South Sutter Water District's Operations Model Documentation and Validation Report

OPERATIONS MODEL DOCUMENTATION AND VALIDATION

CAMP FAR WEST HYDROELECTRIC PROJECT
FERC Project No. 2997

SECURITY LEVEL: PUBLIC

Prepared by
South Sutter Water District
2464 Pacific Ave.
Trowbridge, CA 95659

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EXECUTIVE SUMMARY

South Sutter Water District (SSWD) developed a water and power operations model (Operations Model or Ops Model) of Camp Far West Reservoir and associated hydropower and irrigation facilities. The Ops Model is a tool to examine water supply and hydropower generation under a variety of hydrologic and operational conditions. The Ops Model was developed to meet the following goals:

1. It can be used by all interested Relicensing Participants during the relicensing to simulate current and potential future operations of the Camp Far West Hydroelectric Project (Project).
2. All Relicensing Participants have an opportunity to review the Ops Model and conclude that it is reasonably reliable for these purposes.
3. Relicensing Participants agree to use this single Ops Model to make relicensing recommendations.

The Ops Model addresses operational decisions, including stream flow requirements, water supply, recreation, and hydropower generation. The Ops Model simulates operations subject to the physical constraints of the Project, including maximum and minimum reservoir, outlet, and powerhouse capacities. Ops Model logic focuses on operations of Camp Far West Reservoir. The Ops Model simulates operations at Camp Far West Dam and the non-Project diversion dam located 1.3 miles (mi) downstream of Camp Far West Dam. Diversions into SSWD's Conveyance Canal and Camp Far West Irrigation District's (CFWID) North Canal and South Canal are simulated at the non-Project diversion dam. Irrigation diversions are based on estimated agricultural demands and simulated allocations. The Ops Model also includes a representation of the Bear River downstream of the diversion dam to the confluence of the Bear and Feather rivers. Three additional stream nodes are located downstream of the diversion dam: Bear River at Wheatland (flow gage); Bear River at Pleasant Grove Road; and the Bear River at the confluence with the Feather River. Table ES-1 provides a summary of output available from the Ops Model and Figure ES-1 is an overview of the Project, SSWD, CFWID, and Ops Model nodes.

Table ES-1. Summary of Ops Model nodes and outputs.

Project Nodes		Nodes below Project	
Model Node	**Model Output**	**Model Node**	**Model Output**
Camp Far West Reservoir	Storage and elevation	CFWID North Canal	Diversion
Camp Far West Powerhouse	Generation and release through turbine	CFWID South Canal	Diversion
Camp Far West Dam	Release from low-level outlet and spillway	SSWD Main Canal	Diversion
		Non-Project Diversion Dam	Estimated flow below dam
		Bear River at Wheatland	Estimated flow
		Bear River at Pleasant Grove Road	Estimated flow
		Bear River at Feather River	Estimated flow

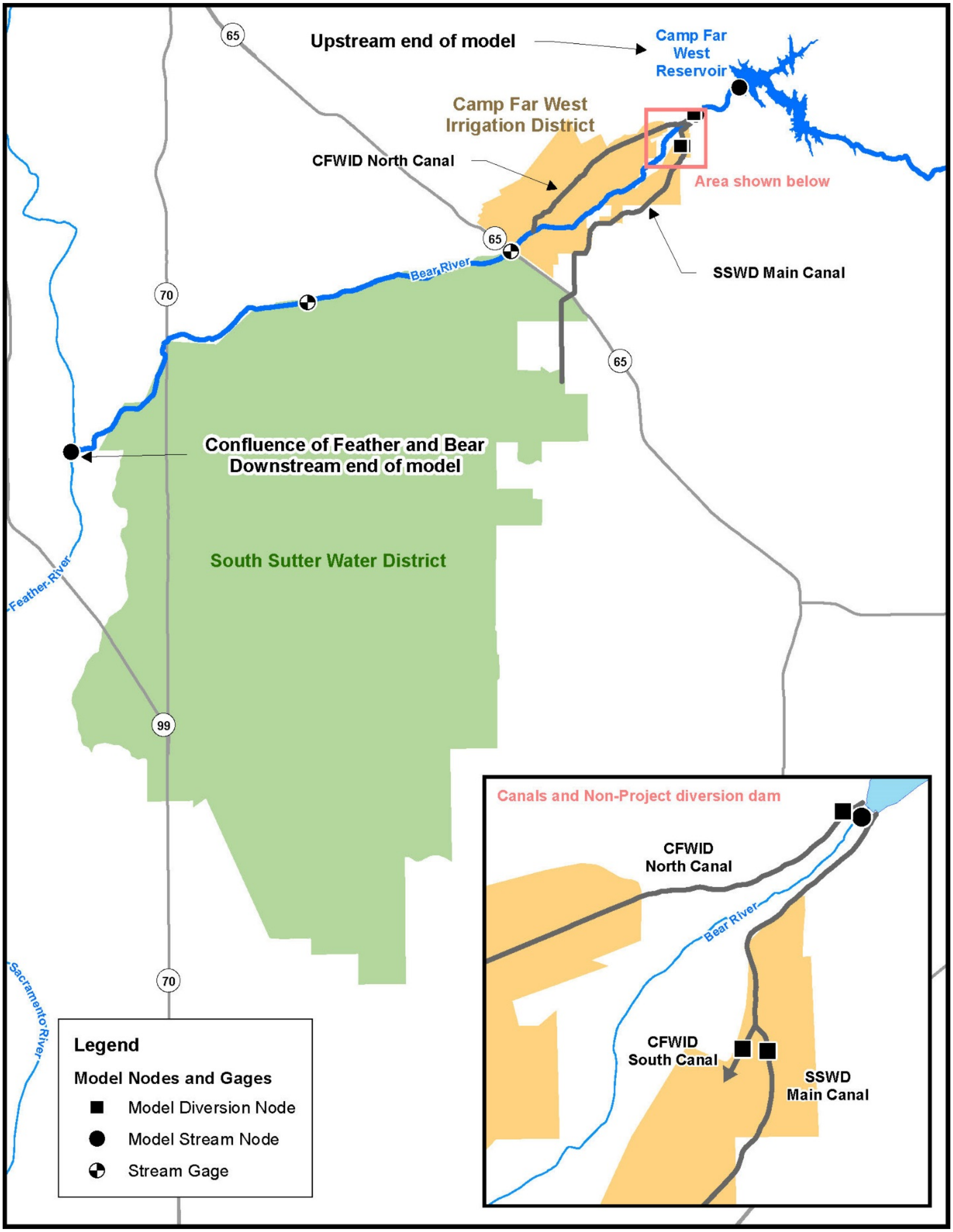

Figure ES-1. Camp Far West Hydroelectric Project, SSWD, CFWID, and Ops Model nodes.

The Ops Model simulates operations on a daily time-step for 39 years of historical hydrology from water year (WY) 1976 through WY 2014. This period covers a range of hydrologic conditions and includes both the driest (1977) and wettest (1983) years on record, based on total annual inflow to Camp Far West Reservoir. The period also includes three multi-year periods of below average inflow: 1976 through 1977; 1987 through 1992; and 2012 through 2014.

The Ops Model is a Microsoft™ Excel spreadsheet. Microsoft™ Excel was selected as Ops Model platform for several reasons, including availability to Relicensing Participants, transparency of model logic and operations, flexibility in developing operational rules, and existing familiarity with spreadsheets for most Relicensing Participants. The Ops Model allows user-defined variables to be changed and different operations to be evaluated. Ops Model operational logic is transparent and editable.

The Ops Model includes preliminary WY types based on WY types proposed for Nevada Irrigation District's (NID) Yuba-Bear Hydroelectric Project (FERC No. 2266) and Pacific Gas and Electric's (PG&E) Drum-Spaulding Project (FERC No. 2310), collectively the Yuba-Bear/Drum-Spaulding (YB/DS) Projects. WY types are used in the Ops Model for reporting model results and to evaluate potential operational decisions. SSWD may re-evaluate these WY types based on information developed during Relicensing.

The Ops Model was developed and validated with inputs designed to represent historical operations and historical inflow. The Ops Model was then used to develop two separate baseline simulations representing Near-Term and Future Conditions, and YB/DS Projects operations and demands. The YB/DS Projects is currently in the process of being relicensed, and the Federal Energy Regulatory Commission (FERC) issued a Final Environmental Impact Statement (FEIS) in December of 2014. Therefore, upstream operations are expected to change in the near future and those changes will affect inflow into Camp Far West Reservoir and SSWD's operations. Inflow into Camp Far West Reservoir was provided by HDR Engineering Inc., consultant to NID and PG&E for relicensing, based on a model of the YB/DS Projects. Two different inflow scenarios are included in the Ops Model. The first scenario, Near-Term Condition, assumes YB/DS Projects' operations with assumed new FERC license requirements based on the FERC-issued FEIS for both projects (FERC 2014) and the current level of development upstream. The second scenario, Future Condition, assumes YB/DS Projects operations with assumed new FERC license requirements and a future level of development upstream. Both the Near-Term and Future Conditions include Camp Far West operations representative of how SSWD currently operates the Project, and include all current physical, regulatory, and contractual constraints.

The Ops Model was validated by comparison with observed data from WY 1996 through WY 2014. This report includes comparisons of simulated results and observed data for the entire simulation period for informational purposes. Recent years are used for validation because SSWD operations have changed during the 39-year simulation period, most notably after 2000. For this reason a separate simulation period was used for model validation. The validation model also includes limited water transfers that occurred during the validation period.

SECTION 1
INTRODUCTION

The purpose of this report is to document and explain Ops Model assumptions and logic, demonstrate the Ops Model reasonably simulates current Project operations, and that it is appropriate (i.e., valid) for use in the FERC relicensing process. The Ops Model will be used to simulate scenarios that may be pertinent to new license operating conditions. The Ops Model was developed with the purpose to provide a flexible tool that could be adapted to simulate a variety of potential conditions.

This report explains and documents the data, assumptions, and logic used to simulate SSWD's operation of Camp Far West Dam and Powerhouse on the Bear River. A spreadsheet model was developed to simulate operations and resulting releases and diversions for studies during the relicensing process. The Ops Model simulates 39 years of hydrology from WY 1976 through WY 2014 on a daily time-step and provides daily results for reservoir release, hydropower generation, and diversions for irrigation at a non-Project diversion dam located 1.3 mi downstream of Camp Far West Dam.

The first sections of this report provide background information on the Bear River, the SSWD's facilities, and agreements and requirements that govern operation of Camp Far West Reservoir. Subsequent sections describe the data and assumptions used to simulate operations in the Ops Model. The report includes a comparison of Model results and recently observed operations as a validation of the Ops Model assumptions and logic.

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SECTION 2
BEAR RIVER WATERSHED

The Bear River basin is located on the western slope of the Sierra Nevada and is bounded by the Yuba River basin to the north, the American River basin to the south, and the Feather River basin to the west. The Bear River originates near Emigrant Gap in Nevada County at an elevation of approximately 4,900 feet (ft), and then flows southwesterly for approximately 75 miles to its confluence with the Feather River northeast of the town of East Nicolaus, California (CA), at an elevation of approximately 50 ft. The Bear River drains approximately 400 square miles in Yuba, Nevada, Sutter, and Placer counties. Figure 2.0-1 is an overview of the Bear River watershed, divided by hydrologic units as defined by the United States Geological Survey (USGS).

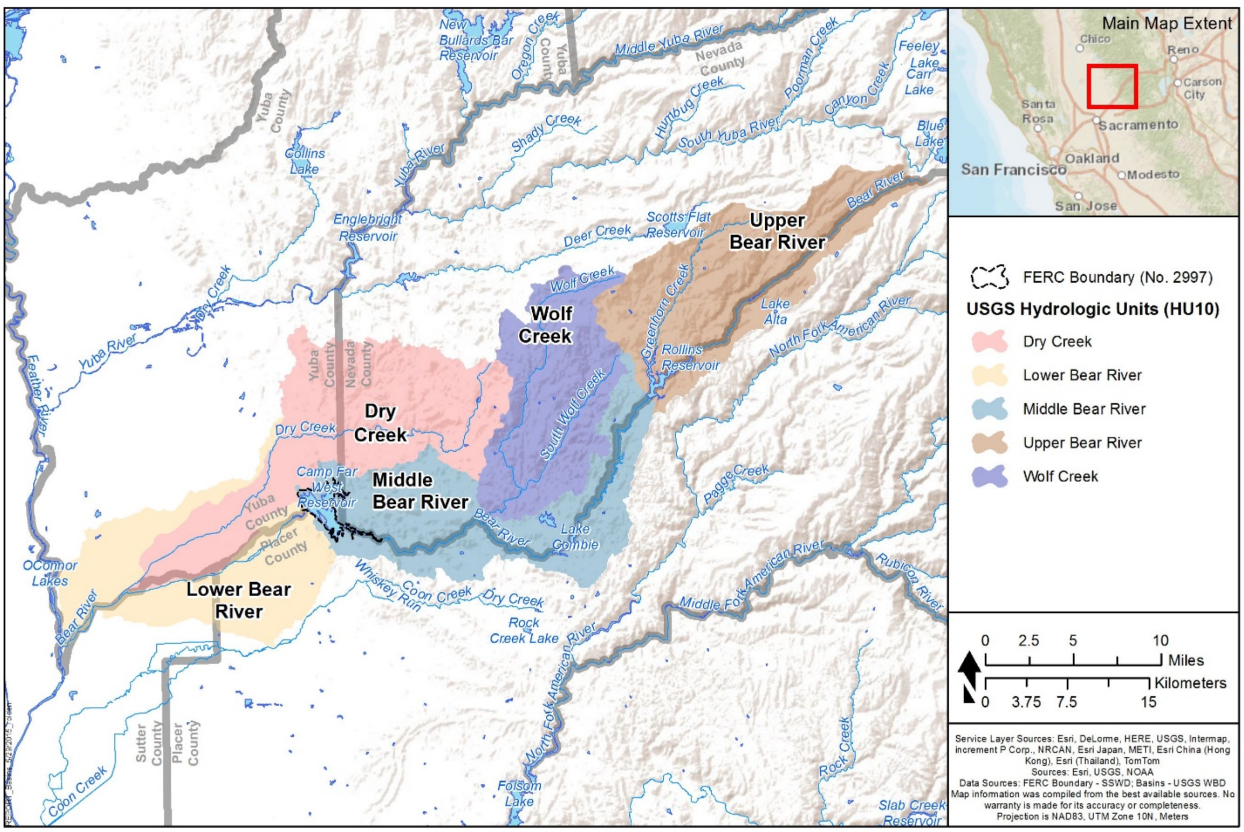

Figure 2.0-1. Bear River Watershed.

Upstream of Camp Far West Reservoir are two large projects: Nevada Irrigation District's (NID) Yuba-Bear Project and Pacific Gas and Electric's (PG&E) Drum-Spaulding Project. These are collectively referred to as the Yuba-Bear/Drum-Spaulding (YB/DS) Projects.

PG&E's 190-MW Drum-Spaulding Project, FERC Project No. 2310, is located on the South Yuba River, Bear River, north fork of the North Fork American River, and tributaries to the

Sacramento River Basin in Nevada and Placer counties, CA. Major project reservoirs include Lake Spaulding (74,773 acre-feet [ac-ft]) on the South Yuba River, and Fordyce Lake (49,903 ac-ft) on Fordyce Creek. The Drum-Spaulding Project includes numerous smaller reservoirs on tributaries to the South Yuba River, as well as diversions from the South Yuba River to Deer Creek via the South Yuba and Chalk Bluff canals (maximum capacity of 107 cubic feet per second [cfs]), and to the Bear River via the Drum Canal (840 cfs).

NID's 79.3-MW Yuba-Bear Hydroelectric Project, FERC Project No. 2266, is a water supply/power project constructed in the 1960s, though some Project facilities were initially constructed in the late 1800s. The Yuba-Bear Hydroelectric Project includes Jackson Meadows Reservoir on the Middle Yuba River with a gross storage capacity of 69,205 ac-ft, five storage reservoirs on Canyon Creek (Jackson, French, Faucherie, Sawmill, and Bowman) with a combined gross storage capacity of 90,790 ac-ft, and Rollins Reservoir on the Bear River with a gross storage capacity of 58,682 ac-ft. The Yuba-Bear Project also includes a diversion via the Milton-Bowman Diversion Dam from the Middle Yuba River to Bowman Lake on Canyon Creek (maximum capacity of approximately 450 cfs), and a diversion via the Bowman-Spaulding Canal (maximum capacity of approximately 300 cfs) from Bowman Lake on Canyon Creek to PG&E's Lake Spaulding on the South Yuba River. NID also owns and operates Lake Combie on the Bear River. Van Geisen Dam, that forms Lake Combie, was originally constructed in 1928. Lake Combie has a gross storage capacity of 5,555 ac-ft. From the Van Giesen Dam, the Bear River flows another 13.8 mi until it reaches Camp Far West Reservoir at approximately river mile (RM) 23.4.

The YB/DS Projects import water into the Bear River watershed from the Yuba River, and export water from both the Yuba and Bear River watersheds into the American and Sacramento River watersheds. The operations of these projects have a significant effect on the timing and magnitude of inflow into Camp Far West Reservoir. Additional information on the Bear River watershed can be found in Section 3.1 of the Pre-Application Document (PAD).

The USGS has maintained gage 11424000, Bear River at Wheatland, at RM 11.5 since 1929. This gage is located downstream of Camp Far West Dam and the non-Project diversion dam used to divert water to SSWD and CFWID. Figure 2.0-2 illustrates the annual flow, by WY, of the Bear River at Wheatland for the entire gage record. The simulation period for the Operations Model, from WYs 1976 through 2014, is highlighted. The long-term average annual flow at this location is approximately 292,000 ac-ft. By comparison, the average annual flow for the simulation period is approximately 273,000 ac-ft.

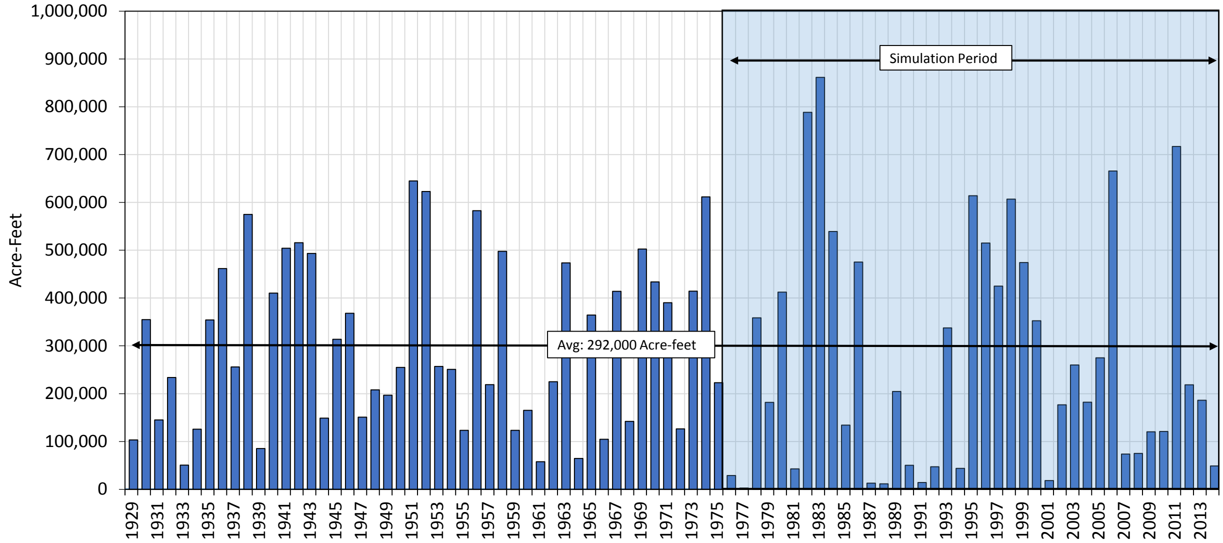

Figure 2.0-2. USGS Bear River at Wheatland.

Figure 2.0-2 illustrates the variability in Bear River flow and the range of annual volumes that have occurred historically.

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SECTION 3
SOUTH SUTTER WATER DISTRICT

South Sutter Water District was formed in 1954 as a conjunctive management district. SSWD constructed Camp Far West Dam in 1964 to create the reservoir and provide a surface water supply to its members. Prior to the development of Camp Far West Reservoir as a surface water supply, all irrigation relied on groundwater, and aquifer levels were in decline. Since the development of a surface water supply, groundwater levels have stabilized. The primary crop grown in the SSWD service area is rice. Other crops include fruit from orchards, as well as pasture and field crops. The SSWD service area covers approximately 66,000 acres, of which approximately 45,000 is planted in any given year.

SSWD operates Camp Far West in compliance with their existing FERC license, water rights issued by the State Water Resources Control Board (SWRCB), and several agreements. Water released from Camp Far West Dam through any of its three outlets flows downstream into an impoundment behind a non-Project diversion dam located 1.3 mi downstream from Camp Far West Dam. During the irrigation season SSWD installs flashboards on the crest of the diversion dam to increase the water surface elevation (WSE) in the impoundment and control the diversion of water into canals. Water is diverted into CFWID’s North Canal and SSWD’s Conveyance Canal at the non-Project diversion dam. SSWD’s Conveyance Canal bifurcates approximately 0.8-mi down-canal from the diversion dam into CFWID’s South Canal and SSWD’s Main Canal. From the non-Project diversion dam, the Bear River flows another 16.9 mi to where it empties into the Feather River.

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SECTION 4
OVERVIEW OF CAMP FAR WEST OPERATIONS

SSWD operates Camp Far West Reservoir as a water supply reservoir. Incidental to water supply, other operational benefits include environmental flows, hydropower, and recreation. The reservoir is typically operated on an annual basis with little or no carryover storage. The reservoir fills and spills in most years. There is no required flood control space in Camp Far West Reservoir so SSWD stores water when available and fills the reservoir as soon as possible each year.

Camp Far West Reservoir has three outlets: an ungated spillway, a 96-in. power outlet leading to the hydroelectric turbine, and a 48-in. low-level bypass outlet. The spillway has a crest elevation of 300 ft. Water will pass over this outlet when the WSE exceeds this level. The power outlet has an intake with a sill elevation at 197 ft. Hydropower generation is incidental to water supply (i.e. water will only be run through the turbines if there is demand for it downstream or the reservoir is spilling). When downstream water demands are such that the required release cannot be run through the turbine, a low-level bypass is used to make releases. The low-level outlet has an intake with an invert elevation at 175 ft.

When originally constructed, the capacity of Camp Far West Reservoir was approximately 104,600 ac-ft. An updated bathymetric survey completed in 2008 found sedimentation reduced the capacity to approximately 93,740 ac-ft.

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SECTION 5
OPERATIONS MODEL OVERVIEW

A model was developed to simulate the operations of Camp Far West Reservoir, including hydropower generation, canal diversions, and downstream flows. The Ops Model uses a daily time-step over 39 years of historical hydrology, from WYs 1976 through 2014. This hydrologic period was chosen due to the availability of historical data. This period is a good sample of the range of hydrologic conditions the Bear River experiences (see Figure 2-2), and includes both the wettest WY (1983) and driest WY (1977) on record. The Ops Model extent is the Bear River from the inflow to Camp Far West Reservoir downstream to the confluence with the Feather River.

The Ops Model is represented as a series of nodes over which mass balance is calculated and maintained. Ops Model nodes are key locations where flows may change due to operations, or locations with observed data that were used for model validation. See Table ES-1 for a summary of Ops Model nodes.

Microsoft™ Excel was chosen as the Ops Model platform for flexibility and transparency in implementing operational criteria. Additionally, Excel is a widely understood platform so Relicensing Participants should be able to review and understand model logic without need for training in specialized software.

The following sections describe the inputs, assumptions, and model operations. The Ops Model is generally described from upstream to downstream. Reservoir operations are described in order of the release priority.

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SECTION 6
INFLOW

Inflow into Camp Far West Reservoir is primarily from the Bear River with additional contributions from local streams including Rock Creek. Upstream YB/DS Projects' operations influence Bear River flow into Camp Far West Reservoir. FERC relicensing and other potential changes in YB/DS Projects' operations are expected to affect inflow to Camp Far West Reservoir in both the near and long-term. Therefore, the Ops Model includes the following three time-series of daily inflows:

- Calculated, historical inflow
- Simulated inflow for YB/DS Projects operations with assumed new FERC license requirements and existing demands (Near-Term Condition)
- Simulated inflow for YB/DS Projects operations with assumed new FERC license requirements and future demands (Future Condition)

Calculated, historical inflow was developed for the purpose of model validation and for comparison with simulated inflows as a general check of the upstream model. Near-term and Future Conditions inflows were developed by HDR Engineering Inc. using the upstream YB/DS Projects' model developed during relicensing of those projects (DTA 2008).

6.1 Historical Inflow

Historical inflow was calculated through mass balance at Camp Far West Reservoir with historical storage and outflow data from SSWD. The following equations were used to calculate inflow for each time-step, *t*.

Equation 1: Reservoir Net Inflow Calculation

$$Net\ Inflow_t = Outflow_t + Storage_t - Storage_{t-1}$$

Net inflow includes the effects of precipitation on the reservoir and evaporation from the reservoir. Therefore, net inflow is adjusted to account for these effects.

Equation 2: Reservoir Inflow Calculation

$$Inflow_t = Net\ Inflow_t + (Evaporation_t - Precipitation_t)*Reservoir\ Surface\ Area_t$$

Calculated daily inflow can vary significantly from one day to the next and be a negative value on some days. These variations are frequently caused by inaccuracies in storage and outflow data. It is typical practice to adjust or smooth daily reservoir inflow calculations by averaging daily values. Calculated, daily inflow used in the Ops Model is a 5-day rolling average of the daily calculated values. Additionally, if the 5-day average resulted in a negative value, it was assumed inflow was zero.

Figure 6.1-1 shows the annual historical inflow, by WY, for the 39-year simulation period. The average annual inflow during this period was 380,000 ac-ft, with a maximum inflow of 1,049,000 ac-ft in WY 1983, and a minimum of 18,700 ac-ft in WY 1977.

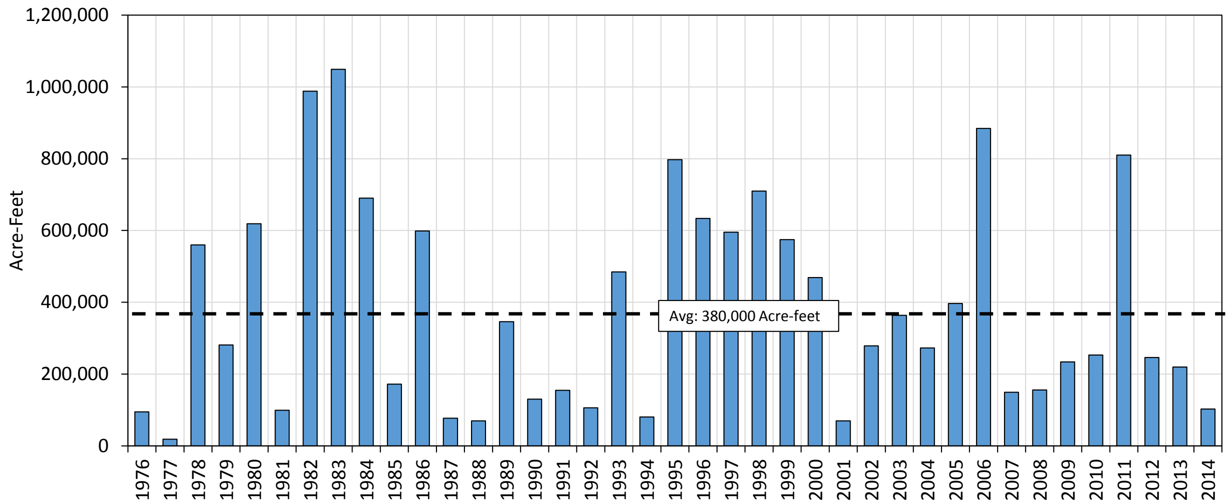

Figure 6.1-1. Historical inflow.

6.2 Near-Term Condition

Inflow in the Near-Term Condition is similar to historical inflow. The average annual inflow in the Near-Term Condition is 320,000 ac-ft, approximately 60,000 ac-ft less than the historical inflow. Figure 6.2-1 is a comparison of the annual inflow, by WY, for the historical and Near-Term Condition.

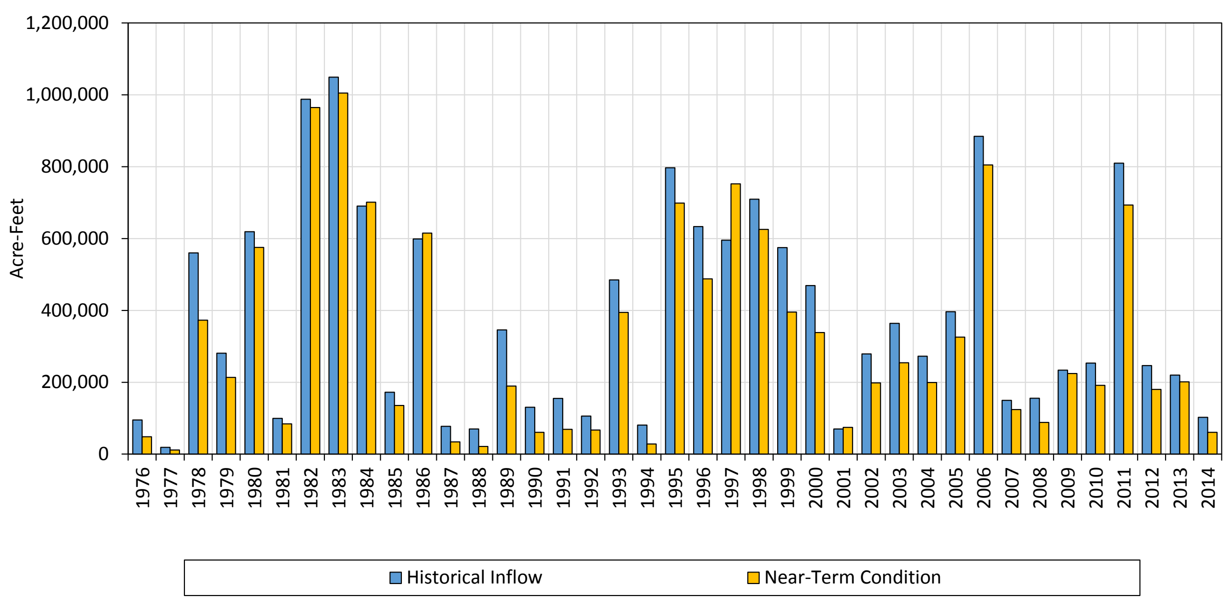

Figure 6.2-1. Comparison of historical and simulated Near-Term Condition inflow.

Differences between the historical inflow and the Near-Term Condition occur for several reasons. First, the Near-Term Condition is a simulated inflow based on available hydrologic and operational data, but it is not intended to exactly match historical operations. Second, the Near-Term Condition represents an existing level of demand in the upstream watershed that did not exist throughout the historical period. Upstream demands increased during the historical period to reach the existing level only near the end of the 39-year period. Finally, the Near-Term Condition represents YB/DS Projects' operations under the expected new FERC license conditions, not the previous FERC license conditions in place historically. Generally, new FERC license conditions require higher flows downstream of YB/DS Projects facilities that reduce the volume of water imported from the Yuba to the Bear watershed.

6.3 Future Condition

Inflow in the Future Condition is also generally similar to, but less than, historical inflow. The average annual inflow in the Future Condition is 292,000 ac-ft, approximately 88,000 ac-ft less than the historical inflow. Figure 6.3-1 is a comparison of the annual inflow, by WY, for the historical and Future Condition.

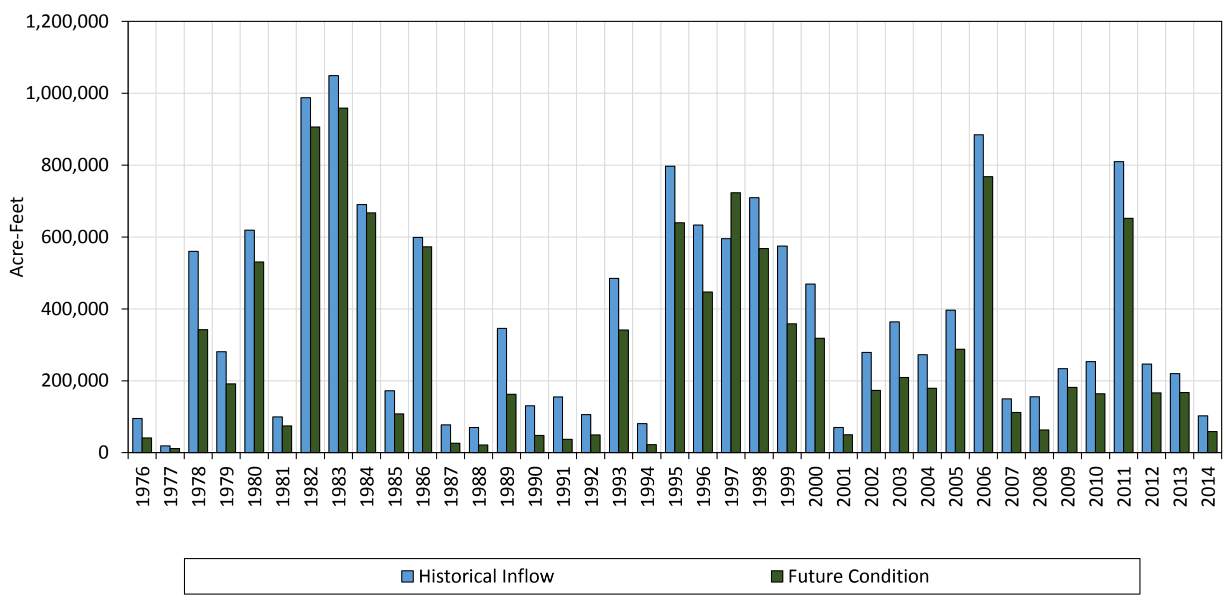

Figure 6.3-1. Comparison of historical and simulated Future Condition inflow.

Differences between the historical inflow and the Future Condition occur for the same reasons as between the historical and the Near-Term Condition. Additionally, the Future Condition includes higher upstream consumptive demands in the YB/DS Projects that further reduce inflow to Camp Far West.

6.4 Unimpaired Bear River Flow

Unimpaired flow of the Bear River at Camp Far West Dam was also developed by HDR Engineering Inc. The daily time-series of unimpaired flow are also included in the Ops Model and used in the inflow forecast procedure. Figure 6.4-1 is the annual volume, by WY, of estimated unimpaired flow of the Bear River at Camp Far West Dam.

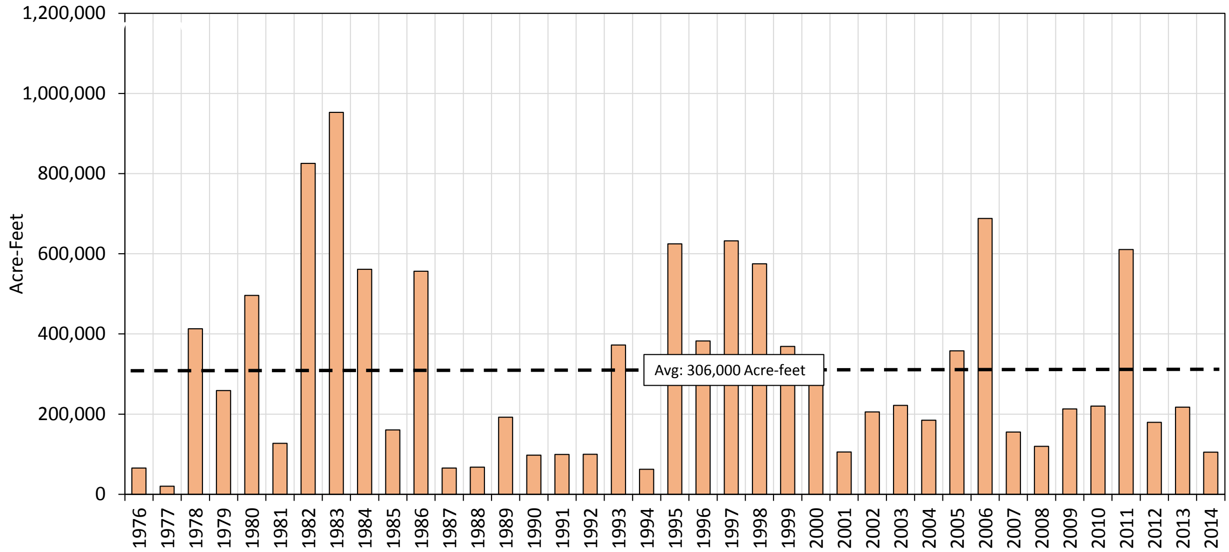

Figure 6.4-1. Estimated unimpaired Bear River flow.

SECTION 7
CAMP FAR WEST RESERVOIR OPERATIONS

The majority of the Ops Model logic focuses on the operation of Camp Far West Reservoir. The following sections describe model operations to meet minimum flow requirements, water supply, and generate hydropower.

The Ops Model includes the physical constraints of Camp Far West Dam and Reservoir. The Ops Model uses the most recent (2008) bathymetry data for the elevation-area-capacity and includes the physical capacity constraints for releases through the three outlets at the dam.

7.1 Required Minimum and Downstream Flows

Regulatory requirements for Bear River flows downstream of Camp Far West Dam include minimum instream flows and Bay-Delta Settlement Agreement (BDSA) releases.

7.2 Minimum Flows

The current minimum flow requirement is specified in SSWD's water rights for both power and consumptive uses, and in Article 29 of the current FERC license. Minimum flows are 25 cfs from April 1 to June 30, and 10 cfs from July 1 to March 31. During times when inflow into the reservoir is less than the above minimums, the total inflow must be bypassed. Minimum flows are constant every year (i.e. there are no increases or reductions based on a WY type).

The Ops Model simulates the release of 10 or 25 cfs, unless the reservoir storage reaches dead pool (approximately 1,300 ac-ft), and then it releases inflow minus evaporation. The Ops Model does not reduce the minimum flow to inflow when above dead pool. This assumption is consistent with actual Camp Far West operations based on review of historical data and discussions with the reservoir operator.

7.3 Bay-Delta Settlement Agreement

In February 2000, the California Department of Water Resources (DWR), SSWD, and CFWID entered into the Bear River Agreement (DWR, SSWD, and CFWID 2000) to settle the responsibilities of SSWD, CFWID, and all other Bear River water rights, to implement the objectives in the *Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary* adopted May 22, 1995 (SWRCB 1995). Under this agreement, SSWD is obligated to release 4,400 ac-ft of water in dry and critical WYs as defined by the Sacramento Valley Water Year Hydrologic Classification, provided adequate water is stored in Camp Far West Reservoir. In dry and critical WYs, when Camp Far West storage is less than 33,255 ac-ft on April 1, the amount of release is equal to the difference between the present storage and 33,255 ac-ft. If April 1 storage is below 28,855 ac-ft, SSWD is not obligated to release water for the BDSA.

To incorporate this agreement into SSWD's water rights, in July 2000 the SWRCB issued Order 2000-10 that amended SSWD's Water Right Licenses 11120 and 11118 to provide that:

> During releases of water in connection with the change of purpose of use and place of use of up to 4,400 ac-ft transferred to DWR during dry and critical years,[1] Licensee shall increase flows in the lower Bear River by no more than 37 cfs from July through September. To avoid stranding impacts to anadromous fish in the Bear River below Camp Far West Reservoir, Licensee shall, by the end of a release period from the reservoir in connection with said change, ramp down flows from the reservoir at a rate not to exceed 25 cubic feet per second over a 24-hour period.

The required flow volume is in addition to the minimum flow requirement in the Project FERC license, and is measured immediately downstream of the diversion dam as spill over the diversion dam (i.e., SSWD installs notched boards on the diversion dam and controls the elevation of the diversion dam impoundment to provide the required flow).

SWRCB's Order 2000-10 states that this arrangement would terminate upon the termination of the Bear River Agreement on December 31, 2035, or sooner if the Bear River Agreement is terminated sooner.

The Ops Model simulates BDSA releases, including determining the volume of release based on storage in Camp Far West Reservoir on April 1 in all dry and critical WYs. BDSA releases are simulated to occur in August and September. Simulated BDSA release is a constant 37 cfs until the annual obligation is fulfilled.

[1] SWRCB Order 2000-10 states: *"Dry and critical years are defined, for purposes of this order, as set forth on page 23 of the Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary (Adopted by the SWRCB in May, 1995), except that such years do not include a year in which water storage in Camp Far West Reservoir on April 1 is at or below 33,255 acre-feet ("extreme critical year")."*

SECTION 8
IRRIGATION AND WATER SUPPLY OPERATIONS

Camp Far West Reservoir is a water supply facility constructed to provide surface water to SSWD's members. Model operations include a representation of both irrigation demands and operations to allocate and deliver water for irrigation. The following sections document the demand and operational assumptions used in the Ops Model.

8.1 Irrigation Demands

Daily time-series of irrigation demands were developed for use in the Ops Model. Separate demands were developed for CFWID and SSWD using a similar method of multiplying a total volume by a daily distribution pattern for the irrigation season.

SSWD and CFWID entered into an agreement in 1957 (and a Supplemental Agreement in 1973) relative to the construction and subsequent enlargement of Camp Far West Reservoir. Under the Supplemental Agreement, SSWD provides CFWID 13,000 ac-ft of water from the reservoir each year to satisfy CFWID's senior water rights along the Bear River. The Ops Model uses 13,000 ac-ft as the annual demand for CFWID in accordance with the agreement. Annual demand is split between CFWID's North Canal (49%) and South Canal (51%). Daily demand time-series for each canal were developed by multiplying annual canal demand by the average daily historical diversion pattern for each canal. Demand for both canals is on a typical irrigation season pattern, however, there are demands outside of SSWD's typical irrigation season. It is possible to divert water into the North and South canals without flashboards installed at the diversion dam.

SSWD is a conjunctive management district that relies on both surface and groundwater for irrigation. The ability to deliver surface water in most years is limited by available supply, not demand. Therefore, a constant annual demand of 110,000 ac-ft was assumed for SSWD. This demand is generally consistent with recent historical records of SSWD Main Canal diversions in years with adequate supply, as illustrated in Figure 8.1-1.

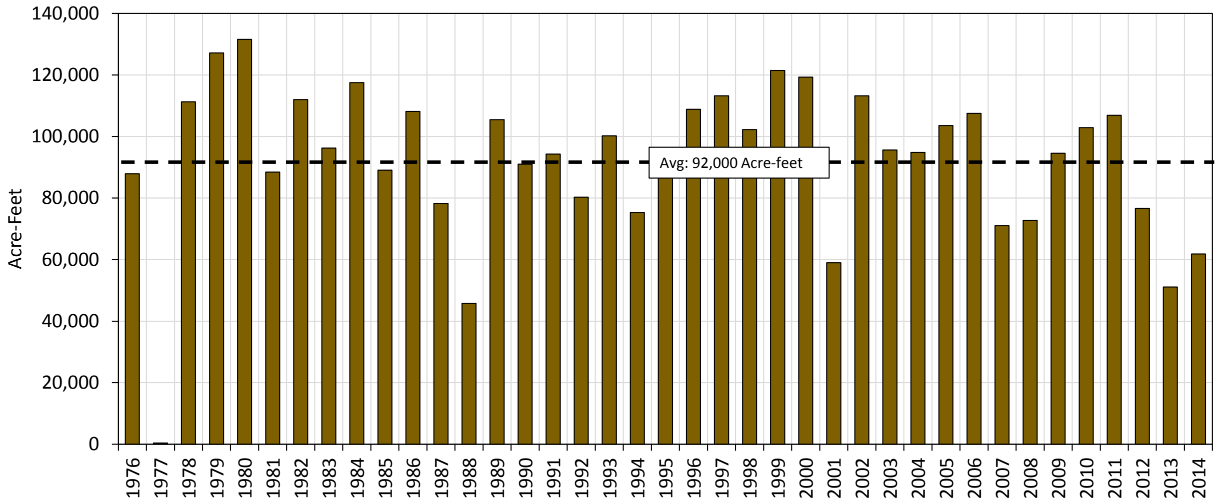

Figure 8.1-1. Annual Main Canal diversions.

A time-series of daily Main Canal demand was developed after review of historical Main Canal diversion records. Daily Main Canal diversions can vary significantly from one year to the next based on numerous factors. One of the more significant factors is precipitation before the start of the irrigation season. Years with higher precipitation from January through April tend to delay the start of Main Canal diversions due to a combination of fields being too wet to prepare for the growing season, higher soil moisture content, and effective precipitation that can delay demand for irrigation water. Therefore, daily Main Canal demands were developed based on historical precipitation records for the January through April period.

Precipitation data for SSWD was developed by spatially interpolating available precipitation gages at Folsom, Marysville, and Sacramento. Precipitation was then summed for the January through April period, preceding the irrigation season, and broken into five different patterns based on percentiles. Historical Main Canal diversions were averaged over each precipitation percentile and scaled to sum to unity. Annual SSWD demand was then scaled on this pattern to simulate historical diversions. Figure 8.1-2 shows the patterns used in the Ops Model broken down by precipitation percentile range. A precipitation range of 0 to 20 percent is for precipitation amounts up to the lower 20 percent of historical totals for January through April.

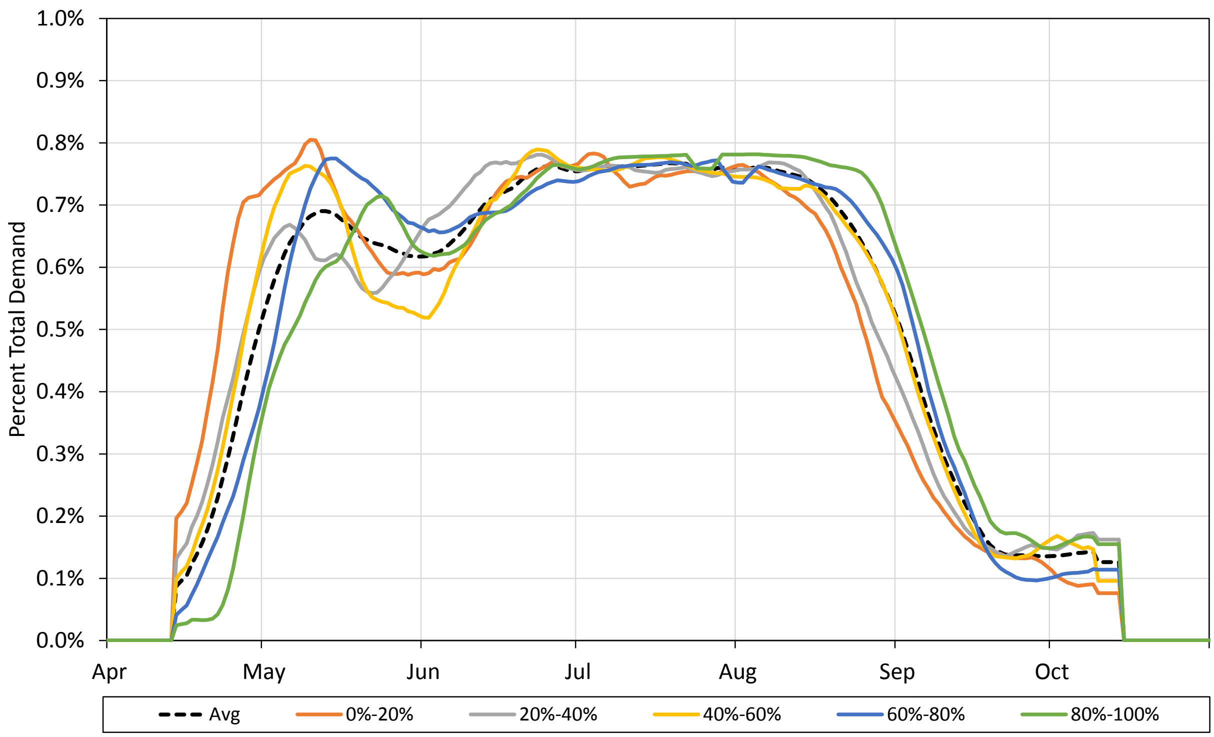

Figure 8.1-2. SSWD Main Canal demand patterns.

8.2 Inflow Forecast Procedure

A key component of the Ops Model is the method used to forecast inflow into Camp Far West Reservoir. The inflow forecast is combined with water currently in storage to determine how to operate the reservoir each year and the volume of water to allocate to each demand. An inflow forecast is made in April for the volume of inflow over the April through September period. The inflow forecast in the Ops Model is comprised of two components: Bear River water supply; and imported water from the Yuba River through the YB/DS Projects. Both components are based on the April DWR Bulletin 120 (B120) unimpaired runoff forecasts for the Yuba River at Smartsville plus Deer Creek.

Regressions were developed between historical B120 Yuba River forecasts and calculated unimpaired flow of the Bear River at Camp Far West for the April through September period. Historical B120 Yuba River forecasts for May were used in the regression analysis to limit the effect of forecast error when developing the relationship between the Bear and Yuba rivers. Initially a single regression was developed based on all years, but review of all 39 years of available data indicated a different relationship was appropriate for drier WYs. Figure 8.2-1 shows the data for all years, segregated into dry and non-dry years and the resulting regressions.

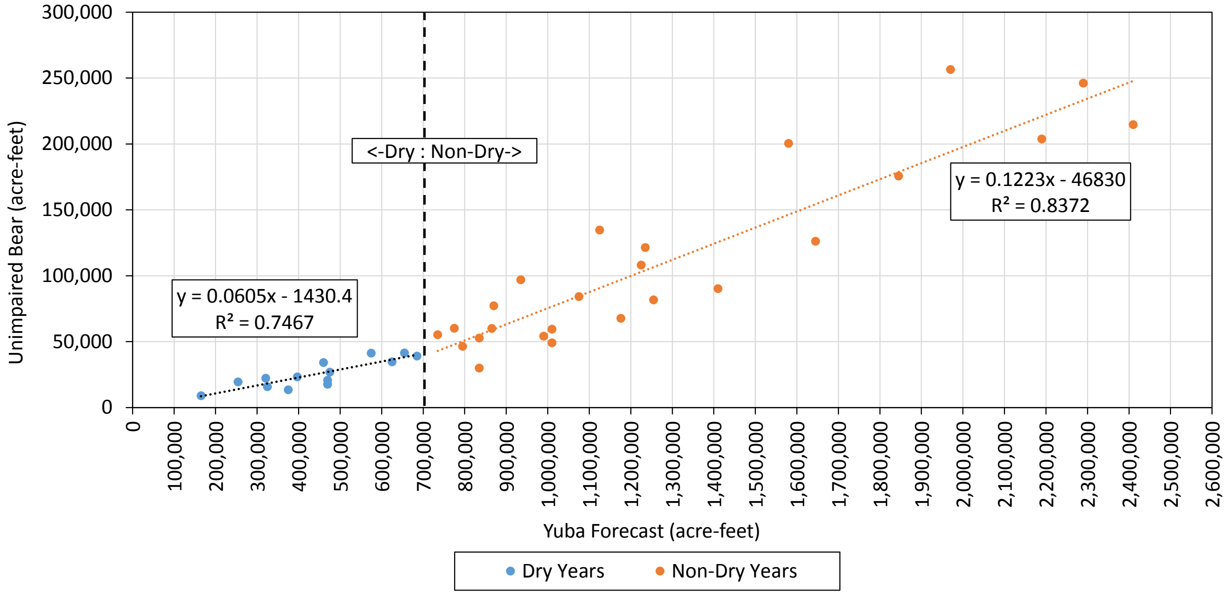

Figure 8.2-1. Relationship between Yuba River forecast and unimpaired Bear River.

Based on review of all years, two regressions were developed: one for dry years when forecasted April through September Yuba River unimpaired flow is less than or equal to 700 thousand ac-ft, and one for all other years.

Regressions are used to estimate the Bear River water supply, although in most years significant water is imported to the Bear River through the YB/DS Projects. A portion of this water becomes inflow into Camp Far West Reservoir. Therefore, the inflow forecast procedure must also address this source of inflow.

The availability of water in the Yuba River is an indicator of the potential for water to be imported to the Bear River. Therefore, the April B120 forecast for the Yuba River is also the basis for the import estimate. The forecasted Yuba River supply was reduced by an estimate of the consumptive demands met from the YB/DS Projects. Any supply remaining after meeting upstream demand was compared with the available capacity in the major storage reservoirs in the YB/DS Projects: Jackson Meadows, Bowman, Fordyce, Spaulding, and Rollins. Available Yuba River water will fill the storage reservoirs in the upstream projects prior to being imported into the Bear River and becoming inflow to Camp Far West Reservoir. Therefore, forecasted Yuba River supply was also reduced by the available capacity in the YB/DS Projects' reservoirs. Forecasted Yuba River supply remaining after meeting upstream demand and filling available reservoir capacity (Remaining Yuba) was used to estimate Bear River imports into Camp Far West Reservoir. Remaining Yuba based on historical B120 forecasts and reservoir storage levels was compared with historical Bear River imports calculated from upstream gage data. This comparison produced a relationship used to create an import estimate based on historical operations. The import estimate based on the Remaining Yuba and historical imports is presented as Figure 8.2-2.

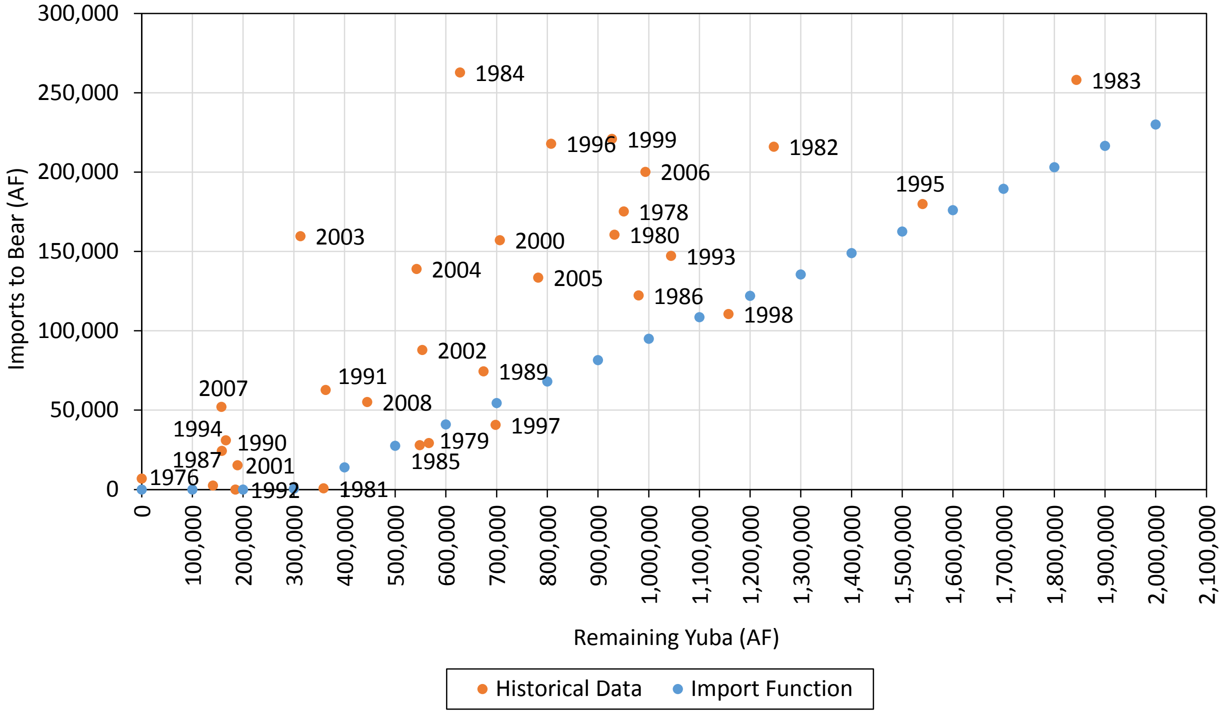

Figure 8.2-2. Historical Bear River imports and model import function.

Figure 8.2-3 shows the simulated forecasted inflow for Bear River Supply and import estimate for the Ops Model validation run.

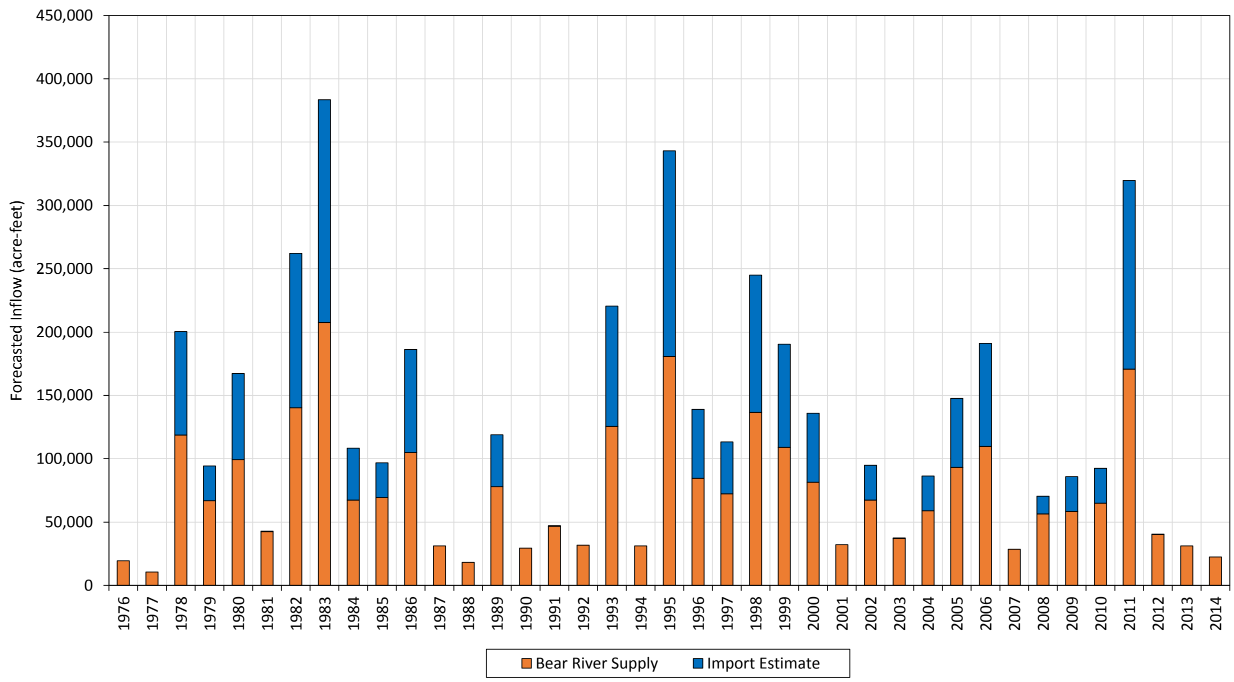

Figure 8.2-3. Forecasted inflow for Ops Model validation.

8.3 Perfect Foresight Option

In addition to the inflow forecast, users also have the option of using a perfect-foresight inflow forecast. If this option is used, the sum of April through September inflow is used and combined with water in storage as the forecasted available water supply. This option is included in the Ops Model as an alternative to the above described forecast procedure.

8.4 Allocation Procedure

SSWD's Board of Directors allocate available surface water each spring for delivery during the irrigation season, typically from April 15 through October 15. The Ops Model allocation procedure is used to simulate the SSWD Board of Directors' methods and considers the forecasted available water supply, required releases, and irrigation demands. Forecasted water supply consists of water in storage on April 1 and forecasted inflow. Available water supply is first used to meet minimum flow requirements and BDSA releases before irrigation demands. The first 13,000 ac-ft of water available for irrigation is allocated to CFWID per its agreement with SSWD. Any remaining water is then allocated to SSWD, up to a full allocation of 110,000 ac-ft. In years when CFWID or SSWD receive less than a full allocation, water is delivered throughout the irrigation season at less than full demand.

Other logic built into the Ops Model includes stopping diversions into SSWD's Conveyance Canal when storage drops below 4,000 ac-ft and reducing all other releases if the reservoir hits dead pool.

8.5 Evaporation

Historical evaporation rates for Folsom Lake were calculated based on reported evaporation by the United States Department of the Interior Bureau of Reclamation. Evaporation rates in inches per day are used in combination with daily simulated reservoir surface area to approximate evaporation from Camp Far West Reservoir. Figure 8.5-1 shows average monthly evaporation calculated from the time-series of daily data used in the Ops Model.

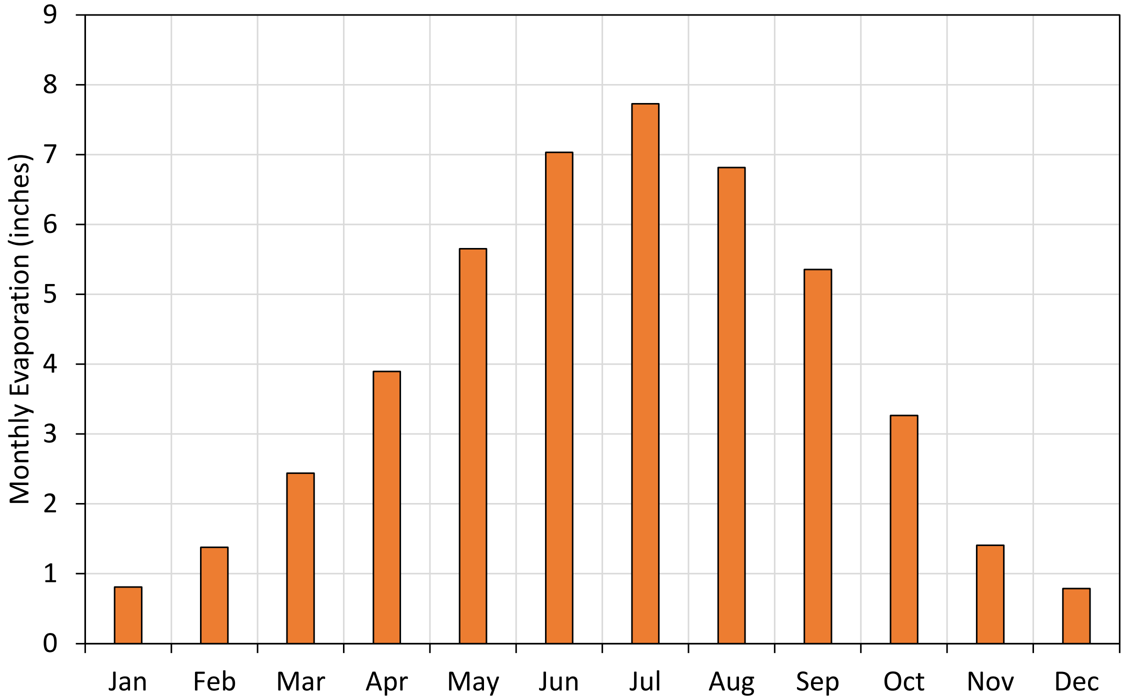

Figure 8.5-1. Average monthly evaporation at Camp Far West Reservoir.

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SECTION 9
CAMP FAR WEST DAM RELEASE PRIORITY

The Ops Model simulates daily releases based on demand, allocation, and water available according to the priorities in Table 9.0-1. If storage in Camp Far West reaches dead pool, the Ops Model will release inflow less evaporation up to the minimum flow requirement.

Table 9.0-1. Camp Far West Dam Release Priority.

Priority	Purpose	Minimum Reservoir Storage (acre-feet)
1	Minimum flow requirement	1,300
2	BDSA release	1,300
3	CFWID diversion	1,300
4	SSWD diversion	4,000

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SECTION 10
HYDROPOWER

The operation of Camp Far West Reservoir is not governed by decisions regarding hydropower generation. Hydropower generation is incidental to water supply operations and water is run through the turbine only when conditions allow. Therefore, the Ops Model does not consider hydropower generation when determining the daily release, however, the Ops Model does simulate hydropower generation when reservoir release is adequate for generation.

The turbine at Camp Far West Powerhouse is subject to the following constraints:

- Physical turbine capacity of 750 cfs
- Minimum WSE of 236 ft
- Minimum turbine flow as a function of WSE
  - WSE above 278 ft, minimum turbine flow is 300 cfs
  - WSE between 278 and 236 ft, minimum turbine flow is 130 cfs

The Ops Model includes these constraints when calculating hydropower generation. Additionally, the Ops Model uses a maximum turbine flow of 650 cfs, rather than the physical turbine capacity, based on review of the historical turbine records.

Other necessary parameters to simulate hydropower generation include net head and turbine efficiency. Net head is the difference between the reservoir WSE and the water surface at the turbine outlet (tailwater elevation) less an estimate of headloss through the penstock and turbine. Tailwater elevation is a function of flow through the turbine, the relationship used in the Operations Model is illustrated below in Figure 10.0-1.

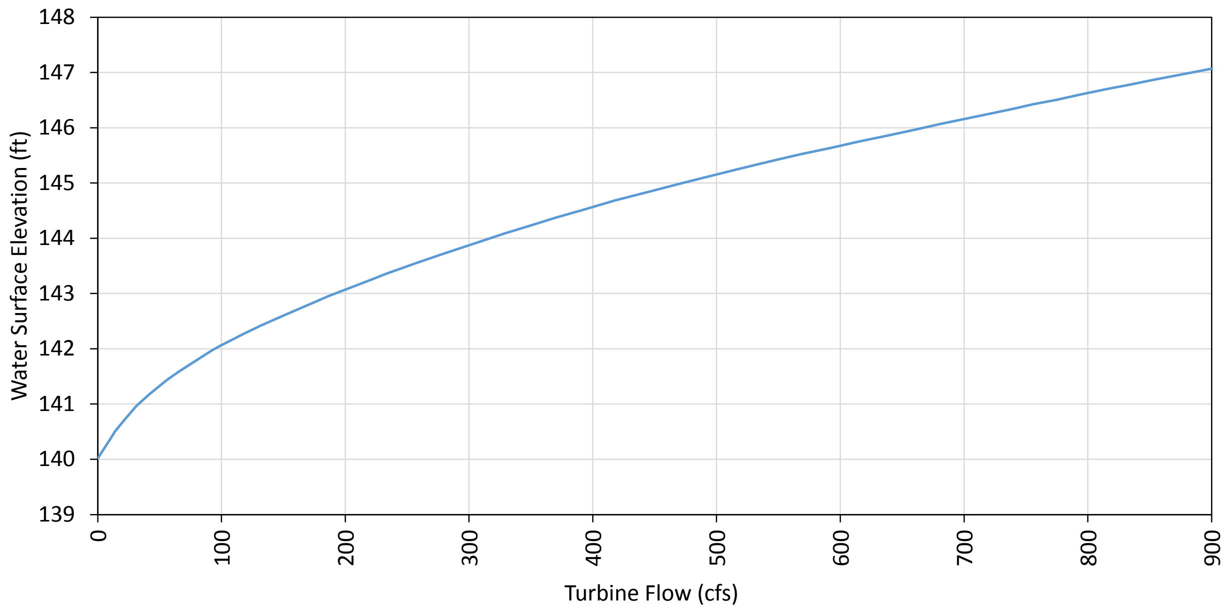

Figure 10.0-1. Tailwater elevation and turbine discharge.

Turbine efficiency curves from a previous hydropower model developed by Mead and Hunt are used in the Ops Model. Turbine efficiency is a function of both net head and turbine flow and a series of curves were developed for several different ranges of net head. Efficiency curves for the Camp Far West Powerhouse turbine are illustrated in Figure 10.0-2.

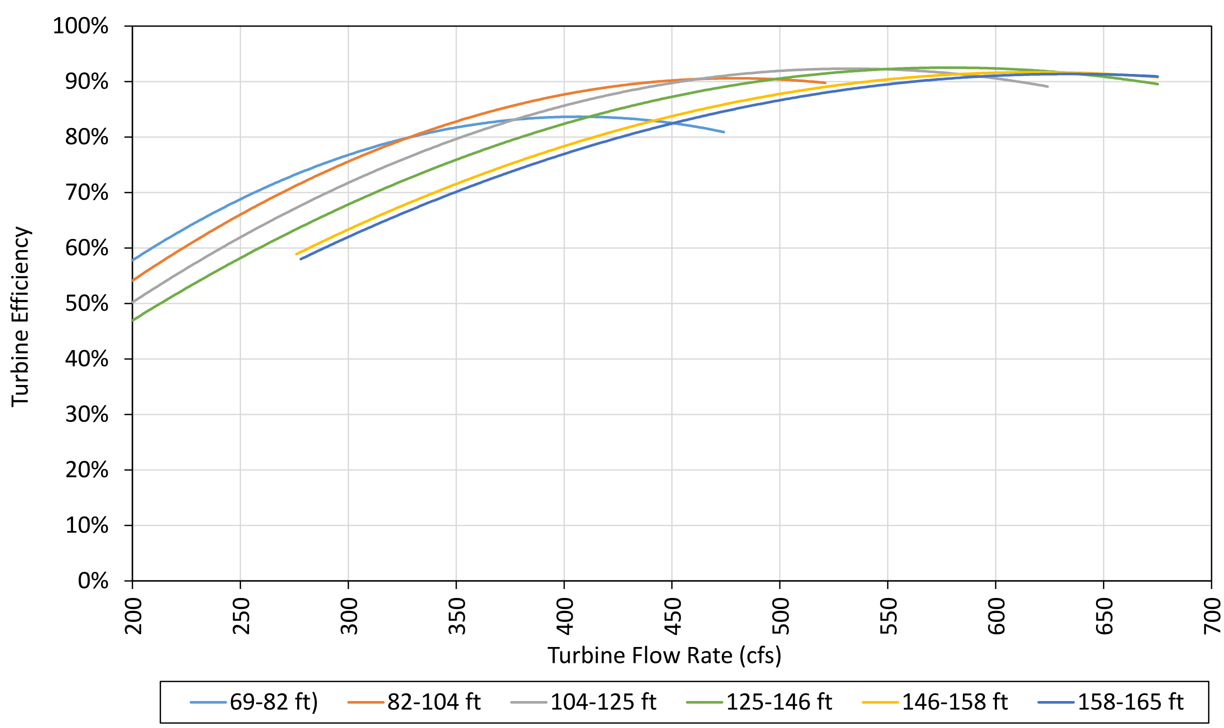

Figure 10.0-2. Camp Far West turbine efficiency curves.

As seen in Figure 10.0-2, efficiency curves are defined down to 200 cfs. For flows between 130 cfs, the minimum flow for generation, and 200 cfs the minimum efficiency from the curves is used in the Ops Model calculation. During model validation, it was determined that turbine efficiencies illustrated in Figure 10.0-2 were too high. Turbine efficiencies used in the Ops Model are 2 percent less than those illustrate in Figure 10.0-2.

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SECTION 11 OPERATIONS DOWNSTREAM OF CAMP FAR WEST DAM

The Ops Model simulates release from Camp Far West Dam through one or more of the outlets. Simulated releases flow into the impoundment behind the non-Project diversion dam. The Ops Model simulates diversion of water at the diversion dam, into CFWID's North and South canals, and SSWD's Conveyance Canal. The Ops Model also simulates flow past the diversion dam to the lower Bear River. Water that flows past the diversion dam includes minimum flows, BDSA releases, and spill.

The Ops Model has three flow nodes downstream of the diversion dam: two at existing stream gages at Wheatland and Pleasant Grove Road; and one at the downstream model boundary-the confluence of the Bear and Feather rivers.

11.1 Bear River Accretions and Depletions

An analysis of historical flow data for the lower Bear River was completed to better understand river gains and losses. SSWD maintains records of water released into the Bear River immediately downstream of the non-Project diversion dam. Further downstream of the non-Project diversion dam, flow is measured at two locations: the Bear River at Wheatland (USGS 1142400); and the Bear River at Pleasant Grove Road (CDEC BPG).

Numerous factors affect flow in the river between these locations. Net inflows (accretions) and outflows (depletions) were calculated for each of these reaches by analyzing the difference between historical data at the upstream flow location and the downstream flow location. These data were compiled and analyzed for trends in flow changes for a particular reach.

The USGS Bear River at Wheatland gage has flow data for the entire period of record. SSWD also has a complete record of flow immediately below the non-Project diversion dam, however, there is considerable uncertainty in the accuracy of flow data at times when there is spill over the diversion dam. The potential inaccuracy of measured flow during these times can introduce error into the calculation of river accretions and depletions. Therefore, calculated accretions/depletions during periods of non-Project diversion dam spill were not included in the analysis. After analyzing the data for trends on a daily, monthly, and seasonal basis, an average monthly accretion was applied for the Bear River between the diversion dam and the Wheatland gage. The average monthly values shown in Figure 11.1-1 are applied each day of the month and the same values are applied in every year of the simulation.

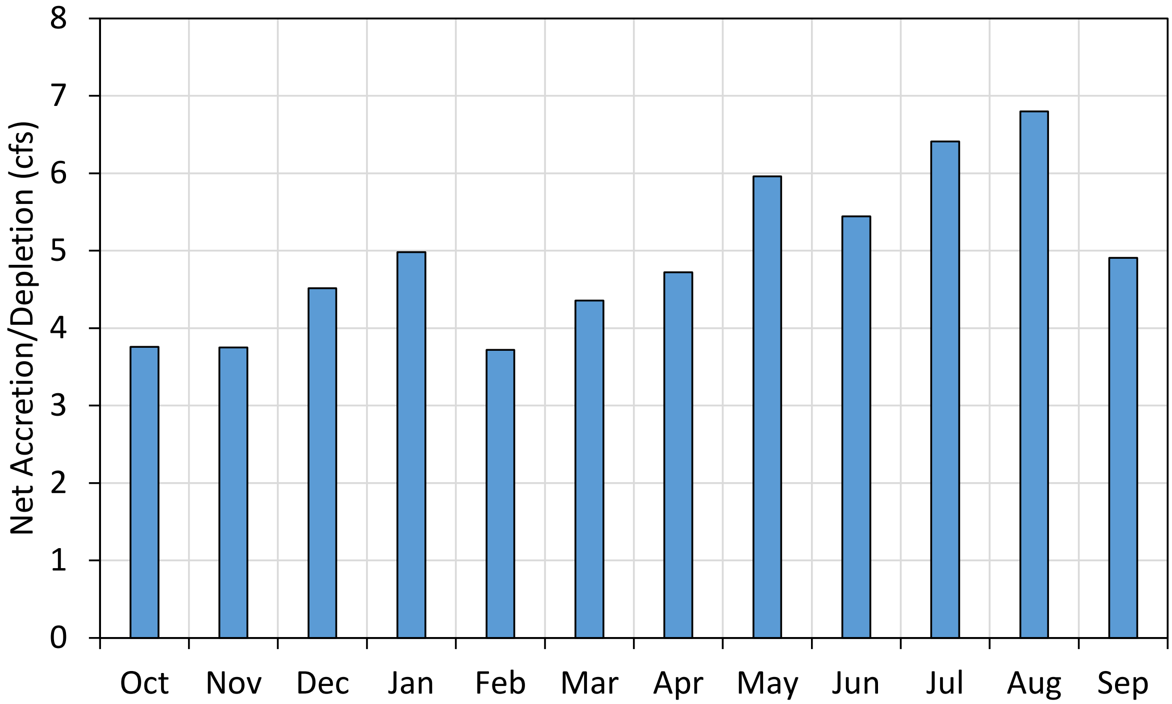

Figure 11.1-1. Monthly average Bear River accretions from non-Project diversion dam to Wheatland.

There is a limited period of record, from January 2006 through 2014, for the CDEC gage for the Bear River at Pleasant Grove Road. Comparison of USGS data at Wheatland and CDEC data at Pleasant Grove Road for the 2006 through 2014 period showed significant variations in calculated accretions/depletions for this reach. Calculated accretions/depletions showed no meaningful trend and were likely significantly affected by the accuracy of the stream gages. Therefore, it was determined that no meaningful accretions/depletions could be calculated for this reach.

The reach from Pleasant Grove Road to the confluence with the Feather River has two sources of additional flow that enter from the north bank of the Bear River: an irrigation return flow; and Dry Creek. There are no readily available data for these two inflows, and no Bear River gages downstream. Therefore, accretions and depletions for the Bear River between Pleasant Grove Road and the confluence with the Feather River are assumed to be zero.

SECTION 12
MODEL USER INPUTS AND SCENARIOS

The following section describes the user inputs and pre-run scenarios included in the Ops Model. The Ops Model was constructed so numerous inputs can be easily changed to assess various scenarios, though it may not be appropriate to change some inputs as part of FERC relicensing. These inputs are set on a worksheet, "User_Inputs," in the Ops Model. User inputs are described in the following section.

12.1 Inflow Alternatives

Three time-series of inflow into Camp Far West are included in the Ops Model: calculated historical inflow for use in model validation, and simulated inflow for a Near-Term Condition and a Future Condition. The inflow alternative can be selected from a drop-down menu.

12.2 User-Defined Minimum Flows

The Ops Model contains a table that allows a user to enter new minimum flow requirements. User-defined minimum flows can be entered in split-month increments with a user-defined day of change for each month, and by five different WY types. Water-year types included in the Ops Model are based on YB/DS Projects WY types and are described in subsequent sections of this report. By default, the Ops Model will impose the current minimum flow requirement downstream of the diversion dam. This requirement is 25 cfs from April 1 through June 30, and 10 cfs at all other times. User-defined minimum flows can be turned on or off in the Ops Model and will supersede existing minimum flows only when greater than the existing minimum flow.

12.3 Volume-Elevation Curve

The initial volume-elevation curve was calculated in 1968 upon completion of the reservoir. In 2008 the volume-elevation curve was recalculated to account for sedimentation. The updated 2008 curve has been used in reservoir operations since 2009. The Ops Model was validated and configured to use the 2008 curve. The user can select either curve, but most analyses in relicensing should use the 2008 curve. Both curves are plotted in Figure 12.3-1.

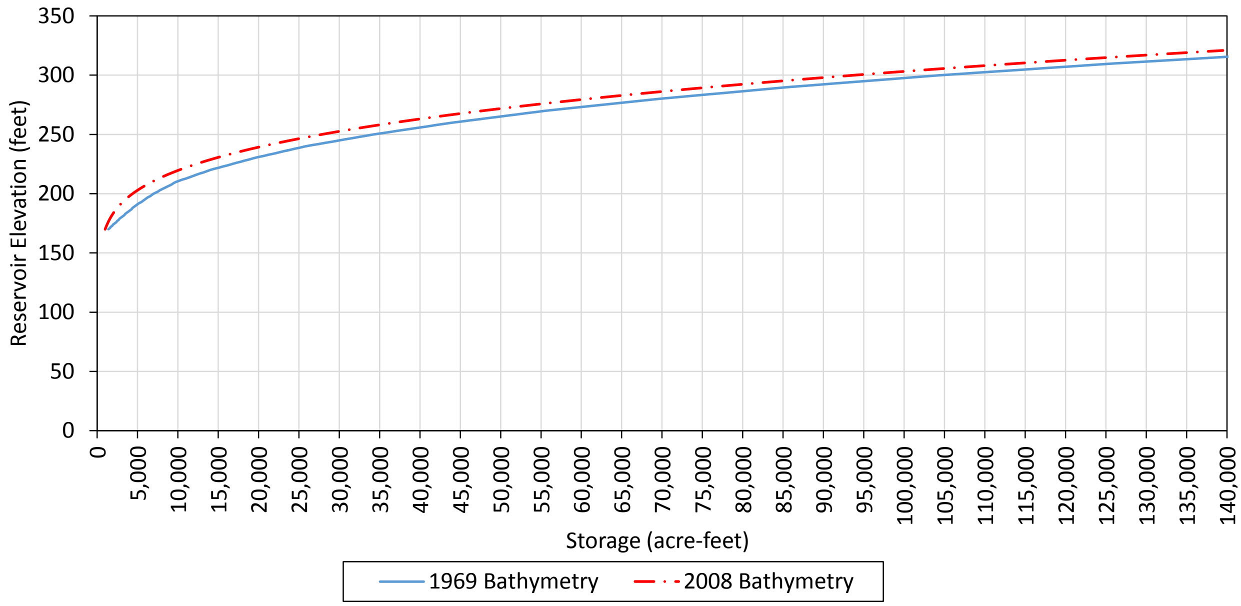

Figure 12.3-1. Volume-elevation curves for 1968 and 2008 bathymetry.

12.4 Bay-Delta Settlement Agreement Release Parameters

The Ops Model includes the flexibility to change the parameters that govern simulation of the BDSA release including reservoir storage levels, release volumes, and rates.

12.5 Irrigation Demand, Delivery, and Allocation Parameters

Inputs for the annual SSWD demand and estimates such as a carryover storage buffer, loss percentage, and estimate of irrigation season evaporative losses from Camp Far West Reservoir are included and affect the allocation of water to SSWD. The Ops Model also includes two parameters that affect when releases for certain purposes are curtailed. Dead pool in Camp Far West Reservoir is approximately 1,300 ac-ft. When storage reaches this level, releases from storage to meet minimum flow requirements, BDSA releases, and CFWID demand are curtailed. The Ops Model includes a separate threshold for curtailing releases from storage to meet SSWD demands. This value is set to 4,000 ac-ft to provide a buffer against taking the reservoir to dead pool.

12.6 Hydropower Parameters

Hydropower parameters define the operation of the power plant and include limits for reservoir WSE, minimum and maximum turbine flow, the tailwater elevation curve, and turbine efficiency curves. Changes to these parameters would likely occur as the result of a physical change to the dam, powerhouse intake, turbine, or outlet.

12.7 Historical Water Transfers

The SSWD Board of Directors has opted to participate in water transfers in some years when a market for water exists. These historical water transfers are included in the Ops Model for the sake of model validation only. It is unknown whether the SSWD Board of Directors will opt to continue participating in water transfers in the future. Therefore, historical water transfers should be turned off in the Ops Model when performing analysis in support of FERC relicensing.

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SECTION 13
PRE-RUN MODEL SCENARIOS

Three scenarios are included with the Ops Model. One, model validation, is included to compare model operations with historical Camp Far West and SSWD operations. The other two scenarios are included for the purpose of comparison with user-developed scenarios. Scenarios are described below.

13.1 Validation

This scenario is configured to most closely match historical operations. It uses calculated inflow and includes historical water transfers.

13.2 Near-Term Condition

This scenario operates the Ops Model using all current operational and hydropower parameters with the Near-Term Condition inflow alternative from the upstream YB/DS Projects' model.

13.3 Future Condition

This scenario is the same as the Near-Term Condition, but with the Future Condition inflow alternative from the upstream YB/DS Projects' model.

13.4 Scenario Creation

In addition to the three pre-run scenarios described above, the Ops Model includes the ability to create and store results of a user-defined scenario for comparison with a second user-defined scenario. A user-defined scenario can be stored by setting the user-defined inputs as desired and then running a Visual Basic for Applications (VBA) macro in the Ops Model that will store the inputs and results within the Ops Model. Model inputs can then be changed again, and results of the current model simulation compared to that of the stored simulation.

13.5 Baseline Run

This worksheet stores results from a user-defined scenario. When the VBA macro is operated by clicking the button titled "Generate New Baseline", it writes values from the "Model" worksheet to the "Baseline_Run" worksheet. Results stored here in the current version of the Ops Model are identical to the Validation scenario.

13.6 Water Year-Type

The Ops Model includes a place-holder for WY types, which as currently defined in the Ops Model are essentially the same as WY types proposed for use in the new licenses for the YB/DS

Projects (NID 2011). This approach was used because the water supply for SSWD is dependent on upstream YB/DS Projects' operations and SSWD's existing FERC license and water rights do not define any WY types. The one difference between WY types as described in the YB/DS Projects' joint FEIS is that the Ops Model does not include an Extreme, Critically Dry WY. This designation applies to only WY 1977 in the simulation period. Development of a WY type for use in relicensing of the Camp Far West Hydroelectric Project will occur during relicensing and after discussion with Relicensing Participants.

Under the YB/DS Projects method, the WY type is based on the forecasted unimpaired runoff of Yuba River at Smartsville for the entire WY. Forecasts from DWR Bulletin 120 are used to determine the WY type based on the thresholds in Table 13.6-1. An initial WY type is determined in February and applies from February 15 through March 14. The WY type is then updated based on the updated B120 forecasts on March 15, April 15, and May15. The May 15 WY type applies until October 15, at which time it is updated based on the reported Full Natural Flow of the Yuba River at Smartsville. The WY type determined from the Full Natural Flow applies from October 15 through February 14 of the following year.

Table 13.6-1. YB/DS Projects WYs Type.

B120 Forecasted Unimpaired Yuba River Runoff or Full Natural Flow (1,000 acre-feet)	Water-Year Type
Less or equal to 900[1]	Critically Dry
901 to 1,460	Dry
1,461 to 2,190	Below Normal
2,191 to 3,240	Above Normal
Greater than 3,240	Wet

[1] YB/DS Projects WYs types include an extreme, critically dry classification for years when unimpaired runoff or full natural flow is less than or equal to 615,000 ac-ft.

The WY type is used in the Ops Model to determine the minimum flow requirement when using the user-defined minimum flow requirements. The use of a WY type provides the user additional flexibility to define up to five different minimum flows, one for each WY type.

SECTION 14
MODEL LIMITATIONS, ASSUMPTIONS, AND USE

The Ops Model is an adequate tool to analyze the water supply, environmental, and hydropower operations of Camp Far West Reservoir under a variety of different hydrologic and operational conditions. Model output can be used to inform decisions in the relicensing process. The Ops Model was designed to function as a planning tool to generally match project operations over a period of time. The Ops Model was not designed to provide absolute predictions of operational or hydrologic parameters on a single day. As the decisions that govern day-to-day operations of Camp Far West Reservoir are often complex, the Ops Model is not designed to predict day-to-day operations in real-time.

Results from the Ops Model are most meaningful when used in a relative sense, where an alternative is compared to a baseline operation of the Project. The Ops Model is designed to be flexible in setting up baseline and alternative scenarios, giving the user control over the same inputs for both scenarios.

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SECTION 15
MODEL VALIDATION

Results of the Ops Model were compared to historical data for the period of record used in this analysis to determine if the Ops Model provides a reasonable representation of current Camp Far West Reservoir operations. Comparisons were made for the following parameters: reservoir storage; total release; canal diversions; hydropower generation; turbine flow; and Bear River flows downstream of the Project.

The period from WYs 1996 through 2014 was used as the validation period. This period was selected because the regulatory conditions are the same as the current regulations simulated in the Ops Model. The BDSA is the only significant regulatory change that occurred during the Ops Model simulation period. Since BDSA releases only apply in dry and critical WYs, and no dry or critical WYs occur from WYs 1996 through 2000, Project operations from WYs 1996 through 2014 were similar to Ops Model operations. The following charts and figures show how historical data and model output match for the entire period of record, with the validation period highlighted in yellow.

In addition to the operational changes noted above, operations of Camp Far West Reservoir include additional complexity, resulting from decisions made based on human experience and judgment. These decisions can be a function of many factors and information that cannot be included in the Ops Model. The Ops Model attempts to simulate normal operations to the extent a normal operation can be defined. Historical data also include errors and uncertainty in the measurement of the actual value. Though data used for validation and in the development of model inputs were reviewed for quality control, error and uncertainty cannot be eliminated.

The following sections provide graphical comparisons of daily model results with historical data. Some parameters are also compared on a monthly basis or on a logarithmic scale. Additionally, model results and historical data are compared in annual tables for most parameters.

15.1 Reservoir Storage

The following figure and tables compare historical to modeled storage in Camp Far West Reservoir for the entire simulation period. Figure 15.1-1 plots the Camp Far West storage on a daily time-step to show how the Ops Model matches the historical data on a day-to-day basis. This comparison illustrates how the Ops Model is simulating the day-to-day storage changes and the timing of when they occur. Historical storage was adjusted to the 2008 volume-elevation-curve as the Ops Model uses this curve for all operational calculations.

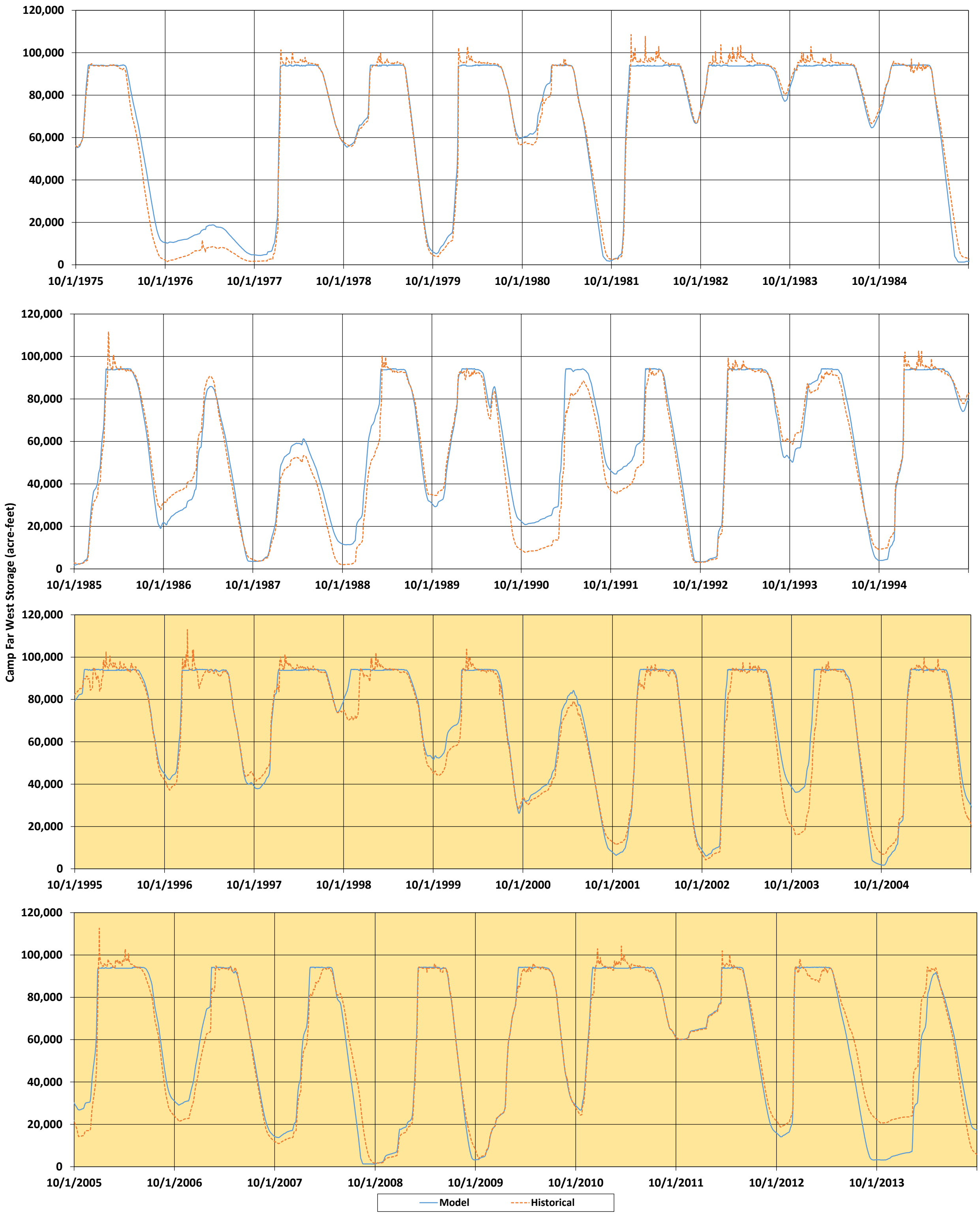

Figure 15.1-1. Comparison of daily historical and modeled Camp Far West Reservoir's storage.

Figure 15.1-1 illustrates that modeled storage is similar to historical storage throughout the period of record. This indicates the Ops Model simulates reservoir operations similar to how SSWD actually operates.

The largest differences between historical and modeled storage occur in 2003 and 2013. In 2003 forecasted inflow in the Ops Model is less than historical inflow. This is largely because there was a larger volume of water imported into the Bear River historically in this year than in other years with a similar Yuba River water supply (Figure 8.2-1). Therefore, the Ops Model forecasted volume of import to the Bear River was less than what actually occurred. The lower forecasted inflow in the Ops Model results in a lower allocation to SSWD (seen below in the comparison of historical and simulated Conveyance Canal diversions), and higher storage compared to the historical operation.

In 2013, SSWD operations were more conservative, resulting in lower Conveyance Canal diversions and higher carryover storage than in similar years. Simulated storage is approximately 20,000 ac-ft lower than historical storage, and simulated Conveyance Canal diversions are approximately 20,000 ac-ft higher. This difference may be explained in part by unusually low inflow to Camp Far West Reservoir in the spring. Low observed inflow may have reduced historical allocations. By comparison, forecasted inflow in the Ops Model exceeded historical inflow during the irrigation season, and simulated storage approached dead pool.

Table 15.1-1 presents a comparison of maximum and minimum annual storages for Camp Far West Reservoir.

Table 15.1-1. Comparison of historical and modeled maximum annual Camp Far West Reservoir's storage.

Water Year	Maximum Annual Camp Far West Storage (acre-feet)			
	Historical (Adjusted to 2008 bathymetry)	Model	Difference	Percent Difference
1976	94,834	94,293	-541	-1%
1977	11,618	18,835	7,217	62%
1978	101,352	94,282	-7,070	-7%
1979	99,715	94,286	-5,429	-5%
1980	102,907	94,290	-8,617	-8%
1981	97,031	94,286	-2,745	-3%
1982	108,547	94,258	-14,288	-13%
1983	103,771	94,291	-9,480	-9%
1984	102,907	94,285	-8,622	-8%
1985	97,031	94,287	-2,744	-3%
1986	111,734	94,279	-17,454	-16%
1987	90,600	85,896	-4,704	-5%
1988	53,308	61,208	7,900	15%
1989	100,173	94,253	-5,919	-6%
1990	94,319	94,286	-33	0%
1991	88,501	94,275	5,774	7%
1992	94,491	94,283	-207	0%
1993	99,358	94,262	-5,097	-5%
1994	93,367	94,284	917	1%
1995	102,907	94,288	-8,619	-8%
1996	102,542	94,267	-8,274	-8%
1997	113,006	94,292	-18,714	-17%
1998	101,172	94,275	-6,896	-7%
1999	102,077	94,291	-7,787	-8%
2000	103,771	94,271	-9,500	-9%
2001	79,202	84,227	5,026	6%
2002	96,478	94,288	-2,189	-2%
2003	97,391	94,287	-3,104	-3%
2004	97,842	94,279	-3,564	-4%
2005	99,536	94,286	-5,250	-5%
2006	112,614	94,280	-18,334	-16%
2007	94,834	94,262	-572	-1%
2008	93,878	94,286	408	0%
2009	95,650	94,285	-1,365	-1%
2010	96,040	94,279	-1,761	-2%
2011	104,190	94,286	-9,904	-10%
2012	101,950	94,282	-7,668	-8%
2013	97,980	94,293	-3,687	-4%
2014	94,310	91,664	-2,646	-3%
Avg	99,368	93,648	-5,720	-5%
Max	113,006	94,293	5,026	6%
Min	79,202	84,227	-18,714	-17%

Table 15.1-1 shows that in most years the historical and modeled maximum storages are reasonably close. Discrepancies occur in years with large inflow events, where the Ops Model is able to pass the event in a single day, avoiding a storage surcharge that occurred historically. This can be seen in Figure 15.1-1 in numerous years where a storage surcharge is visible as sharp peaks. This difference leads to exaggerated differences in maximum annual storage in most years. This is particularly evident in 1997, where the largest flood event on record created the historical high storage in Camp Far West Reservoir.

Simulated storage does not reflect surcharge for two reasons. First, the Ops Model and the calculated historical inflow are on a daily time-step that does not capture peak inflow and resulting storage levels on a smaller time-step. Second, historical inflow is calculated based on daily records and then averaged over a rolling 5-day period to smooth out unrealistic fluctuations in the daily calculations. Smoothing the inflow creates a more realistic estimate of historical daily inflow, but reduces peak inflows during these large events. These differences in maximum annual storage are considered minor in the overall operation of the Ops Model because they only affect operations during periods of high flow.

Minimum storage also tends to vary, with numerous years missing the historical minimum. This is expected in years prior to implementation of the BDSA, as this release is simulated in the entire period despite only coming into effect after 2000. The Ops Model tends to match the historical data better during the validation period in years when the Ops Model both over and under-predicts minimum annual storage.

Dead pool in the reservoir is 1,300 ac-ft according to the most recent bathymetric survey. The reservoir hits dead pool once historically and three times in the Ops Model. In the Ops Model, storage dips slightly below 1,300 ac-ft in two years due to evaporation.

While the Ops Model can under-predict or over-predict historical storage in any given year, the frequency of under-predictions and over-predictions is approximately equivalent, demonstrating the Ops Model contains no particular bias toward one condition or the other.

15.2 Total Camp Far West Release

The following figures compare historical to modeled release from Camp Far West Dam for the entire simulation period. Two sets of figures are presented. Figure 15.2-1 plots the Camp Far West release on a normal vertical scale to illustrate how the magnitude of release can vary at certain times of the year and under different conditions. These comparisons illustrate whether the Ops Model is simulating day-to-day differences in release and the timing of when releases occur. Here, the range of release makes it challenging to see how historical and simulated releases compare during periods of lower release. Figure 15.2-2 plots the same information on a logarithmic vertical scale to allow an easier comparison for periods of lower release.

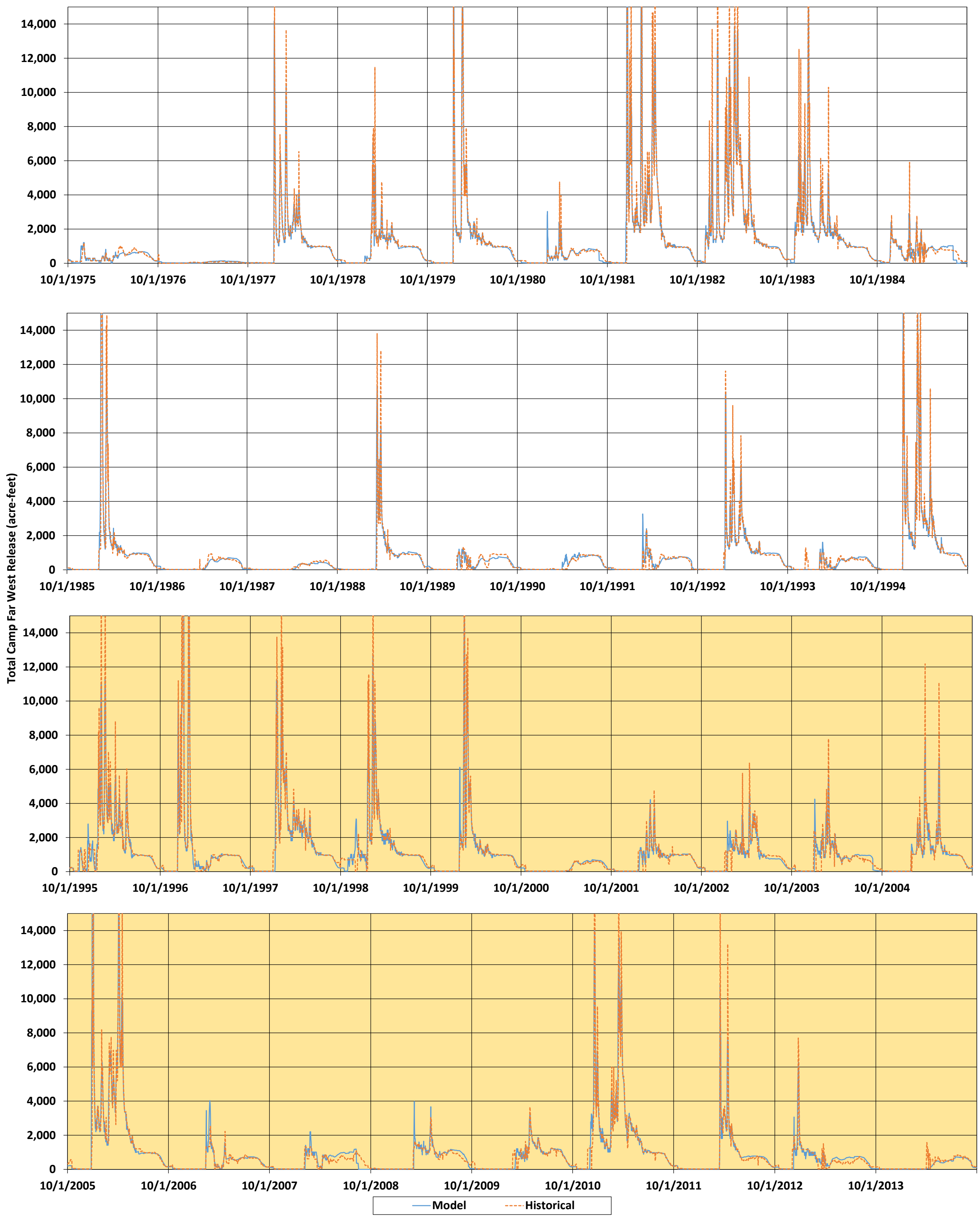

Figure 15.2-1. Comparison of daily historical and modeled Camp Far West Dam release.

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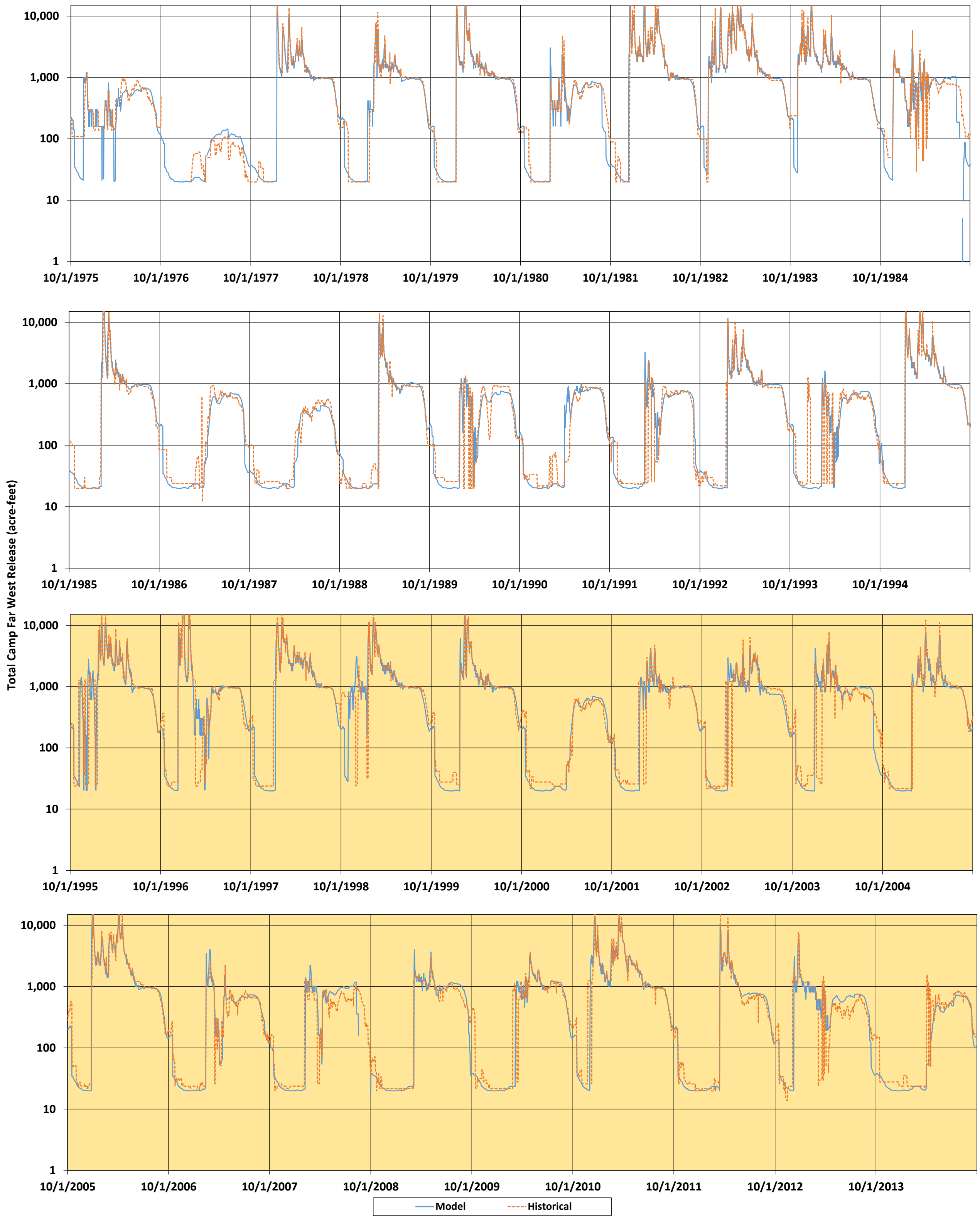

Figure 15.2-2. Comparison of daily historical and modeled Camp Far West Dam release (log scale).

Figure 15.2-1 and Figure 15.2-2 illustrate modeled release timing is similar to historical release timing throughout the simulation period. This indicates the Ops Model simulates reservoir operations similar to how SSWD actually operates.

Table 15.2-1 shows modeled total releases generally coincide with historical releases on an annual basis. Years with the largest differences between simulated and historical release are WYs 2004 and 2014. In both of these years, total release was affected by operational differences in preceding years that created differences in storage. In 2004, simulated total releases are approximately 34,000 ac-ft more than historical data in large part because the reservoir fills and spills earlier in the Ops Model than in historical operations. The reservoir fills and spills earlier because simulated storage was approximately 20,000 ac-ft higher at the end of 2003. Reasons for the difference in storage for 2003 are provided above in the storage comparison.

Table 15.2-1. Comparison of annual historical and modeled Camp Far West Dam releases.

Water Year	Total Camp Far West Release (acre-feet)			
	Historical	Model	Difference	Percent Difference
1976	144,812	136,214	-8,598	-6%
1977	17,096	23,047	5,950	35%
1978	493,513	504,852	11,339	2%
1979	334,407	329,803	-4,604	-1%
1980	557,533	562,496	4,963	1%
1981	153,939	155,170	1,231	1%
1982	908,632	915,874	7,242	1%
1983	1,035,576	1,038,996	3,420	0%
1984	699,700	698,601	-1,099	0%
1985	242,457	239,222	-3,235	-1%
1986	562,185	576,992	14,807	3%
1987	100,454	91,830	-8,625	-9%
1988	68,277	58,939	-9,338	-14%
1989	300,733	323,182	22,450	7%
1990	150,039	135,174	-14,865	-10%
1991	117,574	127,161	9,587	8%
1992	137,127	146,303	9,177	7%
1993	419,084	434,598	15,514	4%
1994	129,453	125,859	-3,594	-3%
1995	715,386	719,974	4,588	1%
1996	671,065	664,755	-6,311	-1%
1997	589,180	597,629	8,449	1%
1998	675,288	668,439	-6,849	-1%
1999	601,396	597,703	-3,693	-1%
2000	477,601	487,495	9,894	2%
2001	86,116	92,071	5,955	7%
2002	274,597	274,102	-495	0%
2003	336,098	330,843	-5,255	-2%
2004	273,662	306,907	33,245	12%
2005	368,612	365,231	-3,381	-1%
2006	872,771	881,746	8,975	1%
2007	149,715	163,637	13,922	9%
2008	151,995	166,556	14,561	10%
2009	215,803	229,083	13,281	6%
2010	228,477	225,620	-2,857	-1%
2011	778,772	779,951	1,179	0%
2012	280,049	290,349	10,300	4%
2013	214,419	231,399	16,980	8%
2014	112,364	85,197	-27,167	-24%
Avg	403,668	407,934	4,266	2%
Max	872,771	881,746	33,245	12%
Min	86,116	85,197	-27,167	-24%

Simulated total releases in 2014 are approximately 26,000 ac-ft less than historical data. Differences in release in 2014 are caused in part by differences in 2013 operations. Lower simulated storage in 2013 resulted in the reservoir not spilling in 2014 and a lower allocation and release for SSWD. The majority of the difference in 2014 is accounted for by a similar magnitude difference in 2013. Reasons for the difference in storage for 2013 are provided in the discussion of simulated storage.

15.3 Conveyance Canal Diversions

Figure 15.3-1 and 15.3-2 compare historical to modeled Conveyance Canal diversions for the entire simulation period. Two sets of figures are presented. Figure 15.3-1 plots the Conveyance Canal diversions on a daily time-step to show how the Ops Model matches the historical data on a day-to-day basis. These comparisons illustrate whether the Ops Model is simulating the differences in diversions and the timing of when they occur. A monthly figure is also included in Figure 15.3-2 to show how diversions match with seasonal variations in historical data over a larger time-step.

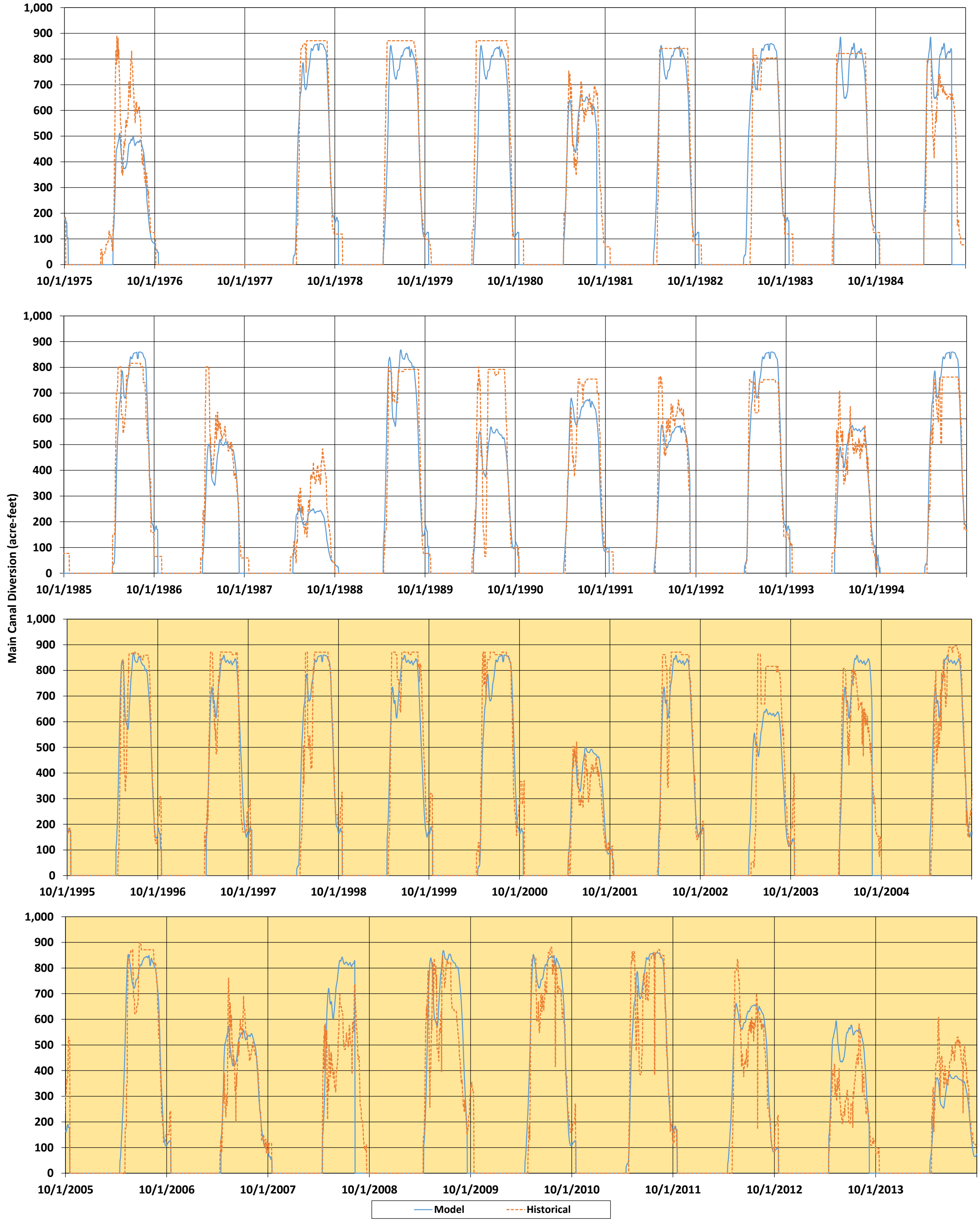

Figure 15.3-1. Comparison of daily historical and modeled Conveyance Canal diversions.

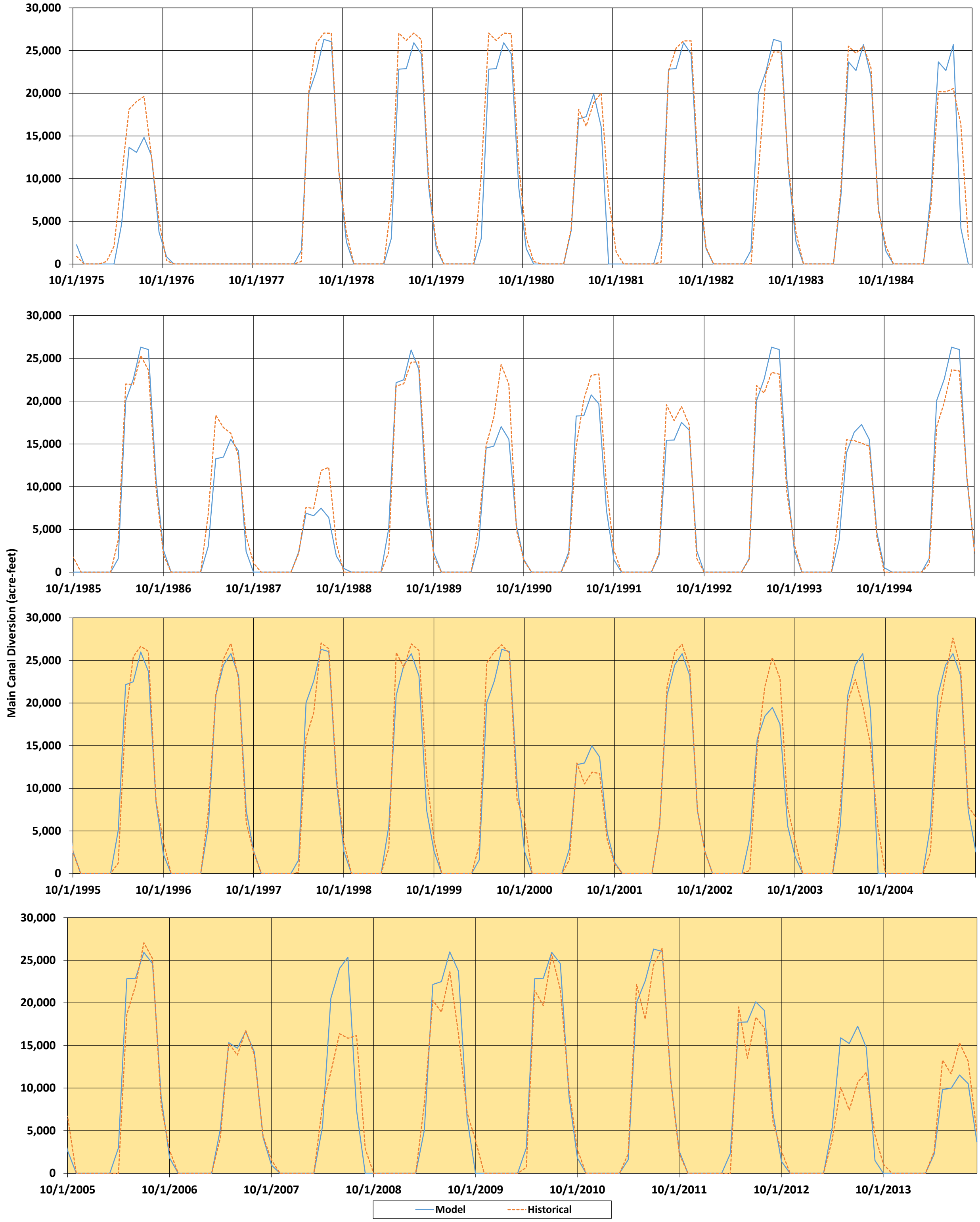

Figure 15.3-2. Comparison of monthly historical and modeled Conveyance Canal diversions.

Figure 15.3-1 and Figure 15.3-2 illustrate the Ops Model simulates Conveyance Canal diversions in a manner similar to historical diversions. The simulated start and end of Conveyance Canal diversions is constrained to the irrigation season in the Ops Model, from April 15 through October 15. The irrigation season is simulated as a hard rule in the Ops Model, while it is more of a guideline in actual SSWD operations, resulting in some discrepancies in timing.

As can be seen in the daily figure, Conveyance Canal diversions are cut short in some years, specifically, WYs 2004, 2008, and 2013. In these years, forecasted inflow in the Ops Model overestimates the historical inflow and as a result allocations to SSWD are too high for the actual available water supply. The Ops Model then simulates releases for SSWD until reservoir storage reaches 4,000 ac-ft and diversions to the Conveyance Canal are cut off. While this operation is not ideal in these three years, the forecast logic tends to provide a reasonable forecast and operation in most years. A variety of different forecast procedures were evaluated during model development and no procedure, with the exception of perfect foresight, simulated operations well in all years.

Table 15.3-1 quantifies the annual differences in Conveyance Canal diversions. Results show that annual volumes of water delivered to SSWD are generally consistent with what was delivered historically.

Table 15.3-1. Comparison of annual historical and modeled Main Canal diversions.

Year	Main Canal Diversions (acre-feet)			
	Historical	Model	Difference	Percent Difference
1976	87,334	63,460	-23,873	-27%
1977	0	0	0	0%
1978	114,950	110,000	-4,950	-4%
1979	125,736	110,000	-15,736	-13%
1980	132,652	110,000	-22,652	-17%
1981	86,435	74,140	-12,295	-14%
1982	112,552	110,000	-2,552	-2%
1983	97,997	110,000	12,003	12%
1984	115,937	110,000	-5,937	-5%
1985	88,663	84,262	-4,401	-5%
1986	108,513	110,000	1,487	1%
1987	77,307	61,886	-15,421	-20%
1988	44,705	32,001	-12,704	-28%
1989	107,170	110,000	2,830	3%
1990	90,706	72,043	-18,663	-21%
1991	95,502	87,982	-7,520	-8%
1992	77,736	69,507	-8,229	-11%
1993	103,412	110,000	6,588	6%
1994	72,055	72,022	-33	0%
1995	98,683	110,000	11,317	11%
1996	110,094	110,000	-94	0%
1997	111,927	110,000	-1,927	-2%
1998	103,414	110,000	6,586	6%
1999	121,806	110,000	-11,806	-10%
2000	121,632	110,000	-11,632	-10%
2001	53,803	63,424	9,621	18%
2002	114,670	110,000	-4,670	-4%
2003	96,872	83,089	-13,783	-14%
2004	91,017	95,967	4,950	5%
2005	110,246	110,000	-246	0%
2006	103,590	110,000	6,410	6%
2007	69,854	71,233	1,379	2%
2008	71,190	82,794	11,603	16%
2009	98,481	105,922	7,441	8%
2010	101,825	110,000	8,175	8%
2011	106,359	110,000	3,641	3%
2012	77,004	85,383	8,379	11%
2013	49,570	70,055	20,485	41%
2014	60,748	47,809	-12,938	-21%
Avg	93,639	95,784	2,144	4%
Max	121,806	110,000	20,485	41%
Min	49,570	47,809	-13,783	-21%

15.4 CFWID North and South Canal Diversions

Figures 15.4-1 and 15.4-2 compare historical to modeled irrigation delivers to CFWID. South and North canal diversions are aggregated as they are calculated in the same manner in the Ops Model. Two sets of figures are presented. Figure 15.4-1 plots the South and North canal diversions on a daily time-step to show how the Ops Model matches the historical data on a day-to-day basis. These comparisons illustrate whether the Ops Model is simulating the day-to-day differences in diversions and the timing of when they occur. A monthly figure is also included as Figure 15.4-2 to show how diversions match with seasonal variations in historical data over a larger time-step.

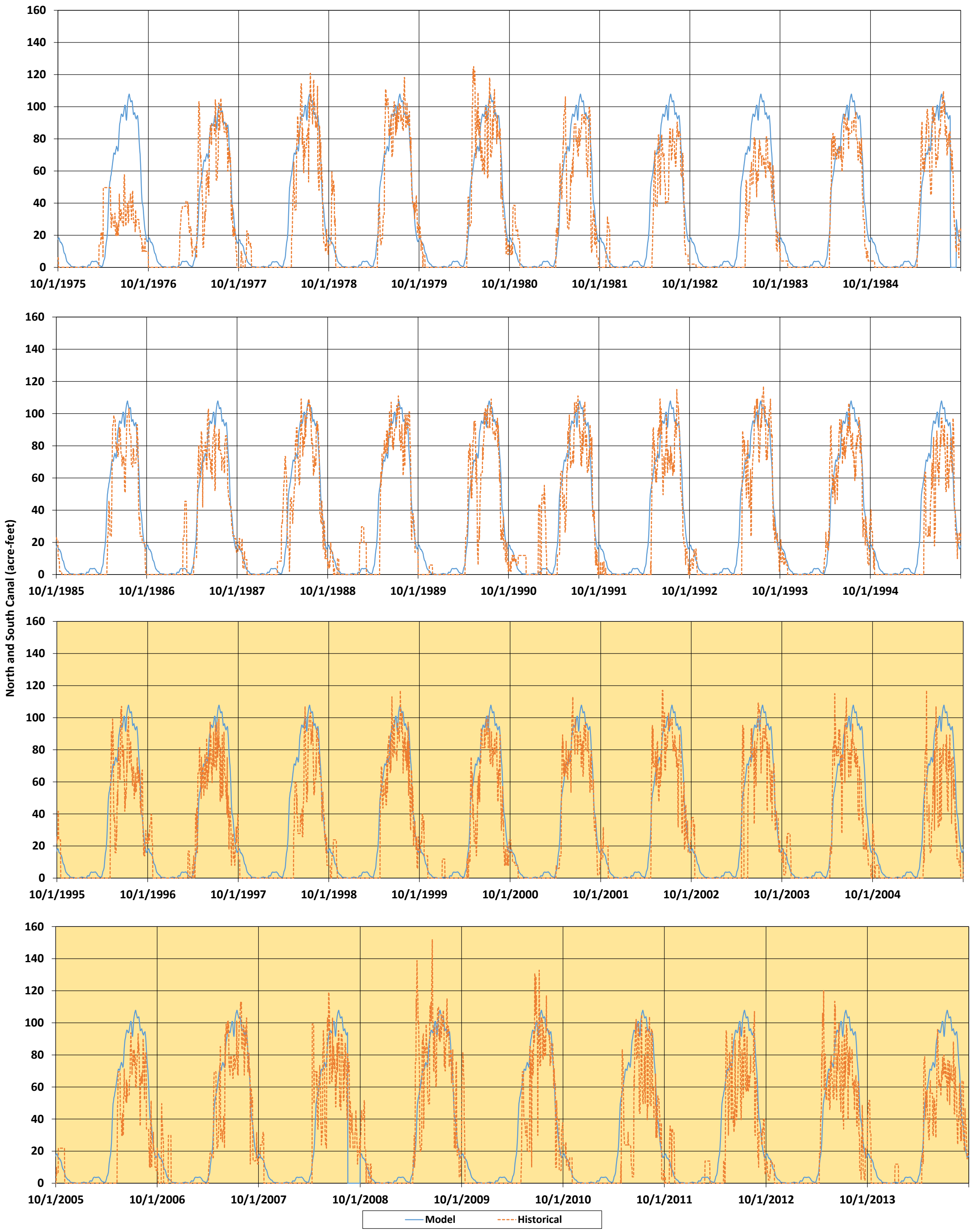

Figure 15.4-1. Comparison of daily historical and modeled CFWID North and South canal diversions.

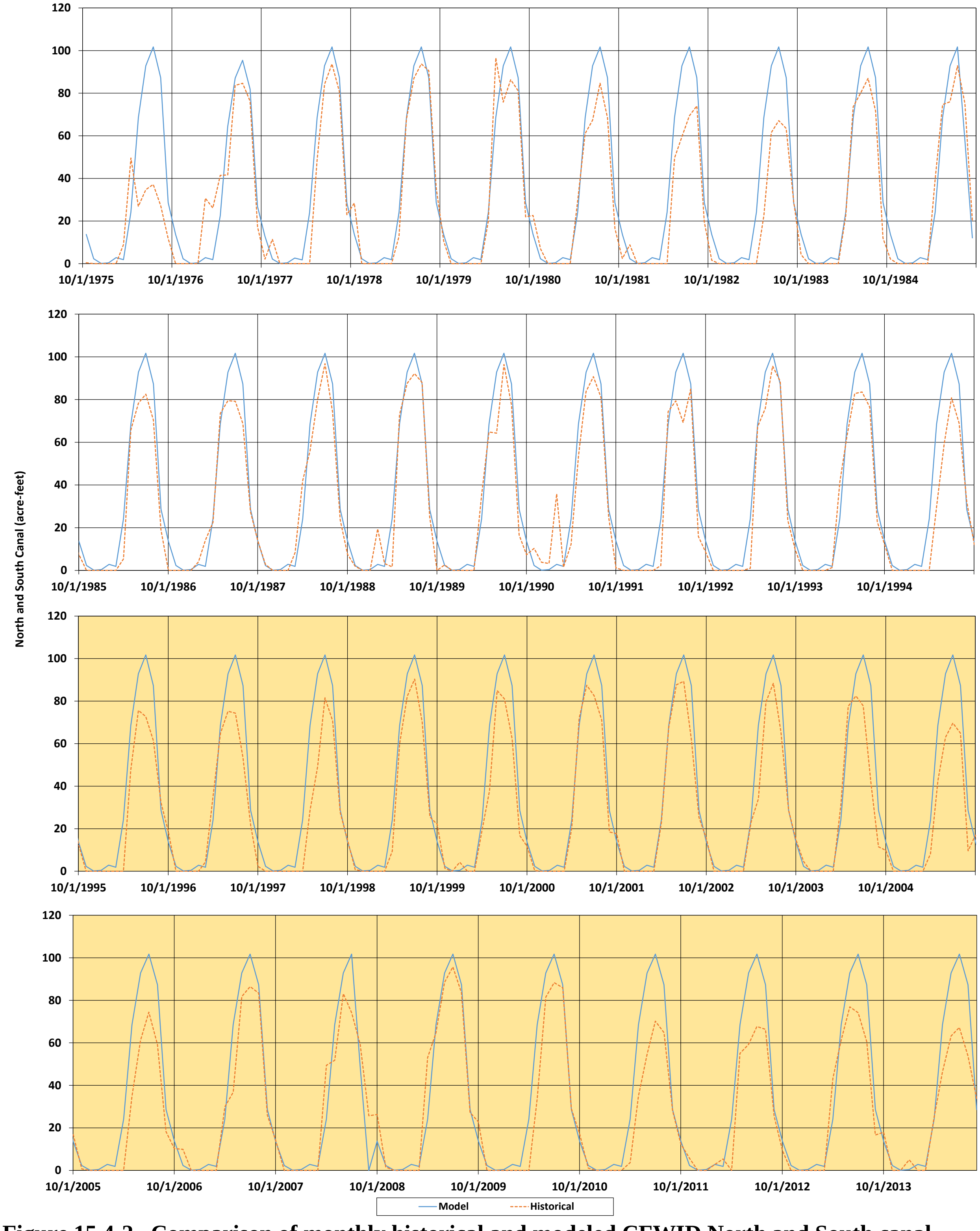

Figure 15.4-2. Comparison of monthly historical and modeled CFWID North and South canal diversions.

Figure 15.4-1 and Figure 15.4-2 show modeled and historical CFWID diversions generally match in timing and magnitude, however, in nearly every year the Ops Model diverts more than what was diverted historically, as shown in Table 15.4-1. This occurs because the Ops Model allocates and provides 13,000 ac-ft to CFWID every year, per the existing agreement, as opposed to the historical demand. CFWID has not requested the entire agreement amount from SSWD every year. This creates a discrepancy between the historical data and the Ops Model results, but SSWD must assume, and have available, the full 13,000 ac-ft for diversion by CFWID. Therefore, for planning purposes it is appropriate to include this volume in the Ops Model.

Table 15.4-1. Comparison of annual historical and modeled North and South canal diversions.

Year	South Canal and North Canal Diversions (acre-feet)			
	Historical	Model	Difference	Percent Difference
1976	5,993	13,004	7,011	117%
1977	12,632	12,210	-422	-3%
1978	11,008	12,991	1,982	18%
1979	12,200	13,000	800	7%
1980	12,631	13,004	373	3%
1981	10,390	13,000	2,610	25%
1982	8,411	13,000	4,589	55%
1983	7,597	13,000	5,403	71%
1984	10,709	13,004	2,295	21%
1985	11,833	11,598	-235	-2%
1986	9,859	13,000	3,141	32%
1987	11,812	13,000	1,188	10%
1988	11,963	13,004	1,041	9%
1989	12,006	13,000	994	8%
1990	11,540	13,000	1,460	13%
1991	11,805	13,000	1,195	10%
1992	10,276	13,004	2,727	27%
1993	11,109	13,000	1,891	17%
1994	11,751	13,000	1,249	11%
1995	8,713	13,000	4,287	49%
1996	9,445	13,004	3,558	38%
1997	10,133	13,000	2,867	28%
1998	8,382	13,000	4,618	55%
1999	11,072	13,000	1,928	17%
2000	9,753	13,004	3,251	33%
2001	11,324	13,000	1,676	15%
2002	11,335	13,000	1,665	15%
2003	10,354	13,000	2,646	26%
2004	10,175	13,004	2,829	28%
2005	8,462	13,000	4,538	54%
2006	8,215	13,000	4,785	58%
2007	10,978	13,000	2,022	18%
2008	11,348	10,949	-400	-4%
2009	13,333	13,000	-333	-2%
2010	10,333	13,000	2,667	26%
2011	8,413	13,000	4,587	55%
2012	8,944	13,004	4,060	45%
2013	10,745	13,000	2,255	21%
2014	9,007	12,501	3,494	39%
Avg	10,023	12,873	2,850	31%
Max	13,333	13,004	4,785	58%
Min	8,215	10,949	-400	-4%

15.5 Bear River at Wheatland

Figure 15.1-1 and 15.5-2 compare historical to modeled Bear River flows at Wheatland for the entire simulation period. Two figures are presented. Figure 15.5-1 plots the Bear River flows at Wheatland on a normal vertical scale to illustrate how the magnitude of flow can vary at certain times of year and under different conditions. These comparisons illustrate whether the Ops Model is simulating the day-to-day differences in flow and the timing of when they occur, but the range of flow makes it challenging to see how observed and simulated flow compare during periods of lower flow. Figure 15.5-2 plots the same information on a logarithmic vertical scale that allows an easier comparison for periods of lower flow.

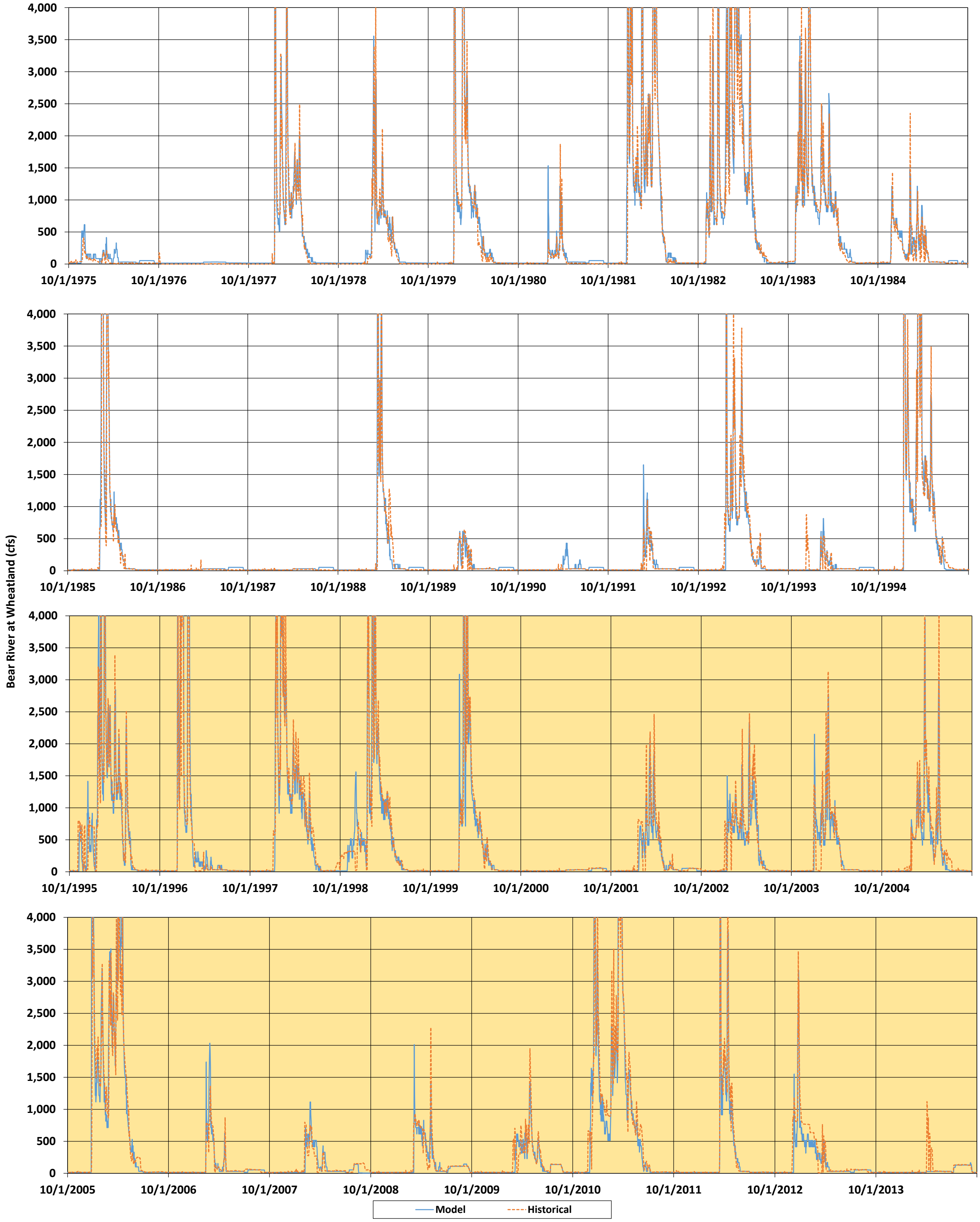

Figure 15.5-1. Comparison of daily historical and modeled Bear River flows at Wheatland (normal scale).

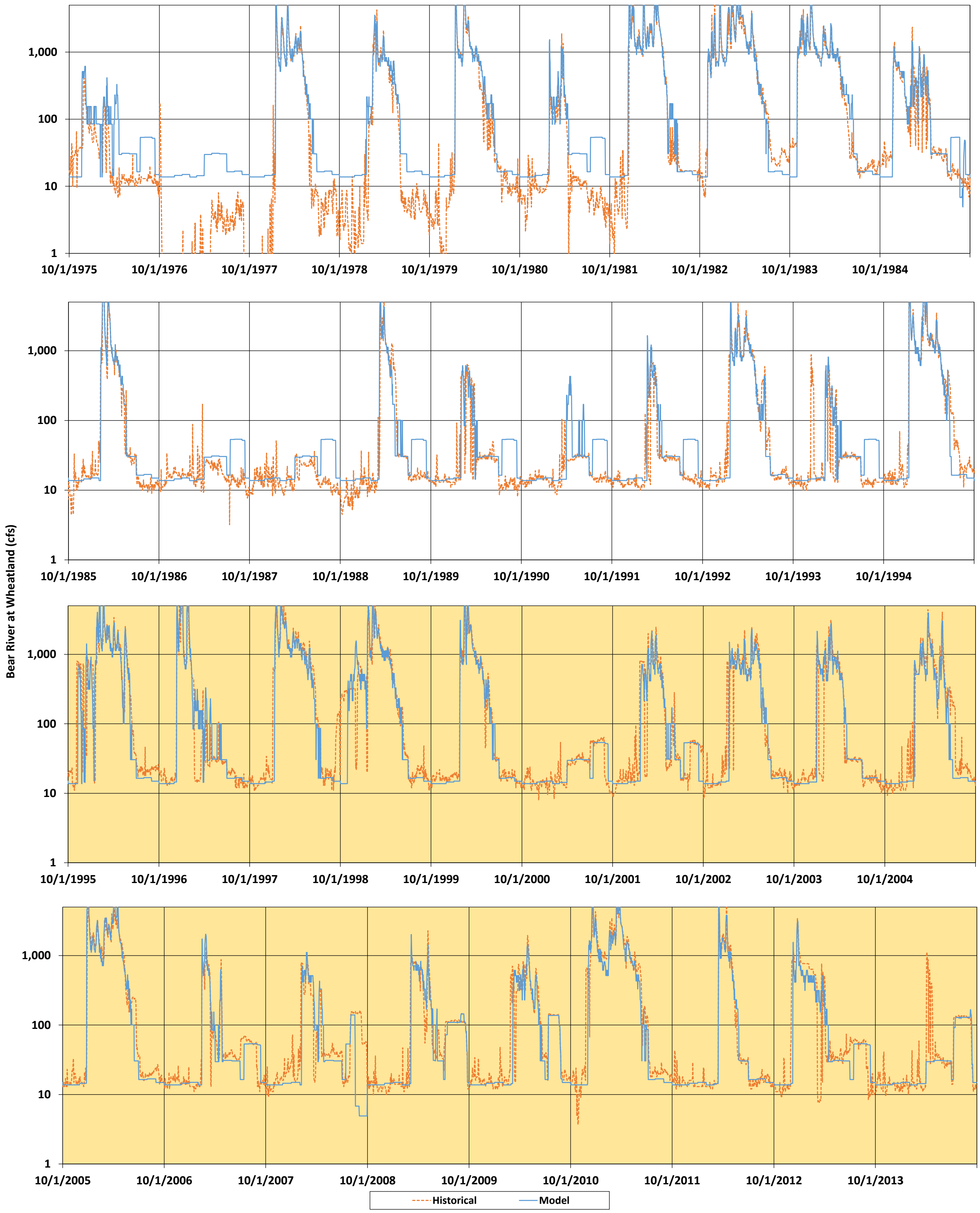

Figure 15.5-2. Comparison of daily historical and modeled Bear River flows at Wheatland (log scale).

As can be seen in Figure 15.5-1 and Figure 15.5-2, modeled Bear River flows at Wheatland generally match historical data on a daily basis. The BDSA releases are visible as the higher summer flows in dry and critical years in Figure 15.5-2. The Ops Model provides BDSA releases for the entire simulation period, while these releases were made historically starting in 2001. This leads to a significant difference in the multi-year drought from 1987 through 1992.

Table 15.5-1 summarizes the average annual flows from the Ops Model and compares them with historical data. Overall the historical data matches with model output in a reasonable manner.

Table 15.5-1. Comparison of annual average historical and modeled Bear River flows at Wheatland.

Water Year	Bear River at Wheatland (cfs)			
	Historical	Model	Difference	Percent Difference
1976	40	85	46	115%
1977	3	19	15	454%
1978	501	541	41	8%
1979	255	295	40	16%
1980	577	618	41	7%
1981	59	97	38	64%
1982	1,099	1,113	15	1%
1983	1,200	1,282	81	7%
1984	744	798	53	7%
1985	187	202	15	8%
1986	688	664	-24	-4%
1987	18	25	7	40%
1988	16	25	9	57%
1989	280	281	1	0%
1990	72	75	3	5%
1991	19	41	22	113%
1992	65	91	26	41%
1993	475	447	-28	-6%
1994	62	60	-1	-2%
1995	845	829	-16	-2%
1996	719	760	42	6%
1997	580	653	73	13%
1998	859	775	-83	-10%
1999	670	677	7	1%
2000	495	518	23	5%
2001	25	25	0	-1%
2002	246	218	-28	-12%
2003	363	332	-31	-9%
2004	255	278	23	9%
2005	382	345	-37	-10%
2006	924	1,055	131	14%
2007	104	117	13	13%
2008	105	106	1	1%
2009	165	156	-9	-5%
2010	166	148	-18	-11%
2011	990	911	-79	-8%
2012	301	268	-33	-11%
2013	258	208	-50	-19%
2014	67	38	-29	-43%
Avg	426	421	-5	-4%
Max	990	1,055	131	14%
Min	25	25	-83	-43%

15.6 Hydropower and Turbine Flow

Figures 15.6-1 through 15.6-4 compare historical to modeled turbine flow and hydropower generation for the period for which historical data are available. Turbine flow data collected by SSWD spans from 1985, when the power house was installed, to 2014. Hydropower generation data are available on a monthly basis from 1993 through 2013, while daily data are available from Sacramento Municipal Utilities District from 2005 through 2014. Four figures are presented. Figure 15.6-1 and Figure 15.6-2 show the modeled turbine flow, on a daily and monthly basis respectively, for the period of record compared to historical turbine flow data. Figure 15.6-3 compares available monthly historical hydropower generation to modeled hydropower generation. Figure 15.6-4 compares available daily historical hydropower generation to modeled hydropower generation.

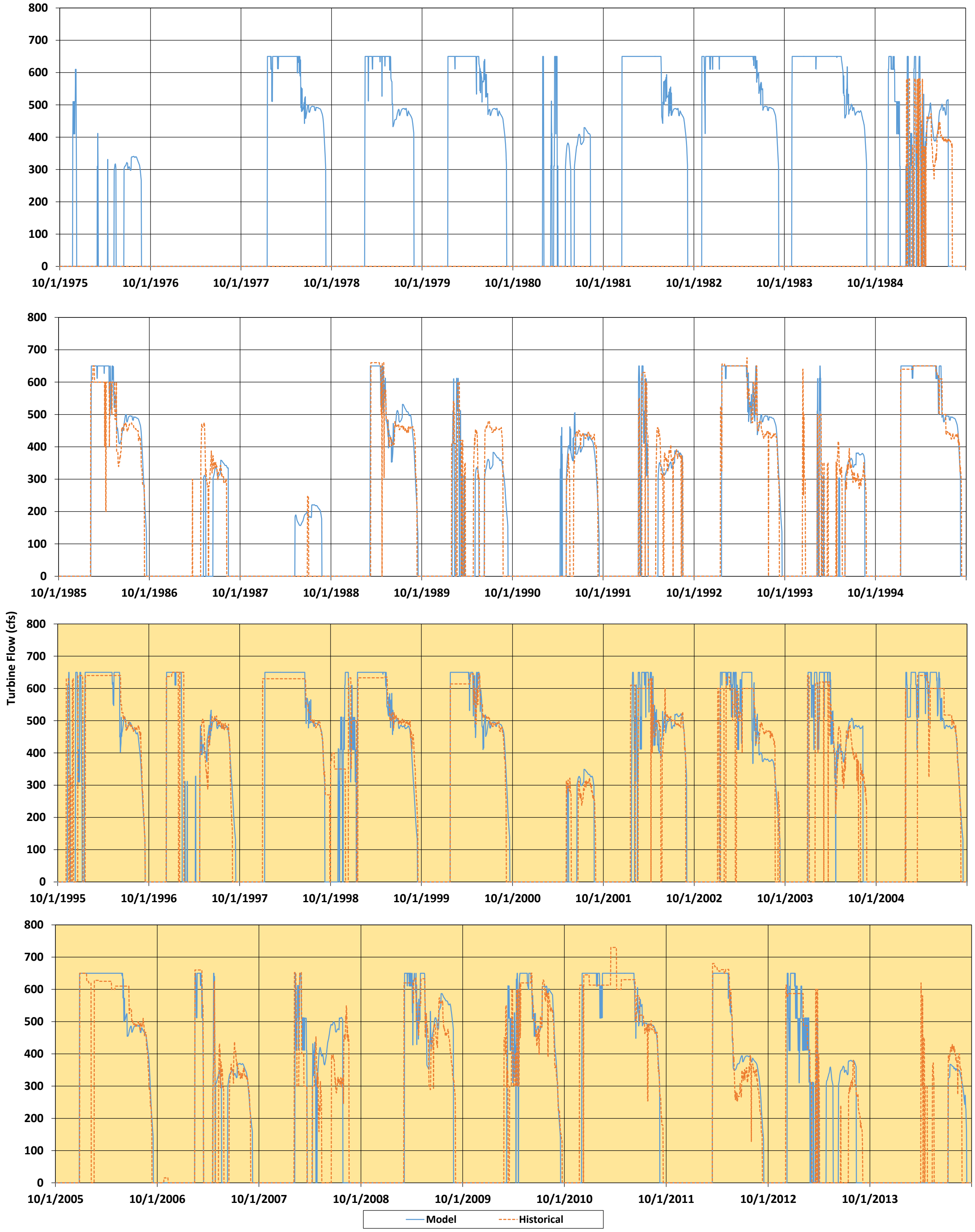

Figure 15.6-1. Comparison of daily historical and modeled turbine flow.

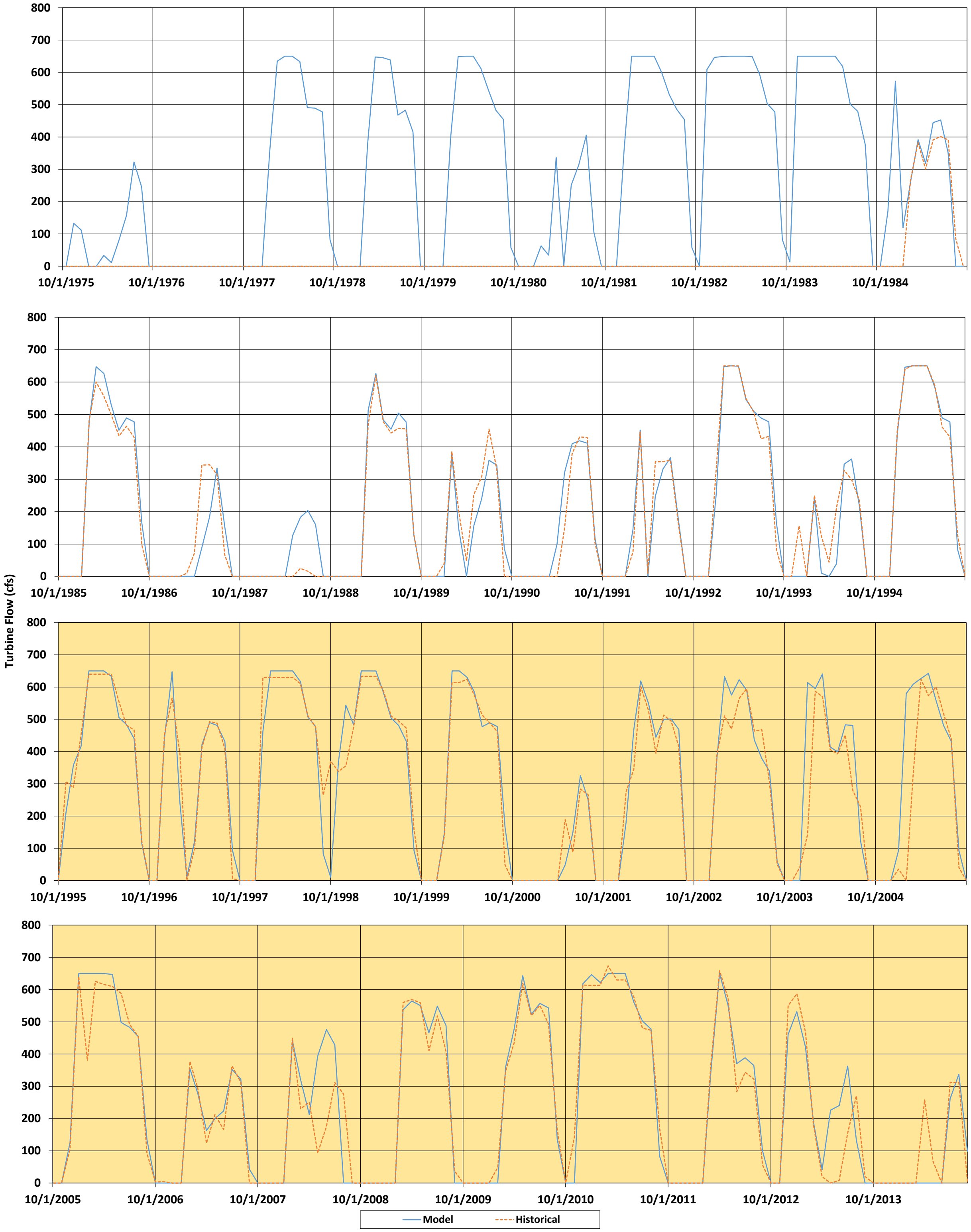

Figure 15.6-2. Comparison of monthly historical and modeled turbine flow.

Results illustrated in Figure 15.6-1 and Figure 15.6-2 demonstrate historical and modeled turbine flow generally match in timing and magnitude.

Table 15.6-1. Comparison of annual average historical and modeled turbine flow.

Water Year	Turbine Flow (cfs)			
	Historical	Model	Difference	Percent Difference
1989	254	266	11	5%
1990	168	142	-26	-16%
1991	124	148	24	19%
1992	147	144	-4	-2%
1993	356	366	9	3%
1994	137	101	-36	-26%
1995	388	389	1	0%
1996	433	426	-7	-2%
1997	277	282	5	2%
1998	418	395	-22	-5%
1999	472	454	-18	-4%
2000	340	356	16	5%
2001	69	65	-4	-6%
2002	297	311	14	5%
2003	318	334	16	5%
2004	258	313	54	21%
2005	263	343	80	30%
2006	384	412	28	7%
2007	155	161	7	4%
2008	149	189	40	27%
2009	255	263	8	3%
2010	265	270	5	2%
2011	468	455	-13	-3%
2012	217	231	14	6%
2013	188	217	29	15%
2014	79	58	-21	-27%
Avg	285	296	12	4%
Max	472	455	80	30%
Min	69	58	-22	-27%

Results summarized in Table 15.6-1 demonstrates average annual simulated turbine flow is generally similar to the average annual historical turbine flow.

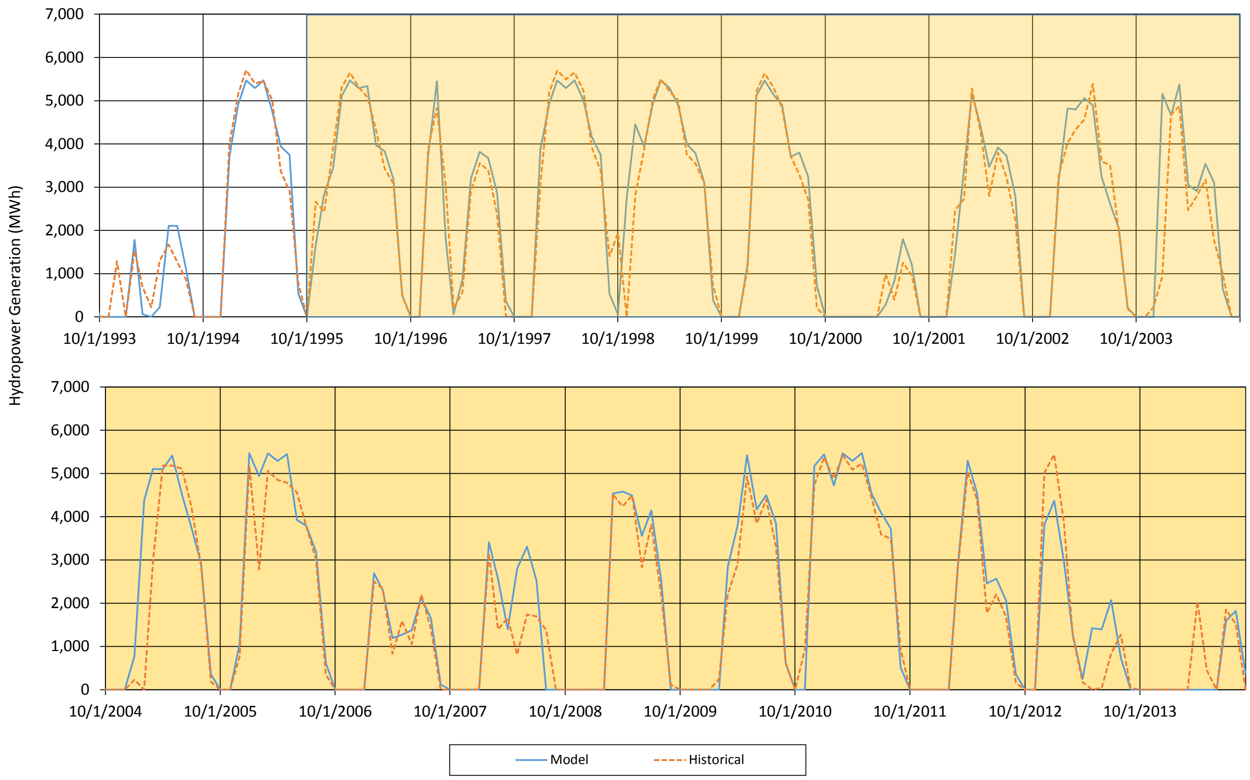

Figure 15.6-3. Comparison of monthly historical and modeled hydropower generation.

As illustrated in Figure 15.6-3, seasonal timing and magnitude of modeled hydropower generation reasonably match historical data for the period of available data.

Table 15.6-2. Comparison of annual historical and modeled hydropower generation.

Water Year	Hydropower Generation (MWh)			
	Historical	Model	Difference	Percent Difference
1992	10,761	11,303	542	5%
1993	34,015	34,692	677	2%
1994	8,855	7,382	-1,474	-17%
1995	37,777	37,824	47	0%
1996	41,638	40,729	-909	-2%
1997	24,766	25,831	1,065	4%
1998	39,078	38,537	-541	-1%
1999	40,533	43,080	2,547	6%
2000	32,063	33,346	1,283	4%
2001	3,608	4,137	528	15%
2002	26,797	28,365	1,568	6%
2003	30,845	30,871	27	0%
2004	21,935	28,452	6,517	30%
2005	25,950	32,319	6,369	25%
2006	35,103	39,192	4,088	12%
2007	11,927	12,726	799	7%
2008	11,828	16,051	4,223	36%
2009	22,224	23,836	1,611	7%
2010	22,454	25,161	2,707	12%
2011	44,115	44,445	330	1%
2012	18,071	20,166	2,095	12%
2013	17,948	18,237	289	2%
2014	5,855	3,780	-2,076	-35%
Avg	25,726	27,354	1,628	7%
Max	44,115	44,445	6,517	36%
Min	3,608	3,780	-2,076	-35%

Results summarized in Table 15.6-2 show simulated hydropower generation tends to agree with historical data on an annual basis.

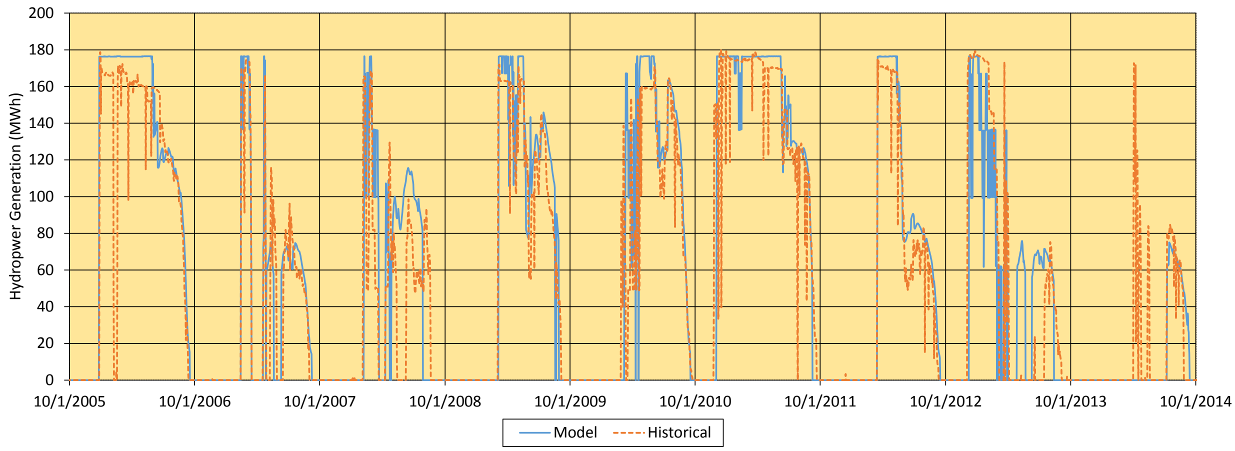

Figure 15.6-4. Comparison of daily historical and modeled hydropower generation.

Figure 15.6-4 presents daily modeled hydropower generation and daily historical generation data. Model results match historical data in most years.

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SECTION 16

REFERENCES

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