Middle Fork American River Project Operations Simulation Model

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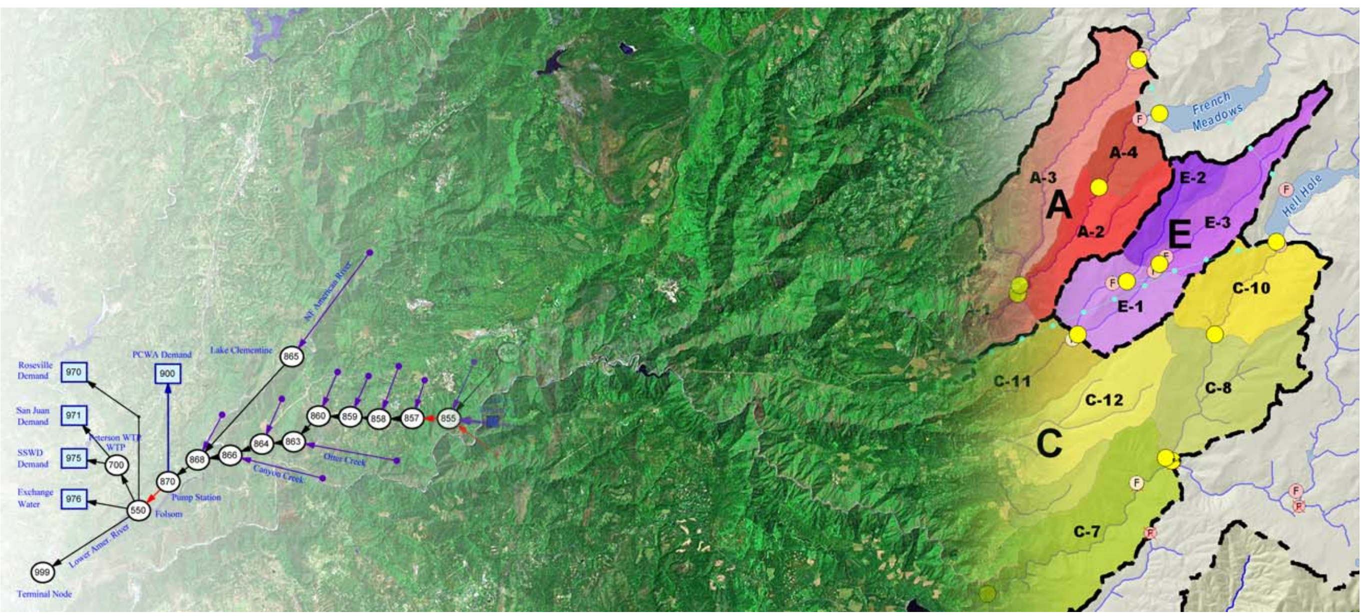

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1.0 Introduction

Placer County Water Agency (PCWA) developed the *MFP – Operations Simulation Model* (model) for the Middle Fork American River Project (MFP) (FERC No. 2079) relicensing. Due to the substantial work effort invested in the model, PCWA built upon the framework of the relicensing model to develop an operations planning model for seasonal dispatch planning and operations forecasting. This document describes the way the model operates the MFP, as well as how to work with the model to set operational goals and constraints.

2.0 Background

The MFP consists of two storage reservoirs (French Meadows and Hell Hole reservoirs), two regulating reservoirs (Middle Fork Interbay and Ralston Afterbay), three small diversions dams, and five powerhouses with interconnecting tunnels and penstocks. Diversions of water for MFP operations directly affect flows in Duncan Creek, the Middle Fork American River, the Rubicon River, and Long Canyon Creek. Operations of the MFP affect flows in the Middle Fork American River below Ralston Afterbay Dam and the Oxbow Powerhouse. For a detailed description of project facilities see Placer County Water Agency, Middle Fork American River Project Draft Pre-Application Document, 2007.

The MFP is water-limited. Sufficient water only is available, on average, to operate water conveyance facilities (tunnels and penstocks) and powerhouses at full capacity part of the time each year. Annual MFP operations generally follow a pattern of refilling the storage reservoirs (French Meadows and Hell Hole) during winter and spring runoff periods, then releasing water through the summer and fall months to meet consumptive water and electrical demands. At all times, releases are made to meet minimum instream flow requirements.

The model has been prepared to allow users to evaluate the following:

- The effect of hydrologic variability (water availability)
- Changes to minimum instream flow requirements
- Changes to minimum reservoir storage levels
- Changes in the annual carryover storage target
- Other specified flow requirements (pulse flows, recreation flows, etc.)
- Limits on the rate of change (ramping rates) in reservoir elevation and river stage over specified time periods
- Implementation of Project betterments
- The effect of electrical power prices on project operations
- The effect of water transfers on project storage and flows in the North Fork American River below PCWA's American River Pump Station.

3.0 Model Structure and Operation

The model is an application of the standard computer-based hydrologic model OASIS with OCL™ developed by Hydrologics, Inc.[1]. Implementation of the OASIS model for the Middle Fork Project includes the following key features.

- MFP Physical Description – The Middle Fork Project's connectivity is described in the model by a network of arcs and nodes. A node is any location of interest; it may be a reservoir, a junction of two river reaches, or a diversion point. An arc connects two nodes and represents a flow of water, be it a river reach, tunnel, or penstock and powerhouse. A diagram of the arc-node structure used to describe the MFP and its related waters is shown in Figure 1 – MFP Operations Simulation Model Arc-Node Structure. The data used to develop the diagram is contained in the Arc and Node tables in the model.

- Operating Constraints – Within the context of running the model, constraints are rules that the model should obey when operating the system. System constraints built into the model include the following:

  Physical Capacities[2]: Maximum reservoir storage capacity, maximum tunnel flow capacity, generating unit flow capacity, minimum operational reservoir elevations.

  Regulatory and Contractual Requirements: Examples of regulatory and contractual requirements include: minimum instream flow requirements (flow rate and time period), minimum reservoir elevations (elevation and time period), maximum allowable diversions (flow rate, seasonal volume and time period) for power and consumptive uses, and contractual delivery requirements.

  These requirements are slightly different than physical constraints. Physical constraints cannot be violated in a simulation, but regulatory and contractual requirements can. Alternatives will be developed and tested with the model. Some of the alternatives tested with the model may not be practicable, and may cause violations, for example, of minimum instream flow requirements or minimum storage requirements. Although these alternatives cause violations, the results can still be useful. Allowing violations is a necessary way to allow the model to complete the simulation. They can also be used to demonstrate whether a proposed operating regime is feasible.

- Operating Objectives[3] –When running a simulation, the model is set to maximize the achievement of specific objectives to the extent possible within the

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[1] OASIS with OCL is a trademark of Hydrologics, Inc. and is a commonly used model for simulation of hydroelectric systems in support of water management decisions.

[2] The physical capacities used in this model may be different than those reported in the Project description or in the Project engineering drawings because the physical capacities in the model may represent typical or known capacities based on 40 years of operating the MFP.

[3] OASIS is a linear program model that requires the designation of "Goals" that the model seeks to achieve. In its formulation for the MFP, the term operating objectives has been used instead of goals but in the modeling context it has the same meaning.

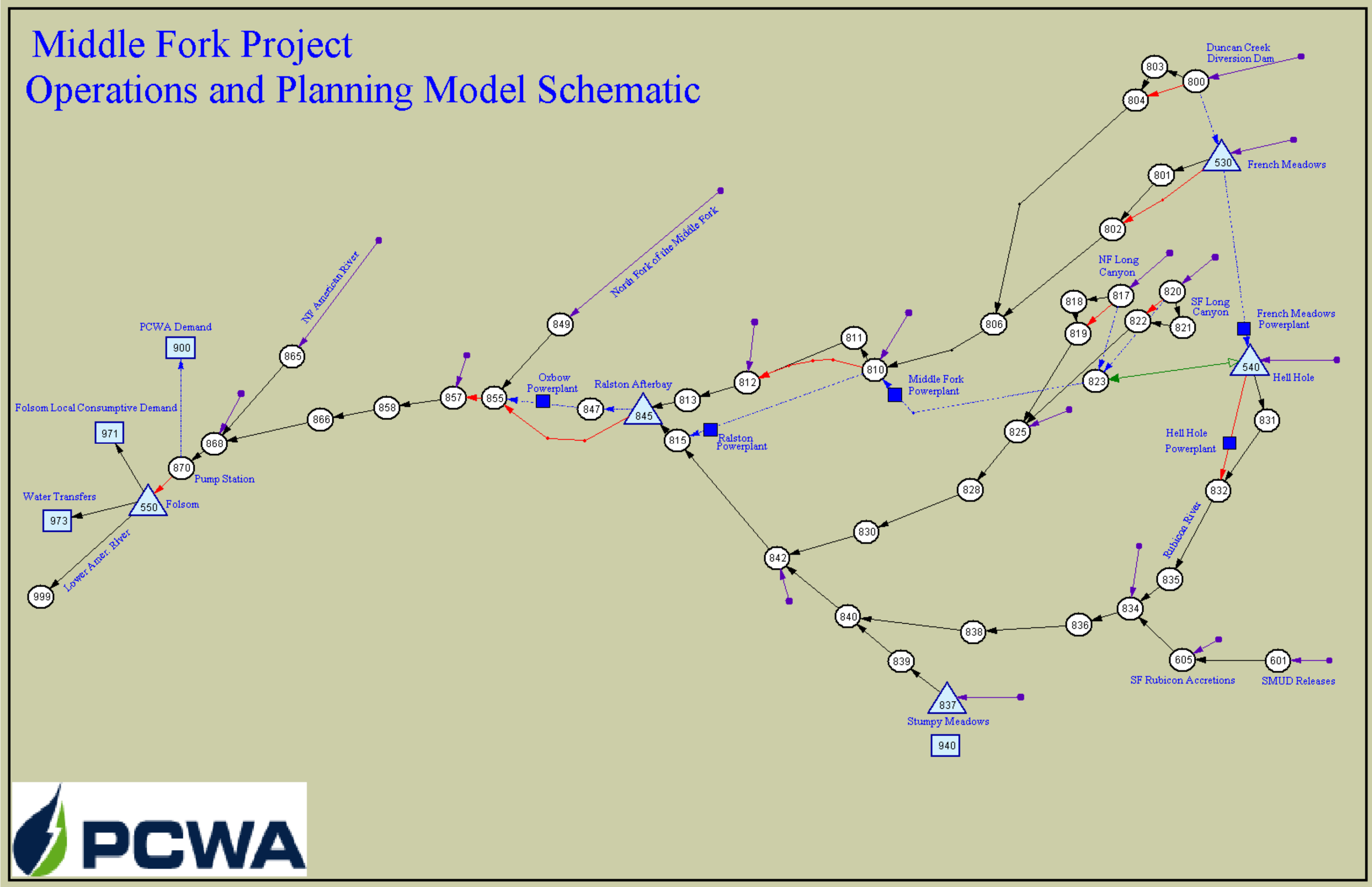
constraints specified. When water supply is limited, the model may not be able to achieve all objectives equally. The model prioritizes the objectives by the "weighting" assigned by the user. The objectives include:

  - Meeting consumptive water demands;
  - Meeting minimum instream flow requirements;
  - Achieving maximum reservoir storage levels by the end of the filling cycle;
  - Avoiding reservoir spills during filling;
  - Operating to hit end of year target carryover levels;
  - Concentrating power generation into periods of greatest electrical demand; and
  - Conducting maintenance during a specified period in the fall.

- <u>Priorities and Weighting</u> – The model uses both priorities and weighting to determine relative importance of operating objectives. Priorities are distinct classes, and objectives that are priority 1 are more important than objectives in priority 2 regardless of weights. Weights are then used within priorities to determine importance. In the MFP model all objectives are priority 1. The ordering of objectives is achieved through the use of relative weighting. The objectives listed above are "in order" (i.e., top to bottom of priority) and represent the weighting structure. Consumptive water demands are all weighted higher than any other objectives. Minimum instream flow requirements are weighted below consumptive demands, but higher than any other objectives, and so on.

- <u>Changes to Operating Constraints</u> - Please note that the fundamental assumptions including the permits, licenses and agreements held by PCWA, priorities, weightings and physical capacities are integral to the operation of the model. Changes to these fundamental assumptions, priorities, weightings and physical capacities may require additional changes to the model architecture, and/or re-benchmarking of model results, to ensure continued model integrity. Changes to the assumptions, priorities, weightings and physical capacity parameters listed in Appendix B require vetting with the model steering committee.

Figure 1 – Operations Simulation Model – Arcs and Nodes Structure



- Model Operation – After operating constraints and operating objectives have been defined and hydrology has been selected, the model is run to simulate the assumptions. The model runs day-by-day in the following sequence of steps.

    1) The OASIS program reads the arc and node tables, the list of Operating Constraints (such as minimum instream flow requirements and reservoir storage requirements), the Operating Objectives (such as consumptive water and energy demands, all other static data e.g., initial reservoir storages, etc.), and the selected hydrology. The OASIS program then creates a numerical model of the MFP, which is a series of mathematical equations to be solved simultaneously.

    2) At each time step, the model reads the river inflows, accretions/depletions, and other time series data for each day. When run with historical hydrology, the model also has access to Blue Canyon precipitation records and DWR Bulletin 120 forecast inflows to Folsom Reservoir that are used as triggering criteria for the model to use specific Operating Constraints (e.g., minimum instream flow requirements for different water year types).

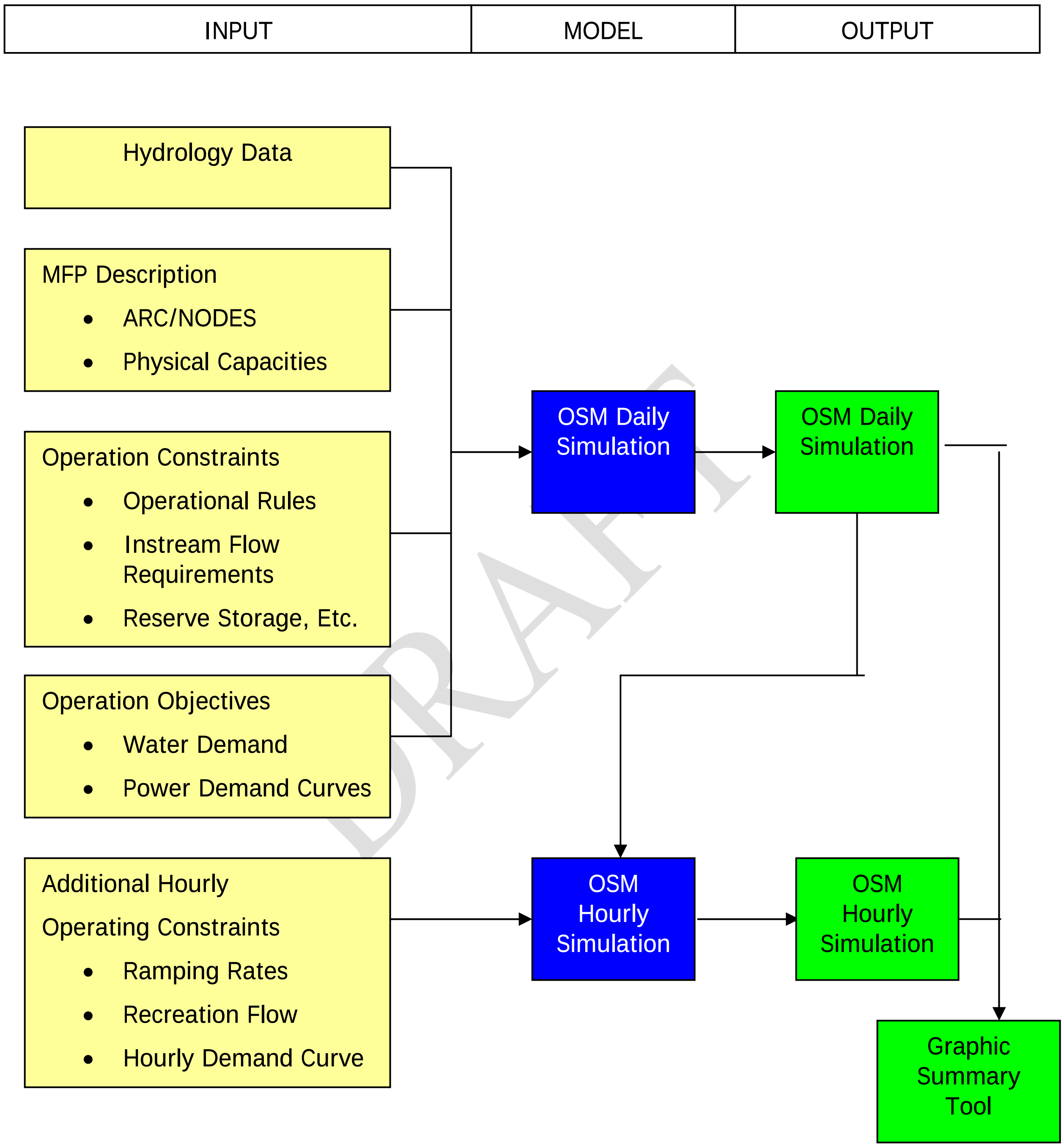
    3) The model processes the daily input data and numerical model through an optimization routine to best meet the operating objectives.

    4) The mathematical equations in the model are solved to determine the system's operation for one day at a time; the results are saved and written to a results file. Each day's results are used as the beginning point for simulation of the next day's operations.

    5) The program goes on to the next day. Through its optimization routine, the daily model run allocates daily power releases to meet consumptive and energy demands after meeting the Operations Constraints. The model continues cycling day-by-day through the time period.

    6) After completion of the model simulation, post-processor computer programs read the results file and summarize the simulation results by preparing tables and graphs showing information selected by the user. The types of tables and graphs that are expected to be prepared are described in Section 6.0 - Model Output.

Figure 2 - Operations Simulation Model - Flow Chart



Model File Structure – The folder that contains all OASIS files and folders is referred to as the model directory. Folders within the model directory include:

- Basedata – This folder contains Hec-dss files with time series data. The model only looks in this folder for all dss files that are included in the run, dss files located elsewhere will not be found.
- Manual – This folder contains the OASIS software manual, both in pdf and Compiled HTML Help file (.chm) formats. These help files can also be accessed from the model GUI[4].
- Metrics – This folder provides a convenient place for user-generated spreadsheets commonly used for analyzing OASIS output.
- Plots – This folder contains access database files (plot definition files) that define OASIS-generated plots. These plot definition files are discussed in more detail in Section 6.0 - Model Output.
- Tables – This folder contains OneVar input files for OASIS-generated text files, dss files, and csv files. These OneVar files are discussed in more detail in Section 6.0 - Model Output.
- Runs – This folder contains model run folders, each of which contain the following items:
    - Input Files
        - Statdata.mdb – This access database contains most of the information that is accessed by the GUI, including pattern tables, SAE curves, evaporation data, Schematic layout, and many other items. This file can be directly accessed, and provides an easier interface to move data to or from Excel than working with the GUI. However, changes to some Access tables can render the run unreadable by the GUI, so proceed with caution.
        - Model.cf – This configuration file contains a few parameters read and written by the GUI, and the file names for input and output files. This file should not need to be altered in normal use of the MFP model.
        - Notes.dat – This is the file that contains the notes that can be entered in the GUI. This file can be directly accessed (opened with any program that reads .txt files) for writing longer notes.
    - Output Files
        - Output.dss – This is the main OASIS output file. This file is written to by the model, and read by the OneVar and Plot programs for preparing output. Values of every variable at every time step are written to this file, and can be used for debugging or understanding model operations.
        - Model Diagnostics – Model Diagnostics are described more fully in Section 7.3, and include debug.out, OCL.out, LP.out, balance.out, and weight.out. The external power module will also write a debug file named PriceModuleDebug.txt when debug output is

[4] The GUI locates the help files using a path specified in the GUI initialization (GUI.ini) file. These paths are listed as the value for the variables _WinHelp and _AcrobatUserManual in the initialization file.

requested from the module. See Section 7.3.6 for information on requesting this debug file and interpreting its output.

- OCL folder – This folder contains all OCL files, including files automatically written by the GUI at the beginning of each run.
- HourlyRun – This is an additional run folder within the main run folder, which functions as a run folder for the hourly run and contains the files listed above, specific to the hourly run.

Model Period – OASIS has an internal variable to keep track of time steps called the Period. For a daily simulation, Period is the number of days since the beginning of the water year. On October 1, Period=1; and on September 30, Period=365 (or Period=366 in a leap year). In daily simulations Period functions as an internal date variable and many inputs are entered as a period, such as carryover dates, maintenance period start dates, rafting start and end dates, water transfer start and end dates, and others. Throughout the model code and this document will be statements such as "Enter the rafting start period", which refers to the water year period referenced here. The table below contains some dates and their associated Period for reference. Period is also described in detail in the OASIS software manual.

Date	Period (Non-Leap Year)	Period (Leap Year)
Oct 01	1	1
Dec 31	92	92
Jan 01	93	93
Feb 01	124	124
Mar 01	152	153
Apr 01	183	184
May 01	213	214
June 01	244	245
July 01	274	275
Aug 01	305	306
Sep 01	336	337
Sep 30	365	366

For the hourly model, period functions the same, but is the number of hours since October 1, and is numbered 1 through 8760 (or 1 through 8784 in a leap year.)

4.0 Model Input

To instruct the model to prepare a simulation, the user must modify selected inputs within user input data files. The inputs are contained in these forms: HEC-DSS files (.dss), static database tables (.mdb), and Operations Control Language (OCL) files (.ocl). The hydrology and other time series input can be found in the HEC-DSS files, which are located in the basedata folder. Information about the physical description of the facilities is generally found in static database tables accessible through the Graphical

User Interface. The OCL files can be used for any conditional operating rules or requirements. The OCL files may contain values or logic that the user may wish to change. Appendix D contains a table that lists the OCL files used with the daily time step model and a general description of the contents of each file. Inputs that can be specified by the user include the following.

4.1 Hydrology

A time series database of unimpaired hydrology is loaded into the model. A single simulation can include: 1) all years of record; 2) any group of sequential years; or 3) any specific time range. The time period to be simulated is selected in the Daily Run tab in the model as shown in Figure 3. A dataset based on the available hydrologic record for the MFP, which is from water years 1975 through 2007, and is described fully in (2006 Hydrology Study Plan Report, 2007, PCWA) is available for long-term planning studies. For operations forecasting, a dataset with forecasted future inflows is used. The time series database is entered into the file '__inflow_file.ocl' as the only line in the file. All time series databases must be placed in the basedata folder within the model directory, and can be placed into subfolders for ease of organization.

The general syntax for including inflow hydrology files is

```
:Substitute:  [Inflow_File] = ExampleTSDatabase.dss
```

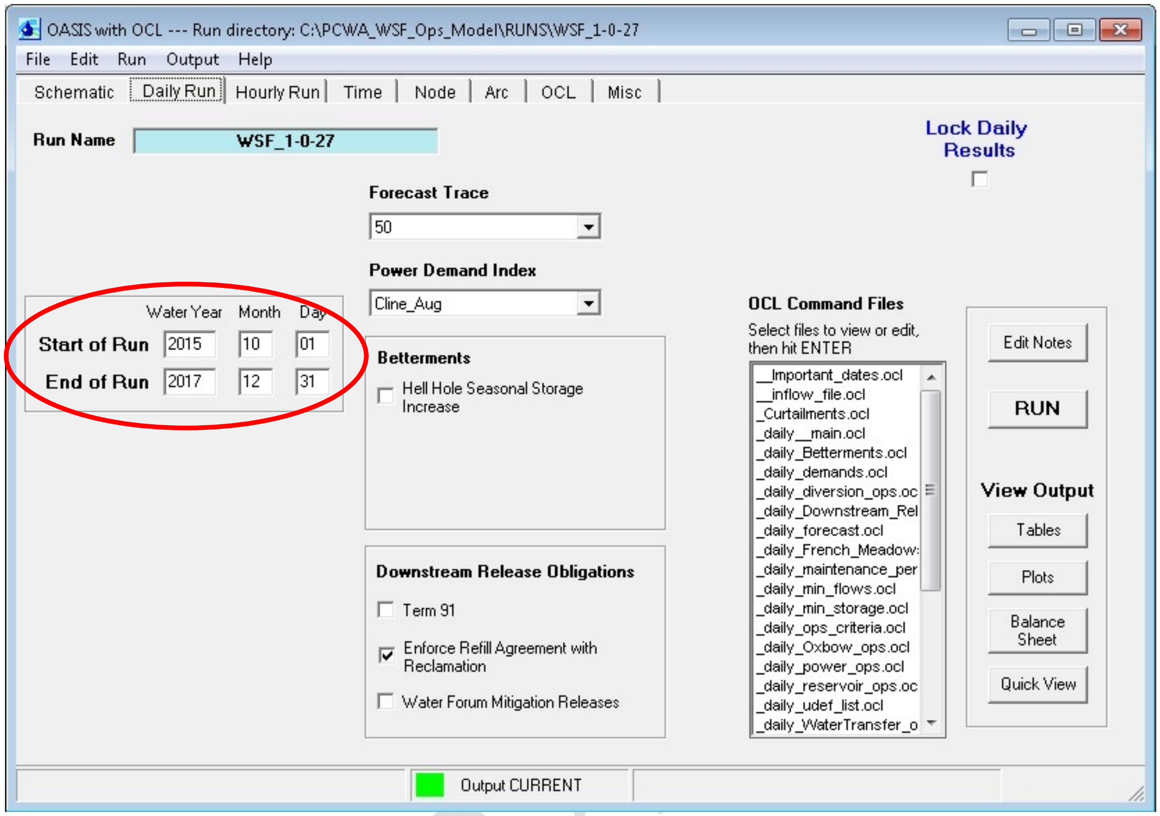
Where ExampleTimeSeriesDatabase.dss is located in \\WSF_OpsModel\Basedata\, or

```
:Substitute:  [Inflow_File] = Subfolder\ExampleTSDatabase.dss
```

Where ExampleTimeSeriesDatabase.dss is located in \\WSF_OpsModel\Basedata\Subfolder\

Note that multiple layers of subfolders can be used, as long as they are located within the basedata folder.

Figure 3 – Time Period Selection



4.2 Hydrology Forecast Trace

When using the model in a forecasting setting, it is often useful to run different forecast traces to evaluate varying hydrologic conditions throughout the upcoming year. To ease the selection of forecast traces, a dropdown is located on the daily tab, as illustrated in Figure 3, and the model will select the forecast with the listed percent exceedance from the forecast hydrology database (which often includes multiple forecast traces at each inflow node). When running forecasts without multiple traces, such as a “percent of average” hydrology set, or a California-Nevada River Forecasting Center (CNRFC) deterministic forecast, those traces will often be labeled as the 50% exceedance level (regardless of actual historical exceedance) and the 50% exceedance should be selected in the drop-down menu.

For other datasets, including the historical hydrology that is provided with the model, that have not been labeled in such a way to be consistent with the drop-down menu, this functionality can be overridden by changes to the file ‘_daily__main.ocl’ (main.ocl). Line 29 of main.ocl contains a line that reads:

```
:Substitute:   [Inflow_Str] = Inflow_[ForecastTrace]-Pct-Exd
```

The forecast trace dropdown will be bypassed if this line is altered to read:

```
:Substitute:   [Inflow_Str] = Inflow
```

Note that this Substitute command is setting the C-part of the dss record that OASIS will search for. Inflow hydrology generally has dss pathnames where the B-part is the inflow node and the C-part says "Inflow". This can be set to any word or phrase that is listed in the C-part of the input hydrology file.

The list of forecast exceedances that are available in the drop-down menu is set in the GUI initialization file, GUI.ini, as the list in the variable List_ForcType.

4.3 Consumptive Water Demands

Consumptive water demands are generally set by multiplying a monthly pattern by an annual demand. The monthly pattern can be found in the pattern table, and annual demands are entered into the file '_daily_demands.ocl' (demands.ocl) in acre-feet. Monthly patterns are described in the pattern table as each month's fraction of the annual demand, and daily demands are the monthly demand distributed equally throughout the month. There are two pattern tables, one for demands at the American River Pump Station (ARPS), labeled DemPatt-ARPS, and one used for demands at the Folsom Pump Station and San Juan Pump Station, labeled DemPatt-Folsom.

This general way of setting consumptive demands can be overwritten; currently, Roseville demands are entered in monthly volumes directly into demands.ocl to represent the dynamic nature of Roseville's demand for MFP water[5]. This could alternatively be setup with Roseville having its own demand pattern table.

4.4 Tunnel and Penstock Capacities

Flow capacities are contained in the maximum flow table, which is accessed through the Arc tab, or are set as the OASIS variable Max_flow in OCL commands, and are outlined in Appendix B – Tunnel and Powerhouse Capacities. The Arc Table, accessed through the Arc tab, lists all arcs in the model. This Arc table has a field for every arc, which lists whether the max flow is set in OCL files or in the maximum flow table. This field can be changed when the user wants to change the method through which maximum flows are entered.

4.5 FERC License Requirements

The Middle Fork Project is currently in transition between two FERC licenses and accompanying FERC license regulatory conditions. The current license expired on March 1, 2013, and the Agency has been given a temporary license until a new license is issued. A new set of license conditions has been negotiated and a final license application has been submitted to FERC[6]. Currently, the Agency is waiting on water

[5] Roseville does not take MFP water throughout the year on a predictable pattern. Roseville takes deliveries through a CVP contract that is subject to CVP allocation cutbacks up to 50%. Roseville generally takes CVP water until the full allocation has been delivered, then switches to MFP water and is dependent on MFP deliveries for its entire consumptive demand through the remainder of the contract year.

[6] At the time of publication of this document, FERC has not issued PCWA a new license. This document will use the term "Current license" or "old license" to describe the license issued in

quality certifications from the State Water Resources Control Board for the new license to be in effect. Because of this, the operations simulation model needs to be able to switch between license conditions, and the model currently has the ability to use the current license conditions for the current water year, and then use new license conditions for subsequent water years when the Agency believes it will be subject to the new license conditions in the near future. Currently, the model uses the old FERC requirements for the entire simulation, but this model code will be used when transitioning into the new FERC requirements.

Compared to the current FERC license, the new FERC license contains a different water year type structure, different minimum instream flow requirements, and different reservoir storage requirements. The license also introduces pulse flow requirements at six locations, spill down-ramping at both storage reservoirs, and recreation flow requirements at two locations.

The model controls which FERC requirements are in place using the variable FERC_Requirements_Scheme, which is set in the file '_daily_ops_criteria.ocl' on approximately line 31. When this variable is set equal to 1, the old license requirements and year-types are used, and when this variable is set to 2, the new license requirements and year-types are used. The user can manipulate this variable's Set statement to assign various license requirements, either for the entire simulation or for selected water years.

4.6 Water Year Types

The model contains two water year type structures available for implementing specific minimum instream flow requirements, reservoir storage requirements, and other regulatory requirements. The two water year type structures correspond to both the current (older) FERC license and the future (new) FERC license. The current FERC license has three flow categories for storage requirements and two categories for flow requirements, but the categories do not match and a structure with four categories is used to capture all possible situations.

The four year-type structure used for current FERC license requirements is shown in Table 1 below.

Table 1 Water Year Types (current license requirements)

Water Year Type	Unimpaired Flow into Folsom Reservoir
Wet	above 2,000,000 AF
Normal	1,200,000 – 2,000,000 AF
Below Normal	1,000,000 – 1,200,000 AF
Dry	0 – 1,000,000 AF

1963 and subsequent annual licenses, and use the term "new license" to describe the as-yet-unissued license that is anticipated sometime in 2015 or 2016.

A six-year-type structure is used for the new license requirements. A discussion of the water-year-type structure used in the new FERC license is described in the memo titled "Proposed Water Year Classification PCWA Middle Fork Project" (Appendix C). Note that when this technical memo was written, the water year classification was merely being proposed, but was subsequently incorporated into the final FERC application.

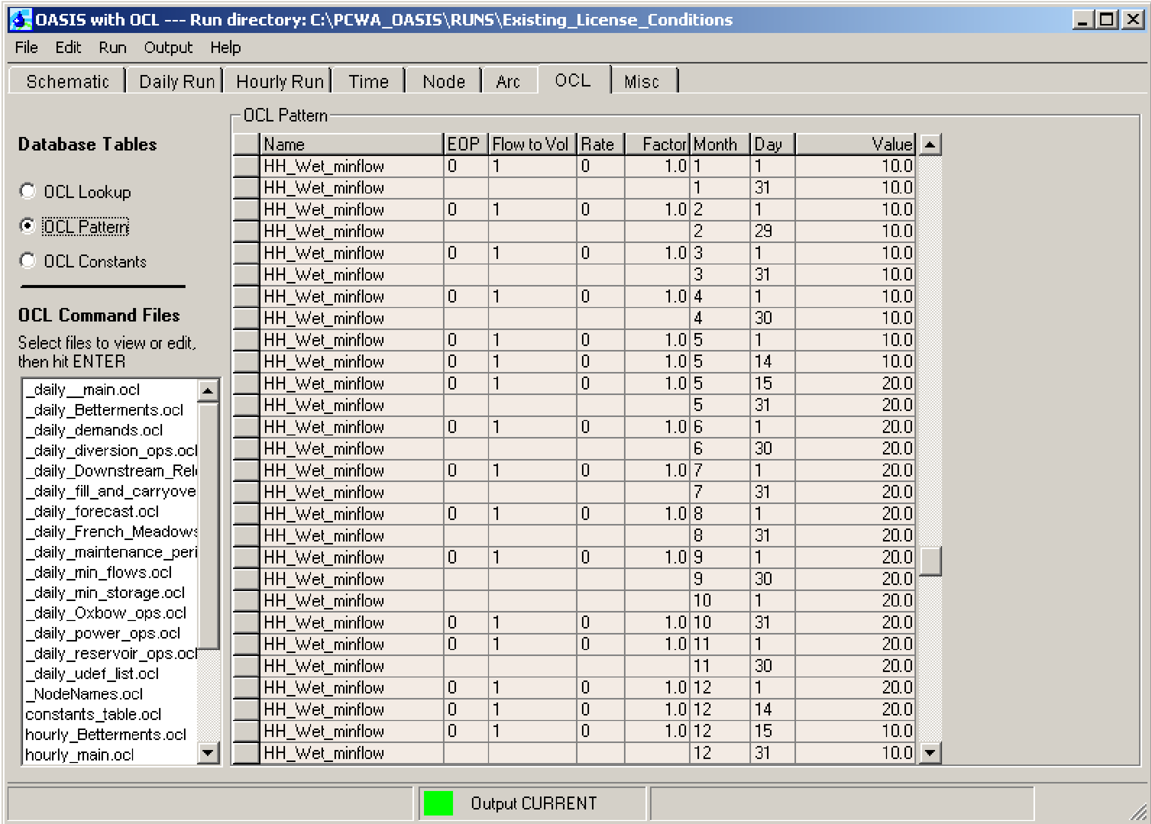
The model's water year type structure is based on the Folsom Reservoir Unimpaired Inflow (FUI) forecasts in DWR Bulletin 120, and when forecasting operations a forecasted Folsom Unimpaired Inflow is used in place of the Bulletin 120 values. The current license conditions require the FUI index to be updated on June 1 of each year, based on the April forecast. The proposed water year type structure would update the FUI Index on the first of the month February through May, based on each month's current forecast. This index would be updated again on October 1, based on actual water year unimpaired inflow to Folsom reservoir. The model determines which method is to be used to update the Folsom Unimpaired Inflow index based on which water year type scheme is being used. The model determines which water year type scheme is used based on the FERC Requirements Scheme discussed in the previous section.

4.7 Minimum Instream Flow Requirements

The MFP is currently required to maintain minimum instream flows at eight locations as a condition of their water rights. Seven of these locations also have their minimum instream flow requirement as a condition of the current FERC license, and an additional requirement in the anticipated new FERC license. The required flows vary in relation to the water year types and, at some locations, by the time of year. As an input into a simulation, the user has the ability to specify variable minimum instream flow criteria at each of these 9 locations (8 FERC requirement locations plus the water right requirement below the ARPS). The user can specify the time period over which the requirement applies, the flow rate, and a water year type to implement the criteria. While these requirements can be user specified, the requirements corresponding to both FERC licenses have been input to the model and the model will correctly implement these minimum instream flow requirements without any user interaction.

Minimum instream flow requirements are set in pattern tables. Figure 4 shows the monthly pattern for minimum instream flow requirements in Rubicon River below Hell Hole Dam. Minimum instream flow requirements in the Rubicon River downstream of Hell Hole Reservoir vary by water year type and are seasonal. These seasonal flow requirements are entered into pattern tables.

Figure 4 – Minimum Instream Flow Requirements Pattern Table Example



Name	EOP	Flow to Vol	Rate	Factor	Month	Day	Value
HH_Wet_minflow	0	1	0	1.0	1	1	10.0
HH_Wet_minflow					1	31	10.0
HH_Wet_minflow	0	1	0	1.0	2	1	10.0
HH_Wet_minflow					2	29	10.0
HH_Wet_minflow	0	1	0	1.0	3	1	10.0
HH_Wet_minflow					3	31	10.0
HH_Wet_minflow	0	1	0	1.0	4	1	10.0
HH_Wet_minflow					4	30	10.0
HH_Wet_minflow	0	1	0	1.0	5	1	10.0
HH_Wet_minflow	0	1	0	1.0	5	14	10.0
HH_Wet_minflow	0	1	0	1.0	5	15	20.0
HH_Wet_minflow					5	31	20.0
HH_Wet_minflow	0	1	0	1.0	6	1	20.0
HH_Wet_minflow					6	30	20.0
HH_Wet_minflow	0	1	0	1.0	7	1	20.0
HH_Wet_minflow					7	31	20.0
HH_Wet_minflow	0	1	0	1.0	8	1	20.0
HH_Wet_minflow					8	31	20.0
HH_Wet_minflow	0	1	0	1.0	9	1	20.0
HH_Wet_minflow					9	30	20.0
HH_Wet_minflow					10	1	20.0
HH_Wet_minflow	0	1	0	1.0	10	31	20.0
HH_Wet_minflow	0	1	0	1.0	11	1	20.0
HH_Wet_minflow					11	30	20.0
HH_Wet_minflow	0	1	0	1.0	12	1	20.0
HH_Wet_minflow	0	1	0	1.0	12	14	20.0
HH_Wet_minflow	0	1	0	1.0	12	15	10.0
HH_Wet_minflow					12	31	10.0

Minimum instream flow requirements are a goal in the model and are allowed to be violated without stopping the model. A post-processing table is available for checking violations of minimum instream flow requirements. Minimum flow requirements are weighted very highly in the model, and will only be violated below project reservoirs when reservoirs reach dead pool, and will never be violated below diversion dams (this is because when inflow to diversions dams is less than the specified minimum instream flow, the minimum instream flow is equal to inflow).

The operations forecasting model contains two sets of minimum flow requirements, corresponding to the requirements in the current FERC license and the requirements in the new FERC license. Model logic (contained in the file '_daily_min_flows.ocl') determines which pattern table to use at each location based on the value of the FERC Requirements Scheme and Water Year Type Scheme, discussed above.

4.8 Minimum Oxbow Powerhouse Throughput

Oxbow Powerhouse has a minimum throughput at which generation can be produced. Generally, project operators will not allow releases from Ralston Afterbay to fall below this minimum in order to maximize project generation. However, there are times when it is advantageous to bypass the powerhouse to provide for a lower Ralston Afterbay outflow volume, such as dry years and maintenance periods. While the model automatically reduces this minimum from the true throughput minimum (180-200 cfs) to a 75 cfs minimum during maintenance periods and extreme critically dry years, the user may wish to change this value to whatever fits the project's needs at the time. This value is set as min_flow845.855, and is set at the end of the minimum flows file, _daily_min_flows.ocl.

4.9 Reservoir Storage Requirements

Reservoir storage requirements currently exist for French Meadows and Hell Hole reservoirs. Similar to the minimum instream flow requirements, the user may input criteria for specified time periods triggered by water year types.

These reservoir storage requirements are interpreted by the model as FERC minimum pools. The model attempts to not violate minimum pools, but minimum pools will be violated in order to meet minimum flow requirements and consumptive demands.

Currently, the model does not plan generation with minimum pools in mind, but the sophistication of the new generation module developed for operations forecasting would allow generation to be scheduled, ensuring minimum pools will not be reached; this feature is planned in future versions. Note that while the model does not consider minimum pools when planning generation, minimum pools are considered when setting the carryover target at each reservoir, and carryover targets will not be set lower than minimum pools.

4.10 Pulse Flow Requirements

The MFP will be required to release pulse flows at six locations as a condition of the new FERC license. These release requirements generally last 15-40 days, depending on location and year type. The pulse flows specified in the USFS Final Terms and Conditions have been specified in the model (within '_daily_min_flows.ocl'), and are released based on water year type and FERC Requirements Scheme. Note that at the diversions (Duncan Creek, North Fork and South Fork Long Canyon Creeks) these pulse flows are only released when sufficient flow is available, and can only stop diverting during pulse flow periods.

4.11 Recreation Flows

The model has the ability to provide recreation flows both below Oxbow Powerhouse and below the confluence with the North Fork American. Historically the Agency has provided recreation flows below the Oxbow powerhouse voluntarily. Providing recreation flows has been added as a condition of the new FERC license, both below Oxbow Powerhouse (at the R-11 streamgage) and below the confluence with the North Fork American. While minimum recreation flows are specified, the Agency will often agree to more recreation flows than required, or in very dry years may determine that recreation flows need to be curtailed due to water supply concerns. For these reasons, recreation flows are not hard-wired into the model but rather need to be entered by the user to reflect the current understanding of water year type and informal agreements with commercial rafting interests. These recreation flows will typically need to be reexamined and reconfigured every year.

There are two seasons for recreation flows. Generally, the agency will begin providing recreational flows on the weekends in late spring, and then increase to some or all weekdays in early summer. The model refers to these as "EarlyRafting" and "Rafting" (or summer rafting), respectively, although it is understood that the "early rafting"-type releases will sometimes be released in September between Labor Day and the end of the month. The start and end date of both seasons are set by the user, and when these two seasons overlap in the model, summer recreation flows are used.

Recreation flows have an hourly component, and the volume required to provide recreation flows can have an effect on Ralston Powerhouse daily volumes. Therefore, recreation flows are input in such a way as to inform both the daily and hourly models. To successfully run recreation flows in both the daily and hourly models, the following information needs to be input:

- Rafting Start and End Periods, and days per week (Constants Table)
- Hourly Recreation Flow Pattern Tables (Lookup Tables)

In the Constants Table, there are start periods, end periods, and days per week for two different recreation time periods: early recreation flows and summer recreation flows. Start and end periods are water year periods, described in more detail earlier in this document.

There are two lookup tables for recreation flows, Recreation_Flows_Patt_Early and Recreation_Flows_Patt_Summer. For both lookup tables, the Independent Variable is the hour of the day (hour ending) and the Dependent Variable is the flow during that hour in cfs. The model will look to these pattern tables both for the number of hours per day of rafting as well as the magnitude of the flows to inform both the daily and hourly models.

4.12 Ralston Afterbay Storage Limits

In the daily model, Ralston Afterbay has two storage-level constraints outside of maintenance outages. The variable Abay_Maximum_Operating_Level sets the elevation at which Ralston Afterbay spills. The variable Abay_Normal_Max_Operating_Level sets the targeted end-of-day elevation at Ralston Afterbay. The model generally keeps Ralston Afterbay storage at Abay_Normal_Max_Operating_Level, and during times of high inflow Ralston Afterbay will fill to Abay_Maximum_Operating_Level. When Ralston Afterbay storage is above Abay_Normal_Max_Operating_Level, Oxbow Powerhouse will run at full capacity until storage is brought back down to Abay_Normal_Max_Operating_Level.

4.13 Maintenance Periods

The user can set the start date and duration (number of days) of both the French Meadows Powerhouse maintenance outage and the Middle Fork Powerhouse maintenance outage in the constants table. Model behavior during maintenance outages is described in Section 5.14.

4.14 Power Demand Index

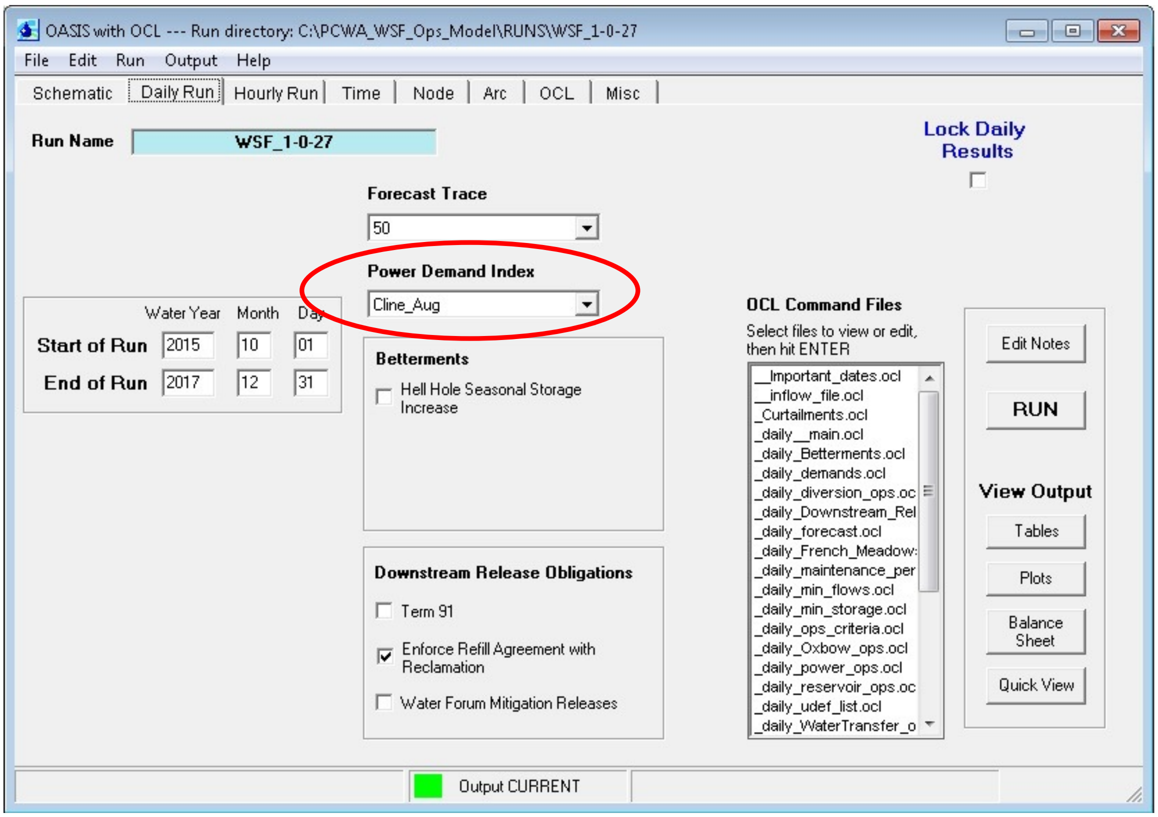
The model utilizes an hourly power demand index to shape generation releases to days of higher overall energy demand. This power demand index can be power prices, electrical load, or any other hourly time series that informs the model of the relative value of each hour of the simulation with respect to powerhouse dispatch where a larger value represents a higher value on generation. The power demand index is set in a drop down box in the daily tab, as shown in Figure 5. A detailed discussion of how the model uses the selected power demand curve is provided in Appendix E.

The drop down box shown in the screenshot is populated with values from the GUI initialization file GUI.ini, which is located in the main model directory, and is not run-specific. In GUI.ini, there is a line which will read:

List_AnnPowDem= *Label1*| *Name1*, *Label2* | *Name2*, *Label3* |*Name3*

Each *Label* specifies the label that will appear in the drop down menu itself, and the corresponding *Name* is the Dss Part C that corresponds to that price series. When Label2 is selected in the drop down menu, the model will look for a timeseries that is labeled (PowerPriceForecast/Name2). Normally these price series datasets will be located in the file PriceCurves.dss, but they can be placed into any dss file that the model run has access to.

Figure 5 – Power Demand Index Selection



4.15 Normal Carryover Target

The model uses a carryover target for dispatch operations. In a year with no water transfers, water forum mitigation or Refill Reservations, the model will target the Normal Carryover Target for an end-of-year storage target. Water Transfers, Water Forum mitigation, and remaining Refill Reservation from previous years will result in a carryover target less than the Normal Carryover Target, but the model will still need to know what the target is in a normal year. This normal year carryover is set at 150,000 AF, a value which has been incorporated into various planning documents, and care should be taken when using any other value to ensure that any discrepancies with other planning studies are acknowledged. This value is set in the constants table.

4.16 Water Transfer Parameters

The model assumes the Agency will find a willing buyer for any Water Forum Agreement mitigation water, and assumes this water will be released as a water transfer. In addition, the Agency can and does find buyers for water transfers in non-Water Forum years or for water transfers in excess of Water Forum Agreement mitigation water. Users can instruct the model to assume a water transfer in excess of Water Forum Agreement mitigation by setting Water_Transfer_Volume in the constants table. The model assumes a water transfer equal to the larger of Water_Transfer_Volume or the calculated Water Forum Agreement mitigation water. If the Agency decides that it does not want to release the calculated Water Forum Agreement mitigation water or negotiates a lower release volume, the Water Forum Mitigation Releases checkbox (on the daily tab) can be unchecked, and Water Forum Mitigation Releases will be set to zero. This can either be left as zero mitigation, or a lower value can be set as the value for Water_Transfer_Volume.

The model has two modes for releasing water transfers: a *start and end period* where the releases within this period are determined by the power demand index, and a *monthly release schedule*, where releases are released evenly throughout the month with monthly fractions entered in the pattern table MitigationReleasePattern. The user selects which of these water transfer modes the model should use by setting the variable Water_Transfer_Operation_Mode in the constants table.

French Meadows Reservoir has higher minimum storage requirements as a proportion of total storage than Hell Hole Reservoir. For this reason, when the two main storage reservoir share the drawdown of water transfer volumes French Meadows Reservoir can encounter potential minimum pool violations. To counter this effect, an option is included in the model to transfer the volume equally out of both reservoirs, or to draw water transfer volumes only from Hell Hole storage. This behavior is set in the variable Water_Transfer_HellHoleOnly in the constants table.

4.17 Diversion Dam Closures

The Agency will close the Long Canyon diversion dams[7] in the summer after the runoff has ceased and when inflows have dropped below minimums to ensure no diversions. Often the Agency will leave the Long Canyon diversion dams closed during the first few rain events in the fall to allow for a flushing of debris and minimize the risk of entraining rocks and debris in the penstocks. In many years, the Long Canyon diversions may be left closed throughout the winter and spring, only being opened during the snowmelt season, sometimes as late as May. In drier years, the diversions may be opened earlier to fully capture project runoff. During the FERC relicensing effort, this behavior was not modeled, as the Agency wanted to show the full potential effects of fall and winter minimum flow requirements at the diversion dams. However, when run as an operations forecasting model, neglecting the effect of diversion dam closures will overestimate the amount of water available for project generation.

[7] Here we define closing the diversion dams as closing the gate that would allow water to enter the diversion tunnel, ensuring that there are no diversions and all inflow to the diversion dam is released.

When the user wishes to inform the model of diversion dam closure schedules, these can be entered into the file _daily_diversion_ops.ocl. This file assumes that the North Fork and South Fork Long Canyon diversions will be closed and opened at the same time, and allows input for the water year period of both opening and closing of each diversion dam. Generally the date of closure (assumed to happen sometime during the summer) has little effect, as diversions naturally cease in May through July as a result of natural hydrology, but the opening date will have an effect on how many precipitation events can be captured by the diversion dams.

4.18 Ramping Rates

There are ramping rate restrictions on the stage of the Middle Fork American River at the "Foresthill" gage (USGS# 11433300, PCWA ID# R-11). In the current FERC license there is a 3 feet per hour ramping rate restriction in both directions. In the new license this restriction is reduced to 1.5 feet per hour, a change that will need to be made by the user. A flow-stage relationship is used to translate the stage-based rate into a flow-based rate, located in the lookup table Foresthill_Rating_Curve.

5.0 Reservoir Operations

5.1 Forecasting inflow

The model utilizes three forecasts of American River unimpaired inflow to Folsom: water year unimpaired inflow; March - November unimpaired inflow; and April – July unimpaired inflow.

- Water year unimpaired inflow is defined as unimpaired runoff from October through the previous month plus the forecasted current month through September runoff. This forecast is used to determine the reservoir storage and minimum instream flow requirements for the Project.
- March through November (M-N) unimpaired inflow is defined as the forecasted unimpaired Folsom inflow from March through September, plus 60,000 AF. 60 KAF is used because this is the average October through November unimpaired inflow to Folsom. This forecast is used to determine the release targets as suggested in the Water Forum Agreement.
- April through July unimpaired inflow is defined as forecasted unimpaired Folsom Inflow during the months of April through July. This is used as an index to determine whether Folsom reservoir will likely be in Flood Control operations during the spring runoff period, and therefore whether the MFP will be able to refill any remaining storage reservation due to previous water transfers or water forum agreement releases. Folsom Reservoir flood control operations are more complex than an index, and are dependent upon timing of inflow, CVP storage balancing across the state, previous year storage drawdown and many other factors, the modeling of which are beyond the scope of the MFP model. This index is used as a best guess of whether Folsom Reservoir will enter into flood control operations in future years.

5.2 Duncan Creek Diversion Dam

Duncan Creek Diversion is a passive system with limited operational control. The dam has a low flow outlet that releases minimum instream flow when diverting or natural inflow, whichever is less. Because the manual gate typically is left open throughout the winter and spring, all flow above the minimum instream flow is diverted to French Meadows Reservoir, up to the capacity of the tunnel (400 cfs.) Additional flows are spilled over the diversion structure.

5.3 Long Canyon Creek Diversion Dams

Diversions from Long Canyon include diversion from South Fork Long Canyon Creek and North Fork Long Canyon Creek. When diverting, the Long Canyon diversions have low-flow outlets that allow flows to pass the diversions to meet flow requirements. Flows above the minimum instream flow are diverted to the Hell Hole-Middle Fork Tunnel, up to the capacity of the tunnels (100 cfs for North Fork Long Canyon Creek diversion and 200 cfs for South Fork Long Canyon Creek diversion). Diversions from the South Fork and North Fork of Long Canyon Creek can flow into Hell Hole Reservoir when the Middle Fork Powerhouse is shut off or operating at a flow lower than is being diverted. This reverse flow is represented in the model as negative flow through the Hell Hole-Middle Fork Tunnel.

5.4 Interbay Operations

The limited storage capacity at Middle Fork Interbay (Interbay) is generally used only for short term balancing when starting up or shutting down the Middle Fork and Ralston powerhouses, and for this reason Interbay is modeled as having no storage in the MFP model. Interbay's minimum instream flow release to the Middle Fork American River is as scheduled or natural flow, whichever is less. Middle Fork powerhouse is not operated to meet minimum instream flow releases from Interbay. Natural flow at Interbay is defined in the model as release from Duncan Creek Diversion Dam plus release from French Meadows Reservoir, plus accretions on Duncan Creek and Middle Fork American River between those control structures and Interbay. When natural flow at Interbay is greater than the minimum instream flow release specified in the FERC license conditions, the excess natural flow will be captured and run through Ralson Powerhouse. Currently the model runs Ralston powerhouse with any amount of accretion flow and does not assume a minimum throughput for Ralston Powerhouse, although this feature could easily be added to the model when PCWA operations staff adopts a policy for such minimum throughput.

5.5 Middle Fork and Ralston Powerhouses Coordination

The Middle Fork and Ralston powerhouses are operated together. That is, Ralston Powerhouse generates whenever Middle Fork Powerhouse is generating and with approximately the same flow. This is because Middle Fork Powerhouse empties into Interbay, the Ralston Powerhouse intakes from Interbay, and both powerhouses have similar capacities. Because of this, throughput is calculated in the model for Middle Fork Powerhouse, and Ralston Powerhouse throughput is approximately equal to Middle Fork Powerhouse plus available accretion flows.

5.6 Combined Reservoir Storage

The Middle Fork Project generally operates Hell Hole and French Meadows reservoirs as a single reservoir from a generation and water supply standpoint. Water for generation at Middle Fork Powerhouse comes from Hell Hole Reservoir and the Long Canyon diversions. In turn, the French Meadows Powerhouse transfers water from French Meadows Reservoir to Hell Hole Reservoir, where it can then be used for generation at Middle Fork Powerhouse. For this reason, generation at Middle Fork Powerhouse is based on combined reservoir storage at both Hell Hole and French Meadows reservoirs and discussion of project generation is often based on combined reservoir storage.

5.7 MFP Carryover Storage Target

The MFP Carryover Storage Target designates the combined total amount of water in storage in French Meadows and Hell Hole reservoirs on the carryover date. The MFP utilizes a carryover storage target date of December 31, although the user can specify this date. The normal MFP Carryover Storage is set in the constants table, as the variable Normal_Carryover. The normal carryover is usually set at 150,000 AF, although the user may elect to revise the carryover storage for an individual simulation run, such as for increased carryover in a wet year or a year where electrical prices are abnormally low. This normal carryover target is the carryover target in normal years with no water transfers or water forum agreement obligations. The actual carryover target that the model uses will be lower than the normal carryover target by the larger of water forum agreement obligations or voluntary water transfers, plus any remaining Refill Reservation (as defined in the 2013 PCWA USBR Refill Agreement) from previous years.

5.8 Generation Cycles

The MFP model was originally constructed with two distinct generation cycles, the fill cycle and the dispatch cycle. The model would attempt to fill the reservoirs completely, only generating to avoid spill, and then dispatch the stored water during the dispatch cycle. The fill cycle is generally January through June, while the dispatch cycle is July through December. These date ranges are user specified and can vary by water year type, with the fill cycle running from the day after the carryover date through the fill date, and the dispatch cycle running from the day after the fill date through carryover date. Most operational models use guide curves to minimize the decisions that need to be made by the model, and the MFP model's method of seasonal storage targets is more flexible and more representative of actual operational decision making. However, during the FERC licensing process most stakeholders and regulatory agencies were not familiar with this dynamic approach, and the two distinct cycles allowed a simple framework to describe the model's decision making process. The two distinct cycles also represented the lackluster operation of the MFP when under PG&E control, with the MFP considered as one generational component in a wide portfolio. However, with the Agency more aggressively pursuing generational opportunities at periods of high electrical prices, the model has been changed to treat the entire calendar year as one cycle, balancing inflow timing and electrical price forecasts to determine how high to fill the reservoir. The method of using two distinct cycles still exists in the model and is available to the user if desired. Whether the year is split into two cycles or treated as one cycle is based on the variable FillDispatchCycles in the constants table. When this variable is set to zero, the model treats the year as a single cycle, and when the variable is set to one, the model splits the year into a distinct fill and dispatch cycles, described in sections 5.8.1 and 5.8.2. When the model is treating the year as a single cycle, it treats it as a dispatch cycle, and never enters the fill cycle.

5.8.1 Reservoir Fill Cycle

From January through the end of the fill cycle (which varies by water year type and can be set by the user), a generation volume is calculated each day. Historic operations indicate that the reservoirs are filled earlier in dry years than in wet years, although the model fill dates are currently set to June 30 in every year type. The generation volume is calculated as the end of the previous day's storage plus the forecasted inflow, minus the fill target and remaining instream flow requirements. During the fill cycle, meeting the required minimum instream flow requirements and filling the reservoirs are more important than generating power. If the forecasted inflow is not enough to meet the flow requirements and fill the reservoir, then generation is minimized to fill the reservoirs as much as possible. If the forecasted inflow suggests that spill is possible, then the generators are run to move water through the system during the spring to avoid spills. During the fill cycle, if the project is under control (i.e., not spilling) and water is available, this generation volume is then passed to the power price module for determination of seasonal generation patterns.

5.8.2 Reservoir Dispatch Cycle

During the dispatch cycle (end of the fill cycle through January) a discretionary generation volume is calculated each day. This discretionary generation volume is calculated as the current storage plus the forecasted inflow from the current day through the end of the dispatch cycle, minus the carryover target and remaining instream flow requirements. This total discretionary generation volume is then passed to the power price module for determination of seasonal generation patterns.

5.9 Generation Dispatch Patterns

Dispatch of discretionary generation is based on an hourly power demand index, usually a forecast of electrical prices. Dispatch of discretionary generation is handled by an external module, which runs in in parallel with OASIS. At two points within each timestep, OASIS calls the module, passes a set of arguments, waits, and then receives a set of output from the module, the values of which are accessible to OCL code. A detailed description of how the external Power Price module determines generation is in Appendix E – Power Price Module Description.

5.10 French Meadows Powerhouse Operations

French Meadows Powerhouse is run in a peaking mode, with a maximum throughput capacity of 400 cfs. The model calculates how much water stored in French Meadows Reservoir can be used for discretionary generation throughout the season considering forecasted inflow, forecasted diversions from Duncan Creek, French Meadows carryover target, remaining minimum flow requirements, and remaining water transfer obligations[8]. The resulting discretionary generation volume is converted to units of

[8] Remaining Water Transfer Obligations are only considered at French Meadows when water transfers are being put out on a specific pattern (and not being distributed using power prices) and when the transfer is being taken out of both reservoirs. The model has an option (described

hours of generation, which are then passed to the Power Price Module, and the module returns the number of hours that will be generated today.

The conversion between generation volume and generation hours at French Meadows Powerhouse is the French Meadows Maximum Efficiency Flow. This sets the preferred one-hour flow rate through French Meadows Powerhouse, usually the flow that results in the highest efficiency. PCWA Power Resources Management staff is planning an analysis of what the preferred setting at French Meadows Powerhouse should be. Previous analysis suggests that PG&E preferred French Meadows Powerhouse at 340-380 cfs and efficiency tests performed in the 1960's suggest that efficiency starts to drop off around 360 cfs, the preferred flow in the model is currently set to 400 cfs. This flow rate can and should be updated as Power Resources Management staff settle on a preferred flow rate. This flow rate is set in the model in the file _daily_ops_criteria.ocl as the variable **FM_Max_Eff_Gen**, on approximately line 13.

There are three situations in which the number of hours of generation returned from the module is overridden at French Meadows Powerhouse. When French Meadows is spilling, or when French Meadows has recently spilled and storage is within 1,000 AF of the spill way, French Meadows Powerhouse will be run at full capacity regardless of the Maximum Efficiency Flow. When storage in French Meadows Reservoir is within 1,000 AF of the minimum pool, the powerhouse will run at half the number of hours suggested by the Power Price module[9]. When storage in French Meadows Reservoir reaches minimum pool or is below minimum pool, generation is shut off at French Meadows Powerhouse, unless or until Hell Hole reaches dead storage and additional water is needed for consumptive demands, in which case French Meadows powerhouse is run as needed until French Meadows storage reaches dead storage.

It has been suggested by PG&E staff that there may be concerns with running French Meadows powerhouse when French Meadows Reservoir is below 35,000-40,000 AF. Once this limitation is verified by PCWA staff and incorporated into an operational rule, this operational rule will be incorporated into the MFP model's French Meadows Powerhouse operation.

5.11 Middle Fork Powerhouse Operations

Middle Fork Powerhouse is run in a peaking mode, with a maximum throughput capacity of 940 cfs. There is a 920 cfs capacity from Hell Hole to the Long Canyon diversions, and then 940 cfs capacity from the Long Canyon diversions to the powerhouse. The model calculates how much Total MFP storage can be used for discretionary generation throughout the season considering forecasted inflow, forecasted diversions from diversion dams, total project carryover target, remaining minimum flow requirements,

in the water transfer section) of taking transfer water out of Hell Hole only, since French Meadows has higher minimum storage requirements as a proportion of total storage, and in this case remaining water transfer obligations are not considered in French Meadows generation calculations.

[9] As mentioned earlier in this document, model updates are planned to provide more sophisticated logic to avoid running French Meadows into minimum pool, at which time this exception will most likely be removed.

and remaining water transfer obligations. The resulting discretionary generation volume is converted to units of hours of generation, which are then passed to the Power Price Module, and the module returns the number of hours that will be generated today.

The conversion between generation volume and generation hours at Middle Fork Powerhouse is the Middle Fork Maximum Efficiency Flow. This sets the preferred one-hour flow rate through Middle Fork Powerhouse, usually the flow that results in the highest efficiency. Previous analysis suggests that PG&E preferred Middle Fork Powerhouse at 875-925 cfs and efficiency tests performed in the 1960's suggest that the efficiency curve is fairly flat in the high flow range. The preferred flow in the model is currently set to 750 cfs, to allow for picking up accretions at Ralston Powerhouse. In actual day-to-day operations, Ralston Powerhouse is run at 920 cfs and Middle Fork powerhouse is run at the proper flow rate to allow Ralston to pick up accretions, but this is a difficult way to program the model due to uncertainty in Interbay accretions. This flow rate is set in the model in the file _daily_ops_criteria.ocl as the variable MF_Max_Eff_Gen, on approximately line 7.

There is one situation when the generation hours specified by the Power Price Module is overridden by the model. When the MFP is in spill control operations, defined by the spill control switch (described in Section 5.12 - Reservoir Spills), Middle Fork Powerhouse will be run at full capacity, regardless of Interbay accretions, which will often cause spills at Interbay.

5.12 Reservoir Spills

French Meadows has a radial spillway gate that must be up from November 1 through the end of March. When the gate is up, French Meadows has a storage capacity of 111,602 AF. When the gate is down, French Meadows storage capacity increases to 134,993 AF. Flow is not allowed in the spillways when the reservoirs are below full capacity. In the model, the reservoirs, when full, will pass the inflow through the spillway arc rather than through the outlet works. Below each reservoir there are two arcs allowing flow to the main channel down below, a minimum instream flow requirement arc and a spills arc. The minimum instream flow requirement arc has a high A weight and a negative B weight to discourage flows above the minimum instream flow requirement, while the spills arc has no weighting. For a thorough discussion of arc weights, including the relationship of A and B weights, see the OASIS user's manual.

In order to reduce spills, a spill control switch is utilized as a flag to determine when reservoirs approach capacity. The spill control switch is turned on when total MFP storage goes above a year type-based threshold, and turned off when total MFP storage reaches 5,000 AF below that threshold. The switch is defined this way to avoid negative feedback with the powerhouse releases. During spill control operations, Long Canyon contributions to Middle Fork Powerhouse are shut off and Middle Fork Powerhouse flows at full capacity. The spill control switches and storage thresholds are set in the file _daily_reservoir_ops.ocl.

5.13 Oxbow Powerhouse

Operation of the Oxbow Powerhouse is contained in the OCL file _daily_oxbow_ops.ocl., although much of the operations at Ralston Afterbay are determined by arc weights and storage weights. Oxbow Powerhouse generation is dependent upon several factors including what is generated at the upstream plants, storage at Ralston Afterbay, recreation flows, consumptive demands, and river inflow to Ralston Afterbay.

When the maintenance period begins, Oxbow generation continues until Ralston Afterbay storage is below 900 AF. The flow level through Oxbow Powerhouse when draining the Afterbay is dependent on hydrological conditions, usually 450 cfs, and increases when river inflows are high. Oxbow generation then ceases until the maintenance period restart, at which time Oxbow releases only the minimum instream flow requirement and consumptive deliveries until the Afterbay is refilled.

Oxbow Powerhouse is operated in peaking mode. On a daily timestep, Oxbow and Ralston powerhouses are operated together and Ralston Afterbay storage is generally not used.

5.14 Maintenance Periods

The French Meadows Powerhouse maintenance period generally begins on the first Monday in May. The start date and length of the maintenance period can both be set in the constants table and is normally set to nine days, although this varies year to year and is a model variable that should be updated when maintenance plans are finalized each year. During this time, flows through the French Meadows Powerhouse are shut off.

The maintenance period for Middle Fork, Ralston, and Oxbow powerhouses normally occurs in October and lasts around 30 days. The start date and length of the Middle Fork maintenance period is set in the constants table. During the maintenance period, the maximum flow through the Middle Fork, Ralston, and Oxbow powerhouses are set to zero and Ralston Afterbay is drawn down to an elevation of 1,149 feet, which corresponds to the crest of the spillway and storage of 818 AF[10]. Lower_Rule and Upper Rule on Ralston Afterbay are both set to 818 AF during the maintenance period to ensure a stable storage level. All Inflows to Ralston Afterbay are passed through the outlet works, and the minimum flow at the Foresthill streamgage is set to 75 cfs.

Restarting the system after the maintenance period is coordinated through a two-stage maintenance restart flag in the model. Historical refilling of Ralston Afterbay begins with 100 cfs through Ralston Powerhouse until Afterbay's elevation reaches 1,155 feet. Flow through Ralston is then increased to 200 cfs until the elevation reaches 1,168 feet. This type of stepped operation is used to reduce stirring up sediment from the bottom of the reservoir. The MFP model uses this two-stage refill, but with minimum instream flows in the new FERC license as high as 150 cfs, we allow Ralston Powerhouse to increase to allow for minimum releases plus 25 cfs, then increasing to minimum releases plus 125 cfs. The maintenance period restart flag has three states; the flag is set to 1 when the maintenance period ends and is set to 2 when the elevation of Ralston Afterbay increases above 1,155 feet. The flag is then set to zero when the elevation reaches 1,168 feet. Targets are set on both Ralston Powerhouse and Middle Fork Powerhouse to

[10] A 2006 comparison of historical bathymetric surveys show that most of the sediment accumulation in Ralson Afterbay is below elevation 1149'. The volume of storage below 1149' varies based on sediment management and recent history of high flow events. 818 AF and other reported volumes are from the original bathymetric survey.

bound the flows during this time to being below these levels of 100 and 200 cfs (or higher as needed). During the maintenance period restart, there are additional targets on releases from the upstream reservoirs to ensure that the reservoirs do not release large amounts of water directly following the maintenance period in an attempt to immediately fill Ralston Afterbay.

Consumptive demands are normally released from Hell Hole Reservoir during the maintenance period in order to optimize project generation. When consumptive demands during the maintenance period are higher than Hell Hole outlet release capacities, the remaining release will come from French Meadows. However, there are occasionally times when PCWA staff will wish to release consumptive demands from French Meadows Reservoir during the maintenance period. The model can be altered to release consumptive demands from French Meadows Reservoir during the maintenance period by changing a single line of code in _daily_reservoir_ops.ocl (Reservoir Ops.ocl). On line 31 of Reservoir Ops.ocl is a Target named Hell_Hole_Minflow_Arc. The first condition of this target is ensuring that outside of the maintenance period, only minimum flows are released through the minimum flow arc. If this condition is commented out (with the use of "//" before the text) and replaced with "Default", then the model will limit the Hell Hole minimum flow arc to minimum flows throughout the year, moving consumptive demand releases to French Meadows during the maintenance period. The set of conditions currently in this target should be commented out instead of deleted, so that they can be reinstated when moving consumptive demand releases back to Hell Hole Reservoir.

5.15 Term 91

Term 91 is a condition added to all new water rights in areas tributary to the Delta for the purpose of making them partially responsible for meeting delta outflow or delta water quality standards. PCWA could potentially fall into this group. The State Water Resources Control Board's attempt to impose Term 91 on the El Dorado Irrigation District was overturned by the Court because the date of their water right, assigned by the State, preceded the imposition of Term 91 on other water right holders. PCWA's water right also has a date assigned by the State which precedes the imposition of Term 91 on other water right holders. If the State Board ultimately decides to impose Term 91 on El Dorado Irrigation District, then it will have to do it in a way that imposes it on all junior water right holders using the State filing assigned dates, including PCWA. When DWR invokes Term 91, direct diversions for consumptive use are not allowed. Diversions for hydropower are still permitted; therefore. the most important effect of Term 91 is that the Auburn and Folsom diversions to meet consumptive demand can only take water released from storage.

5.16 Water Forum Agreement

The Water Forum Agreement is a package of linked elements with two primary goals:

- To provide a reliable water supply for planned development to the year 2030
- To preserve the values of the lower American River

Placer County Water Agency, as a member of the Water Forum, has agreed to several actions that affect both current and future operations. Additional releases are made to compensate for diversions in excess of Water Forum baseline amounts when March through November Folsom Unimpaired Inflow (M-N FUI) is less than 950,000 AF. The amount of water released for compensation of the additional diversions starts at 0 when the M-N FUI threshold of 950,000 AF is reached and increases linearly to a maximum of 47,000 AF as the M-N FUI decreases to 400,000 AF.

- Releases made to compensate for the additional diversions at the American River Pump Station (ARPS) are linearly interpolated from 0 AF when M-N FUI is 950,000 AF to as much as 27,000 AF when M-N FUI is 400,000 AF. The maximum value of mitigation when M-N FUI is 400,000 AF is calculated as the annual ARPS delivery minus 8,500 AF, up to 27,000 AF. There is no assumed mitigation for ARPS deliveries above 35,500 AF. These releases are in addition to scheduled deliveries.
- Releases made to compensate for the additional diversions to Roseville are linearly interpolated from 0 AF when M-N FUI is 950,000 AF to as much as 20,000 AF when M-N FUI is 400,000 AF. The maximum value of mitigation when M-N FUI is 400,000 AF is calculated as annual Roseville deliveries (including CVP deliveries) minus 19,800 AF. These releases are in addition to scheduled deliveries.
- PCWA will deliver up to 25,000 AF to San Juan Water District in years when the M-N FUI is greater than or equal to 950,000 AF. The amount of delivery to San Juan Water District decreases linearly from 25,000 AF to a minimum of 10,000 AF as the M-N FUI decreases from 950,000 AF to 400,000 AF. No additional releases are required for San Juan Water District.
- PCWA will deliver up to 29,000 AF to Sacramento Suburban Water District when the M-N FUI is greater than 1,600,000 AF. When M-N FUI is below 1,600,000 SSWD receives no water from PCWA.

5.17 USBR Refill Agreement

Normal operations of the Middle Fork Project result in a December 31 carryover target of 150,000 AF. When PCWA makes a water transfer, the Agency will sign an agreement with the US Bureau of Reclamation (USBR) detailing when the water will be released into USBR facilities, when the water will be released from USBR facilities, and the terms of PCWA's refill of MFP reservoirs. While the agreement may change from year to year, generally the terms of the agreement are consistent and the model is setup to adhere to the 2013 Refill Agreement for 2013 Water Transfer from Placer County Water Agency to Westlands Water District (2013 Refill Agreement). In a year with a water transfer, the December 31 MFP carryover target becomes 150,000 AF minus the volume of the transfer. The following year, if Folsom Reservoir makes flood control releases, the MFP is considered relieved of the obligations in the refill agreement and may continue to operate as normal.

However, if Folsom Reservoir does not make flood control releases, PCWA will need to operate the reservoir so that the December 31 carryover target is reduced from the normal carryover by the amount of the Refill Reservation. The Refill Reservation is defined in the 2013 Refill Agreement as the lesser of the original water transfer or the difference between Folsom Reservoir's Maximum Permissible Storage and its Actual

Storage, updated daily. This "debt" will continue until Folsom Reservoir begins flood control operations again. The refill agreement is tied not only to the Water Forum Agreement, but also any other water sales that the Agency may make. If the Agency does not get paid for the additional releases that cause the MFP reservoirs to fall below 150,000 AF on December 31, (i.e., the water is not sold), then the refill agreement does not apply and the reservoirs can continued to be operated normally, although the model assumes that the Agency gets paid for all transfers.

5.18 Betterment Operations – Hell Hole Seasonal Storage Increase

Implementation of the Hell Hole Seasonal Storage Increase in the simulation model is done by checking the appropriate box on the daily tab. This will increase the active storage in Hell Hole Reservoir by 7,600 AF, raising the maximum reservoir elevation by six feet. This storage increase is seasonal and occurs when the gates are in place from April through October. The remainder of the year, Hell Hole Reservoir will have no increase in storage capacity.

5.19 Georgetown Divide Public Utility District operations

Georgetown Divide Public Utility District (GDPUD) operates Stumpy Meadows Reservoir, a 20 kAF reservoir on Pilot Creek, a tributary to Rubicon River upstream of the confluence with Long Canyon Creek. This reservoir spills most years, and does not have a set carryover target. GDPUD attempts to make deliveries with accretion flow while filling the reservoir, and then draws on the reservoir for deliveries and minimum instream flows when accretions drop off. Reservoir carryover is dependent on level of accretion flows and what time of the year the accretion flow recedes. This variable carryover then affects what time of year the reservoir starts spilling. For these reasons, the MFP model simulates the operation of Stumpy Meadows Reservoir to estimate what time of year the flow at the mouth of Pilot Creek will increase from minimum instream flow releases to spill releases.

Current GDPUD demand for treated water is 5,885 AF per year. GDPUD demand for raw water is a maximum of 4,500 AF, and is reduced in dry years. Minimum instream flow requirements are 2 cfs in Dry and Critical years, and 4 cfs in Below Normal years and wetter. Reservoir operations are simple, releasing consumptive demands and minimum instream flows and storing any remaining inflow until the reservoirs are full and then spilling the remainder of the runoff season.

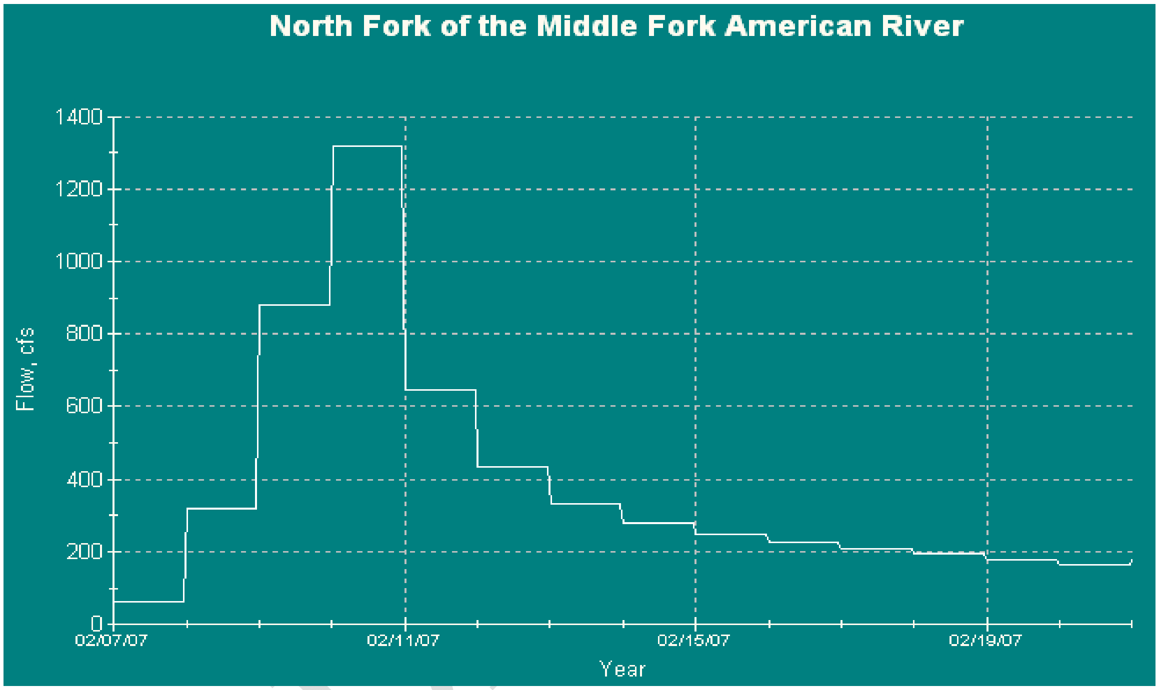
6.0 Hourly Model

The hourly model operates on and redistributes the output from the daily model. Because the hourly model relies on data from the daily model, requirements such as instream flows, consumptive demands, and reservoir elevations must be consistent between the daily and hourly models. The hourly model focuses on the Ralston Afterbay complex, including Middle Fork American and Rubicon river inflow, Ralston Powerhouse discharge, Ralston Afterbay storage, spill at Ralston Dam, and Oxbow Powerhouse discharge.

6.1 Daily Model Disaggregation

Daily inflow into Ralston Afterbay from the Middle Fork American and Rubicon rivers is distributed in the hourly model evenly over the 24-hour period. Similarly, spill from Ralston Afterbay Dam, including the voluntary constant minimum release of 10 cfs, is distributed even over the 24-hour period. The inflow from the North Fork of the Middle Fork American River into the Middle Fork American River downstream of Oxbow Powerhouse is treated the same as well. An example of these hourly flows is shown in Figure 6.

Figure 6 – Hourly Unimpaired Inflow Shaping



6.2 Hourly Generation Demand

Daily generation volumes at the French Meadows, Middle Fork, and Ralston powerhouses are redistributed in the hourly model according to the same hourly price curve as was used in the daily model.

6.3 Ralston Afterbay Storage Limits

In the hourly model, Ralston Afterbay is operated according to a set of criteria that were established based on typical historic operations and physical limits. The model is equipped with four elevation bounds at Ralston Afterbay, all listed in the constants table. The maximum operating elevation of Ralston Afterbay (normally 1,177 ft (2,616 AF)) is the elevation at which the spill gates are opened. The minimum operating level (normally 1,167 ft (1,860 AF)) is generally set at the level at which Oxbow Powerhouse begins to pull a vortex. Additional limits on Ralston Afterbay elevation are provided, called “normal operating limits”. These limits were established to provide a small buffer from encroaching on the reservoir capacity at the top end and pulling a vortex at the Oxbow Powerhouse Intake at the bottom end. These limits are user inputs that can be changed in the constants table, and are entered in units of feet of elevation. The model will attempt to stay within the normal operating limits, and will never go outside the maximum and minimum operating levels (other than for maintenance drawdowns).

6.4 Oxbow Powerhouse Generation

Generation at and discharge from Oxbow Powerhouse is calculated based on the Middle Fork American and Rubicon river inflows, Ralston Powerhouse discharge, Ralston Afterbay storage, the minimum instream flow and ramping requirements downstream of Oxbow Powerhouse, the Ralston Afterbay storage constraints and end-of-week storage target, and the power dispatch demand curve. Oxbow Powerhouse will operate as much as possible at peak generation (1,000 cfs) while ensuring that Ralston Afterbay stays within normal operating limits. In the default operation, Oxbow Powerhouse will generate according to the power dispatch demand curve. If the daily total inflow to Ralston Afterbay (including Ralston Powerhouse discharge) exceeds the capacity of Oxbow Powerhouse, then Ralston Afterbay will spill as much water as necessary to hit an end-of-day storage target of the Maximum Operating Level.

6.5 Ramping Rates

Ramping Rates are provided in the hourly model at the Oxbow Powerhouse. The model has independent up and down ramp rates, entered in feet per hour. The model translates the ramp rates to cfs per hour using the Foresthill streamgage rating table, contained in the lookup table Foresthill_Rating_Curve.

6.6 Recreation Flows

The hourly recreation flow request includes an hour-by-hour flow prescription (in cfs), and a ranking of the day-of-week priority. The day of week priority allows the model to place recreation flows on preferred days when the system is supply limited. The model will provide recreation flows on as many days as possible, up to the number of days requested, using the day-of-week priorities to guide which days get recreation flows.

The model is equipped with two modes of operation when dealing with recreation flow requests. The default mode, after meeting the recreation flow request, will continue Oxbow Powerhouse operation for as many hours as necessary to meet that day's powerhouse volume, resulting in the traditional block-load generation pattern. In the optional "double-peak" mode, after the recreation flow request has been met, Oxbow Powerhouse will shut down and wait until the more valuable hours in the afternoon to generate. This results in a generation pattern with two or more peaks, with the first peak in the morning to provide a recreation flow, and the second peak in the afternoon to generate at the most valuable hours of the day. As more water is available, the second peak widens out and will overlap with the recreation flow request peak, resulting in the block-loaded generation pattern. Depending on the interday shape of the price curve, 'double-peak' mode could result in many peaks during a given day.

7.0 Model Output

7.1 Model Output Data

As the model is running each simulation, the solution for each day is stored in a file of results. This main results file is located in the run folder under the filename output.dss and includes:

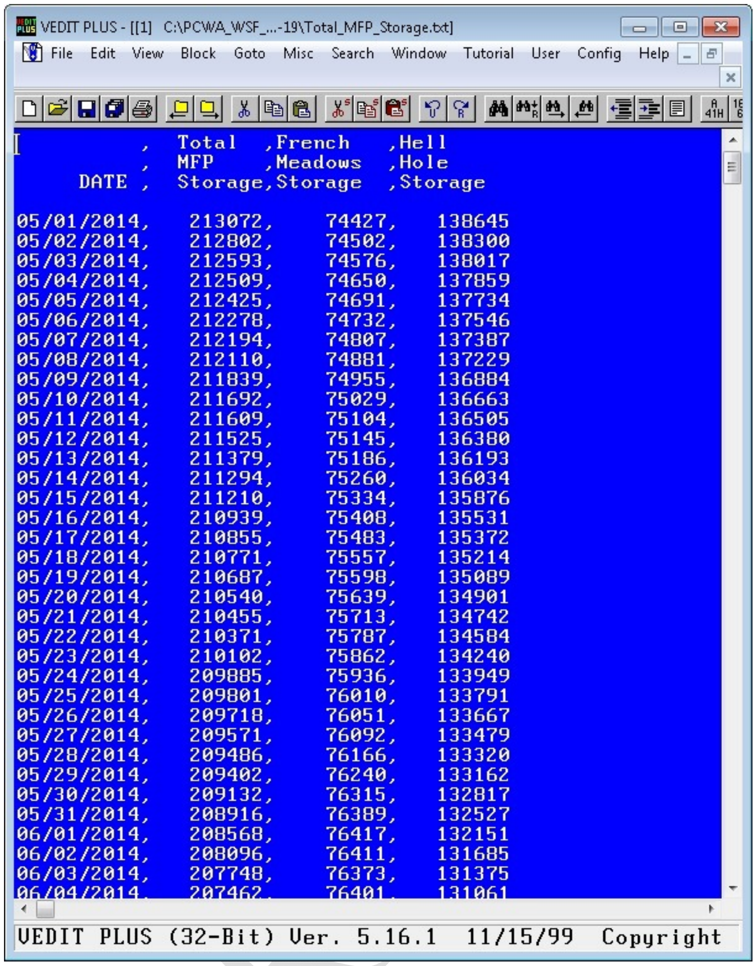
- ***Flows*** for each stream reach and all project tunnels (arcs).
- ***Storage and water surface elevation*** at French Meadows, Hell Hole Reservoirs, and Ralston Afterbay (nodes).
- ***Evaporation*** at each reservoir.
- ***Powerhouse throughput*** at French Meadows, Hell Hole, Middle Fork, Ralston, and Oxbow powerhouses (nodes).
- ***Water Deliveries*** for downstream consumptive use diversion at PCWA's American River Pump Station and from Folsom Reservoir to the City of Roseville, San Juan Water District, Sacramento Suburban Water District, and for water transfers.
- ***User Defined Variables*** such as forecasts, generation volumes, flags, etc.

7.2 Summary of Simulation Results

The model user can selectively extract and format data from the output results file and construct graphs or tables to illustrate specific comparisons. The model user may also use one of a number of pre-set graphic or tabular summaries to more expeditiously display and analyze results.

7.2.1 Tabular Output

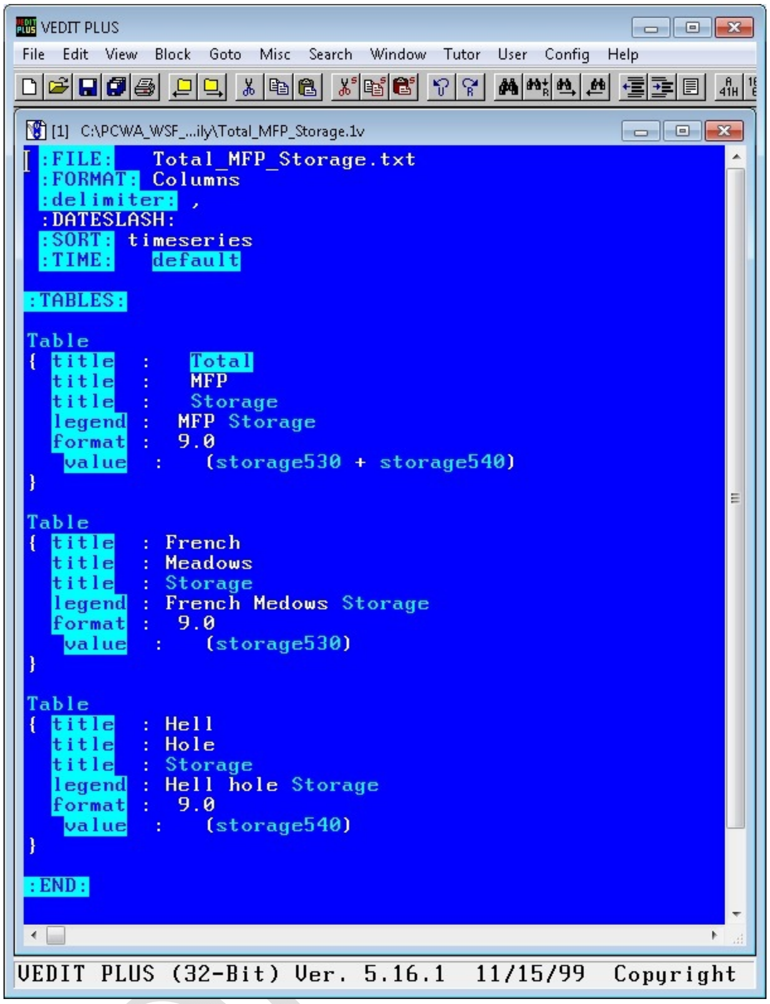
Tabular output can be created for review of several data types including storage, elevation, flow, and generation data and are the basis for the graphical representations discussed in the next section. Every graphical representation must have a tabular counterpart. Tabular information can be requested for specific time periods (a particular year or sequence of years) or for the entire simulation period. Tabular data can be comma delimited for easy export into a spreadsheet for independent analysis. Tabular output can be delimited with any character, written as a text file with any file extension, or can be written to dss files. The following is an example of tabular output.



DATE	Total MFP Storage	French Meadows Storage	Hell Hole Storage
05/01/2014	213072	74427	138645
05/02/2014	212802	74502	138300
05/03/2014	212593	74576	138017
05/04/2014	212509	74650	137859
05/05/2014	212425	74691	137734
05/06/2014	212278	74732	137546
05/07/2014	212194	74807	137387
05/08/2014	212110	74881	137229
05/09/2014	211839	74955	136884
05/10/2014	211692	75029	136663
05/11/2014	211609	75104	136505
05/12/2014	211525	75145	136380
05/13/2014	211379	75186	136193
05/14/2014	211294	75260	136034
05/15/2014	211210	75334	135876
05/16/2014	210939	75408	135531
05/17/2014	210855	75483	135372
05/18/2014	210771	75557	135214
05/19/2014	210687	75598	135089
05/20/2014	210540	75639	134901
05/21/2014	210455	75713	134742
05/22/2014	210371	75787	134584
05/23/2014	210102	75862	134240
05/24/2014	209885	75936	133949
05/25/2014	209801	76010	133791
05/26/2014	209718	76051	133667
05/27/2014	209571	76092	133479
05/28/2014	209486	76166	133320
05/29/2014	209402	76240	133162
05/30/2014	209132	76315	132817
05/31/2014	208916	76389	132527
06/01/2014	208568	76417	132151
06/02/2014	208096	76411	131685
06/03/2014	207748	76373	131375
06/04/2014	207462	76401	131061

The output table above shows four columns of daily data. The first column is the date, followed by three columns of simulated French Meadows, Hell Hole and Total Middle Fork Project storage data. The post-processing tools have the ability to perform mathematical operations. In this example, the French Meadows and Hell Hole storage is added to calculate the total project storage listed in the last column. Each of the columns is comma delimited for easy import to a spreadsheet. In addition, the column titles are repeated so that the user can identify each column as they browse through the file. These repeating column titles can be removed for easier spreadsheet import. For detailed descriptions of all the tabular output options, see the OASIS user's manual.

The tabular output shown above was produced by the tabular output definition file (1v file) shown below. 1v files tell the OASIS software how to prepare the tabular output and can be altered for number formatting, column labeling, and other options. More information about how to prepare 1v files can be found in the OASIS software manual.



7.2.2 Graphical Output

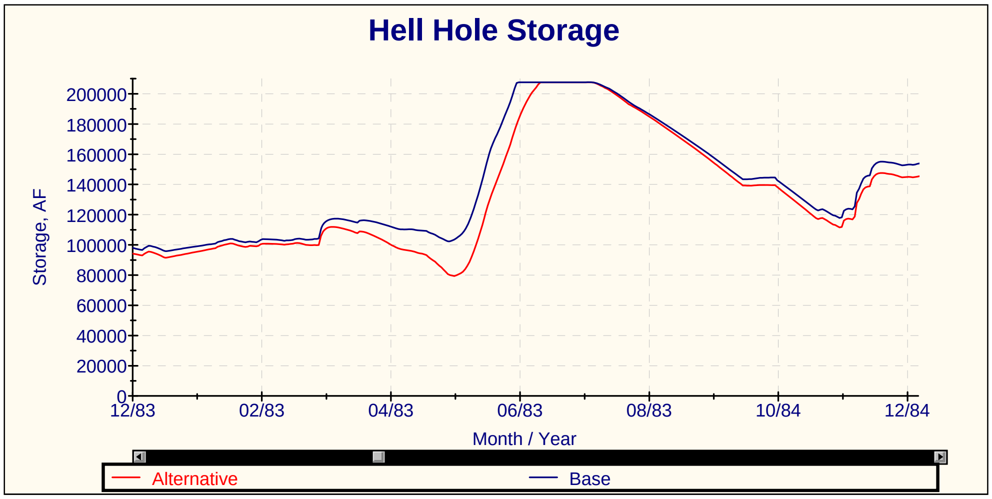
Graphs can be displayed as line graphs or bar graphs for specific time periods (a particular year or sequence of years or the entire simulation period). The sample graphs in the following figures show a "scroll bar" on the bottom of the graph. The slider can be moved to the left or right to change the time period displayed. The slider can also be removed for screenshots.

Data for the results file may also be displayed as an exceedance curve. In this case, the data displayed as the percent of the time interval analyzed that a certain value is exceeded. Examples of exceedance curves are also shown in the following figures.

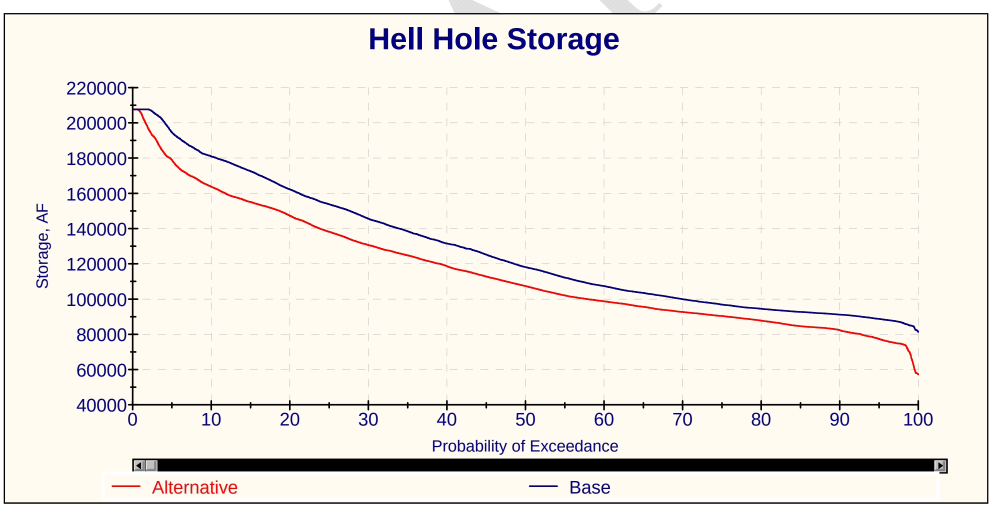
Samples of the displays of the graphic tools are shown in the following figures. Each is an illustration showing what the display will look like. They are for illustration only and do not show actual results.

Reservoir Storage

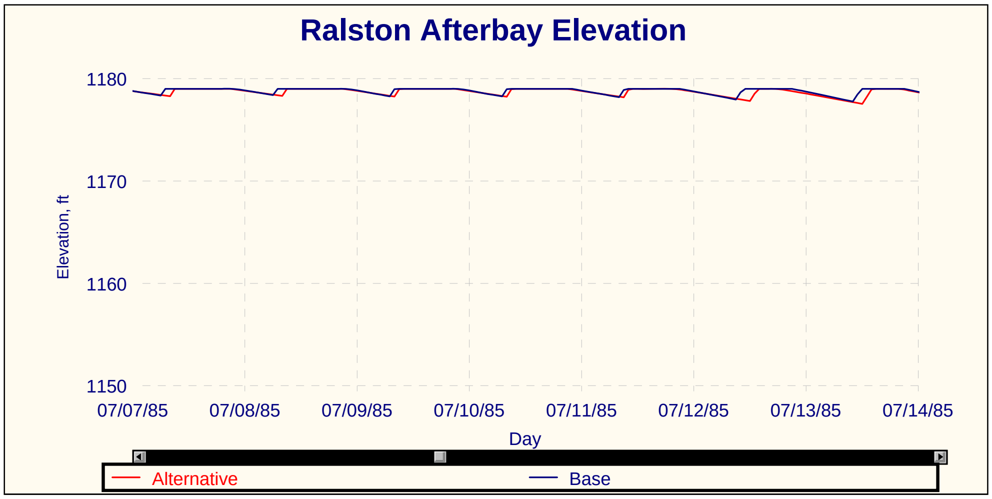
The following illustrate the graphs that are available to analyze user alternative changes to reservoir storage.



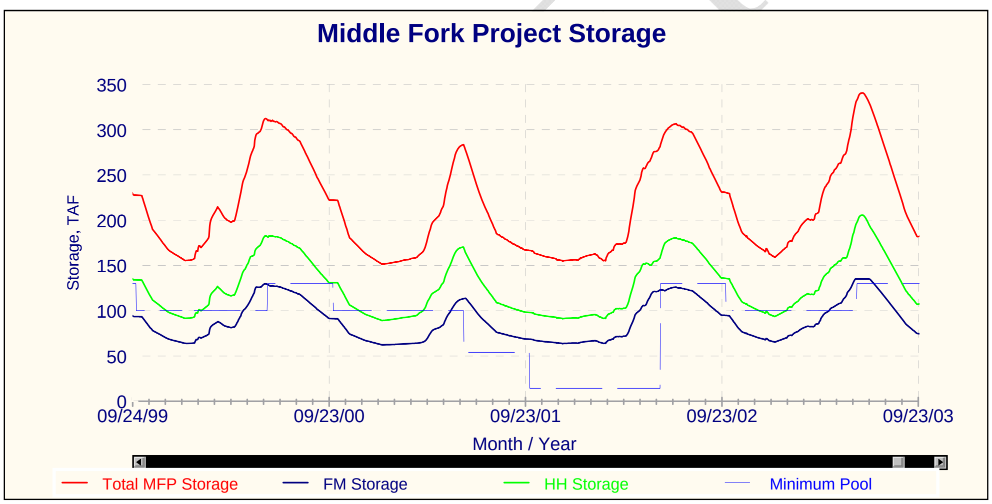
The illustration shows a base case and alternative storage curve for a single year. In the illustration, the user alternative has placed a higher demand on water supply from Hell Hole than the base study. The scroll bar at the bottom of the chart can be used to view any year within the period of record. This type of display can be used to look at several alternatives at once and both the x-axis and y-axis are scalable.



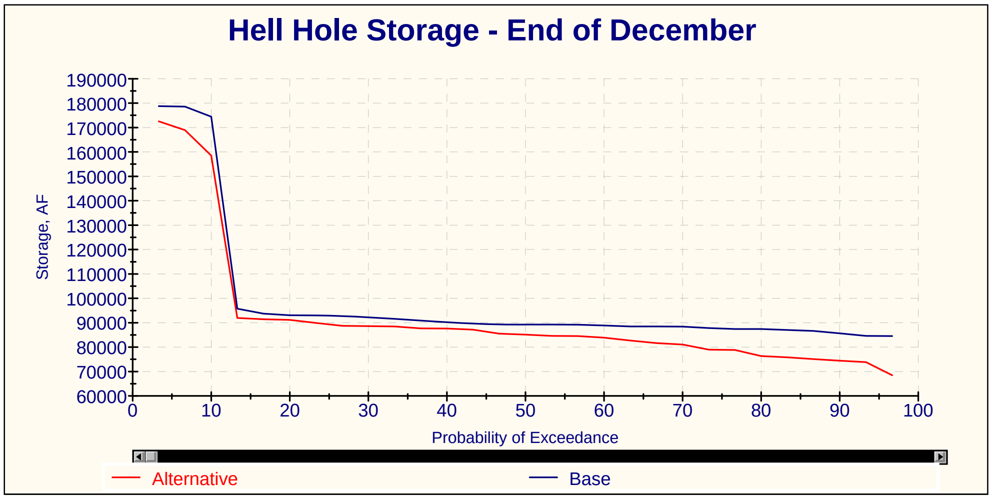
This illustration shows the same comparison as the one above but for the entire period of record as an exceedance plot.



This illustration is an example of Ralston Afterbay operations in terms of elevation for the period of one week. The graph compares the alternative to the base.



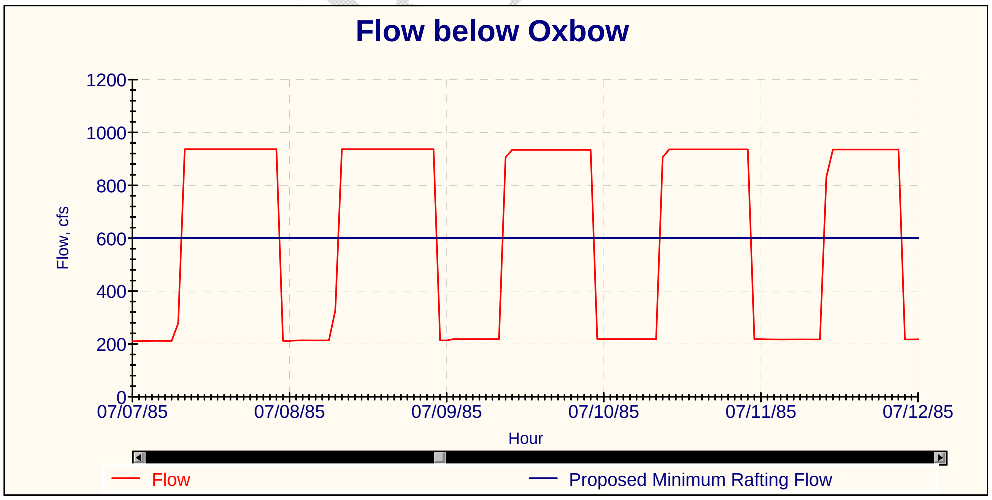
This illustration shows a graph of total Middle Fork Project storage over four sequential years of operation. It includes individual traces for French Meadows storage, Hell Hole storage, total Middle Fork Project storage and the minimum pool (combined minimum storage requirements in the current FERC license).



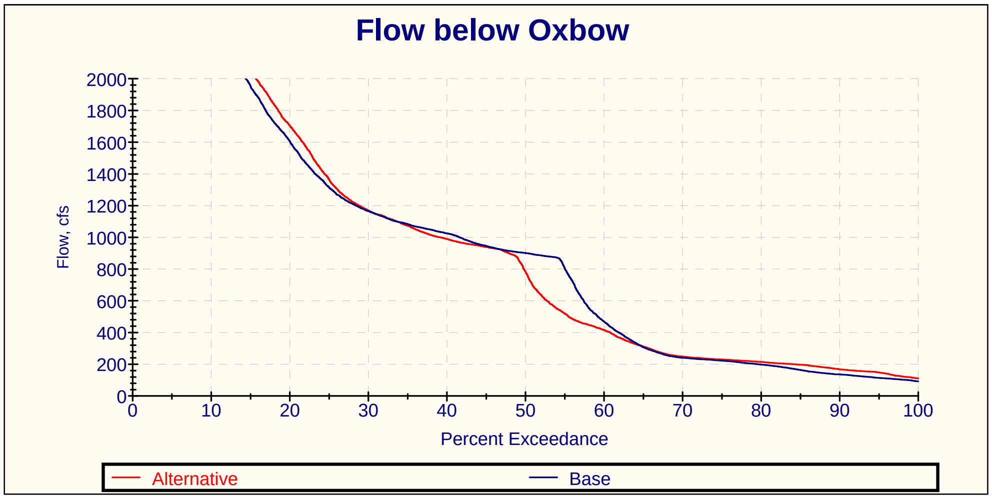
This example shows the storage at Hell Hole Reservoir on December 31, the reference date for the carryover target as an exceedance graph. Such a graph would need to be combined with a similar graph for French Meadows Reservoir to determine if the carry over target has been achieved. This graph shows the contribution of Hell Hole Reservoir to the carryover target.

<u>Flows in Diversion and Downstream Reaches</u>

The following illustrate the graphs that are available to analyze user alternative changes to flows in diversion and downstream reaches.



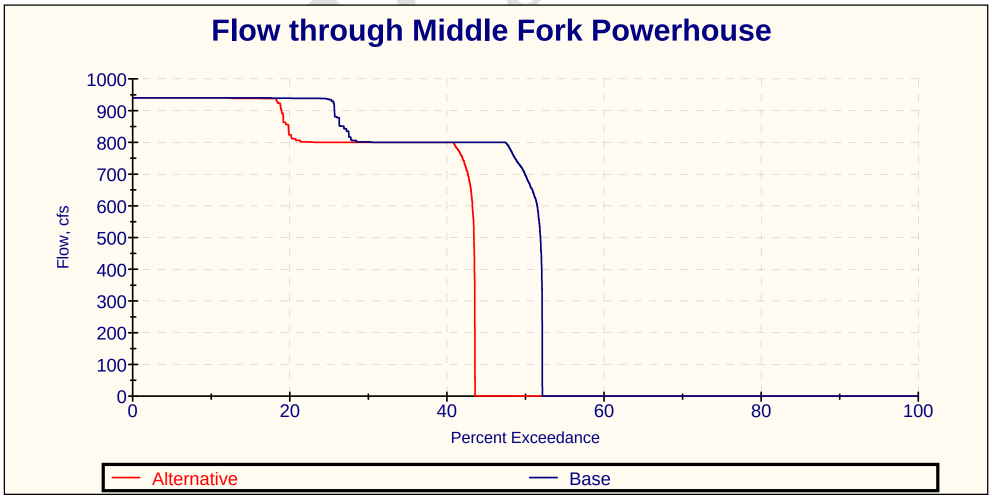
This illustration shows flow for a five-day time period. Its shape is a function of the peaking operation of the Middle Fork, Ralston, and Oxbow powerhouses where the units are on for a block of time (approximately 14 hours) that includes the peak energy demand period, then turned off (approximately 10 hours). In addition, a line has been added to the graph showing a user alternative recreation flow criteria. This graph then compares operating flows below Oxbow Powerhouse with a desired recreation flow.



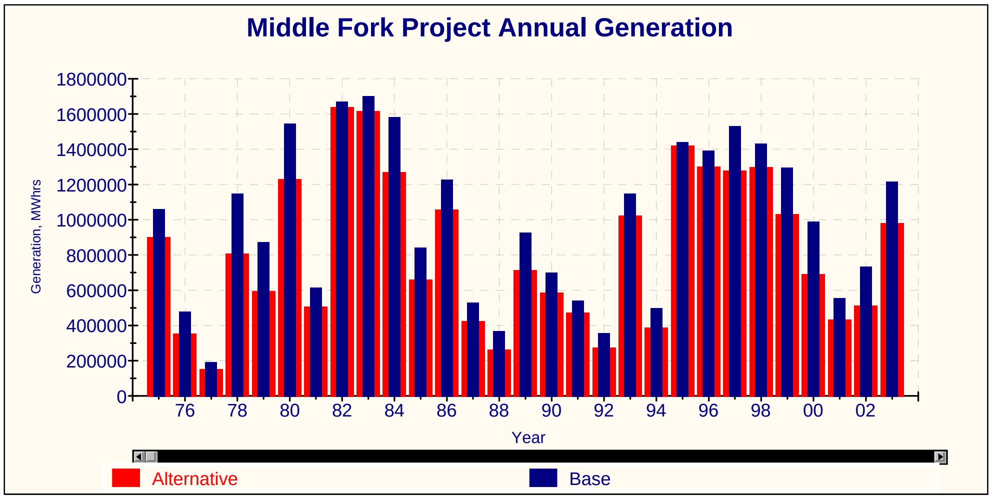
The chart above may also be useful to recreational interests. It shows that the base study provides flows above 600 cfs about 57% of the time while the alternative provides flows above 600 cfs about 53% of the time.

Generation

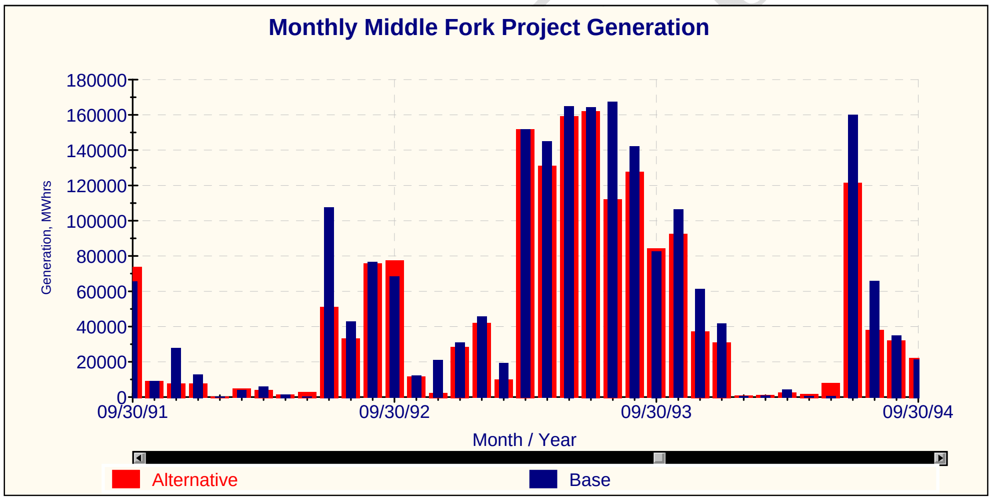
The following illustrate the graphs that are available to analyze user alternative changes to project generation.



This illustration is an exceedance curve of flows through the Middle Fork Powerhouse. It shows that the MFP generates power about 52% of the time and that generation occurs at or near full load when the powerhouse is in operation. The illustration shows that the user alternative further reduces the frequency of generation by approximately 8%.



This illustration is a chart showing total annual generation (in megawatt hours) produced by the Middle Fork Project under the base case and for a user alternative.



This illustration is similar to the one above but is total monthly generation for a three year period and shows the annual pattern of concentrating generation during certain periods of the year. In the illustration, each bar represents generation for a month. The differences in the bars indicate how the alternative effects the project generation.

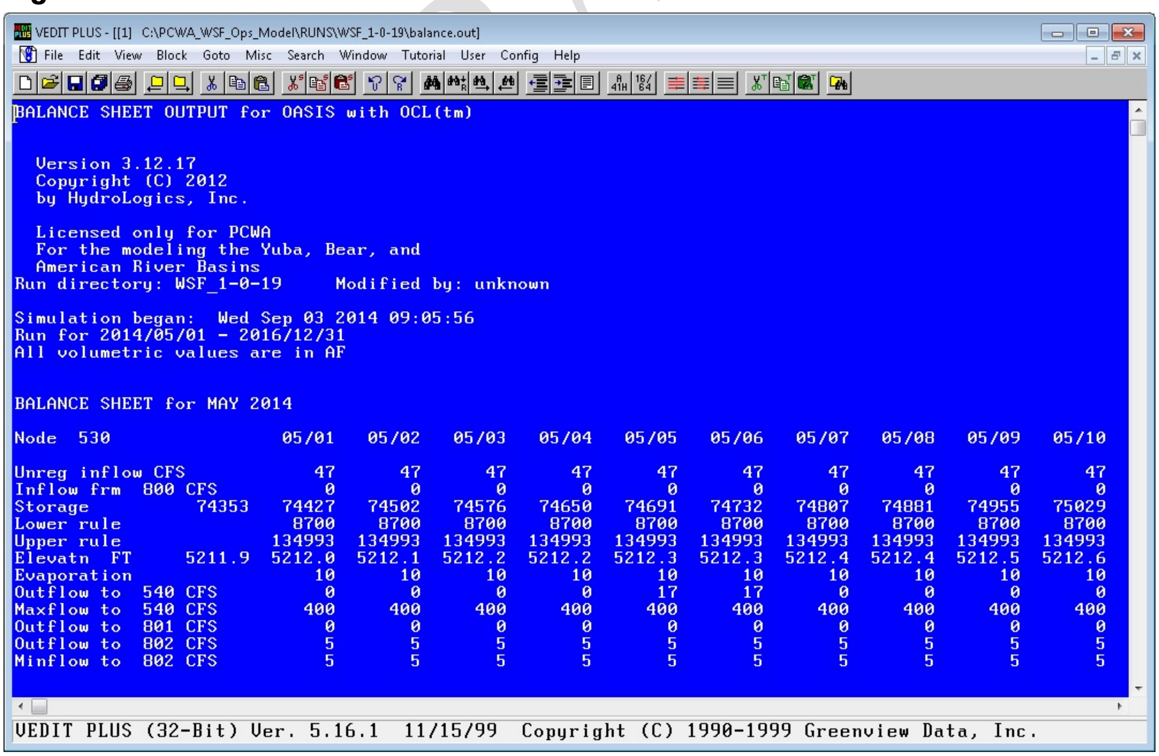
7.3 Diagnostics

OASIS has many diagnostics files that can be used to understand results or debug incorrectly working OCL code. Most diagnostic files are optional, and output is turned on or off in the 'Misc' tab in the GUI. Generally these are left off to minimize runtime and disk space, and then when questions about output arise that could be answered with a diagnostic file, these options are turned on and the model is re-run. Sometimes it is instructive to compare the diagnostic file of a working run to that of a run that is having problems. Diagnostic files can be accessed through the output menu on the GUI, and will give an option to open the diagnostic file of multiple runs at once.

7.3.1 Balance.out

For every simulation, OASIS has the option of creating a large tabular text file called balance.out that contains a balance of water entering and leaving each node in the system for each time step in the simulation. Figure 7 shows the balance of water at French Meadows Reservoir, node 530. This example shows the water balance for May 1 through 10, 2014. The storage value on the far left is the storage at the end of the previous time step, in this case for April 30, 2014. This illustration shows the unimpaired inflow, the diversion from Duncan Creek (node 800), the diversion to Hell Hole (node 540), the release through the spillway (node 801), the release to the river (node 802), and the minimum instream flow requirement below the reservoir. In addition the balance sheet shows the evaporation and the storage at the reservoir and pertinent restrictions such as lower rule, upper rule and maximum storage. The balance sheet displays flows in both acre-feet (AF) and cubic feet per second (cfs).

Figure 7 – Balance.out

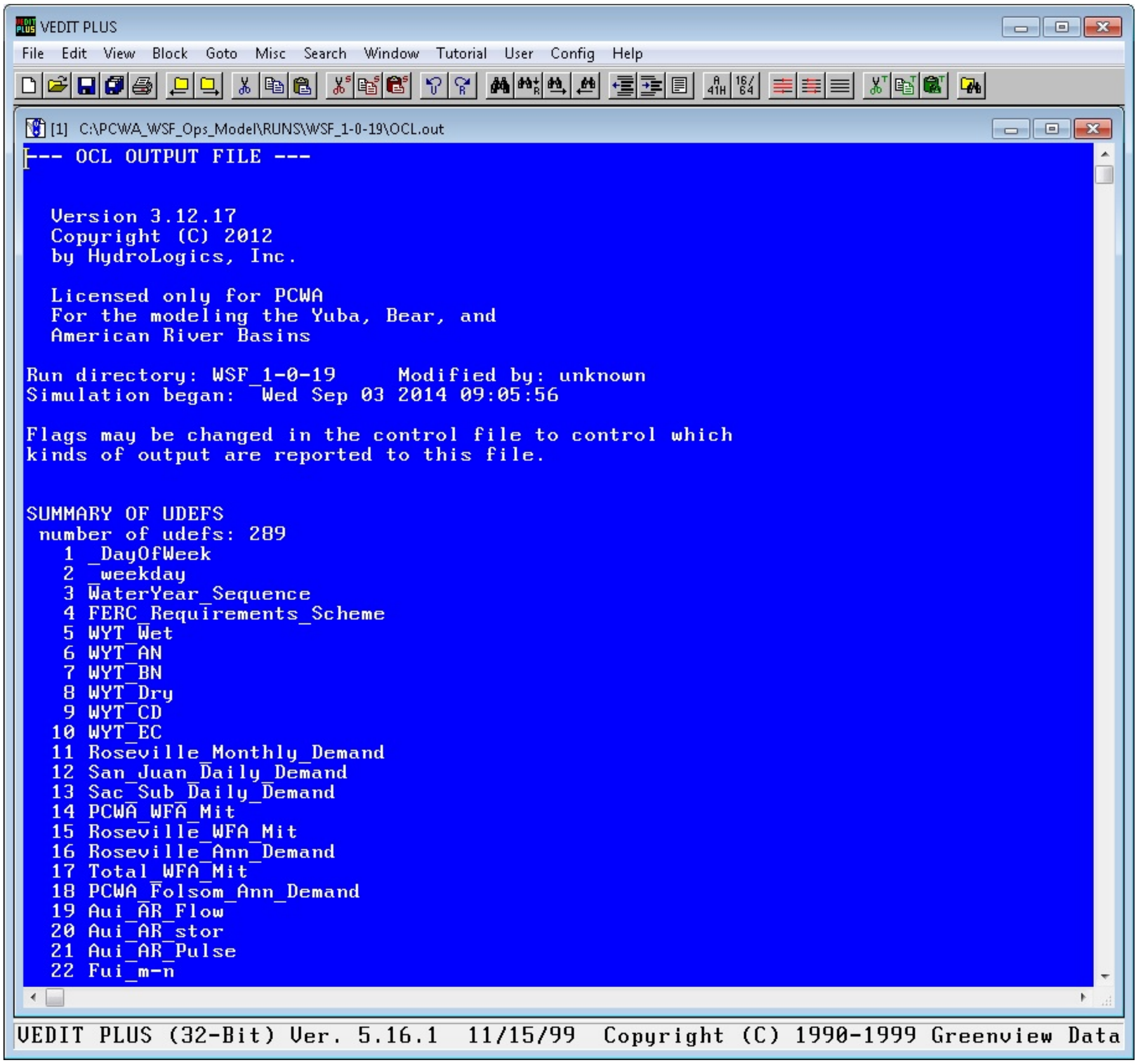



```
BALANCE SHEET OUTPUT for OASIS with OCL(tm)


  Version 3.12.17
  Copyright (C) 2012
  by HydroLogics, Inc.

  Licensed only for PCWA
  For the modeling the Yuba, Bear, and
  American River Basins
Run directory: WSF_1-0-19      Modified by: unknown

Simulation began:  Wed Sep 03 2014 09:05:56
Run for 2014/05/01 - 2016/12/31
All volumetric values are in AF


BALANCE SHEET for MAY 2014

Node  530                 05/01   05/02   05/03   05/04   05/05   05/06   05/07   05/08   05/09   05/10

Unreg inflow CFS             47      47      47      47      47      47      47      47      47      47
Inflow frm  800 CFS           0       0       0       0       0       0       0       0       0       0
Storage           74353   74427   74502   74576   74650   74691   74732   74807   74881   74955   75029
Lower rule                 8700    8700    8700    8700    8700    8700    8700    8700    8700    8700
Upper rule               134993  134993  134993  134993  134993  134993  134993  134993  134993  134993
Elevatn  FT      5211.9  5212.0  5212.1  5212.2  5212.2  5212.3  5212.3  5212.4  5212.4  5212.5  5212.6
Evaporation                  10      10      10      10      10      10      10      10      10      10
Outflow to  540 CFS           0       0       0       0      17      17       0       0       0       0
Maxflow to  540 CFS         400     400     400     400     400     400     400     400     400     400
Outflow to  801 CFS           0       0       0       0       0       0       0       0       0       0
Outflow to  802 CFS           5       5       5       5       5       5       5       5       5       5
Minflow to  802 CFS           5       5       5       5       5       5       5       5       5       5
```

7.3.2 OCL.out

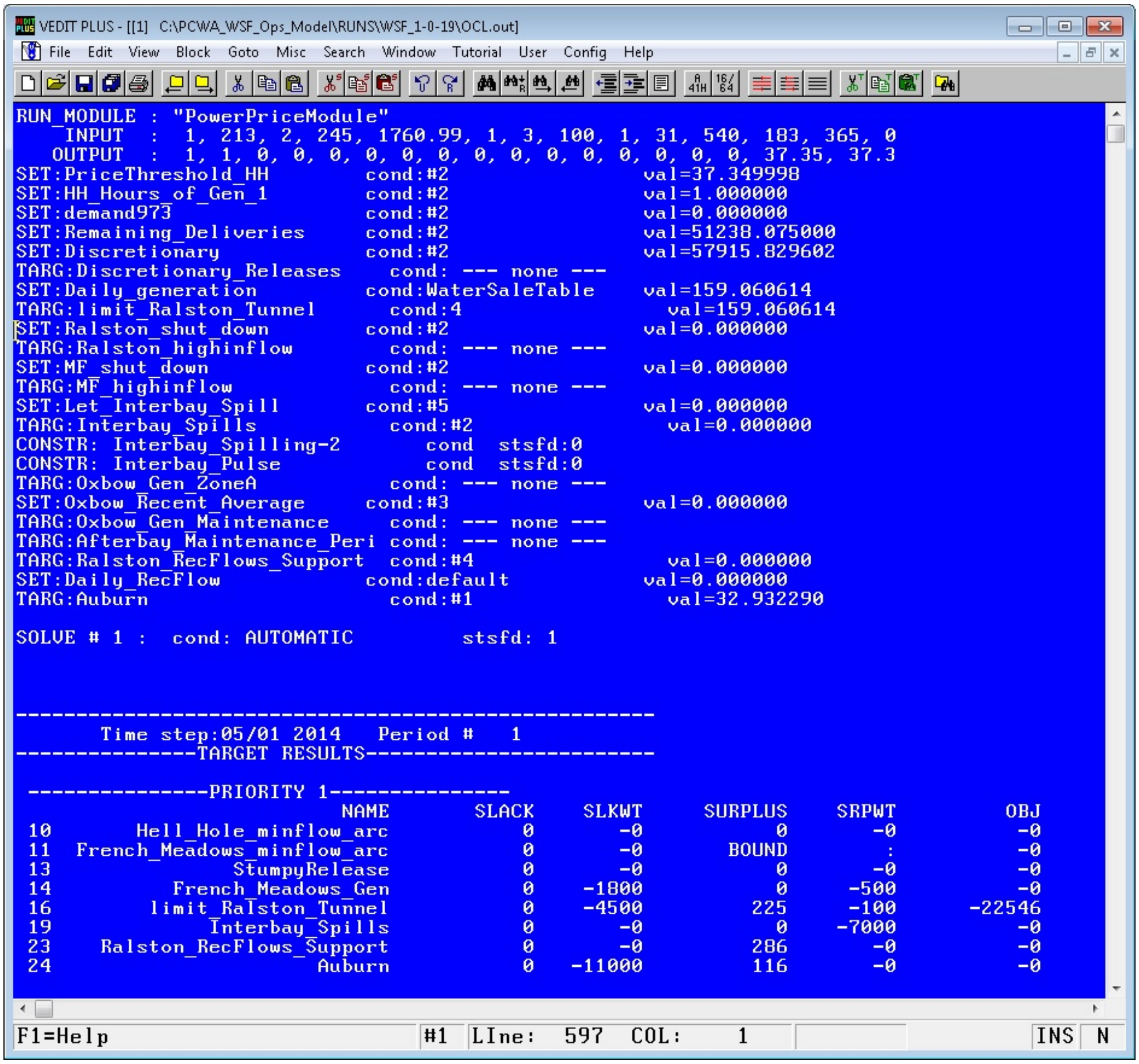
For every simulation, OASIS creates a tabular text file named OCL.out that contains a summary of all user defined variables (udefs), constraints, and targets in the model, shown in Figure 8.

Figure 8 – OCL.out



A small text file is created for every run containing this summary, and in addition, OASIS provides the option for two types of expanded output. When the checkbox “Print OCL Expression Evaluation” is marked, OASIS will write additional output for each timestep (top half of Figure 9) showing the result of every OCL expression contained in the OCL code, which condition was selected, and the resulting value. When the checkbox “Print OCL Target and Minimax Results” is marked, OASIS will write additional output for each timestep (bottom half of Figure 9, “Target Results”) showing all targets, which condition of the target was evaluated, the penalties for being above or below the targeted values, the slack and surplus on each target, and the weighting of the target’s selected condition. Where the value of a target is above or below the targeted value, it multiplies the slack or surplus by the weight to get the total penalty incurred, which is that target's contribution to the objective function.

Figure 9 – OCL.out Detailed Output

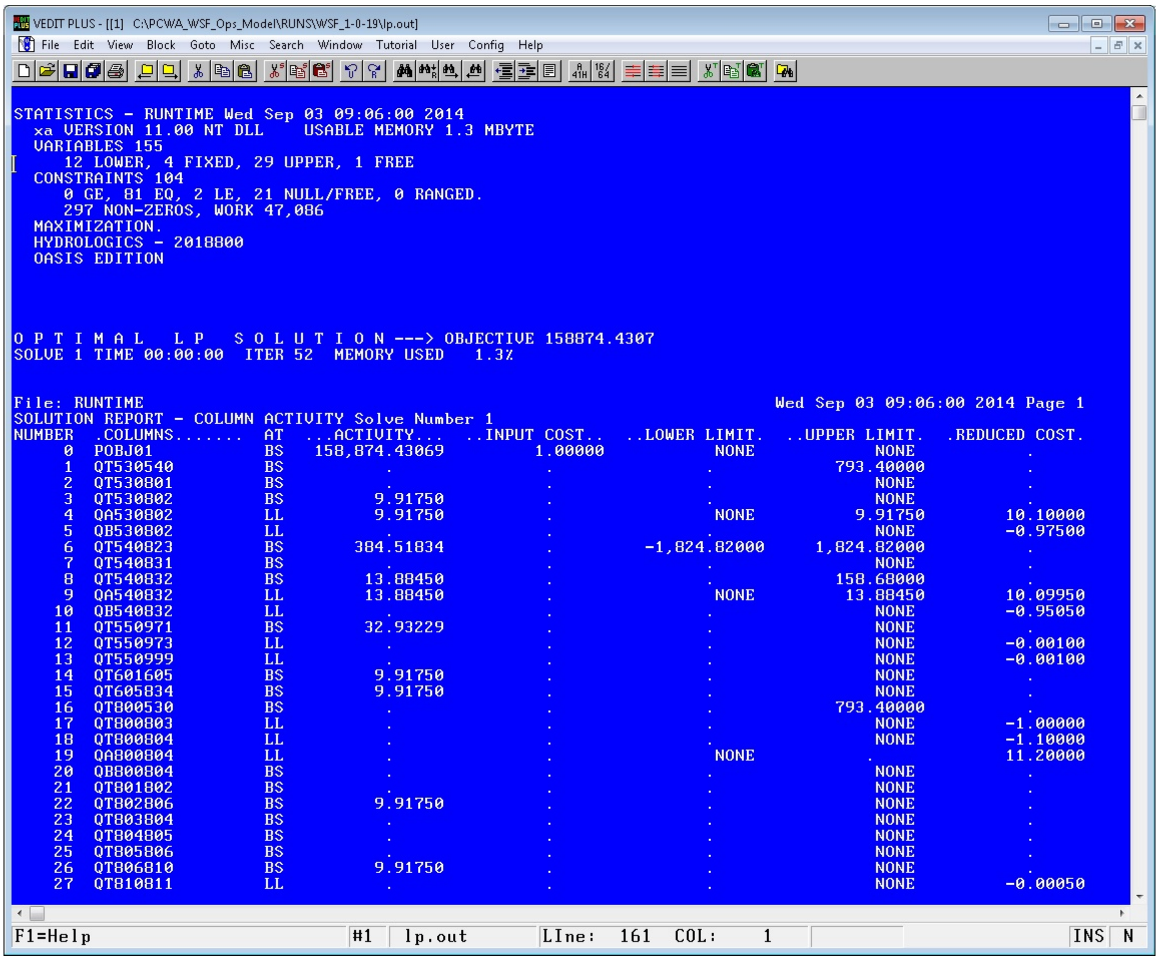


```
VEDIT PLUS - [[1]  C:\PCWA_WSF_Ops_Model\RUNS\WSF_1-0-19\OCL.out]
File  Edit  View  Block  Goto  Misc  Search  Window  Tutorial  User  Config  Help

RUN_MODULE  :  "PowerPriceModule"
    INPUT   :   1, 213, 2, 245, 1760.99, 1, 3, 100, 1, 31, 540, 183, 365, 0
   OUTPUT   :   1, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 37.35, 37.3
SET:PriceThreshold_HH         cond:#2               val=37.349998
SET:HH_Hours_of_Gen_1         cond:#2               val=1.000000
SET:demand973                 cond:#2               val=0.000000
SET:Remaining_Deliveries      cond:#2               val=51238.075000
SET:Discretionary             cond:#2               val=57915.829602
TARG:Discretionary_Releases     cond: --- none ---
SET:Daily_generation          cond:WaterSaleTable   val=159.060614
TARG:limit_Ralston_Tunnel       cond:4                val=159.060614
SET:Ralston_shut_down         cond:#2               val=0.000000
TARG:Ralston_highinflow         cond: --- none ---
SET:MF_shut_down              cond:#2               val=0.000000
TARG:MF_highinflow              cond: --- none ---
SET:Let_Interbay_Spill        cond:#5               val=0.000000
TARG:Interbay_Spills            cond:#2               val=0.000000
CONSTR: Interbay_Spilling-2        cond  stsfd:0
CONSTR: Interbay_Pulse             cond  stsfd:0
TARG:Oxbow_Gen_ZoneA            cond: --- none ---
SET:Oxbow_Recent_Average      cond:#3               val=0.000000
TARG:Oxbow_Gen_Maintenance      cond: --- none ---
TARG:Afterbay_Maintenance_Peri  cond: --- none ---
TARG:Ralston_RecFlows_Support   cond:#4               val=0.000000
SET:Daily_RecFlow             cond:default          val=0.000000
TARG:Auburn                     cond:#1               val=32.932290

SOLVE # 1 :   cond: AUTOMATIC         stsfd: 1



-----------------------------------------------------
       Time step:05/01 2014    Period #    1
---------------TARGET RESULTS------------------------

 ---------------PRIORITY 1---------------
                          NAME        SLACK      SLKWT      SURPLUS     SRPWT           OBJ
 10        Hell_Hole_minflow_arc          0         -0            0        -0            -0
 11   French_Meadows_minflow_arc          0         -0        BOUND         :            -0
 13                StumpyRelease          0         -0            0        -0            -0
 14           French_Meadows_Gen          0      -1800            0      -500            -0
 16         limit_Ralston_Tunnel          0      -4500          225      -100        -22546
 19              Interbay_Spills          0         -0            0     -7000            -0
 23     Ralston_RecFlows_Support          0         -0          286        -0            -0
 24                       Auburn          0     -11000          116        -0            -0

F1=Help                          #1  LIne:   597  COL:     1                    INS  N
```

7.3.3 LP.out

LP.out is an optional diagnostic file that contains all the linear equations that the model uses to route water. In basic model operation the output to LP.out is shut off. Turning on LP output slows down model runs considerably and its detailed output is usually not necessary for basic diagnostics but sometimes can be helpful in understanding unexpected model results or infeasible solutions. LP output is opened under the Output drop-down menu. Shown below is an example of a small selection of one time step. The output contains parameters passed to and received from the XA solver, solve times, and detailed information about how the solver determined the flow in every arc.

Figure 10 – LP.out




```
STATISTICS - RUNTIME Wed Sep 03 09:06:00 2014
  xa VERSION 11.00 NT DLL    USABLE MEMORY 1.3 MBYTE
  VARIABLES 155
     12 LOWER, 4 FIXED, 29 UPPER, 1 FREE
  CONSTRAINTS 104
     0 GE, 81 EQ, 2 LE, 21 NULL/FREE, 0 RANGED.
     297 NON-ZEROS, WORK 47,086
  MAXIMIZATION.
  HYDROLOGICS - 2018800
  OASIS EDITION



O P T I M A L   L P   S O L U T I O N ---> OBJECTIVE 158874.4307
SOLVE 1 TIME 00:00:00  ITER 52  MEMORY USED   1.3%


File: RUNTIME                                                    Wed Sep 03 09:06:00 2014 Page 1
SOLUTION REPORT - COLUMN ACTIVITY Solve Number 1
NUMBER  .COLUMNS.......  AT  ...ACTIVITY...  ..INPUT COST..  ..LOWER LIMIT.  ..UPPER LIMIT.  .REDUCED COST.
     0  POBJ01           BS  158,874.43069        1.00000           NONE           NONE           .
     1  QT530540         BS              .              .              .      793.40000           .
     2  QT530801         BS              .              .              .           NONE           .
     3  QT530802         BS        9.91750              .              .           NONE           .
     4  QA530802         LL        9.91750              .           NONE        9.91750    10.10000
     5  QB530802         LL              .              .              .           NONE    -0.97500
     6  QT540823         BS      384.51834              .   -1,824.82000    1,824.82000           .
     7  QT540831         BS              .              .              .           NONE           .
     8  QT540832         BS       13.88450              .              .      158.68000           .
     9  QA540832         LL       13.88450              .           NONE       13.88450    10.09950
    10  QB540832         LL              .              .              .           NONE    -0.95050
    11  QT550971         BS       32.93229              .              .           NONE           .
    12  QT550973         LL              .              .              .           NONE    -0.00100
    13  QT550999         LL              .              .              .           NONE    -0.00100
    14  QT601605         BS        9.91750              .              .           NONE           .
    15  QT605834         BS        9.91750              .              .           NONE           .
    16  QT800530         BS              .              .              .      793.40000           .
    17  QT800803         LL              .              .              .           NONE    -1.00000
    18  QT800804         LL              .              .              .           NONE    -1.10000
    19  QA800804         LL              .              .           NONE              .    11.20000
    20  QB800804         BS              .              .              .           NONE           .
    21  QT801802         BS              .              .              .           NONE           .
    22  QT802806         BS        9.91750              .              .           NONE           .
    23  QT803804         BS              .              .              .           NONE           .
    24  QT804805         BS              .              .              .           NONE           .
    25  QT805806         BS              .              .              .           NONE           .
    26  QT806810         BS        9.91750              .              .           NONE           .
    27  QT810811         LL              .              .              .           NONE    -0.00050
```

Notice that in the output above, most lines have the form QT (for total flow), followed by two node numbers. A trick for diagnosing infeasible runs is to search for the text "**" in LP.out. This text will appear after the arc listing for the arc that is resulting in an infeasible solution. This will point the user to what section of the model is having trouble. Note that arcs with minimum flows will have listings for QT (total flow), QA (minimum flow), and QB (flows in excess of the minimum).

7.3.4 Weight.out

At the beginning of each simulation OASIS writes a file, weight.out, which contains all weights in the model, including arc weights, reservoir weights, demand weights, and target weights.

7.3.5 Debug.out

At the end of each simulation OASIS writes a file, debug.out, which contains at a minimum the simulation date range and start and end times of run completion, and a message saying that the run completed normally. When the run does not complete normally, OASIS will write a message explaining the error. Common errors are missing timeseries (either completely missing or not covering the entire simulation date range), incorrect OCL expression syntax, or an infeasible LP formulation.

7.3.6 PriceModuleDebug

When requested, the external price series module will write a debug file specific to the operation of the external module. If the user selects the full LP.out option in the 'Misc' tab on the GUI, this will turn on Price Module Debug output. Alternatively, a line can be typed into the run's model configuration file (Model.cf, refer to Section 3.7 for information on this file). To do this, at the end of model.cf insert a line with the text "Module_Output_Flag = 1" and this will turn on module debug output during subsequent model runs.

The Price Module Debug file contains some initialization parameters, then for each simulation period, for each storage reservoir, lists the results of each iteration calculating the module's price threshold for discretionary generation. More information about the operation of the price module can be found in Appendix E.

Appendix A - Checklist for Setting up a New Run

For a new water year:

1. Folsom Refill Reservation
2. Maintenance Period Start Dates and Durations (French Meadows Powerhouse and Middle Fork / Ralston / Oxbow).
3. Recreation Flows
4. Consumptive Demands
   a. PCWA ARPS demands
   b. Roseville Demands
   c. San Juan and Sacramento Suburban estimates/orders.
5. FERC License status (is the new license expected to be in effect in either of the years being simulated?)
6. Seasonal diversion closure schedule
7. Minimum Oxbow Powerhouse Throughput

As you go through the season:

1. Inflow File
2. Folsom Refill Reservation
3. Check that Water Transfer is working
4. Water Transfer Parameters
   a. Start and End Date or Monthly Pattern
   b. Total Volume
   c. Folsom Refill Reservation
5. Recreation Flow Agreements

Appendix B - Tunnel & Powerhouse Capacities

Arc	Upstream Number	Downstream Number	Max Flow	Units
The Following capacities are set in the maximum flow table:				
NF Long Canyon diversion tunnel	817	823	100	cfs
SF Long Canyon diversion tunnel	820	823	200	cfs
Lower Hell Hole - Middle Fork Tunnel	540	823	920	cfs
Hell Hole Powerhouse	540	832	80	cfs
Middle Fork Powerhouse	823	810	940	cfs
Ralston Powerhouse	810	815	924	cfs
Auburn Pump Station	870	900	100	cfs
The Following capacities are set in the OCL code:				
Duncan Diversion Tunnel	800	530	400	cfs
French Meadows Powerhouse	530	540	400	cfs
Oxbow Powerhouse	845	847	1000	cfs

Appendix C - Water Year Type Derivation

Appendix D - Operations Control Language Input Guide

Operations Control Language Input Guide

Filename	Description
_daily__main.ocl	Contains the name and location of input files.
__Important_dates.ocl	Contains the water year period of important dates such as carryover and water transfer.
__Inflow_file.ocl	Contains the name and path of the forecasted inflow file.
_Curtailments.ocl	Sets whether the systems is operating under SWRCB water right curtailments, and the start and expected end period of the water right curtailments.
_daily_Betterments.ocl	Sets the behavior of project betterments.
_daily_demands.ocl	Sets consumptive water demand quantity and calculates water forum mitigation volumes.
_daily_diversion_ops.ocl	Sets basic diversion behavior, including seasonal closure dates.
_daily_Downstream_Release_Obligations.ocl	Contains logic for calculating Term 91 and Water Forum Agreement or water transfer reop water. Also implements the requirements that consumptive deliveries come from rediversion of storage.
_daily_forecast.ocl	Calculates forecasts of project inflows and future release requirements.
_daily_French_Meaadows_power_ops.ocl	Controls French Meadows reservoir dispatch behavior, including carryover target.
_daily_maintenance_period.ocl	Controls project behavior during maintenance outages.
_daily_min_flows.ocl	Implements minimum instream flow requirements.
_daily_min_storage.ocl	Implements minimum pool requirements for French Meadows and Hell Hole.
_daily_ops_criteria.ocl	Contains basic calculations of water year types and other indices.

Filename	Description
_daily_Oxbow_ops.ocl	Contains information about operations at Oxbow Powerhouse, including enforcing recreation flow requirements.
_daily_power_ops.ocl	Contains logic for determining when and how much generation should occur on a daily basis at Middle Fork Powerhouse.
_daily_reservoir_ops.ocl	Contains logic for reservoir spills and reservoir balancing. This file also controls which reservoir is releasing for consumptive demands during the maintenance period.
_daily_udef_list.ocl	Contains list of user defined variable names.
_daily_WaterTransfer_ops.ocl	Sets the monthly water transfer target.
_NodeNames.ocl	Contains list of node names and corresponding node numbers. This list is automatically generated by the OASIS GUI
Constants_table.ocl	Contains list of constant names and corresponding values. This list is automatically generated by the OASIS GUI
x_gui_constants.ocl	Contains information about selections made on Daily Run page. This information is automatically generated by OASIS GUI

Hourly Operations Control Language Input Guide

Filename	Description	Modification Allowed
Hourly_main.ocl	Contains some basic information about the location of input files.	No
Hourly_Oxbow_Operations.ocl	Contains logic controlling operations at Ralston Afterbay.	Yes
Hourly_PH_Operations.ocl	Operates the Middle Fork, Ralston, and French Meadows powerhouses according to the Energy Demand Index.	No
Hourly_set_flows.ocl	Sets minimum flows, maximum flows, and demands to the daily run settings.	Yes
Hourly_set_releases.ocl	Sets releases upstream of Ralston Afterbay to the daily model output.	No
Hourly_TravelTime.ocl	Implements travel time below Ralston Afterbay	No

Appendix E - External Price Module

The model utilizes an external module to augment the capabilities of the OASIS software. The external module (module) is written in C++ and runs parallel to the OASIS model. The sequence of events for a mode run is as follows:

1. The OASIS model runs an initialization.
2. The OASIS model passes a series of arguments to the module, and the module runs an initialization.
3. For each timestep, the model reads the OCL code, and when a module call is found in the code the model stops, sends an argument list to the module and waits.
4. The module performs a series of calculations, and sends a list of output to the model.
5. The model continues to parse the OCL code, passing data to the solver when it has reached the end of the code.
6. The solver returns output to the model, the records the output in the output.dss file and any debug files that are activated.
7. The model proceeds to the next time step.
8. After the last time step, the model tells the module that the simulation is completed, and allows the module to do a shutdown routine.

During the model execution the model calls the module twice, once for French Meadows Powerhouse and once for Middle Fork Powerhouse. Ralston and Oxbow Powerhouse throughputs are a function of Middle Fork Powerhouse throughput and hydrology and do not need to have throughput calculated by the module independently. Here we will describe in detail the calculations being made by the external module in steps 2, 4 and 8 from the sequence above.

The module contains three functions that can be called by OASIS: Module_Initialize, Module_Shutdown, and Module_Step.

As the name indicates, Module_Initialize is called when OASIS is initializing and allows the module to initialize its parameters. When Module_Initialize is called, the module receives from OASIS the name of the price series, the simulation start date, and the run directory. With this information, the module determines the path and file names of the model.cf file, the module debug file, and the price series file. The module reads model.cf to determine whether a debug file has been requested, and creates the file. The module then opens the price series and loads the prices and their respective date and times into a global multi-dimensional array, which avoids having to read the price at each time step. The module does some string manipulation of the data to get into the desired formats, writes some data to the debug file, and returns control to OASIS.

Module_Step is called by OASIS each time OASIS encounters OCL code calling the external module. In OCL, this is done with the Run_Module command (described in detail in the OASIS software user manual). Note that OASIS has the ability to work with multiple external modules simultaneously, so the command to execute this module is, more specifically, Run_Module : PowerPriceModule. This command in the OCL code is followed by a set of OCL variables that are passed to the module (labeled Input) and a set of OCL variables that are set with the results from the module (labeled Output). Module_Step then runs various subroutines:

- The module checks to see if OASIS needs input during this timestep.

- The module takes the last timestep's price threshold for use as an initial guess for this timestep. This initial guess is not binding, and the resulting threshold may be higher or lower than the initial guess. However, the resulting threshold is usually equal to the last timestep's threshold, and using that as an initial guess greatly reduces module runtime.
- The module calculates the price threshold for the dispatch season
  - The module starts with a price threshold of one dollar less than last time step's price threshold, calculates how many hours are above this threshold, and compares to the number of hours of generation requested by OASIS.
  - If the hours above the threshold are less than the number of hours of generation requested by OASIS, the module resets the price threshold guess to zero and begins again.
  - If the hours above the threshold are more than the number of hours of generation requested by OASIS, the threshold is increased by 0.05 dollars and recalculates the number of hours above the threshold and compares to the number of hours requested by OASIS.
  - This continues until the number of hours above the price threshold is equal to or less than the number of hours requested.
- Once the price threshold is calculated, the module calculates the number of hours of generation above the price threshold on the date of simulation, and returns that number to the module. The module was built to accommodate multiple module timesteps, and can be asked to return up to a month of generation values at a time, but is currently asked for input each day of the simulation.
- The module writes information to the debug file about each price threshold guess, the resulting number of hours above the threshold, and the number of hours requested.

Module_Shutdown is called when OASIS has finished the simulation and is done with the module. When this function is called, the module writes a summary to the debug file (if applicable), closes the debug file (if applicable), and deletes some temporary files.

Appendix F - Ralston Afterbay Constraints Memo