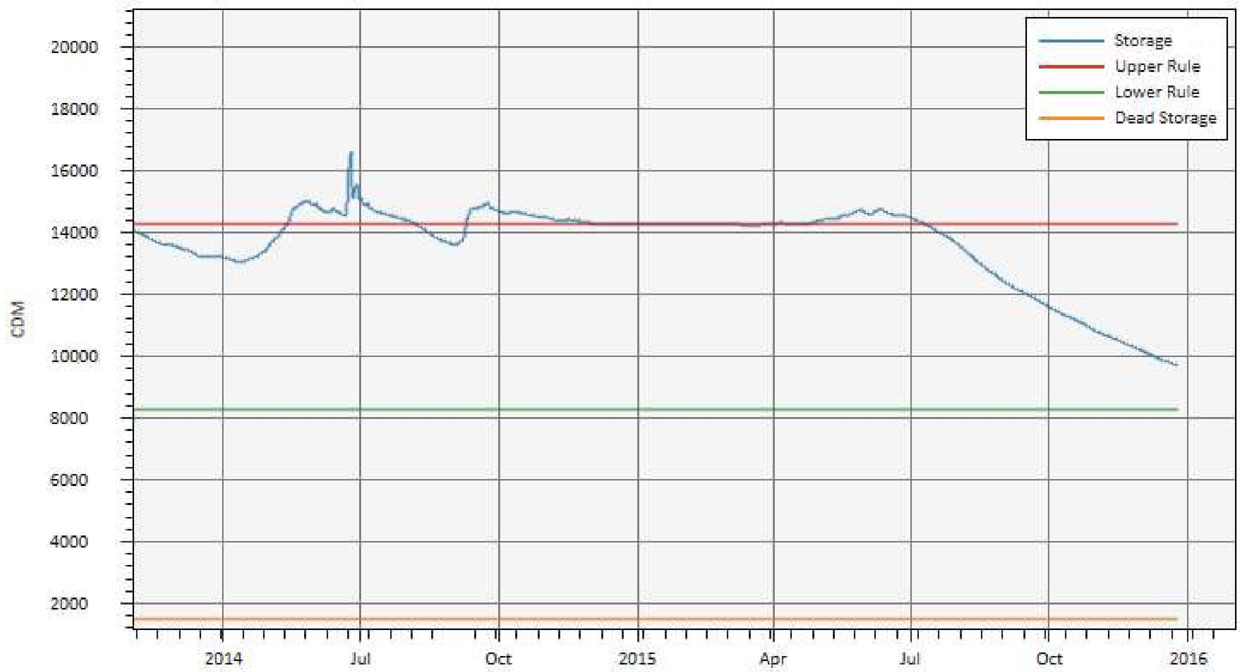

Figure 70. Simulated storage and rule curves implemented in the SSROM for Chain Lakes Reservoir (model label: ChainLk).

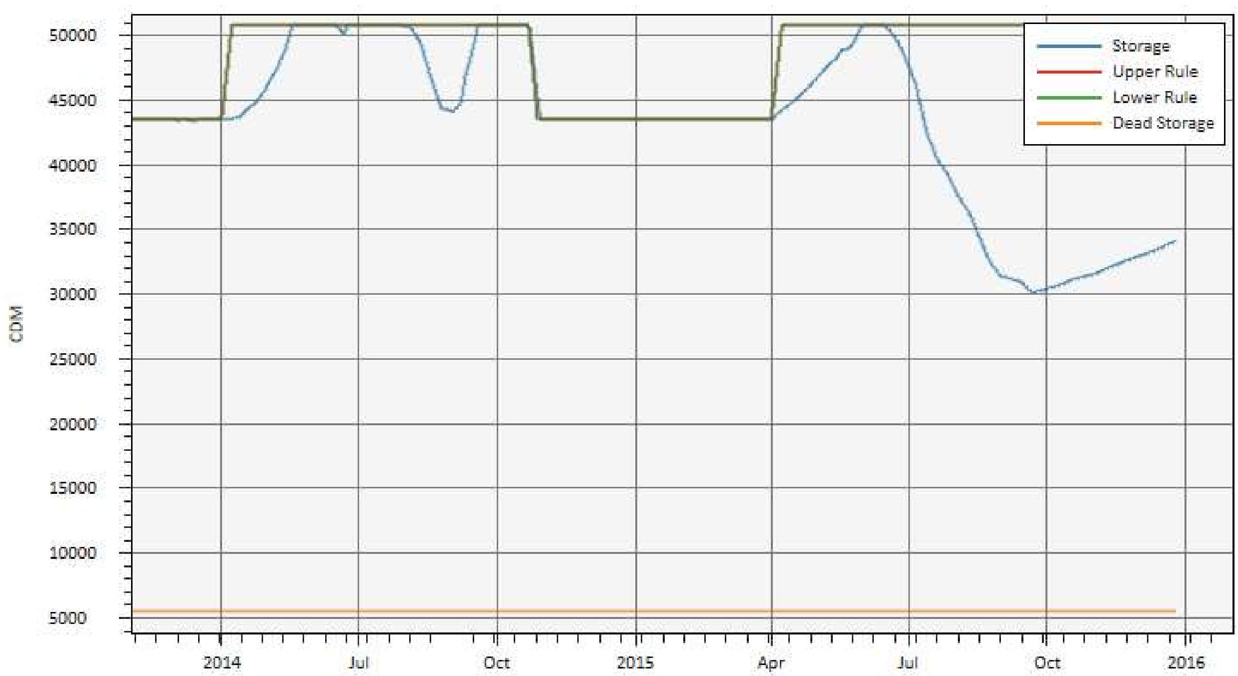

Figure 71. Simulated storage and rule curves implemented in the SSROM for Pine Coulee Reservoir (model label: Pine Coulee).

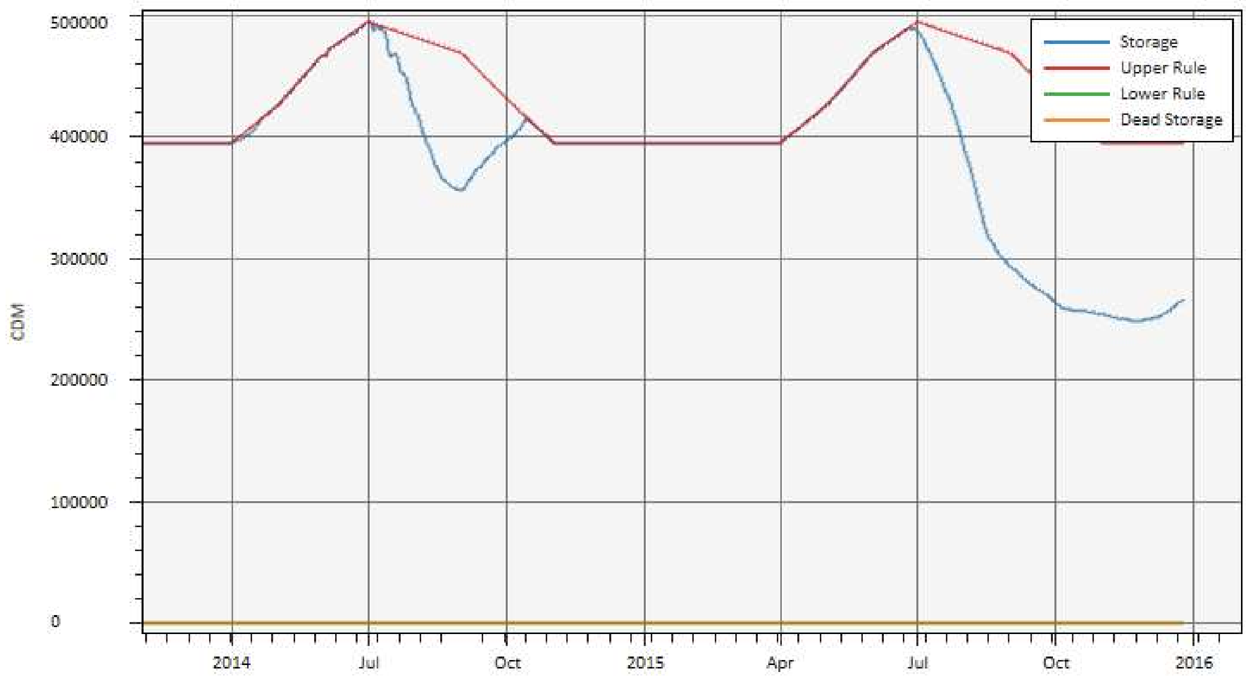

Figure 72. Simulated storage and rule curves implemented in the SSROM for Oldman Reservoir (model label: Oldman).

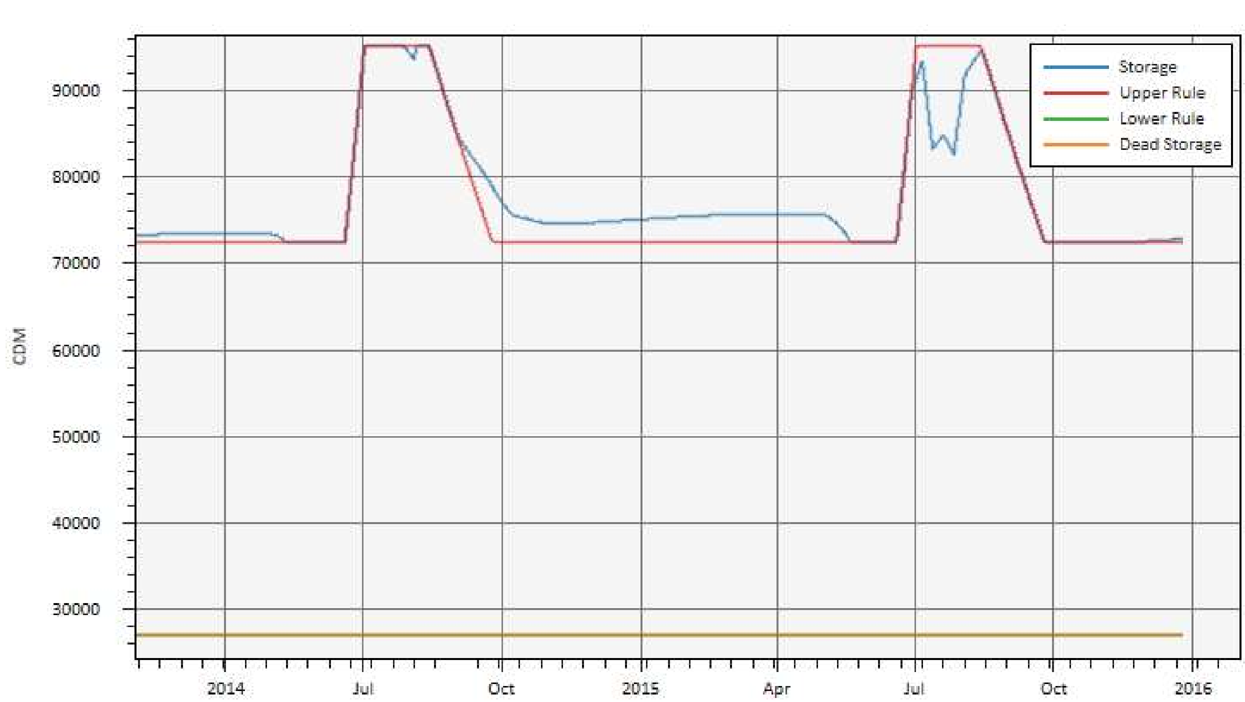

Figure 73. Simulated storage and rule curves implemented in the SSROM for Keho Reservoir (model label: Keho).

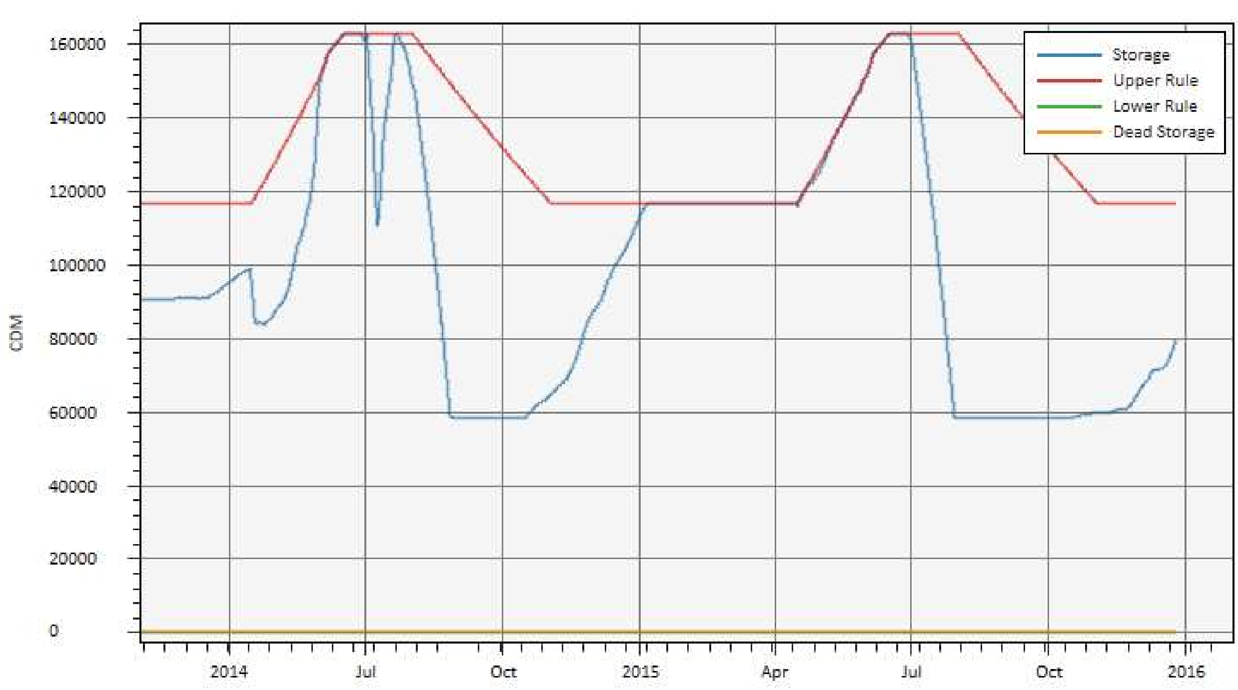

Figure 74. Simulated storage and rule curves implemented in the SSROM for Waterton Reservoir (model label: Waterton).

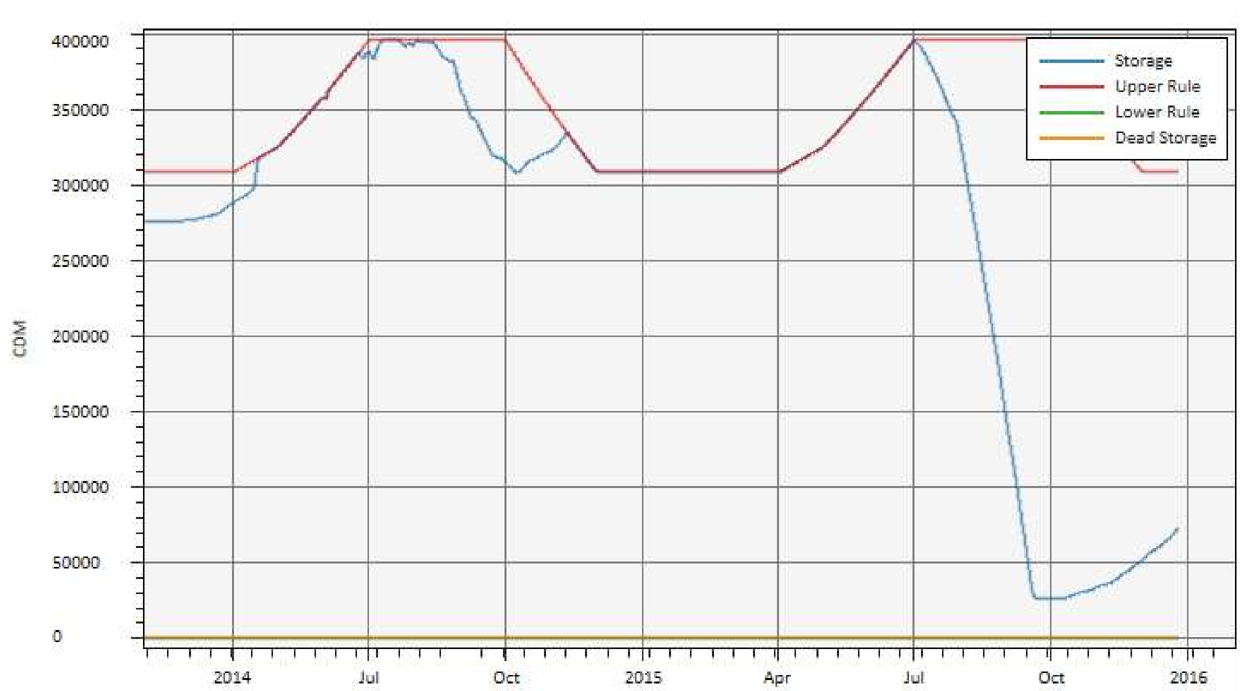

Figure 75. Simulated storage and rule curves implemented in the SSROM for St. Mary Reservoir (model label: StMary).

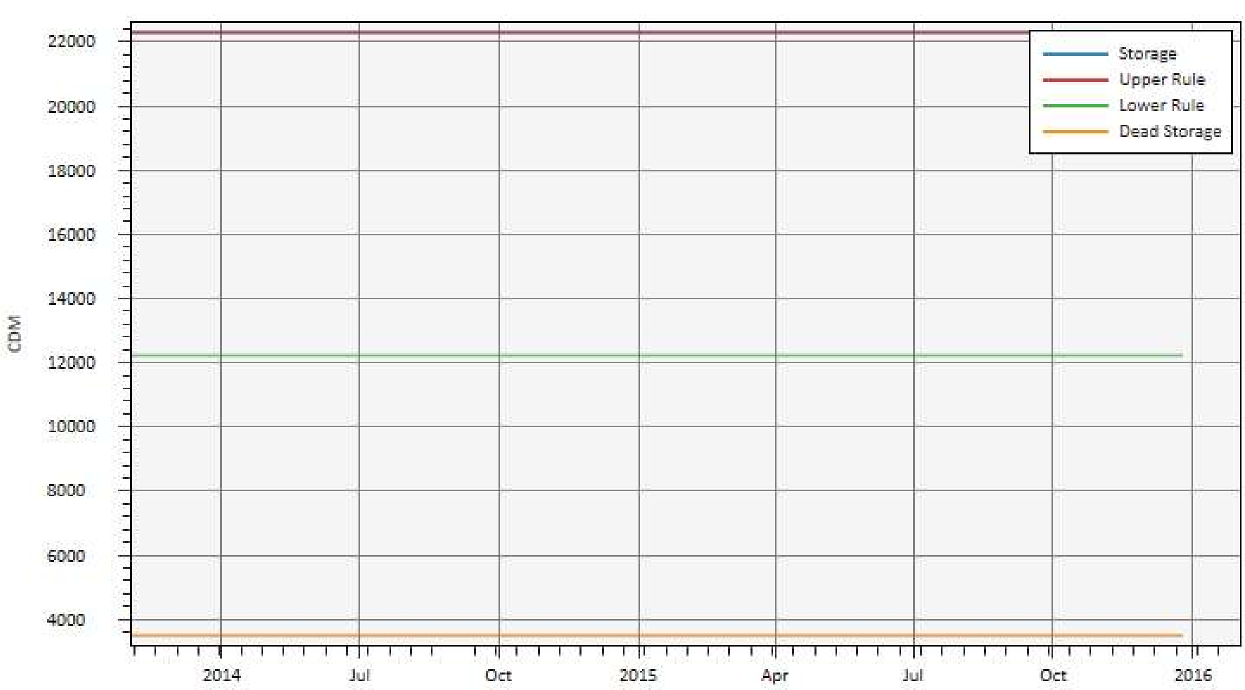

Figure 76. Simulated storage and rule curves implemented in the SSROM for Jensen Reservoir (model label: Jensen reservoir).

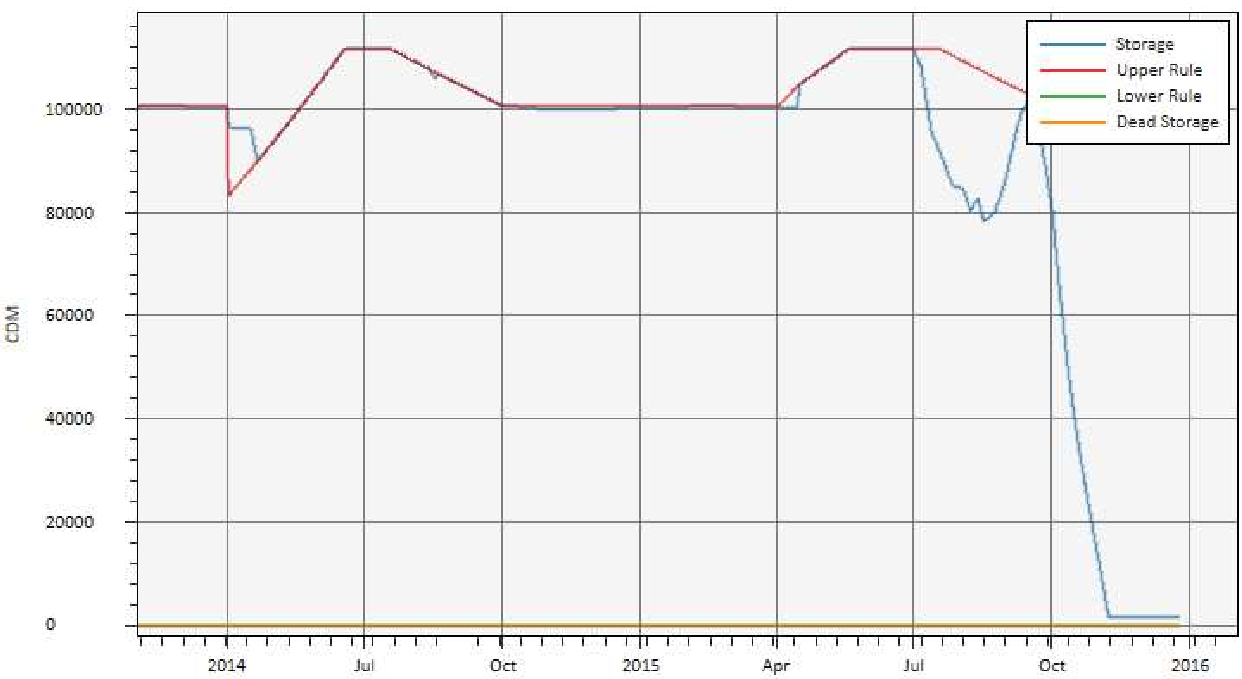

Figure 77. Simulated storage and rule curves implemented in the SSROM for Milk River Ridge Reservoir (model label: Ridge).

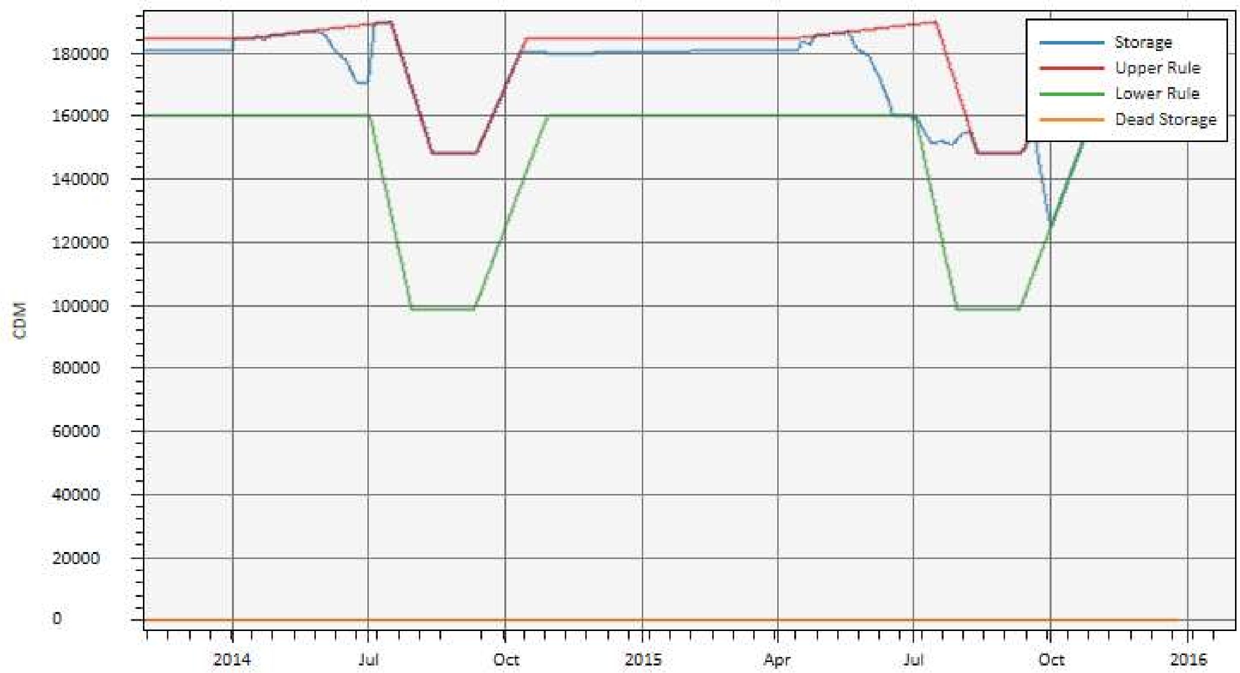

Figure 78. Simulated storage and rule curves implemented in the SSROM for Chin Reservoir (model label: Chin).

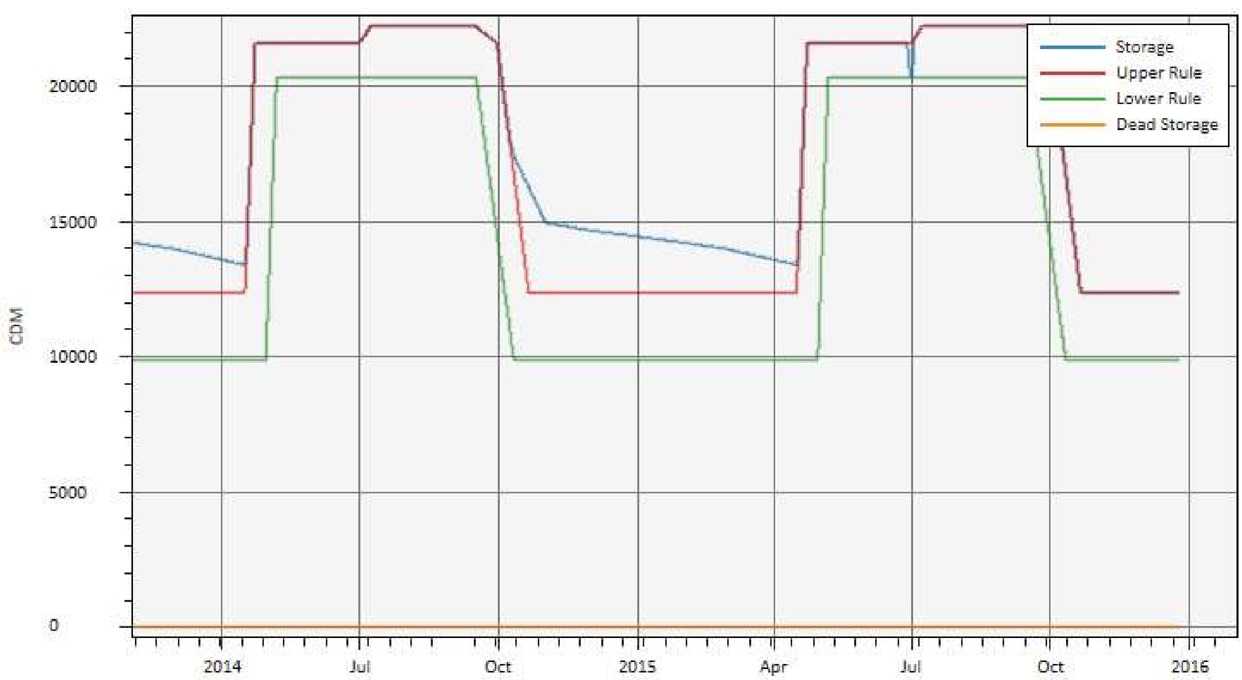

Figure 79. Simulated storage and rule curves implemented in the SSROM for Stafford Reservoir (model label: Stafford).

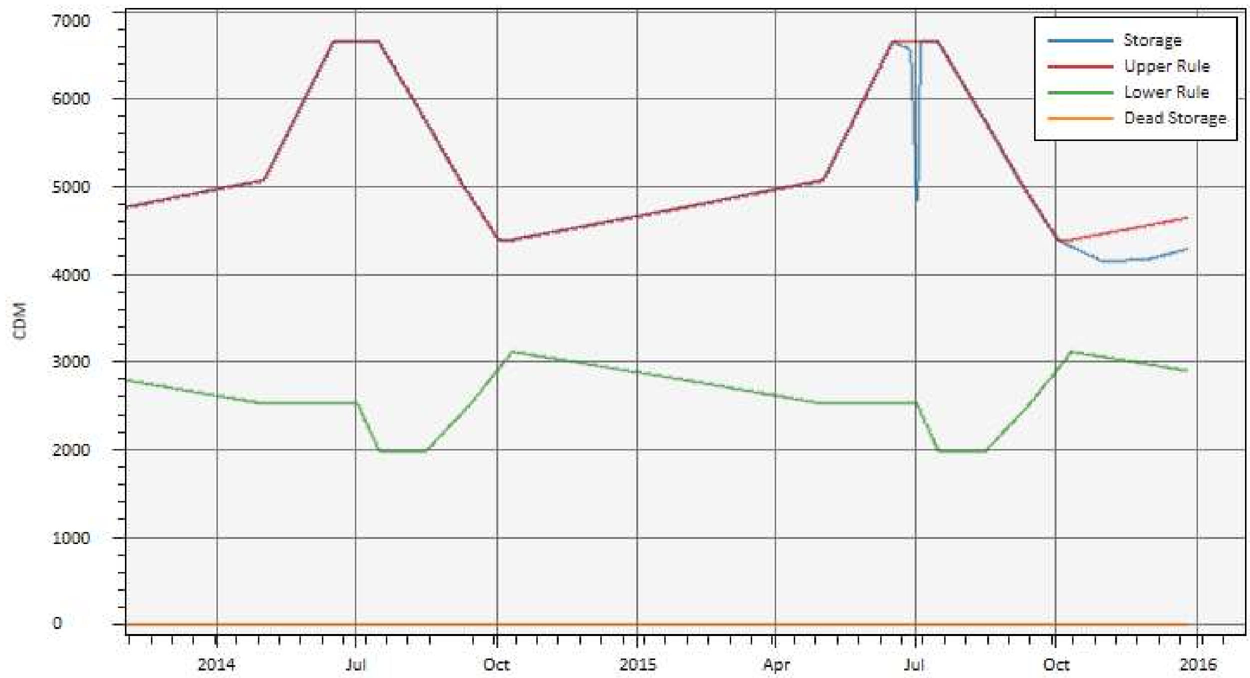

Figure 80. Simulated storage and rule curves implemented in the SSROM for Horsefly Reservoir (model label: Horsefly).

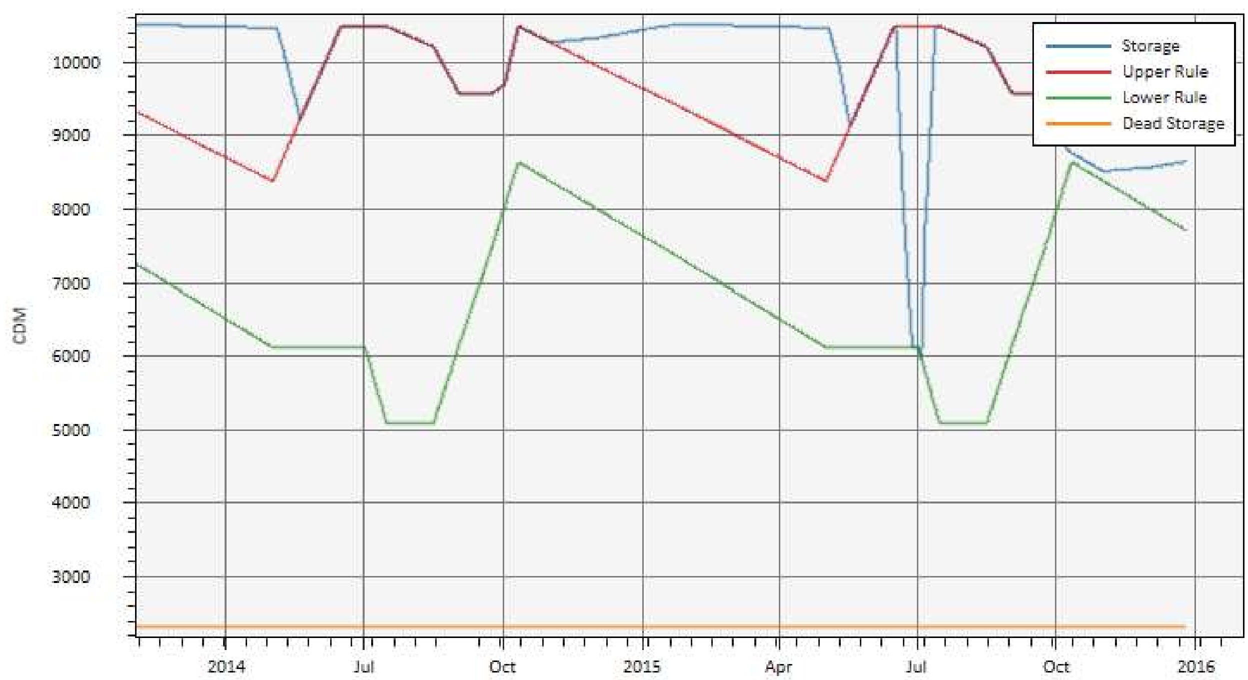

Figure 81. Simulated storage and rule curves implemented in the SSROM for combined Fincastle and Taber Lakes Reservoir (model label: FncslTbr).

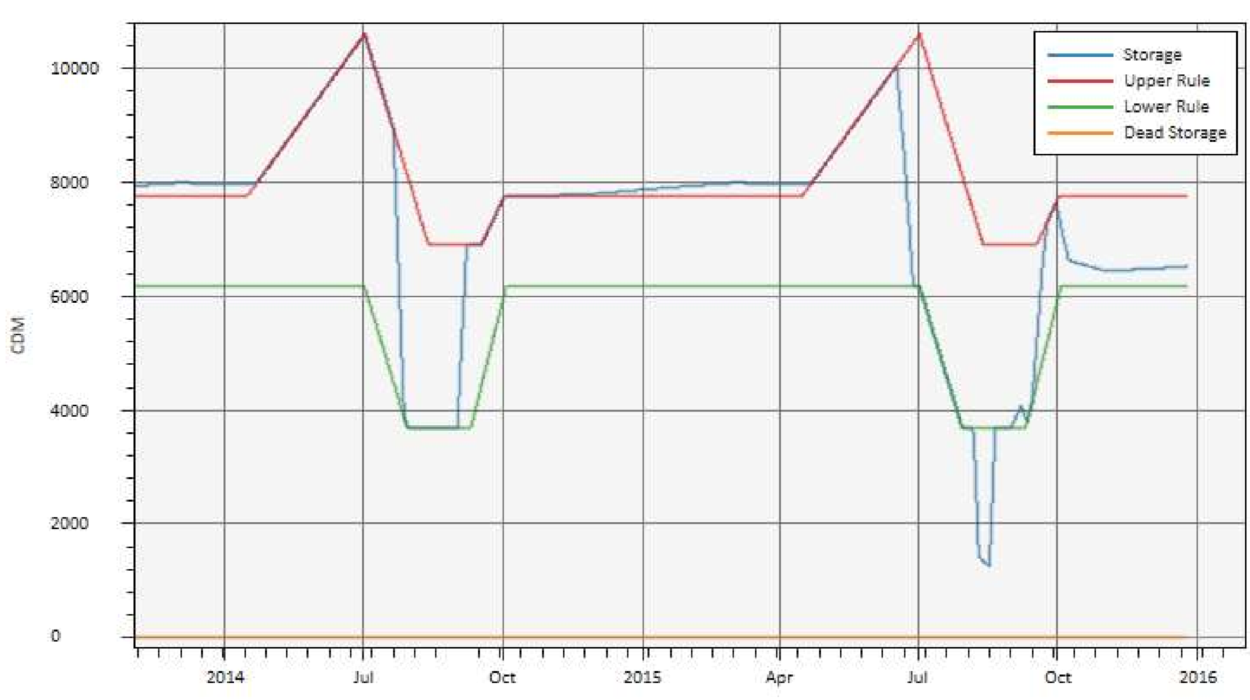

Figure 82. Simulated storage and rule curves implemented in the SSROM for Grassy Reservoir (model label: Grassy).

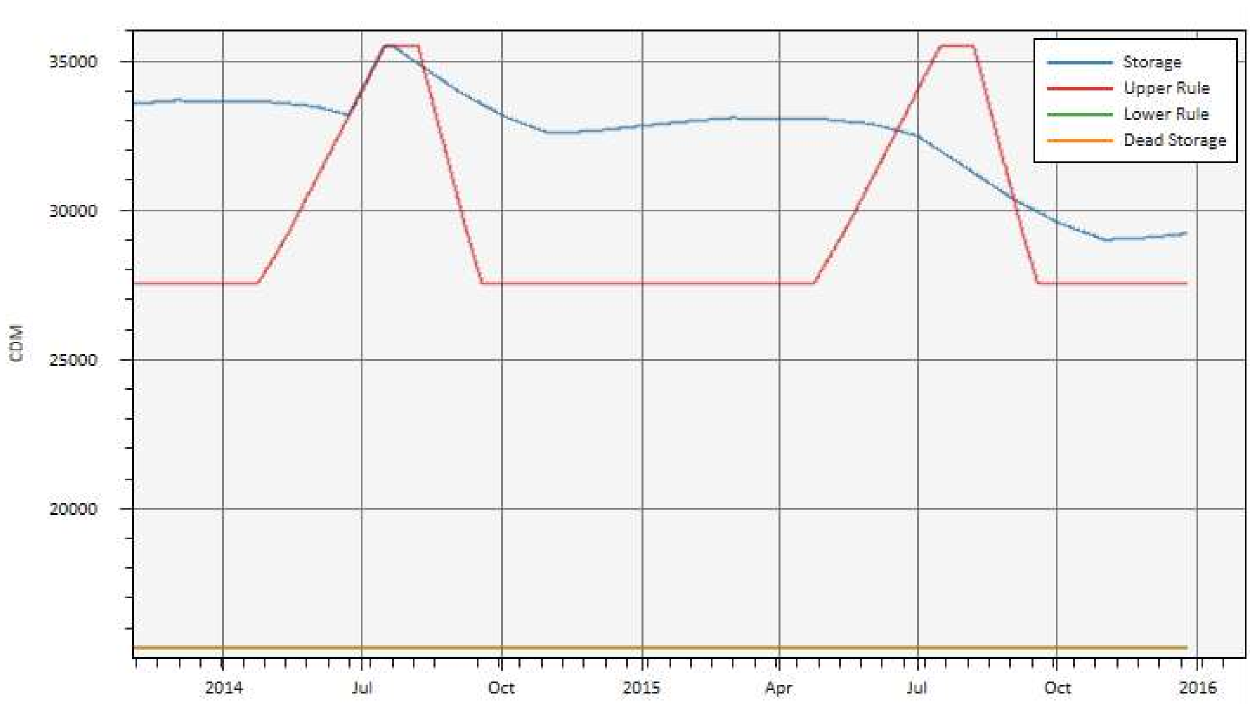

Figure 83. Simulated storage and rule curves implemented in the SSROM for Yellow Reservoir (model label: Yellow).

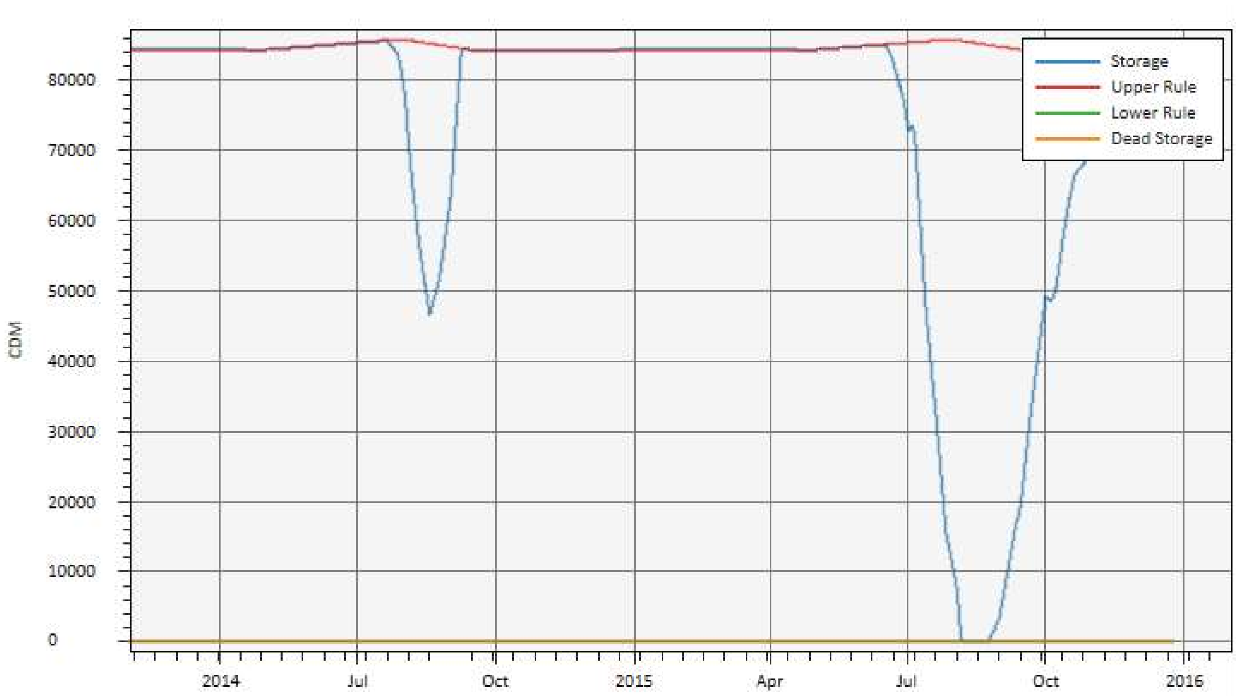

Figure 84. Simulated storage and rule curves implemented in the SSROM for 40-Mile Coulee Reservoir (model label: 40Mile).

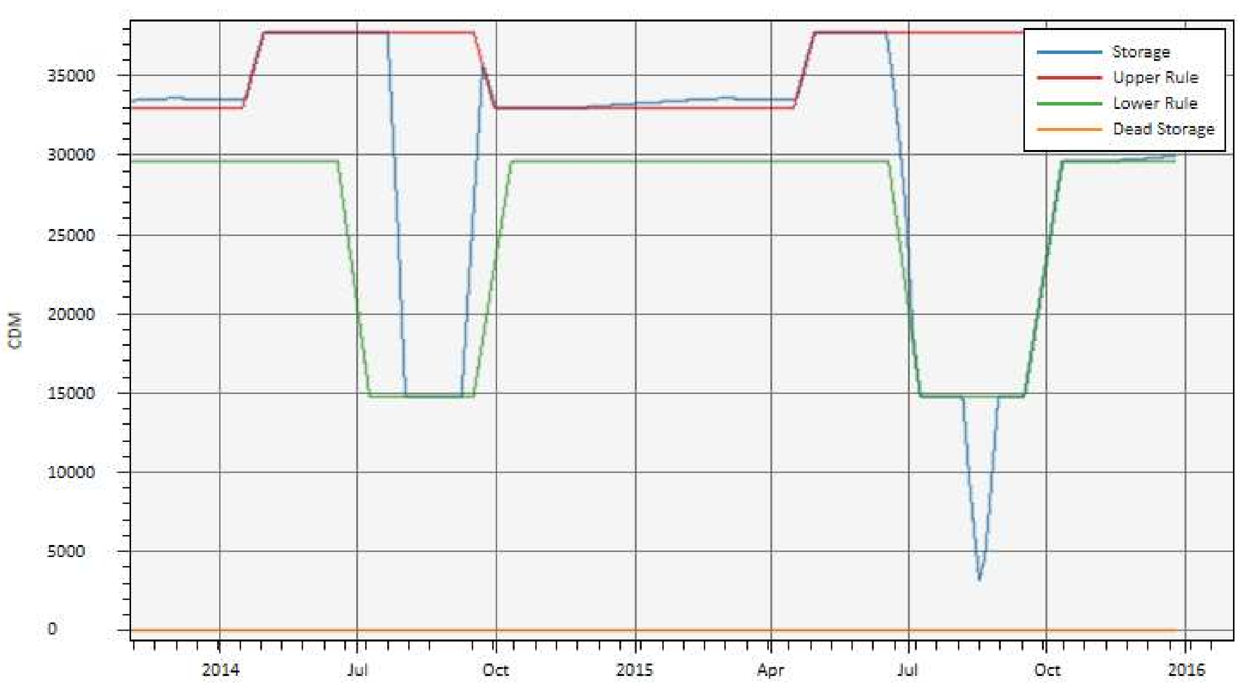

Figure 85. Simulated storage and rule curves implemented in the SSROM for Sauder Reservoir (model label: Sauder).

Appendix E List of model changes

(green)	Model updated
(yellow)	Update noted but not completed as out of scope

Change to the model	Relevant sector/organisation	Notes / Metadata	Complete
Confirm evaporative losses are included in IDM run Confirm WID return flows to Red Deer River	All		Confirmed – evaporative losses from major canals are accounted for in the IDM runs provided
Update Maj/Min block time series	Muni/Ind	Updated WRMM data provided by Government of Alberta.	Complete
Update City of Calgary demands (Bearspaw and Glenmore Treatment plants) and Glenmore Reservoir operations	City of Calgary		Complete - Updated demands and operations of Glenmore reservoir was provided by City of Calgary
Add Springbank Reservoir to the model		Peak flows above Glenmore to be 160m3/s (start diverting when flows hit 160). Release at 26m3/s following flood event (35-40 days to empty from FSL)	Complete - Springbank SR1 added to the model. Information provided by AEP.
Update TransAlta rule curves based on TA data			Complete
Update operations for Travers and McGregor reservoirs	BRID	Irrigate off McGregor while leaving Travers full	Completed - Headworks confirmed as requiring 300 ft^3/s carriage flow.

Change to the model	Relevant sector/organisation	Notes / Metadata	Complete
		When it is not possible to draw off McGregor draw off Travers (operate these reservoirs in tandem)	Travers reservoir is treated as reservoir of first resort.
Confirm the elevation condition on additional irrigation licence off McGregor.	BRID	This irrigation would always be sacrificed to operate McGregor fully	Complete - McGregor reservoir demands updated based on elevation of > 871.74m.
McGregor reservoir Upper rule to 874.15m	BRID		Complete
Confirm Travers elevations: • 854m in the winter • 856.18 in the summer Confirm that Travers levels are kept high until Labour Day for recreation purposes		Levels updated: • 854m in the winter • 856.18m in the summer *Summer elevations can be pushed to 854.4m in extreme cases*	Complete - Travers reservoir confirmed model condition that Travers is kept high until after Labour Day weekend for recreation purposes.
Update maximum diversion rate from the Bow to $51m^3/s$	BRID	Confirmed by Richard Phillips 24/01/2022	Updated in SSROM
Implement minimum carriage flow of 300 ft^3/s on BRID diversion canal *(BRID tries to maintain 300 ft^3/s as a minimum through the canal)*	BRID	Confirmed by Richard Phillips 24/01/2022	Confirmed that this was already represented in the model correctly
Confirm total licensed allocation for the BRID is 490,000 ac-ft including the 40,000 ac-ft 2016 allocation	BRID	Confirmed by Richard Phillips 14/02/2022	Updated in SSROM
2020 total irrigated acres should be 252,144 acres Location of new demands to be reviewed with Richard Phillips once we have the IDM data from AAFRED	BRID	2020 acres confirmed by Richard Phillips 24/01/2022	Acreage updated to align with assessed acres listed in Table 4 of the 2020 Alberta Irrigation Information Report. Location of demands confirmed and updated.
Update Highwood Diversion	BRID	Confirmed by Paul 31/01/2022	Confirmed and updated in SSROM

Change to the model	Relevant sector/organisation	Notes / Metadata	Complete
		Priority 1898-11-10-01 (Highwood River – Little Bow River) 50 ft^3/s Priority 1921-05-14-01 (Highwood River – Little Bow River) 50 ft^3/s	
Updated Chestermere Lake in the model to show that it is not used	WID	Confirmed by WID 11/01/2022	Confirmed that it is represented correctly in the SSROM
Confirm 2020 assessment acres	WID	Confirmed with Brian and Sean that 95,000 acres should be represented in the model	WID in SSROM updated to 95,000 acres
Update Langdon reservoir Live storage – 12,000 ac-ft	WID	Sean and Brian will provide Storage Area Elevation, provide winter, spring and summer storage, dead storage level 31/01/2022	Updated volume but not additional data
Confirm if multiplier of 0.6 is still required for WID IDM demands	WID	Brian and Sean confirmed the 0.6 multiplier was no longer necessary with the updated IDM data	0.6 multiplier removed from WID demands in SSROM
Update 190,500 AF (senior and junior licences combined), 158,000 ac-ft (senior), 32,000 ac-ft (junior to WCO)	WID	Confirmed by Brian and Sean 31/01/2022	Updated in SSROM
Add in Rolling Hills as a reservoir with live storage of 37,000 ac-ft Just to the SE of Lake Newel – by node 1540 – Newel supplies Rolling Hills – Rolling Hills supplies the rolling hills area only (acres from Rolling Hills – 75,000 ac-ft), Newel supplies rolling hills and others	EID		Updated in SSROM using SAE chart, dead storage and operational rule curves provided by EID

Change to the model	Relevant sector/organisation	Notes / Metadata	Complete
Update Lake Newell live storage	EID	Correct live storage 146,000 AF as confirmed by Ivan 28/01/2022	Took 10,000 out of dead storage, made live. New live storage = 146,380 ac-ft
Rename Tilley to Tilley B (SSROM node 1548)	EID	Confirmed by Ivan 28/01/2022	Updated in SSROM
Confirm total irrigated acres to 310,000 acres • 40% river supported • 60% reservoir supported	EID	Confirmed by Ivan 28/01/2022	Acreage updated to align with assessed acres listed in Table 4 of the 2020 Alberta Irrigation Information Report. Location of demands confirmed and updated.
Verify that the EID diversion is 679,000 AF (total EID licence volume)	EID	Confirmed by Ivan 28/01/2022	Confirmed that SSROM shows 680,000 ac-ft which includes 1,000 ac-ft to supply County of Newell
Confirm how Oldman Dam is operated to meet apportionment and to discuss GoA operated reservoirs and reservoirs balancing in the Oldman River Basin		Confirmed by Paul Elser 08/02/2022 Paul provided data on Waterton canal to St. Mary, Belly Diversion to St. Mary, and Max canal on St. Mary	Model updated to remove balancing of reservoirs in the Oldman South Saskatchewan River Basins
Update Yellow reservoir upper and lower rule curves	SMRID	Confirmed with SMRID that 14,000 ac-ft represents total live storage. Upper Rule curve and max storage are 783.2m	Completed and updated in SSROM
Confirm 40 Mile reservoir – FSL storage of 813.0m (70,000 ac-ft)	SMRID	Confirmed by Trevor Helwig 26/01/22	Confirmed already represented correctly in the model
Chin reservoir to be updated based on the SMRID model.	SMRID	"The number listed from AAFRED report is correct for the original design FSL, but have not operated this high in the past 30 years+"	Upper Rule peaks at 154,000 ac-ft ~861.3 in model. Confirmed

Change to the model	Relevant sector/organisation	Notes / Metadata	Complete
		Confirmed by Trevor Helwig 26/01/22	
Confirm Sauder reservoir – FSL of 804.0m (30,640 ac-ft)	SMRID		Confirmed that this is already represented correctly in the model (peak at 30,640 ac-ft)
Confirm that the total irrigated acres of SMRID – 410,000 acres	SMRID	Confirmed by Trevor Helwig 26/01/22	Acreage updated to align with assessed acres listed in Table 4 of the 2020 Alberta Irrigation Information Report. Location of demands confirmed and updated.
LNH (Lethbridge Northern Headworks) canal weir diverts north – max diversion to be updated to 46.5 m^3/s (from 42.5 m^3/s)	LNID	Confirmed by Paul 26/01/2022	Max diversion updated in SSROM
Node 2464 (LNID irrigation block 340) no longer has a return flow – remove return flow *(there used to be a return here, but there is no longer a return)* Double check this with IDM results	LNID	Confirmed by Gary and Chris 26/01/2022	
Update Keho Reservoir rule curves	LNID	Keho Reservoir rule curves confirmed by LNID • upper rule of 963.2m • lower rule of 960.640m • FSL – 964.24, upper quartile 964.15m, winter storage 936.9m	Confirmed and updated in SSROM
IDM demands – check with LNID	LNID	Check return flows for irrigation demands, there may be a 10% bleed addition to the IDM (see IDM data from AAFRED)	IDM demands confirmed with LNID and implemented in SSROM

Change to the model	Relevant sector/organisation	Notes / Metadata	Complete
334,450 ac-ft in total irrigated licences for LNID, as well as 11,000 ac-ft of private licences that come through the system (refer to IDM data to see if we need to include)	LNID	Confirmed by Gary and Chris 26/01/2022 ACTION: compare with IDM data to ensure this is correct	Acreage updated to align with assessed acres listed in Table 4 of the 2020 Alberta Irrigation Information Report. Location of demands confirmed and updated.
Confirm Twin Valley reservoir operations		Twin Valley reservoir licences reviewed to confirm operations	Confirmed Twin Valley reservoir is modelled correctly in SSROM
Review Pine Coulee off stream reservoir to confirm max diversion any flow requirements and min elevation		Pine Coulee reservoir licence Additional note: licence is tied to flow on Willow Creek where to crosses highway 11	Confirmed Pine Coulee reservoir is modelled correctly in SSROM
Review Chain Lakes licence to ensure that this is modelled correctly		Spillway is ungated, reservoir is filled and then once it reaches the crest it will start to spill automatically	Confirmed Pine Coulee reservoir is modelled correctly in SSROM
Ridge Reservoir - Change the upper rule curve	SMRID	31/01/2022 *Rule curves provided by Paul 11/02/2022*	Confirmed Ridge reservoir is modelled correctly in SSROM
Add Jensen Reservoir		Jensen is a flow through reservoir – no useable volume. Town of McGrath has a diversion at Jensen. Confirmed by Paul 31/01/2022	Jensen added as a flow through reservoir in SSROM
Update City of Lethbridge demands	City of Lethbridge		Demands updated as per information from City of Lethbridge
Update UID priority on the Belly River – UID should have higher priority than MVID	UID	Confirmed by Fred 2022/02/07	Model represents correct licence priority among irrigation districts. UID has two licences which are split seniority. Senior to some MVLA/MID licences, junior to others.

Change to the model	Relevant sector/organisation	Notes / Metadata	Complete
UID canal off Belly River should have max diversion rate of 6 m^3/s	UID	Confirmed by Fred 2022/02/07	UID canal added to SSROM with correct diversion rate
UID has 34,400 acres, 16,000 acres can only be supplied by the Belly River. Update model to reflect this	UID	Confirmed by Fred 2022/02/07	Acreage updated to align with assessed acres listed in Table 4 of the 2020 Alberta Irrigation Information Report. Location of demands confirmed and updated.
Update node 2509 to return to the Belly River not the St. Mary canal	UID	Confirmed by Fred 2022/02/07	Completed and updated in SSROM
Review apportionment wording and *calculation* if different		Definition of apportionment as provided by AEP: Recorded flow was 76% of the apportionable flow. Alberta is required to deliver 50% of the apportionable flow to Saskatchewan unless the total annual apportionable flow below the confluence is less than 5,180,000 dam^3, in which case Alberta is allowed a total net depletion of 2,590,000 dam^3 regardless of the percent delivery. However, Alberta cannot consume, divert or store more than 50% of the apportionable flow if the effect reduces the flow below the confluence to less than 42.5 m^3/s at any time. As the apportionable flow for 2018 was 8,385,000 dam^3, and Alberta delivered greater than 50% of the apportionable flow, Alberta has met its obligations."	Complete – Changed "Apportionment Contribution" performance measure title to "Cross-border Contribution" in the SSROM dashboard.

Change to the model	Relevant sector/organisation	Notes / Metadata	Complete
Confirm 16 m^3/s flow downstream of Dickson dam	Red Deer River	Confirmed by Paul 31/01/2022	Confirmed SSROM already operates this way
Compile and add new industrial Red Deer licences		New licences are junior to the WCO	SSROM updated with new industrial licences
Add the Sheerness reservoir (GoA and ATCO) – 18,000 ac-ft (11,200 ac-ft from the river, 6,800 ac-ft from ATCO licence) Licence limits 18,000 ac-ft from the Red Deer River each year Separate out licences so that demands are being supplied by reservoir	Red Deer River	Confirmed by Todd 01/02/2022 In SSROM the individual licences in the WRMM data block cannot be disaggregated either spatially of temporally. This means the reservoir exists and functions, but the annual limit is not applied.	Complete – See note for details
Update return flows from Red Deer River (Node 3203) Double check what the IDM says (possibly remove return flows – follow up with Todd)	Red Deer River	Upstream of Caroline reservoir, (highway 9): there are a few Ducks Unlimited waterfowl propagation which has zero allocation in EMS on their licence that distorts Barry Creek, the return flow comes from Barry Creek	Review complete return flow for this node is from the IDM. SSROM will continue to use IDM data in this location.
Update Deadfish diversion 16,700 ac-ft 1.7 m^3/s (Max diversion rate) 8.5 m^3/s instream objective	Red Deer River	Confirmed by Todd 01/02/2022	Licence blocks from WRMM could be disaggregated to appropriately model this in SSROM; however, it was out of scope for this project. See Section 2.2 for more information
Understand more of Deadfish-Sheerness return flow	Red Deer River		Complete – Sheerness-Deadfish return flows updated
Update Red Deer River with TDL's upstream (mostly Blindman) *(note: it was determined that none of the other basins would include TDLs as*	Red Deer River	AER provided a list of TDLs from the last 5 years an annual average volume was calculated from this information and modelled in SSROM	Complete – TDL volume updated in SSROM

Change to the model	Relevant sector/organisation	Notes / Metadata	Complete
the volumes are not meaningful in other basins – Todd 01/02/2022)			
Update City of Red Deer demands	City of Red Deer		City of Red Deer is in at full licence volume. There is an actual use option that would pull this data, but it is not engaged in the Base Case
SSROM Dashboard: • Add natural flows for cross-border contribution • Make note in the dashboard about Oldman and South Saskatchewan volumes • Draw 50% natural flow line to the dashboard to see apportionment targets		Updates per feedback from the SSROM Working Group Meetings	Complete

Appendix F Licence groupings

Refer to the licence groupings spreadsheet which is attached separately from this document.

Appendix G Additional Performance Measures (PMs)

The following performance measures exist for the SSROM, these PMs have been brought over from previous phases of work, and can be accessed, but have not been included in the updated SSROM Dashboard.

Performance Measure	Description
Annual weekly minimum flow	This PM attempts to capture a sense of biological performance by examining the absolute minimum weekly flows for each year in a particular scenario at various locations. Minimum flow is measured in m^3/s.
Cottonwood recruitment	This PM estimates the likelihood of successful cottonwood recruitment and captures the quality of successful recruitment events. It shows the number of years when optimal recruitment can be expected and the number of years when partial recruitment can be expected.
Cumulative irrigation shortage days	This PM examines the effects of operations schemes on irrigation districts by assessing shortage days. Shortage means that water delivered was less than water demanded. Some of these shortages might be volumes too small to be significant.
Fish Weighted Usable Area (WUA)	This set of PMs is designed to capture the effects of operations on fish habitat in selected stream reaches (the St. Mary River below St. Mary Reservoir and the Oldman River near Lethbridge) for selected indicator species. WUA is the wetted area of a stream weighted by its suitability for use by aquatic organisms or recreational activity. This PM is expressed as a proportion of total usable area.
Total annual outflow from Oldman River as a percentage of natural flow (apportionment proxy)	This PM indicates the likelihood of violating the Apportionment Agreement by comparing natural flows at the Oldman-Bow confluence with simulated flow under various operations scenarios.
Energy generation	This PM examines the effects of operations schemes on power generation opportunities. It is shown as total energy generated in megawatt-hours over the historical period for hydro generation facilities.
Additional drought capacity	This PM refers to the number of days in a specific year by which total storage in AEP reservoirs will extend water availability and thus capacity to respond to drought conditions. It is plotted as AEP total storage in dam^3.
TransAlta System Low Storage Days	This PM notes the number of times that TransAlta live storage reaches critical (<5% storage remaining) and near empty (<1% storage remaining) levels.

Performance Measure	Description
Shortage days	This PM captures the number of days of shortages experienced by various groups of licence holders.
Flow at Red Deer mouth (weekly)	This PM identifies periods of low flows that might be of concern for environmental, economic, and social objectives as well as noting violations of the WCO.
Elevation of Gleniffer Reservoir (daily/annual)	As Gleniffer Reservoir is the only on-stream storage in the Red Deer system, remaining storage in the reservoir is of critical importance, in particular during drought periods. Gleniffer Reservoir serves to maintain the WCO in the winter. Monitoring its storage helps to identify years where both the WCO and junior licences would be at risk.
Outflow from Gleniffer Reservoir	Gleniffer Reservoir releases are primarily of interest in terms of the functional flow alternatives looking at environmental flows below the dam and correlating those with reservoir storage targets and operational priorities.
Shortages to New Demands (Red Deer)	Since existing demands in the Red Deer system are nearly all senior to the WCO and never saw shortage in any scenario or alternative, shortages in the system were analyzed as how many occurred in demands junior to the WCO (i.e., new demands introduced in sub-basin scenarios).
Mid-stream storage (Red Deer River)	This PM tracks the drawdown in the hypothetical mid-stream storage on the Red Deer River and uses hypothetical operations to estimate the additional volume of storage needed to remedy shortages to new and current users and occasional deficits in Gleniffer Reservoir storage.

Appendix H Comparison to previous work

Comparison of basin diversion volume

A comparison between pre-update and updated total diversions across the historical timeseries in the various basins was competed. Figure 86 to Figure 91 show visual representations of the comparison between the previous iteration of the model and the 2022 updated data. The total diversion volume across the historical timeseries was compared for each river basin, along with a volume differential that was calculated between model years a differential between model years.

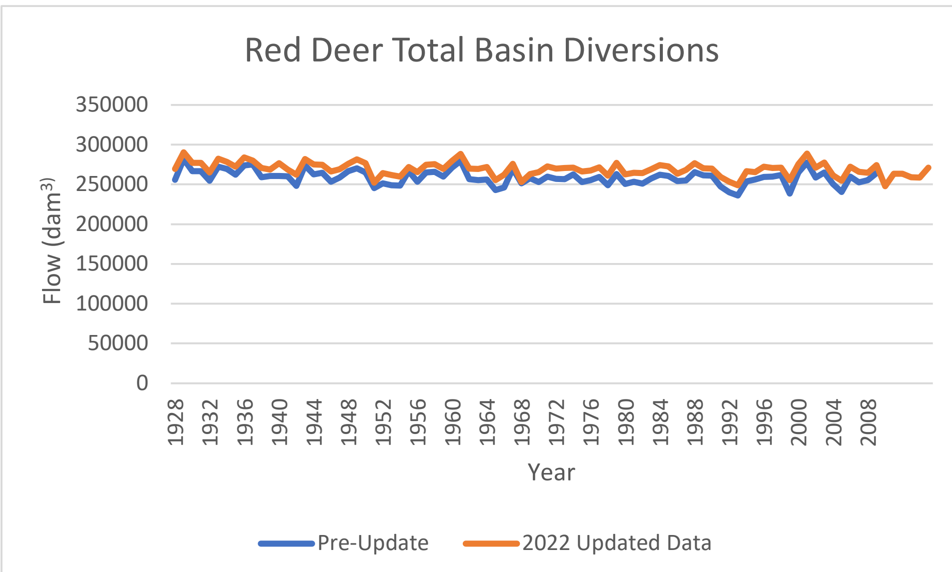

Figure 86. Comparison between pre-update and updated total diversions across the historical timeseries in the Red Deer basin.

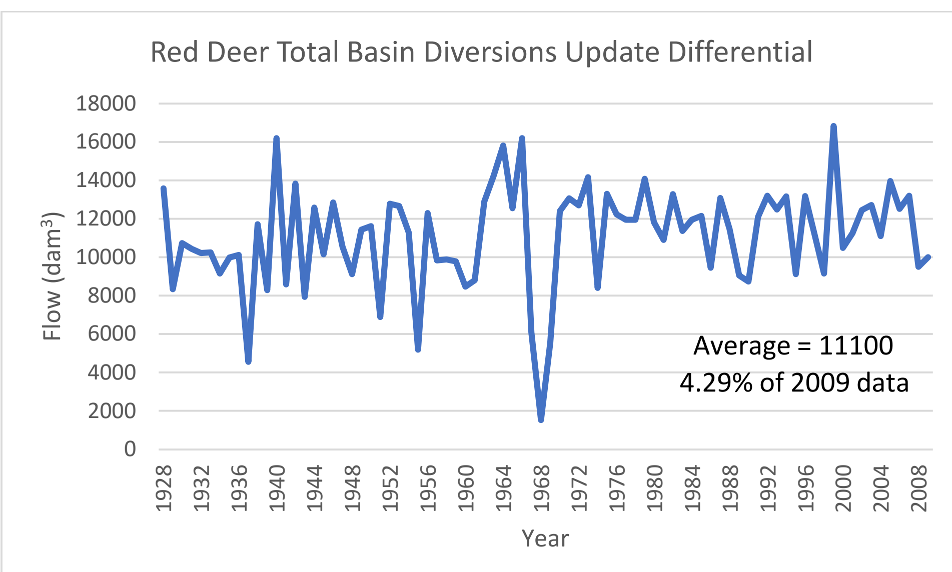

Figure 87. Diversion volume differential between pre-update and updated model across the historical timeseries

for the Red Deer basin.

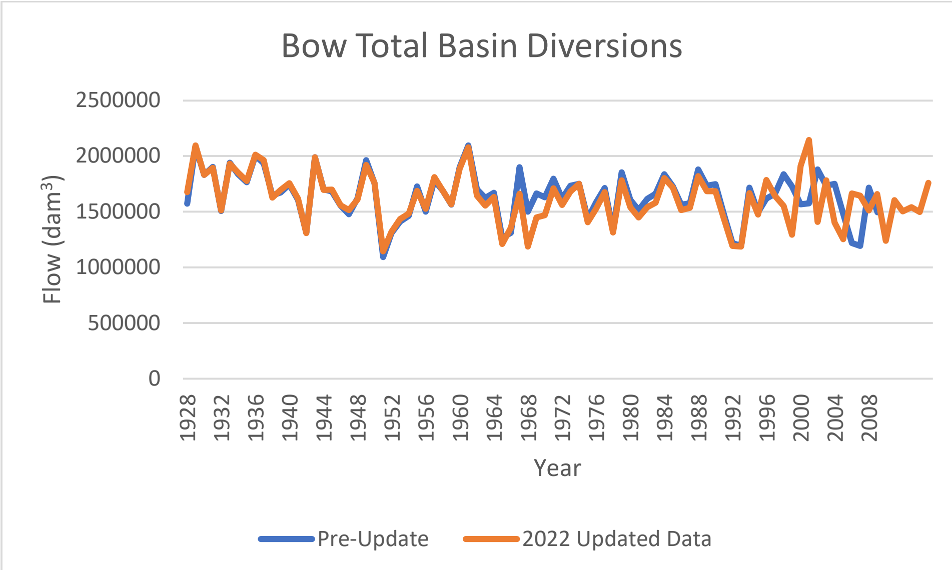

Figure 88. Comparison between pre-update and updated total diversions across the historical timeseries in the Bow basin.

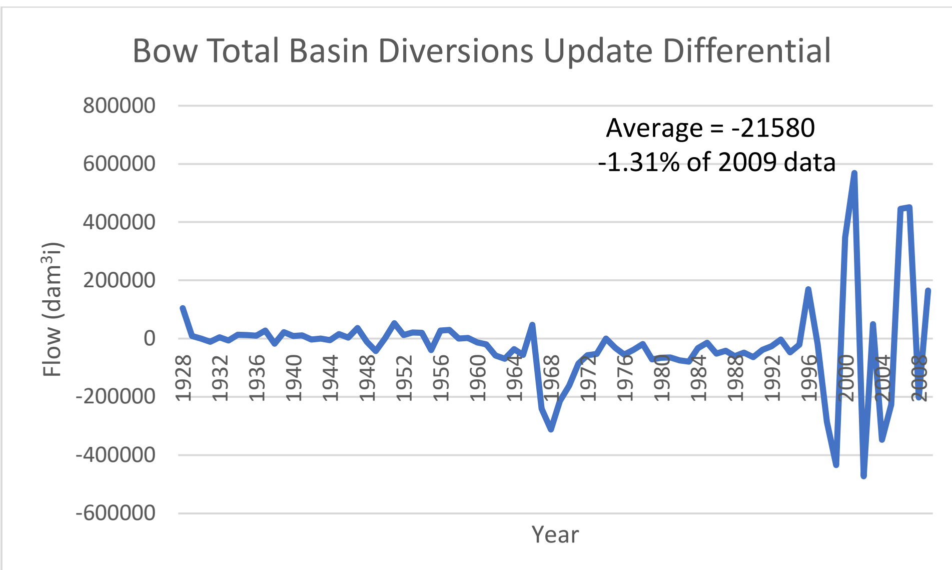

Figure 89. Diversion volume differential between pre-update and updated model across the historical timeseries for the Bow basin.

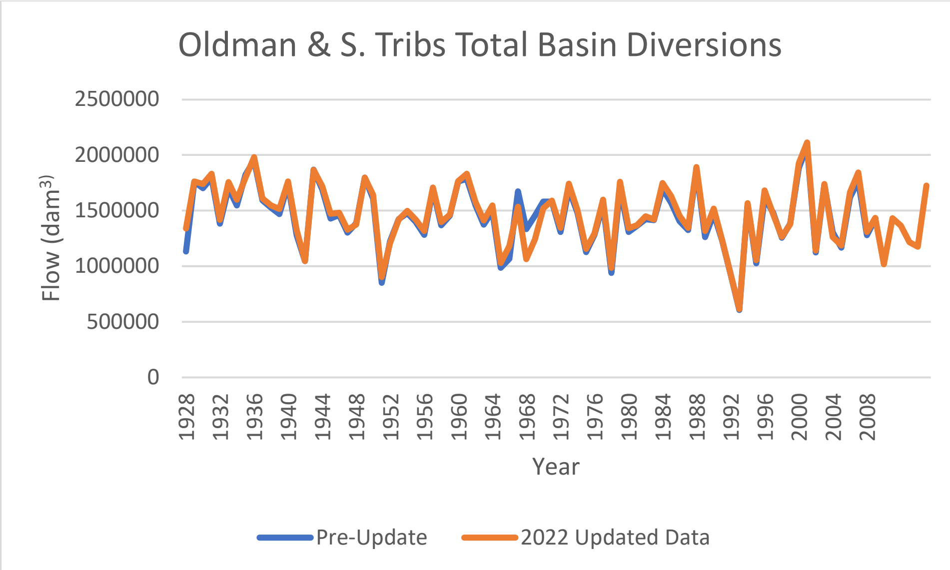

Figure 90. Comparison between pre-update and updated total diversions across the historical timeseries in the Oldman and Southern Tributaries basin.

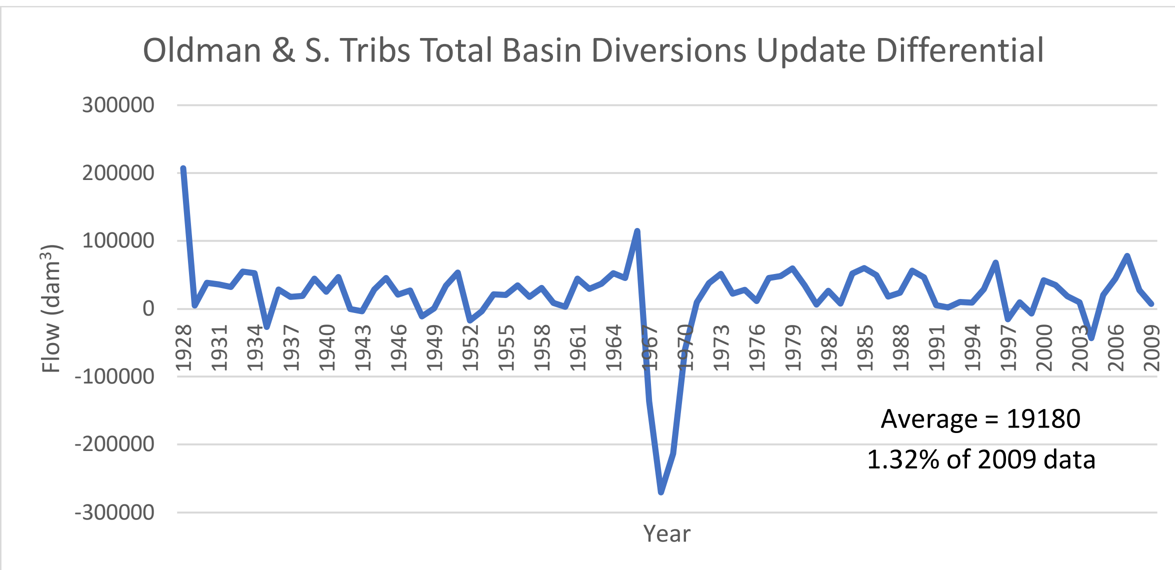

Figure 91. Diversion volume differential between pre-update and updated model across the historical timeseries for the Oldman and Southern Tributaries basin.

Comparison of irrigation shortages

The updated model showed considerable differences in shortages to irrigation districts in the Oldman basin. Feedback from irrigators indicated the updated data was more in line with their expectations. Figure 92 throughFigure 97 show the comparison of shortages between the previous model and the updated model data. Detailed discussion of causative factors can be found in Section 3.2: Comparison of model impacts

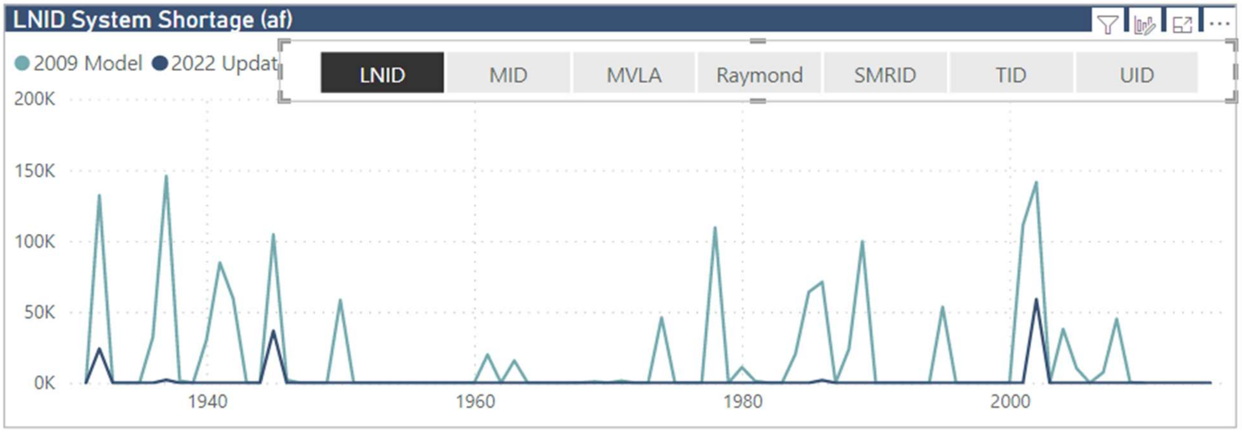

Figure 92. Shortage comparison between previous model data and updated data for Lethbridge Northern Irrigation District (LNID).

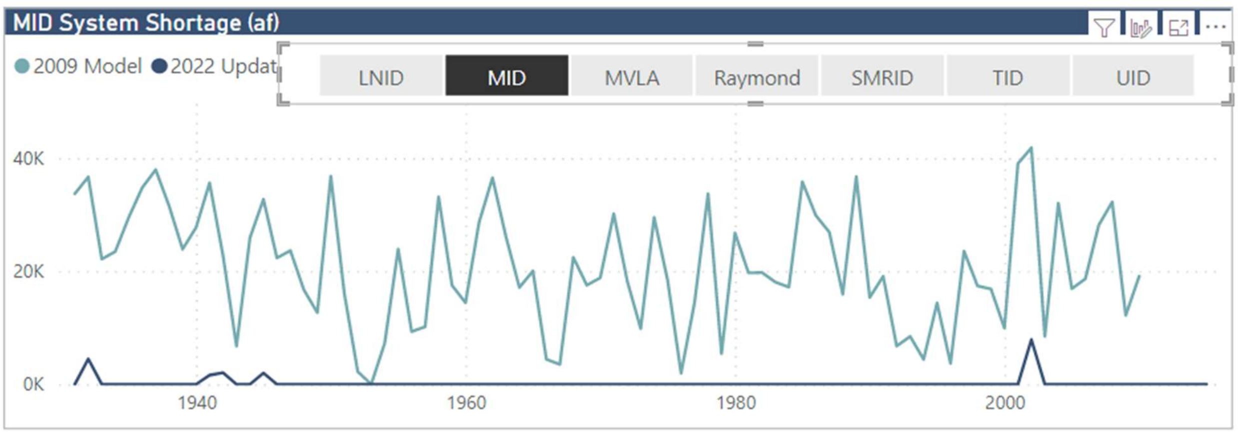

Figure 93. Shortage comparison between previous model data and updated data for Magrath Irrigation District (MID).

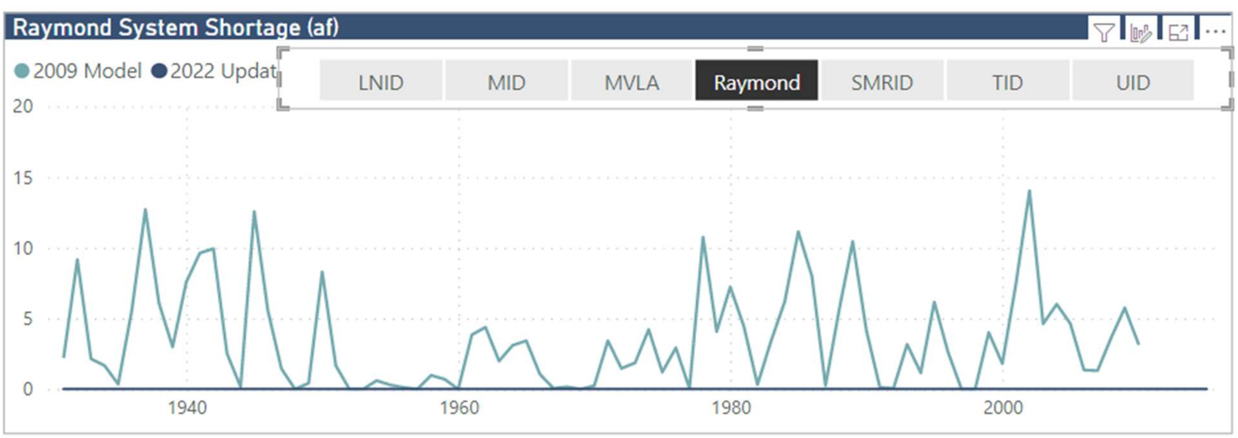

Figure 94. Shortage comparison between previous model data and updated data for Raymond Irrigation District (RID).

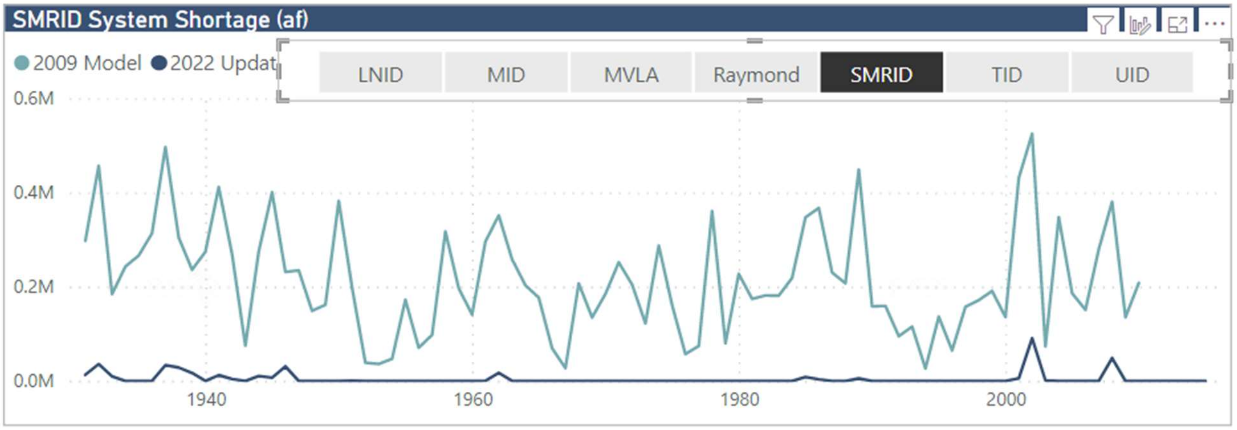

Figure 95. Shortage comparison between previous model data and updated data for St. Mary River Irrigation District (SMRID).

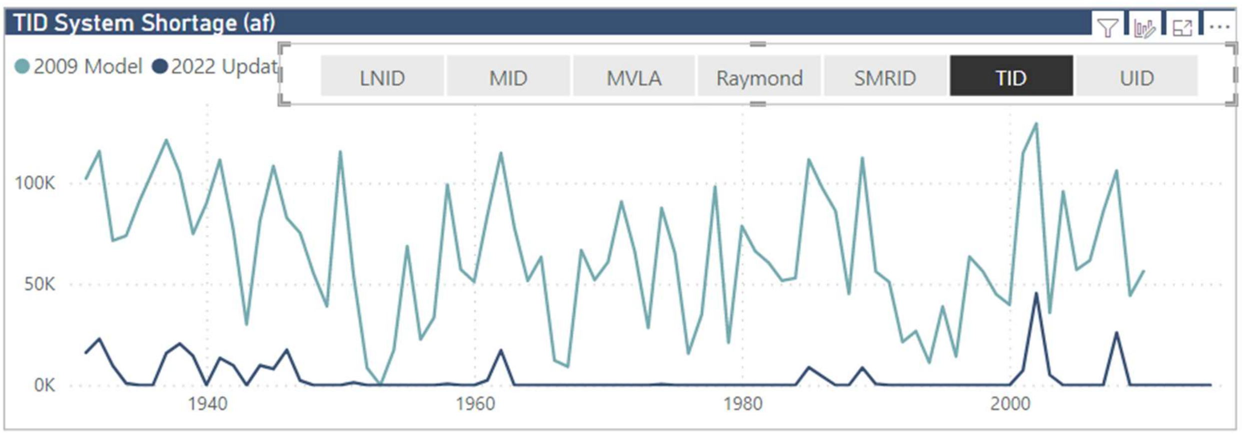

Figure 96. Shortage comparison between previous model data and updated data for Taber Irrigation District (TID).

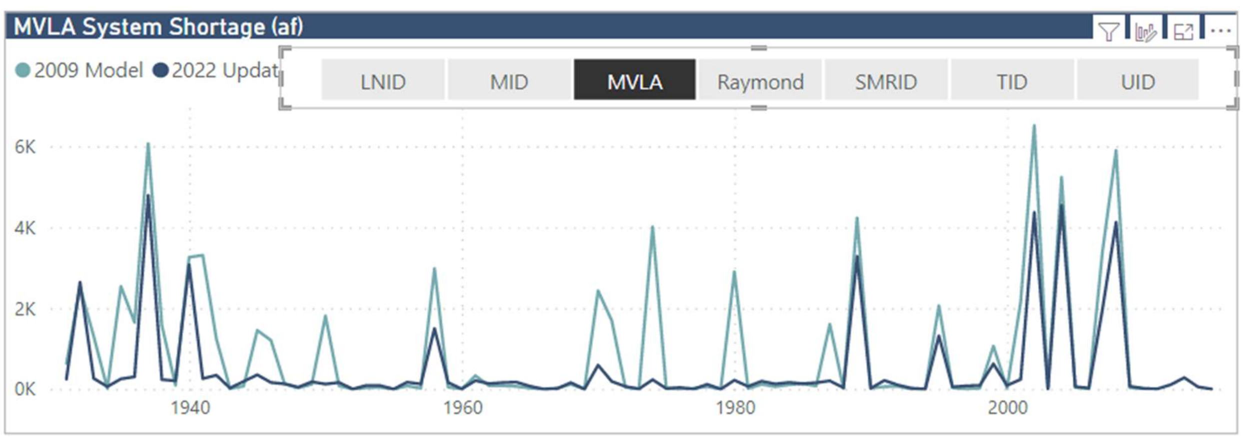

Figure 97. Shortage comparison between previous model data and updated data for the Mountain View, Leavitt and Aetna irrigation system (MVLA).

Appendix I Training slides

Refer to Appendix I - SSROM User Training Slides PDFs which are attached separately from this document.