Klamath RiverWare Operations Model Documentation

Report # ENV-2020-034

Klamath Project, Oregon and California
Mid-Pacific Region

U.S. Department of the Interior
Bureau of Reclamation

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Mission Statements

The mission of the Department of the Interior is to protect and manage the Nation's natural resources and cultural heritage; provide scientific and other information about those resources; and honor its trust responsibilities or special commitments to American Indians, Alaska Natives, and affiliated island communities.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

Acknowledgements

Peer review was performed by Reclamation's Klamath Basin Area Office.

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Klamath Project, Oregon and California
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Acronyms and Abbreviations

AF	acre-feet
BiOp	Biological Opinion
cfs	cubic feet per second
CNRFC	California Nevada River Forecast Center
CU-CADSWES	University of Colorado Boulder, Center for Advanced Decision Support for Water and Environmental Systems
DMI	Data Management Interface
DSS	Data Storage System
ESA	Endangered Species Act
EWA	Environmental Water Account
HDB	Hydrologic Database
HEC	Hydrologic Engineering Center
IGD	Iron Gate Dam
KBAO	Klamath Basin Area Office
KDD	Klamath Drainage District
KROM	Klamath RiverWare Operations Model
LKNWR	Lower Klamath National Wildlife Refuge
LRDC	Lost River Diversion Channel
NRCS	Natural Resources Conservation Service
Reclamation	Bureau of Reclamation
RBS	rulebased simulation
SCT	System Control Tables
SOP	Standing Operating Procedures
TSC	Technical Service Center
UKL	Upper Klamath Lake
USGS	U.S. Geological Survey
WSF	Water Supply Forecasts

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1. Introduction

The Bureau of Reclamation's (Reclamation) Klamath Basin Area Office (KBAO) and Technical Service Center (TSC) partnered with the University of Colorado Boulder, Center for Advanced Decision Support for Water and Environmental Systems (CU-CADSWES) to develop a daily water operations model for the Klamath Project (Figure 1) using RiverWare. Until the beginning of water year 2020, KBAO has relied on an Excel spreadsheet model called the Iron Gate Dam (IGD) Calculator for daily water operations decisions. The model operating policy was based on the 2013 Biological Opinion (BiOp) (National Marine Fisheries Service and U.S. Fish and Wildlife Service 2013) and was updated in water year 2019 for a revised 2019 BiOp operating policy. While this approach has generally met the needs of operators, changes in policy and infrastructure in the near-term highlight the need for a flexible tool with capability to easily handle changing hydrologic and policy conditions.

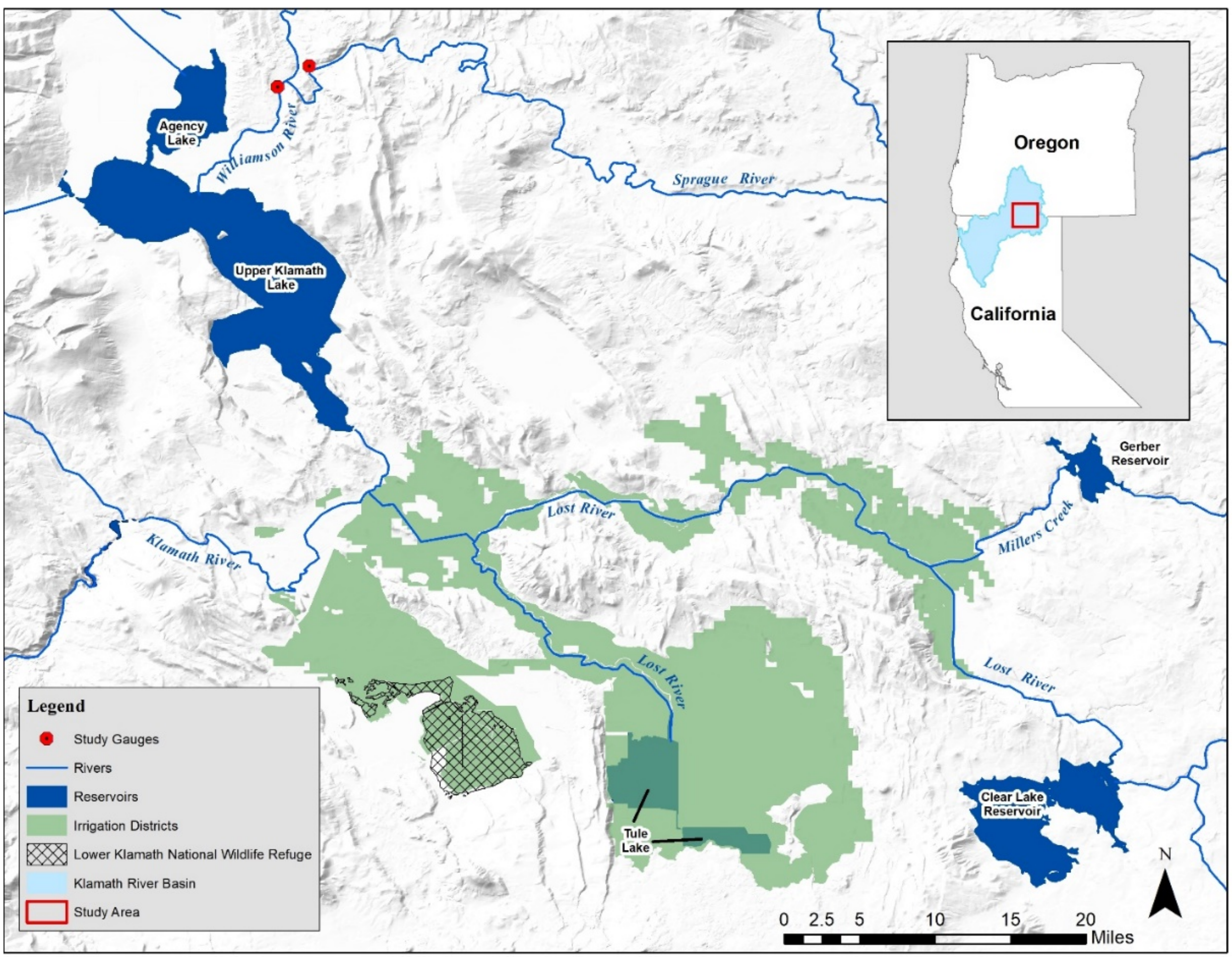

Figure 1. Overview map of Klamath Project area (green shading).

In this effort, Reclamation leveraged the capabilities and expertise of CU-CADSWES to develop a flexible model to support water management and handle changing conditions in the basin. This model was developed using the 2013 BiOp operating policy. Primary objectives for model development included a flexible structure to account for changing hydrologic, policy, and infrastructure conditions; automated data management for data input and output; automated reporting capabilities for improved stakeholder communication; and modular model structure to tailor model versions to specific stakeholder needs.

This report provides an overview of the Klamath RiverWare Operations Model (KROM) and detailed documentation for operators new to KROM to facilitate understanding of model components and workflow, and to provide a guide on how to run the model.

2. Physical Model Configuration

This section presents information on the physical KROM configuration, including timestep, time range, observed and forecast data handling, and data objects and methods.

2.1. Timestep and Time Range

KROM has a daily timestep which corresponds with the frequency of operating decisions for the Klamath Project and Endangered Species Act (ESA) related requirements. The time ranges for observational and forecasted data are set to ensure the model can run successfully based on model operating policy. The model was configured to use a date, termed the *Operations Start Date*, which defines the date where the model transitions from using observational data to forecast data. In typical water operations, this date would be set to the current day. It could also be a previous day if the system has to be re-operated due to missing data, holidays, etc. The *Operations Start Date* was devised to handle several challenges in modeling water operations, including the need to handle setting initial conditions throughout the model, and to account for routing time lags within the river system. In examining model operating policy, all other dates required by the model are keyed off of the *Operations Start Date*.

Water operations fall into two distinct periods: the run period which determines the model *Start Timestep* and *End Timestep* and the forecast season which determines the forecast information used. Together, these periods comprise the model's *Run Range*. The *Start Timestep* and *End Timestep* for the current model configuration are summarized in Table 1 for each *Operations Start Date* month. In the future, the *Start Timestep* and *End Timestep* may become more dynamic.

Table 1. *Run Range* Based on Operations Start Date Month

Operations Start Date Month	Operations Period	Start Timestep	End Timestep
October	Fall-Winter	September 24, Previous Water Year	30 September, Current Water Year
November	Fall-Winter	September 24, Previous Water Year	30 September, Current Water Year
December	Fall-Winter	September 24, Previous Water Year	30 September, Current Water Year
January	Fall-Winter	September 24, Previous Water Year	30 September, Current Water Year
February	Fall-Winter	September 24, Previous Water Year	30 September, Current Water Year
March	Spring-Summer	February 22, Current Water Year	30 September, Current Water Year
April	Spring-Summer	February 22, Current Water Year	30 September, Current Water Year
May	Spring-Summer	February 22, Current Water Year	30 September, Current Water Year
June	Spring-Summer	February 22, Current Water Year	30 September, Current Water Year
July	Spring-Summer	February 22, Current Water Year	30 September, Current Water Year
August	Spring-Summer	February 22, Current Water Year	30 September, Current Water Year
September	Spring-Summer	February 22, Current Water Year	30 September, Current Water Year

Model runs with an *Operations Start Date* in the Fall-Winter operations period (including months October- February) have a *Start Timestep* of September 24 of the previous water year and an *End Timestep* of September 30 of the following water year (for example, September 24, 2018 through September 30, 2019). These start and end timesteps allow the model to simulate water operations through the Fall-Winter season and the following Spring-Summer season to examine the impact of short-term water operations decisions on the upcoming irrigation season.

Model runs with an *Operations Start Date* in the Spring-Summer operations period (including months March- September) have a *Start Timestep* of February 22 of the current water year and an End Timestep of September 30 of the current water year (for example, February 22, 2019 through September 30, 2019). These start and end timesteps allow the model to simulate water operations through the previous Fall-Winter season and the current Spring-Summer season to examine the impact of short-term water operations decisions on the upcoming season.

2.2. Observed and Forecast Data Handling

For both Fall-Winter and Spring-Summer operations, the model period from the *Start Timestep* up to the *Operations Start Date* is populated with observed historical data. The model is not actually run for the period prior to this date, although some computations may be made using the observed data. The model uses this data for plotting and analysis purposes. This is called the observed period.

Computations from the *Operations Start Date* forward use a mix of observed and forecast data. This is the period that the operators are actively scheduling. Additionally, some manual adjustments to data may be made to test alternative scenarios. As the *Operations Start Date* progresses through time, observational data replace forecast data.

Computations past the short-term forecast period use forecasted data.

For model runs with an *Operations Start Date* from October-December, the model first uses deterministic forecasts from the California Nevada River Forecast Center (CNRFC) for the first 7 days and then use an analog forecast for the remainder of the run period. For model runs with an *Operations Start Date* from January-September (inclusive), CNRFC deterministic forecasts are used for the first 7 days and then Natural Resources Conservation Service (NRCS) Water Supply Forecasts (WSF) are used and disaggregated from seasonal volumes to daily flows for the remainder of the run period.

2.3. Handling of Streamflow Routing Time

Due to the fact that it takes multiple days for water to flow from Upper Klamath Lake (UKL) to IGD, the model operates based on the concept of a local timestep. When the RiverWare controller is executing, it is on the "current timestep." All flows and operations at the top of the system (UKL, Gerber, and Clear Lake) will be operated on the same, current timestep. However, downstream objects will be operated on a future timestep. For example, rules will be setting values on the object slot, *IGD Outflow* at t+N timesteps. The projected/computed values will remain on those slots until the *Operations Start Date* catches up. Then the actual values will be set on the reservoir slots.

In this version of the model using the 2013 BiOp operating policy, the number of days it takes water to flow from UKL to IGD (i.e., the lag) is defined as 7 days, thus N = 7. In the 2019 BiOp, the lag is defined as 3 days, thus N = 3. Refer to Section 2.4.7. River Routing for descriptions of lag locations.

2.4. Objects and Methods

This section describes major features in the basin represented in KROM. Major features include river reaches, reservoirs, diversions, gages, water users, pumps, local inflows, and power facilities. RiverWare objects and methods are required to model these features. Model features are briefly described by region within the model domain.

2.4.1. Extent

Model extents in KROM include the entire Klamath River basin from the headwaters to the mouth at the Pacific Ocean. Water operations and model operating policy are focused on the Upper Klamath River, upstream of Iron Gate Dam, and are included in the 2013 BiOp. The Lost River system is included in the model. However, the model does not include water operations or policy in the Lost River System at this time. The Lower Klamath River, downstream of Iron Gate Dam, is include, but also does not include any water operations or policy at this time.

2.4.2. Upper Klamath Basin

The Upper Klamath basin encompasses the watershed of the Klamath River upstream of Iron Gate Dam. Reclamation's Klamath Project is in the Upper Klamath basin, where KBAO's river operations occur. The input locations for the RiverWare model in the Upper Klamath basin include *Williamson River Inflow*, *Sprague River Inflow*, *Willow Creek Inflow* (i.e., inflow to Clear Lake Reservoir), and Gerber Reservoir inflow. Local inflows are also represented along the Keno to JC Boyle reach, JC Boyle to Copco reach, and Copco to Iron Gate reach.

The RiverWare model includes the main diversion canals to the Klamath Project, but the model does not include representation of more fine scale water distribution within the Klamath Project (e.g., at the irrigation district scale). Klamath Project water users are lumped according to the following groupings: *Area 1 North of the Lost River Diversion Channel (LRDC)* and *Area 1 South the LRDC*, *Area 2*, *Area K*, and the Lower Klamath National Wildlife Refuge (LKNWR, object called *Refuge*). *Area 1 North of LRDC* receives water via the *A Canal* diversion object. *Area 1 South of LRDC* receives water via the LRDC, *Miller Hill Pump*, and *Station 48*. *Area 2* receives water via North Canal and *Ady Canal*. *Area K* and the *Refuge* receive water via *Ady Canal*.

Stream gage locations for which observations are available are included in the model to compare with simulated values.

2.4.3. Lost River System

The Lost River system encompasses the watersheds upstream of Gerber and Clear Lake reservoirs, as well as the contributing area flowing through the Lost River to Tule Lake. This is essentially a closed basin with the exception of the overflow diversion of water into and out of the Klamath River via the LRDC. Water may also be pumped from the Tule Lake sumps via D Pumping Plant, to the Klamath Straits Drain and ultimately the Klamath River.

The Lost River system is included in the RiverWare model; operations are estimated using available data, but these operations have not yet been verified. Water management in the Lost River system is generally independent of management of the remainder of the Klamath Irrigation Project which relies on UKL and the Klamath River for its water supply. An exception to this independent management is the LRDC which can be operated to transfer Klamath River water to the Lost River system and vice-versa.

For this model, flows from the Lost River into the LRDC represent observed historical conditions. In addition, water users along the Lost River are lumped into a single water user object. Future work on KROM may include more explicit operations policy for the Lost River system.

2.4.4. Lower Klamath Basin

The Lower Klamath basin encompasses the area contributing to the Klamath River downstream of Iron Gate Dam. Streamflow gage data are used as the tributary inflows to this part of the model. Water operations, including on the Trinity River, are not included in KROM at this time.

2.4.5. Reservoirs

The following reservoirs in the Upper Klamath basin are represented for storage and use of water for irrigation and environmental purposes: UKL, Clear Lake Reservoir, and Gerber Reservoir.

UKL is represented in RiverWare as a storage reservoir. The RiverWare methods associated with the reservoir include a hydrologic inflow (i.e., local inflows) and a diversion directly from the reservoir, which is the A canal. Gerber and Clear Lake reservoirs on the Lost River system are represented in RiverWare as storage reservoirs. The reservoirs incorporate mean seepage rates by month. The model does not include simulation of reservoir evaporation. In the case of UKL, evaporation is incorporated into the value of (observed or forecast) net UKL inflow.

The five reservoirs managed by PacifiCorp (i.e., Keno, JC Boyle, Copco 1, Copco 2, and Iron Gate) are represented in the model. Keno Reservoir, which has very limited active storage, is represented as a storage reservoir. JC Boyle, which has little storage and provides hydropower, is represented as a storage reservoir with a separate power facility. Copco 1, which also has little active storage and provides hydropower, is represented as a power reservoir. Copco 2, which is essentially a secondary power reservoir, is represented only as a reach with an attached power facility. Iron Gate Dam, which generates power and is used to moderate Klamath River flows downstream for salmon habitat and survival, is represented as a power reservoir. Because there is little information on day-to-day operations, these reservoirs are modeled by setting a constant pool elevation, to essentially pass all of the inflows. Spill is computed for JC Boyle and Copco 1.

Power is computed for Copco 1. These computations are based on publicly available data which were gathered as part of the Klamath River Basin Study (Klamath River Basin Study Technical Working Group 2016) but, because of the constant elevation, the results are not meaningful.

2.4.6. Local Inflows / Accretions

Accretions represent all of the local inflows, return flows, and any other gains or losses in the system. Accretions occur on the "Gain" reaches, for example, *Lake Ewuana Gain* and *Keno to Boyle Gain*, and at the Lost River Diversion Channel and F and FF Pump where a portion of the flow is an accretion.

All accretions between Keno and IGD are included on the *Keno to Boyle Gain*, directly downstream of the 7-day lag described Section 2.4.7 River Routing. In general, the accretions are specified on the Local Inflow slot as known values throughout the *Run Range*. Accretions are computed during the observational period by looking at the gaged data. Accretions for the forecast period are computed as part of the initialization rules. Forecasting computations are documented in the initialization rules.

2.4.7. River Routing

Routing in the river is performed on the Reach objects using the Time Lag routing method. In this version of the model, routing only occurs at one location on the Upper Klamath River at the *Keno To Boyle Routing* reach. On this reach, the time lag is set to 7 days to match how the IGD Calculator delays flows between UKL and IGD.

2.4.8. Diversions and Demands

Water diversions to canals are modeled with *Diversion* objects. Consumptive use of water is modeled with *Water User* objects. Enough detail for diversions and depletions is provided to represent main canals and lumped diversion areas, but this model does not perform a detailed depletions analysis. There are water users on the west side of the Klamath River who are not a part of the Klamath Project and who divert water from the Klamath River. These "non-project" users on the west side of Klamath River are not represented explicitly; their usage is currently tied in with accretions. The following sections describe the two main diversions and usage areas modeled: Area 1 and Area 2.

LRDC can move water in either direction. In the model, this is represented as two distinct flow paths. When water is diverted from the Klamath to the canal, it is diverted at *LRDC Draw from Klamath* to the *Div To LRDC* object. When water is diverted from the Lost River, it is removed from the *Wilson Dam* reach to the *Lost to LRDC* object and is subsequently routed to *Station 48* and *Miller Hill Pump*. Any unused or non-diverted water can return to the Klamath River at *Lost River to Klamath River* confluence.

The Klamath Drainage District (KDD) and the LKNWR are represented by gages, diversion objects, reaches, and water users as shown in Figure 2 and Figure 3.

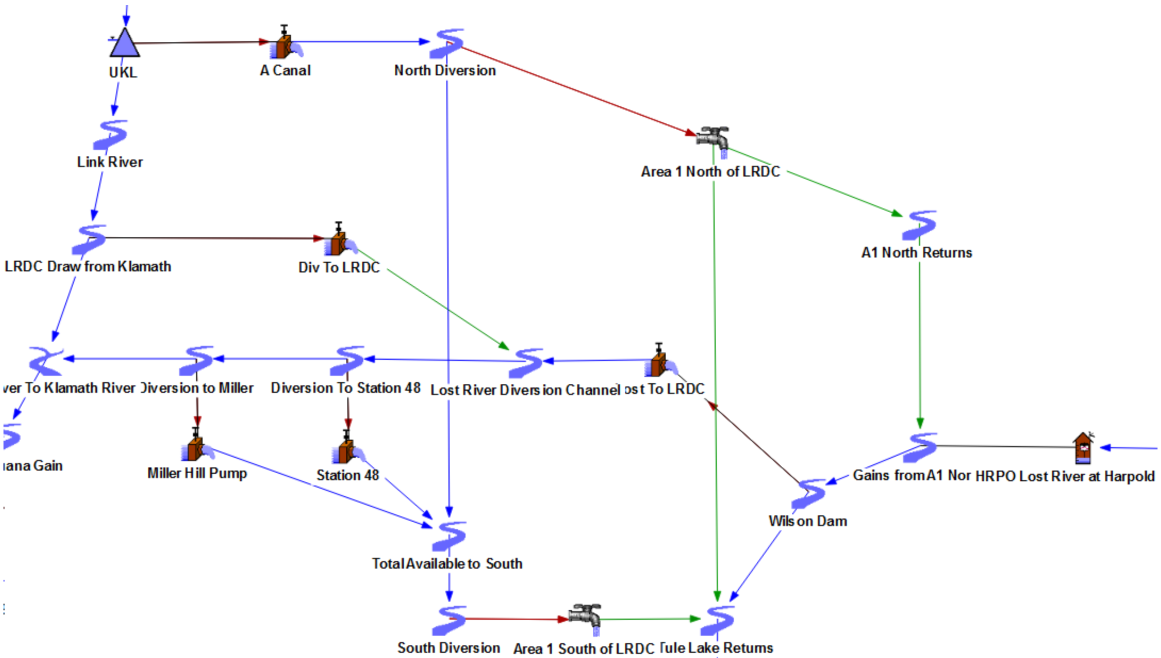

Figure 2. Area 1 KROM representation.

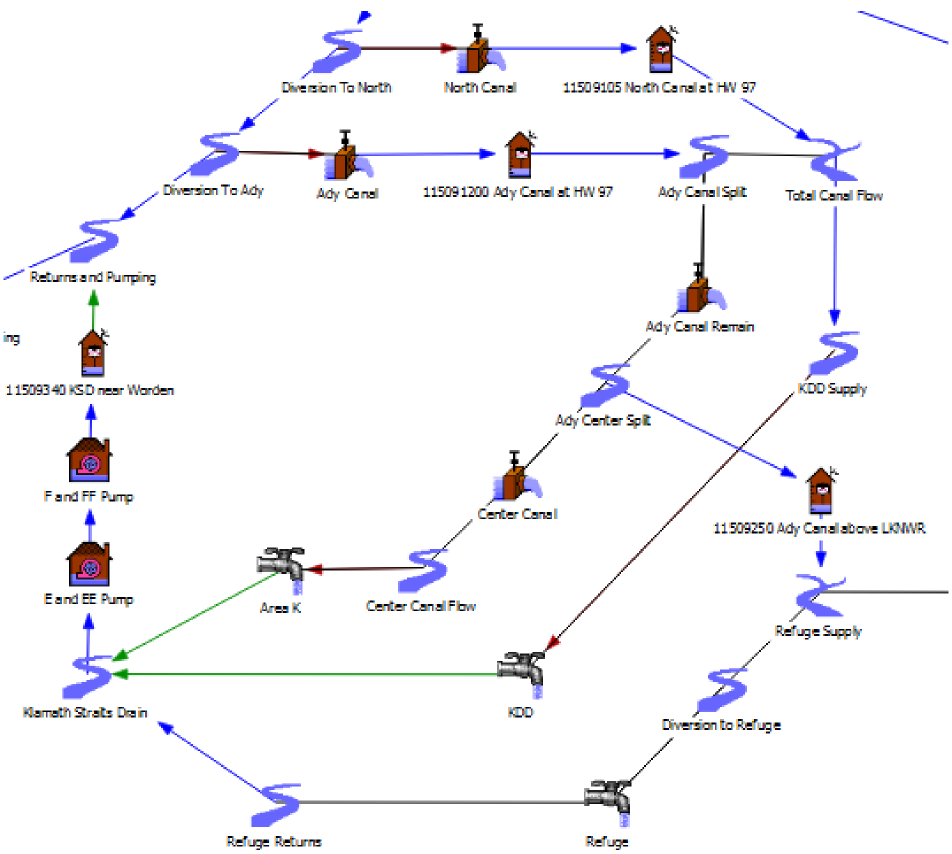

Figure 3. Area 2 KROM representation.

The objects are used to move the water from the Klamath River to the *North Canal* and *Ady Canal* objects. Water is then split into the components that go to *Area K*, *KDD*, and the *Refuge* Water User objects. *North Canal* only diverts agricultural water, whereas *Ady Canal* diverts both agricultural and *Refuge* water. Return flows and other accretions are conveyed through the F and FF pumps at the terminus of the Klamath Straits Drain.

3. Operating Policy

The operating policy in KROM is contained in *Initialization Rules*, *Rulebased Simulation (RBS) Rules*, and *Global Functions*. This section describes these three policy sets in the general order of the model's execution routine. Initialization rules execute first, at the beginning of a model run. *RBS Rules* execute on each model timestep. Both *Initialization Rules* and *RBS Rules* can call *Global Functions* and are described in their own section after the other two policy sets.

3.1. Initialization Rules

Initialization Rules prepare the model for a run. *Initialization Rules* execute once each at the beginning of a run. Rules either perform policy initialization or process observed Data. The associated rules in the model are classified as *Area Initialization* or *Model Setup* as shown in Figure 4.

The execution of *Initialization Rules* follows the same process as *RBS Rules*. It starts at the lowest priority rule and finishes on the highest priority rule. Unlike the *RBS Rules*, the *Initialization Rules* only execute on one timestep: the run start timestep. *Initialization Rules* can set either:

- The lowest priority (R flag and IR priority). Any *RBS Rule* may overwrite a slot they set. The model intends for this overwrite since some *Initialization Rules* set a placeholder value that allows the *RBS Rules* to begin an iterative process to set said slot.
- The highest priority (Z flag and 0 priority). If a slot set by *Initialization Rule* intends to be unaltered, the rule's priority is set as a Z or DMI Input. Thus, any *RBS Rule*, regardless of priority, cannot overwrite that slot.

Each *Initialization Rule* is described in more detail in Appendix A (on GitHub https://github.com/usbr/KlamathOpsModel). The following two sections provide two types of initialization that are performed.

3.1.1. Policy Initialization

Initialization Rules set initial values that are required for the run solution at the first timestep. In addition, rules set values that don't change throughout the run. For example, the *Lower Klamath Initialization Rule*, sets pool elevations of PacifiCorp managed reservoirs to constant values as this model does not include explicit operation of these reservoirs.

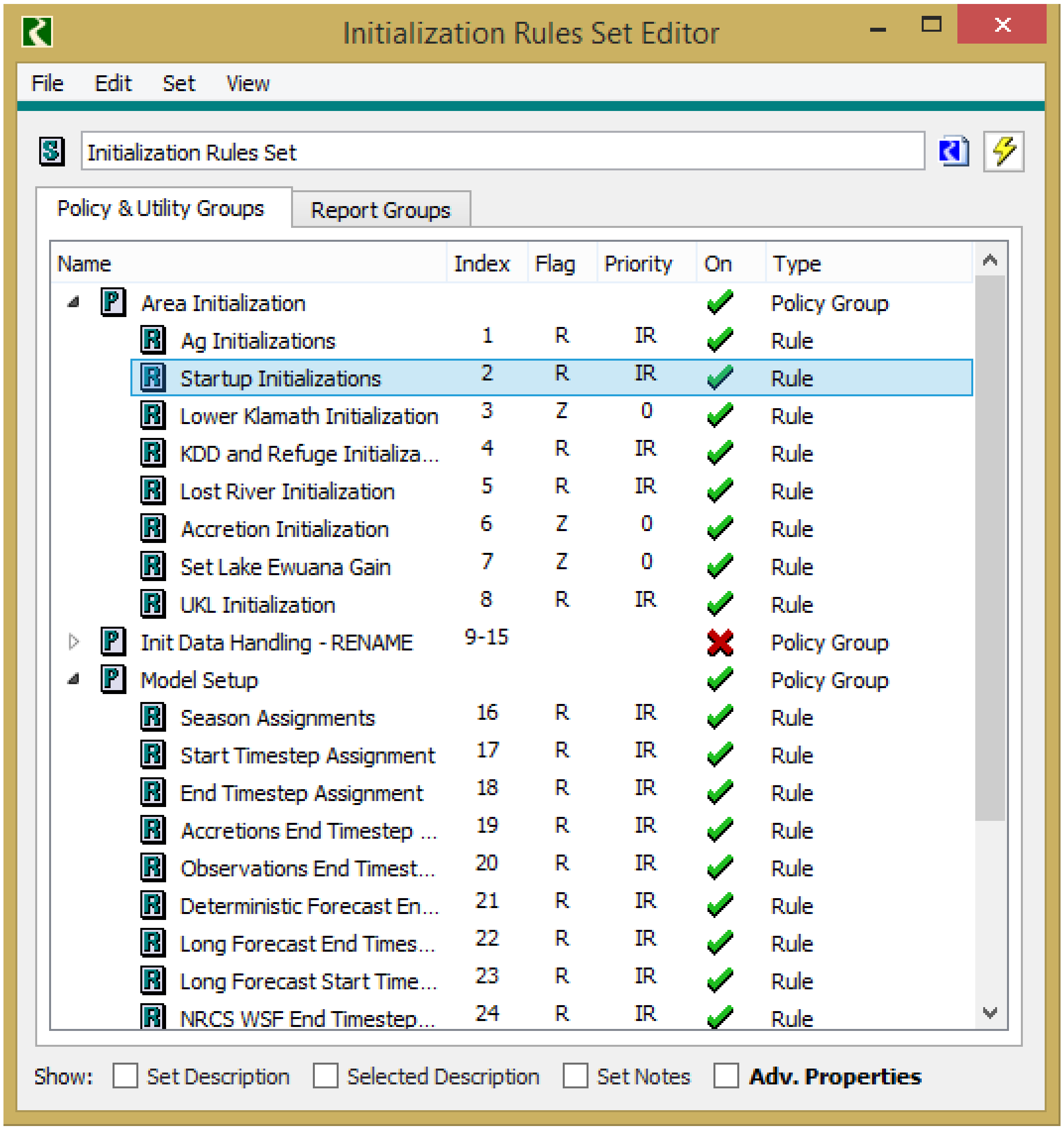

Figure 4. Policy Groups organizing logic in the KROM Initialization ruleset.

3.1.2. Importing Observed Data

Initialization Rules are used to populate input slots in RiverWare with observed data for the time periods up to the *Operations Start Date*, or time periods according to Table 1. These data may originate from a variety of sources and may be quality controlled before importing into KROM.

3.2. Rulebased Simulation Rules

The KROM 2013 BiOp operating policy is contained in *RBS Rules*. The rules are grouped into the operation they perform: *Lost River Operations*, *General Klamath Project Operations*, *Dilution and Flushing*, *KDD and Refuge Delivery*, *Winter Operations*, and *Summer Operations*. The ruleset and its policy groups are shown in Figure 5.

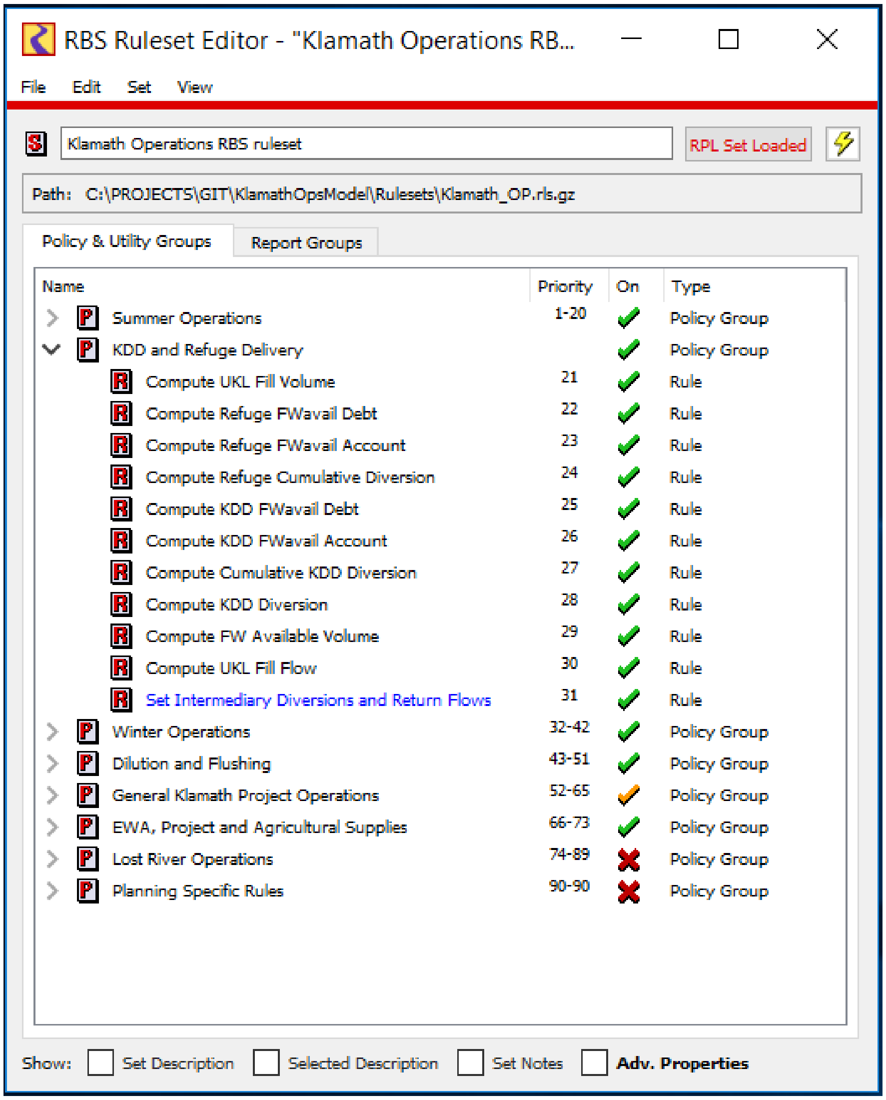

Figure 5. Policy Groups categorizing logic in the KROM Ruleset.

Each rule executes in reverse priority order (i.e., 3, 2, 1) on every run timestep; that is, rule 81 executes first and is the lowest priority. Conversely, rule 1 executes last and is the highest priority. Higher priority rules can overwrite values set by lower priority rules, but not vice-versa. A rule can re-execute on the same timestep after the highest priority rule if one of its dependencies changes.

The rules are documented in the model using inline comments and descriptions. Figure 5 shows a sample rule with inline comments (lines starting with red #) and description. Further, Appendix B (on GitHub https://github.com/usbr/KlamathOpsModel) provides a model report documenting all of the *RBS Rules*. Refer to Appendix B or the model for more information on any particular group or rule. Appendix B is also ordered by execution order. The following sections provide an overview of each group.

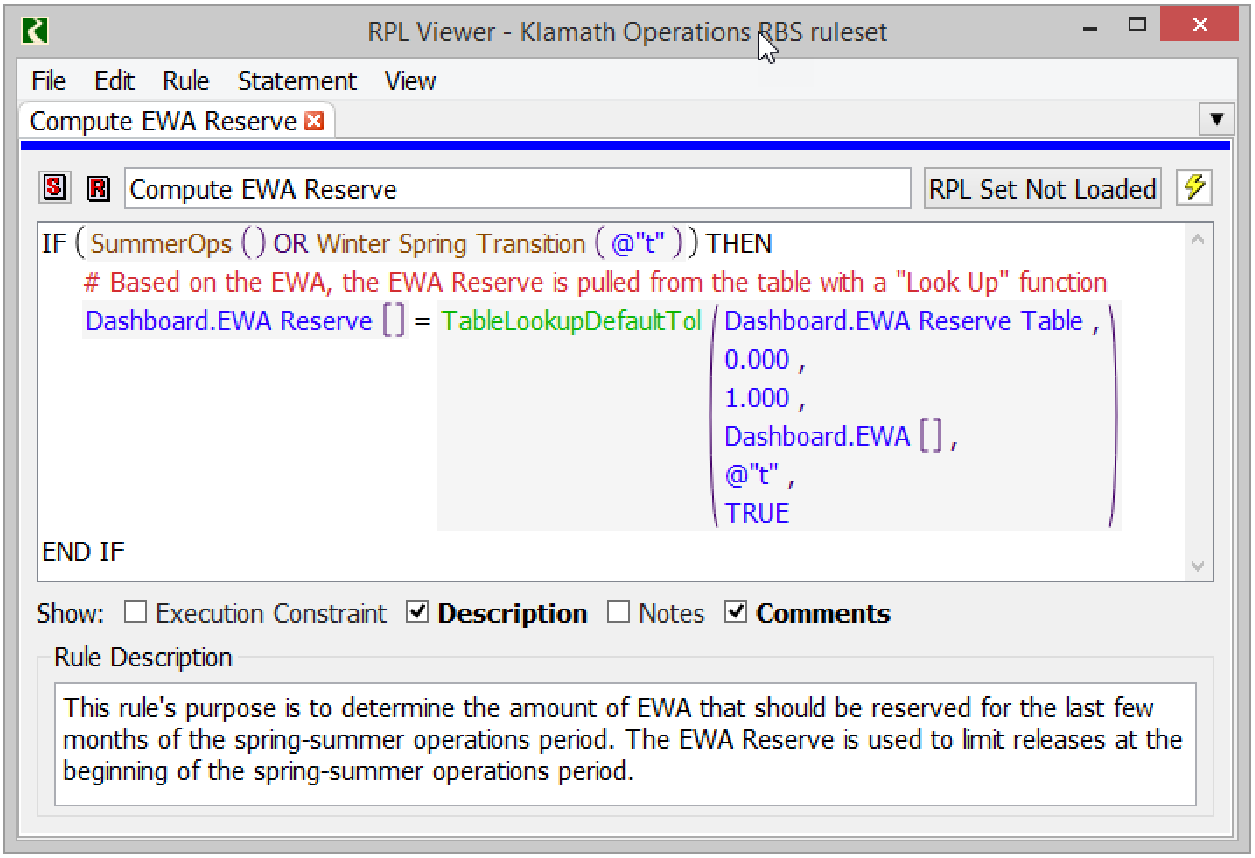

Figure 6. Sample rule showing inline comments (red # lines) and *Rule Description* at the bottom.

3.2.1. General Klamath Project Operations

Rules in the *General Klamath Project Operations* Policy Group provide computations that are not specific to Fall-Winter or Spring-Summer operations. A portion of the rule-set calculates projected inflow, elevation, or demand in various model objects, while other rules compute intermediate components that subsequent rules require.

The following sections describe the projections and intermediate components separately.

3.2.1.1. Computing Projections

Depending on the *Operations Start Date*, the model calculates certain model *Object* slot values to route water and calculate other variables. These other variables include:

- Williamson River Inflow
- LRDC Inflow
- Agricultural Diversion Requests
- UKL Inflow
- Klamath to LRDC Diversion Request
- Keno Pool Elevation

Many of these rules compute (or project) values for a number of future timesteps (i.e,. 3 days for LRDC), while some rules compute values on the current (or local) timestep. The projection value may be the result of either a table reference, past timesteps' average, allocation volume proportion, calculated shortage supply, or some combination of these. For example, the agricultural diversions' respective base demands are computed prior to setting the final adjusted value. Regarding UKL inflow, the model first computes this value based on climate scenario and corresponding table reference.

3.2.1.2. Computing Intermediate Values

Regardless of the current (or local) timestep within the *Run Range*, there are several rules that calculate intermediate values. These intermediate values are used by later rules. The *Net Accrete* is the most integral of these values. *Accretion Adjustment Factor*, *Spring Fill Rate Adjust*, and other calculations all involve *Net Accrete* in their computation.

3.2.1.3. Rule Descriptions

The following is a brief description of each rule in the *General Klamath Project Operations* Policy Group (Table 2), in reverse priority order:

Table 2. *General Klamath Project Operations* Policy Group

Priority	Rules
65	**Set Williamson Inflow:** This rule predicts the Williamson River inflow using data available from the CNRFC. The Williamson River inflow is a key factor in determining variables that set UKL releases in all season's operations
64	**Set LRDC Flow:** This rule predicts the accretion coming from the Lost River Diversion Channel. The accretion water is meant to be the excess amount left for environmental purposes after agricultural diversions have occurred.
63	**Set KDD Accounting Supplies:** This rule keeps track of water diverted to KDD via North Canal and Ady Canal.
62	**Compute UKL Agriculture Demand:** This rule determines the amount of water being released from UKL for agricultural purposes. The UKL agriculture demand is a key component of the calculation used to predict outflows at UKL in both Fall-Winter and Spring-Summer operations.
61	**Compute Scenario Percentile:** This rule sets the medium scenario percentile. This variable may be used to predict inflows at UKL.
60	**Set UKL Inflow:** This rule predicts the inflow at UKL using the flow scenario set by the operator.
59	**Set Klamath to LRDC Diversion Request:** This rule re-routes some of the release from UKL to make up for a shortage of water to divert in the LRDC.
58	**Compute Misc Flows:** This rule sums all the miscellaneous flow considerations to set the total. If the timestep is past the "Operation Start Date" and the total is a positive flow, then the total miscellaneous flow is assigned to UKL as a Hydrologic Inflow.
57	**Compute UKL Flood Release:** This rule sets the flood release at UKL to prevent the elevation from exceeding the limits determined by the operational policy. Ramp-down operations are used in flooding to prevent the downstream flows from varying excessively.

Priority	Rules
56	**Compute UKL Threshold:** This rule determines the maximum elevation of UKL based on month, guide curve, projected inflows, and current storage.
55	**Set Keno PE to Previous Value:** This rule sets the Keno Pool Elevation to the last timestep's value to allow the model to solve. Since this part of the basin is operated by PacifiCorp, the intent is to keep the elevation near constant.
54	Not used
51	**Compute LRDC to North & Ady Canal:** When there is excess water exiting LRDC, this rule determines what portion is used by North and Ady Canal. This only happens in the observed period, hence the predicted values are set to 0 cubic feet per second (cfs).
50	**Compute Net Accrete:** This rule sums all the individual accretions to find the net accretion in the basin. Winter and Summer operations differ in which individual accretions they consider. The net accretion is a key component used to determine releases at UKL and IGD in both Fall-Winter and Spring-Summer operations.

3.2.2. Dilution and Flushing

Rules in the *Dilution and Flushing* Policy Group determine large releases from UKL to remove algae and parasitic organisms in the Klamath River. Three types of releases perform this task: surface and deep flushing, long dilution, and short dilution. Each release in the *Dilution and Flushing* Policy Group occurs for a short period (< 1 month) within a specified window of dates. In addition to the timestep controlling these releases, a multitude of other factors initiate their calculation. They can be operator-set triggers, ramp-down operations, or even previous dilution or flushing releases. These factors affect each release. Thus, each release is described separately and then the rules themselves are listed in priority (reverse) order.

3.2.2.1. Surface and Deep Flushing

The flushing release is the earliest release of the group. It can be initiated between the beginning of January through the end of April. There is a toggle within the model that the operator may set to initiate a flushing release. The actual flushing release occurs for three days. At IGD, the release's magnitude ranges from ~ 4,000 to 6,000 cfs. Afterward, ramp-down operations steadily reduce flushing releases until they reach the regular policy rate. Typical ramp-down of flows takes 6 to 8 days; however, if the third day of flushing flow is high, then ramp-down can take up to 12 or even 17 days.

3.2.2.2. Long Dilution

Basin operations allow for one type of dilution release per year, long dilution or short dilution. If a dilution release is determined to be needed, the operator determines whether it will be a long dilution or short dilution release, based on information from fishery biologists and stakeholders. There is a toggle within the model where the operator may initiate this dilution release. A long dilution can be initiated as early as the beginning of April until the middle of June. The operator's setting initiates the long dilution release. Unlike flushing, a constant period does not control the long dilution release. Instead, an allocation volume is the limiting component. Any release from UKL for long dilution depletes the allocation volume. Once projected dilution releases exceed the allocation volume, ramp-down operations begin. Based on the allocation volume (~50,000 acre-feet [AF]) and release range (~3,000 to 6,000 AF at UKL), long dilution releases typically occur for 12 to 18 days, which include ramp-down operations.

3.2.2.3. Short Dilution

If a long dilution release is not made, then a short dilution release can be made. Short dilution releases can be initiated between the middle of May and the middle of June. The short dilution release is unique in that it has both a maximum allocation volume and a maximum duration over which releases may be made. The maximum allocation is 50,000 AF and the maximum duration is 8 days. The short dilution release magnitude is in the range of 1,500 cfs to 3,500 cfs at UKL, which means it usually occurs for the 8-day span. The short dilution release includes no rampdown operations.

The operator can alter triggers to initiate, increase or prolong releases up to the maxima. Those decisions depend on the projected basin conditions (wet, med, or dry).

3.2.2.4. Rule Descriptions

The following table (Table 3) describes the prioritized rules that control the dilution and flushing.

Table 3. Dilution and Flushing Policy Group Rule Description

Priority	Rules
51	**Compute IGD with Accretion:** This rule determines the release that occurs at IGD when all of the net accretion is available for its use. The net accretion may be the value determine by the Set *Net Accrete* rule or a table referenced value when the operator wants to use another year's flow characteristics.
50	**Compute Day Count:** This rule tracks the number of days it takes UKL to ramp down from dilution and flushing releases. The day count can also be used to reference a ramp-down flows for the IGD release for dilution and flushing calculation.
49	**Compute IGD Release for D&F:** This rule determines the release from IGD that sends dilution and flushing flows downstream. This variable is used to determine dilution and flushing releases from UKL.
48	**Compute Surface or Deep Flushing:** This rule sets the surface and/or deep flushing release. This release is a large pulse to remove algae and parasites from the river.
47	**Compute Short Dilution Flow:** This rule sets the short dilution release. The yearly sum of these releases are to be hard capped at 50,000 AF.
46	**Compute Dilution Rampdown Cost and Period:** This rule determines the released water for ramp down as well as the duration of the ramp down.
45	**Compute Dilution Ramping Trigger and Rate:** This rule sets over what timesteps the dilution release needs to be made and sets the flow rate.
44	**Compute Long Dilution Flow:** This rule sets the dilution release. The yearly sum of these releases are to be capped at 50,000 AF unless the releases are being made for rampdown
43	**Compute Cumulative Dilution Flow:** This rule tracks the cumulative dilution releases over the year, both short and regular. The cumulative value is used to limit the dilution releases once they reach a certain threshold, typically 50,000 AF.

3.2.3. Winter Operations

Rules in the *Winter Operations* Policy Group execute to model water operations during the Fall-Winter period and transition period between Fall-Winter and Spring-Summer, and include refill of UKL while still allocating water for agricultural diversions at KDD, minimum flow requirements, flood control, and release ramping procedures. They are active throughout the Fall-Winter period, which is defined as October 1 through February 28. In addition, some of the rules are active in the transitional period between Summer and Winter operations, which is September 24 until October 1. Rules are also active in the transitional period due to the 7-day flow lag.

Just as in Summer operations, the main decision point for winter operations is UKL and the secondary decision point is IGD. Operations satisfy the basin's water allocations by computing and assigning a release at these two reservoirs. To compute the UKL releases, a series of factors are required. These factors are described in the following subsections.

3.2.3.1. Adjustment Factors

Three adjustment factors can increase or decrease the release from UKL: *Williamson River Proportion Factor*, Klamath net accretion factor (*Net Accrete)*, and the UKL filling rate factor (*Fill Rate Adjust)*. For the *Williamson River Proportion Factor*, the model table interpolates the corresponding daily flow to set the factor such that the value is dependent on the month (Table 4). The accretion adjustment factor is based on a cumulative inflow index at UKL. It compares the cumulative inflow at UKL with the period of record minimum and maximum cumulative flows for each timestep. When that value exceeds the threshold value, the accretion factor is calculated (*Fill Rate Adjust)*. In addition, the cumulative inflow index at UKL interacts with the UKL filling rate factor. Due to the complexity of its calculation, it is discussed separately in the next section.

Table 4. Winter Operations Adjustment Factor Rules

Priority	Rules
42	**Compute Williamson Proportion Factor:** This rule sets the *Williamson River Proportion Factor* by interpolating the previous day's Williamson River inflow to a value in the associated table. The Williamson proportion factor is used to reduce or increase the Link Fall-Winter release.
41	**Compute Cumulative Inflow Index:** This rule tracks the cumulative UKL inflow for the winter operational period and set the UKL cumulative inflow index. The cumulative inflow index is used to initiate the use of the accretion adjustment factor for the Link Fal-Winter release.

3.2.3.2. UKL Filling Rate Factor

Starting in November, UKL begins its refill operations. Initially, the model calculates the rate of fill over the past seven days and the rate needed to reach the target elevation at UKL. Then, to assign the adjustment factor, a table references the difference between the recent and needed fill rate. This adjustment factor also depends on the index calculated from the cumulative UKL inflow. If the index denotes a dry year, the factor limits the release to a greater extent than in a wet year. In cases where the index indicates a wet year, the adjustment factor can increase the release to prevent the reservoir from reaching the flood elevation level (Table 5).

Table 5. Refill Rule Description

Priority	Rules
40	**Compute UKL Fill Rates:** This rule determines the recent and needed fill rates at UKL as well as track their difference. The fill rate difference is used to determine the fill rate adjustment factor.
39	**Compute UKL Fill Rate Adjust:** This rule tables select the fill rate adjustment factor based on the inflow conditions at UKL and the fill rate difference. The fill rate adjustment factor is used to reduce or increase the Link Fall-Winter release.

3.2.3.3. Demands

The two most common demands from UKL during *Winter Operations* are for:

- KDD agricultural diversions and
- minimum flow requirements below either IGD or UKL.

These are the base demands that the operations must satisfy during the Fall-Winter. In drier years, when reservoir inflows are limited, they are the only demands met since policy directs operations to conserve as much water as possible to fill the UKL for the Spring-Summer. Operations typically restrict releases for ramping and flood control to wet years when reservoir releases fluctuate greatly or the UKL pool elevation nears its flood elevation level respectively.

The Fall-Winter UKL release computation also includes considerations for miscellaneous flows. Although, these flows tend to be less frequent and of smaller magnitude during this period. Once again, the IGD operates to pass incoming flow from UKL with adjustments arising for minimum flows or ramping releases.

3.2.3.4. Rule Descriptions

The following table provides descriptions of additional rules in the *Winter Operations* Policy Group (Table 6).

Table 6. *Winter Operations* Policy Group Rule Description

Priority	Rules
38	**Compute Accretion Adj Factor:** The rule computes the accretion adjustment factor by interpolating the net accretion on a monthly table. The accretion adjustment factor is used to reduce or increase the Link Fall-Winter release.
37	**Compute Link Release for IGD Min:** The rule determines the release from UKL that supplies IGD with enough water to meet its minimum flow requirement. The UKL release for IGD min is used as a floor value for the UKL Fall-Winter release target.
36	**Compute Link Release Fall Winter:** This rule computes the Link release during the fall winter operational period. The Link Fall-Winter release is one of the flows used to determine the Link Fall-Winter target.
35	**Compute Link Fall Winter Target:** This rule computes the fall winter target release at Link. The Fall-Winter target release is a key component used to predict the UKL outflow during the Fall-Winter operations period.

Priority	Rules
34	**Set UKL Outflow Winter:** This rule sets the UKL outflow in the predicted period.
33	**Compute IGD General Flow Components:** This rule computes the flows at IGD that are controlled by upstream releases at Link. These different IGD flow components are used to calculate the IGD outflow in the predicted period.
32	**Set IGD Outflow and Compute Rampdown:** This rule computes the ramp-down flows at IGD as well as set the IGD outflow during the Fall-Winter operations period.

3.2.4. KDD and Refuge Delivery

Rules in the KDD and *Refuge Delivery* Policy Group have two purposes. The first purpose is to route water entering Ady and North canals through the Refuge, KDD, or Area K and calculate return flows that pass through the Klamath Straits Drain back into the Klamath River. This region is also known as Area 2 and is shown in Figure 3. The second purpose of these rules is to track the cumulative diversion by the Refuge and KDD during the Fall-Winter. Since each area has a set allocation volume during this period, any volume they divert above the allocation volume must be recorded and returned to the river at a later date.

Modeled flows through Ady Canal, North Canal, F and FF Pumps, and Refuge are either measured or calculated. However, there are a number of objects at which flow passes through and there are rules to route flows between these objects. These rules base their logic on simple algebra, but require some assumptions about diversions to Area K and KDD and return flows to the Klamath River. Thus, the model uses supplemental data provided by KBAO to approximate the fraction of total diversions going to Area K and KDD. Then, these fractions of the total diversion are multiplied by the total flow to result in a simulated flow to each area.

In general, debt and accrual calculations for the Refuge and KDD depend on the respective cumulative diversion and allocation volumes. To supplement their requests, without further accumulation, additional water becomes available under a set of flow conditions. This water is known as Fall-Winter Available or *FWavail*. *FWavail* is usable when UKL inflow exceeds the daily inflow needed to reach its target elevation by the last day of the Fall-Winter season. Since the allocation volume for the Refuge is far greater than the KDD, the KDD is almost always the only user with access to the *FWavail* water.

Refuge and KDD delivery rules are described in Table 7.

Table 7. KDD and Refuge Delivery

Priority	Rules
31	**Set Intermediary Diversions and Return Flows:** This rule computes and set the diversions and return flow fractions for the intermediary objects in Area 2 to successfully route water through this section of the model network. Known flows are at Ady Canal, North Canal, and F and FF Pump. Thus, this logic partitions these flows in between.
30	**Compute UKL Fill Flow:** This rule computes the average daily inflow at UKL needed to reach its target elevation by the end of the Fall-Winter Season.
29	**Compute FW Available Volume:** This rule computes the available flow from UKL that can be used for Area 2 diversion without counting towards the operations' debt.
28	**Compute KDD Diversion:** This rule computes the daily volume of water diverted for agriculture at KDD in the Fall-Winter season.

Priority	Rules
27	**Compute Cumulative KDD Diversion:** This rule computes the cumulative daily volume of water diverted for agriculture use at KDD during the Fall-Winter Season.
26	**Compute KDD FWavail Account:** This rule computes the cumulative available volume available for KDD diversion without accruing debt.
25	**Compute KDD FWavail Debt:** This rule computes the cumulative debt KDD has accrued from diverting agricultural water over the allocated volume during the Fall-Winter season.
24	**Compute Refuge Cumulative Diversion:** This rule computes the cumulative diversion, cumulative project diversion, and cumulative diversion over the allocated project volume.
23	**Compute Refuge FWavail Account:** This rule computes the cumulative available volume for refuge diversion without accruing further debt during the Fall-Winter season.
22	**Compute Refuge FWavail Debt:** This rule computes the cumulative debt the refuge has accrued from diverting water over the allocated project volume during the Fall-Winter season.
21	**Compute UKL Fill Volume:** This rule computes the volume difference between the current volume and target volume at UKL.

3.2.5. Summer Operations

Rules in the *Summer Operations* Policy Group allocate water for agricultural diversions, downstream reservoir releases, minimum flow requirements, flood control, and release ramping procedures. The rules are active throughout the Spring-Summer season which is defined as March 1 through September 30. In addition, some rules are active in the transitional period between Winter and Summer Operations, February 22 through March 1, to account for the flow lag between the Upper Klamath basin and Lower Klamath basin. The rules active during the transition period ensure all model objects have values starting on March 1st.

The rules focus on computing releases for UKL to satisfy the basin's water allocation. UKL release is based on many intermediate computations that are described in the following subsections.

3.2.5.1. Compute F and FF Pump Outflow

There is one rule that computes the amount of F and FF outflow that is meant for PacifiCorp (Table 8).

Table 8. F and FF Pump Outflow Rule Description

Priority	Rules
20	**Compute F AND FF Pump Outflow Reduction:** This rule determines the amount of F and FF Pump Outflow that is meant for PacifiCorp. This is not a physical reduction in flow, but an accounting reduction in flow available for environmental purposes.

3.2.5.2. Environmental Water Account

The Environmental Water Account (EWA) is the volume of water predicted to be available from UKL for environmental releases at IGD, flood control releases, releases for minimum flows, and ramping releases. When these releases occur, the cumulative volume used is tracked on a daily timestep. To exhaust the predicted volume by the end of each water year, the "used" volume adjusts the next timestep's releases of EWA water. The used EWA volume controls the adjustment of releases until July. Then, the remaining EWA volume is partitioned over the following months until the end of the season. Rules performing these operations are summarized in Table 9.

Table 9. EWA Rule Description

Priority	Rules
19	**Compute UKL for River Observed:** This rule sets initial values for a slot called UKL for River Observed. This is the UKL for River amount used before the Operations Start Date.
18	**Compute EWA Reserve:** This rule determines the amount of EWA that should be reserved for the last few months of the Spring-Summer operations period. The EWA Reserve is used to limit releases at the beginning of the Spring-Summer operations period.
17	**Compute EWA Used:** This rule tracks the amount of the EWA volume that has used by releases in the basin. The EWA used limits or increases future releases to reach the EWA volume by the end of Spring-Summer operations.
16	**Compute EWA Remain:** This rule tracks the EWA volume left for the remainder of the Spring-Summer operations period. It is only re-calculated at the beginning of each month from March through September. Once the timestep reaches July, the remaining EWA is portioned over the last few months to assign the UKL release for IGD.

3.2.5.3. Williamson River Inflow Volume

The Williamson River Inflow Volume rules are similar to the EWA. The forecasted volume is set for the season, and the cumulative actual inflow adjusts the UKL release based on its trajectory to meet the forecasted volume. It also adjusts releases until July. After that point, Williamson River inflows continue to be tracked, but these inflows no longer influence releases for the rest of the season. Rules performing this operations are summarized in Table 10.

Table 10. Williamson River Inflow Rule Description

Priority	Rules
15	**Compute Williamson Cumulative Inflow:** This rule tracks the cumulative volume of inflows at Williamson River over the Spring-Summer operations period. The Williamson cumulative inflow is used to set the Williamson River cumulative proportion factor.
14	**Compute Williamson Cumulative Proportion:** This rule sets the Williamson cumulative proportion factor. The Williamson cumulative proportion factor is used to limit or increase the UKL release for IGD based on whether there is an excess or a shortage of inflow into the Williamson River.

3.2.5.4. Spring Reservoir Refill

An objective during Spring, when flows are higher due to precipitation and snowmelt, is to fill UKL to provide storage for later in the Summer. Rules in this section compute the maximum target elevation and the fill rate. Considerations for refill stop after June or when UKL reaches its target elevation. Rules performing this operation are summarized in Table 11.

Table 11. Williamson River Inflow Rule Description

Priority	Rules
13	**Compute UKL Max Elevation:** This rule computes the max Summer elevation. The max Summer elevation is used to switch on and off the Spring fill rate factor.
12	**Compute Spring Fill Rate:** This rule computes the Spring fill rate factor. The Spring fill rate factor is used to reduce the UKL release for IGD so that the UKL pool elevation can reach the target elevation.

3.2.5.5. Flood Control and Ramping

Flood control commonly occurs from March through April since inflows at UKL are high and agricultural demands are low—which cause the pool elevation to rise rapidly. Ramping releases are not seasonally dependent but typically follow a large release or a flood release since the transition back to regular flows differs greatly in magnitude. Minimum flow releases occur occasionally throughout the Spring-Summer due to limited releases for UKL to refill in the early Spring and lower local inflows to the Klamath during the middle to end of Summer.

In addition, the Spring-Summer UKL release computation has considerations for miscellaneous flows in the basin. Miscellaneous flows are not determined by the *Summer Operations* Policy Group. Rather, the *Dilution and Flushing* and *General Klamath Project Operations* groups compute these values.

A key control point for Summer operations is Iron Gate Dam (IGD). The allocations met by the computed release at IGD diminish since no agriculture diversions for the Klamath Project exist below the dam and the majority of miscellaneous flows route above the IGD. Generally, the IGD operates to pass through the incoming flow from UKL with adjustments arising for minimum flows or ramping releases. Rule descriptions are provided in Table 12.

Table 12. *Summer Operations* Policy Group Rule Description

Priority	Rules
11	**Compute IGD Summer Ramping:** This rule sets the ramp-down flow rate from IGD during the Spring-Summer operational period. The ramp-down prevents the release from dropping excessively from one day to another.
10	**Compute UKL for IGD:** This rule computes the UKL release for IGD. The UKL release from IGD is used to determine the overall release for the river and transitively predict the release at UKL during the Spring-Summer operational period.
9	**Compute IGD Preliminary Flow:** This rule provides a preliminary estimate of the flow at IGD based on UKL release types, accretions, and accretion diversions. The preliminary flow estimate used to determine other releases from IGD and even influences the predicted outflow at IGD during the Spring-Summer operational period.
8	**Compute IGD Corrected Override Flow:** This rule converts the override flow into a variable that can be used to calculate other releases at IGD. These other releases are the override corrected flow at UKL and the UKL release for the river.

Priority	Rules
7	**Compute UKL for Flood Control:** This rule determines what portion of the release at UKL is meant for flood control. The flood control release is used to determine the overall release for the river and transitively predict the release at UKL during the Spring-Summer operational period.
6	**Compute UKL Ramping & Proj Min Release for IGD:** This rule determines what portion of the release at UKL is meant for ramping and the projected minimum flow at IGD. These releases are used to determine the overall release for the river and transitively predict the release at UKL during the Spring-Summer operational period.
5	**Compute UKL Corrected Override Flow:** This rule converts the override flow into a variable that can be used to calculate other releases at UKL. These other releases are the UKL release for the river and the predicted IGD outflow.
4	**Set UKL Outflow Summer:** This rule predicts the outflow at UKL during the Spring-Summer operations period.
3	**Set IGD Outflow:** This rule computes the final estimated IGD outflow and set the IGD outflow during the Spring-Summer operations period.
2	**Reset IGD Outflow with D&F Considerations:** This rule increases the IGD outflow to pass dilution and flushing flows when they occur. The original IGD outflow prediction rule did not have considerations for dilution and flushing.
1	**Compute UKL for River:** This rule computes the release from UKL made for the river. It is a key component in determining the predicted UKL outflow.

3.2.6. Lost River Operations

Rules representing Lost River operations are in progress at this time. Lost River operations largely do not impact Klamath River operations as part of the 2013 operating policy. River and reservoir objects in this part of the basin incorporate any available data. Rules currently operate the reservoirs to meet flood control restrictions according to Reclamation Standing Operating Procedures (SOP) for Clear Lake and Gerber reservoirs. The rules that exist at this time have not undergone thorough testing. Refinement and testing of the Lost River operations rules may be performed as part of future work.

3.3. Global Functions

Rules employ certain expressions or computations more than once. To avoid repetitive coding and to help condense a rule's structure, global functions were created to house these expressions and computations. A global function provides a named, modular, and reusable expression that is available to all policy sets that may be part of a given model. To provide further flexibility, some functions pass in arguments of objects, slots, numbers, strings, booleans, lists, or datetimes. Arguments allow the function to pass in the variable they use in their evaluation. *The Global Klamath Operation Functions* policy groups are shown in Figure 7. Each line in this figure represents a policy group.

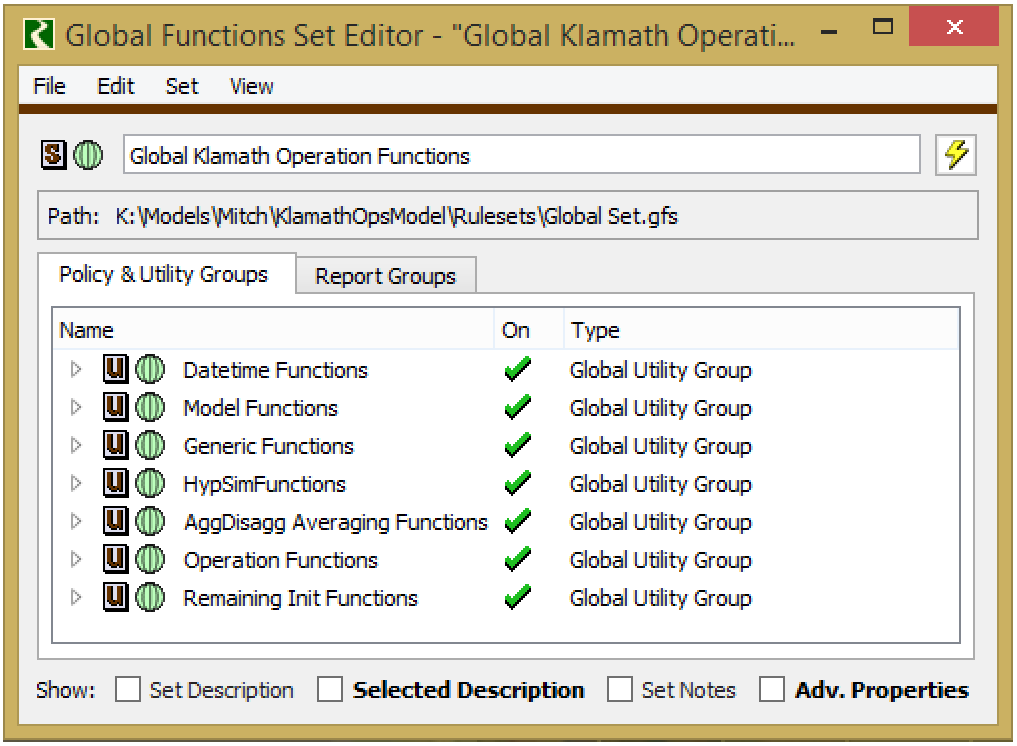

Figure 7. Policy Groups organizing logic in the Global Klamath Operation Functions set.

Over 130 global functions are defined in this set. These are listed and/or described in Appendix C (on Github https://github.com/usbr/KlamathOpsModel).

4. Workflow and Usage

Managing input to and output from the KROM and establishing a streamlined workflow are critical because Klamath Project operators must be able to accomplish their work quickly and efficiently. Additionally, the workflow needs to be reproducible to allow operators to run a variety of scenario simulations.

Four commonly used RiverWare utilities that facilitate data management and multiple scenario simulations are: Data Management Interface (DMI), System Control Tables (SCT), Scripts, and Output Devices. The following sections summarize these utilities and provide examples of what they can do.

4.1.1. Data Management Interface

The Data Management Interface (DMI) allows RiverWare to import or export datasets in a variety of formats, including text files, Excel databases, Hydrologic Engineering Center (HEC) Data Storage System (DSS) databases, and Reclamation's Hydrologic Database (HDB). The RiverWare model slots and *Run Range* are controllable from the DMI Manager window. The *Run Range* is dynamic and allows datetime functions to denote the beginning or end time step of the data being imported or exported. RiverWare models can assign multiple DMIs to handle both model input and output data. Interacting with a variety of data formats can be achieved by using different types of DMIs.

KROM uses Excel-based DMIs to import data into the model, wherein underlying Excel sheets house data from KBAO, the Natural Resource Conservation Service (NRCS), and the U.S. Geological Survey (USGS). Table 13 lists the DMIs that link observational data to the RiverWare model as input.

Table 13. DMIs used by the Klamath River Operations Model

DMI Name	Data Source
Import Basin Inputs Remain	Existing Iron Gate Dam Calculator
Import Hand Inputs	Existing Iron Gate Dam Calculator
Import Hand Inputs 2017	Existing Iron Gate Dam Calculator
Import Observations KBAO	Observational data collected by KBAO
Import Observations USGS	Observational gage data compiled from USGS website
Import Op Percentiles	Existing Iron Gate Dam Calculator
Import Op Percentiles 2017	Existing Iron Gate Dam Calculator

Figure 8 is a screenshot of the *Import Observations KBAO* DMI. The linked Excel database houses historical observational data collected by KBAO manually and not through an automated source such as Hydromet or USGS website. Figure 8 shows the RiverWare slot categories to which the KBAO observational data are copied and the time series range over which the data are copied. The time period over which data are imported into RiverWare slots can be specified using functions and can be dynamic (i.e., unique time series range for different slots).

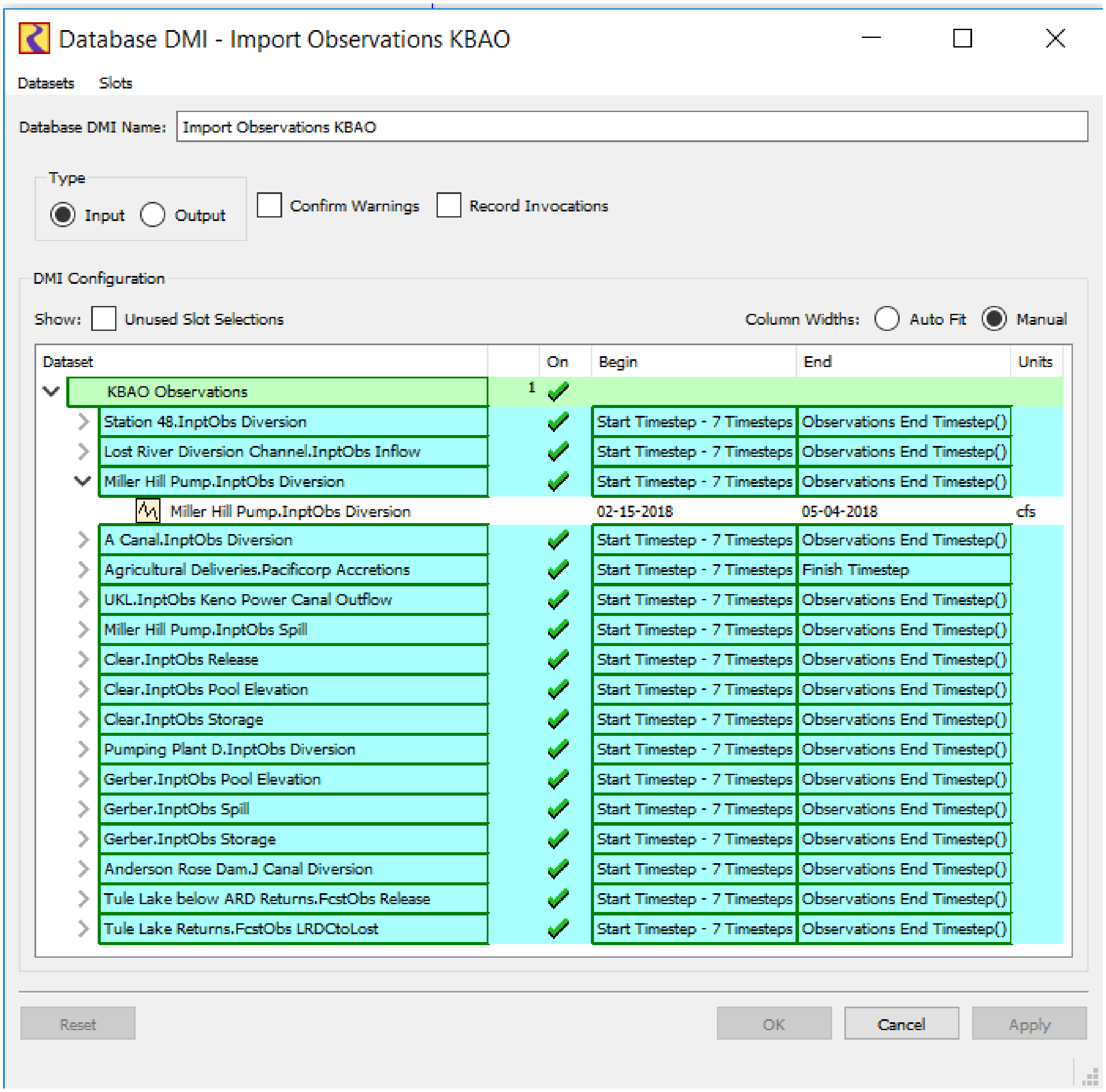

Figure 8. Import Observations KBAO slot categories and data time series ranges.

4.1.2. System Control Tables

System Control Tables (SCT) are highly customizable, editable spreadsheet-like views of the data stored in RiverWare model slots. The model developer or operator can create one or more SCTs tailored to individual needs. If desired, different operators can have different SCTs, allowing each operator to have their own customized view. The data in the SCT can be edited directly, and runs can be made using edited data. In addition, DMIs and scripts can be executed directly within the SCT.

KROM was developed with 6 SCTs. These SCTs correspond with existing tabs in the Iron Gate Dam Calculator, including Winter Ops (i.e., Winter Operations), Summer Ops (i.e., Summer Operations), Agricultural Ops (i.e., water distribution for the Klamath Project), Dilution and Flushing (i.e., special operations for dilution flushing flow releases), UKL Overview (i.e., UKL variables), and All Slots. Figure 9 is a screenshot of the KROM's SCT Klamath Ops Overview showing the slots on the Winter Ops tab.

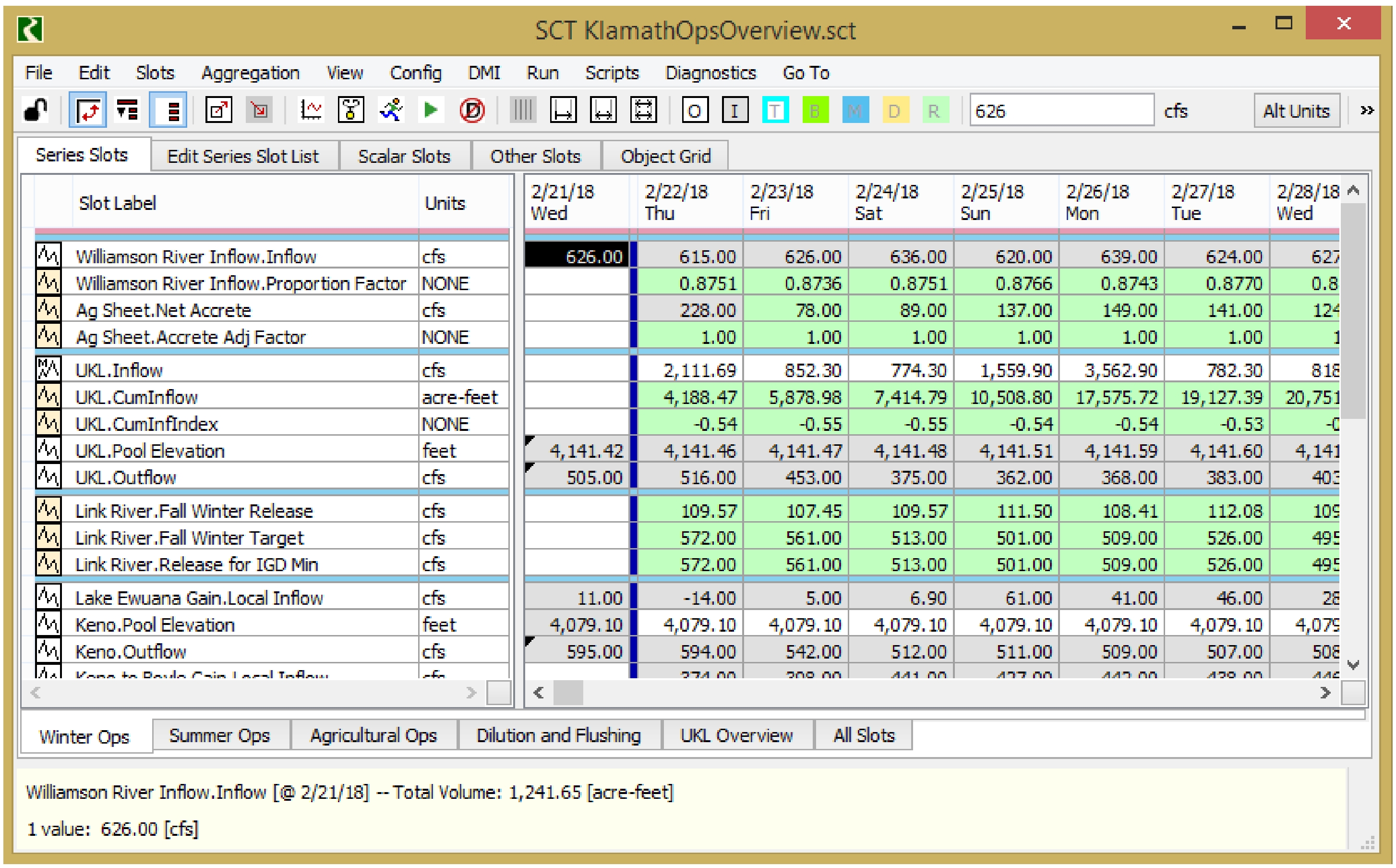

Figure 9. Screenshot of the Overview SCT showing the Winter Ops sheet.

4.1.3. Scripts

Scripts are a way to automate commonly repeated tasks in the implementation of KROM. Scripts are particularly useful for operations modeling because there are often a set of tasks that operators perform regularly, perhaps every day, once a month, or once a year. For example, KROM contains one script to prepare the model for a daily operations simulation. It performs tasks such as loading the operations ruleset, running DMIs, and setting the operation start date.

Figure 10 is a screenshot of KROM's script "Prepare for Operation" that shows the automated model tasks and the editable controls for the operator (or modeler).

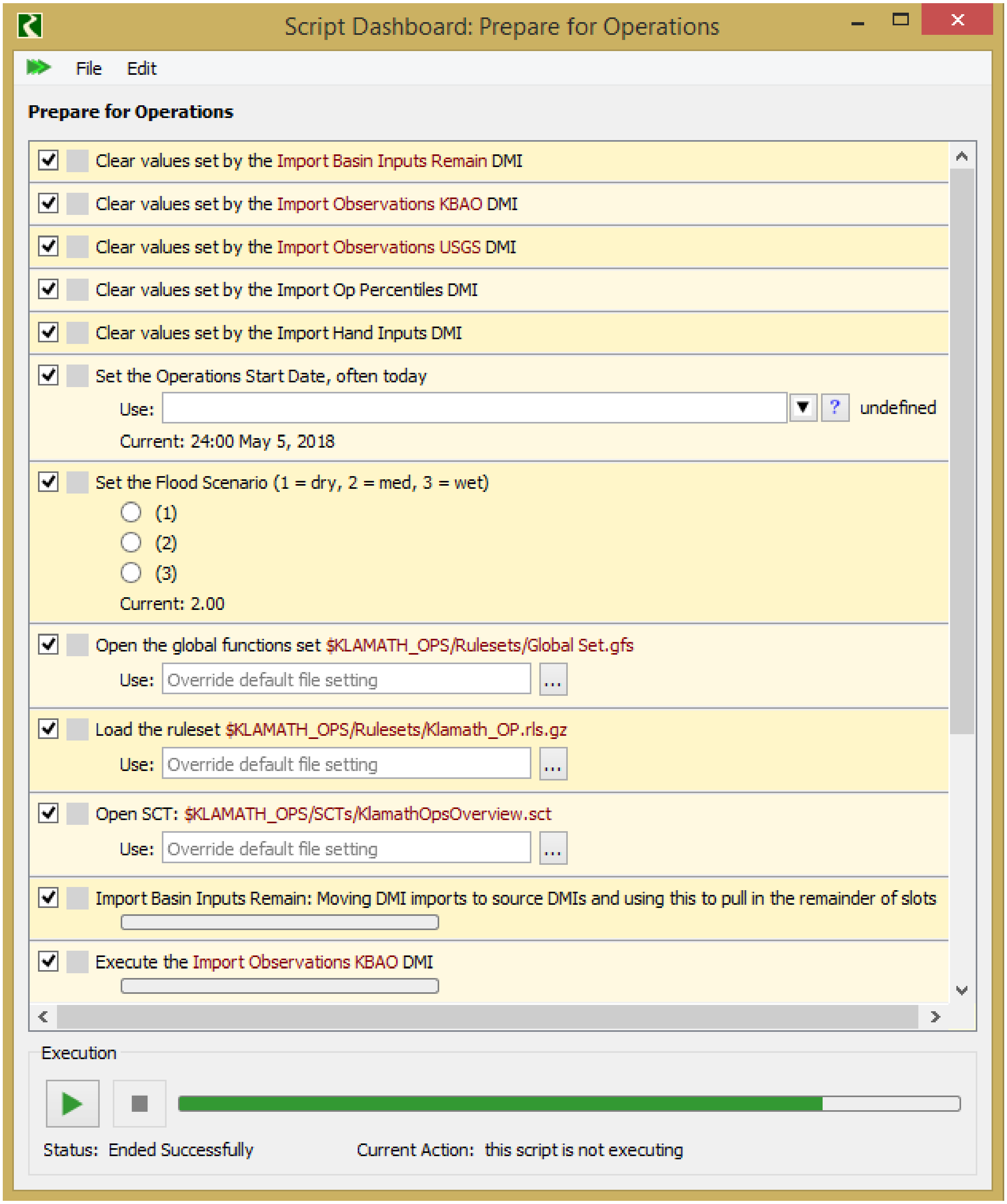

Figure 10. Tasks and operators input selections as part of the Prepare for Operations script.

4.1.4. Output Devices

RiverWare has many output devices including plots, reports, charts, and the output canvas. This section provides a brief overview of each output device and how it is used in KROM.

4.1.4.1. Plots

RiverWare has a feature-rich plotting package. Plot templates can be configured to display data from model slots and dynamically update with each model run. Figure 11 shows a sample plot with UKL threshold and Pool Elevation information. The black line is observed data while the red line is the forecasted pool elevation resulting from a model run simulation. The dotted blue line shows the *Operations Start Timestep*.

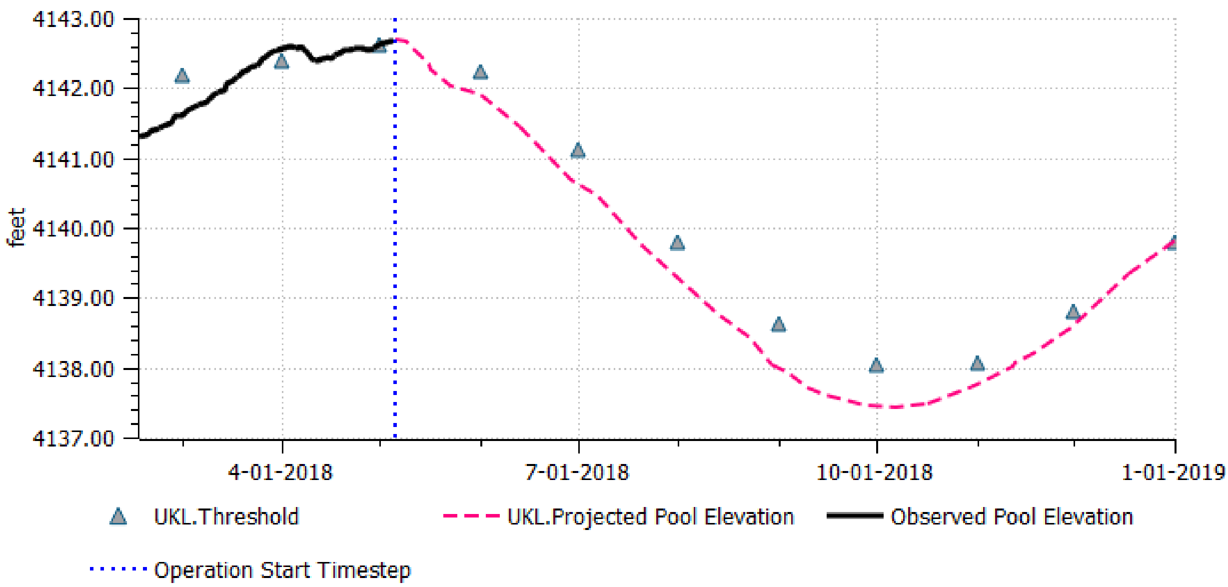

Figure 11. Screenshot of a sample plot from an operations model.

4.1.4.2. Model Reports

RiverWare has the ability to automatically write output information to a HTML report using the *Model Report* output device. The content, organization, and formatting of the *Model Report* is highly configurable. *Model Reports* are commonly used for two purposes: documenting the model and ruleset and providing output results for distribution to stakeholders, operations partners, or others. Results can be output in both tabular and graphical format, including plots, charts, and the output canvas. Text, such as comments describing individual operating rules, may also be included in a *Model Report.*

4.1.4.3. Output Canvas

The Output Canvas provides spatially distributed output and can include teacup diagrams (denoting reservoir or other storage volume), flow lines, and other items. Figure 12 shows a screenshot of an output canvas on May 16, 2018, as an example. The canvas can be animated to show how volumes (represented by teacups) and flows (represented by varying widths of flow lines) change over time. As flows increase, the lines get thicker; as they cross defined thresholds the colors and line types change. The animation can be exported as an image or a movie file.

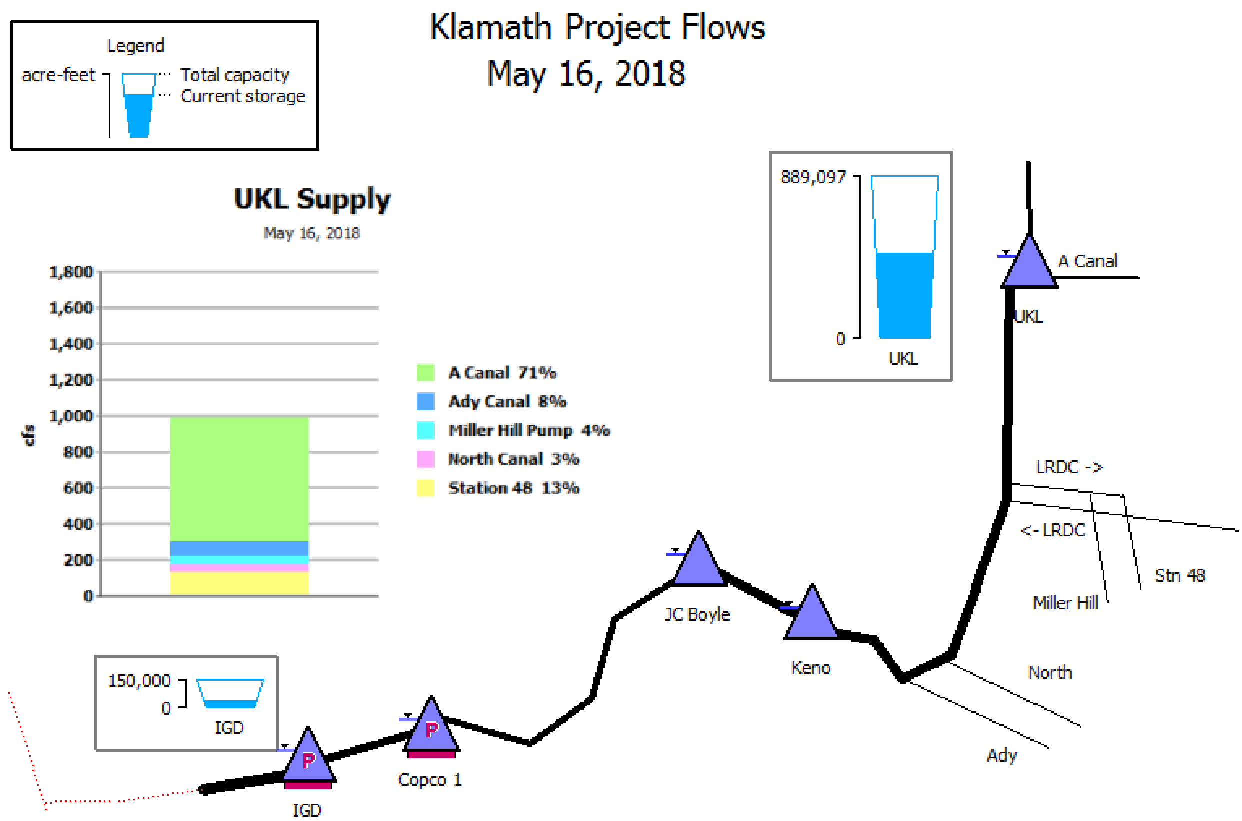

Figure 12. Screenshot of Output Canvas showing teacups, a chart, and flow lines.

4.1.5. How to Run

The modeling framework creates a simple setup-and-run process for daily operations by using DMIs and scripts. The KROM Script Manager serves as the operator's main control and dashboard, while DMIs serve as data import devices. Externally, Excel sheets hold the data that the DMIs import. The Excel sheets must include data up to the date of the *Operations Start Timestep*. The SCT provides organized views of model inputs and outputs based on type of operation or object specific flows, and other variables. Plots provide graphical views of select slots as well.

The model files are held in a working directory, *KlamathOpsModel* which contains subfolders for Models, Rulesets, Database, SCT, and Documentation. The model relies on Environment Variables to locate rulesets, global function sets, and DMI files. Before opening RiverWare, set the KLAMATH_OPS environmental variable to this working directory, for example, C:\Temp\KlamathOpsModel. You can find instructions on how to set environment variables for your operating system on the internet.

Use the following steps to run the model:

1. **Update Excel Sheets**. Confirm each sheet has timeseries data spanning the beginning of the initial water year until the *Operations Start Timestep*. An Excel sheet houses the operational percentiles that control the prediction of the four accretions. Adjust values if they do not match the water year's scenario forecast. This can also be done in the model after running the script. It is a good idea to organize the directory structure so that all Excel-based DMI files holding timeseries data, operational percentiles, and/or other data, be contained within a central folder location (e.g., C:\Temp\KlamathOpsModel\Database\Ingest).

2. **Adjust the Script**. Open the *Prepare for Operations* script. Set the *Operations Start Timestep* and *Flood Scenario* and run the script. The script automatically clears slots set by the previous run's DMIs and initialization rules. In addition, the script automates the execution of the DMIs and the loading of the global functions, *RBS Rules*, and SCT.

3. **Check Parameters**. Confirm that the model run period, adjustment factors, and triggers are set as intended. Since adjustment factors and triggers change less frequently, they are not set in the script. Rather, adjust these values in the corresponding *object.slot* (i.e., UKL Inflow Season Adj Factor and *UKL.Season Adj Factor*).

4. **Run the Model**. Run the model from the *Run Control* dialog.

5. **Investigate Outputs**. Open the SCT window. This contains important slots organized by specific operation or object. Select each by their tab. The following tabs are available: *Winter Ops*, *Summer Ops*, *Agricultural Ops*, *Dilution & Flushing*, and *UKL Overview*. View graphical representations of flows by selecting the plot icon. The following plots are available: *Upper Klamath Flows*, *Iron Gate Release*, *Gerber & Clear Inflows/Outflows*, *UKL Elevation and Threshold*, and *UKL Flows*. Observe other slots by selecting directly from the object viewer.

5. References

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