SACRAMENTO MUNICIPAL UTILITY DISTRICT
UPPER AMERICAN RIVER PROJECT
(FERC NO. 2101)

WATER BALANCE MODEL
TECHNICAL REPORT

Prepared by:

Sacramento Municipal Utility District
Sacramento, California

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EXECUTIVE SUMMARY

This report describes the computer program used to model the operation of the Upper American River Project (UARP) and the Chili Bar Project. The Water Balance Model for the UARP and Chili Bar Project is based on a commercial deterministic model that was customized by SMUD specifically for this purpose.

The Water Balance Model is a planning tool that uses the historical hydrologic record and the operational characteristics of the reservoirs, powerhouses, and other facilities to define and assess the typical operation of the UARP and Chili Bar Project from 1975 to 2001 and the proposed operation of the Iowa Hill Development. This makes the model well suited to analyze questions about monthly, seasonal, or inter-annual operation of the project. For example, the Water Balance Model can evaluate the feasibility of maintaining carryover storage targets at Union Valley, estimate monthly on-peak energy generation, and compare annual energy production for multiple flow regime proposals.

Pacific Gas & Electric's (PG&E) participation in the model development process has been limited to primarily the Chili Bar Project portion of the model. PG&E's participation in the UARP's Water Balance Model Subcommittee does not constitute acceptance or agreement of model results with respect to any contractual agreements between SMUD and PG&E.

The program requires extensive input data. This document describes energy demand periods, facility characteristics, operating practices, and details the values of many of the parameters that were used in the so-called Base Cases. The parameters are listed in an appendix to this report, and can be cross-referenced with other reports that include more detailed listings of program inputs.

1.0 INTRODUCTION

Sacramento Municipal Utility District (SMUD) owns and operates the Upper American River Project (UARP), which is located on South Fork of the American River, Silver Creek, and branches of the Rubicon River. Pacific Gas and Electric Company (PG&E) owns and operates the Chili Bar Project, which is located on South Fork of the American River immediately downstream of the UARP.

Under contract with SMUD, Devine Tarbell & Associates' (DTA) adapted their CHEOPS™ (Computerized Hydroelectric Operations Planning Software) Water Balance Model computer program to model the operations of the UARP and Chili Bar Project. SMUD and PG&E entered into a trilateral contract with DTA as the primary means of incorporating Chili Bar Project parameters into the Water Balance Model.

This document describes the Water Balance Model, including data input and model computations. A detailed listing of all input data is provided in Appendix A. A description of the model configuration and solution algorithm is provided in Appendix B.

1.1 Overview of Water Balance Model

The Water Balance Model takes as input hydrologic data and operating parameters. The hydrologic data consist of mean daily inflow to each of the UARP and Chili Bar Project reservoirs. The operating parameters include details of data summarized in this document, including powerhouse characteristics and reservoir physical and operational limits. The model simulates the real-world operation of the hydraulic features of the UARP, constrained by these inputs. The simulation focuses on water allocation and flow; energy generation is an output and not explicitly constrained by system load.

The model was developed to operate over a 26-year-long period of record from 1975 through 2000, based on the recommendation of the UARP relicensing process Water Balance Subcommittee. This period of record covers a variety of different water year types from the back-to-back very dry water years of 1976 and 1977 to very wet water years in the late 1990s.

To simulate UARP operation, the Water Balance Model steps sequentially through each day in the period of record. It allocates water through tunnels and powerhouses each day, and then shapes the daily volume in 15-minute increments according to the operating parameters. The output consists of time series of flow, reservoir storage, and energy generated at each location in the UARP and in the Chili Bar Project.

PG&E's participation in the model development process has been limited to primarily the Chili Bar Project portion of the model. PG&E's participation in the UARP's Water Balance Model Subcommittee does not constitute acceptance or agreement of model results with respect to any contractual agreements between SMUD and PG&E.

1.2 Base Case Specification

This document includes a description of the existing projects, operated within the constraints of the current licenses. This is called the *base case.*

Two separate base cases area specified in the model to deal with the two alternatives considered by SMUD in its License Application for the UARP:

1. The existing UARP and Chili Bar Project ("UARP/CB-Only Base Case").

2. The existing projects with the addition of the Iowa Hill Development proposed by SMUD ("UARP/CB with Iowa Hill Base Case").

This document describes both base cases. All project features except inclusion of Iowa Hill Development are identical in both.

2.0 OVERARCHING CONSTRAINTS

This section describes the general constraints incorporated into the Water Balance Model. The Water Balance Model employs logic that attempts to represent the considerations made in the day-to-day operation of the projects. Because no planning model can capture the diverse circumstances and dynamic real-time operating conditions of the projects, the Water Balance Model is designed to model their long term operation. This depiction is forward-looking and does not reflect historical operations.

2.1 Physical Operation Constraints

2.1.1 Existing UARP and Chili Bar

The Water Balance Model utilizes the following information for each reservoir and powerhouse in the model:

- Storage-elevation relationship
- Area-elevation relationship
- Evaporation rate
- Spillway flow-elevation relationship, with and without flashboards
- Tunnel flow-head relationship
- Powerhouse head loss, turbine performance, and generator performance

Subsequent to the publication of the Initial Information Package and First Stage Consultation documents, numerous detailed analyses conducted during the relicensing process resulted in updates to this information. The data shown in the tables in Appendix A reflect the operational and physical constraints built into the Water Balance Model base case.

2.1.2 Iowa Hill Development

Iowa Hill Development is a proposed project that consists of a pumping/generation powerhouse adjacent to Slab Creek Reservoir and a 6,500 ac-ft reservoir. There are three individually dispatched units. Data for Iowa Hill Development are presented in Appendix A, Line 67. Because this project is in the conceptual design stage, these data may change.

2.2 Daily Operation Constraints

SMUD's operation of the UARP is guided by several factors. These include: 1) following power demand and control-area regulation and reliability requirements; 2) meeting FERC license requirements; and 3) meeting dam safety requirements.

PG&E's operation of Chili Bar Reservoir is guided by the need to meet FERC license requirements and dam safety requirements. When possible, operations also follow power demand.

In the model, flows through UARP and Chili Bar Project powerhouses and reservoirs are scheduled on an hourly basis. Discharge and powerhouse operations are evaluated on a 15-minute basis. The various powerhouses in the UARP and Chili Bar Project are used to fulfill different needs (Table 2.2-1).

Table 2.2-1. Summary of powerhouse operation modes.

Powerhouse	Operational Mode	Notes
Loon Lake, Jones Fork, Jaybird, Camino, White Rock, Union Valley	Peaking	These are generally operated in a true peaking mode, with limited constraints on minimum powerhouse flows and sufficient storage for daily and weekly peaking cycles.
Robbs Peak	Run-of-the-river	The Gerle Creek–Robbs Peak system has only nominal storage. Robbs Peak Powerhouse provides significant peaking power benefits, as its primary inflow during most of the year is the Loon Lake Powerhouse discharge.
Chili Bar	Peaking Hourly schedule Ramping rates	Generation may be shifted away from the assumed load curve to accommodate whitewater boating and ramping rate restrictions.
Iowa Hill	Hourly schedule	Pump/generation units operated to fulfill two purposes: (1) pump off-peak and generate on-peak; and (2) generate as needed to support regulation and reliability.

In actual practice, the operation of the UARP and the Chili Bar Project is constantly reacting to changes in hydrology, customer demand, system needs and energy market conditions. However, the UARP and the Chili Bar Project operate within an envelope of over-arching objectives and constraints that have evolved over time. These are:

- Load Shape
- Preferred Reservoir Storage Objectives

- Monthly Energy Reliability Objective
- Operating Reserve
- Minimum Reservoir Releases
- Maintenance and Ramping
- Hydrology

These objectives and constraints are described in the sections that follow.

2.2.1 Load Shape

The Water Balance Model uses a daily volume of water to generate power according to an hourly schedule. The power demand ("load") varies substantially during the different hours of the day. The Water Balance Model distributes the daily generation among the hours of the day to prioritize power production when the load is greatest ("peak" hours). Some additional generation is modeled during off-peak hours to provide system regulation.

Each day is defined as 24 hours beginning at midnight (the hour ending at 1:00 AM, designated HE01) to midnight (the hour ending at midnight, designated HE24). Moreover, the demand for power is markedly different on weekdays compared to weekends.

As depicted in the Figure 2.2-1, the load shape varies by day of the week:

- For weekdays, shown on the lower half of the figure, Monday through Saturday, the load shape depicts a peak demand period from HE07 through HE22. Energy production is further prioritized to the period including HE15 through HE20.
- On Sundays, energy production is prioritized during a peak period that occurs from HE09 through HE22.

The depiction shown in Figure 2.2-1 is an example. Line 3 in Appendix A shows the load shape for each month that was used in the Water Balance Model.

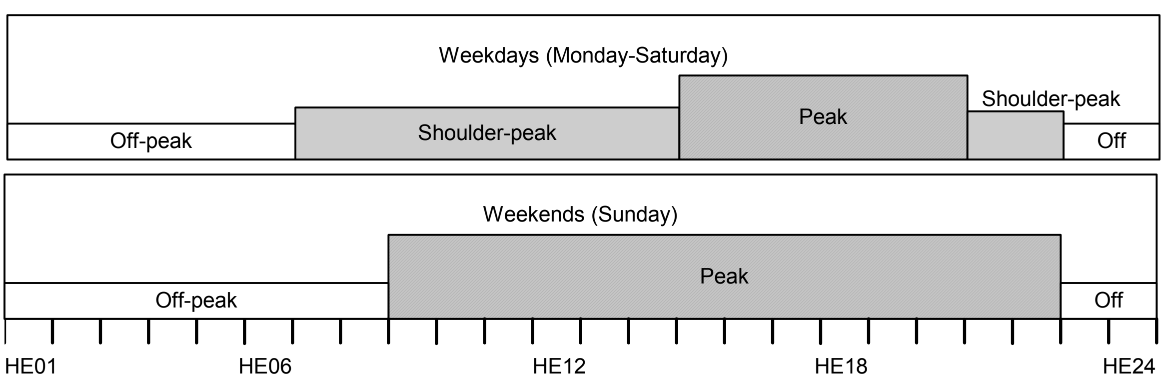

Figure 2.2.1-1. Example load shapes for weekdays and for weekends.

At every 1-day time step, the program allocates a volume of water. Then, with this daily volume:

- The program first allocates water for non-generation objectives uniformly among the hours of the day.
- The remaining water is available for generation. The program allocates his daily volume among the hours of the day using the load shape to maximize the amount of on-peak generation.
- The program will first allocate water to hours in the peak periods. If shoulder peak periods are identified, it allocates water to those periods next.
- Finally, it allocates any remaining water volume, to the hours in the off-peak periods.

The efficiency with which powerhouses generate power varies with the rate of flow. The Water Balance Model attempts to operate the turbines at or near peak efficiency. It optimizes generation by distributing the water in 15-minute intervals. This is done starting in the last hour of each of the periods mentioned, then working backward to earlier hours in the period.

2.2.2 Preferred Reservoir Storage Objectives

Typical of mixed-elevation Sierra Nevada watersheds, the pattern of natural runoff to UARP and Chili Bar Project reservoirs is shaped by a combination of rainfall and snowmelt. The significant precipitation season occurs between November and April, and typically occurs as rainfall in lower elevations and snow in upper elevations.

Rainfall runoff occurs during rainfall events while accumulated snow typically runs off during the spring and early summer, April through July. During the summer and early fall natural runoff is minimal, and often zero at the higher elevations.

Three UARP reservoirs (Loon Lake, Ice House, and Union Valley) are operated to store water during the winter and spring and release it for power generation during the summer and fall.

In actual practice, the selection and application of reservoir storage objectives during the course of a year requires the anticipation of future runoff within the year. In the Water Balance Model, the preferred reservoir storage objectives guide the program to draw down reservoir storage during the summer and to maintain storage during the winter and spring, in anticipation of a dry year. This provides:

- **Spill avoidance**: the preferred reservoir storage objectives provide sufficient available reservoir space to regulate runoff with generation capability and avoid spill during the winter and spring.
- **Carry over storage**: the preferred reservoir storage objectives guide the use of stored water for generation during the summer to meet system needs while also drawing down the reservoirs for the subsequent year’s runoff.

The preferred reservoir storage objectives are modeled as sets of reservoir elevations that serve as operating targets. At each point in the simulation, each reservoir elevation target is determined by the snowmelt runoff expected and the season within the year. In actual operation of the UARP, these elevations are fine tuned throughout the developing water year as runoff forecasts are updated and electricity needs unfold as a function of summer conditions, primarily air temperatures in Sacramento.

These preferred reservoir storage curves were developed through the testing and review of multiple iterations of the model, through events that have occurred, with an attempt made to balance the criteria of spill avoidance and seasonal carry over of reservoir storage. They are represented as a set of daily elevation values, one for each reservoir and wetness index. The program uses these sets of reservoir elevations as a form of constraints that are considered when arriving at a simulated operation for a year.

During development of the Water Balance Model, the elevations were adjusted until they resulted in a simulated operation that efficiently manages the reservoirs (reasonably avoids spills) while also reasonably capturing runoff into storage for the summer season.

Five sets of preferred reservoir storage objectives were defined for each of the three major reservoirs (Loon Lake, Ice House and Union Valley). They are plotted in Figures 2.2.2-1 through 2.2.2-3, and tabulated in Appendix A, Lines 12, 26, and 32.

The choice of which of the five sets to use for a particular water year is made using a "wetness index" equal to an anticipated runoff condition for the basin. This index is the April-July unimpaired runoff at American River at Fair Oaks gage as computed by the Snow Surveys section of California Department of Water Resources (DWR). This is equivalent to the computed natural inflow to Folsom Reservoir. It is a value expressed as a water volume in units of thousands of acre-feet (TAF). Table 2.2.2-1 illustrates the range of unimpaired runoff associated with each preferred reservoir storage objective year type. It is important to note that this index is different from the criterion used to determine minimum flow releases as described later in Table 2.2.2-4.

Table 2.2.2-1. Preferred reservoir storage objective wetness index designations and range of applicability.

Designation in Water Balance Model	Minimum index value (TAF)
A	0
B	500
C	1,000
D	1,500
E	2,000

The program establishes the wetness index in October of a water year and it remains unchanged during the remainder of the water year.

The objectives are consistent with the conditions stated on the DWR Division of Safety of Dams (DSOD) dam certificates.

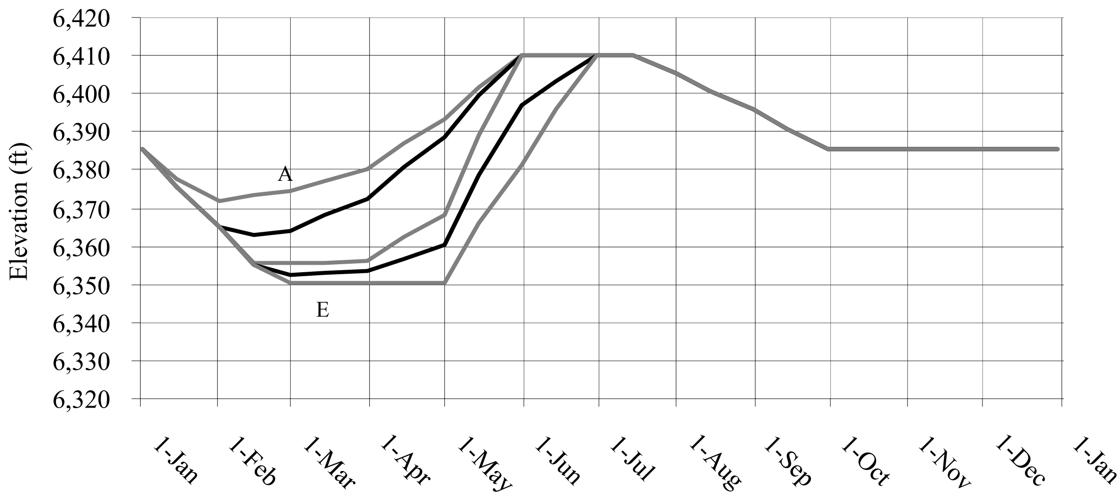

Figure 2.2.2-1. Loon Lake Reservoir preferred storage objective.

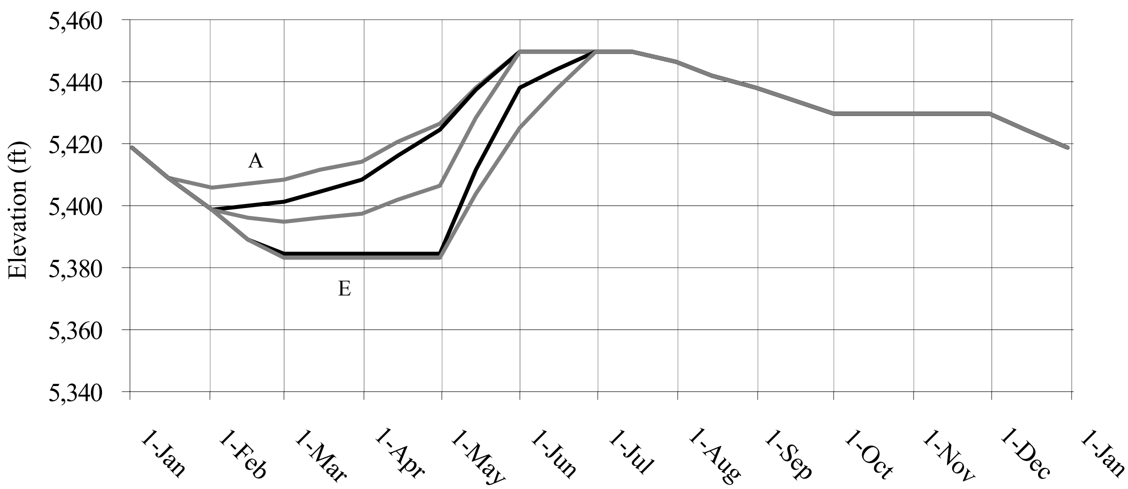

Figure 2.2.2-2. Ice House Reservoir preferred storage objective.

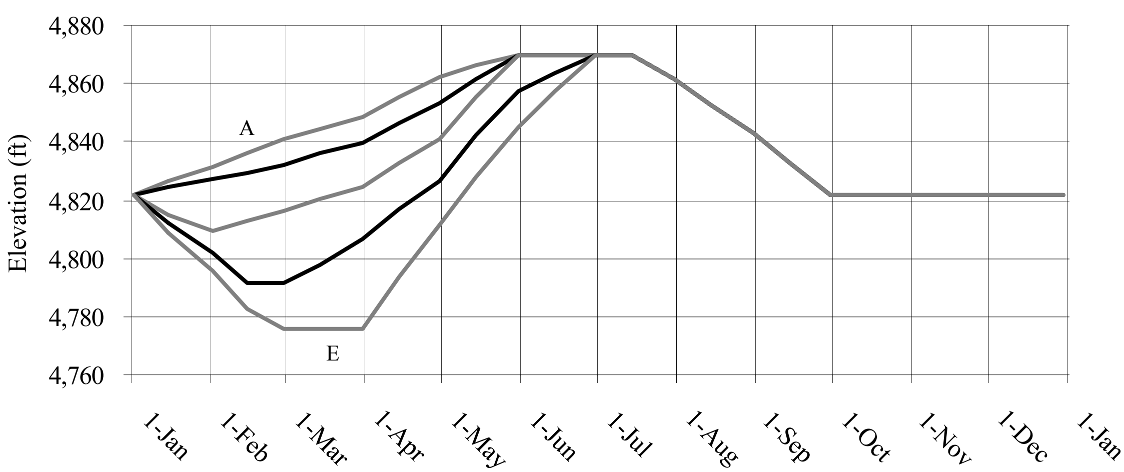

Figure 2.2.2-3. Union Valley Reservoir preferred storage objective.

2.2.3 Monthly Energy Reliability Objective

The monthly energy reliability objective guides the Water Balance Model to manage water to generate at least the minimum amount of energy needed meet system regulation and reliability needs.

The monthly energy reliability objective defines an amount of minimum monthly generation from the project that will be produced. In actual project operation and system planning, this generation is anticipated to be that amount minimally required by the UARP to meet control area needs. Control area needs are mandated external to SMUD and include the instantaneous balancing of loads and resources, ramping to follow load, and stabilizing the variability in other resources such as solar and wind projects.

However, a "minimum" generation objective provides only limited guidance for the management of reservoir storage. Great flexibility exists in utilizing stored water from the UARP:

- UARP reservoirs could be heavily drawn upon during a season or a year at the expense of having stored water available in subsequent periods.
- Stored water could be retained in anticipation of a prolonged drought.

To guide the management of its resource, SMUD developed a planning principle for the UARP that recognizes the value of assuring the availability of UARP generation during drought. The underpinning of this principle a generation plan that does not impair the UARP's ability to provide a minimum sustained generation during a recurrence of the worst drought of record.

The monthly energy reliability objective has been modeled to accomplish two goals of long-term operation planning:

1. **Reliability and demand**. In a year when the preferred reservoir storage objectives result in insufficient generation to meet reliability and demand needs, the monthly energy reliability objective will call for additional generation. Additional water from Union Valley, Loon Lake, and Ice House reservoirs will be drawn to generate more power.

2. **Drought protection**. In general, achieving the first goal will draw reservoirs down below the preferred reservoir storage objectives. The monthly energy reliability objective values were established by a review of historical operations. They were adjusted and simulated until the monthly energy reliability objective was achieved every year of the simulation including the worst drought in the period of record.

For modeling purposes, the energy reliability objective is expressed in terms of power releases from Union Valley Reservoir. These releases are given in Appendix A, Line 2.

This volume of water for power generation will be allocated as follows:

1. When the energy reliability objective controls the release from Union Valley Reservoir, part of the incremental volume will be released during the on-peak period. The on-peak fraction can vary by month and is listed in Appendix A, Line 2.

2. All of the water needed to meet the energy reliability objective will be drawn from Union Valley Reservoir except when its usable capacity falls below 25%. Usable capacity is defined as the water volume between flood elevation and minimum elevation.

3. If sufficient water is not available from Union Valley Reservoir, additional water will be drawn from Ice House Reservoir and Loon Lake into Union Valley Reservoir to provide sufficient water for the release. The relative contribution of these two reservoirs is shown in Table 2.2.3-1.

Table 2.2.3-1. Apportionment of water to support energy reliability at Union Valley Reservoir.

Reservoir	Apportionment (percent)
Ice House Reservoir	40
Loon Lake Reservoir	60

2.2.4 Operating Reserve

SMUD's status as a control area requires it to maintain operating reserve or "spinning reserve" based on its load, generation, and transmission resources. SMUD normally obtains about half of its system operating reserve from the UARP during the summer, and all of its operating reserve from the UARP during the winter.

For the base case models, the operating reserve requirement is labeled as spinning reserve, as shown in Line 2 of Appendix A. A separate value is provided for each of the UARP reservoirs. The model uses this capacity to avoid spill during periods such as large-runoff storm events.

2.2.5 Minimum Reservoir Releases

The Water Balance Model includes the existing FERC license conditions for minimum flow releases at all UARP reservoirs and at Chili Bar Reservoir. These requirements are shown for each reservoir in Appendix A under the Bypass Flows and Minimum Flows tables. The flow requirements at several dams are uniform across water year types. At other locations the flow requirements vary by water year type. For these locations, up to four different release schedules can occur associated with four water year types. The index for the water year is the forecasted unimpaired runoff at the Fair Oaks gage on the American River as published by the California Department of Water Resources (DWR) in Bulletin 120. This runoff is essentially equivalent to the basin inflow to Folsom Lake. The four classifications are listed in Table 2.2.5-1.

Table 2.2.5-1. Minimum stream flow water year type designations and thresholds.

Common designation	Designation in Water Balance Model	Minimum threshold TAF
Water year type 1	A	0
Water year type 2	B	1000
Water year type 3	C	1500
Water year type 4	D	2000

It is important to note that this index is different from the criterion used to determine the preferred storage objective, described in Table 2.2.2-1. The Water Balance Model is capable of handling five water year types. The model was configured to allow five water year types because the Water Balance Subcommittee of the UARP relicensing process determined that five water year types were more appropriate for the operation of the UARP.

The unimpaired runoff forecast is published by DWR at various times of the year. For many of the locations where minimum stream flow requirements are identified, the April 1 forecast is used to identify the schedule of flows to be implemented during April for the ensuing twelve months. At other locations, either an earlier forecast initiates the current year's schedule or a subsequent forecast updates the current year's schedule. Entries of an "X" in Table 2.2.5-2 designate when these forecast updates apply. The model uses these criteria to adjust minimum releases over different water year types and different months within a given water year.

Table 2.2.5-2. Months when minimum reservoir release schedules are updated.

Location	March update	April update	May update
Rubicon Reservoir		X	
Buck Island Reservoir		X	
Loon Lake Reservoir		X	
Gerle Creek Reservoir		X	
Robbs Peak Reservoir		X	
Ice House Reservoir		X	X
Union Valley Reservoir		X	
Junction Reservoir		X	
Camino Reservoir		X	
Brush Creek Reservoir	X	X	X
Slab Creek Reservoir	X	X	X
Chili Bar Reservoir		X	

2.2.6 Maintenance and Ramping

Two additional operational constraints are imposed on certain powerhouses within the model. Each powerhouse is typically taken out of service for a period of weeks in the autumn. Also, there are regulatory restrictions on certain powerhouse's discharge rate of change. The program enforces this through ramping rate restrictions, which can vary during each year.

Maintenance schedules and ramping rate restrictions are specified in Appendix A under the headings for each reservoir with an associated powerhouse.

2.2.7 Hydrology

Rainfall and snowmelt supply water to each of the reservoirs in the UARP and to Chili Bar Reservoir. This information is specified in the Water Balance Model in the form of daily time series of flow. Each reservoir has a time series that includes the sum of natural tributary stream flows, and local shoreline inflow, and accretions along each stream up leading to the next reservoir. The *Hydrology Technical Report* prepared for this relicensing describes how these values were developed for the period of record, 1975-2000. These values are used in the base case.

FERC Project 184 regulates flow along the South Fork American River upstream of the UARP. This regulation is included in the base case Slab Creek Reservoir inflow.

3.0 SPECIFIC CONSTRAINTS

3.1 Slab Creek Powerhouse

The 400 kW Slab Creek Powerhouse is part of the UARP but it is not in the Water Balance Model.

3.2 Chili Bar Reservoir

3.2.1 Scheduling Chili Bar Project Operations and Whitewater Boating Flows

Chili Bar Powerhouse is operated during times of peak power demand to the extent possible, dependent on the timing and quantity of water provided during White Rock Powerhouse operations. While peak power demands vary seasonally, the highest demands are typically between 4:00 PM and 10:00 PM.

Recent Chili Bar Project operations have reflected non-license, annual agreements between SMUD, PG&E, and whitewater boating interests. These operations have scheduled releases of approximately 1,200 cfs between 9 am and noon from Tuesday through Sunday to accommodate whitewater boating in the Reach Downstream of Chili Bar during normal and wet water years. Considerable volumes of water may also be released at other times of the day, but the timing of these other releases is based on unpredictable power demand. If recreational flow magnitudes and durations increase, the flexibility of SMUD and PG&E to meet variable power demand is believed to decrease. In wetter years, release magnitude and duration are generally larger and longer. In drier years, releases are generally smaller, more variable and less predictable.

3.2.2 Chili Bar Project Operation Restrictions

The existing license imposes a minimum streamflow requirement of 100 cfs, but 200 cfs is the low end of the operating range of Chili Bar Powerhouse. As inflow to Chili Bar Reservoir decreases, Chili Bar Powerhouse draft is reduced to 200 cfs to meet the reservoir target elevation of approximately 994 feet. This target elevation has been based on the need to retain adequate storage in the reservoir to maintain the base flow for several days if minimal inflow occurs.

Ramping restrictions in the current Chili Bar Project license require Chili Bar Powerhouse to take 2-3 hours to go from a base flow of 200 cfs to full flow and from full load to base flow.

3.3.3 Chili Bar Project Operation Modes

The hourly discharge pattern from Chili Bar Powerhouse is modeled to follow the load shape used with reservoirs in the UARP. Optionally, this schedule can be adjusted so that additional water is provided at times suitable for whitewater boating. To provide the daily volume to support the minimum instream flow or the whitewater boating flow, there are three modes of operation:

1. **Delinked mode**. There is no flow volume support from Slab Creek Reservoir for whitewater boating or for minimum flow requirements. Chili Bar Reservoir outflow is shaped for power demand and adjusted if possible to accommodate the whitewater boating demand.

2. **Linked mode**. Releases will be made from Slab Creek Reservoir the day before as needed to provide sufficient volume for minimum streamflow releases, if possible, but without reoperating the UARP upstream.

3. **Linked mode with raft flow support**. The volume of water in excess of incremental accretion that is required to support whitewater boating flows is discharged from Slab Creek Reservoir (if available) on the day prior to the whitewater boating flow.

Furthermore, the following options can be set:

- **Raft flow support up UARP option**. This option is available when the “linked with raft flow support” mode is selected. The volume of water, in excess of available storage in Slab Creek Reservoir and incremental accretion, which is required to support whitewater boating flows will be discharged from UARP reservoirs upstream of Slab Creek Reservoir on the day prior to the whitewater boating flow.
- **Spill prevention option**. This option is available when either the “linked” or “linked with raft flow support” mode is selected. White Rock Powerhouse discharge schedules may be reduced to avoid spills at Chili Bar Reservoir.

Calculation of a daily discharge from Chili Bar Reservoir is based upon inflow plus the change in storage. If a scenario is specified that includes whitewater boating flows, the volume is calculated and entered as a daily average requirement. If no whitewater boating flow is specified, the daily discharge is bounded by a minimum instantaneous flow limit (required minimum streamflow). These data are listed in Appendix A, Line 63.

3.3.4 Operation Mode Selected

For the base cases, the whitewater boating flow release schedule is as listed in Appendix A, Line 64. The reservoir is modeled in delinked mode.

In SMUD's analyses used for its license application, the reservoir is modeled in linked mode.

3.3.5 Computation of Inflow to Chili Bar Reservoir

The program calculates reservoir inflow based on White Rock Powerhouse discharge and Slab Creek bypass flow plus incremental accretion. Then:

- If **delinked** mode is selected, inflows are modified to calculate today's White Rock powerhouse discharge as an average of today's discharge and yesterday's discharge.
- If **linked** is selected, inflows are estimated and averaged based upon a forecast period of two days. The program checks calculated inflow and start-of-day elevation against storage criteria. Then:
- If **raft flow support** is selected, the program schedules sufficient White Rock Powerhouse draft to augment Slab Creek Reservoir instream release and accretion flow to meet the whitewater boating flow.
- If **raft flow support** is not selected, then if the sum of the usable storage and inflow volume is inadequate, the whitewater boating volume requirement may be abandoned, or the minimum discharge may be decreased below the desired minimum to the license-required minimum. These values are listed in Appendix A, Line 63.

3.3.6 Detailed Daily Scheduling

Detailed daily scheduling depends upon whitewater boating requirements.

- If a period to be scheduled is during a whitewater boating flow period and on a whitewater boating flow day, the program schedules a ramp up to the whitewater boating flow for the whitewater boating period duration. The program then schedules the remaining available volume during the peak power demand period.
- If the day is not during a whitewater boating flow period, the schedule is set for the peak demand power generation period.

Detailed reservoir elevations are calculated from inflow versus outflow during each day after referring to the starting day's storage and elevation, as follows:

- If **Spill Prevention** is selected, then White Rock Powerhouse draft will be rescheduled to attempt to modify total discharge to avoid the spill.
- If **Spill Prevention** is not selected, then if spill occurs and total discharge is below capacity, the program increases scheduled discharge and recalculates available volume.
- If a minimum elevation violation occurs, the program reduces total daily discharge down to no lower than minimum instantaneous flow, then reduces set generation to zero and continues to calculate inflow and reservoir storage.

UARP facility discharges are then scheduled as follows:

- If the program option **linked** is selected, then Chili Bar Project's bypass flows and minimum instantaneous flows (less incremental accretion) are built into the upstream reservoir's daily discharge volume up to Union Valley.
- If the option **raft support** is checked, tomorrow's whitewater boating flow volume, less Chili Bar incremental accretion, is set as a daily average requirement for White Rock's discharge for today.
- If **raft flow up UARP** is selected, then each reservoir from Union Valley to Slab Creek may be re-operated so that sufficient volume will be provided to deliver the next day's whitewater boating flows to Chili Bar Reservoir.

3.3 Iowa Hill Development

Iowa Hill Powerhouse is modeled with an hourly schedule that varies by the day of the week and the month of the year. Generally, the powerhouse would be operated to pump during off-peak hours and to generate during on-peak hours. The Water Balance Model can schedule this in one of two modes for each month of the year:

1. **Not linked**. Iowa Hill is scheduled as specified, independently of Slab Creek Reservoir and White Rock Powerhouse.

2. **Linked**. Iowa Hill and Slab Creek Reservoir are evaluated conjunctively.

For the UARP with Iowa Hill Base Case, the linked option is specified. This means that the program will operate these reservoirs conjunctively.

The hourly schedule modeled for the base case is a weekly pattern that varies by month. It is specified in Appendix A, Lines 70-72.

APPENDIX A

WATER BALANCE MODEL INPUT

- System Settings
- Rubicon Reservoir
- Buck Island Reservoir
- Loon Lake Reservoir
- Gerle Creek Reservoir
- Robbs Peak Reservoir
- Ice House Reservoir
- Union Valley Reservoir
- Junction Reservoir
- Camino Reservoir
- Brush Creek Revervoir
- Slab Creek Reservoir
- Chili Bar Reservoir (Pacific Gas and Electric Co.)
- Iowa Hill Development
- Addenda

APPENDIX A

WATER BALANCE MODEL INPUT

The tables in this appendix summarize the inputs to the Water Balance Model for the two base cases. The UARP/CB-only base case includes operational features that deal with all UARP developments and Chili Bar Project but not including the Iowa Hill Development. The UARP/CB + Iowa Hill base case includes all input data provided in this appendix for UARP, Chili Bar Project, and the proposed Iowa Hill Development.

Due to their quantity, the individual tables are not numbered. Instead, line numbers have been included along the left margin. The line numbers here correspond to line numbers in the input data report. A program external to the Water Balance Model generates this report.

Several of the tables are listed in abridged form at their proper line number. This is indicated with a notation at the bottom of the table. The full content of such tables is listed in the Addenda, at the bottom of this Appendix.

System settings

1 System settings
Name: HRBC5RCNOFORS
Desc: mah14jan04
Water year type profile
Name: Base Case
Filename: WaterYearTypes1.xls
Modified: 16-Jan-04 13:54
Preferred Storage Obj.
Name: BasecaseSmooth
Filename: RCBasecase.xls
Modified: 17-Jun-04 15:20

General options
Carry over elevations: Yes
Forecast nbr of days: 2
Forecast accuracy: 1
Hydrology
Filename: inflow.dat
Size: 1207.4 kB (1236426 bytes)
Modified: 18-Mar-04 09:26
Tagline:

Summary of plant settings

Reservoir	Physical	Operational	Generating
Rubicon	HRBC	HRBC	Base Case
Buck Island	HRBC	HRBC	Base Case
Loon Lake	HRBC	HRBC	Base Case
Gerle Creek	HRBC	HRBC	Base Case
Robbs Peak	HRBC	HRBC	HRBC
Ice House	HRBC	HRBC	HRBC
Union Valley	HRBC	HRBC	HRBC
Junction	HRBC-1	HRBC	HRBC
Camino	HRBC	HRBC	HRBC
Brush Creek	HRBC	HRBC	Base Case
Slab Creek	HRBC	HRBC	HRBC
Chili Bar	Base Case	Base Case	HRBC
Iowa Hill	Base Case Generating	Dommer1	Base Case

2 Energy Reliability Objective (HRBC)

Month	Vol, af	Peak
Jan	19500	0.95
Feb	5000	0.95
Mar	5000	0.95
Apr	5000	0.95
May	5000	0.95
Jun	25000	0.95
Jul	25000	0.95
Aug	25000	0.95
Sep	19500	0.95
Oct	19500	0.95
Nov	19500	0.95
Dec	19500	0.95

Spinning Reserve (HRBC)

Plant	Reserve, MW
Loon Lake	2
Robbs Peak	0
Jones Fork	0
Union Valley	0
Jaybird	28
Camino	50
White Rock	28

3 Monthly load shape, durations in hours beginning 0000 (HRBC6x16Super) 6x16 with 6 hour of super peak every month

January	Off	Sec	Pri	Sec	Off	Pri	Sec	Off
Weekday	6	8	6	2		0	0	2
Weekend	8		14		0		0	2

February	Off	Sec	Pri	Sec	Off	Pri	Sec	Off
Weekday	6	8	6	2		0	0	2
Weekend	8		14		0		0	2

March	Off	Sec	Pri	Sec	Off	Pri	Sec	Off
Weekday	6	8	6	2		0	0	2
Weekend	8		14		0		0	2

April	Off	Sec	Pri	Sec	Off	Pri	Sec	Off
Weekday	6	8	6	2		0	0	2
Weekend	8		14		0		0	2

May	Off	Sec	Pri	Sec	Off	Pri	Sec	Off
Weekday	6	8	6	2		0	0	2
Weekend	8		14		0		0	2

June	Off	Sec	Pri	Sec	Off	Pri	Sec	Off
Weekday	6	8	6	2		0	0	2
Weekend	8		14		0		0	2

July	Off	Sec	Pri	Sec	Off	Pri	Sec	Off
Weekday	6	8	6	2		0	0	2
Weekend	8		14		0		0	2

August	Off	Sec	Pri	Sec	Off	Pri	Sec	Off
Weekday	6	8	6	2		0	0	2
Weekend	8		14		0		0	2

September	Off	Sec	Pri	Sec	Off	Pri	Sec	Off
Weekday	6	8	6	2		0	0	2
Weekend	8		14		0		0	2

October	Off	Sec	Pri	Sec	Off	Pri	Sec	Off
Weekday	6	8	6	2		0	0	2
Weekend	8		14		0		0	2

November	Off	Sec	Pri	Sec	Off	Pri	Sec	Off
Weekday	6	8	6	2		0	0	2
Weekend	8		14		0		0	2

December	Off	Sec	Pri	Sec	Off	Pri	Sec	Off
Weekday	6	8	6	2		0	0	2
Weekend	8		14		0		0	2

Rubicon Reservoir (1)

4

Storage (HRBC)

Elev, ft	Vol, af
6550.0	2016
6549.0	1894
6548.0	1774
6546.0	1545
6545.0	1435
6544.0	1329
6543.0	1226
6542.0	1127
6541.0	1032
6540.0	940
6539.0	853
6538.0	769
6537.0	689
6535.0	541
6533.2	425
6532.0	352
6530.0	248
6527.0	127
6525.0	71
6522.0	24
6520.0	19

Area (HRBC)

Elev, ft	Area, ac
6550.0	122.0
6548.0	116.0
6546.0	110.0
6544.0	103.0
6542.0	95.0
6540.0	87.0
6538.0	80.0
6536.0	72.0
6534.0	63.0
6532.0	54.0
6530.0	45.0
6528.0	36.0
6526.0	26.0
6524.0	15.0
6522.0	5.0
6520.0	0.0

Evaporation (HRBC)

Mon	Evp, in/d
Jan	0.000
Feb	0.000
Mar	0.065
Apr	0.095
May	0.169
Jun	0.197
Jul	0.259
Aug	0.242
Sep	0.208
Oct	0.107
Nov	0.029
Dec	0.000

Spillway (HRBC)

Elev, ft	Flow, cfs
6552.0	43775.0
6551.0	32731.0
6550.0	24533.0
6548.2	12125.0
6548.1	11333.0
6548.0	10737.0
6547.8	9294.0
6547.5	7922.0
6547.3	6627.0
6547.0	5412.0
6546.8	4284.0
6546.5	3250.0
6546.3	2305.0
6546.0	1507.0
6545.8	818.2
6545.5	360.8
6545.3	159.5
6545.2	83.6
6545.1	23.6
6545.0	0.0

Tunnel/plant flow (HRBCnew)

Elev, ft	Flow, cfs
6546.0	910.0
6545.1	819.7
6544.3	741.9
6543.4	657.4
6542.6	585.1
6541.8	515.4
6541.4	481.1
6540.7	420.7
6540.1	371.1
6539.4	316.2
6538.8	271.6
6538.2	229.5
6537.4	174.9
6536.9	143.4
6536.4	114.3
6535.7	77.2
6535.3	58.2
6534.7	33.0
6534.3	18.6
6533.9	6.2
6533.7	1.9
6533.5	0.0

5

Node options
Name: Base Case
Min flow: 0 cfs
Capacity: unlimited
Op type: Diversion

Flood elevations (Base Case)

Date	Elev, ft
01-Jan	6545.0
31-Dec	6545.0

Target elevations (HRBC)

Date	Elev, ft
01-Jan	6533.8
30-Apr	6533.8
01-May	6539.2
09-May	6539.2
09-Sep	6539.2
10-Sep	6533.8
31-Dec	6533.8

Minimum elevations (Base Case)

Date	Elev, ft
01-Jan	6533.0
31-Dec	6533.0

6

Bypass flows, cfs (HRBC)

Date	A	B	C	D	E	Inflow
01-Jan	6	6	6	6	0	Yes
01-Feb	6	6	6	6	0	Yes
01-Mar	6	6	6	6	0	Yes
01-Apr	6	6	6	6	0	Yes
01-May	6	6	6	6	0	Yes
01-Jun	6	6	6	6	0	Yes
01-Jul	6	6	6	6	0	Yes
01-Aug	6	6	6	6	0	Yes
01-Sep	6	6	6	6	0	Yes
01-Oct	6	6	6	6	0	Yes
01-Nov	6	6	6	6	0	Yes
01-Dec	6	6	6	6	0	Yes
31-Dec	6	6	6	6	0	Yes

Gate
Setting name: HRBCnew
Desc: Data from Randy 10-10-03
Install: 1000 cfs
Remove: 10-Sep
Average days: 3
Volume date: 22-Jul
Volume remain: 2 taf

Diversion with gate down

Elev, ft	Flow, cfs
6545.4	681.2
6545.2	642.4
6544.8	579.9
6544.4	518.4
6544.0	459.1
6543.6	401.9
6543.2	347.1
6542.8	294.7
6542.4	245.0
6542.0	198.2
6541.6	154.4
6541.3	123.8
6540.9	86.3
6540.5	53.3
6540.1	26.7
6539.7	7.9
6539.6	0.6
6539.5	0.0

Buck Island Reservoir (2)

7

Storage (HRBC)

Elev, ft	Vol, af
6446.0	1700
6440.0	1400
6436.0	1077
6432.0	808
6428.0	587
6425.0	450
6424.0	410
6420.0	272
6416.0	169
6412.0	95
6408.0	46
6404.0	17
6400.0	4

Area (HRBC)

Elev, ft	Area, ac
6446.0	114.0
6444.0	100.0
6440.0	86.0
6436.0	72.0
6432.0	60.0
6428.0	48.0
6424.0	38.0
6420.0	29.0
6416.0	21.0
6412.0	14.0
6408.0	9.0
6404.0	4.0
6400.0	0.0

Evaporation (HRBC)

Mon	Evp, in/d
Jan	0.000
Feb	0.000
Mar	0.065
Apr	0.095
May	0.169
Jun	0.197
Jul	0.259
Aug	0.242
Sep	0.208
Oct	0.107
Nov	0.029
Dec	0.000

Spillway (HRBC)

Elev, ft	Flow, cfs
6449.0	57283.0
6447.0	41656.0
6443.0	16834.0
6441.0	9427.0
6439.0	4147.0
6438.8	3594.0
6438.5	3068.0
6438.3	2571.0
6438.0	2105.0
6437.8	1671.0
6437.5	1273.0
6437.3	915.0
6437.0	580.0
6436.8	334.0
6436.5	152.0
6436.3	70.0
6436.2	37.0
6436.1	12.0
6436.0	0.0

Tunnel/plant flow (HRBCnew)

Elev, ft	Flow, cfs
6437.6	1160.0
6437.0	1078.0
6436.4	998.0
6435.8	919.0
6435.1	828.5
6434.5	752.6
6433.8	666.0
6433.2	593.7
6432.5	511.5
6431.8	432.0
6431.2	366.2
6430.6	302.8
6430.0	242.1
6429.4	184.5
6428.8	128.6
6428.2	71.7
6427.6	24.5
6427.0	0.1

Note: Table abridged; full printout in addenda

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Node options
Name: Base case
Min flow: 0 cfs
Capacity: unlimited
Op type: Diversion

Flood elevations (Base Case)

Date	Elev, ft
01-Jan	6436.0
31-Dec	6436.0

Target elevations (Base Case)

Date	Elev, ft
01-Jan	6427.0
31-Mar	6427.0
01-Apr	6433.0
01-Oct	6433.0
02-Oct	6427.0
31-Dec	6427.0

Minimum elevations (HRBC)

Date	Elev, ft
01-Jan	6424.5
31-Dec	6424.5

9

Bypass flows, cfs (HRBC)

Date	A	B	C	D	E	Inflow
01-Jan	1	1	1	1	0	No
01-Feb	1	1	1	1	0	No
01-Mar	1	1	1	1	0	No
01-Apr	1	1	1	1	0	No
01-May	1	1	1	1	0	No
01-Jun	1	1	1	1	0	No
01-Jul	1	1	1	1	0	No
01-Aug	1	1	1	1	0	No
01-Sep	1	1	1	1	0	No
01-Oct	1	1	1	1	0	No
01-Nov	1	1	1	1	0	No
01-Dec	1	1	1	1	0	No
31-Dec	1	1	1	1	0	No

Gate
Setting name: HRBCnew
Desc: Data from Randy 10-10-03
Install: 31-Dec
Remove: 31-Dec
Average days: 3
Volume date: 31-Dec
Volume remain: 0 taf

Diversion with gate down

Elev, ft	Flow, cfs
6435.0	137.0
6434.9	126.5
6434.8	116.7
6434.7	107.5
6434.6	99.0
6434.5	91.0
6434.4	81.3
6434.3	72.5
6434.2	64.6
6434.1	57.4
6434.0	51.0
6433.9	43.8
6433.8	37.5
6433.7	31.0
6433.6	25.5
6433.5	18.8
6433.4	13.7
6433.3	10.0
6433.2	5.6
6433.1	3.0
6433.0	1.3
6433.0	0.0

Loon Lake Reservoir (3)

10

Storage (HRBC)

Elev, ft	Vol, af
6430.0	97318
6420.0	82646
6410.0	69308
6400.0	55970
6390.0	44009
6380.0	33472
6370.0	24151
6360.0	16247
6350.0	9856
6340.0	5124
6330.0	2420
6325.5	0

Area (HRBC)

Elev, ft	Area, ac
6420.0	1574.0
6410.0	1419.0
6400.0	1264.0
6390.0	1124.0
6380.0	992.0
6370.0	863.0
6360.0	712.0
6350.0	567.0
6340.0	372.0
6330.0	176.0
6320.0	90.0
6310.0	35.0

Evaporation (Base Case)

Mon	Evp, in/d
Jan	0.000
Feb	0.000
Mar	0.065
Apr	0.095
May	0.169
Jun	0.197
Jul	0.259
Aug	0.242
Sep	0.208
Oct	0.107
Nov	0.029
Dec	0.000

Spillway (HRBC)

Elev, ft	Flow, cfs
6418.0	15243.0
6417.0	12476.0
6416.0	9901.0
6415.0	7532.0
6414.0	5389.0
6413.0	3500.0
6412.0	1905.0
6411.0	674.0
6410.0	0.0

Tailwater (Base Case)

Flow, cfs	Elev, ft
1	5270

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Node options
Name: Base Case
Min flow: 0 cfs
Capacity: 1178 cfs
Op type: Strictly peaking

Flood elevations (Base Case)

Date	Elev, ft
01-Jan	6410.0
31-Dec	6410.0

Minimum elevations (HRBC)

Date	Elev, ft
01-Jan	6348.5
31-Mar	6348.5
01-Apr	6335.0
31-Oct	6335.0
01-Dec	6348.5
31-Dec	6348.5

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Bypass flows, cfs (HRBC)

Date	A	B	C	D	E	Inflow
01-Jan	8	8	8	8	0	No
01-Feb	8	8	8	8	0	No
01-Mar	8	8	8	8	0	No
01-Apr	8	8	8	8	0	No
01-May	8	8	8	8	0	No
01-Jun	8	8	8	8	0	No
01-Jul	8	8	8	8	0	No
01-Aug	8	8	8	8	0	No
01-Sep	8	8	8	8	0	No
01-Oct	8	8	8	8	0	No
01-Nov	8	8	8	8	0	No
01-Dec	8	8	8	8	0	No
31-Dec	8	8	8	8	0	No

Preferred storage objective (elevation), ft (BasecaseSmooth)

Day	A	B	C	D	E
Jan 01	6385.3	6385.3	6385.3	6385.3	6385.3
Jan 15	6377.5	6375.3	6375.3	6375.3	6375.3
Feb 01	6372.0	6365.3	6365.3	6365.3	6365.3
Feb 15	6373.2	6362.7	6355.5	6355.3	6355.3
Mar 01	6374.3	6364.0	6355.5	6352.3	6350.2
Mar 15	6377.3	6368.1	6355.5	6352.8	6350.2
Apr 01	6380.3	6372.2	6356.3	6353.3	6350.2
Apr 15	6386.8	6380.5	6362.2	6356.7	6350.2
May 01	6393.3	6388.8	6368.0	6360.1	6350.2
May 15	6401.7	6399.4	6389.0	6378.4	6365.8
Jun 01	6410.0	6410.0	6410.0	6396.8	6381.5
Jun 15	6410.0	6410.0	6410.0	6403.4	6395.7
Jul 01	6410.0	6410.0	6410.0	6410.0	6410.0
Jul 15	6410.0	6410.0	6410.0	6410.0	6410.0
Aug 01	6405.3	6405.3	6405.3	6405.3	6405.3
Aug 15	6400.6	6400.6	6400.6	6400.6	6400.6
Sep 01	6395.8	6395.8	6395.8	6395.8	6395.8
Sep 15	6390.5	6390.5	6390.5	6390.5	6390.5
Oct 01	6385.2	6385.2	6385.2	6385.2	6385.2
Oct 15	6385.2	6385.2	6385.2	6385.2	6385.2
Nov 01	6385.2	6385.2	6385.2	6385.2	6385.2
Nov 15	6385.2	6385.2	6385.2	6385.2	6385.2
Dec 01	6385.2	6385.2	6385.2	6385.2	6385.2
Dec 15	6385.2	6385.2	6385.2	6385.2	6385.2
Dec 31	6385.2	6385.2	6385.2	6385.2	6385.2

13 Powerhouse settings summary - Loon Lake
(Base Case)

Unit	Headloss	Generator	Turbine
1	Base Case	Base Case U1	Base Case U1

Maintenance
(Maintenance)

Date	Units
01-Jan	0
20-Sep	1
30-Sep	0
31-Dec	0

Peak/max schedule
(Peak All Year)

Date	Setting
01-Jan	1.00
31-Dec	1.00

14 Head loss coefficients, ft/cfs^2
(Base Case)

Unit	Unit loss	Common loss	Max unit	Com2?
1	0.000000000	0.000000000	1	No

Generator performance, unit 1
(Base Case U1)

Output, MWh	Eff	Cap
1.0	1.00	80.0
80.0	1.00	80.0

15 Turbine performance, unit 1
(Base Case U1), Gate leakage: 0.0 cfs

Head 1060.0 ft		Head 1100.0 ft		Head 1115.0 ft		Head 1125.0 ft		Head 1140.0 ft	
Flow, cfs	Eff	Flow, cfs	Eff	Flow, cfs	Eff	Flow, cfs	Eff	Flow, cfs	Eff
28.0	0.3982	28.0	0.3838	28.0	0.3786	28.0	0.3752	28.0	0.3703
67.0	0.4993	65.0	0.4959	65.0	0.4893	64.0	0.4925	64.0	0.4860
92.0	0.7272	90.0	0.7164	89.0	0.7147	88.0	0.7164	87.0	0.7151
246.0	0.8159	238.0	0.8127	235.0	0.8120	233.0	0.8117	230.0	0.8114
320.0	0.8363	310.0	0.8319	307.0	0.8287	304.0	0.8295	301.0	0.8267
344.0	0.8428	333.0	0.8390	329.0	0.8378	327.0	0.8354	323.0	0.8346
368.0	0.8484	356.0	0.8451	352.0	0.8433	350.0	0.8405	346.0	0.8391
551.0	0.8500	531.0	0.8499	523.0	0.8513	518.0	0.8519	511.0	0.8522
600.0	0.8549	580.0	0.8522	573.0	0.8510	569.0	0.8494	562.0	0.8487
624.0	0.8578	604.0	0.8539	596.0	0.8538	592.0	0.8519	585.0	0.8507
648.0	0.8604	627.0	0.8569	619.0	0.8563	614.0	0.8556	607.0	0.8541
675.0	0.8590	651.0	0.8583	643.0	0.8573	637.0	0.8577	630.0	0.8558
702.0	0.8578	675.0	0.8596	666.0	0.8595	660.0	0.8596	652.0	0.8587
811.0	0.8525	780.0	0.8541	769.0	0.8547	761.0	0.8560	751.0	0.8560
838.0	0.8516	806.0	0.8532	794.0	0.8545	787.0	0.8544	776.0	0.8551
866.0	0.8498	832.0	0.8524	820.0	0.8532	813.0	0.8529	801.0	0.8543
893.0	0.8491	858.0	0.8516	846.0	0.8521	838.0	0.8526	827.0	0.8525
920.0	0.8484	885.0	0.8499	872.0	0.8510	864.0	0.8512	852.0	0.8519
963.0	0.8479	974.5	0.8490	978.5	0.8495	982.0	0.8496	987.0	0.8498
1006.0	0.8474	1064.0	0.8481	1085.0	0.8481	1100.0	0.8480	1122.0	0.8477

Gerle Creek Reservoir (4)

16

Storage (HRBC)

Elev, ft	Vol, af
5253.0	3385
5249.0	2494
5245.0	1876
5237.0	1148
5235.0	1035
5230.0	784
5225.0	564
5220.0	383
5215.0	248
5210.0	143
5205.0	69
5200.0	25
5195.0	5
5190.0	0

Spillway (HRBC)

Elev, ft	Flow, cfs
5246.0	55223.0
5241.5	23696.0
5237.0	9379.0
5235.0	4951.0
5234.0	3084.0
5233.5	2255.0
5233.0	1487.0
5232.5	952.0
5232.0	438.0
5231.8	258.0
5231.5	130.0
5231.5	127.0
5231.3	71.0
5231.2	45.0
5231.1	21.0
5231.0	0.0

Tunnel/plant flow (HRBC)

Elev, ft	Flow, cfs
5246.0	1025.0
5229.3	1025.0
5228.4	907.6
5227.5	786.7
5226.6	671.7
5225.8	562.9
5224.9	460.7
5224.0	365.6
5223.1	278.1
5222.3	199.0
5221.4	129.3
5220.5	70.4
5219.6	24.9
5218.8	0.0

Tailwater (Base Case)

Flow, cfs	Elev, ft
1	1

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Node options
Name: Base Case
Min flow: 0 cfs
Capacity: unlimited
Op type: Non-generating

Flood elevations (Base Case)

Date	Elev, ft
01-Jan	5231.0
31-Dec	5231.0

Target elevations (Base Case)

Date	Elev, ft
01-Jan	5225.0
31-Dec	5225.0

Minimum elevations (Base Case)

Date	Elev, ft
01-Jan	5219.0
31-Dec	5219.0

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Bypass flows, cfs (HRBC)

Date	A	B	C	D	E	Inflow
01-Jan	4	4	4	4	0	No
01-Feb	4	4	4	4	0	No
01-Mar	4	4	4	4	0	No
01-Apr	4	4	4	4	0	No
01-May	4	4	7	7	0	No
01-Jun	4	4	7	7	0	No
01-Jul	4	4	7	7	0	No
01-Aug	4	4	7	7	0	No
01-Sep	4	4	7	7	0	No
01-Oct	4	4	7	7	0	No
01-Nov	4	4	4	4	0	No
01-Dec	4	4	4	4	0	No
31-Dec	4	4	4	4	0	No

Robbs Peak Reservoir (5)

19 Storage (HRBC)

Elev, ft	Vol, af
5247.0	860
5241.0	390
5232.0	148
5231.0	136
5230.0	123
5229.0	110
5228.0	98
5227.0	88
5226.0	78
5225.0	70
5224.0	61
5222.0	47
5220.0	35
5218.0	26
5216.0	20
5214.0	17
5206.0	11

Spillway (HRBC)

Elev, ft	Flow, cfs
5244.0	88206.0
5242.0	70237.0
5240.0	53846.0
5238.0	39232.0
5236.0	26717.0
5234.0	17127.0
5233.0	13953.0
5232.0	11004.0
5231.0	8298.0
5230.0	5861.0
5229.0	3725.0
5228.0	1885.0
5227.0	517.0
5226.0	0.0

Tailwater (Base Case)

Flow, cfs	Elev, ft
1	4821

20 Node options
Name: Base Case
Min flow: 0 cfs
Capacity: 1250 cfs
Op type: Pure run of river

Flood elevations (Base Case)

Date	Elev, ft
01-Jan	5225.6
31-Dec	5225.6

Target elevations (HRBC)

Date	Elev, ft
01-Jan	5225.6
31-May	5225.6
01-Jun	5230.0
27-Sep	5229.0
28-Sep	5228.0
29-Sep	5227.0
30-Sep	5226.0
01-Oct	5225.6
31-Dec	5225.6

Minimum elevations (Base Case)

Date	Elev, ft
01-Jan	5224.0
31-Dec	5224.0

21 Bypass flows, cfs (HRBC)

Date	A	B	C	D	E	Inflow
01-Jan	1	1	1	1	0	No
01-Feb	1	1	1	1	0	No
01-Mar	1	1	1	1	0	No
01-Apr	1	1	1	1	0	No
01-May	1	1	3	3	0	No
01-Jun	1	1	3	3	0	No
01-Jul	1	1	3	3	0	No
01-Aug	1	1	3	3	0	No
01-Sep	1	1	3	3	0	No
01-Oct	1	1	3	3	0	No
01-Nov	1	1	1	1	0	No
01-Dec	1	1	1	1	0	No
31-Dec	1	1	1	1	0	No

Flashboards
Setting name: HRBC
Desc: Developed from MAHs sheet RobbsPeakSWRatinfMAH.xls
Install: 31-May
Remove: 01-Oct
Average days: 1
Volume date: 31-Dec
Volume remain: 0 taf

Spillway with flashboards

Elev, ft	Flow, cfs
5246.0	84006.0
5244.0	66000.0
5242.0	49528.0
5240.0	34753.0
5238.0	21907.0
5236.0	11368.0
5234.0	4063.0
5233.0	2147.0
5232.0	667.0
5231.0	0.0

22 Powerhouse settings summary - Robbs Peak (HRBC)

Unit	Headloss	Generator	Turbine
1	Base Case	Base Case U1	Base Case U1

Maintenance (Maintenance)

Date	Units
01-Jan	0
20-Sep	1
30-Sep	0
31-Dec	0

Peak/max schedule (Peak All Year)

Date	Setting
01-Jan	1.00
31-Dec	1.00

23 Head loss coefficients, ft/cfs^2
(Base Case)

Unit	Unit loss	Common loss	Max unit	Com2?
1	5.6230e-005	0.000000000	1	No

Generator performance, unit 1
(Base Case U1)

Output, MWh	Eff	Cap
1.0	1.00	26.0
26.0	1.00	26.0

24 Turbine performance, unit 1
(Base Case U1), Gate leakage: 0.0 cfs

Head 275.0 ft		Head 310.0 ft		Head 340.0 ft		Head 370.0 ft		Head 400.0 ft	
Flow, cfs	Eff	Flow, cfs	Eff	Flow, cfs	Eff	Flow, cfs	Eff	Flow, cfs	Eff
97.0	0.2530	103.0	0.2530	107.9	0.2530	112.5	0.2530	117.0	0.2530
131.0	0.4476	139.1	0.4476	145.7	0.4476	152.0	0.4476	158.0	0.4476
179.1	0.5903	190.1	0.5903	199.1	0.5903	207.7	0.5903	216.0	0.5903
290.2	0.6875	308.1	0.6875	322.7	0.6875	336.6	0.6875	350.0	0.6875
401.3	0.7587	426.1	0.7587	446.2	0.7587	465.5	0.7587	484.0	0.7587
446.1	0.7752	473.6	0.7752	496.0	0.7752	517.4	0.7752	538.0	0.7752
509.1	0.8212	540.5	0.8212	566.1	0.8212	590.5	0.8212	614.0	0.8212
562.2	0.8531	596.9	0.8531	625.1	0.8531	652.1	0.8531	678.0	0.8531
611.9	0.8692	649.7	0.8692	680.4	0.8692	709.8	0.8692	738.0	0.8692
688.2	0.8974	730.7	0.8974	765.2	0.8974	798.3	0.8974	830.0	0.8974
801.8	0.8924	851.3	0.8924	891.5	0.8924	930.0	0.8924	967.0	0.8924
917.9	0.9339	974.5	0.9339	1020.6	0.9339	1064.7	0.9339	1107.0	0.9339
1195.6	0.9002	1269.4	0.9002	1329.5	0.9002	1386.9	0.9002	1442.0	0.9002

Ice House Reservoir (6)

25

Storage (HRBC)

Elev, ft	Vol, af
5480.0	65672
5460.0	50024
5450.0	43504
5440.0	36984
5430.0	31038
5420.0	25551
5410.0	20537
5400.0	16026
5390.0	12000
5380.0	8439
5370.0	5420
5360.0	3053
5350.0	1407
5327.5	0

Area (HRBC)

Elev, ft	Area, ac
5460.0	732.0
5450.0	675.0
5440.0	618.0
5430.0	571.0
5420.0	526.0
5410.0	475.0
5400.0	426.0
5390.0	379.0
5380.0	330.0
5370.0	271.0
5360.0	200.0
5350.0	126.0
5340.0	65.0
5330.0	18.0

Evaporation (Base Case)

Mon	Evp, in/d
Jan	0.000
Feb	0.000
Mar	0.022
Apr	0.061
May	0.111
Jun	0.178
Jul	0.215
Aug	0.195
Sep	0.138
Oct	0.065
Nov	0.016
Dec	0.000

Spillway (HRBC)

Elev, ft	Flow, cfs
5454.5	23827.0
5453.5	21869.0
5452.5	19968.0
5451.5	18126.0
5450.5	16344.0
5450.0	15476.0
5448.5	12970.0
5446.5	9866.0
5444.5	7060.0
5442.5	4585.0
5440.5	2496.0
5438.5	882.0
5436.5	0.0

Tailwater (Base Case)

Flow, cfs	Elev, ft
1	4838

26

<u>Node options</u>
Name: Base Case
Min flow: 0 cfs
Capacity: 291 cfs
Op type: Strictly peaking

Flood elevations (HRBC)

Date	Elev, ft
01-Jan	5436.6
31-Mar	5436.6
01-Apr	5436.6
02-Apr	5445.0
15-Apr	5445.0
16-Apr	5447.0
30-Apr	5450.0
31-Oct	5450.0
01-Nov	5450.0
02-Nov	5436.6
31-Dec	5436.6

Minimum elevations (Base Case)

Date	Elev, ft
01-Jan	5380.0
31-Dec	5380.0

Preferred storage objective (elevation), ft (BasecaseSmooth)

Day	A	B	C	D	E
Jan 01	5418.9	5418.9	5418.9	5418.9	5418.9
Jan 15	5408.9	5408.9	5408.9	5408.9	5408.9
Feb 01	5405.7	5398.9	5398.9	5398.9	5398.9
Feb 15	5407.0	5400.0	5396.3	5388.9	5388.9
Mar 01	5408.4	5401.3	5394.8	5384.4	5383.0
Mar 15	5411.3	5404.8	5396.0	5384.4	5383.0
Apr 01	5414.3	5408.4	5397.2	5384.4	5383.0
Apr 15	5420.4	5416.4	5401.9	5384.4	5383.0
May 01	5426.5	5424.5	5406.6	5384.4	5383.0
May 15	5438.2	5437.2	5428.3	5411.4	5404.2
Jun 01	5450.0	5450.0	5450.0	5438.3	5425.4
Jun 15	5450.0	5450.0	5450.0	5444.2	5437.7
Jul 01	5450.0	5450.0	5450.0	5450.0	5450.0
Jul 15	5450.0	5450.0	5450.0	5450.0	5450.0
Aug 01	5446.2	5446.2	5446.2	5446.2	5446.2
Aug 15	5442.3	5442.3	5442.3	5442.3	5442.3
Sep 01	5438.3	5438.3	5438.3	5438.3	5438.3
Sep 15	5434.1	5434.1	5434.1	5434.1	5434.1
Oct 01	5429.9	5429.9	5429.9	5429.9	5429.9
Oct 15	5429.9	5429.9	5429.9	5429.9	5429.9
Nov 01	5429.9	5429.9	5429.9	5429.9	5429.9
Nov 15	5429.9	5429.9	5429.9	5429.9	5429.9
Dec 01	5429.9	5429.9	5429.9	5429.9	5429.9
Dec 15	5424.4	5424.4	5424.4	5424.4	5424.4
Dec 31	5418.9	5418.9	5418.9	5418.9	5418.9

27 Bypass flows, cfs
(HRBC)

Date	A	B	C	D	E	Inflow
01-Jan	5	5	3	3	0	No
01-Feb	5	5	3	3	0	No
01-Mar	5	5	3	3	0	No
01-Apr	5	5	3	3	0	No
01-May	5	5	8	8	0	No
01-Jun	5	5	8	8	0	No
01-Jul	5	5	15	15	0	No
01-Aug	5	5	15	15	0	No
01-Sep	5	5	15	15	0	No
01-Oct	5	5	12	12	0	No
01-Nov	5	5	10	10	0	No
16-Nov	5	5	4	4	0	No
01-Dec	5	5	4	4	0	No
31-Dec	5	5	4	4	0	No

Flashboards
Setting name: HRBC
Desc: to Simulate gate closure
Install: 01-Apr
Remove: 01-Nov
Average days: 1
Volume date: 31-Dec
Volume remain: 0 taf

Spillway with flashboards

Elev, ft	Flow, cfs
5454.5	2520.0
5453.5	1729.0
5452.5	1044.0
5451.5	485.0
5450.5	93.0
5450.0	0.0

Minimum mean daily release
(HRBC)

Date	Flow, cfs	Inflow
01-Jan	11	No
31-Mar	11	No
01-Apr	0	No
30-Nov	0	No
01-Dec	11	No
31-Dec	11	No

28 Powerhouse settings summary - Jones Fork
(HRBC)

Unit	Headloss	Generator	Turbine
1	Base Case U1	Base Case	Base Case U1

Maintenance
(Maintenance)

Date	Units
01-Jan	0
02-Oct	1
12-Oct	0
31-Dec	0

Peak/max schedule
(Peak All Year)

Date	Setting
01-Jan	1.00
31-Dec	1.00

29 Head loss coefficients, ft/cfs^2
(Base Case U1)

Unit	Unit loss	Common loss	Max unit	Com2?
1	0.000538100	0.000000000	1	No

Generator performance, unit 1
(Base Case)

Output, MWh	Eff	Cap
1.0	1.00	11.5
11.5	1.00	11.5

30 Turbine performance, unit 1
(Base Case U1), Gate leakage: 0.0 cfs

Head 465.0 ft		Head 510.0 ft		Head 550.0 ft		Head 580.0 ft		Head 610.0 ft	
Flow, cfs	Eff	Flow, cfs	Eff	Flow, cfs	Eff	Flow, cfs	Eff	Flow, cfs	Eff
31.9	0.1937	33.4	0.1937	34.7	0.1937	35.6	0.1937	36.5	0.1937
43.4	0.4602	45.5	0.4602	47.2	0.4602	48.5	0.4602	49.7	0.4602
49.4	0.5091	51.7	0.5091	53.7	0.5091	55.1	0.5091	56.5	0.5091
60.1	0.5880	62.9	0.5880	65.4	0.5880	67.1	0.5880	68.8	0.5880
70.1	0.6342	73.4	0.6342	76.3	0.6342	78.3	0.6342	80.3	0.6342
81.8	0.6748	85.7	0.6748	89.0	0.6748	91.4	0.6748	93.8	0.6748
90.3	0.7028	94.6	0.7028	98.2	0.7028	100.8	0.7028	103.4	0.7028
102.5	0.7340	107.4	0.7340	111.5	0.7340	114.5	0.7340	117.4	0.7340
117.2	0.7766	122.7	0.7766	127.4	0.7766	130.9	0.7766	134.2	0.7766
138.6	0.8038	145.1	0.8038	150.7	0.8038	154.8	0.8038	158.7	0.8038
157.5	0.8252	164.9	0.8252	171.3	0.8252	175.9	0.8252	180.4	0.8252
179.0	0.8408	187.4	0.8408	194.6	0.8408	199.9	0.8408	205.0	0.8408
205.6	0.8465	215.3	0.8465	223.6	0.8465	229.6	0.8465	235.5	0.8465
232.8	0.8490	243.8	0.8490	253.2	0.8490	260.0	0.8490	266.6	0.8490
267.6	0.8477	280.2	0.8477	291.0	0.8477	298.8	0.8477	306.5	0.8477

Union Valley Reservoir (7)

31

Storage (HRBC)

Elev, ft	Vol, af
4890.0	327920
4880.0	294311
4870.0	266303
4860.0	238295
4850.0	212354
4840.0	188501
4830.0	166439
4820.0	146237
4810.0	127757
4800.0	111204
4790.0	96282
4780.0	82875
4770.0	70892
4760.0	60171
4750.0	50621
4740.0	42310
4730.0	35147
4720.0	29018
4710.0	23761
4700.0	19245
4690.0	15439
4680.0	12250
4670.0	9610
4660.0	7417
4650.0	5615
4640.0	4199
4630.0	3090
4628.0	0

Area (HRBC)

Elev, ft	Area, ac
4880.0	3022.0
4870.0	2847.0
4860.0	2672.0
4850.0	2479.0
4840.0	2294.0
4830.0	2108.0
4820.0	1936.0
4810.0	1749.0
4800.0	1569.0
4790.0	1414.0
4780.0	1265.0
4770.0	1130.0
4760.0	1014.0
4750.0	894.0
4740.0	770.0
4730.0	661.0
4720.0	568.0
4710.0	487.0
4700.0	414.0
4690.0	349.0
4680.0	290.0
4670.0	241.0
4660.0	199.0
4650.0	161.0

Evaporation (Base Case)

Mon	Evp, in/d
Jan	0.000
Feb	0.000
Mar	0.022
Apr	0.061
May	0.111
Jun	0.178
Jul	0.215
Aug	0.195
Sep	0.138
Oct	0.065
Nov	0.016
Dec	0.000

Spillway (HRBC)

Elev, ft	Flow, cfs
4882.5	41533.0
4880.0	36000.0
4877.5	30737.0
4875.0	25760.0
4872.5	21084.0
4870.0	16731.0
4867.5	12728.0
4865.0	9107.0
4862.5	5900.0
4860.0	3220.0
4857.5	1138.0
4855.0	0.0

Tailwater (Base Case)

Flow, cfs	Elev, ft
3000	4448
2500	4448
2000	4447
1750	4446
1250	4446
1000	4445
750	4445
500	4445
250	4444
100	4444
1	4444

32

Node options
Name: Base Case
Min flow: 0 cfs
Capacity: 1838 cfs
Op type: Strictly peaking

Flood elevations (HRBC)

Date	Elev, ft
01-Jan	4855.0
31-Mar	4855.0
01-Apr	4855.0
02-Apr	4855.0
15-Apr	4865.0
30-Apr	4867.0
15-May	4870.0
31-Oct	4870.0
01-Nov	4855.0
31-Dec	4855.0

Minimum elevations (Base Case)

Date	Elev, ft
01-Jan	4645.0
31-Dec	4645.0

Preferred storage objective (elevation), ft (BasecaseSmooth)

Day	A	B	C	D	E
Jan 01	4821.9	4821.9	4821.9	4821.9	4821.9
Jan 15	4826.7	4824.5	4815.0	4811.9	4808.9
Feb 01	4831.6	4827.1	4809.1	4801.9	4795.9
Feb 15	4836.1	4829.6	4812.6	4791.9	4782.9
Mar 01	4840.6	4832.1	4816.1	4791.7	4775.9
Mar 15	4844.6	4835.9	4820.2	4798.0	4775.9
Apr 01	4848.6	4839.8	4824.3	4806.5	4775.9
Apr 15	4855.3	4846.6	4832.5	4816.7	4793.6
May 01	4862.0	4853.3	4840.6	4826.8	4811.2
May 15	4866.0	4861.7	4855.3	4842.2	4828.0
Jun 01	4870.0	4870.0	4870.0	4857.6	4844.8
Jun 15	4870.0	4870.0	4870.0	4863.8	4857.4
Jul 01	4870.0	4870.0	4870.0	4870.0	4870.0
Jul 15	4870.0	4870.0	4870.0	4870.0	4870.0
Aug 01	4861.3	4861.3	4861.3	4861.3	4861.3
Aug 15	4852.2	4852.2	4852.2	4852.2	4852.2
Sep 01	4843.1	4843.1	4843.1	4843.1	4843.1
Sep 15	4832.5	4832.5	4832.5	4832.5	4832.5
Oct 01	4821.9	4821.9	4821.9	4821.9	4821.9
Oct 15	4821.9	4821.9	4821.9	4821.9	4821.9
Nov 01	4821.9	4821.9	4821.9	4821.9	4821.9
Nov 15	4821.9	4821.9	4821.9	4821.9	4821.9
Dec 01	4821.9	4821.9	4821.9	4821.9	4821.9
Dec 15	4821.9	4821.9	4821.9	4821.9	4821.9
Dec 31	4821.9	4821.9	4821.9	4821.9	4821.9

33 Flashboards

Setting name: HRBC
Desc: Gates down spillway curve calculated by MAH from Randy Jenson data
Install: 01-Apr
Remove: 01-Nov
Average days: 1
Volume date: 31-Dec
Volume remain: 0 taf

Spillway with flashboards

Elev, ft	Flow, cfs
4882.5	11667.0
4880.0	8348.0
4877.5	5422.0
4875.0	2952.0
4872.5	1044.0
4870.0	0.0

34 Powerhouse settings summary - Union Valley (HRBC)

Unit	Headloss	Generator	Turbine
1	Base Case U1	Base Case	Base Case U1

Maintenance (Maintenance)

Date	Units
01-Jan	0
14-Oct	1
24-Oct	0
31-Dec	0

Peak/max schedule (Peak All Year)

Date	Setting
01-Jan	1.00
31-Dec	1.00

35 Head loss coefficients, ft/cfs^2 (Base Case U1)

Unit	Unit loss	Common loss	Max unit	Com2?
1	8.5890e-006	0.000000000	1	No

Generator performance, unit 1 (Base Case)

Output, MWh	Eff	Cap
1.0	1.00	46.0
46.0	1.00	46.0

36 Turbine performance, unit 1 (Base Case U1), Gate leakage: 0.0 cfs

Head 170.0 ft		Head 235.0 ft		Head 300.0 ft		Head 365.0 ft		Head 430.0 ft	
Flow, cfs	Eff	Flow, cfs	Eff	Flow, cfs	Eff	Flow, cfs	Eff	Flow, cfs	Eff
139.5	0.2640	164.0	0.2640	185.3	0.2640	204.4	0.2640	221.9	0.2640
191.7	0.4420	225.4	0.4420	254.7	0.4420	280.9	0.4420	304.9	0.4420
260.4	0.5810	306.2	0.5810	346.0	0.5810	381.6	0.5810	414.2	0.5810
351.1	0.6630	412.9	0.6630	466.5	0.6630	514.5	0.6630	558.5	0.6630
424.7	0.7270	499.3	0.7270	564.2	0.7270	622.3	0.7270	675.4	0.7270
497.5	0.7570	585.0	0.7570	660.9	0.7570	729.0	0.7570	791.3	0.7570
577.2	0.8000	678.7	0.8000	766.8	0.8000	845.8	0.8000	918.0	0.8000
664.5	0.8180	781.3	0.8180	882.8	0.8180	973.7	0.8180	1056.8	0.8180
758.7	0.8210	892.0	0.8210	1007.8	0.8210	1111.6	0.8210	1206.6	0.8210
819.1	0.8680	963.1	0.8680	1088.1	0.8680	1200.3	0.8680	1302.7	0.8680
863.8	0.8750	1015.6	0.8750	1147.5	0.8750	1265.7	0.8750	1373.8	0.8750
946.3	0.8940	1112.5	0.8940	1257.0	0.8940	1386.5	0.8940	1504.9	0.8940
1027.3	0.9010	1207.9	0.9010	1364.7	0.9010	1505.3	0.9010	1633.9	0.9010

Junction Reservoir (8)

37 Storage (HRBC)

Elev, ft	Vol, af
4550.0	20000
4540.0	12514
4525.0	10052
4510.0	8000
4495.0	6290
4480.0	4876
4465.0	3698
4460.0	3306
4450.0	2610
4440.0	2018
4430.0	1529
4420.0	1131
4410.0	819
4400.0	572
4390.0	381
4380.0	241
4370.0	144
4360.0	74

Spillway (HRBC)

Elev, ft	Flow, cfs
4475.0	114478.0
4470.0	64149.0
4466.0	41172.0
4465.0	36885.0
4462.0	25037.0
4458.0	11238.0
4454.0	2640.0
4450.0	0.0
4446.0	0.0

Tailwater (HRBC)

Flow, cfs	Elev, ft
1	2915

38 Node options
Name: Base Case
Min flow: 0 cfs
Capacity: 1477 cfs
Op type: Strictly peaking

Flood elevations (Base Case)

Date	Elev, ft
01-Jan	4450.0
31-Dec	4450.0

Target elevations (HRBC)

Date	Elev, ft
01-Jan	4441.0
31-Dec	4441.0

Minimum elevations (Base Case)

Date	Elev, ft
01-Jan	4397.0
31-Dec	4397.0

39 Bypass flows, cfs (HRBC)

Date	A	B	C	D	E	Inflow
01-Jan	5	6	8	10	0	No
01-Feb	5	6	8	10	0	No
01-Mar	5	6	8	10	0	No
01-Apr	5	6	8	10	0	No
01-May	5	10	15	20	0	No
01-Jun	5	10	15	20	0	No
01-Jul	5	10	15	20	0	No
01-Aug	5	10	15	20	0	No
01-Sep	5	10	15	20	0	No
01-Oct	5	10	15	20	0	No
01-Nov	5	6	8	10	0	No
01-Dec	5	6	8	10	0	No
31-Dec	5	6	8	10	0	No

40 Powerhouse settings summary - Jaybird (HRBC)

Unit	Headloss	Generator	Turbine
1	Base Case	Base Case U1 U2	HRBCU1
2	Base Case	Base Case U1 U2	HRBCU2

Maintenance (Maintenance)

Date	Units
01-Jan	0
25-Oct	1
04-Nov	0
05-Nov	2
15-Nov	0
31-Dec	0

Peak/max schedule (Peak All Year)

Date	Setting
01-Jan	1.00
31-Dec	1.00

41 Head loss coefficients, ft/cfs^2
(Base Case)

Unit	Unit loss	Common loss	Max unit	Com2?
1	1.9500e-005	5.6500e-005	2	No
2	3.5000e-005	5.6500e-005	2	No

Generator performance, unit 1
(Base Case U1 U2)

Output, MWh	Eff	Cap
1.0	1.00	70.7
70.7	1.00	70.7

Generator performance, unit 2
(Base Case U1 U2)

Output, MWh	Eff	Cap
1.0	1.00	70.7
70.7	1.00	70.7

42 Turbine performance, unit 1
(HRBCU1), Gate leakage: 0.0 cfs

Head 1350.0 ft		Head 1440.0 ft		Head 1498.0 ft		Head 1515.0 ft		Head 1530.0 ft	
Flow, cfs	**Eff**	**Flow, cfs**	**Eff**	**Flow, cfs**	**Eff**	**Flow, cfs**	**Eff**	**Flow, cfs**	**Eff**
256.3	0.9025	264.7	0.9025	270.0	0.9025	271.5	0.9025	272.9	0.9025
306.6	0.9060	316.7	0.9060	323.0	0.9060	324.8	0.9060	326.4	0.9060
362.6	0.9080	374.5	0.9080	382.0	0.9080	384.2	0.9080	386.1	0.9080
391.1	0.9081	403.9	0.9081	412.0	0.9081	414.3	0.9081	416.4	0.9081
418.6	0.9079	432.4	0.9079	441.0	0.9079	443.5	0.9079	445.7	0.9079
530.7	0.9055	548.1	0.9055	559.0	0.9055	562.2	0.9055	564.9	0.9055
597.1	0.9025	616.7	0.9025	629.0	0.9025	632.6	0.9025	635.7	0.9025

43 Turbine performance, unit 2
(HRBCU2), Gate leakage: 0.0 cfs

Head 1350.0 ft		Head 1440.0 ft		Head 1498.0 ft		Head 1515.0 ft		Head 1530.0 ft	
Flow, cfs	**Eff**	**Flow, cfs**	**Eff**	**Flow, cfs**	**Eff**	**Flow, cfs**	**Eff**	**Flow, cfs**	**Eff**
196.5	0.8390	203.0	0.8390	207.0	0.8390	208.2	0.8390	209.2	0.8390
329.4	0.8640	340.2	0.8640	347.0	0.8640	349.0	0.8640	350.7	0.8640
387.3	0.8700	400.0	0.8700	408.0	0.8700	410.3	0.8700	412.3	0.8700
490.8	0.8690	506.9	0.8690	517.0	0.8690	519.9	0.8690	522.5	0.8690
598.1	0.8640	617.7	0.8640	630.0	0.8640	633.6	0.8640	636.7	0.8640
757.6	0.8600	782.4	0.8600	798.0	0.8600	802.5	0.8600	806.5	0.8600

Camino Reservoir (9)

44 Storage (HRBC)

Elev, ft	Vol, af
2960.0	9810
2950.0	3596
2940.0	1534
2935.0	1100
2930.0	850
2925.0	706
2915.0	541
2910.0	459
2905.0	379
2900.0	311
2895.0	253
2890.0	205
2885.0	165
2880.0	130
2875.0	100
2870.0	74
2865.0	53
2860.0	35
2855.0	21
2850.0	11

Spillway (HRBC)

Elev, ft	Flow, cfs
2925.0	90000.0
2918.0	64000.0
2915.0	62000.0
2897.5	14500.0
2895.0	0.0

Tailwater (HRBC)

Flow, cfs	Elev, ft
2800	1856.09
2700	1855.93
2400	1855.50
1600	1854.48
1200	1853.88
1000	1853.52
800	1853.12
600	1852.65
400	1852.11
200	1851.49
0	1850.77

45 Node options
Name: Base Case
Min flow: 0 cfs
Capacity: 1458 cfs
Op type: Strictly peaking

Flood elevations (Base Case)

Date	Elev, ft
01-Jan	2915.0
31-Dec	2915.0

Target elevations (HRBC)

Date	Elev, ft
01-Jan	2900.0
31-Dec	2900.0

Minimum elevations (HRBC)

Date	Elev, ft
01-Jan	2895.0
30-Mar	2895.0
31-Mar	2865.0
29-Nov	2865.0
30-Nov	2895.0
31-Dec	2895.0

46 Bypass flows, cfs (HRBC)

Date	A	B	C	D	E	Inflow
01-Jan	5	6	8	10	0	No
01-Feb	5	6	8	10	0	No
01-Mar	5	6	8	10	0	No
01-Apr	5	6	8	10	0	No
01-May	5	10	15	20	0	No
01-Jun	5	10	15	20	0	No
01-Jul	5	10	15	20	0	No
01-Aug	5	10	15	20	0	No
01-Sep	5	10	15	20	0	No
01-Oct	5	10	15	20	0	No
01-Nov	5	6	8	10	0	No
01-Dec	5	6	8	10	0	No
31-Dec	5	6	8	10	0	No

47 Powerhouse settings summary - Camino (HRBC)

Unit	Headloss	Generator	Turbine
1	Base Case	Base Case U1	Base Case U1
2	Base Case	Base Case U2	HRBC U2

Maintenance (Maintenance)

Date	Units
01-Jan	0
16-Nov	1
25-Nov	0
26-Nov	2
05-Dec	0
31-Dec	0

Peak/max schedule (Peak All Year)

Date	Setting
01-Jan	1.00
31-Dec	1.00

48 Head loss coefficients, ft/cfs^2
(Base Case)

Unit	Unit loss	Common loss	Max unit	Com2?
1	1.2000e-005	8.0000e-006	2	No
2	2.6500e-005	8.0000e-006	2	No

Generator performance, unit 1
(Base Case U1)

Output, MWh	Eff	Cap
1.0	1.00	80.0
80.0	1.00	80.0

Generator performance, unit 2
(Base Case U2)

Output, MWh	Eff	Cap
1.0	1.00	70.0
70.0	1.00	70.0

49 Turbine performance, unit 1
(Base Case U1), Gate leakage: 0.0 cfs

Head 940.0 ft		Head 970.0 ft		Head 1000.0 ft		Head 1030.0 ft		Head 1065.0 ft	
Flow, cfs	Eff	Flow, cfs	Eff	Flow, cfs	Eff	Flow, cfs	Eff	Flow, cfs	Eff
213.3	0.5370	216.7	0.5370	220.0	0.5370	223.3	0.5370	227.0	0.5370
347.1	0.6860	352.6	0.6860	358.0	0.6860	363.3	0.6860	369.5	0.6860
553.6	0.7940	562.4	0.7940	571.0	0.7940	579.5	0.7940	589.3	0.7940
762.1	0.8470	774.1	0.8470	786.0	0.8470	797.7	0.8470	811.1	0.8470
879.4	0.8560	893.3	0.8560	907.0	0.8560	920.5	0.8560	936.0	0.8560
986.0	0.8570	1001.6	0.8570	1017.0	0.8570	1032.1	0.8570	1049.5	0.8570
1051.0	0.8560	1067.6	0.8560	1084.0	0.8560	1100.1	0.8560	1118.7	0.8560

50 Turbine performance, unit 2
(HRBC U2), Gate leakage: 0.0 cfs

Head 940.0 ft		Head 970.0 ft		Head 1000.0 ft		Head 1030.0 ft		Head 1065.0 ft	
Flow, cfs	Eff	Flow, cfs	Eff	Flow, cfs	Eff	Flow, cfs	Eff	Flow, cfs	Eff
105.7	0.1000	107.4	0.1000	109.0	0.1000	110.6	0.1000	112.5	0.1000
128.9	0.2460	131.0	0.2460	133.0	0.2460	135.0	0.2460	137.3	0.2460
152.2	0.3480	154.6	0.3480	157.0	0.3480	159.3	0.3480	162.0	0.3480
195.8	0.5090	198.9	0.5090	202.0	0.5090	205.0	0.5090	208.5	0.5090
425.6	0.7210	432.4	0.7210	439.0	0.7210	445.5	0.7210	453.0	0.7210
657.3	0.8110	667.8	0.8110	678.0	0.8110	688.1	0.8110	699.7	0.8110
772.7	0.8240	785.0	0.8240	797.0	0.8240	808.9	0.8240	822.5	0.8240
902.6	0.8180	916.9	0.8180	931.0	0.8180	944.9	0.8180	960.8	0.8180
992.8	0.8050	1008.5	0.8050	1024.0	0.8050	1039.2	0.8050	1056.8	0.8050
1041.3	0.8000	1057.8	0.8000	1074.0	0.8000	1090.0	0.8000	1108.4	0.8000

Brush Creek Reservoir (10)

51 Storage (HRBC)

Elev, ft	Vol, af
2930.0	10000
2920.0	1454
2915.0	1350
2910.0	1250
2905.0	1155
2900.0	1064
2895.0	976
2890.0	893
2885.0	813
2880.0	737
2875.0	665
2870.0	597
2865.0	531
2860.0	468
2855.0	411
2850.0	354
2845.0	302
2840.0	253
2835.0	206
2830.0	163
2825.0	124
2820.0	89
2815.0	59
2810.0	34
2805.0	16
2800.0	8

Spillway (HRBC)

Elev, ft	Flow, cfs
2925.0	20428.0
2923.0	14617.0
2922.0	11964.0
2921.0	9494.0
2920.0	6462.0
2919.0	4352.0
2918.0	2827.0
2917.0	1250.0
2916.0	340.0
2915.0	0.0

52 Node options
Name: Base Case
Min flow: 0 cfs
Capacity: 710 cfs
Op type: Non-generating

Flood elevations (Base Case)

Date	Elev, ft
01-Jan	2915.0
31-Dec	2915.0

Target elevations (Base Case)

Date	Elev, ft
01-Jan	2900.0
31-Dec	2900.0

Minimum elevations (HRBC)

Date	Elev, ft
01-Jan	2895.0
31-Dec	2895.0

53 Bypass flows, cfs (HRBC)

Date	A	B	C	D	E	Inflow
01-Jan	4	4	6	6	0	Yes
01-Jun	2	2	3	3	0	Yes
01-Nov	4	4	6	6	0	Yes
31-Dec	4	4	6	6	0	Yes

Slab Creek Reservoir (11)

54

Storage (HRBC)

Elev, ft	Vol, af
1870.0	18206
1860.0	15549
1850.0	13335
1845.0	12228
1840.0	11203
1835.0	10232
1830.0	9330
1825.0	8496
1820.0	7755
1810.0	6509
1800.0	5457
1790.0	4500
1780.0	3644
1770.0	2889
1760.0	2248
1750.0	1702
1740.0	1245
1730.0	865
1720.0	589
1710.0	390
1700.0	226
1690.0	100
1680.0	26

Spillway (HRBC)

Elev, ft	Flow, cfs
1864.0	79678.0
1862.0	59240.0
1860.0	41763.0
1858.0	27273.0
1856.0	15800.0
1855.0	11307.0
1854.0	7860.0
1853.0	5050.0
1852.0	2720.0
1851.5	1760.0
1851.0	990.0
1850.5	395.0
1850.0	30.0
1849.9	0.0

Tailwater (Base Case)

Flow, cfs	Elev, ft
4250	998
4000	998
3750	998
3500	997
3250	997
3000	997
2750	996
2500	996
2250	995
2000	995
1750	995
1500	994
1250	994
1000	994
750	993
500	993
250	993
100	992
1	992

55

Node options
Name: Base Case
Min flow: 0 cfs
Capacity: 3950 cfs
Op type: Strictly peaking

Flood elevations (Base Case)

Date	Elev, ft
01-Jan	1850.0
31-Dec	1850.0

Target elevations (Base Case)

Date	Elev, ft
01-Jan	1844.0
31-Dec	1844.0

Minimum elevations (HRBC)

Date	Elev, ft
01-Jan	1820.0
31-Dec	1820.0

56

Bypass flows, cfs (HRBC)

Date	A	B	C	D	E	Inflow
01-Jan	10	10	36	36	0	No
01-Feb	10	10	36	36	0	No
01-Mar	10	10	36	36	0	No
01-Apr	10	10	36	36	0	No
01-May	10	10	36	36	0	No
01-Jun	36	36	36	36	0	No
01-Jul	36	36	36	36	0	No
01-Aug	36	36	36	36	0	No
01-Sep	36	36	36	36	0	No
01-Oct	36	36	36	36	0	No
01-Nov	36	36	36	36	0	No
16-Nov	10	10	36	36	0	No
01-Dec	10	10	36	36	0	No
31-Dec	10	10	36	36	0	No

Minimum release, cfs (HRBC)

Date	Flow, cfs	Inflow
01-Jan	40	No
31-Dec	40	No

57

Powerhouse settings summary - White Rock (HRBC)

Unit	Headloss	Generator	Turbine
1	Base Case	Base Case U1	HRBC U1
2	Base Case	Base Case U2	HRBC U2

Maintenance (Maintenance)

Date	Units
01-Jan	0
06-Dec	1
14-Dec	0
15-Dec	2
25-Dec	0
31-Dec	0

Peak/max schedule (Peak All Year)

Date	Setting
01-Jan	1.00
31-Dec	1.00

58 Head loss coefficients, ft/cfs^2
(Base Case)

Unit	Unit loss	Common loss	Max unit	Com2?
1	4.3550e-006	0.000000000	2	No
2	4.3550e-006	0.000000000	2	No

Generator performance, unit 1
(Base Case U1)

Output, MWh	Eff	Cap
1.0	1.00	105.0
105.0	1.00	105.0

Generator performance, unit 2
(Base Case U2)

Output, MWh	Eff	Cap
1.0	1.00	125.0
125.0	1.00	125.0

59 Turbine performance, unit 1
(HRBC U1), Gate leakage: 0.0 cfs

Head 730.0 ft		Head 760.0 ft		Head 795.0 ft		Head 830.0 ft		Head 860.0 ft	
Flow, cfs	Eff	Flow, cfs	Eff	Flow, cfs	Eff	Flow, cfs	Eff	Flow, cfs	Eff
395.8	0.5340	403.8	0.5340	413.0	0.5340	422.0	0.5340	429.6	0.5340
658.4	0.6420	671.7	0.6420	687.0	0.6420	702.0	0.6420	714.6	0.6420
800.9	0.6880	817.2	0.6880	835.8	0.6880	854.0	0.6880	869.3	0.6880
1030.7	0.7340	1051.6	0.7340	1075.6	0.7340	1099.0	0.7340	1118.7	0.7340
1178.8	0.7510	1202.8	0.7510	1230.2	0.7510	1257.0	0.7510	1279.5	0.7510
1313.0	0.7630	1339.7	0.7630	1370.2	0.7630	1400.0	0.7630	1425.1	0.7630
1438.6	0.7660	1467.9	0.7660	1501.3	0.7660	1534.0	0.7660	1561.5	0.7660
1554.0	0.7590	1585.6	0.7590	1621.7	0.7590	1657.0	0.7590	1686.7	0.7590

60 Turbine performance, unit 2
(HRBC U2), Gate leakage: 0.0 cfs

Head 730.0 ft		Head 760.0 ft		Head 795.0 ft		Head 830.0 ft		Head 860.0 ft	
Flow, cfs	Eff	Flow, cfs	Eff	Flow, cfs	Eff	Flow, cfs	Eff	Flow, cfs	Eff
417.3	0.5960	425.8	0.5960	435.5	0.5960	445.0	0.5960	453.0	0.5960
613.3	0.6890	625.8	0.6890	640.1	0.6890	654.0	0.6890	665.7	0.6890
795.3	0.7500	811.5	0.7500	829.9	0.7500	848.0	0.7500	863.2	0.7500
1057.9	0.7990	1079.4	0.7990	1104.0	0.7990	1128.0	0.7990	1148.2	0.7990
1372.0	0.8330	1399.9	0.8330	1431.8	0.8330	1463.0	0.8330	1489.2	0.8330
1616.8	0.8530	1649.7	0.8530	1687.3	0.8530	1724.0	0.8530	1754.9	0.8530
1869.1	0.8580	1907.1	0.8580	1950.5	0.8580	1993.0	0.8580	2028.7	0.8580
2059.5	0.8570	2101.4	0.8570	2149.2	0.8570	2196.0	0.8570	2235.3	0.8570

Chili Bar Reservoir (Pacific Gas and Electric Co.) (12)

61 Storage
(Base Case)

Elev, ft	Vol, af
1020.0	5979
1014.0	5152
1008.0	4376
1002.0	3651
996.0	2976
990.0	2353
984.0	1800
978.0	1335
972.0	958

Note: Table abridged; full printout below

Spillway
(Base Case)

Elev, ft	Flow, cfs
1017.5	60167.0
1017.0	57667.0
1016.0	52800.0
1015.0	48667.0
1014.0	44667.0
1013.0	40000.0
1012.0	35533.0
1011.0	31333.0
1010.0	28133.0
1009.0	23533.0
1008.0	20133.0
1007.0	16870.0
1006.0	14200.0
1005.0	11333.0
1004.0	9000.0
1003.0	7000.0
1002.0	5333.0
1001.0	3700.0
1000.0	2200.0
999.0	1100.0
998.0	300.0
997.5	0.0

Tailwater
(Base Case)

Flow, cfs	Elev, ft
1	933

62 Node options
Name: Base Case
Min flow: 200 cfs
Capacity: unlimited
Op type: Peaking w/ ramp rates

UARP support
Linked: No
Spill prevention: No
Raft flow support
General: No
Up UARP: No

Flood elevations
(Base Case)

Date	Elev, ft
01-Jan	997.5
31-Dec	997.5

Target elevations
(HRBC)

Date	Elev, ft
01-Jan	996.0
31-Dec	996.0

Minimum elevations
(Base Case)

Date	Elev, ft
01-Jan	984.0
31-Dec	984.0

63 Bypass flows, cfs
(Base Case)

Date	A	B	C	D	E	Inflow
01-Jan	0	0	0	0	0	No
23-Nov	120	120	120	120	120	No
07-Dec	0	0	0	0	0	No
31-Dec	0	0	0	0	0	No

Minimum release, cfs
(Base Case)

Date	A	B	C	D	E	Inflow
01-Jan	120	120	120	120	120	No
31-Dec	120	120	120	120	120	No

64 Powerhouse settings summary - Chili Bar
(Base Case)

Unit	Headloss	Generator	Turbine
1	Base Case	Base Case	Base Case

Whitewater boating release schedule (flow/duration) (cfs/hours)

Day	Start	A	B	C	D	E
Sunday	9:00	1200 / 3	1500 / 6	1750 / 8	1750 / 8	1750 / 8
Monday	9:00	0 / 1	1200 / 3	1200 / 6	1500 / 6	1500 / 6
Tuesday	9:00	0 / 1	1200 / 3	1200 / 6	1500 / 6	1500 / 6
Wednesday	9:00	1200 / 3	1200 / 3	1200 / 6	1500 / 6	1500 / 6
Thursday	9:00	0 / 1	1200 / 3	1200 / 6	1500 / 6	1500 / 6
Friday	9:00	1200 / 3	1200 / 3	1200 / 6	1500 / 6	1500 / 6
Saturday	9:00	1200 / 3	1500 / 6	1750 / 8	1750 / 8	1750 / 8
Start date		26 May	26 May	26 May	1 Mar	1 Mar
End date		15 Sep	15 Sep	15 Sep	31 Oct	31 Oct

65 Generator performance, unit 1
(Base Case)

Output, MWh	Eff	Cap
0.1	1.00	8.1
8.1	1.00	8.1

Maintenance
(Maintenance)

Date	Units
01-Jan	0
23-Nov	1
07-Dec	0
31-Dec	0

Ramping rates, cfs or ft
(Base Case)

Date	Hourly up	Hourly dn	Daily up	Daily dn
01-Jan	500	500	unl.	unl.
31-Dec	500	500	unl.	unl.

66 Turbine performance, unit 1
(Base Case), Gate leakage: 0.0 cfs

Head 56.1 ft		Head 59.2 ft		Head 61.1 ft		Head 62.9 ft		Head 64.5 ft	
Flow, cfs	**Eff**	**Flow, cfs**	**Eff**	**Flow, cfs**	**Eff**	**Flow, cfs**	**Eff**	**Flow, cfs**	**Eff**
150.0	0.4170	150.0	0.3850	150.0	0.3530	150.0	0.3760	150.0	0.3150
250.0	0.5890	250.0	0.5500	250.0	0.5320	300.0	0.5680	250.0	0.4840
400.0	0.7040	400.0	0.6620	400.0	0.6490	400.0	0.6270	400.0	0.6090
650.0	0.7790	650.0	0.7310	700.0	0.7070	600.0	0.6740	600.0	0.6640
900.0	0.8020	900.0	0.7680	900.0	0.7310	1000.0	0.7220	950.0	0.6920
1000.0	0.8030	1000.0	0.7760	1100.0	0.7460	1350.0	0.7370	1200.0	0.7030
1100.0	0.8050	1100.0	0.7800	1300.0	0.7510	1600.0	0.7100	1500.0	0.7000
1200.0	0.8030	1200.0	0.7850	1500.0	0.7360	1800.0	0.6900	1700.0	0.6750
1300.0	0.7890	1300.0	0.7830	1700.0	0.7260	2000.0	0.6650	1950.0	0.6520
1343.0	0.7820	1407.0	0.7820	1933.0	0.6950	2200.0	0.6250	2200.0	0.6250

Base Case from Operational Data - formula created from operational data observations, grouped into 5 head bands.

Iowa Hill Development (13)

67 Storage (Base Case)

Elev, ft	Vol, af
3073.0	6572
3070.0	6358
3060.0	5668
3050.0	5015
3040.0	4398
3030.0	3817
3020.0	3269
3010.0	2755
3000.0	2272
2990.0	1821
2980.0	1400
2970.0	1009
2960.0	645
2950.0	309
2945.0	152
2940.0	0

Peak/max schedule (Max All Year)

Date	Setting
01-Jan	2.00
31-Dec	2.00

Head loss coefficients, ft/cfs^2 (Base Case)

Unit	Unit loss	Common loss	Max unit	Com2?
1	0.000000000	8.8636e-007	3	No
2	0.000000000	8.8636e-007	3	No
3	0.000000000	8.8636e-007	3	No

68 Node options
Name: Generating
Min flow: 1100 cfs
Capacity: 4500 cfs
Op type: Strictly peaking

Flood elevations (Base Case)

Date	Elev, ft
01-Jan	3070.0
31-Dec	3070.0

Minimum elevations (Base Case)

Date	Elev, ft
01-Jan	2950.0
31-Dec	2950.0

69 Pump Operations
Name: Dommer1
Ancillary only: No
Ancillary dual: No

Pump Capacity (test)

Head	Eff	Min MW	Max MW	Min cfs	Max cfs
1117	0.92	112.0	152.0	1089.8	1479.1
1157	0.93	107.0	157.0	1010.6	1482.9
1197	0.93	109.0	163.0	995.1	1488.1
1238	0.93	115.0	163.0	1015.1	1438.8
1278	0.92	120.5	163.0	1024.8	1386.3

Weekly cycle drawdown settings

Month	Days	Volume, ac-ft
Jan	6	2975.00
Feb	6	2970.00
Mar	6	1730.00
Apr	6	2968.00
May	6	2227.00
Jun	6	1482.00
Jul	6	1482.00
Aug	6	1482.00
Sep	6	1482.00
Oct	6	2968.00
Nov	6	2968.00
Dec	6	2968.00

70 Weekday operation schedule: number of units generating or pumping during HE01 through HE24 (Dommer1)

Month	Linked	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Jan	No	3	3	3	3	3	1	1	1	1	1	1	1	1	1	1	1	1	3	3	3	3	3	3	3
Feb	No	3	3	3	3	3	1	1	1	1	1	1	1	1	1	1	1	1	3	3	3	3	3	3	3
Mar	No	3	3	3	3	3	1	1	1	1	1	1	1	1	1	1	1	1	1	3	3	3	3	3	3
Apr	No	3	3	3	3	3	1	1	1	1	1	1	1	1	-	-	1	1	1	1	3	3	3	3	3
May	No	3	3	3	3	3	1	1	1	1	1	1	1	1	1	3	3	3	3	3	3	3	3	3	3
Jun	No	3	3	3	3	3	3	1	1	1	1	1	1	3	3	3	3	3	3	3	3	3	3	3	3
Jul	No	3	3	3	3	3	3	1	1	1	1	1	1	3	3	3	3	3	3	3	3	3	3	3	3
Aug	No	3	3	3	3	3	3	1	1	1	1	1	1	3	3	3	3	3	3	3	3	3	3	3	3
Sep	No	3	3	3	3	3	3	1	1	1	1	1	1	3	3	3	3	3	3	3	3	3	3	3	3
Oct	No	3	3	3	3	3	1	1	1	1	1	1	1	1	1	1	1	1	3	3	3	3	3	3	3
Nov	No	3	3	3	3	3	1	1	1	1	1	1	1	1	1	1	1	1	3	3	3	3	3	3	3
Dec	No	3	3	3	3	3	1	1	1	1	1	1	1	1	1	1	1	1	3	3	3	3	3	3	3

71 Saturday operation schedule: number of units generating or pumping during HE01 through HE24 (Dommer1)
Same as weekday schedule

72 Sunday operation schedule: number of units generating or pumping during HE01 through HE24 (Dommer1)

Month	Linked	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Jan	No	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Feb	No	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Mar	No	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Apr	No	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
May	No	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Jun	No	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Jul	No	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Aug	No	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Sep	No	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Oct	No	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Nov	No	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Dec	No	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3

(Black on white: generation. White on black and underlined: pumping.)

73 Generator performance, unit 1 (Base Case)

Output, MWh	Eff	Cap
0.1	0.98	133.0
133.0	0.98	133.0

Generator performance, unit 2 (Base Case)

Output, MWh	Eff	Cap
0.1	0.98	133.0
133.0	0.98	133.0

Generator performance, unit 3 (Base Case)

Output, MWh	Eff	Cap
0.1	0.98	133.0
133.0	0.98	133.0

74 Turbine performance, unit 1
(Base Case), Gate leakage: 0.0 cfs

Head 1073.0 ft		Head 1112.0 ft		Head 1151.0 ft		Head 1189.0 ft		Head 1228.0 ft	
Flow, cfs	Eff	Flow, cfs	Eff	Flow, cfs	Eff	Flow, cfs	Eff	Flow, cfs	Eff
191.5	0.3360	193.5	0.3449	197.4	0.3543	201.6	0.3639	203.8	0.3666
287.3	0.4873	290.2	0.4922	296.2	0.5028	302.4	0.5136	305.6	0.5175
383.1	0.6128	386.9	0.6138	394.9	0.6181	403.2	0.6221	407.5	0.6236
478.8	0.6827	483.7	0.6837	493.6	0.6867	504.0	0.6896	509.4	0.6906
574.6	0.7387	580.4	0.7393	592.3	0.7352	604.8	0.7414	611.3	0.7414
670.3	0.7818	677.1	0.7822	691.1	0.7823	705.6	0.7815	713.1	0.7811
766.1	0.8164	773.8	0.8169	789.8	0.8169	806.4	0.8164	815.0	0.8161
861.9	0.8456	870.6	0.8462	888.5	0.8460	907.2	0.8451	916.9	0.8444
957.6	0.8707	967.3	0.8706	987.2	0.8702	1008.0	0.8690	1018.8	0.8680
1053.4	0.8894	1064.0	0.8892	1086.0	0.8887	1108.8	0.8873	1120.6	0.8864
1149.2	0.9043	1160.8	0.9041	1184.7	0.9032	1209.6	0.9009	1222.5	0.8992
1244.9	0.9144	1257.5	0.9143	1283.4	0.9133	1310.4	0.9113	1324.4	0.9102
1340.7	0.9213	1354.2	0.9212	1382.1	0.9206	1411.2	0.9187	1426.3	0.9169
1436.4	0.9260	1451.0	0.9257	1480.9	0.9249	1512.1	0.9232	1528.1	0.9213
1532.2	0.9288	1547.7	0.9283	1579.6	0.9269	1612.9	0.9257	1630.0	0.9239
1596.1	0.9302	1612.2	0.9293	1645.4	0.9274	1680.1	0.9260	1697.9	0.9246
1628.0	0.9293	1644.4	0.9290	1678.3	0.9272	1713.7	0.9258	1731.9	0.9242
1723.7	0.9265	1741.1	0.9266	1777.0	0.9257	1814.5	0.9232	1833.8	0.9219
1819.5	0.9209	1837.9	0.9209	1875.8	0.9199	1915.3	0.9176	1935.6	0.9164
1915.3	0.9116	1934.6	0.9209	1974.5	0.9111	2016.1	0.9176	2037.5	0.9079

75 Turbine performance, unit 2
(Base Case), Gate leakage: 0.0 cfs
Same as unit 1

76 Turbine performance, unit 3
(Base Case), Gate leakage: 0.0 cfs
Same as unit 1

Addenda

77 **Buck Island Reservoir** Tunnel/plant flow (HRBCnew)

Elev, ft	Flow, cfs
6437.6	1160.0
6437.5	1146.0
6437.4	1133.0
6437.3	1119.0
6437.2	1105.0
6437.1	1092.0
6437.0	1078.0
6436.9	1065.0
6436.8	1051.0
6436.7	1038.0
6436.6	1025.0
6436.5	1011.0
6436.4	998.0
6436.3	984.7
6436.2	971.5
6436.1	958.3
6436.0	945.1
6435.9	932.0
6435.8	919.0
6435.7	905.9
6435.6	892.9
6435.5	880.0
6435.4	867.0
6435.2	841.3
6435.1	828.5
6435.0	815.8
6434.9	803.0
6434.8	790.4
6434.7	777.7
6434.6	765.2
6434.5	752.6
6434.4	740.1
6434.3	727.6
6434.1	702.9
6434.0	690.5
6433.9	678.3
6433.8	666.0
6433.7	653.9
6433.6	641.7
6433.5	629.6
6433.4	617.6
6433.3	605.6
6433.2	593.7
6433.0	569.9
6432.9	558.1
6432.8	546.4
6432.7	534.7
6432.6	523.1
6432.5	511.5
6432.4	500.0
6432.3	488.5
6432.2	477.1
6432.1	465.7
6431.9	443.2
6431.8	432.0
6431.7	420.9
6431.6	409.8
6431.5	398.8
6431.4	387.9

Camino Reservoir Tailwater (HRBC)

Flow, cfs	Elev, ft
2800	1856
2700	1856
2600	1856
2500	1856
2400	1856
2300	1855
2200	1855
2100	1855
2000	1855
1900	1855
1800	1855
1700	1855
1600	1854
1500	1854
1400	1854
1300	1854
1200	1854
1100	1854
1000	1854
900	1853
800	1853
700	1853
600	1853
500	1852
400	1852
300	1852
200	1851
100	1851
0	1851

Chili Bar Reservoir Storage (Base Case)

Elev, ft	Vol, af
1020.0	5979
1019.0	5837
1018.0	5697
1017.0	5559
1016.0	5422
1015.0	5286
1014.0	5152
1013.0	5019
1012.0	4888
1011.0	4758
1010.0	4629
1009.0	4502
1008.0	4376
1007.0	4252
1006.0	4129
1005.0	4007
1004.0	3887
1003.0	3768
1002.0	3651
1001.0	3535
1000.0	3420
999.0	3307
998.0	3195
997.0	3085
996.0	2976
995.0	2868
994.0	2763
993.0	2658
992.0	2555
991.0	2453
990.0	2353
989.0	2255
988.0	2159
987.0	2065
986.0	1974
985.0	1886
984.0	1800
983.0	1716
982.0	1635
981.0	1556
980.0	1480
979.0	1406
978.0	1335
977.0	1266
976.0	1200
975.0	1136
974.0	1074
973.0	1015
972.0	958
971.0	904
970.0	853
922.0	0

6431.3	377.0
6431.2	366.2
6431.1	355.5
6431.0	344.8
6430.9	334.2
6430.8	323.7
6430.7	313.2
6430.6	302.8
6430.5	292.5
6430.4	282.3
6430.3	272.1
6430.2	262.1
6430.1	252.0
6430.0	242.1
6429.9	232.3
6429.8	222.5
6429.7	212.9
6429.6	203.3
6429.5	193.8
6429.4	184.5
6429.3	175.2
6429.2	166.0
6429.1	156.9
6429.0	147.9
6428.9	139.0
6428.8	128.6
6428.7	118.5
6428.6	108.7
6428.5	99.2
6428.4	90.0
6428.3	80.7
6428.2	71.7
6428.1	63.1
6428.0	55.0
6427.9	46.7
6427.8	39.0
6427.7	31.4
6427.6	24.5
6427.5	18.1
6427.4	12.6
6427.3	8.1
6427.2	4.6
6427.1	2.0
6427.0	0.1
6427.0	0.0

APPENDIX B

MODEL CONFIGURATION AND SOLUTION ALGORITHM

- Data flow
- Components of a Scenario
- Physical Settings
- Unit Dispatch
- Daily Time Step Sequence
- Fifteen-Minute Time Step
- Model Logic and scheduling flow chart

APPENDIX B

MODEL CONFIGURATION AND SOLUTION ALGORITHM

The Water Balance Model takes as input hydrologic data and operating parameters. The hydrologic data consist of mean daily inflow to each UARP reservoir and to Chili Bar Reservoir. The operating parameters include details of data summarized in this document, including powerhouse characteristics and reservoir physical and operational limits. The model simulates the real-world operation of the hydraulic features of the UARP and the Chili Bar Project, constrained by these inputs. The simulation focuses on water allocation and flow; energy generation is an output and not explicitly constrained by system load.

To simulate UARP and Chili Bar Project operation, the Water Balance Model steps sequentially through each day in the period of record. It allocates water through tunnels and powerhouses each day, and then shapes the daily volume in 15-minute increments according to the operating parameters. The output consists of time series of flow, reservoir storage, and energy generated at each location in the UARP and the Chili Bar Project.

Data flow

Two types of data are input to the Water Balance Model, and one type of data is output. Input data consist of:

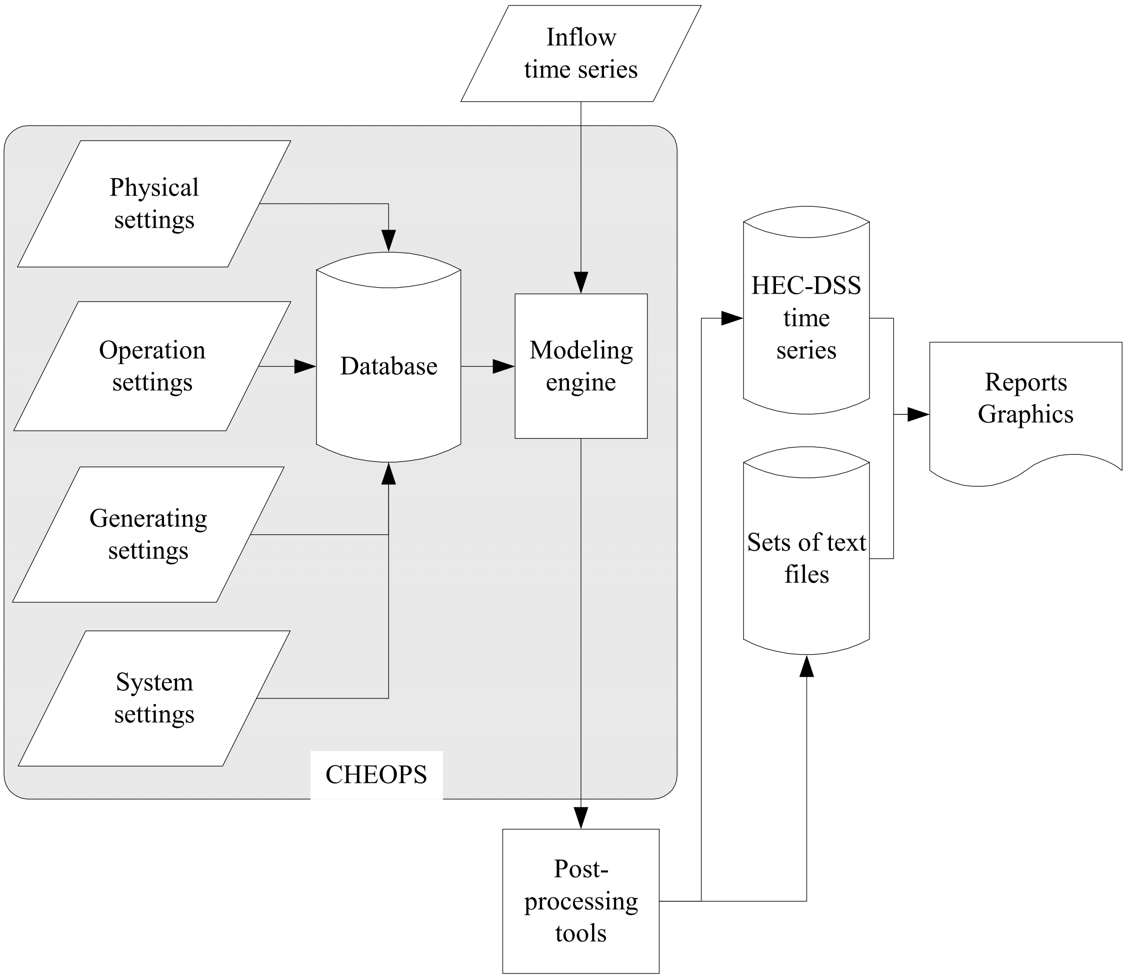
- Parameters. These consist of tables of data, such as water release schedules, turbine performance curves, and reservoir elevation targets. Parameters are grouped together as settings: physical settings, operation settings, generation settings, and system settings.
- Time series. These consist of day-by-day inflow volumes to project reservoirs. Each project reservoir, such as Rubicon Reservoir or Junction Reservoir, receives water each day from precipitation, snowmelt, or base flow. A time series of these volumes is provided to each reservoir in the model, for each day in the simulation, in units of sfd (second-foot-day, $ft^3/s \cdot d$).

Output data consist of time series in two intervals: 15-minute and daily. The 15-minute data are transformed to hourly data. The hourly and daily data are stored in a HEC-DSS database and summarized to various text files and Excel workbooks.

The figure is a flow chart illustrating data paths in the Water Balance Model. The crosshatched area represents the CHEOPS™ software. This software executes model runs.

Within the crosshatched area is one key component, the database. The database consists of numerous files: a Microsoft Access *mdb* file, Microsoft Excel files, and text files.

A single simulation scenario is called a model run. The software evaluates model runs non-interactively, and often several model runs are batched together. A model run consists of developing a scenario, which is a selection of settings stored in the database, and then invoking the modeling engine. A model run requires 45-90 minutes of scientific grade personal computer workstation execution time (year 2003).



After the execution is complete, post-processing software tools translate the modeling engine's raw output to two standard formats: HEC-DSS and text files. Other tools use these data to generate specific tabular reports and graphical views of the model run output.

The following are terms used in the Water Balance Model.

Accretion flow	The incremental volume of baseflow, interflow, and direct runoff that enters a reservoir. Expressed in units of second-feet-day.
Bypass flow destination	The location to which bypass flow is directed, either a downstream reservoir or leaving the system altogether.
Bypass flows	Flows released from a reservoir and are not passed through a powerhouse.
CHEOPS™	Computer Hydro-Electric Operations and Planning Software, a

	trademark of Devine Tarbell & Associates, Inc.
Condition	The main building block of a setting, containing specific data.
Discharge	Water released from a reservoir to a powerhouse, canal or tunnel.
Dispatch	A procedure that determines the most efficient way to divide flow among powerhouse units.
Diversion	An outlet to divert water, a tunnel or canal.
Fill and spill	A powerhouse that peaks with the defined load shape but will spill its forebay in order for an upstream reservoir to follow the load shape as closely as possible.
Flood elevation	The elevation of a reservoir above which it may spill. When a reservoir exceeds its flood elevation, the model will change operation of associated powerhouses to reduce the amount of spill.
Gate leakage	The amount of water that leaks through the turbine wicket gates or needle valves when closed.
Generator	A device that converts shaft power to electric power.
Gross head	A unit of pressure, describing the difference between the headwater elevation and the tailwater elevation.
Headloss	The total amount of pressure that is lost, or not available to the turbine, between the headwater and the tailwater at a powerhouse.
Inflow	The flow of water entering a node.
Level fluctuation	The change in reservoir surface elevation.
Level fluctuation limit	A constraint on the amount of level fluctuation, expressed in units of feet per day.
Level fluctuation rate	A constraint on the maximum rate of level fluctuation, expressed in units of feet per hour.
Load shape	The daily pattern of generation, categorized as primary peak, secondary peak, and off peak.
Local inflow	The incremental volume of baseflow, interflow, and direct runoff that enters a reservoir. Expressed in units of second-feet-day.
Maintenance	A period when a powerhouse does not pass water or generate power.
Minimum daily average flow	A constraint on the daily volume of water that must be released from a reservoir through its associated powerhouse.
Minimum elevation	The lowest allowable reservoir elevation, below which no release will be made through its associated powerhouse. Often is the top of a penstock tunnel inlet.
Minimum flow unit	A small unit that is installed specifically to generate power from the reservoir instream release outlet. Typically this unit is separate from the powerhouse.
Minimum instantaneous flow	A lower constraint on the release from a reservoir through its associated powerhouse.

Net head	The head or pressure difference across the turbine unit itself.
Node operation type	The manner in which water is scheduled through a powerhouse, tunnel, or canal: diversion, fill and spill, non-generating, peaking, peaking with ramp rates, run-of-river, or re-regulating.
Non-generating	A non-generating discharge, peaked to follow the load shape.
Peaking	A powerhouse that peaks its discharge and attempts to schedule water into the highest demand periods of the day. This powerhouse can instantaneously change load.
Peaking with Ramp Rates	A powerhouse where the discharge closely follows the load shape; however, the powerhouse is constrained by ramping rates.
Ramping rate	An upper constraint on the rate at which a node's discharge can change.
Ramping rate curve	The river flow-stage relationship at the location where ramping rate compliance is measured.
Re-regulating	A powerhouse designed to regulate peaked discharges from upstream plants into smooth discharges. This powerhouse releases constant outflow. Re-regulating powerhouses may be constrained by ramping rates. When constrained they are required to ramp between days.
Reservoir storage curve	A reservoir's contents (acre-ft) at various surface elevations.
Run-of-River	A powerhouse where inflows are equal to outflows on an instantaneous basis.
Scenario	A collection of settings, which constitutes a model run.
Second-foot-day	A unit of water volume (from informal "second-feet," equivalent to cfs, over one day) equal to 86400/43560 or about 1.98 acre-feet.
Setting	A collection of conditions that form a building block of a scenario. A setting is made up of conditions.
Spill	Water passed over a spillway.
Spillway capacity curve	A relationship that defines the flow rate over a spillway at a reservoir elevation.
Tailwater curve	A relationship that describes tailwater elevation versus powerhouse flow. Used when the tailwater elevation is not controlled by a reservoir elevation.
Tailwater elevation	The water surface elevation that determines the static head on the downstream side of a reaction turbine.
Turbine	A machine that converts kinetic power and pressure to shaft power.
Unit	The combined turbine-generator machine. A powerhouse may have one or more units.
Water withdrawals	Water that is withdrawn from or returned (a negative quantity) to a reservoir.

Components of a Scenario

A scenario is a collection of settings, each of which in turn is a collection of conditions.
System Settings

The system setting consists of the conditions that refer to data applicable to all nodes in the system, or unique data solely applicable to one node in the system. For example, the system setting includes the load shape condition, which contains the data for the preferred daily scheduling of powerhouse generation by hour. The load shape condition applies to each node in the system with a powerhouse. Alternatively, a system setting can also be a condition that applies to only one node. The system setting conditions are discussed below.

Load Shape Condition

The load shape condition includes typical scheduling data for the daily period-durations by month. The model uses the load shape data to schedule the release of water throughout the day, prioritizing generation during the higher demand periods.

The Water Balance Model weekday load shape allows for peak, secondary-peak (or shoulder-peak), and off-peak periods to be described. The weekday load shape is applied to every Monday through Saturday of each month, and can vary by month. The weekend load shape is described by two periods, peak and off-Peak. This load shape is used every Sunday of each month and can also vary by month.

Preferred Monthly Energy Reliability Objective Condition

The preferred monthly energy reliability objective condition defines an amount of monthly generation from the system that will, at a minimum, be produced. This parameter provides guidance to the model for monthly generation when other constraints such as the preferred reservoir storage objective does not provide sufficient generation to meet the needs of the system. The model meets this condition (defined in acre-feet) from generation at Union Valley Reservoir and subsequent downstream generation facilities. If insufficient water is available at Union Valley Reservoir, the model will schedule water from Ice House and Loon Lake for release into Union Valley so that Union Valley can meet its flow requirement.

Reserve Volume Condition

The reserve volume condition establishes the minimum volume of water to remain in storage for peaking purposes. The model meets this requirement at Union Valley Reservoir, and if necessary will release water from Ice House and Loon Lake reservoirs into Union Valley Reservoir to meet the condition.

Spinning Capacity Condition

The spinning capacity condition defines the amount of spinning reserve capacity (MW) set aside for each powerhouse in the system. The model limits each powerhouse's generation to the powerhouse's maximum generation capability less the amount set aside for spinning reserve. This condition is negated when the condition would otherwise contribute to spills.

Carry Over Elevations Condition

This condition defines the establishment of beginning-of-year reservoir elevations. The model begins an analysis on January 1 of the start year with each reservoir at its preference elevation. A multi-year analysis can either start the subsequent year with the reservoirs at their preference elevations or at the ending elevations of the previous year.

Forecast Set-up Condition

The Water Balance Model can simulate the ability to forecast inflows and use the forecasted inflows to provide an estimate of the sensitivity of system performance to inflow forecast ability.

Water Year Types Condition

This condition identifies the name of an external Microsoft Excel file (e.g., WaterYearTypes.xls) that contains data pertaining to the bypass flows (minimum streamflow release schedules) and the months these schedules are to be implemented for each reservoir. This file must be identified for a scenario.

Preferred Reservoir Storage Objective Condition

This condition identifies the name of an external Microsoft Excel file (e.g., PRSO.xls) containing data for the preferred reservoir storage objective (described by reservoir level elevation) for Loon Lake, Ice House and Union Valley reservoirs. This file must be identified for a scenario if the user would like to use this option. The preferred reservoir storage objective is one of the parameters used by the model to guide reservoir operations through a year. These values, described by year type (different than the year type described for the Water Year Types Condition above) and for the end and mid-point of each month, influence the drawing or gaining of reservoir storage based on the year's water supply condition. The preferred reservoir storage objective is not an absolute objective, but instead works in concert with other objectives to guide a reservoir operation that reduces the potential of spill from the reservoirs.

Physical Settings

Each scenario contains a unique physical setting for each node. The physical setting contains the conditions that can be categorized as physical attributes of the system. The conditions included in a physical setting are described below. All elevation data must be based on a consistent datum (mean sea level, for example) as the model performs head calculations between nodes.

Reservoir Storage Curve Condition

The reservoir storage curve describes the reservoir elevation (feet) versus contents (acre-feet) relationship. The model uses this curve to calculate elevations throughout the day based on inflows and discharges. The reservoir storage curve must extend beyond the flood elevation so that the model has the ability calculate reservoir elevations during times of spill.

Reservoir Area Curve Condition

The reservoir area curve is similar to the storage curve except the relationship is elevation versus surface area (acres). The model uses these data for daily net evaporation loss calculations.

Daily Net Evaporation Condition

The daily net evaporation condition contains daily net evaporation coefficients (feet/day) for each node by month. To calculate net evaporation, the model multiplies each day's surface area by the month's coefficient to get a net evaporation volume (acre-feet) for the day. The net evaporation volume is converted into a flow for the day and is removed from the reservoir evenly throughout the day.

Tailwater Curve Condition

The tailwater curve describes the relationship between tailwater elevation (feet) and the powerhouse discharge (cfs). The model uses this relationship to calculate a tailwater elevation from the instantaneous powerhouse discharge. The tailwater elevation is subtracted from the reservoir elevation to determine the gross head available to a powerhouse unit. If the downstream reservoir elevation is greater than the calculated tailwater elevation, the model uses that downstream reservoir elevation as the tailwater elevation in the gross head calculations.

Spillway Curve Condition

The spillway curve describes the relationship between reservoir elevation (feet) and spillway maximum discharge (cfs). This relationship allows the model to determine the maximum amount of water that can be spilled at a reservoir elevation.

Ramp Rating Curve

The Ramp Rating Curve condition contains the data used to constrain a node discharge with ramping rates. The relationship is river stage (feet) versus flow (cfs) at the point of measured ramping rate compliance. The model uses this relationship to determine the allowable rate of change for the powerhouse's discharge based on river stage. Because it is expressed as a change rather than an absolute elevation, the ramp rating curve elevation data is the one elevation that does not need to be based on the common datum.

Tunnel/Canal Curve

This condition describes the tunnel or gate discharge curve for diversion or non-generating nodes. This condition applies to the Rubicon, Buck Island and Gerle Creek nodes. For the upper two diversion reservoirs, the curve is reservoir elevation (feet) versus tunnel flow (cfs), while for Gerle Creek the relationship is reservoir elevation (feet) versus canal discharge (cfs).

Node Options Condition Overview

The node options condition contains three pieces of information about the individual node. These three data values are: penstock capacity, minimum flow for powerhouse operation, and node operation type.

The penstock capacity describes the maximum amount of flow that can arrive at the powerhouse. UARP tunnel capacities are entered for these values to constrain scheduled generation within the tunnel capacity.

The minimum flow for powerhouse operation is the lowest flow that the powerhouse will use for generation. This value can constrain model discharges to occur only above a certain flow threshold (e.g., for consideration of rough unit operation). Without this data the model will use the full performance range of the units.

The node operation type defines how the model classifies and operates the node. There are seven node operation types: non-generating, peaking, peaking with ramp rates, re-regulating, fill and spill, run-of-river and diversion. Certain nodes are restricted to diversion only due to physical characteristics of the node and model logic for these characteristics. Dan, he wanted to list the six and then have the seventh, diversion, in a separate sentence but it is not structured this way to handle it. I will let you modify.

Non-Generating Node

A non-generating node is a node that does not have a powerhouse but has the ability to control discharges.

Peaking Node

A peaking node includes a powerhouse that can instantaneously peak from no discharge to maximum discharge. It peaks discharges to generate in the peak period, then the secondary-peaks and then the off-peak periods. This powerhouse can have a single-day double peak.

Peaking with Ramp Rates Node

This type of node includes a powerhouse which prioritizes its discharge into the peak periods but is constrained by ramping rates. The powerhouse will not double peak but will ramp up to the peak period daily discharge, remain at constant discharge and then ramp back down to the off-peak period discharge. The powerhouse can be constrained by ramping rates based on stage (feet/time) or flow (flow/time). This node operation type must be selected if the user is investigating ramping rates at a particular powerhouse. Setting the node operating type to "peaking with ramp rates" and describing the ramping rate constraint must occur for the ramping rates to be used.

Re-Regulating Node

A re-regulating node includes a powerhouse that releases a constant discharge for the entire day, ramps to the next day's discharge and releases constant flows again. This type of node is usually found downstream from a peaking powerhouse and oftentimes represents the last powerhouse in the system. This node operating type is also constrained by ramping rates. If there is no ramping rate to apply to the node, an entry of an extremely large ramping rate in the ramping rate constraint condition will negate the constraint.

Fill and Spill Node

A fill and spill node includes a powerhouse that operates like a peaking node except that it is allowed to spill. This type of facility is usually found downstream from a much larger powerhouse. The powerhouse of a fill and spill node may be undersized compared to upstream facilities; thus the fill and spill node is allowed to spill to give priority to the operation of the upstream node.

Run-of-River Node

A run-of-river node matches releases to its inflow on an instantaneous basis. If the node includes a powerhouse, releases can be made up to the maximum of its capacity or inflow, and spills any excess.

Diversion Node

A diversion node does not have a powerhouse and cannot control its discharge. These nodes do not use the load shape to control their releases. Discharge is based on reservoir elevation. Rubicon, Buck Island and Gerle Creek are examples of diversion nodes.

Operation Settings

Similar to the physical settings, operational settings are node specific. Each scenario contains one operation setting for each node. The operation settings contain conditions that define how the node is operated: reservoir elevation constraints and required flow releases. The conditions for operation settings are described below. When described, all elevations are in units of “feet,” and should be based on the same datum as the physical settings.

Flood Elevation Condition

The flood elevation is the elevation at which a reservoir begins to spill. The elevation can relate to a variety of physical situations (spillway crest, partial gate coverage, etc.), and will describe the reservoir elevation at which the model determines that a spill will occur. When the model calculates an elevation above the flood elevation, the model will calculate spill. For nodes with gates that control the spillway discharge, the flood elevation should be the elevation at which operators start spilling to prevent overtopping. For reservoirs with uncontrolled spillway crests, the flood elevation is the spillway crest elevation. The user may enter flood elevations that vary through the year. The reservoir storage curve needs to extend beyond the flood elevation so that the model has the ability to calculate reservoir elevations during times of spill. The model’s logic attempts to reduce or eliminate occurrences of spill when the reservoir elevation exceeds the flood elevation.

Target Elevations Condition

The target elevations are the reservoir elevations at which the model tries to operate the reservoir during the year. These elevations can change each day and the model attempts to end each day at the target elevation. The target elevations should be less than the flood elevations and greater than the minimum elevations. The target elevations condition and the preferred reservoir storage objective condition cannot concurrently guide operations for Loon, Ice House and Union Valley reservoirs. The preferred reservoir storage objective condition takes precedent for these three reservoirs.

Minimum Elevations Condition

The minimum elevation condition describes the minimum allowable reservoir elevation. The elevation can represent a regulation or a physical limit (e.g., lowest available outlet invert). The model will not provide an operation where the reservoir elevation drops below this elevation. This elevation should be lower than the flood elevations, target elevations, and preferred reservoir storage objective elevations.

Water Withdrawal Condition

The water withdrawal condition allows the user to model water removal and return at a node. This operation can represent diversions for irrigation and municipal water use. The model allows the user to enter a daily withdrawal rate (cfs) that is constant throughout the year and a daily discharge rate (cfs) that is constant throughout the year. The model calculates a net withdrawal and accounts for this withdrawal each day.

Fluctuation Limits Condition

Fluctuation limits describe the maximum allowable change in reservoir surface elevation, from maximum elevation to minimum elevation, within a single day. In addition to setting the maximum fluctuation for the day, the limits can be described as "hard" limits. Hard fluctuation limits reset the flood and minimum elevations based on the fluctuation limits and the target elevation. With hard limits the user enters a percentage of the fluctuation limit that is above the target and the model calculates the percentage that is below the target. This type of control allows the model to follow target elevations closer. The difference between hard level fluctuation limits and regular limits is that a hard limit will force the model to spill if the upper limit is exceeded.

Fluctuation Rates Condition

Fluctuation rates are similar to the fluctuation limits except fluctuation rates define the maximum rate of change in reservoir surface elevation. If the node has fluctuation rates (feet/hour) the reservoir operation may be constrained thus leading to a less aggressive powerhouse peaking operation.

Minimum Instantaneous Flow Condition

Minimum instantaneous flows are flows that must be released either through a low level outlet or through a powerhouse to the stream 24 hours a day. The model will meet this requirement before scheduling any excess water in the peak period.
Minimum instantaneous flow can be based on natural inflows to a node in the system. This constraint can be set to an "or inflow" option. The "or inflow" option sets the minimum instantaneous flow equal to the lesser of the user defined flow or the total natural inflow into the node.

Minimum Daily Average Flow Condition

The minimum daily average flow condition represents the minimum volume, defined as a daily average flow (cfs), that the node must release for the day. This constraint can be set to an "or inflow" option. The "or inflow" option sets the minimum daily average flow equal to the lesser of the user defined flow or the total natural inflow into the node.

Bypass Flow Condition

The bypass flow condition describes flows that are released into bypass reaches that normally go around the powerhouse. The values typically represent minimum streamflow release requirements. Bypass flows are not available for generation unless routed through a minimum flow unit. These flows have units of "cfs" and the flow is released as a constant flow for the entire day. A destination node for the flow, which could be a lower reservoir or a destination out of the system, is also defined. The minimum bypass flow can be defined to be the lesser of the user-defined flow or the total natural inflow.

Ramping Rates Condition

The ramping rate condition constrains the rate of change allowed to a powerhouse's discharge. This constraint is only used if the node operations type is set to "peaking with ramp rates" or "re-regulating." Separate rates for increasing discharges and decreasing discharges can be defined along with separate ramping rates for hourly and daily ramping. The ramping rates can be defined as the allowable change in river stage per time (feet/hour and feet/day) or flow per time (cfs/hour and cfs/day). When ramping rates are defined as stage versus time, the relationship is defined by the ramp rating curve in the physical setting. Flow based ramping rates do not require that the entry of a ramp rating curve.

Flashboards Condition

The flashboard condition allows the user to simulate the installation and removal of flashboards. Currently the parameters that trigger the installation and removal of flashboards are: day, flow and elevation. Flashboards can be located on the spillway, as is the case with most projects or in the tunnel as is the case with Rubicon and Buck Island. Along with defining the installation and removal of the flashboards, the flashboard condition contains the discharge curve (flow versus elevation) for the outlet when the flashboards are installed.
Additional specialized logic is incorporated into the model to simulate the flashboard operation at Buck Island Reservoir. The operation is dependent on the inflows to Rubicon Reservoir and flashboard installation at Rubicon Reservoir.

Generation Settings

Generation settings are node specific and contain the data necessary to simulate power generation. The data includes turbine performance, generator performance, headloss data, gate leakage, and maintenance scheduling.

Turbine-Generator Condition

The turbine generator-condition describes each turbine-generator in the powerhouse. Performance characteristics such as the efficiency of the turbine and generator, headloss and gate leakage are included in this condition.

Headloss Component

Two common headloss coefficients for the powerhouse and an individual coefficient for each unit are available.

Turbine Component

Turbine performance is entered by node with performance data assigned to a particular powerhouse unit. Each turbine performance data set can be assigned to multiple units. If the powerhouse has three identical units, the performance data set is only entered once.

Generator Component

The generator data, like the turbine data, is defined by node and then associated with a powerhouse unit. If the powerhouse has three identical generators, the performance data need only be entered once. The generator performance data is generator output versus generator efficiency. The generator condition also includes a maximum generator output. This value is the maximum generator output the model will allow assuming that there is turbine capacity to meet this limit. This feature allows the user to limit generator outputs if other auxiliary equipment can not handle maximum generator output. The model will limit turbine output based on the generator maximum desired output.

Gate Leakage Component

Gate leakage is the amount of water that leaks through the wicket gates when the turbine is off-line. The model leaks this amount of water when that unit is off-line. For instance if the powerhouse has three units each with gate leakage of 15 cfs, if units 1 and 2 are operating and unit 3 is off-line, then only unit 3 is leaking 15 cfs. When a unit is out for maintenance, the gate leakage for that unit is assumed to be zero.

Maintenance Schedule Condition

The maintenance schedule condition describes when specific powerhouse units are out of service. The inclusion of systematic maintenance can be simulated. The maintenance schedule allows the removal of a single unit from service at a time.

Minimum Flow Unit Condition

The minimum flow unit condition defines low-level outlet generating units. This condition contains the necessary data to calculate the energy generated by a minimum flow unit. This condition requires headloss, generator performance, turbine performance and rated net head data for the minimum flow unit.

There are two types of Minimum Flow units. The first type operates 24 hours a day and uses the bypass flows as its flow source. The second type operates during those periods when the main powerhouse is not running.

Unit Dispatch

The model uses the unit dispatch to predict generation based on the user-defined turbine-generator data. The purpose of the unit dispatch is to produce a matrix (lookup table) where powerhouse generation is plotted against gross head and total powerhouse flow. The lookup table is only created once for each turbine-generator condition.

The first step of the process is to generate a unit dispatch table to describe the best way to distribute powerhouse discharge between units. This step results in the optimal unit dispatch solution. The unit dispatch logic begins with very small flows through the powerhouse. The routines calculate the optimal unit dispatch for each small flow. The rough estimate of the individual unit distribution is fine-tuned using partial differential equations to arrive at an optimal distribution for the given flow. The fine-tuning process incrementally adds and subtracts flow from the units to hone in on the maximum possible generation for the given total powerhouse discharge. As the dispatch routine increases the total flow through the powerhouse the model uses the previous unit dispatch distributions as well as new distributions to find the largest possible generation given the flow through the powerhouse. In this way the model is using previous solutions to "learn" about future solutions. The final result is a collection of flow distributions by unit for the entire range of powerhouse discharge flows. When provided total powerhouse discharge and gross head, the model uses the matrix to determine generation.

Daily Time Step Sequence

The final program output can be a 15-minute, detailed schedule of node operation. Prior to creating the 15-minute operation, there are several intermediate steps which must be performed by the model. First, monthly operational objectives such as target elevations and preferred monthly energy reliability objective conditions must be translated to daily operation objectives. The methodology for translating data from monthly to daily objectives will vary depending upon the parameter. For example, the model linearly interpolates between the use-defined target elevations to compute the daily target elevation objectives, and preferred monthly energy reliability objective volumes are computed for each day by equally distributing the monthly volume over each day of the month.

Once the daily objectives have been calculated, the operation at the node is evaluated on a daily time step. The first priority is to set the minimum bypass or flow constraints at the node. Next, the net evaporation is subtracted from the inflow. Based on the remaining inflow to the node, and the release, storage and other constraints at the node, the discharge is computed. The discharge is the release from a penstock, canal or tunnel. Once the daily discharge has been calculated that meets the daily constraints, the model will break down the operation into a 15-minute time step, distributing the discharge throughout the day based on the load shape and other hourly operation constraints supplied by the user. This section will detail the method used to compute the daily discharge values.

Retrieval of Constraint Data

The first step in the node loop is to retrieve the constraints for that node for that day. The model calculates the target elevation, minimum flows, bypass flow, water withdrawals, and other node constraints. All characteristics for that node, for that day, that is day specific, are calculated and loaded into the model logic.

Sum of Inflows

With the daily constraint data loaded into the model, the model retrieves the upstream node's discharges for the day, local accretions, bypass flows and spill flows that will arrive at that node. The model sums these inflows and calculates a detailed 15-minute inflow profile for the node.

Daily Discharge Calculation

After the model determines the inflow volume for the node it calculates a daily average discharge. The daily average discharge is a function of the total daily inflow, forecasted project inflows, target elevations, release capacity (powerhouse, tunnel or canal) and minimum release requirements.

With the daily discharge calculated, the model checks the discharge against daily constraints such as minimum daily average flows, minimum instantaneous flows, downstream requirements and minimum and flood elevations. Adjustments are made to the daily average discharge as necessary to meet the node constraints.

Fifteen-Minute Time Step

Once the daily average flows have been set, the model schedules the node's 15-minute discharge. The first priority is to meet the minimum instantaneous flow for the node. This minimum instantaneous flow volume is removed from the volume available for peaking purposes. All daily constraint flows were accounted for in the derivation of the daily discharge volume. The primary guide for the 15-minute schedule is the filling of the load shape.

Discharge Priorities Based on Load Shape

The load shape contains the period-durations for both weekdays and weekends for each month. The model uses this data to create the 15-minute schedule along with the powerhouse's peak unit capacities. The model allocates the peaking volume of water into the peak periods first, the secondary peak periods and finally the off-peak periods. The model attempts to operate the units at peak efficiency in order to maximize the generation for the period.

If the powerhouse has ramp rates the model will schedule the powerhouse to not violate the ramp rate constraints. If the node is a re-regulating type the model will schedule a flat discharge, characteristic of a re-regulating facility. If the node is a run-of-river type, the model will schedule discharges to match the inflows.

Constraint Checking

After the peaking volume has been scheduled, the model calculates 15-minute reservoir elevations based on the 15-minute inflows and discharges. Reservoir elevations are checked for reservoir constraint violations. If violations are found, the model will incrementally shift water either at the current node or the upstream node to remove reservoir violations. When the violations are eliminated the model proceeds to the next downstream node.

MODEL LOGIC AND SCHEDULING FLOW CHART

The following figure is an overview of scenario development and model execution. The top section shows the basic steps followed when creating a new scenario. The bottom section describes the steps followed when making a model run. Between the two sections, the Water Balance Model database is shown. The database serves as the repository for the model input behind each scenario.