Appendix 4: Proposed Action

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Section C - LKNWR Historical Deliveries

Table C1. Historical LK NWR Water Deliveries
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Section D - Clear Lake Reservoir and Gerber Reservoir Water Supply Forecast Models

Table D1. Clear Lake Reservoir Operational Forecast Model
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A.4.1. Model Overview

The Klamath Basin Planning Model (KBPM) was used to simulate the operation of the Klamath River system over a range of hydrologic conditions. The model is a generalized reservoir-river basin simulation model that allows for specification and achievement of user-defined goals. Figure A.4.1.1 shows the overall Klamath River watershed and the Klamath and Lost rivers. The KBPM extent covers from Upper Klamath Lake (UKL) to Iron Gate Dam (IGD), just upstream of the Shasta River confluence.

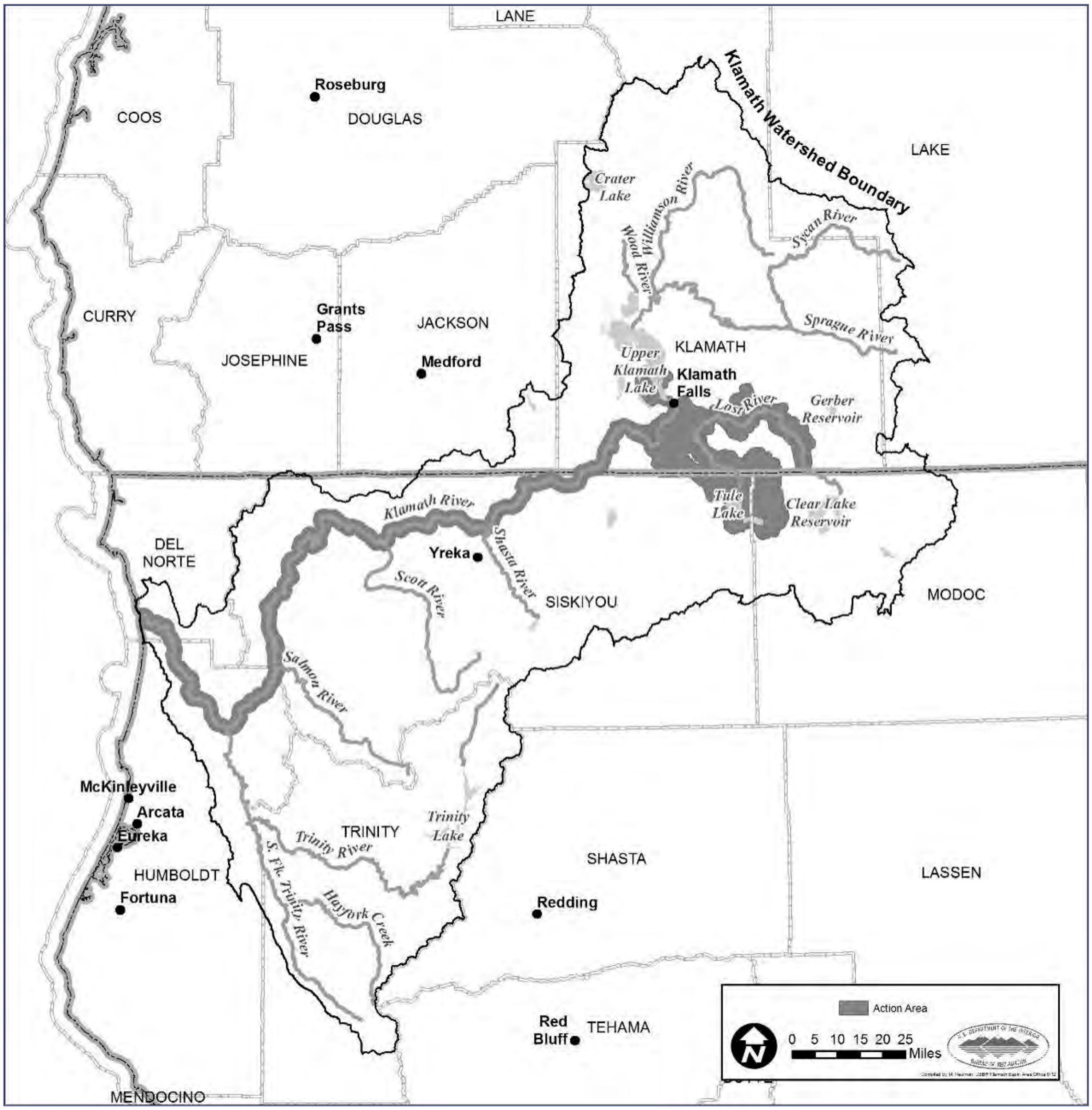


Figure A.4.1.1 Location of Upper Klamath Basin, Oregon and California, and locations of major rivers.

Inputs to the KBPM were developed at a daily timestep and include water diversion requirements (demands), system gains and losses (accretions), UKL net inflows, inflow from the Lost River through the Lost River Diversion Channel (LRDC) and return flow ratios. The Klamath Basin daily inflow data set was developed by a working team of hydrologists and modelers from various organizations using historical data from a variety of sources for the 36-year period of record (POR) including water years 1981 through 2016. The resulting hydrology represents the water supply available from the Klamath River system, including UKL, to the service area at the current level of development. This data development is discussed further in Section A.4.3.

The KBPM produces daily outputs for river flows, Klamath Project (Project) diversions (including deliveries to the Lower Klamath National Wildlife Refuge [LKNWR]) and reservoir storage. The model output also serves as input data for other analysis tools.

It's important to note that the KBPM is a planning tool that assisted in the development of the Proposed Action and, though modelers have strived to make modeled actions implementable in actual operations, some of the processes built into the model cannot be implemented. For example, perfect foresight of Project diversion of return flows was used to ensure that all water available to the Project in a given year was utilized. While the assumption that the Project will utilize all water made available for irrigation under this management regime is sound, there is no assurance that all available return flows will be captured and reused for irrigation purposes in real-time operations. Real-time implementation of the Proposed Action may not result in fully efficient use of these flows. The actual availability and efficiency of use of Project return flows is heavily dependent upon current hydrologic and meteorological conditions and will vary from year to year. This is just one example of how some of the processes built into a planning model may not be implemented during actual operations. Therefore, although much effort has been made to make the KBPM as operationally realistic as possible, its output cannot be viewed as the certain outcomes that will be realized when implementing the Proposed Action.

A.4.2 WRIMS and WRESL Code

The KBPM is built on the Water Resources Integrated Modeling System (WRIMS) platform. WRIMS uses a mixed integer linear programming solver to route water through a user-defined network of flow arcs and nodes representing locations in the river system. Policies and priorities for water routing are implemented through user-defined weights applied to flow arcs and storage nodes in the network. System variables and the constraints on them are specified with a scripting language called the "water resources engineering simulation language" (WRESL). WRESL code is developed in simple ascii text files. Time series input data and model results are stored in HEC-DSS files. Relational data (lookup tables) are stored in ascii text files.

A.4.3 Model Representation

A.4.3.1 Modeled Rivers, Lakes, Conveyance Facilities, and Model Schematic

The KBPM simulates water-supply related operations of the Project within the Klamath River system. Because this model operates on a mass-balance basis, Project operations which do not affect water supply such as pesticide use or intermittent maintenance operations were not modeled. Within this system, the components that are specifically modeled include UKL, Lake Ewauna (i.e., Keno Reservoir), the Klamath River from Keno Dam to IGD, and all associated Reclamation-owned facilities that are expected to be operable over the time period covered by this Biological Assessment. Facilities include the Link River Dam (LRD), A Canal, LRDC, North Canal, Ady Canal, Klamath Straits Drain (KSD), and all associated pumping facilities. Note that Reclamation does not own the North Canal headworks, and Reclamation therefore has limited control over deliveries through this canal.

The model does not simulate the Lost River system upstream of Harpold Dam. After runoff from the Lost River catchment has subsided, the area upstream of Harpold Dam is typically operated as a closed system during the irrigation season when the releases from Clear Lake and Gerber reservoirs (and any natural flow) equal the water used prior to flows reaching Harpold Dam. Harpold Dam is a flash board dam where the flash boards are added and removed as needed. The boards are up when releases are being made from Clear Lake and Gerber reservoirs (typically during the spring/summer operational period) and are removed once Clear Lake and Gerber dams stop releases for the fall/winter operational period.

Downstream of Harpold Dam, agricultural water diversions are largely supplied by A Canal diversions from UKL. Flow passing Harpold Dam mixes with return flow, and the combined flow is measured at the headworks of the LRDC at Lost River Diversion Dam, into which the Lost River is diverted. This diversion either flows into Station 48 or Miller Hill pump station (when open) or continues flowing into the Klamath River. The KBPM accounts for flows from the Lost River to the LRDC through a historical daily input time-series (I91). This value is very low when Harpold Dam is operational because it is comprised only of Harpold Dam leakage, runoff and return flows between Harpold and Wilson Dams. When Harpold Dam is not operational, this value can be very high as it includes the entire flow of the Lost River.

Return flows from the Area A2 (which receives water from North and Ady canals) and the LKNWR are also incorporated (Figure A.4.3.1.1) as flows through the Klamath Straits Drain (pumping plants E/EE and F/FF). The direct effect of Project operations ends at the KSD above Keno Dam, Oregon, which is the last feature of Project infrastructure, although the model itself simulates operations down to IGD with the daily accretion between Keno Dam and IGD based on historical data. The model schematic is shown in Figure A.4.3.1.2. For a more detailed description of each link and object referenced in the schematic, please see the definitions in Table A.4.3.4.1 – Key Model Variables.

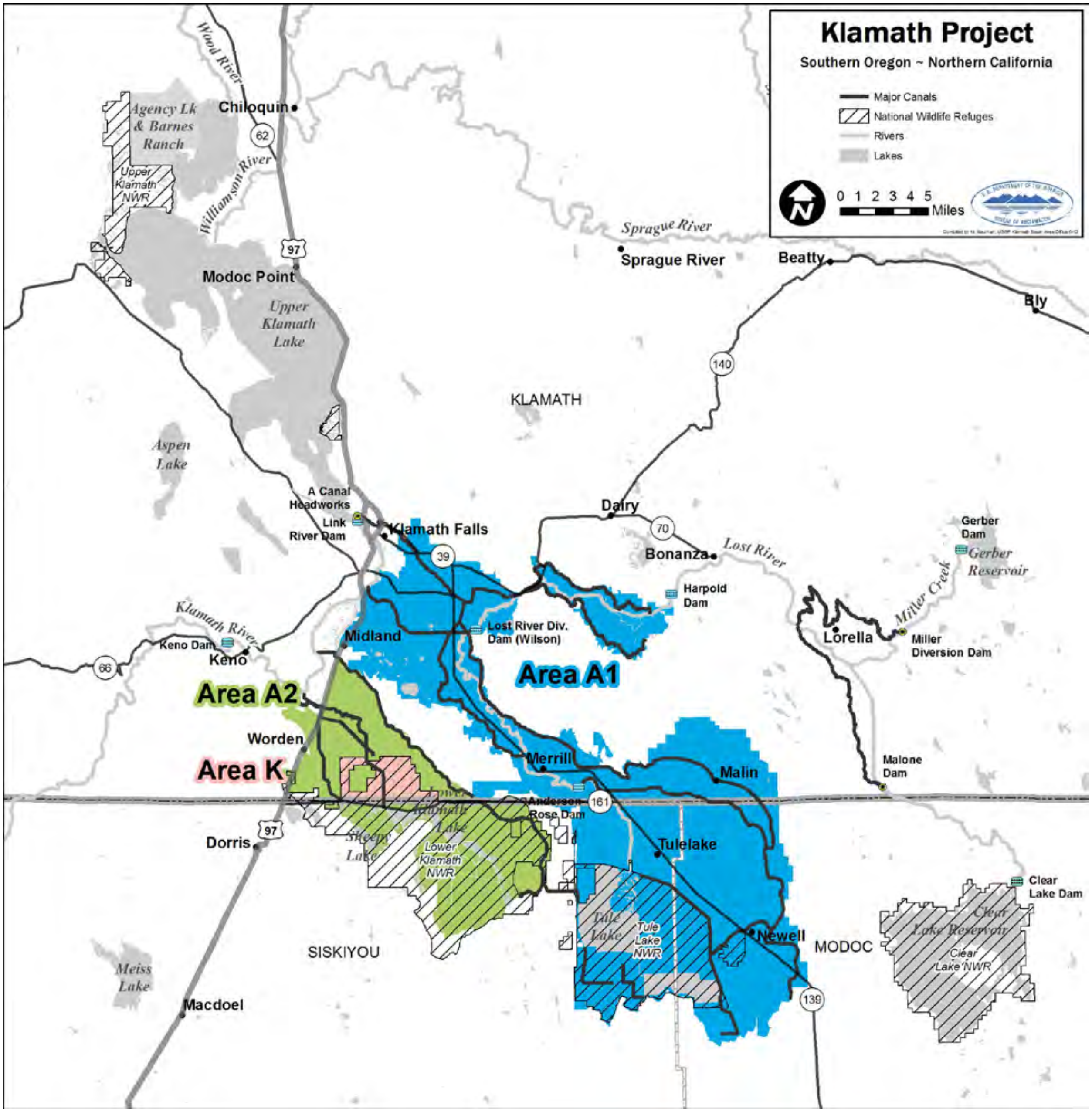
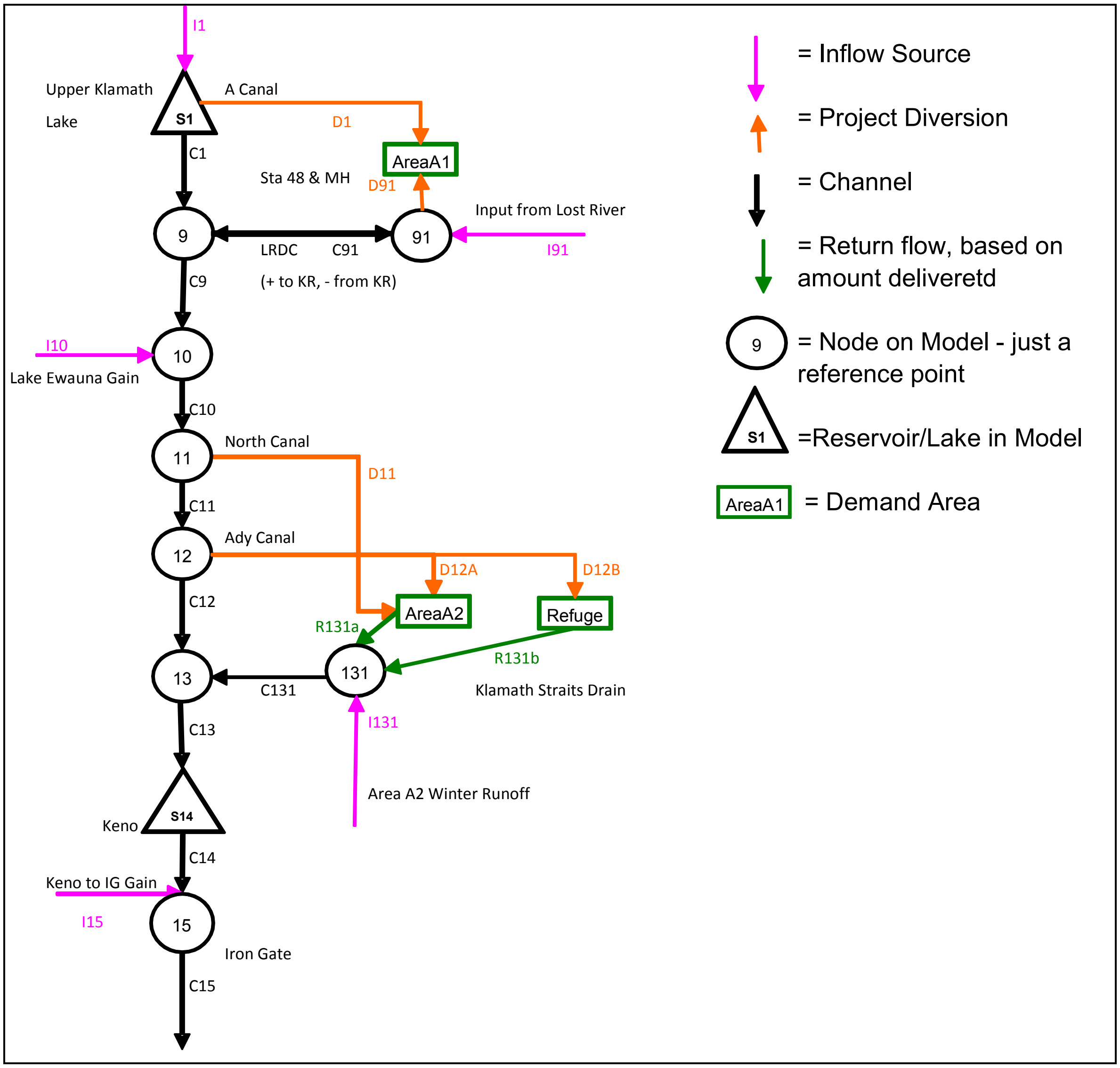


Figure A.4.3.1.1 Upper Klamath Lake and the portion of the Klamath Project served by UKL and the Klamath River in southern Oregon and northern California.


I1
Upper Klamath Lake
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Ady Canal
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C131
Klamath Straits Drain
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Area A2 Winter Runoff
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Iron Gate
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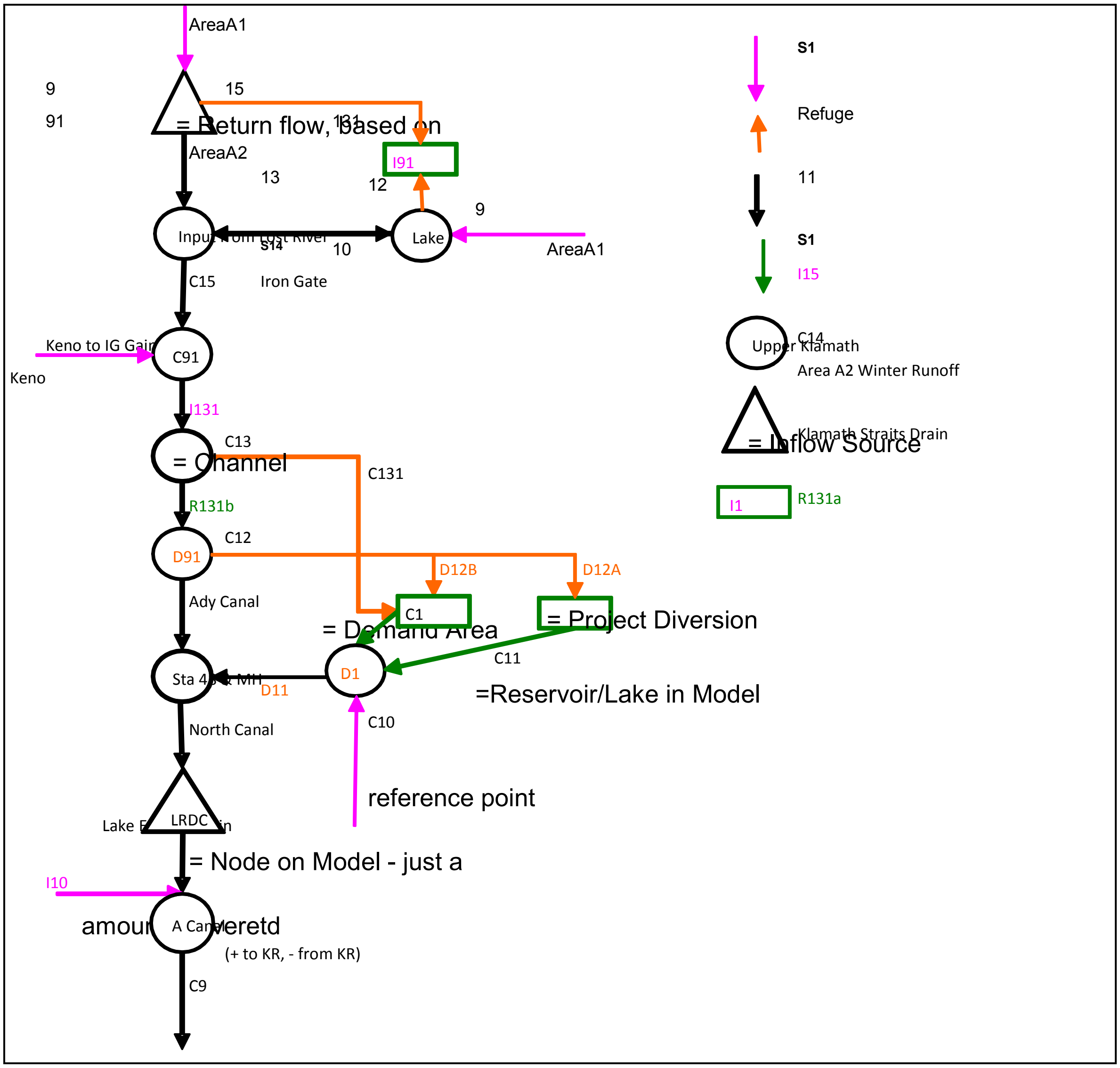
=Reservoir/Lake in Model
= Demand Area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Area A2 Winter Runoff
Klamath Straits Drain
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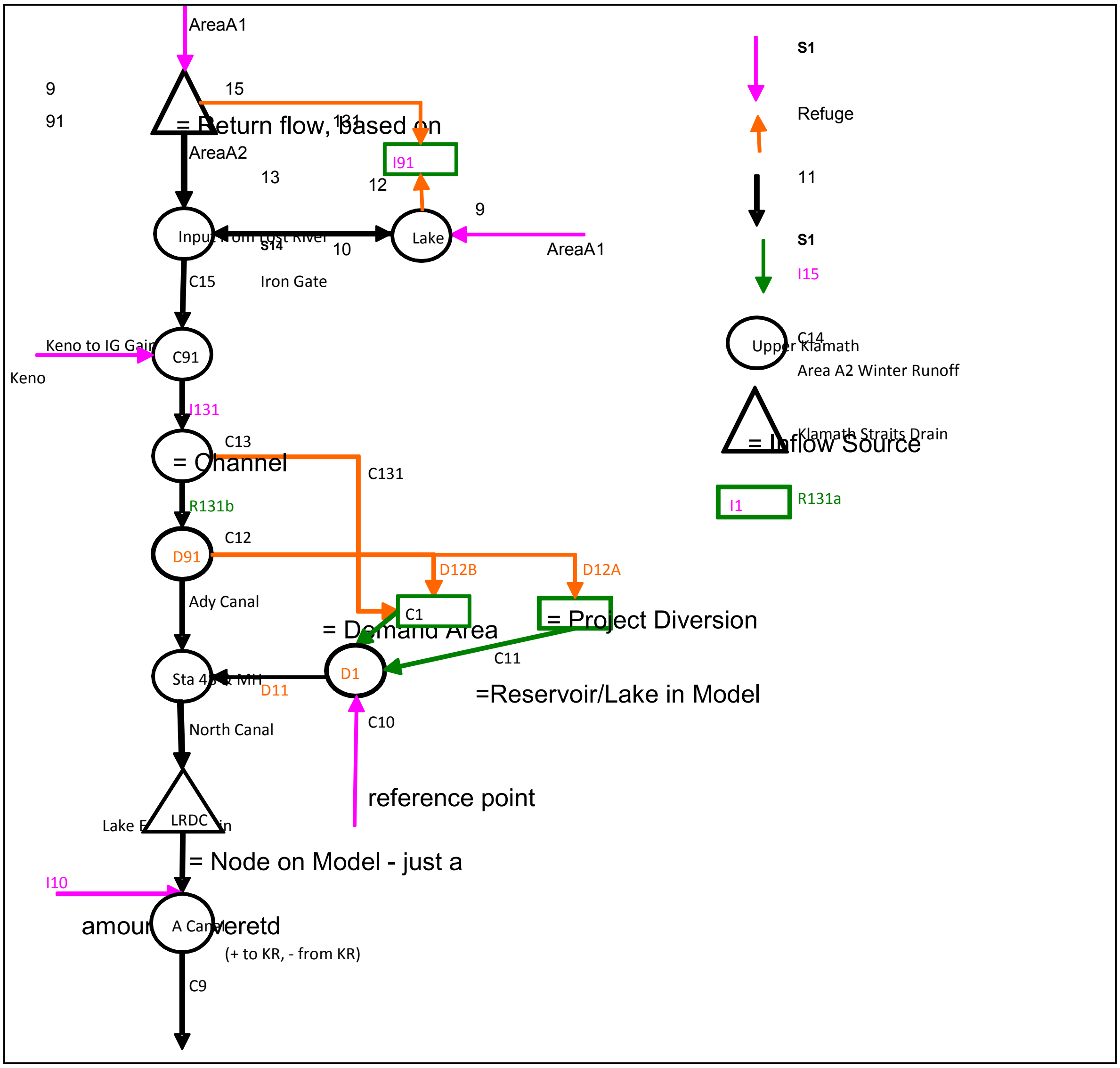
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Keno to IG Gain
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Ady Canal
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Upper Klamath
Area A2 Winter Runoff
Klamath Straits Drain
= Inflow Source
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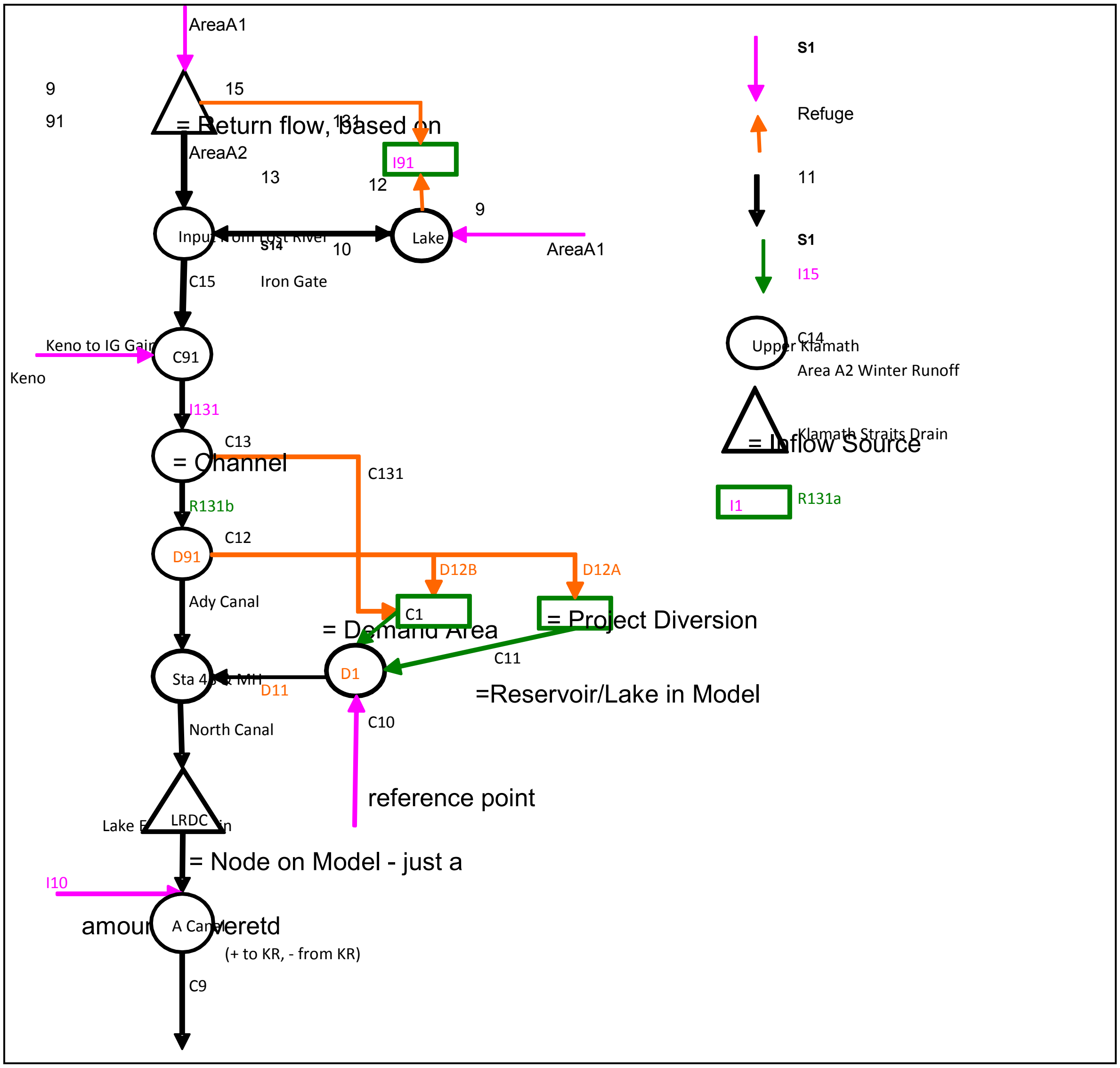
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Upper Klamath
Area A2 Winter Runoff
Klamath Straits Drain
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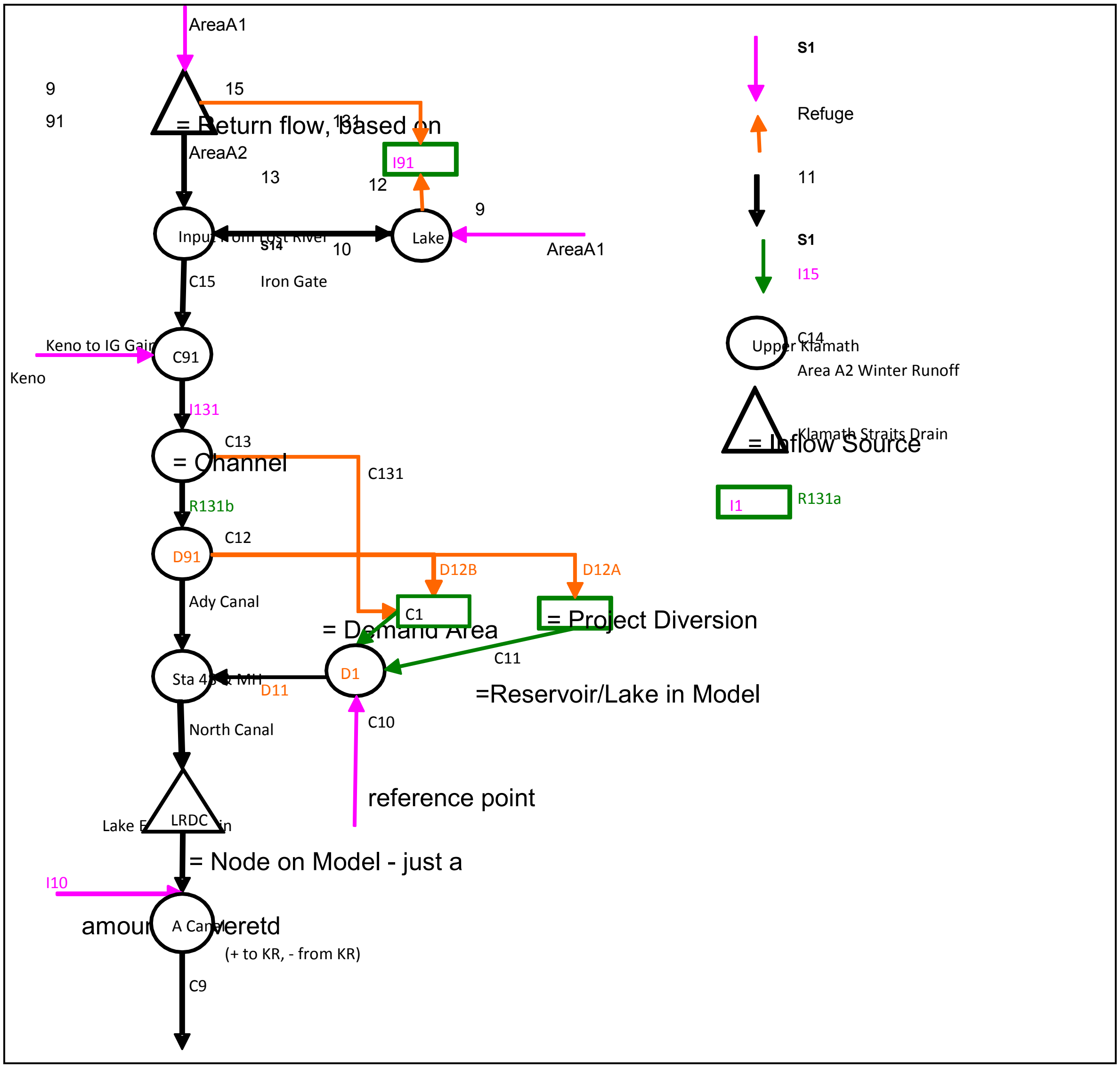
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R131b
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D11
C10
North Canal
LRDC
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(+ to KR, - from KR)
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Area A2 Winter Runoff
Klamath Straits Drain
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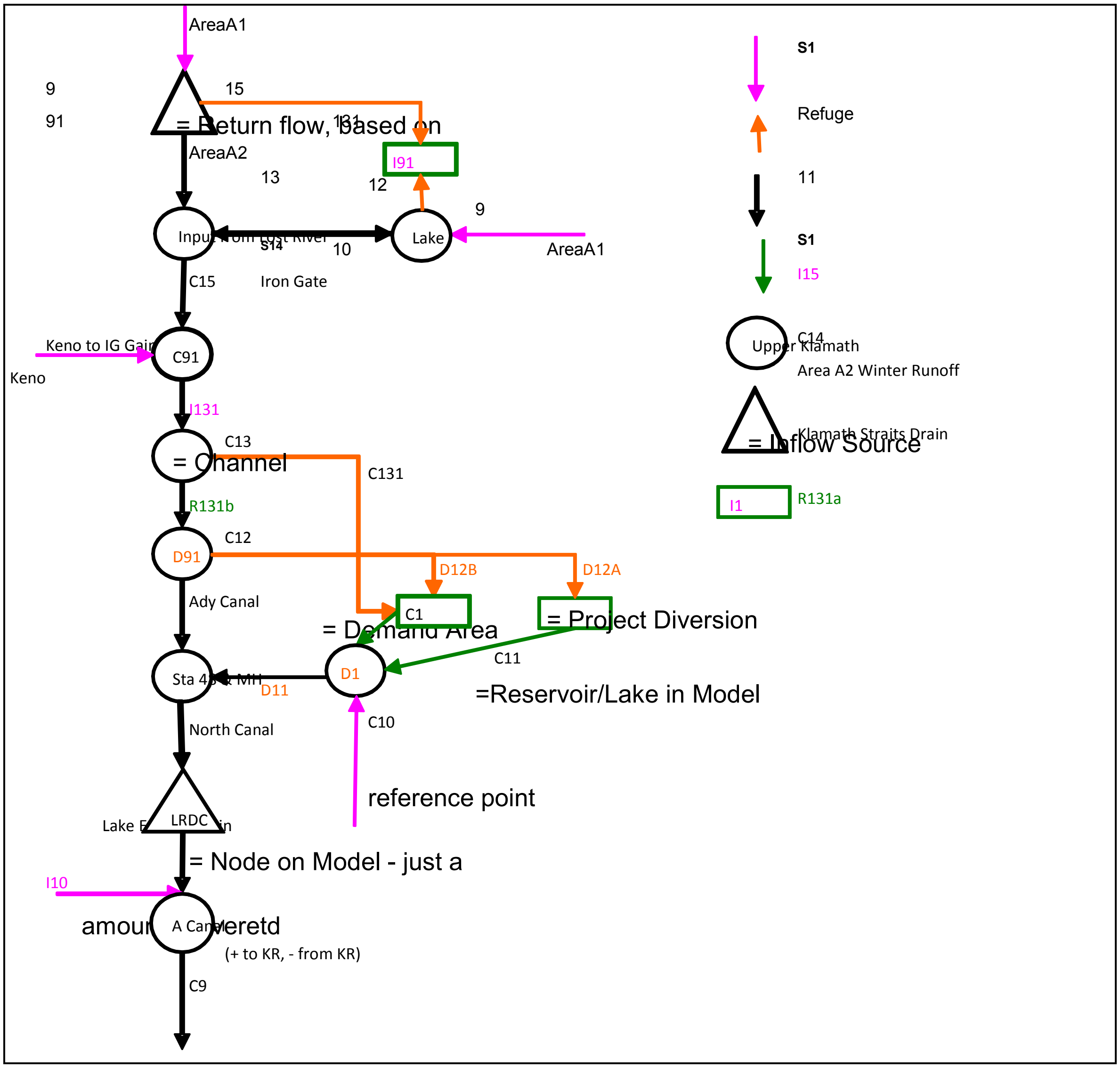
=Reservoir/Lake in Model
reference point
= Node on Model - just a
= Inflow Source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Iron Gate
Keno to IG Gain
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R131b
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Ady Canal
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= Project Diversion
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=Reservoir/Lake in Model
North Canal
C10
reference point
LRDC
= Node on Model - just a
I10
(+ to KR, - from KR)
C9
S1
Refuge
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Area A2 Winter Runoff
Klamath Straits Drain
I1
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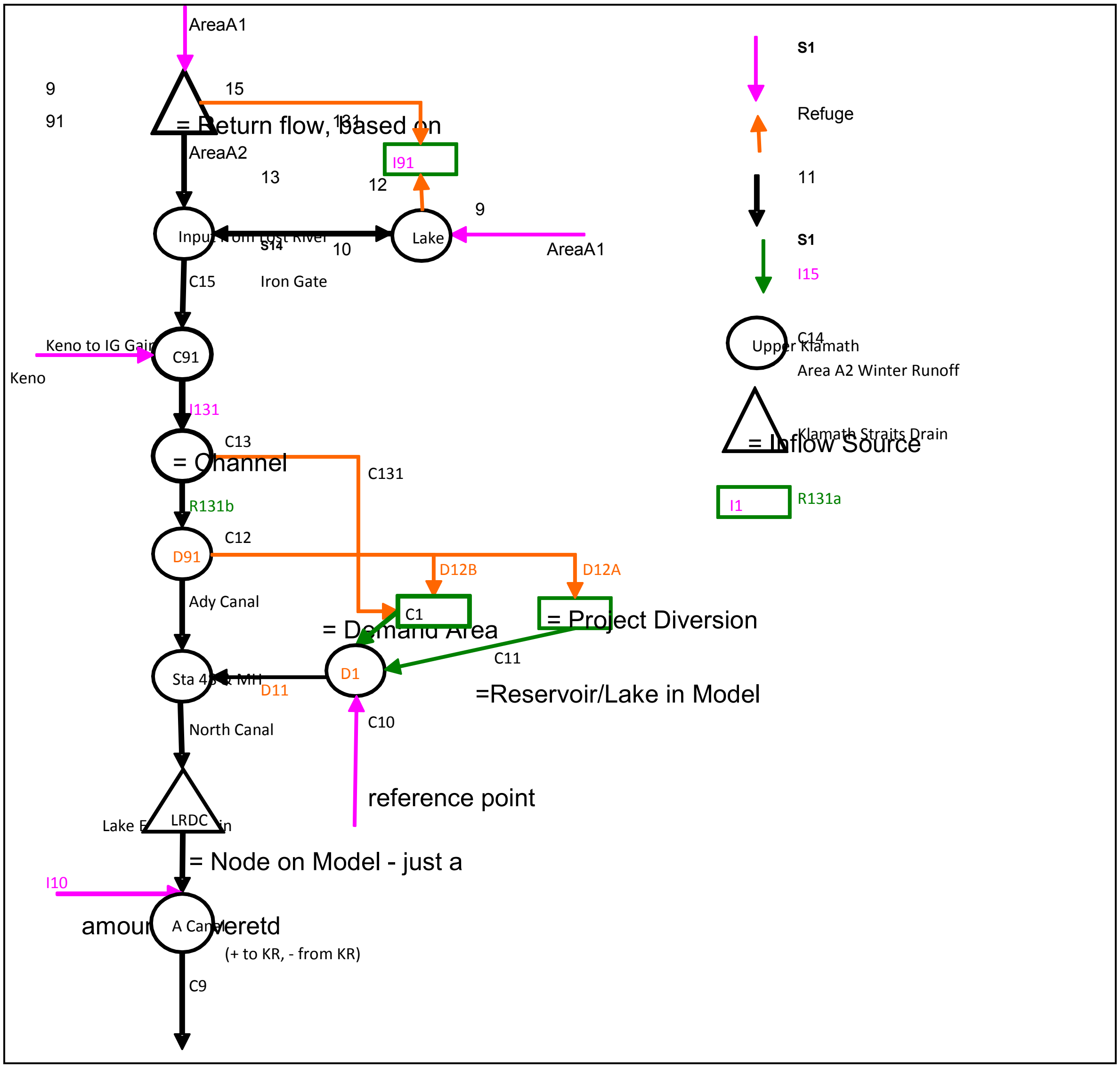

Figure A.4.3.1.2 Model schematic

A.4.3.2 Period of Record

The current KBPM uses a daily timestep, starting October 1, 1980 and running through November 30, 2016. The period between water years 1981 through 2016 includes a reasonable distribution of wet, average and dry years. With this range of data, the model can evaluate a particular operations strategy across the full available range of inflows.

The daily timestep 36-year input data set provides the following advantages over the previous 31-year iteration of the daily timestep model utilized in the 2012 BA:

- Essential daily data inputs are available electronically for water years 1981-2016. These data sets have been extensively evaluated for quality assurance and subjected to quality control over the full POR and are significantly improved over those utilized in the 2012 BA.

- An improved UKL bathymetry addresses important issues from the 2012 BA relating to the relationship between lake elevation and storage volume.

- Forecasts from the Natural Resources Conservation Service (NRCS) for March, April, May, and June have been updated including the additional years in the POR. These forecasts were updated based on the new, current forecasting methods and include several years in which the state of Oregon regulated diversions in accordance with calls to determined claims from The Klamath Tribes and the Project.

- 1981-2016 still include a wide range of hydrologic conditions (lowest [1992] and highest [1983] inflow years), and includes various multi-year hydrologic cycles:

    - Oscillating extreme years such as 1992/1993/1994 when UKL net inflows for April-September measured 141,000/658,000/167,000 acre-feet (AF), respectively.

    - Repetitive wetter years such as 1982/1983/1984 when UKL net inflows for April-September measured 713,000/893,000/833,000 AF, respectively.

    - Repetitive drier years such as 2013/2014/2015 when UKL net inflows for April-September measured 295,000/225,000/195,000 AF, respectively.

A.4.3.3 Hydrology Inputs

A.4.3.3.1 Definitions

<u>Area 1</u> is the portion of the Project that includes lands served by A Canal and the LRDC including Klamath Irrigation District (KID), Tulelake Irrigation District, and Warren Act contractors and Districts served by KID.

<u>Area 2</u> is the portion of the Project that includes Klamath Drainage District and LKNWR served by the Ady and North canals.

<u>Quality Assurance</u> is process oriented to ensure the correct steps are completed in the correct manner. Additionally, planned and systematic activities are implemented in a quality system so that quality requirements for a product or service will be fulfilled. In the context of data sets for the WRIMS model, quality assurance will relate to the configuration of the physical infrastructure of water diversions structures, gauging systems, and how data are collected.

<u>Quality Control</u> (QC) is product oriented to ensure the results meet the expectations of the project. It includes the techniques and activities used to fulfill requirements for quality. QC emphasizes testing of products to uncover defects. In the context of data sets for the WRIMS

model, quality control will relate to proofing of the data and correcting/adjusting data so that a final reliable dataset is created.

A.4.3.3.2 Data Sets

1. Project Daily Data and Project Historical Use Data
2. UKL net inflow
3. Lake Ewauna (Keno Reservoir) accretions
4. Keno Dam to IGD accretions
5. LRDC inflow from the Lost River
6. Area 2 winter runoff
7. NRCS forecasts

A.4.3.3.3 Project Daily Data and Project Historical Use Data

All data sets utilized in the 2012 Biological Assessment were updated to include the additional years (2012-2016) in the POR, and all data were subjected to extensive QC. As a term and condition of the 2013 Biological Opinion, gages at A Canal, LRDC, Ady Canal at Highway 97 (Klamath Drainage District delivery), Ady Canal above LKNWR (Refuge delivery), North Canal, and KSD are regularly maintained and recalibrated. Using these more accurate gage data, all relevant data from the 2012 BA was QC'ed via comparison with the new data sets. Comprehensive detail on all data analysis and correction to Project diversion data can be found in Dunsmoor (2017a). Quality control was conducted and finalized on daily data for A Canal, LRDC total flow, Station 48, Miller Hill Pump, Miller Hill Spill, North Canal, Ady Canal, Ady Canal to LKNWR, and F/FF pumps via KSD.

The QC'ed daily dataset was finalized for October 1, 1974 through November 30, 2016 for Area 1, and January 1, 1980 through November 30, 2016 for Area 2. Where possible, approved daily data from U.S. Geological Survey (USGS) gages have been used, replacing older data. Where these records do not exist, other approaches were taken. For the most recent time periods, provisional USGS data were used. For older time periods that predate USGS monitoring, appropriate corrections have been applied to existing data sets to bring them in line with USGS measurements and/or other best available measurement standards. All gaps in the record have been examined and appropriately filled. For more detail see Dunsmoor (2017a).

Project daily data are contained in the spreadsheet:
Daily_Project_Diversions_Final_Dec2016_corrected_Jun2017.xlsx.

A.4.3.3.4 Upper Klamath Lake Net Inflow and Maximum Release

The UKL daily net inflow dataset is calculated from QC'ed data (Dunsmoor, 2017b) for (1) A Canal diversions (Reclamation), (2) average daily flows for the Link River at LRD (USGS), (3) Westside Power Canal (often referred to as the Keno Canal) flows (PacifiCorp), (4) Agency Lake Ranch operations (Reclamation), and (5) active storage data for UKL (Reclamation). Revisions to this data set include an altered elevation-capacity relationship, based on a new UKL bathymetry, corrected A Canal diversions, and a more accurate accounting of flows through the Westside Power Canal.

The UKL daily net inflow is calculated using the following equation:

Net Inflow = {(UKL storage volume today – UKL storage volume yesterday) + (Link River + Westside Canal) + A Canal +/- (Volume pumped to/from Agency Lake Ranch) – (Volume from Caledonia Marsh)}.

The KBPM uses both raw daily data and a single exponential smooth of daily data for UKL inflow, utilizing an alpha value of 0.22. The raw daily data input variable is I1_raw and is used in a calculation of cumulative inflow into UKL. The single exponential smooth of inflow input variable is I1 and defines the inflow element of the mass balance equation for UKL, as well as being a key factor in computation of the daily IGD release. In the 2013 Biological Opinion, a 3-day moving average of UKL net inflow was used to minimize the effects of daily variability in the calculation of UKL net inflow. However, during development of the current PA, modelers felt that the 3-day moving average could be improved upon utilizing a statistical smoothing technique. Initially, a locally estimated scatterplot smoothing (LOESS) was applied to produce daily values for UKL net inflow. This method relies upon a subset of inflow values near the day upon which an inflow value was being estimated. While this technique produced a smooth representation of net inflow, the reliance on inflow data from both before and after the date being estimated was deemed operationally infeasible. In order to produce an operationally feasible prediction of daily net UKL inflow that was similar to the desirable LOESS curve, a simple exponential smoothing technique is used. The difference between yesterday's observed inflow and yesterday's predicted inflow is multiplied by a smoothing parameter (α). This smoothing parameter is optimized by minimizing the error in observed values (i.e. the difference between observed and predicted). However, because the LOESS curve values were the desired curve to approximate, error was determined using the LOESS curve values. Once the appropriate smoothing parameter is obtained and applied to the difference between observed and predicted inflows, this is added to yesterday's predicted value to determine today's forecasted net inflow. The smoothing parameter obtained through the optimization process for use in KBPM inputs is 0.22, as mentioned above. The equation is as follows:

UKL net inflow = predicted inflow (-1) + (α* (observed inflow(-1) – predicted inflow(-1))

where: (-1) indicates yesterday's value

Upper Klamath Lake net inflow data and data for the UKL area-capacity curve are contained in the spreadsheet: **Daily_UKL_net_inflow_Apr2017_FINAL.xlsx**. In the KBPM, the time series I1_raw and I1, for UKL daily net inflow and single exponential smooth data are contained in the file: **PA_4Jan2017_newBathy_I1ExpSm1x_SV.dss**. In KBPM, these data are contained in the files: **res_info.table** and **res_info2.table**.

In addition to changes to UKL net inflow datasets, a new relationship was developed describing the maximum possible release from LRD relative to the range in possible lake elevations and the associated head behind the dam. The basis for these data are contained in the Upper Klamath Lake Flood Operations Review and Risk Assessment, table 3.2-2 (PacifiCorp 1996). This document provided maximum UKL discharge at 1 ft. intervals; releases were then linearly interpolated to 0.01 ft. intervals for use in the KBPM. The UKL elevation/maximum discharge relationship can be found in the file: **20170502_UKLElev_LinkQ_Relation.xlsx**. In KBPM, these data are in the file: **Link_max.table**.

A.4.3.3.5 Lake Ewauna (Keno Reservoir) Accretions

The Lake Ewauna daily accretion dataset is calculated from QC'ed data for (1) LRDC spill to the Klamath River, (2) LRDC delivery to Area 1 from the Klamath River, (3) pumps F/FF, (4) North Canal, (5) Ady Canal, (6) ungauged Area 2 diversions, (7) PacifiCorp data for the Westside Power Canal, and (8) USGS average daily flow data for Link River at LRD and Klamath River at Keno Dam.

The Lake Ewauna accretions are calculated using the following equations:

Accretions = (Measured Keno Flow) – (Computed Keno Flow), and
Computed Keno Flow = [(Link River + Westside Canal) + (LRDC spill to the Klamath River) + (Pumps F/FF) – (LRDC delivery to Area 1 from the Klamath River) – (North Canal) – (Ady Canal) – (Ungauged Area 2 diversions)]

The WRIMS model uses a 3-day moving average of the daily Lake Ewauna accretion data. The input variable is I10.

Lake Ewauna accretions data are contained in the spreadsheet: **Keno Reservoir accretions Oct2017 revision.xlsx**. In KBPM, Lake Ewauna accretion data are contained in the file: **PA_4Jan2017_newBathy_I1ExpSm1x_SV.dss**.

A.4.3.3.6 Keno Dam to Iron Gate Dam Accretions

In the version of the KBPM used to develop the Proposed Action analyzed in the 2013 Biological Opinion, accretions to the reach of the Klamath River between Keno Dam and IGD (the KIG reach) were treated as known inputs. That is, a time series of daily estimates of the KIG accretions was developed and assigned to the KBPM variable named I15. When calculating such things as the release from LRD necessary to provide the targeted flow at IGD, the KBPM used the value of this variable from the previous day.

Several shortcomings have become apparent in the prior treatment of KIG accretions. First, the I15 variable was developed in a manner that did not account for the change in storage of the three hydroelectric reservoirs (JC Boyle, Copco, and Iron Gate reservoirs) in the KIG reach. Second, prior estimates of I15 did not account for travel time through the KIG reach. Finally, use of I15 was confined to its value on the prior day. Now that surface flushing flow events (flows of 6,030 cfs or greater for at least 72 hours measured at the IGD gauge) are management targets, it is important to use forecasted KIG accretions as part of the calculation of LRD releases needed to achieve a targeted flow at the IGD gauge. Use of forecasts will allow managers to use water stored in UKL more efficiently by triggering surface flushing flows when KIG accretions are forecasted to be relatively high, thereby requiring less UKL water to achieve the IGD flow target.

In this section, the time series of historical KIG accretions is recomputed, taking account of travel time and daily change in reservoir storage, and development of sub-models used to forecast KIG accretions is described. Incorporation of KIG accretion forecasts into the KBPM is addressed in subsequent sections. Before the KIG accretion forecast model could be developed, a model estimating the combined daily storage of the hydroelectric reservoirs had to be developed to fill gaps in the storage record, a necessary precursor to computing a daily time series of accretions to the KIG reach.

A.4.3.3.6.1. Temperature and Precipitation Variables

Temperature and precipitation variables were developed from data obtained from the PRISM Climate Group. Parameter-elevation Relationships on Independent Slopes Model (PRISM) is an interpolation method that estimates precipitation and temperature variables at gridded locations across the conterminous United States based on measurements from a large network of meteorological stations (Daly et al., 2008). Because the PRISM web page (http://prism.oregonstate.edu/explorer/) providing access to daily time series uses a map overlaid by the 4km PRISM grids, a map from this web page was used to delineate the approximate boundaries of sub-basin 18010206 along the edges of the PRISM grids (Figures A.4.3.3.6.1.1 and A.4.3.3.6.1.2). The closed basin of Butte Valley was excluded, as were the areas draining to the Klamath River downstream of the IGD gauge or upstream of the Keno gauge, thus crudely delineating the catchment within the KIG reach. This area was stratified by the PRISM grid elevations as being either lower or higher than 4,500 ft. Four PRISM grids were then randomly selected from each elevation stratum, conditioned on selected grids being separated by at least 3 grids (Figure A.4.3.3.6.1.1). Daily time series of average temperature (°F) and precipitation (inches) were downloaded for these 8 grids for the period from 1/1/1981-11/30/2016.

Monthly PRISM data for total monthly precipitation and average temperature at the same locations were downloaded for the period from 10/1/1980-12/31/1980. These monthly data were disaggregated to daily data, as follows. Daily data for precipitation and maximum temperature for the period from 10/1/1980-12/31/1980 were downloaded from the National Climatic Data Center, Climate Data Online (https://www.ncdc.noaa.gov/cdo-web/) for three stations (Figure A.4.3.3.6.1.1): Howard Prairie Dam, OR (Station USC00354060), Copco #1 Dam, CA (Station USC00041316), and Keno, OR (precipitation only; Station USC00354403). Across these stations within each month, the daily average of maximum temperature or precipitation was divided by the monthly average maximum temperature or monthly total precipitation, as appropriate. Monthly PRISM variables were disaggregated to daily values by multiplying them by this daily proportion. Use of the maximum daily temperature to disaggregate the average daily temperature variable was unintentional; clearly, average daily temperature should have been used instead. This mistake was not discovered until after the entire analysis was complete but has been retained in the analysis because it affects only the first 3 months of the POR, and average daily and maximum daily temperatures display very similar patterns.

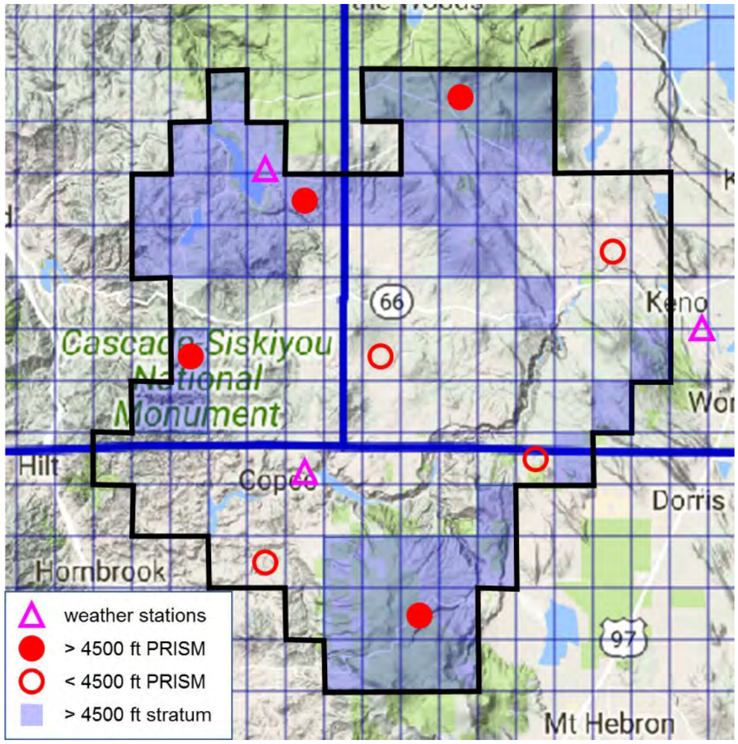

Figure A.4.3.3.6.1.1. PRISM grids and sampled grids, weather stations, and elevation strata in the KIG catchment.

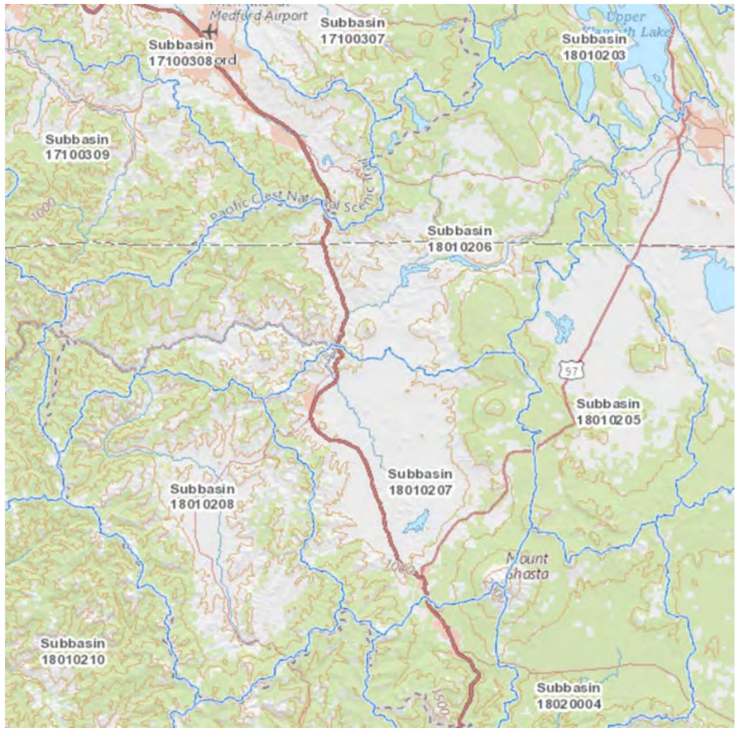

Figure A.4.3.3.6.1.2. Sub-basins encompassing the KIG and mid-Klamath (MK) reaches of the Klamath River.
Source: USGS National Map:
https://viewer.nationalmap.gov/basic/?basemap=b1&category=nhd&title=NHD%20View

Treatment of temperature and precipitation for the mid-Klamath (MK) reach was nearly identical to that of the KIG reach, except that different PRISM grids and weather stations were used, and sampled grids were separated by at least 5 grids (Figure A.4.3.3.6.1.3a). That portion of sub-basin 18010206 contributing runoff to the Klamath River downstream of the IGD gauge, and all of sub-basins 18010208 (Scott River) and 1801207 (Shasta River) were included in the catchment for the MK reach (Figures A.4.3.3.6.1.2 and A.4.3.3.6.1.3a), hereafter called the MK catchment. Weather stations used to disaggregate monthly data to daily time steps for the MK catchment included: Callahan, CA (USC00041316); Yreka, CA (USC00049866); and Big Red Mountain, OR (USS0022G21S). Removing the Scott and Shasta river catchment area from the MK catchment leaves the ungauged MK catchment (Figure A.4.3.3.6.1.3b), for which accretions are also estimated.

After assembling the daily time series of precipitation and average temperature for each sampled PRISM grid, variables were computed that summarized these climate data in various ways. Daily (i = day) averages were computed for two of the catchments: $kippt_i$ and $kitavg_i$ for the KIG catchment; and $mkppt_i$ and $mktavg_i$ for the MK catchment. Daily averages weighted by the proportion of the total number of PRISM grids in a catchment below or above 4,500 ft were computed for each catchment: $kipptwa_i$ and $kitavgwa_i$ for the KIG catchment; and $mkpptwa_i$ and $mktavgwa_i$ for the MK catchment. Daily averages of the PRISM grids within each elevation stratum in each catchment were computed: $lekippt_i$, $hekippt_i$, $lekitavg_i$, and

$hekitavg_i$ for the KIG catchment; and $lemkppt_i$, $hemkppt_i$, $lemktavg_i$, and $hemktavg_i$ for the MK catchment.

Temperature and precipitation variables were transformed, rescaled, and stationarized (Van den Berg et al., 2006; Montgomery et al., 2015) by first applying a $\ln(x_i + c)$ transformation (note that the *tavg* variables were not ln transformed), where x_i is the daily variable and c is a constant added to increase the minimum x_i above 1. Then, the ln transformed variables were seasonally adjusted (rescaled), and then the first difference was taken. Seasonal adjustment consisted of centering each $\ln(x_i + c)$ by subtracting from it the mean for the corresponding day of the water year across the POR. The centered variable was then divided by the standard deviation of the transformed variable for the corresponding day of the water year across the POR. The first difference was then taken as the seasonally adjusted x_i minus the seasonally adjusted x_{i-1}. The prefix *dsaln_* (*d* is for difference, *sa* is for seasonally adjusted, *ln* is for ln transformed, and _ is the *c* added prior to ln transformation) was appended to each variable name to reflect these manipulations.

Perhaps the greatest utility of the KIG accretion model to water management decision-making is during the late winter and spring seasons, when accretions tend to be largest and most variable, and when use of the accretion forecasts would be involved in decisions whether to trigger releases from UKL for flushing flows. Reasoning that the runoff response to precipitation events would likely be different when the ground is frozen (faster, more variable), a variable was constructed that tracked whether the ground was likely to be frozen or not. Air and soil temperature (2 inches depth) were downloaded for the Beatty, Oregon AgriMet weather station (https://www.usbr.gov/pn/agrimet/webarcread.html) for the period from 10/20/2004 – 12/31/2016). A threshold regression relating the 10-day trailing average of the mean daily air temperature (°F) to the daily soil temperature (°F) at a depth of 2 inches was used to identify the threshold at which this relationship changes (i.e. ground freezing threshold). The results (not shown) indicate that the freezing transition occurred when the 10-day trailing average of the mean daily air temperature was 35.2 (°F). Accordingly, the variables $lekitavg10d_i$ and $hekitavg10d_i$ were computed as the 10-day trailing average of the mean daily air temperature (°F) within the two elevation strata.

Further, because the objective was to develop models forecasting accretions based on recent conditions, precipitation was viewed from the perspective of its availability for immediate (i.e. within days) runoff. Three temperature classes were established to roughly classify this availability for runoff based on some expression of average temperature: ≤28°F was thought to be low availability because it likely fell as snow that did not rapidly melt; >28°F - ≤60°F was thought to be moderate to high availability because it likely fell as rain (or as snow that rapidly melted) and evapotranspiration was low to moderate; >60°F was thought to be low availability because evapotranspiration was moderate to high.

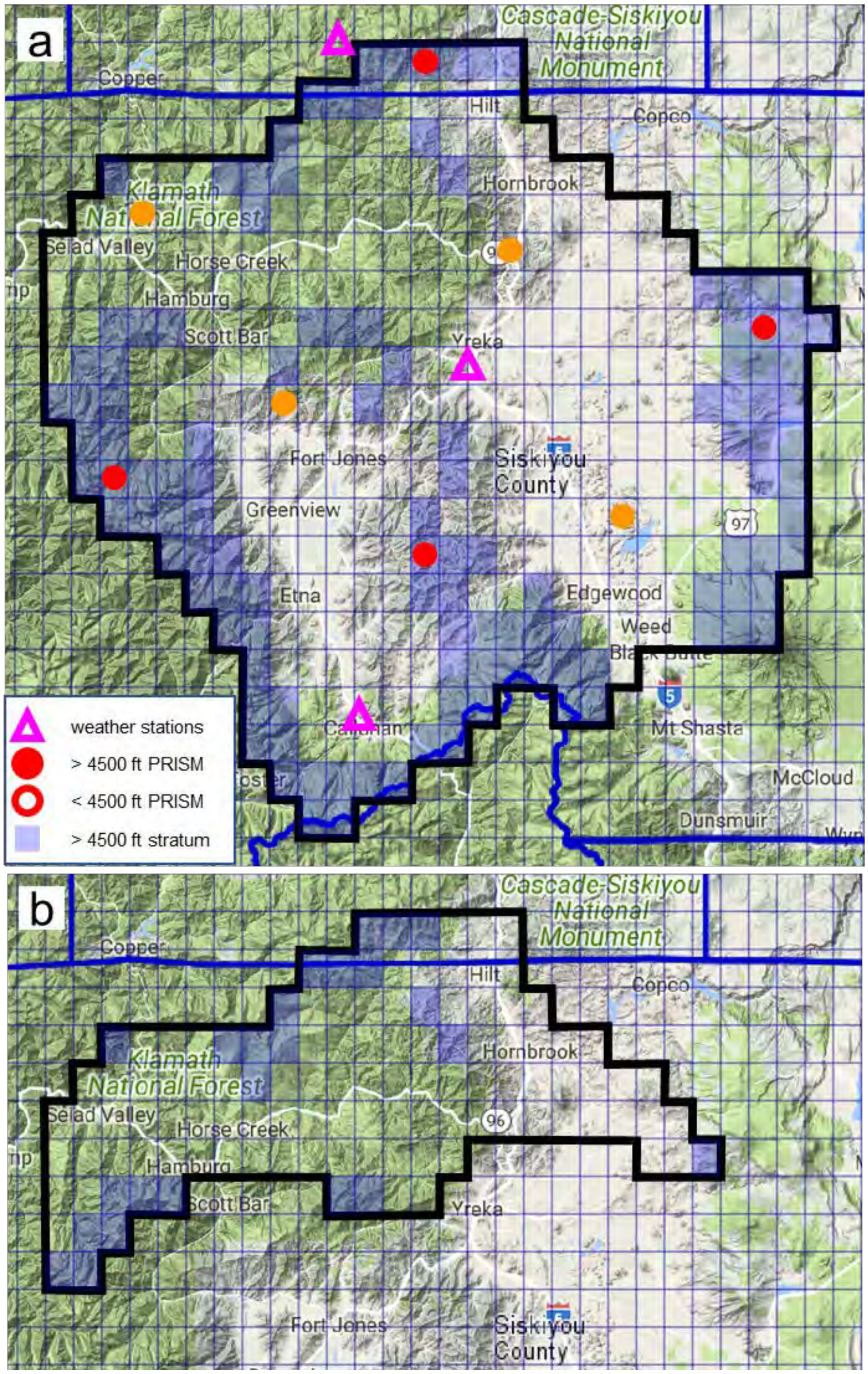

Figure A.4.3.3.6.1.3. PRISM grids and sampled grids, weather stations, and elevation strata in the MK reach used to construct climate variables appropriate to the MK catchment (a). The ungauged MK catchment (b) is the remaining area within the MK catchment after removing the Scott and Shasta river catchments.

To capture potential dynamics associated with interactions among elevation, temperature, precipitation, ground status (frozen/unfrozen), and subsequent runoff, the following series of variables were developed:

$$coldkippt_i = \begin{cases} dsaln1kipptwa_i & if\ kitavgwa_i \leq 28°\text{F} \\ 0 & if\ kitavgwa_i > 28°\text{F} \end{cases}$$

$$coolkippt_i = \begin{cases} dsaln1kipptwa_i & if\ kitavgwa_i > 28°\text{F}\ and\ \leq 60°\text{F} \\ 0 & if\ kitavgwa_i \leq 28°\text{F}\ \ or\ \ > 60°\text{F} \end{cases}$$

$$warmkippt_i = \begin{cases} dsaln1kipptwa_i & if\ kitavgwa_i > 60°\text{F} \\ 0 & if\ kitavgwa_i \leq 60°\text{F} \end{cases}$$

$$coldhekippt_i = \begin{cases} dsaln1hekippt_i & if\ hekitavg_i \leq 28°\text{F} \\ 0 & if\ hekitavg_i > 28°\text{F} \end{cases}$$

$$coolhekippt_i = \begin{cases} dsaln1hekippt_i & if\ hekitavg_i > 28°\text{F}\ and\ \leq 60°\text{F} \\ 0 & if\ hekitavg_i \leq 28°\text{F}\ \ or\ \ > 60°\text{F} \end{cases}$$

$$warmhekippt_i = \begin{cases} dsaln1hekippt_i & if\ hekitavg_i > 60°\text{F} \\ 0 & if\ hekitavg_i \leq 60°\text{F} \end{cases}$$

$$coldlekippt_i = \begin{cases} dsaln1lekippt_i & if\ lekitavg_i \leq 28°\text{F} \\ 0 & if\ lekitavg_i > 28°\text{F} \end{cases}$$

$$coollekippt_i = \begin{cases} dsaln1lekippt_i & if\ lekitavg_i > 28°\text{F}\ and\ \leq 60°\text{F} \\ 0 & if\ lekitavg_i \leq 28°\text{F}\ \ or\ \ > 60°\text{F} \end{cases}$$

$$warmlekippt_i = \begin{cases} dsaln1lekippt_i & if\ lekitavg_i > 60°\text{F} \\ 0 & if\ lekitavg_i \leq 60°\text{F} \end{cases}$$

$$coollekiint_i = coollekippt_i \times dsalekitavg_i$$

$$coolkiint_i = coolkippt_i \times dsalekitavg_i$$

$$kippttavgint_i = dsaln1kipptwa_i \times dsakitavgwa_i$$

$$soilfrzheppt_i = \begin{cases} dsaln1hekippt_i & if\ hekitavg10d_i \leq 35.2\ °\text{F} \\ 0 & if\ hekitavg10d_i > 35.2\ °\text{F} \end{cases}$$

$$soilfrzleppt_i = \begin{cases} dsaln1lekippt_i & if\ lekitavg10d_i \leq 35.2\ °\text{F} \\ 0 & if\ lekitavg10d_i > 35.2\ °\text{F} \end{cases}$$

$$soilthwheppt_i = \begin{cases} dsaln1hekippt_i & if\ hekitavg10d_i > 35.2\ °\text{F} \\ 0 & if\ hekitavg10d_i \leq 35.2\ °\text{F} \end{cases}$$

$$soilthwleppt_i = \begin{cases} dsaln1lekippt_i & if\ lekitavg10d_i > 35.2\ °F \\ 0 & if\ lekitavg10d_i \leq 35.2\ °F \end{cases}$$

$$thwleint_i = soilthwleppt_i \times dsalekitavg_i$$

In addition to variables summarizing precipitation and temperature in various ways, an attempt was made to use data tracking snowpack dynamics. However, no NRCS SNOTEL sites with an adequate POR were located within the KIG catchment. The nearest SNOTEL site was at Fish Lake (SNOTEL 479; data download: https://wcc.sc.egov.usda.gov/reportGenerator/view_csv/customGroupByMonthReport/daily/479:OR:SNTL%7Cid=%22%22%7Cname/POR_BEGIN,POR_END/WTEQ::value), for which daily snow water equivalent data was acquired. These data were seasonally adjusted and differenced, but no ln transformation was applied; the variable was named $dsadfishswe_i$.

A.4.3.3.6.2. Flow Volume and Accretion Variables

Accretions to the KIG reach were quantified using daily inflow volume (TAF; measured at USGS gauge 11509500 below Keno Dam; variable $kenotaf_i$), outflow volume (TAF; measured at USGS gauge 11516530 below IGD [often referred to as the IGD gauge]; variable $igtaf_i$), change in combined reservoir storage volume ($kigstoretaf_i$), and travel time.

Computing accretions to the MK reach required daily flow volumes (TAF) entering the reach at the IGD gauge ($igtaf_i$) and leaving the reach at the Seiad Valley gauge (USGS 11520500; variable $seiadtaf_i$), and travel time. Isolating the portion of MK accretions from ungauged sources required daily flow volumes (TAF) measured at the Shasta River gauge (USGS 11517500; variable $shastataf_i$) and the Scott River gauge (USGS 11519500; variable $scotttaf_i$).

Travel time of water between gauges was accounted for in the estimates of daily accretions. Hourly flows at the IGD and Seiad Valley gauges were compared, and when the flow pattern at IGD was clearly discernable at Seiad Valley, the corresponding flows were used to compute the travel time in hours (Figure A.4.3.3.6.2.1a). Repeated many times, this process produced 104 measurements of travel time, which were used to develop regression equations predicting travel time based on flows measured at IGD (Figure A.4.3.3.6.2.1b) and at Seiad Valley (Figure A.4.3.3.6.2.1c) gauges. Travel time varied with flow, from about 9 hours at high flows (about 10,000 cfs at IGD; 16,000 cfs at Seiad Valley) to about 16 hours at low flows (about 900 cfs at IGD; about 1,070 cfs at Seiad Valley).

The equation estimating travel time between the IGD and Seiad Valley gauges on day *i* based on daily average flow at the IGD gauge ($igtaf_i$) is:

$$tt\_igsd\_ig_i = e^{-0.24311\ln(igtaf_i) + 2.91288},$$

where *e* is the base of the natural logarithm (2.71828).

The equation estimating travel time over the same distance, but based on the daily average flow at the Seiad Valley gauge ($seiadtaf_i$) is:

$$tt\_igsd\_sd_i = e^{-0.22153\ln(seiadtaf_i) + 2.98041}.$$

The average of these two estimates is taken to calculate mean travel time between the two gauges:

$$tt\_igsd_i = \frac{tt\_igsd\_ig_i + tt\_igsd\_sd_i}{2}$$

A similar process was used to estimate travel time between the Scott River gauge and the Seiad Valley gauge (Figure A.4.3.3.6.2.2):

$$tt\_scsd_i = e^{-0.66034\ln(seiadtaf_i) + 3.09763}.$$

Travel time between the Shasta River gauge and the Seiad Valley gauge was estimated in a different way. Because the Shasta River gauge is located 0.64 miles upstream of the confluence with the Klamath River, travel time was estimated as tt_igsd_i times the proportion of the distances between gauges:

$$tt\_shsd_i = \frac{49.64}{61.90} tt\_igsd_i$$

where 49.64 miles is the distance between the Shasta River and Seiad Valley gauges, and 61.90 miles is the distance between the IGD and Seiad Valley gauges. Distances were measured using Google Earth Pro.

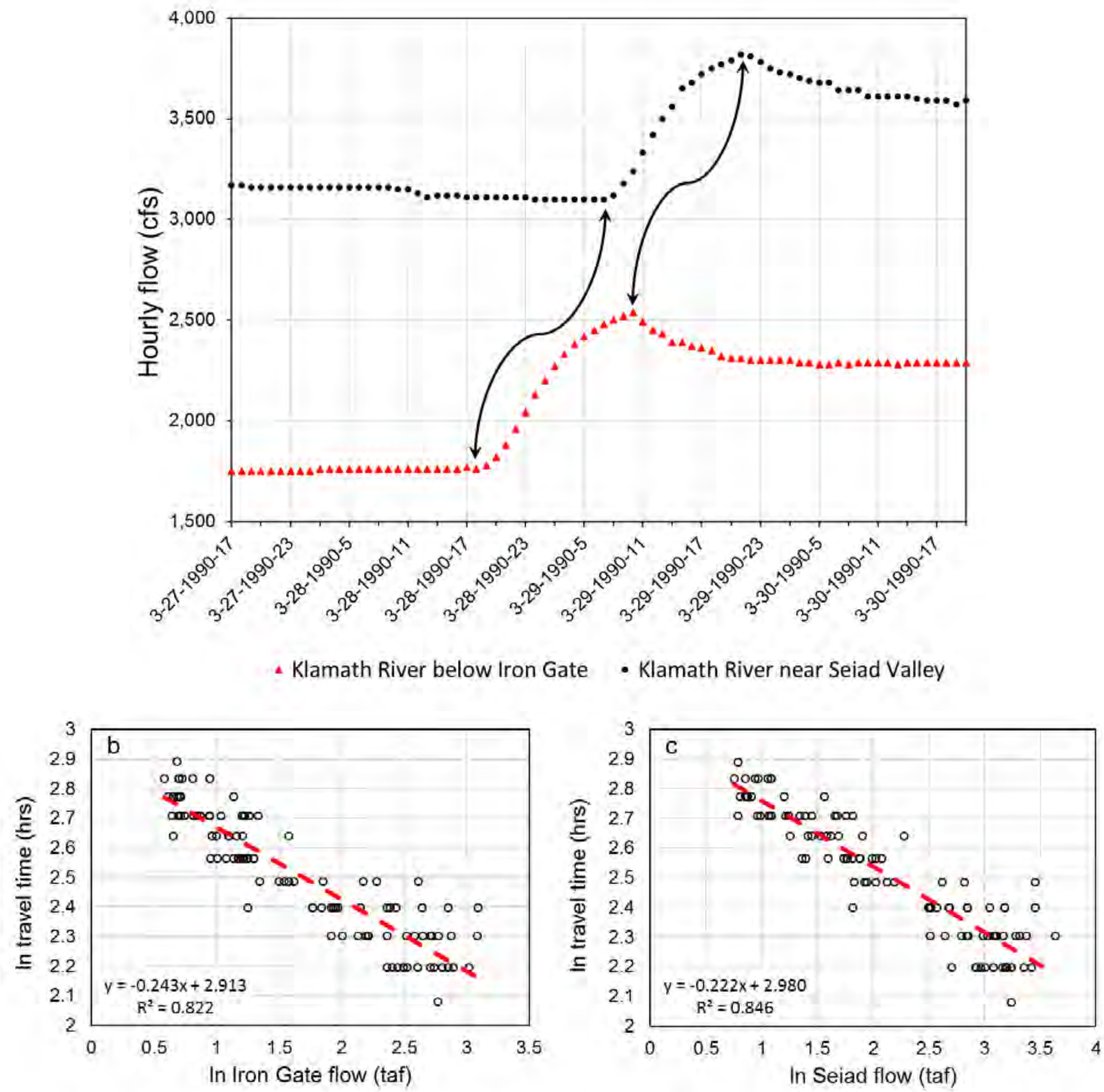

Figure A.4.3.3.6.2.1. Example of estimating travel time between the flow gauges below Iron Gate Dam and near Seiad Valley. In a, each point on a flow time series is an hourly flow measurement at one of the gauges. When the pattern of flow change at Iron Gate was clearly identifiable at Seiad Valley (indicated by the arrows), the travel time in hours was calculated. For reference, ln(9 hrs) = 2.197, and ln(18 hrs) = 2.890. Repeating this process many times (n=104) yields the measured travel times relative to flow at Iron Gate (b) and Seiad Valley (c); all values in b and c are ln transformed. Regressions (equations and dashed lines) provide the means to compute travel time as a function of flow measured at either flow gauge.

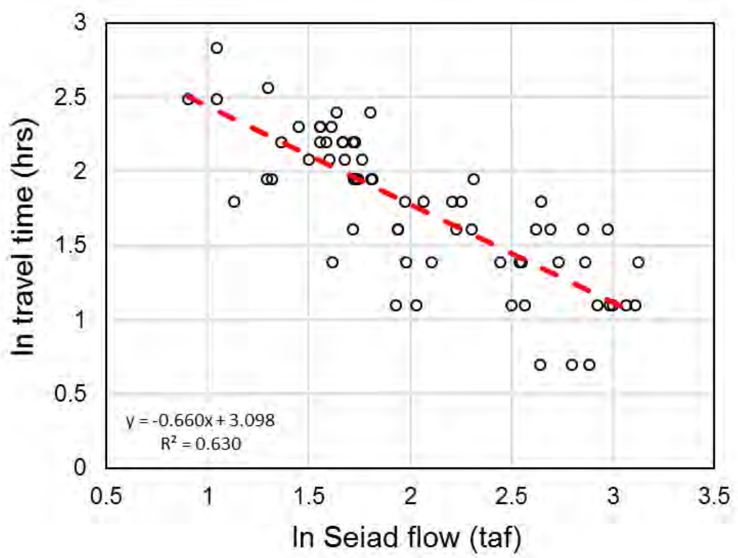

Figure A.4.3.3.6.2.2. Estimating travel time (hours) from the Scott River gauge to the Seiad Valley gauge from n=65 measurements.

Initially the same process used to estimate travel time between the IGD and Seiad Valley gauges was applied to estimate travel time through the KIG reach (between the Keno and IGD gauges). However, this approach did not work, because operations of the hydroelectric project reservoirs obscured or altered the hourly patterns of flow at IGD. Therefore, the travel time estimated between the IGD and Seiad Valley gauges was divided by the distance between them (61.90 miles), and then multiplied by the distance between the gauges at Keno and IGD (42.30 miles) to estimate travel time through the KIG reach:

$$tt\_kenoig_i = \frac{tt\_igsd_i}{61.90} 42.30$$

This approach assumed equivalent rates of travel through the KIG and MK reaches.

Accretions to the MK reach were computed in two ways, one that applies to the entire MK catchment, and the other based solely on the ungauged MK catchment. Accretions to the Klamath River to the MK reach based on the entire MK catchment were computed as:

$$mkawa_i = \left(\left(1 - \frac{tt\_igsd_i}{24}\right) \times (seiadtaf_i - igtaf_i)\right) + \left(\frac{tt\_igsd_i}{24} \times (seiadtaf_i - igtaf_{i-1})\right)$$

Because travel time between the gauges is less than a day (Figure A.4.3.3.6.2.1), accretions were computed as the average flow difference between the Seiad Valley gauge on day *i* and the IGD gauge on days *i* and *i*-1, weighted by travel time (expressed as a fraction of a day).

Accretions from the ungauged MK catchment were computed by subtracting from $mkawa_i$ the accretions from the Shasta and Scott rivers, which were computed as averages weighted by travel time in a manner similar to that for $mkawa_i$:

$$ugmkawa_i = mkawa_i - \left(\left(1 - \frac{tt\_shsd_i}{24}\right) shastataf_i + \frac{tt\_shsd_i}{24} shastataf_{i-1}\right) - \left(\left(1 - \frac{tt\_scsd_i}{24}\right) scotttaf_i + \frac{tt\_scsd_i}{24} scotttaf_{i-1}\right)$$

Computation of accretions to the KIG reach ($kigaccwa_i$) involved accounting for the daily change in storage of the combined hydroelectric reservoirs, $kigstoretaf_i$ (after gaps had been filled in that record):

$$kigacc_i = (igtaf_i - kenotaf_i) + (kigstoretaf_i - kigstoretaf_{i-1})$$

$$kigaccwa_i = \left(1 - \frac{tt\_kenoig_i}{24}\right) kigacc_i + \frac{tt\_kenoig_i}{24} kigacc_{i-1}$$

The time-series for $kigaccwa_i$ is used in the KBPM as the inflow arc I15, the daily accretions to the reach of the Klamath River between Keno Dam and IGD.

One final variable, an expression of KIG accretions that does not account for daily change in storage, was prepared for use as a predictor:

$$kiqdfwa_i = \left(\left(1 - \frac{tt\_kenoig_i}{24}\right) \times (igtaf_i - kenotaf_i)\right) + \left(\frac{tt\_kenoig_i}{24} \times (igtaf_i - kenotaf_{i-1})\right)$$

As with many of the variables previously described, the flow volume and accretion variables were also transformed with $\ln(x_i + c)$, seasonally adjusted, and differenced, yielding the following variables: $dsalnkenotaf_i$, $dsalnigtaf_i$ (note that c=0 for the flow volume variables), $dsaln3mkawa_i$, $dsaln6ugmkawa_i$, $dsaln1kigaccwa_i$, and $dsaln3kiqdfwa_i$. Daily combined storage of the hydro reservoirs was not ln transformed ($dsakigstoretaf_i$).

A.4.3.3.6.3. Filling Gaps in the Reservoir Storage Record

Daily change in combined storage of hydroelectric reservoirs was quantified using reservoir storage data provided to Reclamation and the US Fish and Wildlife Service (USFWS) by PacifiCorp under a Non-disclosure Agreement. Certain aspects of the following analyses were not reported here in keeping with the terms of the Non-disclosure Agreement. After summing the daily storage of JC Boyle, Copco, and Iron Gate reservoirs into a single variable ($kigstoretaf_i$) used to compute KIG accretions, gaps in the record were apparent. Out of the 13,210 days in the period-of-record used in this analysis (10/1/1980 – 11/30/2016), 662 days were missing. The initial task was to develop a model to fill these gaps in the $kigstoretaf_i$ time series, so that daily change in total reservoir storage could be calculated, subsequently enabling computation of daily KIG accretion.

In addition to the gaps caused by the absence of data, during some time periods $kigstoretaf_i$ patterns reflected reservoir management for reasons other than typical operations (e.g. maintenance events, emergency outages, federal agency "borrowing", etc.). Periods of atypical management were identified by reviewing re-licensing documents in the FERC eLibrary (https://www.ferc.gov/docs-filing/elibrary.asp; project P-2082) and consulting with water operations personnel at Reclamation. These periods were removed from the data (n=649) used to develop a model for filling gaps in $kigstoretaf_i$, but were retained in the final data set used to compute KIG accretions.

Methodological details were the same as for those reported in the sub-section addressing development of the KIG accretion model, so many are deferred to that description. In brief summary, 7 time-series regression models with ARMA (Autoregressive Moving Average) disturbances were developed using Stata 15 (StataCorp, 2017a; Hyndman and Athanasopoulos, 2014; Montgomery et al., 2015; Table A.4.3.3.6.3.1). Predictive performance of each was assessed using 10-fold cross-validation (James et al. 2013); the model with the smallest mean square error (error = actual $kigstoretaf_i$ – predicted $kigstoretaf_i$) averaged across the 10 folds was used to fill the gaps in $kigstoretaf_i$ series. Overall, this approach appeared to do a reasonably good job of filling the gaps. Further details of the analysis are not presented, in keeping with the Non-disclosure Agreement with PacifiCorp.

Table A.4.3.3.6.3.1. Models evaluated for use in filling gaps in the $kigstoretaf_i$ series. The dependent variable in all models was $dsakigstoretaf_i$. Variables included in models include autoregressive (ar) and moving average (ma) terms for errors from the structural equation. Entries show the lags of each variable used in each model. For example, 0/2 indicates use of lags *i*-0, *i*-1, and *i*-2 (*i* = day). The model that yielded the smallest average mean square error (MSE) from 10-fold cross-validation was model 3.

	Model number						
Variables	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Dsalnigtaf				0/5	0/5	0/5	0/5
Dsalnkenotaf				0/5	0/5	0/5	0/5
dsaln1kipptwa	0/5	0/5	0/4	0/5	0/5	0/3	0/3
dsaln3kiqdfwa	0/5	0/5	0/5				
Dsakitavgwa	0/2	0/2	0/1	0/2	0/2	0	0
dsaln3mkawa			0/5			0/4	0/4
dsaln1kipptwa x dsakitavgwa		0					
dsaln1kipptwa x dsaln3kiqdfwa		0					
dsalnigtaf x dsaln1kipptwa					0		0
Ar	1/3	1/3	1/3	1/2	1/2	1/3	1/3
Ma	1/2	1/2	½	1/2	1/3	1/4	¼
average MSE	0.1394	0.1395	0.1330	0.1442	0.1446	0.1411	0.1398

A.4.3.3.6.4. Modeling Accretions Between Keno and Iron Gate Dams

KIG accretions were modeled using time-series regression models with ARMA (Autoregressive Moving-average) disturbances using Stata 15 (StataCorp, 2017a; Hyndman and Athanasopoulos, 2014; Montgomery et al., 2015). This approach fitted the model:

$$y_i = \mathbf{x}_i\boldsymbol{\beta} + \mu_i \qquad \text{(structural equation)}$$

$$\mu_i = \sum_{h=1}^{p} \rho_h \mu_{i-h} + \sum_{j=1}^{q} \theta_j \epsilon_{i-j} + \epsilon_i \qquad \text{(disturbance equation)}$$

where

- y_i is the dependent variable at time *i*;
- $\mathbf{x}_i$ is the matrix of regressors;
- $\boldsymbol{\beta}$ is the vector of regressor coefficients;
- μ_i is the error associated with the structural equation;
- ρ_h is the autocorrelation parameter of order h from 1 to p;
- θ_j is the moving-average parameter of order j from 1 to q;
- ϵ_i is the error associated with the disturbance equation, assumed to be a white-noise process.

All variables were transformed with ln($x + c$) as appropriate, seasonally adjusted, and differenced (see prior sections detailing construction of variables). The dependent variable for each model was $dsaln1kigaccwa_i$. The eigenvalue stability condition of each model was checked, confirming the required invertibility condition of the MA process, and confirming the process to be covariance stationary (StataCorp, 2017a). Stationarity of *dsaln1kigaccwa* in each model was confirmed by the rejection of the null hypothesis that the variable followed a unit-root process, using the augmented Dickey-Fuller test (StataCorp, 2017a). Bartlett's white noise test on residuals from each model failed to reject the null hypothesis (95% confidence level) that they came from a white noise process of uncorrelated random variables having a constant mean and a constant variance (StataCorp, 2017a). Residuals were not normally distributed but were symmetric, so the Huber/White sandwich estimator was used to compute standard errors that are robust to symmetric non-normality in the disturbances (StataCorp, 2017a).

Predictive performance of each was assessed using 10-fold cross-validation (James et al., 2013; Hyndman and Athanasopoulos, 2014). In this approach, the model was fitted to the data for water years 1981-1986, which was then used to predict $dsaln1kigaccwa_i$ for water years 1987-1989 (fold $k = 1$). Predicted values were converted back to the original scale of the data, and the mean square error (MSE_k) was computed for fold 1. Then the model was fitted to water years 1981-1989, used to predict $dsaln1kigaccwa_i$ for fold $k = 2$ (the next 3 water years, 1990-1992), and the MSE_k was computed (on original data scale) for fold 2. This process was repeated through fold $k = 10$ (2014-2016), and then the average MSE was computed across all 10 folds. This average MSE was used as the best estimate of the error and predictive capability of each model.

Using these techniques, 23 models were developed (Table A.4.3.3.6.4.1). Note that lags of 0 were commonly used for temperature and precipitation variables and related interactions. This indicates the expected reliance on forecasts of these variables based on products currently available from the California-Nevada River Forecast Center (https://www.cnrfc.noaa.gov/). Attempts were made to obtain historical time-series of forecasts for these variables across the POR used for the modeling, but such data were unavailable. Therefore, historical values of temperature and precipitation were used when forecasting accretions for days 0-3. Use of perfect foresight in this way produced models that do not exhibit the same error characteristics that will be encountered when using forecasted temperature and precipitation to make daily operational decisions. Operational error will be larger than that shown in Table 2 and will need to be quantified through operational use of these models.

Model 21 had the lowest average MSE (0.077) from the cross-validation (Table A.4.3.3.6.4.1, Figure A.4.3.3.6.4.1), and was subsequently used to forecast dsaln1kigaccwai (day 0). The day 0 forecast predicts the accretion for the current day and is intended for use in making a final decision as to whether a flushing flow should be implemented on a given day. Forecasts were also needed for days *i*+1 (day 1) through *i*+3 (day 3), when forecasts would be used to guide actions that would necessarily precede release of a flushing flow (e.g. adjusting reservoir elevations to permit spill operations). However, because Model 21 included *dsaln6ugmkawa* for lags of i-1 and i-2, for which no forecasts were available, a different model had to be used for the days beyond day 0. Model 20 was selected for this purpose, because it did not include any regressors for which forecasts were unavailable, its average MSE from cross-validation was very similar to the other candidate models, and the regressor variables were very similar to those in Model 21 (Table A.4.3.3.6.4.1), which would minimize the additional effort necessary to operate using 2 models.

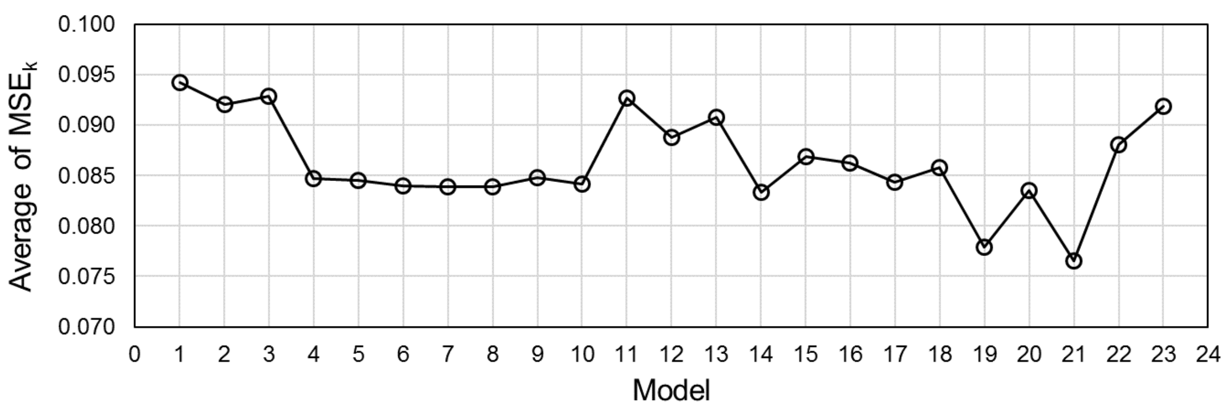

Figure A.4.3.3.6.4.1. Average of the mean square error (error = actual $kigaccwa_i$ – predicted $kigaccwa_i$) across the k=10 folds in the 10-fold cross-validation. Model 21 minimized this MSE_k, and was therefore selected as the final model.

Table A.4.3.3.6.4.1. Models evaluated for predicting KIG accretions. The dependent variable in all models was $dsaln1kigaccwa_i$. Variables included in models include autoregressive (ar) and moving average (ma) terms for errors from the structural equation. Entries show the lags of each variable used in each model. For example, 0/2 indicates use of lags *i*-0, *i*-1, and *i*-2, whereas 0 2 indicates use of lags *i*-0 and *i*-2 only (*i* = day). The model that yielded the smallest average mean square error (MSE) from 10-fold cross-validation was model 3.

	Model number																						
Variables	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**
dsadfishswe			2/5		3		3										2/5	3	3				
dsaln3kiqdfwa		2																					
dsaln1kipptwa	0/7	0/7	0/7	0/7	0/7	0/7	0/7	0/7	0/7	0/7	0/7				0/7	0/7	0/7		0/7				
dsakitavgwa	0/1	0/1	0/1	0/1	0/1	0/1	0/1	0/1	0/1	0/1	0/1	0/1			0/1 3	0/1 3	0/1 3		0/1				0/3
dsaln3mkawa				1/3	1/3	1/3	1/3	1/3															
dsaln1mkpptwa						0/1	0/1																
dsaln6ugmkawa									1/2	1/2				1/2					1/2		1/2		
dsahekitavg													0/3	0/3				0/3		0/3	0/3	0/3	
dsalekitavg													0/3	0/3				0/3		0/3	0/3	0/3	
dsaln1kipptwa x dsakitavgwa										0 2													
coolhekippt												5 7											
warmhekippt												6											
coldlekippt											0	0/4	0/1	0/1								0/1 4	
coollekippt											0	0/6	0/4	0/1								0/7	
warmlekippt												0/5	0/5	0/1								0/5	
soilfrzheppt															0/1	0/1	0/1	0/1	0/1	0/1	0/1		
soilfrzleppt															0/1	0/1	0/1	0/1	0/1	0/3	0/1		
kippttavgint																0 3	0/1 3		0				
soilthwheppt																		6/7		6/7	6/7		
soilthwleppt																		0/5		0/5	0/5		
thwleint																				1 3	0 2		
coollekiint																						0/3	
coldkippt																							0/1 3/4
coolkippt																							0/7
warmkippt																							0/1 3/7
coolkiint																							0/3
ma	1/3	1/3	1/3	1/3	1/3	1/3	1/3	1/3	1/3	1/3	1/3	1/3	1/3	1/3	1/3	1/3	1/3	1/3	1/3	1/3	1/3	1/3	1/3
average MSE	.094	.092	.093	.085	.084	.084	.084	.084	.085	.084	.093	.089	.091	.083	.087	.086	.084	.086	.078	.084	.077	.088	.092

The model 21 equation used to forecast $dsaln1kigaccwa_i$ on day 0 was (Table A.4.3.3.6.4.2):

$$\widehat{dsaln1kigaccwa_i} = \beta_{1,i}dsahekitavg_i + \beta_{1,i-1}dsahekitavg_{i-1} + \beta_{1,i-2}dsahekitavg_{i-2} + \beta_{1,i-3}dsahekitavg_{i-3} + \beta_{2,i}dsalekitavg_i + \beta_{2,i-1}dsalekitavg_{i-1} + \beta_{2,i-2}dsalekitavg_{i-2} + \beta_{2,i-3}dsalekitavg_{i-3} + \beta_{3,i}soilfrzheppt_i + \beta_{3,i-1}soilfrzheppt_{i-1} + \beta_{4,i}soilfrzleppt_i + \beta_{4,i-1}soilfrzleppt_{i-1} + \beta_{5,i-1}dsaln6ugmkawa_{i-1} + \beta_{5,i-2}dsaln6ugmkawa_{i-2} + \beta_{6,i-6}soilthwheppt_{i-6} + \beta_{6,i-7}soilthwheppt_{i-7} + \beta_{7,i}soilthwleppt_i + \beta_{7,i-1}soilthwleppt_{i-1} + \beta_{7,i-2}soilthwleppt_{i-2} + \beta_{7,i-3}soilthwleppt_{i-3} + \beta_{7,i-4}soilthwleppt_{i-4} + \beta_{7,i-5}soilthwleppt_{i-5} + \beta_{8,i}thwleint_i + \beta_{8,i-2}thwleint_{i-2} + \theta_1(dsaln1kigaccwa_{i-1} - \widehat{dsaln1kigaccwa_{i-1}}) + \theta_2(dsaln1kigaccwa_{i-2} - \widehat{dsaln1kigaccwa_{i-2}}) + \theta_3(dsaln1kigaccwa_{i-3} - \widehat{dsaln1kigaccwa_{i-3}})$$

The model 20 equation used to forecast $dsaln1kigaccwa_i$ on days 1-3, where *i* = the day being forecasted, was (Table A.4.3.3.6.4.2):

$$\widehat{dsaln1kigaccwa_i} = \beta_{1,i}dsahekitavg_i + \beta_{1,i-1}dsahekitavg_{i-1} + \beta_{1,i-2}dsahekitavg_{i-2} + \beta_{1,i-3}dsahekitavg_{i-3} + \beta_{2,i}dsalekitavg_i + \beta_{2,i-1}dsalekitavg_{i-1} + \beta_{2,i-2}dsalekitavg_{i-2} + \beta_{2,i-3}dsalekitavg_{i-3} + \beta_{3,i}soilfrzheppt_i + \beta_{3,i-1}soilfrzheppt_{i-1} + \beta_{4,i}soilfrzleppt_i + \beta_{4,i-1}soilfrzleppt_{i-1} + \beta_{4,i-2}soilfrzleppt_{i-2} + \beta_{4,i-3}soilfrzleppt_{i-3} + \beta_{6,i-6}soilthwheppt_{i-6} + \beta_{6,i-7}soilthwheppt_{i-7} + \beta_{7,i}soilthwleppt_i + \beta_{7,i-1}soilthwleppt_{i-1} + \beta_{7,i-2}soilthwleppt_{i-2} + \beta_{7,i-3}soilthwleppt_{i-3} + \beta_{7,i-4}soilthwleppt_{i-4} + \beta_{7,i-5}soilthwleppt_{i-5} + \beta_{8,i-1}thwleint_{i-1} + \beta_{8,i-3}thwleint_{i-3} + \theta_1(dsaln1kigaccwa_{i-1} - \widehat{dsaln1kigaccwa_{i-1}}) + \theta_2(dsaln1kigaccwa_{i-2} - \widehat{dsaln1kigaccwa_{i-2}}) + \theta_3(dsaln1kigaccwa_{i-3} - \widehat{dsaln1kigaccwa_{i-3}})$$

Forecasts were restored to the original measurement scale using:

$$\widehat{kigaccwa_i} = e^{\left(sd\_ln1kigaccwa_{dowy}\left(\widehat{dsaln1kigaccwa_i}+saln1kigaccwa_{i-1}\right)\right)+mn\_ln1kigaccwa_{dowy}} - 1$$

where

$sd\_ln1kigaccwa_{dowy}$ is the standard deviation of $ln1kigaccwa$ across the POR for day of water year *dowy*;

$mn\_ln1kigaccwa_{dowy}$ is the mean of $ln1kigaccwa$ across the POR for day of water year *dowy*;

e is the base of the natural logarithm (2.71828).

Table A.4.3.3.6.4.2. Coefficients and lags associated with each variable in model 21, used for day 0 forecasts of *dsaln1kigaccwa*, and model 20, used for day 1-3 forecasts of *dsaln1kigaccwa*. In the variables column, *ma* stands for the moving average component of the disturbance equation; all other variables are components of the structural equation.

		Model 21		Model 20	
Variables	β	**Lag**	**Coefficient**	**Lag**	**Coefficient**
dsahekitavg	$\beta_{1,i}$	0	-0.084751935	0	-0.079570007
	$\beta_{1,i-1}$	1	-0.131145783	1	-0.135250777
	$\beta_{1,i-2}$	2	-0.09675344	2	-0.12393146
	$\beta_{1,i-3}$	3	-0.07496754	3	-0.108007704
dsalekitavg	$\beta_{2,i}$	0	0.162509412	0	0.159638178
	$\beta_{2,i-1}$	1	0.166952852	1	0.180184281
	$\beta_{2,i-2}$	2	0.084205439	2	0.121336316
	$\beta_{2,i-3}$	3	0.076453299	3	0.114166256
soilfrzheppt	$\beta_{3,i}$	0	0.052230518	0	0.056741619
	$\beta_{3,i-1}$	1	0.038355313	1	0.043526354
soilfrzleppt	$\beta_{4,i}$	0	0.167098975	0	0.160364016
	$\beta_{4,i-1}$	1	0.126016131	1	0.138847704
	$\beta_{4,i-2}$			2	0.052549174
	$\beta_{4,i-3}$			3	0.038833972
dsaln6ugmkawa	$\beta_{5,i-1}$	1	0.104267816		
	$\beta_{5,i-2}$	2	0.12480171		
soilthwheppt	$\beta_{6,i-6}$	6	0.029347092	6	0.035972385
	$\beta_{6,i-7}$	7	0.01785531	7	0.021610083
soilthwleppt	$\beta_{7,i}$	0	0.113246571	0	0.106772664
	$\beta_{7,i-1}$	1	0.081135696	1	0.103718791
	$\beta_{7,i-2}$	2	0.021968845	2	0.056118604
	$\beta_{7,i-3}$	3	0.027132767	3	0.041983045
	$\beta_{7,i-4}$	4	0.01865496	4	0.034074352
	$\beta_{7,i-5}$	5	0.018046125	5	0.02754767
thwleint	$\beta_{8,i}$	0	0.02233405		
	$\beta_{8,i-1}$			1	0.022579397
	$\beta_{8,i-2}$	2	-0.019003767		
	$\beta_{8,i-3}$			3	-0.020293628
ma	θ_1	1	-0.354124765	1	-0.338305637
	θ_2	2	-0.569710264	2	-0.562316149
	θ_3	3	0.086079682	3	0.079656475

Day 0 forecasts made with model 21 performed well in the cross-validation process (Figures A.4.3.3.6.4.2 - A.4.3.3.6.4.11). While there was a tendency to under-predict higher accretions and over-predict lower accretions, model 21 captures the pattern of accretions very well. False positives (i.e. predicting peaks that do not appear) were rare. Use of model 21 to inform final decisions triggering implementation of surface flushing flows appears likely to enhance the efficient use of stored water in UKL by piggybacking on KIG accretion events.

Day 1-3 forecasts made with model 20 do not perform as well (Figures A.4.3.3.6.4.12 - A.4.3.3.6.4.17). The tendency to under-estimate peaks and over-estimate troughs is more pronounced, and many peaks and troughs are missed entirely. This arises in part because as forecasts are made further into the future, the disturbance components of the predictive equation for which the actual accretion is unavailable (because it has not yet happened) are assumed to be zero. When forecasting day 1, $dsaln1kigaccwa_{i-1}$ is not available, and so the quantity $\theta_1(dsaln1kigaccwa_{i-1} - dsaln\widehat{1kig}accwa_{i-1})$ is assumed to be zero. Forecasts made for day 3 assume that all 3 *ma* components of the disturbance equation are zero, and the forecasts reduce to those from the structural equation alone. Despite the lower quality of these forecasts, simulations with the KBPM have demonstrated their worth in informing preliminary decisions regarding preparation for triggering surface flushing flows. Nonetheless, future efforts to improve these forecasts could significantly enhance their utility.

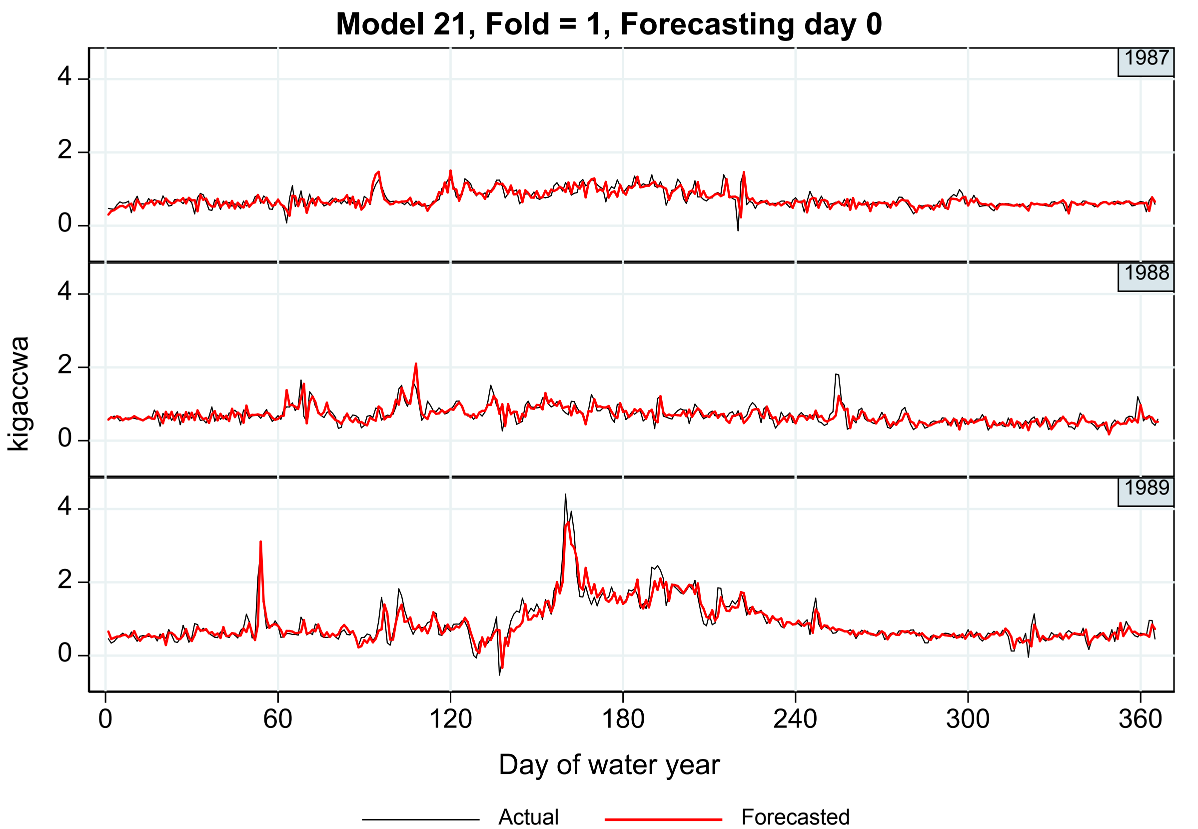

Figure A.4.3.3.6.4.2. Forecasted and actual KIG accretions for day 0 (*kigaccwa*$_i$) for fold 1 from the 10-fold cross-validation process. The model was trained on water years 1981-1986, then used to forecast water years 1987-1989.

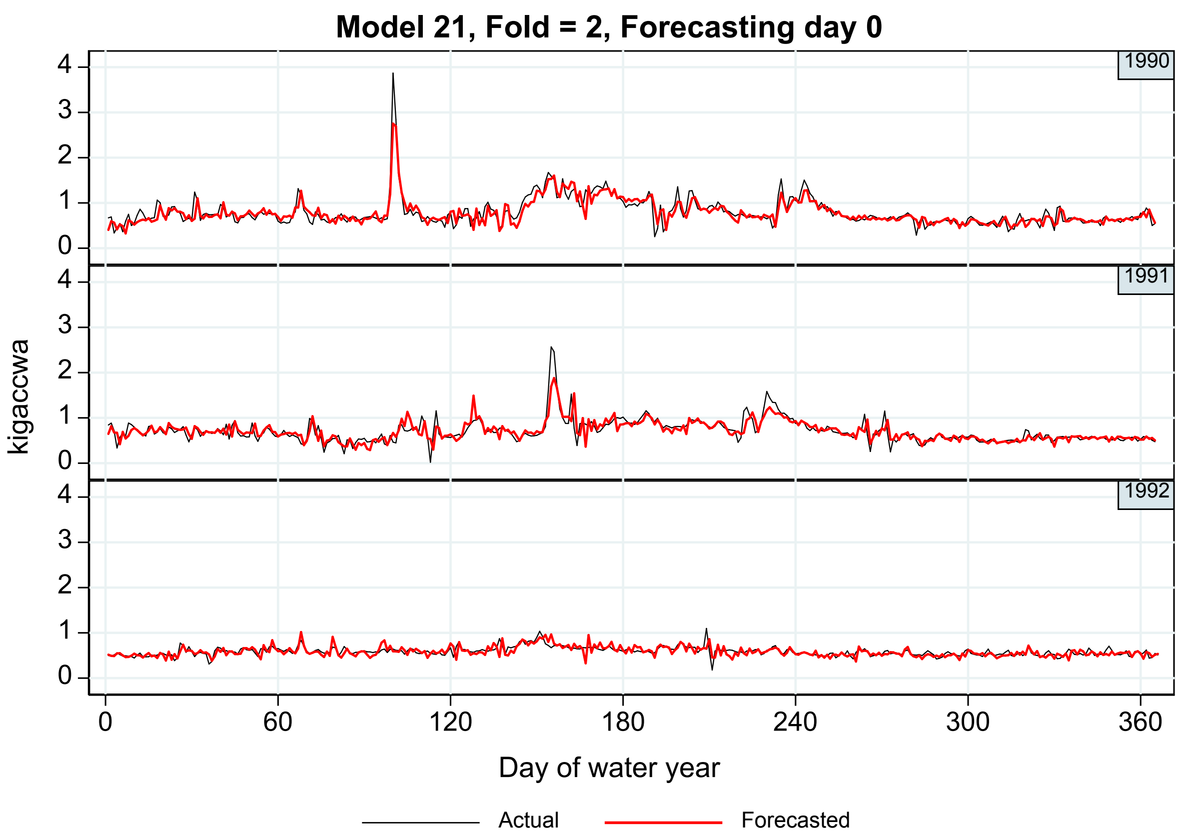

Figure A.4.3.3.6.4.3. Forecasted and actual KIG accretions for day 0 (*kigaccwa*$_i$) for fold 2 from the 10-fold cross-validation process. The model was trained on water years 1981-1989, then used to forecast water years 1990-1992.

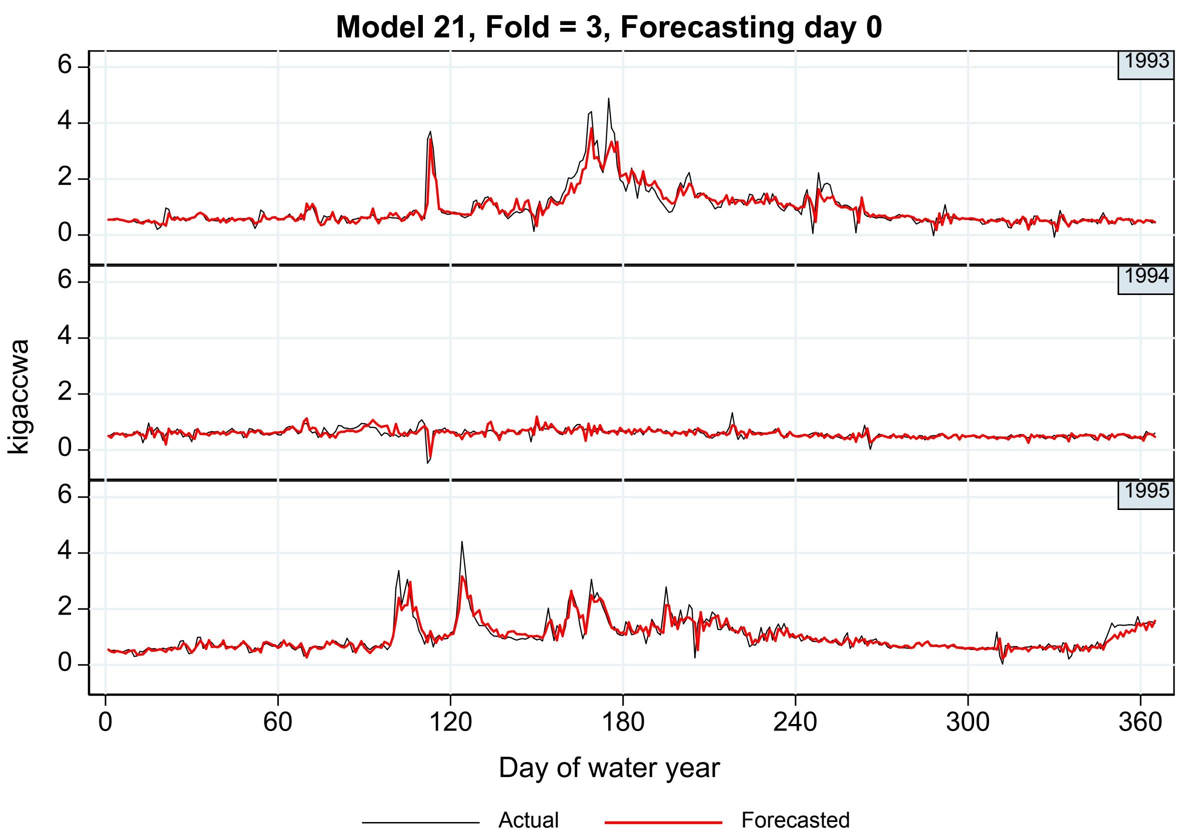

Figure A.4.3.3.6.4.4. Forecasted and actual KIG accretions for day 0 (*kigaccwa*$_i$) for fold 3 from the 10-fold cross-validation process. The model was trained on water years 1981-1992, then used to forecast water years 1993-1995.

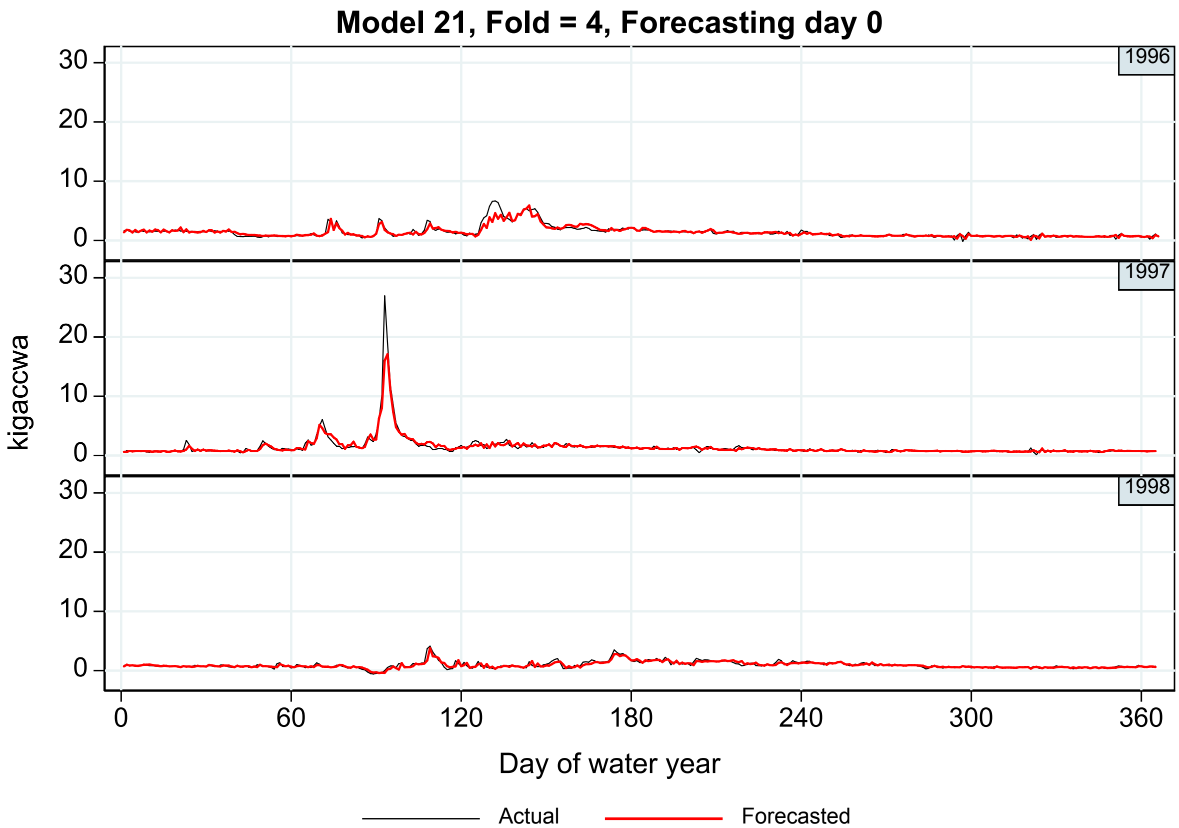

Figure A.4.3.3.6.4.5. Forecasted and actual KIG accretions for day 0 (*kigaccwa*$_i$) for fold 4 from the 10-fold cross-validation process. The model was trained on water years 1981-1995, then used to forecast water years 1996-1998.

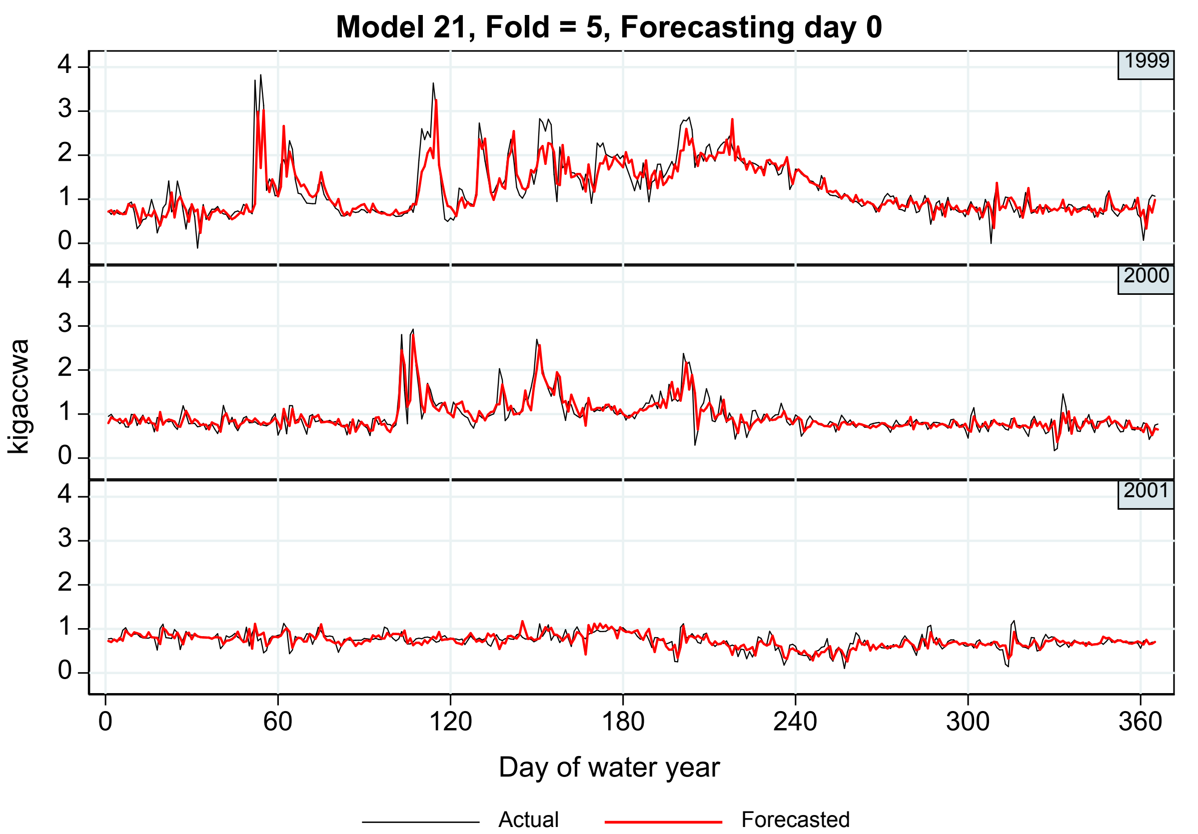

Figure A.4.3.3.6.4.6. Forecasted and actual KIG accretions for day 0 (*kigaccwa*$_i$) for fold 5 from the 10-fold cross-validation process. The model was trained on water years 1981-1998, then used to forecast water years 1999-2001.

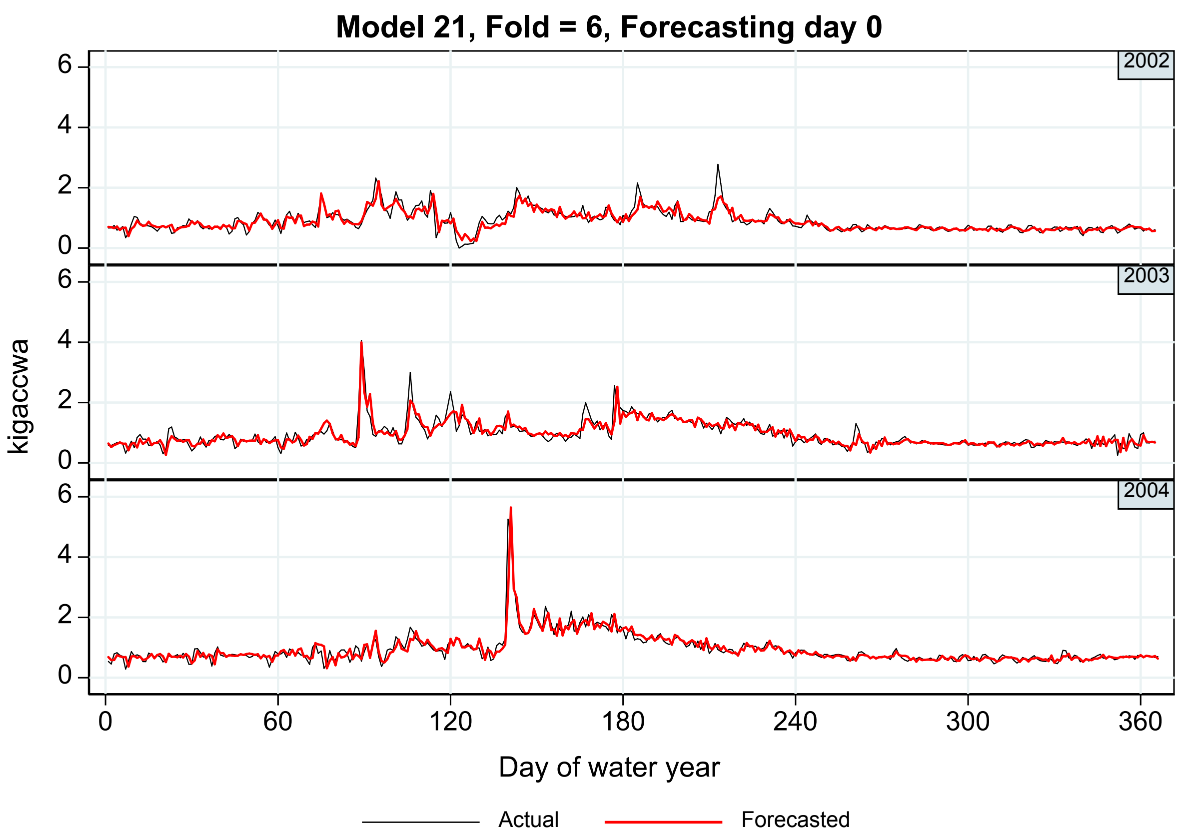

Figure A.4.3.3.6.4.7. Forecasted and actual KIG accretions for day 0 (*kigaccwa*$_i$) for fold 6 from the 10-fold cross-validation process. The model was trained on water years 1981-2001, then used to forecast water years 2002-2004.

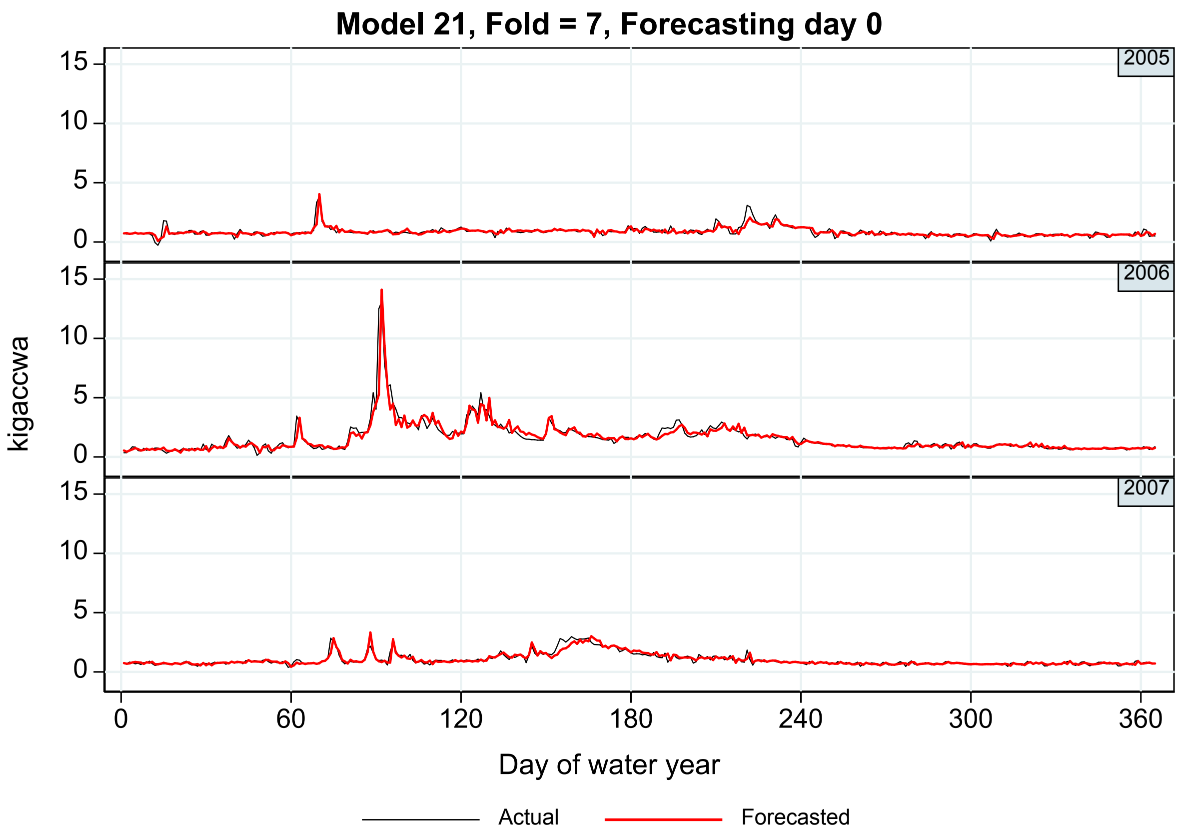

Figure A.4.3.3.6.4.8. Forecasted and actual KIG accretions for day 0 (*kigaccwa*$_i$) for fold 7 from the 10-fold cross-validation process. The model was trained on water years 1981-2004, then used to forecast water years 2005-2007.

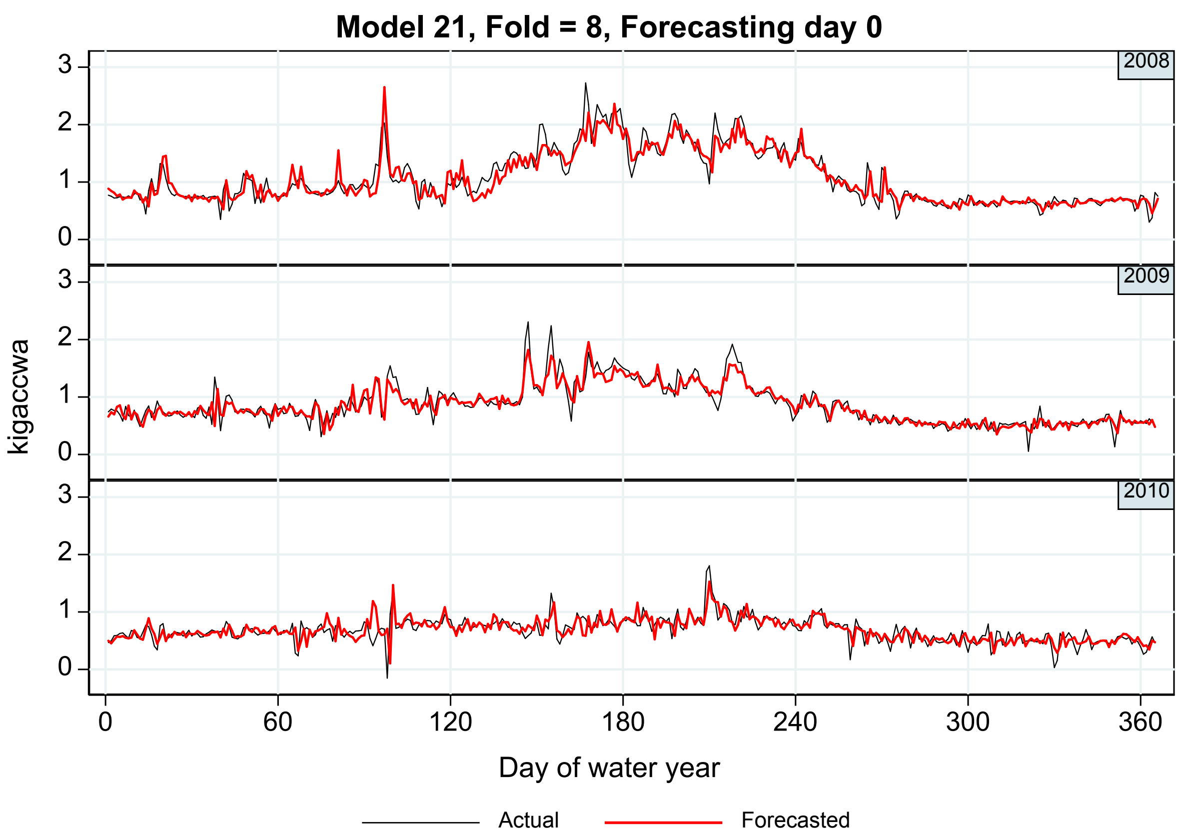

Figure A.4.3.3.6.4.9. Forecasted and actual KIG accretions for day 0 (*kigaccwa$_i$*) for fold 8 from the 10-fold cross-validation process. The model was trained on water years 1981-2007, then used to forecast water years 2008-2010.

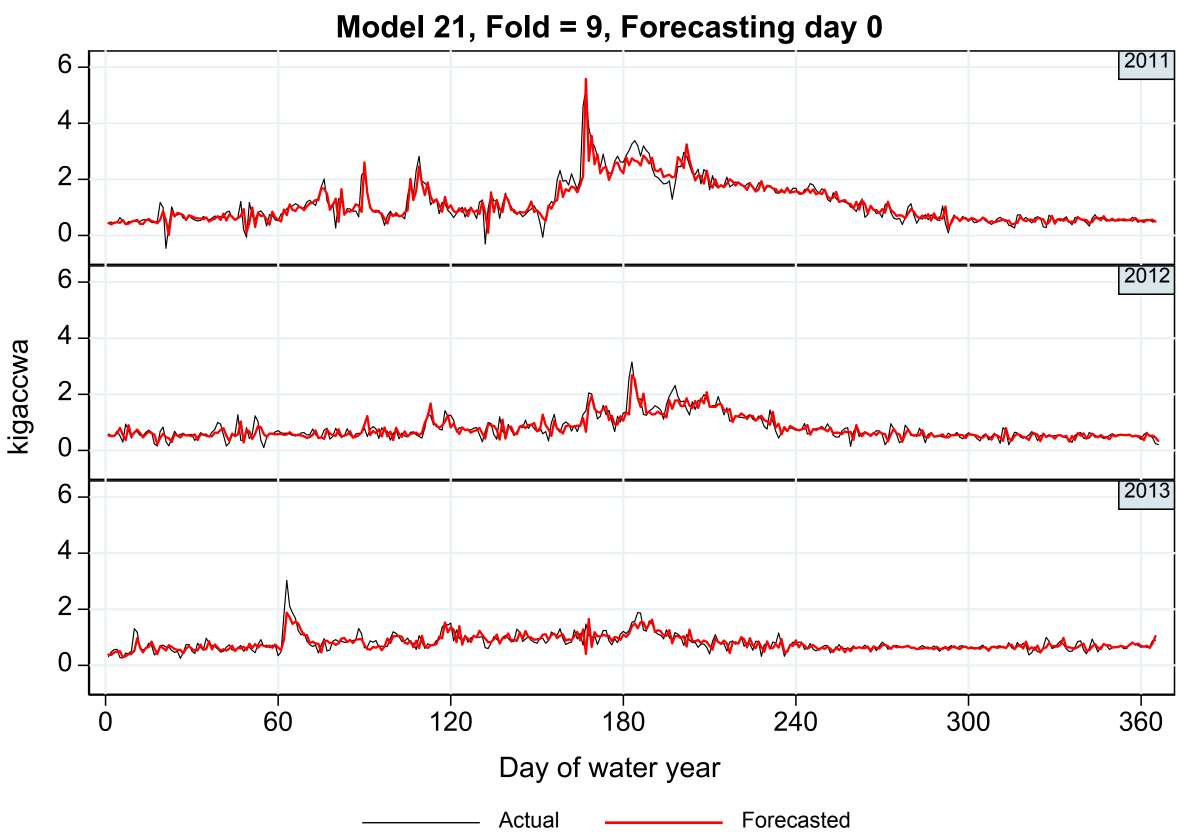

Figure A.4.3.3.6.4.10. Forecasted and actual KIG accretions for day 0 (*kigaccwa*$_i$) for fold 9 from the 10-fold cross-validation process. The model was trained on water years 1981-2010, then used to forecast water years 2011-2013.

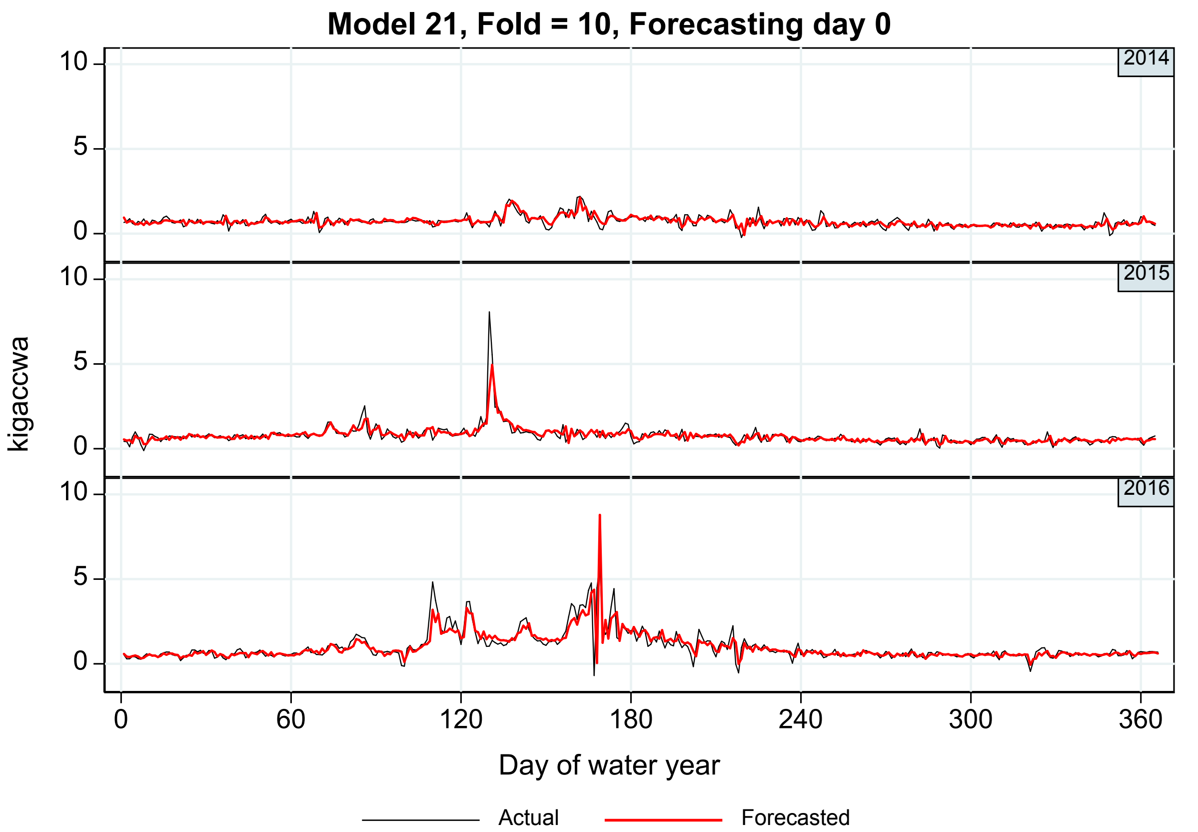

Figure A.4.3.3.6.4.11. Forecasted and actual KIG accretions for day 0 (*kigaccwa$_i$*) for fold 10 from the 10-fold cross-validation process. The model was trained on water years 1981-2013, then used to forecast water years 2014-2016.

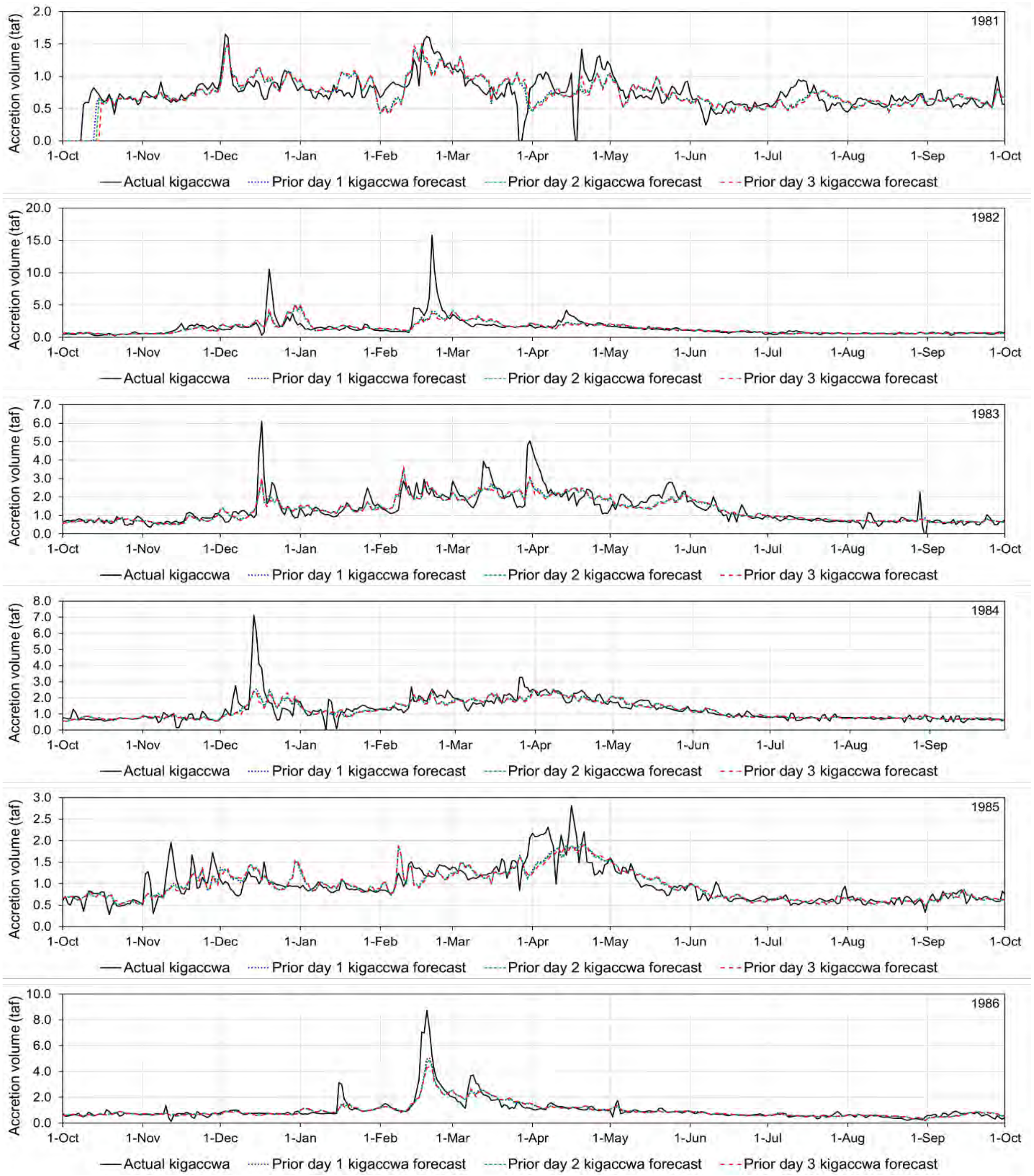

Figure A.4.3.3.6.4.12. Prior KIG accretion forecasts for water years 1981-1986 (based on model 20 fitted across all water years) compared to the actual accretions on those days.

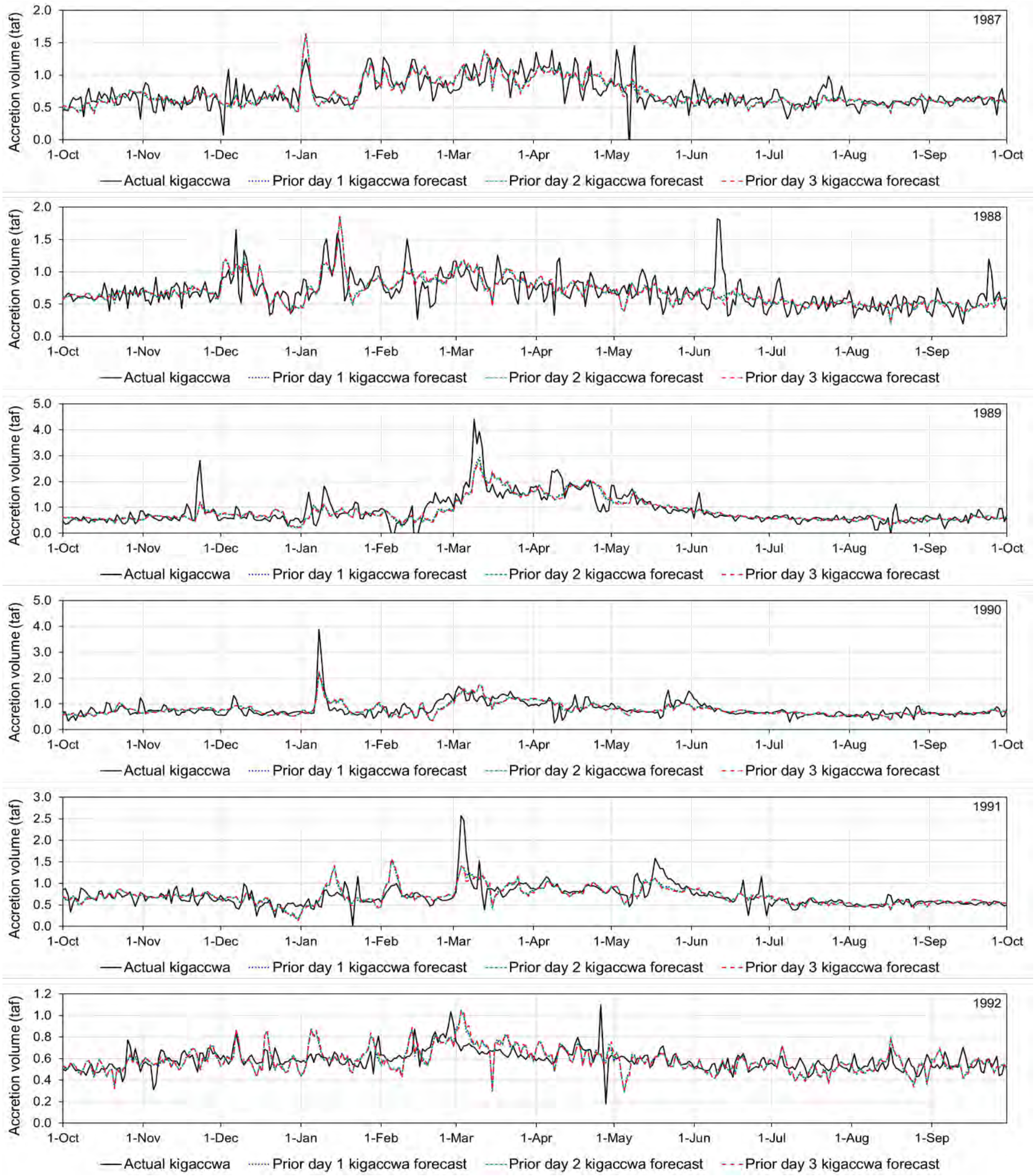

Figure A.4.3.3.6.4.13. Prior KIG accretion forecasts for water years 1987-1992 (based on model 20 fitted across all water years) compared to the actual accretions on those days.

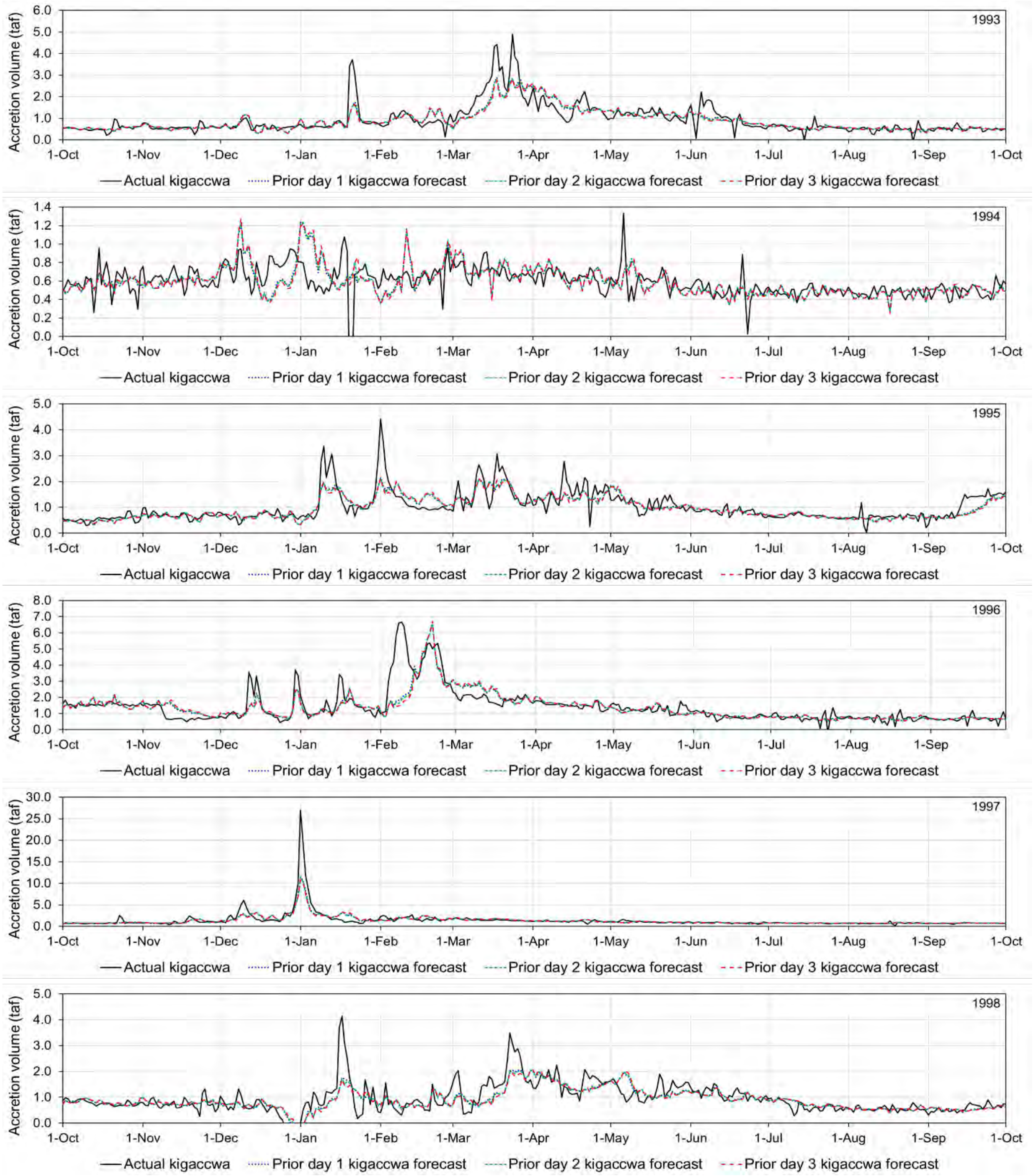

Figure A.4.3.3.6.4.14. Prior KIG accretion forecasts for water years 1993-1998 (based on model 20 fitted across all water years) compared to the actual accretions on those days.

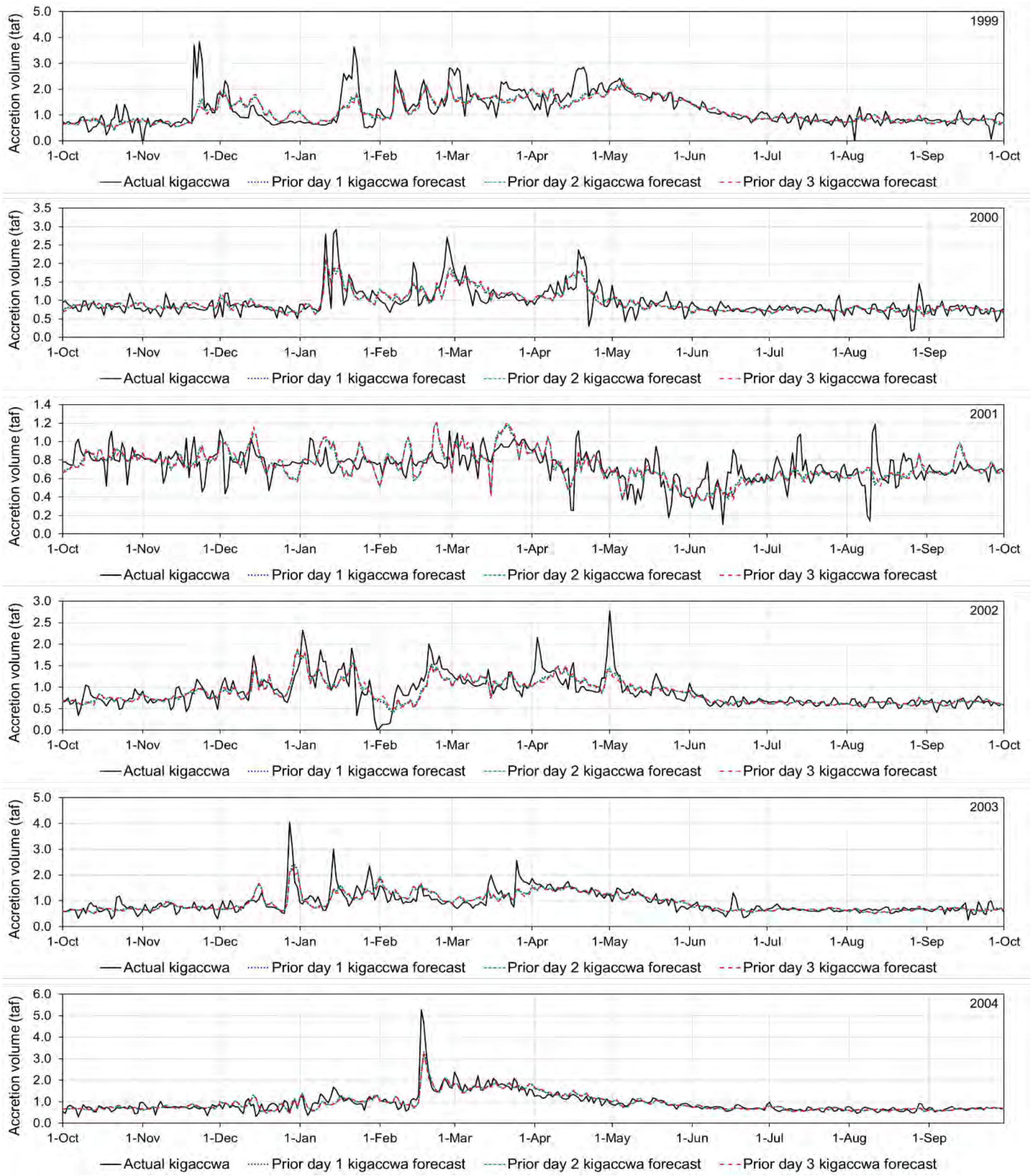

Figure A.4.3.3.6.4.15. Prior KIG accretion forecasts for water years 1999-2004 (based on model 20 fitted across all water years) compared to the actual accretions on those days.

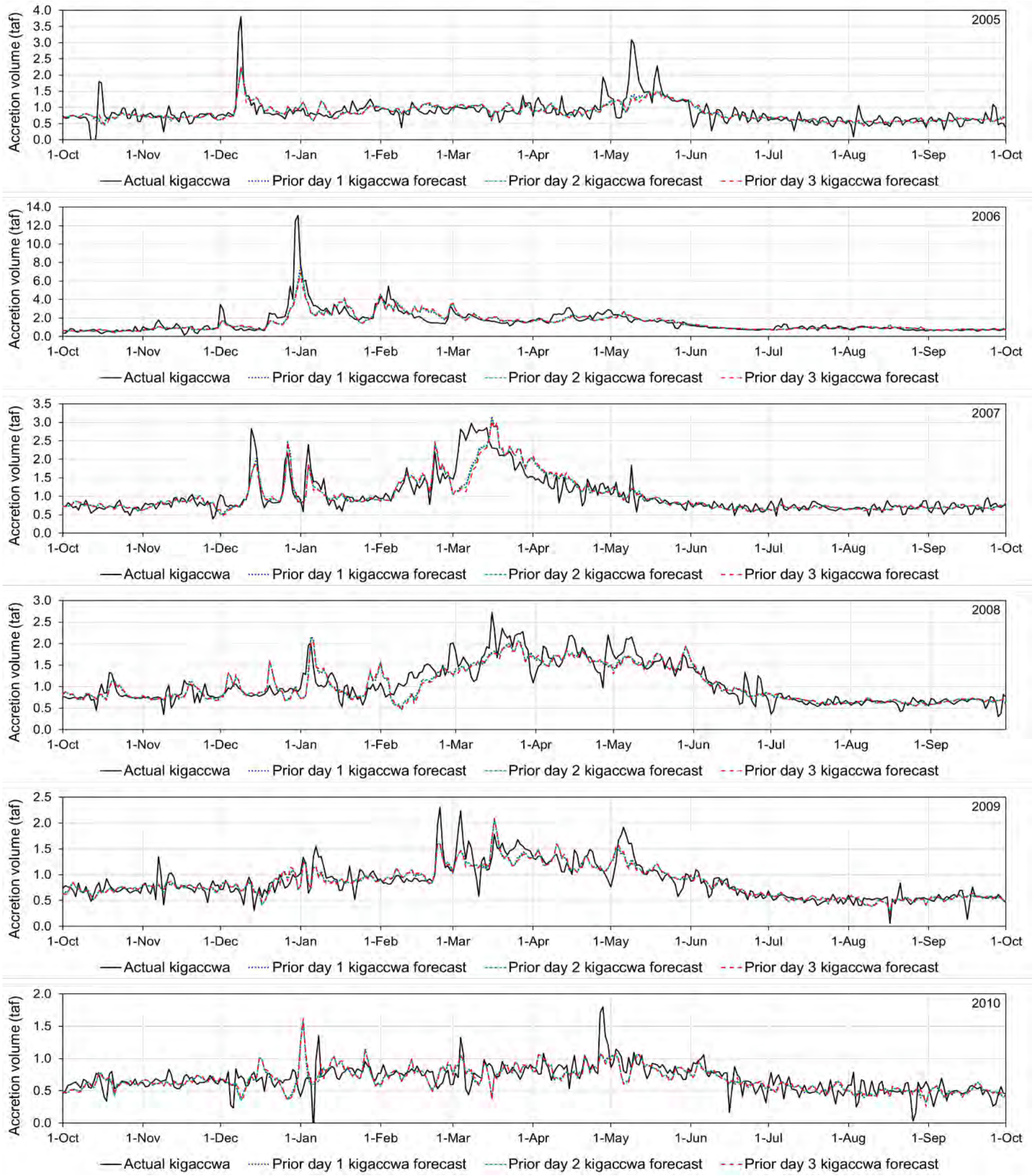

Figure A.4.3.3.6.4.16. Prior KIG accretion forecasts for water years 2005-2010 (based on model 20 fitted across all water years) compared to the actual accretions on those days.

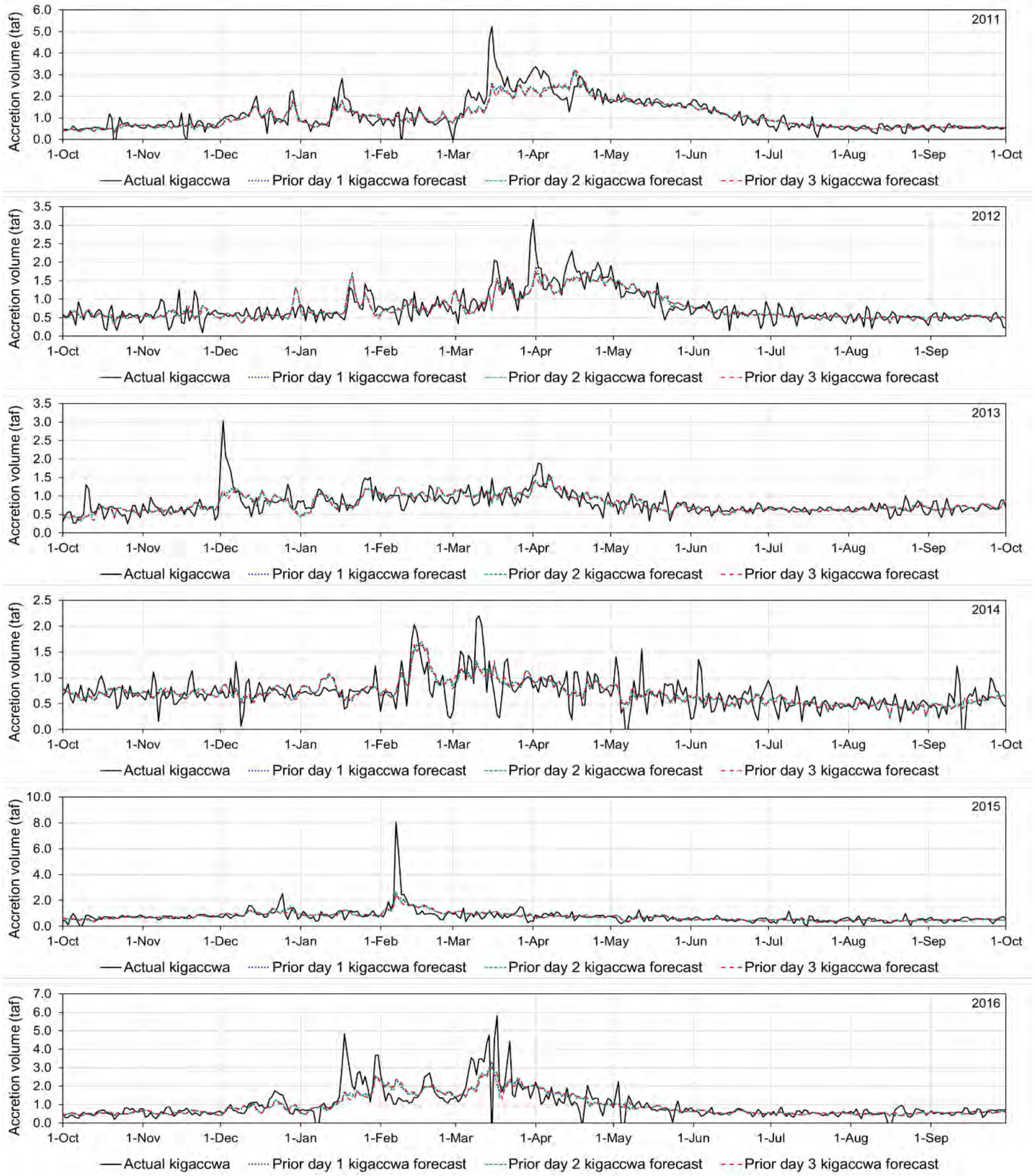

Figure A.4.3.3.6.4.17. Prior KIG accretion forecasts for water years 2011-2016 (based on model 20 fitted across all water years) compared to the actual accretions on those days.

A.4.3.3.7 Lost River Diversion Channel Inflow From Lost River

A mixture of runoff from the Lost River catchment and return flows (primarily from A Canal diversions) is diverted into the LRDC at the Lost River Diversion Dam. Data for these return flows are included in the QA/QC'ed **Daily_Project_Diversions_Final_Dec2016_corrected_Jun2017.xlsx** dataset.

A.4.3.3.8 Area 2 Winter Runoff

The Area A2 Winter Runoff data input is an error closure term for return flows from the Area A2 to the Klamath River. Essentially, this term accounts for water that was introduced to or deducted from the KSD beyond that which would have been expected as a result of agriculture or LKNWR activities, or winter and spring precipitation events that may create runoff that also drains into the KSD. In addition, gage errors, changes in pumping efficiency, changes in canal dimensions and increased or decreased efficiency in area A2 water use could all contribute to this balancing term. Area A2 Winter Runoff is a state variable, meaning that these data are static and unaffected by model adjustment of A2 deliveries or F/FF pumping. It is a timeseries calculated based on the difference between measured F/FF discharge to the Klamath River and simulated return flows from KDD and Area K using the historical gauged deliveries through North and Ady canals. The model assumes no return flow from LKNWR.

These data, as well as data and formulae related to the calculation of these data, are contained in the spreadsheet named: **KDD return flow analysis 18Sep2018 version 4 FINAL.xlsx**. More detail is provided in Section A.4.4.5. In KBPM, Area A2 Winter Runoff data are contained in the file: **PA_4Jan2017_newBathy_I1ExpSm1x_SV.dss**.

A.4.3.3.9 Natural Resources Conservation Service Forecasts

The NRCS provided reconstructed UKL net inflow forecasts for water years 1981 through 2016 using the revised UKL net inflow data (Dunsmoor 2017b). The most recent reconstructed forecasts were completed by NRCS in October 2017.

The KBPM utilizes the 50^{th} percentage of exceedance forecast for UKL inflow for the months of January through June. Operationally, forecasts are provided by NRCS on the first of each month, and forecasts used in the model reflect this constraint. The March through September forecast is used on January 1, February 1, and March 1. Thereafter, forecasts for the forecast month through September are used (e.g. April – September on April 1). Spring/summer forecasted UKL net inflow is calculated in-season using the following formula:

Forecasted UKL Net Inflow = Previous month measured net inflow + Current month inflow forecast through September

The final forecast is issued and used on June 1. Further detail on use of these forecasts is discussed in Section A.4.4.

NRCS forecast reconstructions are contained in the spreadsheet: **Klamath_forecast_reconstructions_new_flow_data 13Oct2017.xlsx**. In KBPM, NRCS forecast data are contained in the file: **forecasts50pct.table**.

A.4.3.4 Model Variables

In many cases, the actual variables used in the model code have names which are not clearly descriptive of their definition. This is a function of multiple model developers, changing intentions and strategies, and general model adaptation. In order to connect the actual model code to the operations described below, please refer to Table A.4.3.4.1, which defines WRIMS variables used in the modelling of the Proposed Action with a common name (as referenced in the operations sections below) and location within the model files. Due to size, this table is located in Section A found at the end of this document.

A.4.4 Simulated Operations

A.4.4.1 Important Annual Operations

A.4.4.1.1 Upper Klamath Lake Control Logic

One of the greatest challenges identified in previous proposed actions was how to manage UKL elevations in such a way that the needs of endangered suckers in UKL are met while also providing a sure water supply to meet the needs of both threatened coho in the Klamath River and Project irrigators. While many approaches were explored, modelers ultimately created model logic that would allow flexibility in managing lake elevations while also discouraging overuse of the finite hydrologic resource, both within years and inter-annually. The UKL control logic was added to KBPM in order to control releases from UKL to the river and the Project based on UKL elevation relative to a hydrologically-dependent central tendency.

The central tendency is based on user-defined end-of-month UKL elevations which are subsequently interpolated to daily values; note that the generic central tendency end-of-month UKL elevations were arrived at through an iterative modeling process and are not intended to change during operations under this PA. This results in a generic annual hydrograph that accounts for seasonal needs of suckers, seasonal water demand for the Klamath River and Project, and end-of-season elevations that create conditions likely to result in storage volumes appropriate to meet the next year's demands on UKL. Table 4.4.1.1.1 provides information on the generic hydrograph.

Table 4.4.1.1.1 End-of-month UKL elevations associated with the generic (i.e., unadjusted) central tendency and the lower and upper bounds within which the tendency can be adjusted, by month. The lower and upper bounds represent the limits of adjustment that can be made to the central tendency in response to hydrology.

Month	Central Tendency Base UKL Elevation (ft.)	Central Tendency Lower Bound UKL Elevation (ft.)	Central Tendency Upper Bound UKL Elevation (ft.)
October	4139.1	4138.7	4139.5
November	4139.6	4139.2	4140.0
December	4140.6	4140.2	4141.0
January	4141.6	4141.2	4142.0
February	4142.4	4142.1	4142.7
March	4142.8	4142.6	4143.0
April	4142.8	4142.6	4143.0
May	4142.4	4142.1	4142.7
June	4141.1	4140.7	4141.5
July	4140.1	4139.7	4140.5
August	4139.4	4139.0	4139.8
September	4139.1	4138.7	4139.5

This generic hydrograph is then adjusted daily, based on a normalized 60-day trailing average of net inflow to UKL. Normalization of the daily UKL net inflow involves taking the current day's 60-day trailing average, subtracting the minimum UKL inflow for that date in the POR, and dividing this value by the difference between the maximum value for that date in the POR and the minimum value. This produces a value on any given day that is between zero and one, which can then be used to adjust the central tendency. The result of the adjustment by the normalized 60-day trailing average of net inflow to UKL is an adjusted central tendency, one that is reactive to hydrologic trends experienced in the upper basin of the preceding approximately 8 weeks. As each day passes, the trailing 60-day average is updated with the most recent past hydrologic input to UKL inflow and removes the oldest data from consideration (i.e. yesterday's data replaces that from 61 days prior).

Normalized 60-day average of net inflow to UKL:

Norm_uklinf_60avg = (uklinf_60avg – uklinf_min(-1)) / (uklinf_max(-1) – uklinf_min(-1))

where: uklinf_60avg = today's average of UKL net inflow for the past 60 days
uklinf_min(-1) = yesterday's minimum UKL net inflow for that day of the water year (dowy) across the POR
uklinf_max(-1) = yesterday's maximum UKL net inflow for that dowy across the POR

The magnitude of the daily adjustment in UKL central tendency is bounded by user-defined limits which have been tailored to meet the needs outlined above. The final result is a central tendency line that both accounts for hydrologic needs (ESA and irrigation) and accounts for the impact of seasonal hydrology in any given year.

Adjustment of UKL central tendency:

Adj_uklcentral = ukltraj_central + (norm_uklinf_60avg – 0.5)

where: ukltraj_central = daily interpolated value for the central tendency
norm_uklinf_60avg = normalized 60-day average of net UKL inflow

The adjusted central tendency is used to signal the need for, and to quantify the magnitude of reduction in, releases from UKL. On any given day, if lake elevations are above the adjusted central tendency, then releases to the river or to the Project proceed unchanged from the delivery rules in the model. However, when UKL elevations are below the adjusted central tendency, Klamath River and Project (when applicable) releases are reduced by a magnitude commensurate with how far UKL is below the adjusted central tendency, which facilitates but does not force the return of UKL to a trajectory in line with the adjusted central tendency.

Release reductions occur based on a storage difference ratio. This ratio determines the magnitude of required reduction based on how far below the adjusted central tendency UKL sits; the further below the adjusted central tendency, the greater the percentage by which releases may be reduced. The storage difference ratio is updated every 5 days, meaning that an action taken on reduction (e.g., no reduction, reduction of 10%) will remain in effect for 5 days from the date of implementation. This was done to maintain operational feasibility of this approach. There are two different storage difference ratios in the model, one that is applied to Klamath River releases and one that is applied to Project releases.

LRD releases may be reduced by up to 80% from the daily calculated release and may be reduced at any time of the year; IGD minima for the Klamath River (as defined in the 2013 Biological Opinion) are still in effect and river flows cannot go below these values. Project releases may be reduced by up to 80% and these reductions can only occur to Project releases for fall/winter water deliveries, November through February, and releases to LKNWR in December through February. This reduction does not apply to the LKNWR transferred water right described in Section A.4.4.9 (additionally, see Section A.4.4.9 and in the Biological Assessment, Section 4.3.2.2.2.2 for additional information about delivery of Project Supply to LKNWR). Both storage difference ratios have an upper bound of 0, meaning that modeled releases will not increase if UKL elevations are above the adjusted central tendency. The lower bounds are -0.8 for LRD and fall/winter Project/LKNWR deliveries. The first step in calculating the storage difference ratio is to determine the volumetric difference between the current UKL elevation and the adjusted central tendency. This is done taking into account the UKL credit that has been accumulated, since this water is intended to remain in UKL (see Section A.4.4.1.2). Once this volumetric difference is determined, the ratio is created by dividing that volume by a volumetric "envelope" on UKL within which UKL may fluctuate. This envelope varies slightly throughout the year, from 20,000 AF to 60,000 AF, with intermediary values linearly interpolated. The broadest envelope (i.e., highest values) is allowed in the spring (Table 4.4.1.2.1.2), when demands on UKL are highest. As this value is used in the denominator of the storage difference ratio calculation (see below), the size of the envelope will dictate the increment by which the storage difference ratio may be applied to releases. A larger envelope value results in a more gradual implementation of adjustment before maximum adjustment is achieved; a smaller envelope value results more rapid increase in adjustment percentage as UKL elevations drop below the central tendency. Table 4.4.1.1.2 and the following equations define the storage difference ratio:

Storage difference pre-adjustment:

Stor_diff_preadj = S1(-1) – prj_UKL_credit – adj_uklcentral_storage

where: S1(-1) = yesterday's UKL storage volume
prj_UKL_credit = accumulated credit volume in UKL (see Section A.4.4.1.2)
adj_uklcentral_storage = storage volume associated with today's adjusted central tendency

Table 4.4.1.1.2 UKL adjustment width for each day of the water year; values for intermediate days are linearly interpolated within KBPM.

Day of Water Year	UKL Adjustment Width (TAF)
1	20
124	20
152	60
212	60
227	20
366	20

Storage difference ratio:

Stor_diff_ratio = min (u_bound, max (l_bound, stor_diff_preadj / UKL_adj_width))

where: u_bound = upper bound of storage difference ratio
l_bound = lower bound of storage difference ratio
stor_diff_preadj = unadjusted storage difference ratio
UKL_adj_width = the UKL elevation "envelope" described above

It is important to note that the UKL control logic is not designed to utilize the adjusted central tendency line as a management target. Rather, it is part of an overall management scheme to ensure that needs of the UKL, Klamath River, and the Project are met in the majority of water years. The adjusted central tendency is one step in the process of setting spring/summer and fall/winter releases to the Klamath River from UKL and fall/winter releases to the Project from UKL. The other steps in this process are described in Sections A.4.4.2 and A.4.4.3.

A.4.4.1.2 Upper Klamath Lake Credit

In the 2013 BiOp, both LRDC accretions in excess of Project diversions and F/FF discharge to the Klamath River were included in the formulated IGD flow target. The current proposed action has removed the IGD flow target reliance on these accretions and return flows during the irrigation season; to compensate for this, EWA will have a higher share of UKL Supply to provide IGD flows that were previously met by excess LRDC flow and F/FF pumping. These accretions and return flows will be shared between Project irrigators and UKL for mutual benefit. Irrigators can directly divert Lost River flow to the LRDC or F/FF discharge and it does not count as a diversion of Project Supply. The LRDC flows and F/FF pumping in excess of direct diversion supports controlled IGD flow in lieu of LRD releases. This reduction in LRD release results in higher UKL storage, and the increment of higher storage is termed an Upper Klamath Lake Credit (UKL Credit).

A UKL Credit may be accrued only from March through September, while the EWA is in effect and releases at LRD and IGD are managed (i.e., not in flood operations). Flows from LRDC and F/FF must be in excess of concurrent agricultural diversions, meaning that those flows are potential irrigation water that is instead going to support IGD releases. High rainfall runoff events from the Lost River do not contribute to the UKL Credit. If UKL experiences flood spill during this time period, further UKL Credit cannot be accrued during spill; additionally, during flood control operations, UKL Credit will be considered the first UKL storage spilled.

The purpose of the UKL Credit is to hold water in UKL to facilitate the ability to establish a minimum Project Supply on April 1 with no later reduction, and the possibility of increase in subsequent May 1 and June 1 allocations. Accrual of UKL Credit ensures that there is a volume of water in UKL that can be drawn upon in the case of an early season over-forecast of seasonal inflow to UKL. However, any UKL Credit accrued in UKL above and beyond that necessary to ensure full delivery of Project Supply will remain in UKL to facilitate refill of the lake in the ensuing fall/winter period. There is no carryover of accrued UKL Credit from season to season.

UKL credit calculation:

Prj_UKL_credit = prj_UKL_credit(-1) + (C91_F_IG(-1) + C131_IG(-1) – C15_EXC(-1)) – D1(-1) – C1_AG(-1)

where: prj_UKL_credit(-1) = yesterday's UKL Credit amount
C91_F_IG(-1) = yesterday's LRDC contribution to IGD release
C131_IG(-1) = yesterday's F/FF contribution to IGD release
C15_EXC(-1) = yesterday's IGD flood release
D1(-1) = yesterday's A Canal diversion
C1_AG(-1) = yesterday's LRD release for agricultural diversion

EWA use includes the LRDC flow and F/FF discharge that goes downstream to support IGD releases in controlled flow situations.

A.4.4.2 Fall/Winter Operations

The fall/winter Project operational procedure distributes the available fall/winter UKL inflows between the following:

1. UKL
    a. Increase UKL elevation to meet ESA-listed habitat needs throughout the fall/winter period and the following spring/summer period and increase storage for spring/summer EWA releases and irrigation deliveries.
    b. This is achieved through the UKL control logic.

2. Klamath River
    a. Release sufficient flow from IGD to meet ESA-listed species needs in the Klamath River downstream of IGD; this includes flows to support salmon spawning from October 1 – November 15.
    b. This is achieved through the formulaic approach to calculating IGD targets.

3. Project:
    a. Klamath Drainage District (Area A2 – serviced by North Canal and Ady Canal)
    b. Lease Lands in Area K (within Area A2 – serviced by Ady Canal)
    c. LKNWR (serviced by Ady Canal)

Additionally, sufficient flood pool capacity must be maintained in UKL to protect the surrounding lake levees.

The fall/winter operations period begins on November 1 and ends on February 28/29. Note that there is often overlap between the spring/summer (see Section A.4.4.3 for details) and fall/winter operations in October and November because Area A1 and the LKNWR will likely divert a portion of the spring/summer Project Supply during these months, while EWA accounting ends on October 1. Spring/summer and fall/winter diversion accounts must be kept separate during the overlap period.

During the fall/winter season, the primary goal of operations is to refill UKL in order to support high demands on UKL in early spring, including the possibility of disease prevention/mitigation flows for the Klamath River, ensuring adequate spawning habitat for shoreline spring spawning suckers, and supporting the beginning of Project deliveries. To this end, a premium is placed on the fill rate needed to achieve a UKL elevation of 4,143 feet by the end of February. Note that this target elevation is utilized to calculate a refill trajectory that effectively refills UKL; flood control elevations will prevent UKL from reaching this elevation at the end of February (see Section A.4.4.10). In addition, KDD is provided a reserve supply of up to 28,910 AF between November 1 and February 28/29 via a state water right, and LKNWR is provided maintenance flows of up to 62 cfs/day, with a cap of 11,000 AF in total delivery volume from December through February. Both of these deliveries are subject to the UKL control logic, and so may be reduced based on hydrologic conditions. The remaining inflow to UKL is released to support Klamath River flows at IGD. IGD releases are heavily affected by the accretions downstream of Keno Reservoir. In wetter hydrologic patterns, or during periods immediately following lower-basin storms, the downstream accretions can account for a substantial portion of the flows downstream of IGD.

Following are instructions for implementing fall/winter operations.

Fall/winter releases from UKL for IGD flows are intended to support salmon spawning in October through November 15 and are determined by UKL net inflow and the fill trajectory of UKL thereafter. All KDD and LKNWR deliveries are calculated as shown below and subject the UKL control logic. No UKL credit can be accrued during the fall/winter season. Key model variables referenced throughout this document can be defined in Table A.4.3.4.1 found in Section A at the end of this document.

1. Lookup **Link_min**, which is the minimum flow release from LRD from Oct-Feb. Link River minima are only for modeling purposes and lower Link River flows may be observed in real-time operations. Note that it is operationally possible to reduce LRD flows below these flow minimums, but this requires Reclamation to conduct a fish stranding assessment below LRD (and possibly below Keno Dam). This requires additional personnel and other resources. Given these concerns, it is necessary to weigh the benefit of flows below LRD minimums against personnel and resource requirements for stranding assessments. See the Biological Assessment, section 4.3.2.2.1 for additional details.

Table A.4.4.2.1 Link River Dam minimum flow release; these discharges refer to cfs at Link River Dam, rather than the USGS gauge downstream.

Month	Link_min (cfs)
October	400
November	400
December	300
January	300
February	300

2. Determine IGD flow for the October – November 15 salmon spawning period, **IG_spawn_flow**. This flow determination begins with the lookup of **IG_spawn** flow value based on the normalized 60-day trailing average of net UKL inflow; this value is linearly interpolated between a minimum of 1000 cfs and a maximum 1200 cfs. To this base value, an additional 0 – 125 cfs may be added at intervals of about 10 days based on the 60-day trailing average of UKL net inflow and the date between October 1 and November 15; this is the **IG_spawn_inc**. On any given day during the time period:
   IG_spawn_flow = IG_spawn + IG_spawn_inc

3. Calculate **Needed_fill_rate**, which is the average daily fill rate from yesterday's UKL level to attain 4143 ft. on February 28.

   Needed fill rate = (fill_target_approx_vol – S1(-1)) / (105 – (daynumDV(-1) – 47))

   where: fill_target_approx_vol = volume associated with an UKL elevation of 4143 ft. (534,502 AF);
   S1(-1) = yesterday's storage volume in UKL;
   daynumDV = the current day of the water year, numbered since October 1.

   Note: 105 is the number of days between November 16 and February 28 and 47 is the number of days from October 1 to November 16. This allows for a daily calculation of how much volume should be added to UKL between November 16 and February 28 if 4143 ft. in elevation is to be achieved.

4. Calculate **Link_release_FW**, which is the amount of water that should be released from LRD between October 1 and February 28/29 based on UKL net inflow, UKL filling trajectory, and accretions between LRD and IGD.

   a. First, **Link_release_FW_prep** is calculated, which is a release from LRD that is unadjusted by interaction with the UKL control logic. Flow releases in October – November 15 depend on the IG_spawn_flow, which is implemented in the calculation of C15_target (see below), and so this period is omitted here. From November 16 through February, UKL net inflow is adjusted by 1.5 times the Needed_fill_rate.

      November 16 – February 28/29:
      Link_release_FW_prep = I1(-1) – (1.5 * Needed_fill_rate)

      where: I1(-1) = yesterday's UKL net inflow

b. Then, Link_release_FW_prep is adjusted by an appropriate daily storage difference ratio, resulting in:

Link_release_FW = Link_release_FW_prep + (stor_diff_ratio5d * Link_release_FW_prep)

5. Establish **Link_max**, the maximum release possible from LRD, based on the UKL elevation. This is done by selecting the appropriate maximum release based on the associated UKL elevation from the lookup table **Link_max.table**. This value will limit how much water can possibly be released from UKL to support Klamath River, KDD, and LKNWR flows on any given day. Maximum possible releases range from a high of 8,600 cfs when UKL level is 4143.3 ft, to a low of 900 cfs when UKL level is 4137.0 ft.

6. Determine the **Link_WF_target**, which is the maximum value of either Link_min or Link_release_FW.

7. Determine volumes of water needed to meet needs for KDD and LKNWR winter needs.

   a. KDD has a winter water right for a volume of up to 28,910 AF. KDD daily deliveries are subject to UKL control logic and can be reduced by an appropriate percentage on a daily basis as dictated by the UKL control logic. KDD daily deliveries (in cfs) are determined as follows:

   D11_fw_calc_no_UKL_ctrl = min (200 cfs, KDDReserve) * pctNorth
   D12A_fw_calc_no_UKL_ctrl = min (200 cfs, KDDReserve) * pctAdy

   where: KDDReserve = remaining amount of unused state water right, converted to cfs in this calculation
   pctNorth = percentage of delivery to be put down North Canal, based on water year type
   pctAdy = percentage of delivery to be put down Ady Canal, based on water year type

   D11_fw_calc_no_UKL_ctrl and D12A_fw_calc_no_UKL_ctrl are both subject to an appropriate UKL control adjustment.

   b. LKNWR can receive up to 62 cfs/day via Ady Canal from December 1 through February, up to a total volume of 11,000 AF. These deliveries are also subject to UKL control logic and can be reduced by an appropriate percentage on a daily basis.

8. Lookup **IGmin**, which is the minimum flow at the gauge below IGD (minima for other months not shown here):

Table A.4.4.2.2 Minimum Flow Below Iron Gate Dam, October to February

Month	IG_MIF (cfs)
October	1000
November	1000

December	950
January	950
February	950

9. Set **C1forC15**, the LRD release to support IGD flows. For the fall/winter period, this is equal to Link_WF_target.

10. Calculate **C15_target**, which is the targeted release at IGD. From October 1 through November 15, this target is IG_spawn_flow + stor_diff_ratio5d * IG_spawn_flow. This calculation relies upon operational values from 3 days prior (the operational delay accounted for in the model) and a forecast of accretions from 3 days prior. Operationally, IGD releases may vary from those calculated here due to real-time accretion values, flood control operations, and/or other facility operational emergencies and malfunctions.

    C15_target = C1forC15 + I10(-3) + I15_forecast2(-3) + (C131(-3) + max (C91_F(-3) – D11_ss_LRDC(-3) – D12A_ss_LRDC(-3) – D12B_LRDC(-3), 0))

    where: I10 = Link River Dam to Keno Dam accretions;
    I15_forecast2 = forecasted Keno Dam to Iron Gate Dam accretions;
    C131 = F/FF discharge;
    C91_F = LRDC flows toward the Klamath River;
    D11_ss_LRDC = North Canal diversion of LRDC return flow;
    D12A_ss_LRDC = Ady Canal diversion of LRDC return flow to ag;
    D12B_LRDC = Ady Canal diversion of LRDC return flow to LKNWR;

(-3) = operational lag of three days assumed in the model.

A.4.4.3 Spring/Summer Operations

The Project irrigation season runs from March 1 through October 31, although irrigation can continue through November 15 in areas served by D91. The previous section described the fall/winter operations which are the first half of each water year. This section describes the second half of each water year, which covers the irrigation season. The irrigation season operations are controlled by defining the available UKL Supply (WRIMS variable name UKLSupply), which is computed from storage in UKL, forecasted March-September inflow, and target carryover storage. Division of this supply between the Klamath River (EWA_river) and Project (PrjSupply) is dependent on the size of UKL Supply (described below). Any UKL inflow that is not delivered or released for flow will remain in UKL as storage. All water which leaves UKL through either LRD or the A Canal is accounted for against one of these two identified volumes; this includes flood control releases with the exception of spill of UKL credit. LKNWR can receive a portion of the Project Supply or other delivery from UKL. Details for these operations are included in the sections below.

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Both volumes are calculated on March 1 and April 1 with updates on May 1 and June 1. The March and April processes divide up the UKL Supply to help the irrigators and river managers plan out the spring/summer operational period. The May and June processes manage the change in supply by adjusting the volumes. The steps for determining the Project Supply and the EWA are below. Key model variables referenced throughout this section can be found in Table A.4.3.4.1 at the end of this Appendix 4-1.

1. Calculate **UKLSupply** - The UKL supply is updated on the 1st of each month March through June using the most current forecasted net inflow, the end of February storage and the end of September target. This formula is as follows (all values in TAF):

   UKLSupply = [End of February UKL Storage] + [50% exceedance forecast UKL inflow for March through September] – [End of September UKL Storage Target]

   a. The end of February UKL storage is simply the storage in UKL as determined on the last day of February. This is determined using the UKL weighted mean average elevation as determined by USGS for that date along with the elevation-storage table included as Table A.4.4.3.1 found at the end of this Appendix.

   b. The forecasted UKL net inflow for March through September changes each month from March through June. The formulas used for this variable (called **Mar50vol** in the model code) are as follows:
      i. March = [March 1st 50% exceedance probability forecast for UKL net inflows for March through September]
      ii. April = [April 1st 50% exceedance probability forecast for UKL net inflows for April through September] + [Actual net inflows that occurred in March]
      iii. May = [May 1st 50% exceedance probability forecast for UKL net inflows for May through September] + [Actual net inflows that occurred in March] + [Actual net inflows that occurred in April]
      iv. June = [June 1st 50% exceedance probability forecast for UKL net inflows for June through September] + [Actual net inflows that occurred in March] + [Actual net inflows that occurred in April] + [Actual net inflows that occurred in May]

   c. The **End of September UKL Storage Target** is determined each month, March through June, and is dependent on the end of September UKL central tendency (4139.1 ft), the end of September high and low central tendency increments (0.4 ft), and Mar50vol as defined above. The lowest end of September storage target is 4138.7 ft (central tendency minus the low increment) and the highest end of September storage target is 4139.5 ft (the central tendency plus the high increment). The end of September storage target equals the low target (4138.7 ft) if Mar50vol is equal to or less than the lowest Mar50vol in the simulated period of record (160,000 AF). The end of September storage target equals the high target (4139.5 ft) if Mar50vol is equal to or greater than the highest Mar50vol in the simulated period of record (1,316,258 AF). For any Mar50vol in between 160,000 AF and 1,316,258 AF, the end of September storage target is linearly interpolated as follows:

i. Target = 4138.7 + 0.8*(Mar50vol – 160)/1156.258 when Mar50vol > 160,000 AF and Mar50vol < 1,316,258 AF
ii. The elevation target is converted to TAF for use in the UKL supply formula with the elevation-storage table included as Table A.4.4.3.1 found at the end of this Appendix.

2. Calculate **EWA_River_temp** as a portion of UKLSupply. When UKLSupply is less than 670,000 AF, EWA_River_temp is at the EWA minimum of 400,000 AF. When UKLSupply is greater than 1,035,000 AF, EWA_River_temp includes all UKLSupply above the project supply maximum (UKLSupply – 350,000). For UKLSupply between 670,000 AF and 1,035,000 AF, EWA_River_temp is calculated as follows:

   EWA_River_temp = 0.00029127 * UKLSupply^2 + 0.29190568 * UKLSupply + 73.17532589

   In even years (e.g., 2020, 2022), EWA_River_temp is further increased by 7,000 AF to cover releases for the Yurok Boat Dance ceremony.

3. Determine if a **MayJuneAugment** is needed (see Section A.4.4.8 for details on Enhanced May and June IGD flows). A MayJuneAugment is required if April 1 EWA_River_temp is greater than 400,000 AF (407,000 AF in Boat Dance years) and less than 576,000 AF.

4. Calculate **EWA_River**.

   a. If no MayJuneAugment is required:

      EWA_River = EWA_River_temp

      If a MayJuneAugment is required, EWA_River_temp is calculated as above. However, on July 1 an additional 20,000 AF is added to the EWA_River to account for the use of the additional volume in May and June.

   Note that, if there is no MayJuneAugment, there is no re-calculation of EWA_River on July 1.

5. Calculate the **Project Supply.**

   a. The maximum Project Supply (PrjSupply) is 350,000 AF. Maximum Project Supply occurs when UKLSupply is greater than 1,035,000 AF.

   b. When UKLSupply is less than 1,035,000 AF, Project Supply = UKLSupply – EWA_River.

c. If a MayJuneAugment is required, April 1 Project Supply is reduced by 10,000 AF from the calculated value to support the augmented May/June river flows. This 10,000 AF reduction is applied to May 1 and June 1 Project Supply calculations as well.

d. In May and June, Project Supply cannot be reduced below the April 1 allocation.

e. In June, if UKLSupply had decreased relative to the May determination, the Project Supply can be reduced, but to no lower than the April value.

The final determination for Project Supply is made in June and is then fixed through the end of September.

A.4.4.4. Agricultural Water Delivery Sub-model

A.4.4.4.1. Methods

Delivery of irrigation water to agriculture during the spring/summer operational period was simulated using methods that produced realistic patterns of water delivery. Diversion data for the POR from March 1, 1980 through November 15, 2016 (Dunsmoor 2017a) was used to develop the agricultural delivery sub-model. During this time frame, the Project experienced a wide variety of conditions, including periods of essentially unconstrained diversion, periods of moderate to severe diversion constraints, and wet or dry conditions in single years and over sequences of multiple years. Of particular note are years in which regulatory actions changed irrigation patterns so substantially that the historical data was deemed to be unusable for sub-model development. Included in this category are the years 2001 (irrigation shutoff until July), 2010 (extremely late start, irrigation started in mid-May), and 2014-2015 (Ady Canal shutoff for significant portions of both summer irrigation seasons). Accordingly, these years were excluded from the data sets used to develop the sub-model. In addition, 3 test years (1991, 1998, and 2003) were randomly selected, excluded from model derivation, and reserved for evaluating the predictive capability of the final sub-model (James et al. 2013).

The sub-model was structured around 5-day periods within an irrigation water year, which extends from March 1 through the end of February and is comprised of 73 five-day periods (period 73 has 6 days in leap years; Table A.4.4.4.1.1). Period 49 ends on October 31, encompassing the season-of-use for D1, and the summer season-of-use for D11 and D12A. Period 52 ends on November 15, encompassing the season-of-use for D91.

Summing historical delivery volumes (in TAF) across the season-of-use for all 4 diversion arcs yielded what is called Total A, which represents the total water volume diverted during the spring/summer operational period from all surface water sources. In the development of these sub-models, Total A was the sum of deliveries from UKL and deliveries made from the inflow measured at the LRDC headworks at Lost River Diversion Dam.

Historical daily diversion data for years that were not excluded from model development were divided by Total A diversions for each year. The resulting proportions were multiplied by 100, and these percentages were summed within each 5-day period across periods 1-49 for diversion arcs D1, D11, and D12A, and periods 1-52 for diversion arc D91. For each diversion arc, models were fitted to these percentages of Total A diversions, which were subsequently used in the KBPM to estimate the percentage of Total A diversions to be delivered in each timestep (i.e. the irrigation pattern).

Irrigation patterns in any given 5-day period were deemed likely to be influenced by a number of factors, including precipitation, temperature, crop type and distribution, overall water availability, and prior irrigation. Crop type and distribution were eliminated from further consideration because insufficient data were available across the POR. The remaining variables were prepared for use in the sub-model development as follows.

Table A.4.4.4.1.1. Beginning and ending days of 5-day periods within the irrigation water year.

5-day period	First day	Last day		5 day period	First day	Last day		5 day period	First day	Last day
1	1-Mar	5-Mar		26	4-Jul	8-Jul		51	6-Nov	10-Nov
2	6-Mar	10-Mar		27	9-Jul	13-Jul		52	11-Nov	15-Nov
3	11-Mar	15-Mar		28	14-Jul	18-Jul		53	16-Nov	20-Nov
4	16-Mar	20-Mar		29	19-Jul	23-Jul		54	21-Nov	25-Nov
5	21-Mar	25-Mar		30	24-Jul	28-Jul		55	26-Nov	30-Nov
6	26-Mar	30-Mar		31	29-Jul	2-Aug		56	1-Dec	5-Dec
7	31-Mar	4-Apr		32	3-Aug	7-Aug		57	6-Dec	10-Dec
8	5-Apr	9-Apr		33	8-Aug	12-Aug		58	11-Dec	15-Dec
9	10-Apr	14-Apr		34	13-Aug	17-Aug		59	16-Dec	20-Dec
10	15-Apr	19-Apr		35	18-Aug	22-Aug		60	21-Dec	25-Dec
11	20-Apr	24-Apr		36	23-Aug	27-Aug		61	26-Dec	30-Dec
12	25-Apr	29-Apr		37	28-Aug	1-Sep		62	31-Dec	4-Jan
13	30-Apr	4-May		38	2-Sep	6-Sep		63	5-Jan	9-Jan
14	5-May	9-May		39	7-Sep	11-Sep		64	10-Jan	14-Jan
15	10-May	14-May		40	12-Sep	16-Sep		65	15-Jan	19-Jan
16	15-May	19-May		41	17-Sep	21-Sep		66	20-Jan	24-Jan
17	20-May	24-May		42	22-Sep	26-Sep		67	25-Jan	29-Jan
18	25-May	29-May		43	27-Sep	1-Oct		68	30-Jan	3-Feb
19	30-May	3-Jun		44	2-Oct	6-Oct		69	4-Feb	8-Feb
20	4-Jun	8-Jun		45	7-Oct	11-Oct		70	9-Feb	13-Feb
21	9-Jun	13-Jun		46	12-Oct	16-Oct		71	14-Feb	18-Feb
22	14-Jun	18-Jun		47	17-Oct	21-Oct		72	19-Feb	23-Feb
23	19-Jun	23-Jun		48	22-Oct	26-Oct		73	24-Feb	29-Feb
24	24-Jun	28-Jun		49	27-Oct	31-Oct				
25	29-Jun	3-Jul		50	1-Nov	5-Nov				

Precipitation and temperature variables were developed from data obtained from the PRISM Climate Group. PRISM (Parameter-elevation Relationships on Independent Slopes Model) is an interpolation method that estimates precipitation and temperature variables at gridded locations across the conterminous United States based on measurements from a large network of meteorological stations (Daly et al., 2008). Daily time series of maximum temperature (°F) and precipitation (inches) were downloaded (http://prism.oregonstate.edu/explorer/) for 9 randomly selected 4-kilometer grids (Figure A.4.4.4.1.1) for the period from 1/1/1981-11/30/2016. Daily data for the same variables for the period from 3/1/1980-12/31/1980 were downloaded from the National Climatic Data Center, Climate Data Online (https://www.ncdc.noaa.gov/cdo-web/) for three stations (Figure A.4.4.4.1.1): Tulelake, CA (Station USC00049053), Malin 5 E, OR (Station USC00355174), and Klamath Falls 2SSW (Station USC00354506). Mean daily maximum temperature and precipitation were computed for the Project area across either 9 PRISM grids or 3 meteorological stations for the time spans described above. Then total precipitation and average maximum temperature were computed for each 5-day period in each irrigation water year; these variables were named ppt_p and $tmax_p$, where p is the 5-day period.

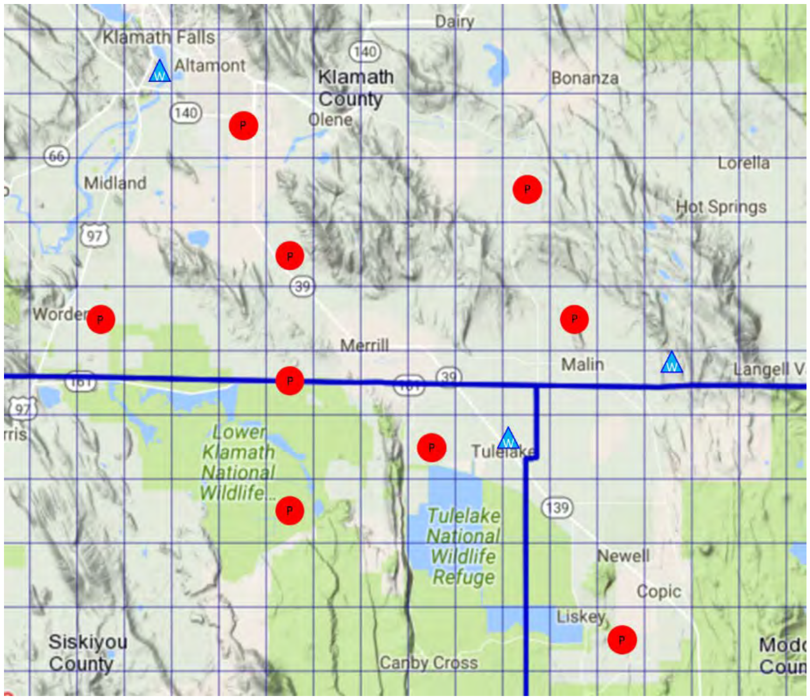

Figure A.4.4.4.1.1. PRISM grid (circles) and weather station (triangles) locations used to compute Project area precipitation and temperature variables.

In addition to using precipitation and maximum temperature variables individually, they were also combined into a single variable. Each was normalized (re-scaled to range between 0 and 1), based on the values of these variables over the period-of-record used in this analysis. For each variable, $x_{p_{norm}}$ was computed as:

$$x_{p_{norm}} = \frac{x_p - x_{p_{min}}}{x_{p_{max}} - x_{p_{min}}}$$

where p is the 5-day period, and p_{min} (p_{max}) is the minimum (maximum) value of the variable for period p across the period-of-record.

Then the normalized maximum temperature $tmax_{p_{norm}}$ was subtracted from 1, so that it ranged from warmest (0) to coolest (1) in a manner complementary to normalized precipitation $ppt_{p_{norm}}$, which ranged from driest (0) to wettest (1). These two normalized variables were combined into one, called the $ptdayindex_p$:

$$ptdayindex_p = ppt_{p_{norm}} + \left(1 - tmax_{p_{norm}}\right)$$

The $ptdayindex_p$ can range from 0 (warm and dry) to 2 (cool and wet).

Variables that summarized winter precipitation and water deliveries were also developed. Total precipitation (inches) and total water deliveries (TAF) through D11 and D12A arcs over the period from December – February preceding each irrigation water year ($cumpptwint_{y-1}$, $cumd11wint_{y-1}$, and $cumd12awint_{y-1}$, respectively) captured the influence of winter precipitation and delivery on the pattern of early season diversions. For use in models for the D11 and D12A diversion arcs, these variables were also normalized (see above; across irrigation water years instead of periods) and combined into $pdindexd11_{y-1}$ and $pdindexd12a_{y-1}$:

$$pdindexd\__{y-1} = cumpptwint_{y-1_{norm}} + cumd\_wint_{y-1_{norm}}$$

where *y*-1 is the previous irrigation water year, and $d\_$ denotes either delivery arc D11 or D12A. Finally, the variable d_taf_p is the volume (TAF) of deliveries made in each 5-day period, where $d\_$ denotes either delivery arc D11 or D12A.

Anticipated differences in pattern of water use in years with restricted supplies were captured by classifying such years as being water-short, and using a dummy variable (water-short = 1, not water-short = 0) to represent this effect in the models. For model development, data on snow-water-equivalent and Total A diversions was used to classify irrigation water year-type. Daily snow-water-equivalent (SWE; inches) data was downloaded from the NRCS Report Generator site (https://wcc.sc.egov.usda.gov/reportGenerator/) for the following sites: Fish Lake, Billie Creek Divide, Fourmile Lake, Cold Springs Camp, Sevenmile Marsh, Diamond Lake, Chemult Alternative, Silver Creek, Taylor Butte, Summer Rim, Quartz Mountain, and Strawberry. The daily average SWE at these sites was computed, from which the maximum SWE for the March-April period was computed for each year. An irrigation water year was classified as water-short if the maximum SWE for March-April was less than the median of that variable for the period from 1981-2016, and if the Total A diversion was less than the median for that same time period. Irrigation water years designated as being water-short based on these criteria included: 1992, 1995, 2001, 2003, 2005, 2010, 2013, 2014, and 2015.

An information-theoretic approach coupled with model averaging techniques (Burnham and Anderson, 2002; Anderson, 2008) were applied to a sequence of Ordinary Least Squares (OLS) regressions (the model set) predicting the percent delivery of Total A diversions for each 5-day period and delivery arc. In this approach, multiple models were hypothesized *a priori* (the model set), and the OLS results were used to quantify and formally evaluate the relative strength of evidence for each competing hypothesis in the model set. A single, final model for each delivery arc and 5-day period was produced by averaging the model parameters across all models, weighted by the model probabilities.

Model sets were nearly identical for the diversion arcs D1 and D91 (Table A.4.4.4.1.2). Historical D1 deliveries never started before period 6 (Mar 26-30), which is why no models were applied to prior periods for D1, whereas D91 delivery models begin in period 1. D1 delivery models extend through period 49 (through Oct 31), and D91 models extend through period 52 (through Nov 15). Model sets were also nearly identical for the diversion arcs D11 and D12A (Table A.4.4.4.1.3), for which delivery models extend through period 49. Model sets were dissimilar between these pairs of arcs, however, reflecting the differences in how irrigation is managed between the areas served by these arcs.

Table A.4.4.4.1.2. Model sets for the D1 and D91 delivery arcs. In the model notation column, 5-day periods of the irrigation water year are denoted by *p*, and variables lagged to the prior 5-day period are denoted by the subscript *p*-1. Diversion arcs are specified by *d_*, where _ would be either 1 or 91 as appropriate to the delivery arc being modeled. Irrigation water year (March-February) is denoted by *y*, with *y*-1 referring to winter conditions in the prior irrigation water year. OLS regression coefficients are denoted as β.

Model	Model description	Model notation	Periods for D1	Periods for D91
1	delivery %	$\beta_0 + \beta_1 d\_pcta_{p-1}$	7-49	2-52
2	delivery % + precipitation	$\beta_0 + \beta_1 d\_pcta_{p-1} + \beta_2 ppt_{p-1}$	7-49	2-52
3	delivery % + warmth	$\beta_0 + \beta_1 d\_pcta_{p-1} + \beta_3 tmax_{p-1}$	7-49	2-52
4	delivery % + (precipitation & warmth)	$\beta_0 + \beta_1 d\_pcta_{p-1} + \beta_4 ptdayindex_{p-1}$	7-49	2-52
5	delivery % + short supply	$\beta_0 + \beta_1 d\_pcta_{p-1} + \beta_5 shortdum_y$	7-49	2-52
6	delivery % + winter precipitation	$\beta_0 + \beta_1 d\_pcta_{p-1} + \beta_6 cumpptwint_{y-1}$	7-18	2-18
7	winter precipitation + short supply	$\beta_0 + \beta_6 cumpptwint_{y-1} + \beta_5 shortdum_y$	6	1
8	winter precipitation + (precipitation & warmth)	$\beta_0 + \beta_6 cumpptwint_{y-1} + \beta_4 ptdayindex_{p-1}$	6	1
9	winter precipitation + warmth	$\beta_0 + \beta_6 cumpptwint_{y-1} + \beta_3 tmax_{p-1}$	6	1
10	winter precipitation + precipitation	$\beta_0 + \beta_6 cumpptwint_{y-1} + \beta_2 ppt_{p-1}$	6	1

The arcs in Area A1 (D1 and D91) use irrigation water (nearly) exclusively during the growing season, whereas the arcs in Area A2 divert water extensively during the winter, when it is available, as well as during the growing season. Therefore, the variables influencing diversion patterns in the early periods differ between areas. In Area A1, winter precipitation and recent temperature were thought to be the most likely determinants of the delivery pattern, as modified by short supplies in some years, in the earliest period (models 7-10 in Table A.4.4.4.1.2). Similarly, the first period was thought to be influenced by delivery volume in the previous period, as well as by winter diversion volume, winter precipitation totals, or both (models 9-12 in Table A.4.4.4.1.3). Effects of winter precipitation were expected to be influential through period 18 in Area A1 (model 6 in Table A.4.4.4.1.2), and its influence coupled with that of winter diversion volume was expected to affect diversion patterns through period 18 in Area A2 (models 6-8 in Table A.4.4.4.1.3).

For the remainder of the growing season, delivery patterns in Areas A1 and A2 were thought to be influenced by the same variables, namely prior diversion, precipitation, and temperature, as modified by the effects of short supply (models 1-5 in Tables A.4.4.4.1.2 and A.4.4.4.1.3). Period-specific variables used in models were lagged to the prior period, reflecting the potential desire to use the result of this modeling effort in operations. By lagging to previous time periods, no information is used to forecast the percent delivery of Total A diversions in period *p* that would not be available in real-time water management. The sole exception is the reliance in this analysis on the historical percentage of Total A diversion delivered through a diversion arc in the previous time period. While appropriate in terms of using the results of this analysis in the KBPM, which simulates years that have already been experienced, operationally an estimate of Total A diversions would be needed to compute the percentage of Total A diversions delivered in the prior time step. Since in this analysis these percentages were computed from historical data, Total A was known, but operationally Total A would have to be estimated, which would inject more error into the resulting estimates of delivery pattern than is present in this analysis.

Table A.4.4.4.1.3. Model sets for the D11 and D12A delivery arcs. In the model notation column, 5-day periods of the irrigation water year are denoted by *p*, and variables lagged to the prior 5-day period are denoted by the subscript *p*-1. Diversion arcs are specified by *d_*, where _ would be either 1 or 91 as appropriate to the delivery arc being modeled. Irrigation water year (Mar-Feb) is denoted by *y*, with *y*-1 referring to winter conditions in the prior irrigation water year. OLS regression coefficients are denoted as *β*.

Model	Model description	Model notation	Periods for D11 and D12A
1	delivery %	$\beta_0 + \beta_1 d\_pcta_{p-1}$	2-49
2	delivery % + precipitation	$\beta_0 + \beta_1 d\_pcta_{p-1} + \beta_2 ppt_{p-1}$	2-49
3	delivery % + warmth	$\beta_0 + \beta_1 d\_pcta_{p-1} + \beta_3 tmax_{p-1}$	2-49
4	delivery % + (precipitation & warmth)	$\beta_0 + \beta_1 d\_pcta_{p-1} + \beta_4 ptdayindex_{p-1}$	2-49
5	delivery % + short supply	$\beta_0 + \beta_1 d\_pcta_{p-1} + \beta_5 shortdum_y$	2-49
6	delivery % + winter diversion	$\beta_0 + \beta_1 d\_pcta_{p-1} + \beta_6 cumd\_wint_{y-1}$	2-18
7	delivery % + winter precipitation	$\beta_0 + \beta_1 d\_pcta_{p-1} + \beta_7 cumpptwint_{y-1}$	2-18
8	delivery % + (winter delivery & precipitation)	$\beta_0 + \beta_1 d\_pcta_{p-1} + \beta_8 pdindexd\_{}_{y-1}$	2-18
9	delivery volume + winter diversion	$\beta_0 + \beta_9 d\_taf_{p-1} + \beta_6 cumd\_wint_{y-1}$	1
10	delivery volume + winter precipitation	$\beta_0 + \beta_9 d\_taf_{p-1} + \beta_7 cumpptwint_{y-1}$	1
11	delivery volume + (winter delivery & precipitation)	$\beta_0 + \beta_9 d\_taf_{p-1} + \beta_8 pdindexd\_{}_{y-1}$	1
12	delivery volume	$\beta_0 + \beta_9 d\_taf_{p-1}$	1

OLS regressions were performed using Stata 15 software (StataCorp, 2017b; regress command). Individual regressions were restricted to no more than 2 variables to avoid overfitting (Babyak, 2004). After removing the excluded and test years from the analysis, sample size within each 5-day period was 29 for those models using the variable *cumpptwint* (which was not computed for 1980), and 30 for all other models. Adequacy of OLS regressions was assessed following guidance in StataCorp (2017b), Sheather (2009), and Hyndman and Athanasopoulos (2014). Residual normality was evaluated graphically (Stata commands: qnorm and pnorm); serious deviation from residual normality was rare, confined mostly to the earliest 5-day periods in which 0% deliveries were common. Multicollinearity among predictor variables was evaluated using variance inflation factors (Stata command: estat vif), which never exceeded 2.3 in any of the delivery arcs. Autocorrelation plots and Durbin's alternative test for serial correlation (Stata commands: acf and estat durbinalt, respectively) assessed serial autocorrelation across years within each 5-day period; it was rarely detected. Finally, plots of residuals vs. predicted y and residuals vs. predictors were examined for inappropriate patterns reflecting heteroskedasticity or non-linearity.

Using the equations described in Burnham et al. (2011), and following the admonitions of Anderson and Burnham (2002), the following series of calculations quantified the relative performance of models used to estimate the percentage of Total A deliveries for each diversion arc, culminating in a single model-averaged predictive equation for each diversion arc in each 5-day period. Specifically, for each 5-day period ($p = 1, 2, \dots, P$), and model ($m = 1, 2, \dots, M$), the corrected Akaike Information Criterion $AIC_{c_{p,m}}$ was computed as:

$$AIC_{c_{p,m}} = -2\ln L_{p,m} + 2K_{p,m} + \frac{2K_{p,m}(K_{p,m}+1)}{n_{p,m} - K_{p,m} - 1}$$

where K is the number of estimable parameters, which includes the intercept, slope parameters, and the residual variance, $\ln L$ is the maximized log-likelihood of the model, and n is sample size. Then the $\Delta_{p,m}$ was computed as:

$$\Delta_{p,m} = AIC_{c_{p,m}} - AIC_{c_{p,min}}$$

where $AIC_{c_{p,m}}$ is the AIC_c for model m in 5-day period p, and $AIC_{c_{p,min}}$ is the minimum AIC_c for period p, which is to say it is the best model for that period in that it minimizes the Kullback-Leibler (K-L) information loss (see Burnham and Anderson, 2002 for a complete explanation). $\Delta_{p,m}$ directly quantifies the K-L information loss of model m relative to the best model in the model set, and so provides a valid basis for ranking models and computing Akaike weights, which were calculated as:

$$w_{p,m} = \frac{exp(-0.5\Delta_{p,m})}{\sum_{m=1}^{M} exp(-0.5\Delta_{p,m})}$$

Once the Akaike weights were obtained, they were used to compute weighted averages of the OLS coefficients for each variable in the model set using:

$$\widehat{\hat{\beta}}_p = \sum_{m=1}^{M} w_{p,m}\hat{\beta}_{p,m}$$

where $\widehat{\hat{\beta}}_p$ is the model averaged coefficient, and $\hat{\beta}_{p,m}$ is the coefficient estimated by OLS for the mth model in period p.

To make the model-averaged prediction for each period, the Akaike weights were used to compute weighted averages of the OLS predictions of the percentage of Total A delivery for the models within each period:

$$\hat{\hat{Y}}_p = \sum_{m=1}^{M} w_{p,m}\hat{Y}_{p,m}$$

where $\hat{\hat{Y}}_p$ is the model-averaged prediction, and $\hat{Y}_{p,m}$ is the OLS estimate of y.

Finally, the Akaike weights were used to compute the unconditional (that is, not conditioned on any single model) standard error of the model-averaged predictions for each period using:

$$SE\left(\hat{\hat{Y}}_p\right) = \sqrt{\sum_{m=1}^{M} w_{p,m}\left(var\left(\hat{Y}_{p,m}\right) + \left(\hat{Y}_{p,m} - \hat{\hat{Y}}_p\right)^2\right)}$$

where $SE\left(\hat{\hat{Y}}_p\right)$ is the unconditional standard error of the model-averaged predictions for period p, $var\left(\hat{Y}_{p,m}\right)$ is the variance of the OLS estimate for model m in period p, and $\hat{Y}_{p,m}$ is the OLS estimate for model m in period p.

A.4.4.4.2. Results and Discussion

Based on model ranking and error analysis procedures, details of which are provided after the results below, a final model-averaged equation predicting the percent of Total A (the total water volume diverted during the spring/summer operational period from all surface water sources) to be delivered in any given period was developed for each diversion arc:

$$\begin{aligned}\widehat{d1pcta}_p = {} & \hat{\hat{\beta}}_{0,p} + \hat{\hat{\beta}}_{1,p} d1pcta_{p-1} + \hat{\hat{\beta}}_{2,p} ppt_{p-1} + \hat{\hat{\beta}}_{3,p} tmax_{p-1} + \hat{\hat{\beta}}_{4,p} ptdayindex_{p-1} \\ & + \hat{\hat{\beta}}_{5,p} shortdum_y + \hat{\hat{\beta}}_{6,p} cumpptwint_y\end{aligned}$$

$$\begin{aligned}\widehat{d91pcta}_p = {} & \hat{\hat{\beta}}_{0,p} + \hat{\hat{\beta}}_{1,p} d91pcta_{p-1} + \hat{\hat{\beta}}_{2,p} ppt_{p-1} + \hat{\hat{\beta}}_{3,p} tmax_{p-1} + \hat{\hat{\beta}}_{4,p} ptdayindex_{p-1} \\ & + \hat{\hat{\beta}}_{5,p} shortdum_y + \hat{\hat{\beta}}_{6,p} cumpptwint_y\end{aligned}$$

$$\begin{aligned}\widehat{d11pcta}_p = {} & \hat{\hat{\beta}}_{0,p} + \hat{\hat{\beta}}_{1,p} d11pcta_{p-1} + \hat{\hat{\beta}}_{2,p} ppt_{p-1} + \hat{\hat{\beta}}_{3,p} tmax_{p-1} + \hat{\hat{\beta}}_{4,p} ptdayindex_{p-1} \\ & + \hat{\hat{\beta}}_{5,p} shortdum_y + \hat{\hat{\beta}}_{6,p} cumd11wint_{y-1} + \hat{\hat{\beta}}_{7,p} cumpptwint_y \\ & + \hat{\hat{\beta}}_{8,p} pdindexd11_{y-1} + \hat{\hat{\beta}}_{9,p} d11taf_{p-1}\end{aligned}$$

$$\begin{aligned}\widehat{d12apcta}_p = {} & \hat{\hat{\beta}}_{0,p} + \hat{\hat{\beta}}_{1,p} d12apcta_{p-1} + \hat{\hat{\beta}}_{2,p} ppt_{p-1} + \hat{\hat{\beta}}_{3,p} tmax_{p-1} + \hat{\hat{\beta}}_{4,p} ptdayindex_{p-1} \\ & + \hat{\hat{\beta}}_{5,p} shortdum_y + \hat{\hat{\beta}}_{6,p} cumd12awint_{y-1} + \hat{\hat{\beta}}_{7,p} cumpptwint_y \\ & + \hat{\hat{\beta}}_{8,p} pdindexd12a_{y-1} + \hat{\hat{\beta}}_{9,p} d12ataf_{p-1}\end{aligned}$$

Predicted values from these equations in the years used to fit the models are plotted against the historical values in Figures A.4.4.4.2.1 through A.4.4.4.2.4. The results from the model-averaged equations reproduced diversion patterns reasonably well. In Figures A.4.4.4.2.5 through A.4.4.4.2.8, the model-averaged equations were used to forecast diversion patterns in the test years, illustrating how the model-averaged equations would perform if used operationally. Again, historical diversion patterns were depicted reasonably well by the models. Summary statistics of forecast errors in the test years (Table A.4.4.4.2.1) provided further insight into potential errors associated with operational use of these models. However, the small sample size (n=3 per period) used to compute these summary statistics did not provide a comprehensive view of the forecast error structure. If used operationally, more work could be done to more thoroughly quantify likely error of these forecasts.

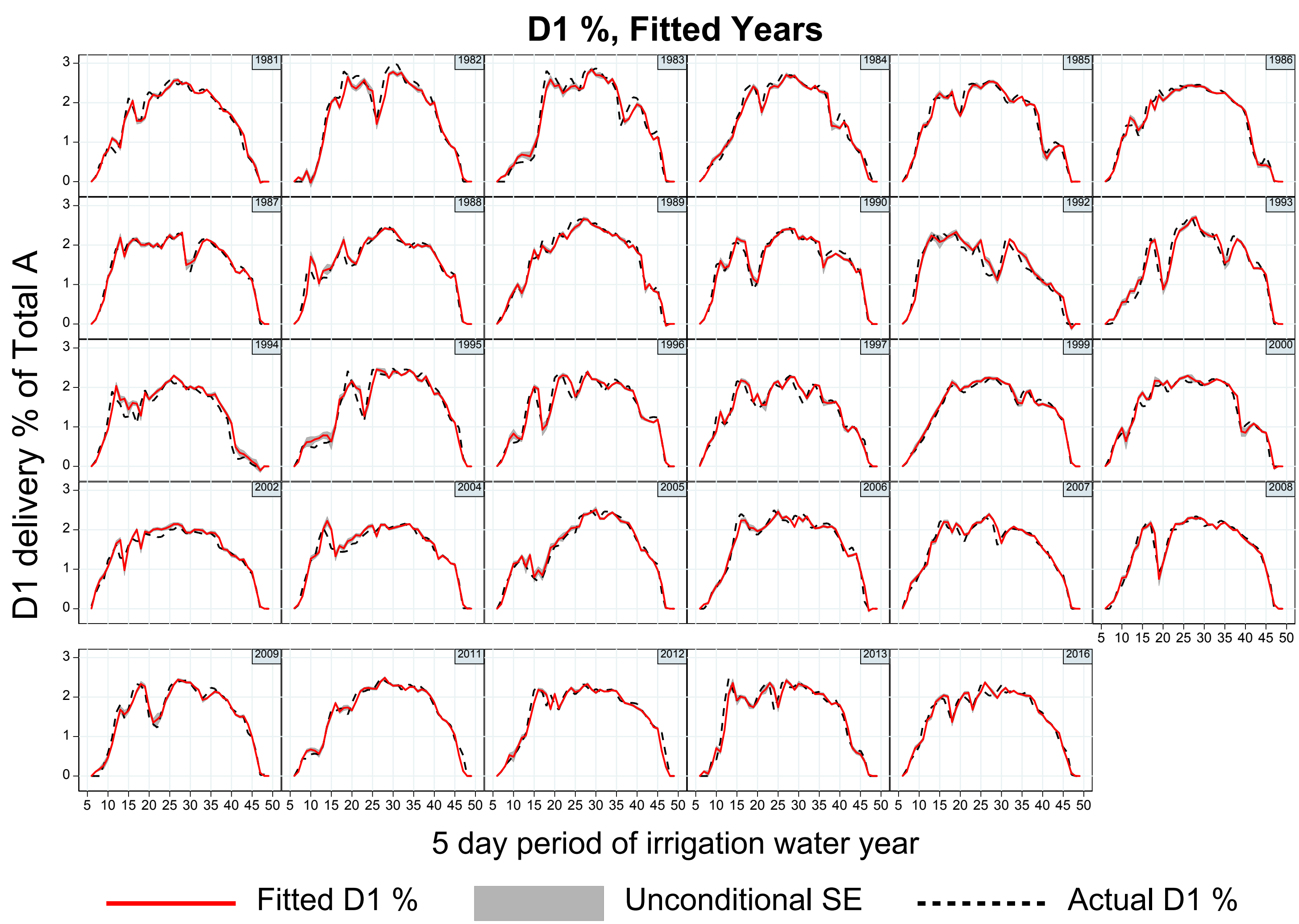

Figure A.4.4.4.2.1. Actual percent delivery of Total A diversions through diversion arc D1 compared to that predicted by the model-averaged predictive equation.

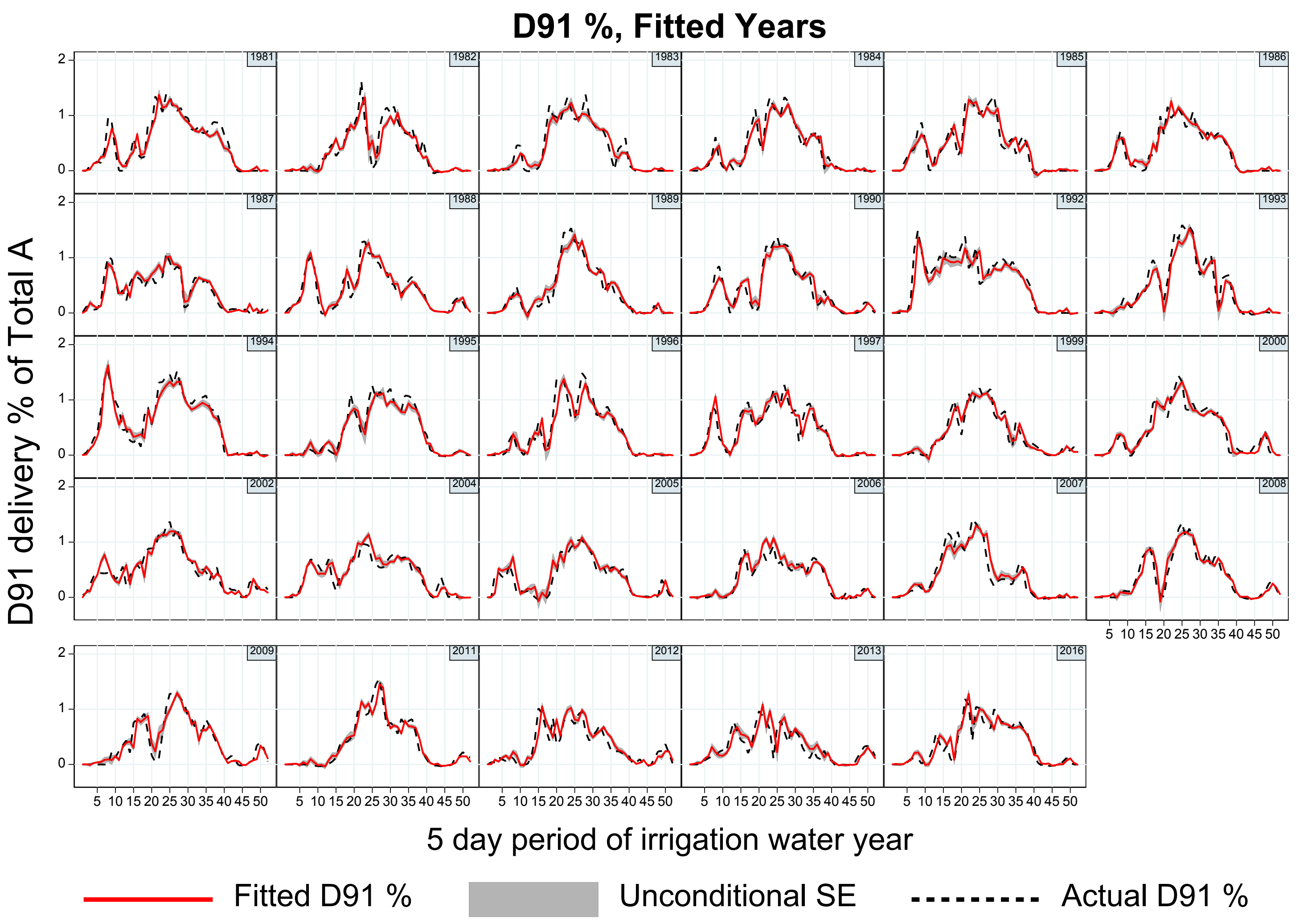

Figure A.4.4.4.2.2. Actual percent delivery of Total A diversions through diversion arc D91 compared to that predicted by the model-averaged predictive equation.

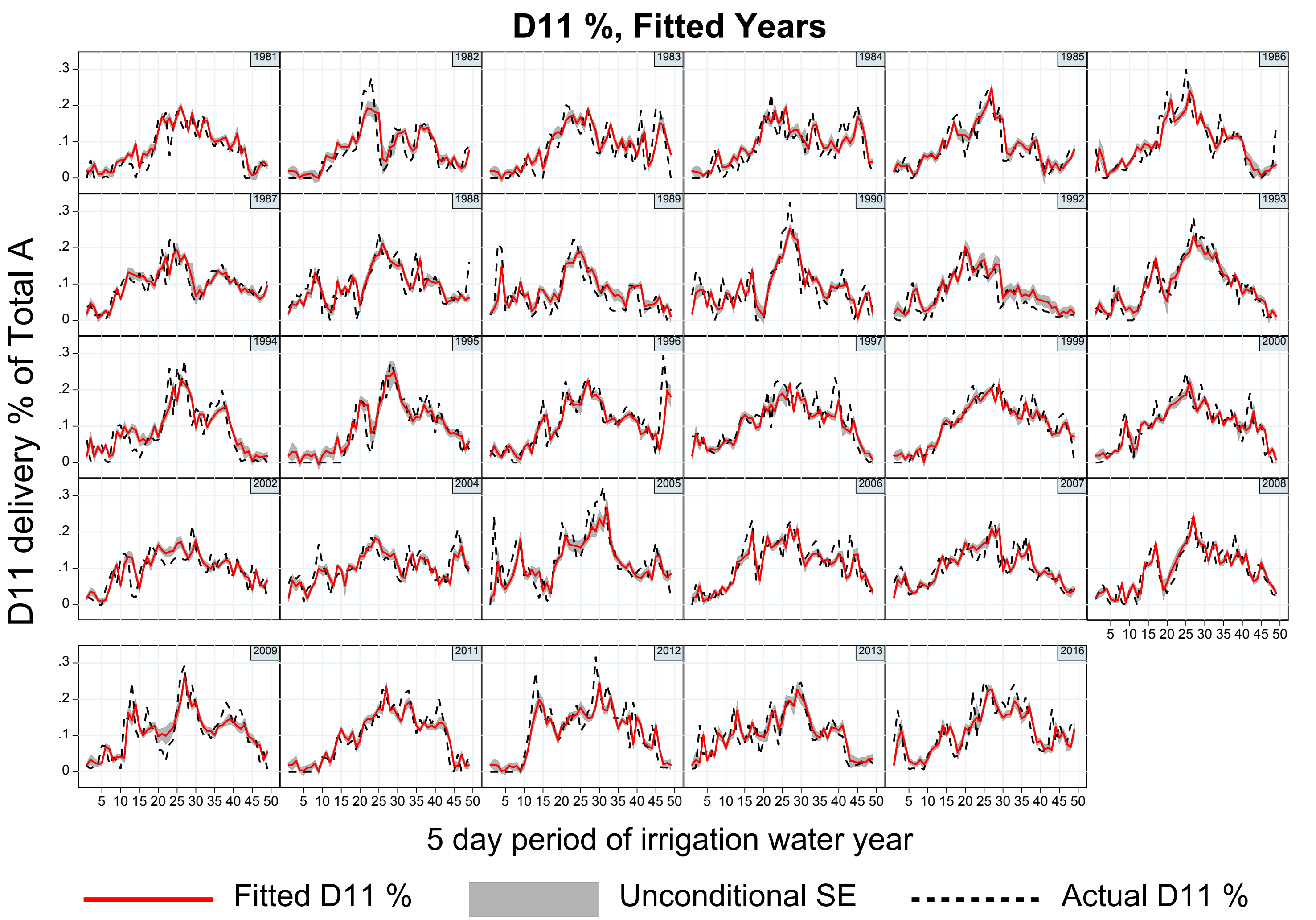

Figure A.4.4.4.4.2.3. Actual percent delivery of Total A diversions through diversion arc D11 compared to that predicted by the model-averaged predictive equation.

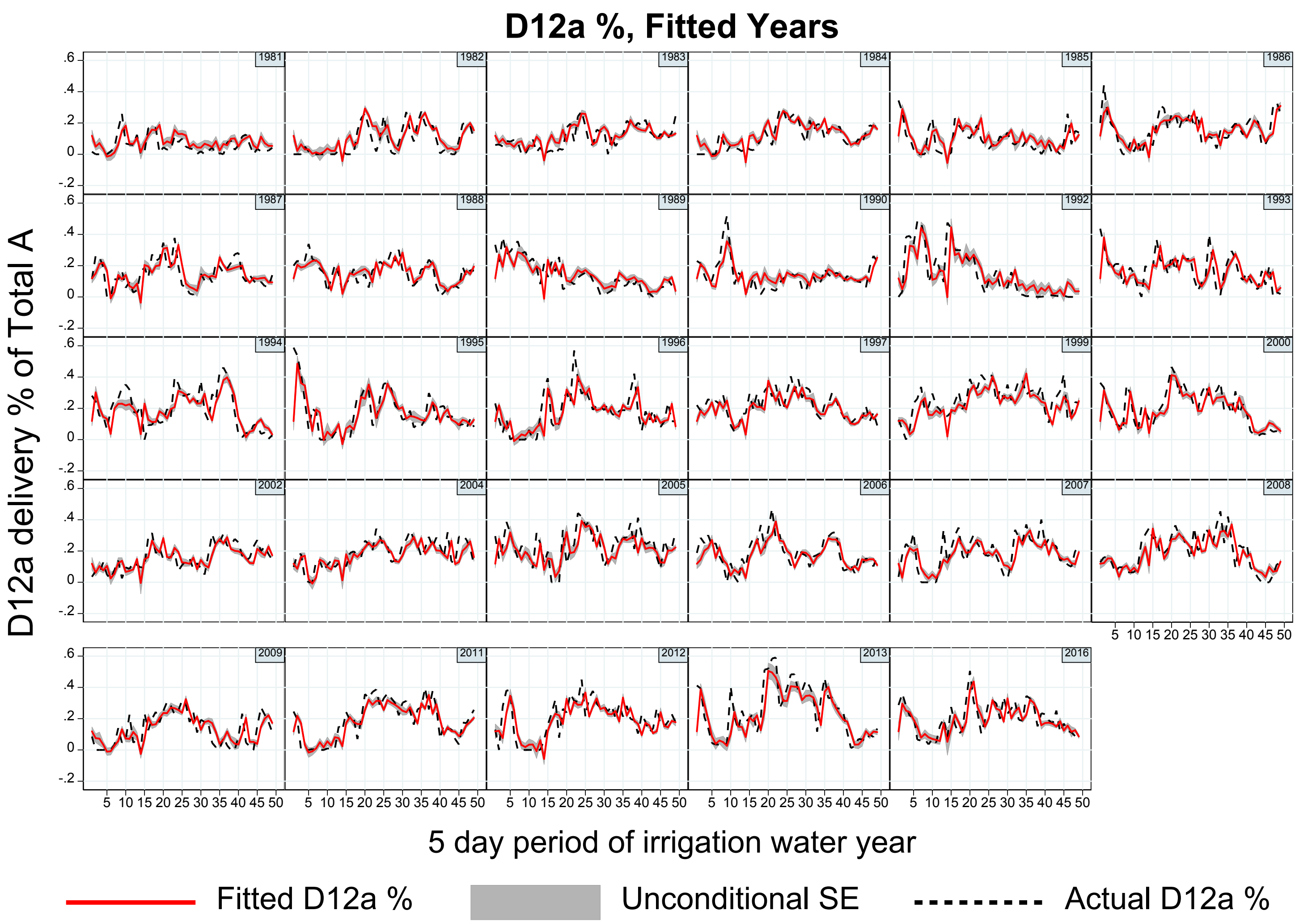

Figure A.4.4.4.2.4. Actual percent delivery of Total A diversions through diversion arc D12A compared to that predicted by the model-averaged predictive equation.

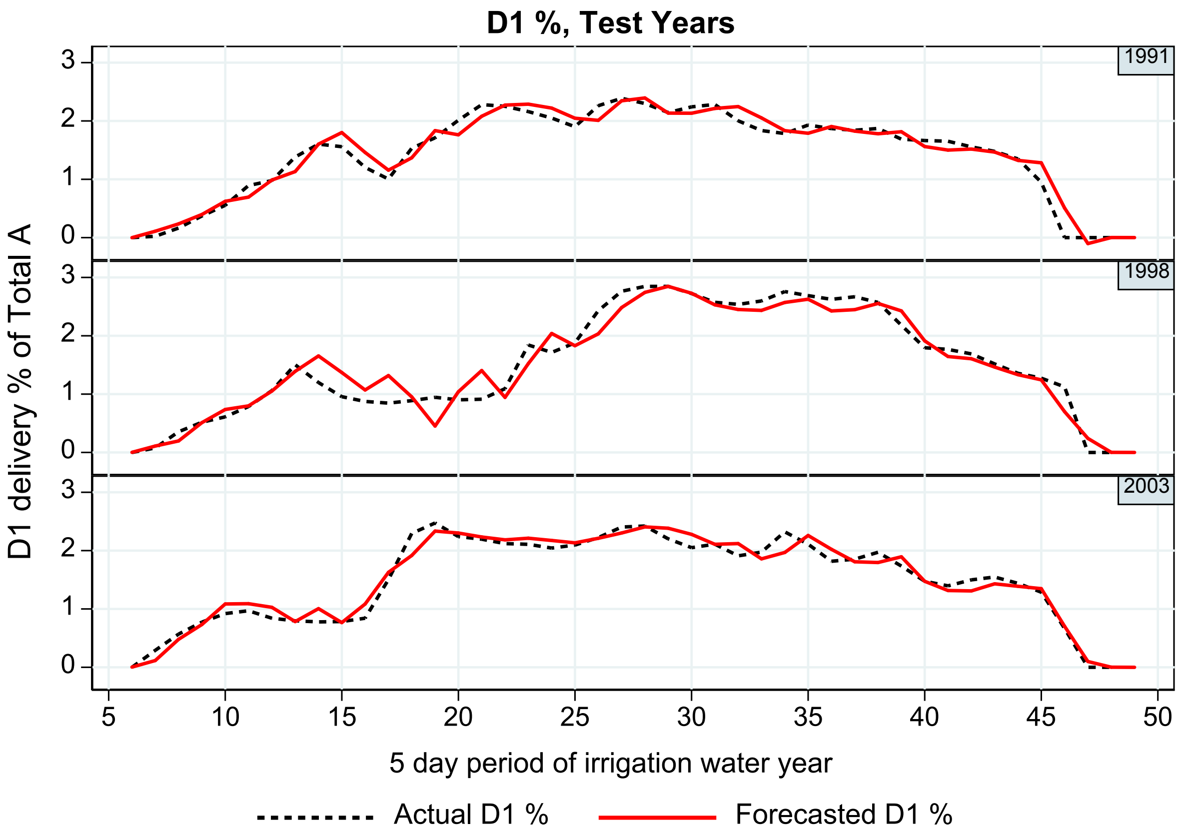

Figure A.4.4.4.2.5. Actual percent delivery of Total A diversions through diversion arc D1 compared to that forecasted by the model-averaged predictive equation in the test years.

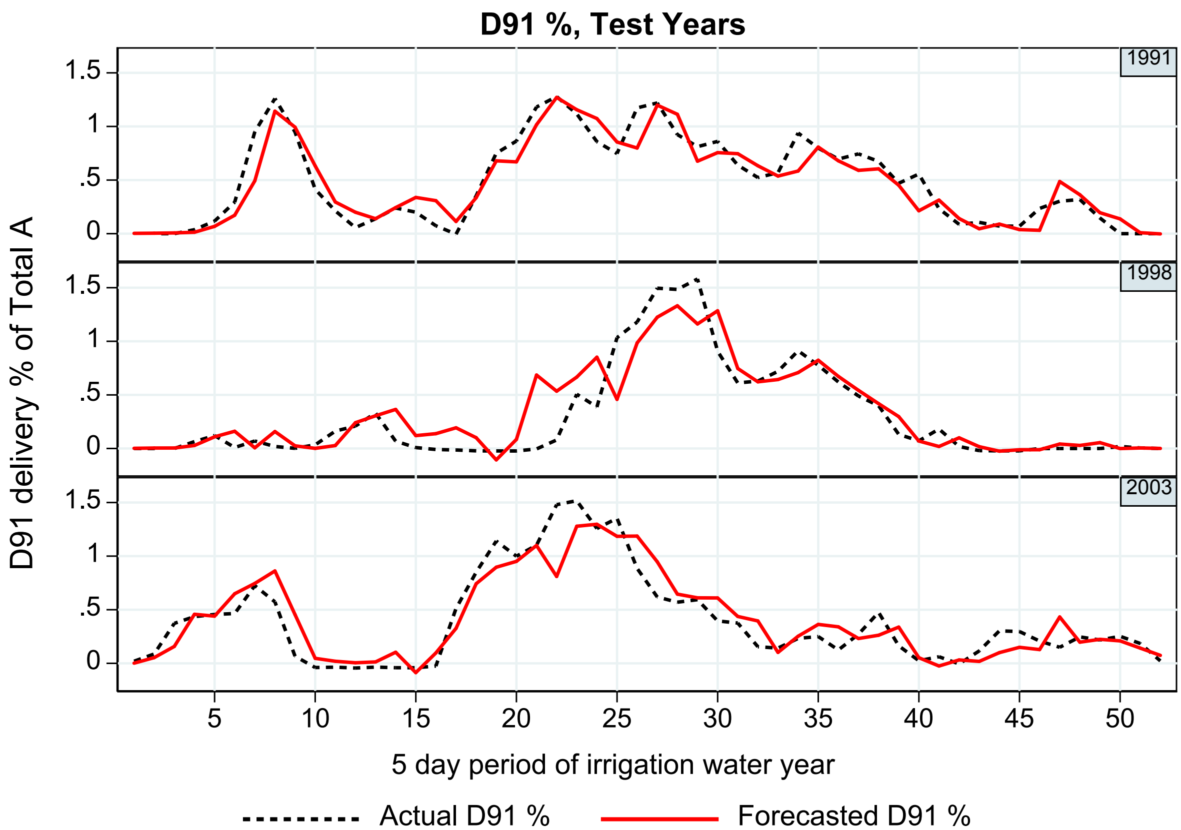

Figure A.4.4.4.4.2.6. Actual percent delivery of Total A diversions through diversion arc D91 compared to that forecasted by the model-averaged predictive equation in the test years.

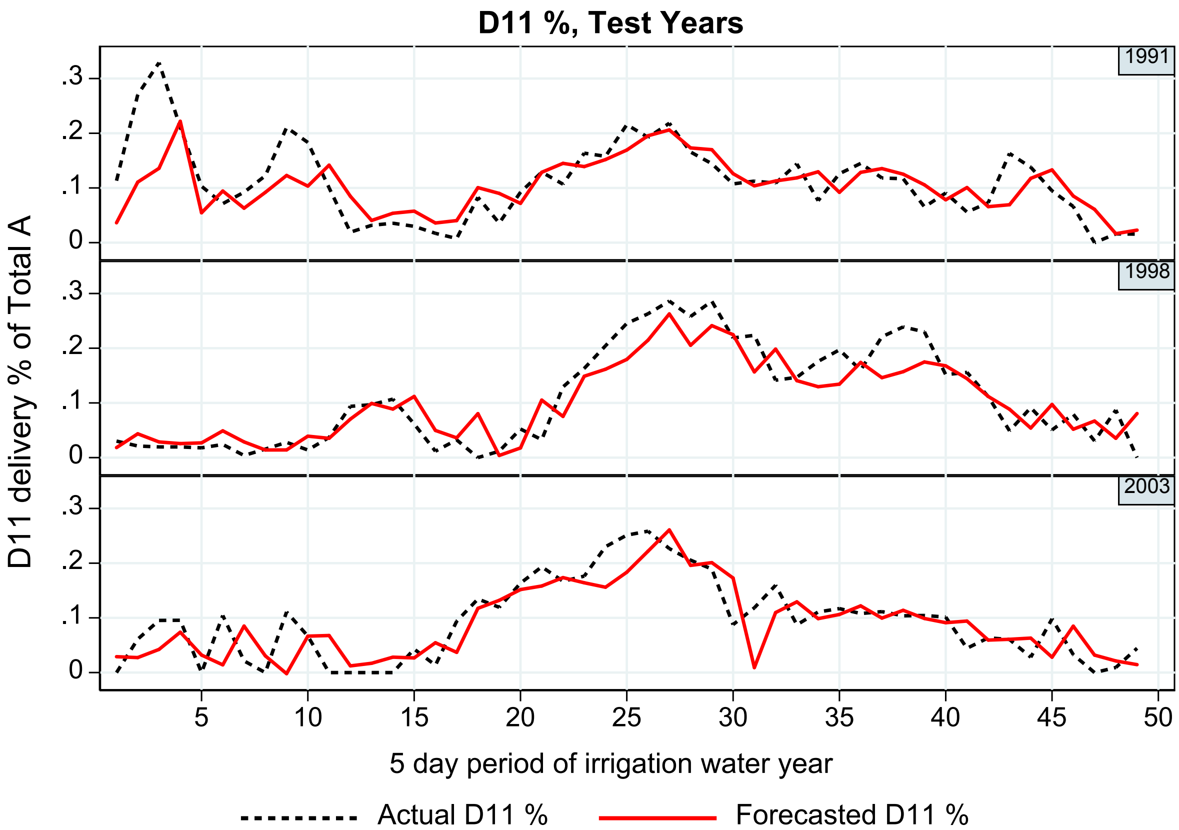

Figure A.4.4.4.2.7. Actual percent delivery of Total A diversions through diversion arc D11 compared to that forecasted by the model-averaged predictive equation in the test years.

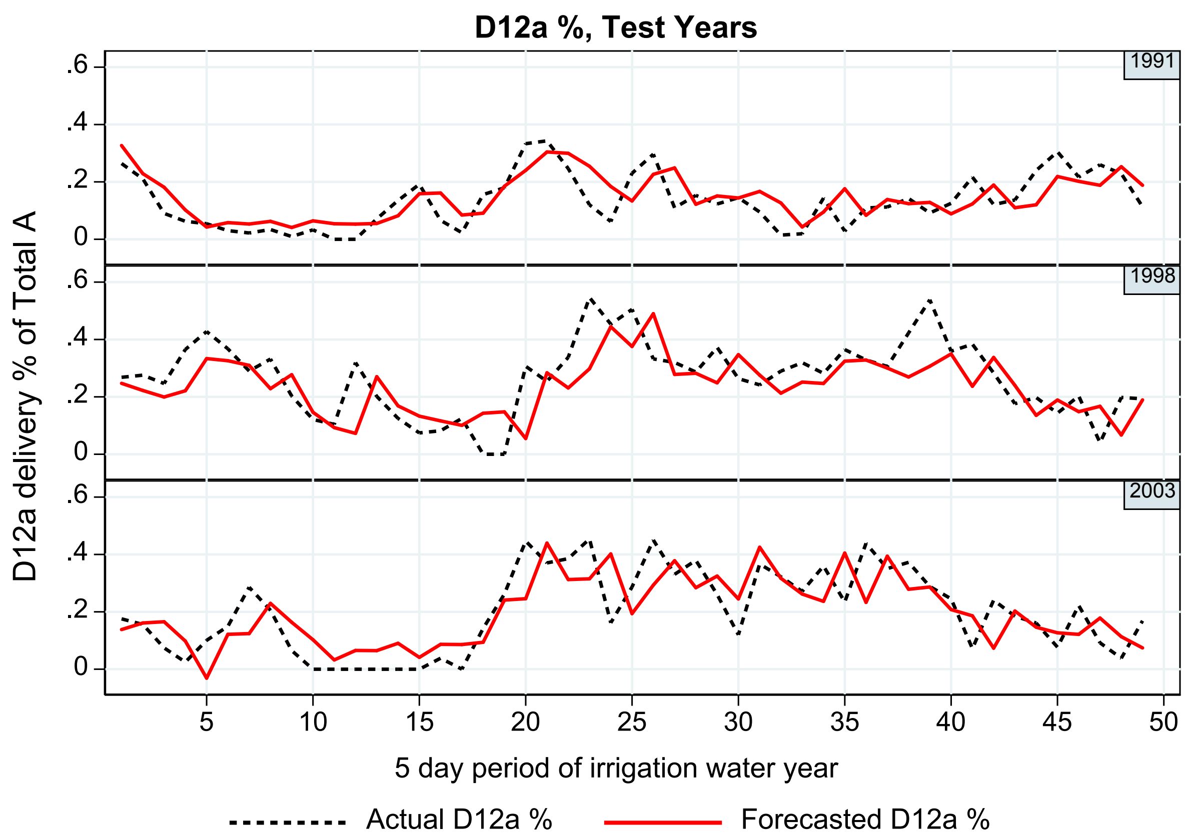

Figure A.4.4.4.2.8. Actual percent delivery of Total A diversions through diversion arc D12A compared to that forecasted by the model-averaged predictive equation in the test years.

Table A.4.4.4.2.1. Error statistics for forecasts of the percent of Total A delivery for each diversion arc in the test years (1991, 1998, and 2003). These one-step-ahead forecasts were generated using the model-averaged equations, using the historic percent of Total A diversion from the prior period as the β_1 predictor. Mean and standard deviation (sd) of forecast errors (actual delivery % - forecasted delivery %) were calculated for each 5-day period of the irrigation water year (Period). Sample size was 3 per period.

	d1pcta		d91pcta		d11pcta		d12apcta	
Period	mean	Sd	Mean	sd	mean	sd	mean	sd
1			0.004	0.012	0.020	0.053	-0.001	0.054
2			0.008	0.022	0.057	0.093	0.010	0.038
3			0.068	0.128	0.079	0.104	-0.045	0.080
4			0.013	0.031	0.002	0.018	0.010	0.117
5			0.026	0.020	0.002	0.041	0.079	0.061
6	-0.002	0.002	-0.071	0.168	0.014	0.066	0.014	0.037
7	0.019	0.138	0.167	0.255	-0.020	0.047	0.037	0.108
8	0.058	0.118	-0.103	0.206	0.001	0.030	0.017	0.075
9	0.008	0.034	-0.152	0.204	0.071	0.051	-0.068	0.034
10	-0.120	0.049	-0.090	0.125	0.018	0.055	-0.053	0.043
11	0.022	0.162	-0.001	0.118	-0.036	0.035	-0.025	0.033
12	-0.063	0.108	-0.075	0.060	-0.018	0.045	0.043	0.177
13	0.125	0.119	-0.008	0.037	-0.009	0.007	-0.039	0.048
14	-0.228	0.228	-0.148	0.146	-0.009	0.024	-0.027	0.073
15	-0.213	0.218	-0.068	0.099	-0.021	0.034	-0.022	0.049
16	-0.232	0.031	-0.168	0.059	-0.033	0.012	-0.059	0.032
17	-0.249	0.194	-0.047	0.206	0.007	0.046	-0.041	0.058
18	0.159	0.222	0.001	0.116	-0.027	0.049	-0.010	0.115
19	0.169	0.309	0.133	0.096	-0.020	0.032	-0.044	0.091
20	0.017	0.206	0.045	0.151	0.022	0.012	0.182	0.081
21	-0.110	0.351	-0.174	0.454	-0.012	0.055	-0.020	0.055
22	0.022	0.113	0.074	0.565	0.003	0.047	0.042	0.084
23	0.029	0.252	0.013	0.204	0.017	0.007	0.084	0.197
24	-0.209	0.103	-0.240	0.213	0.041	0.034	-0.118	0.125
25	-0.045	0.097	0.212	0.344	0.060	0.012	0.106	0.020
26	0.220	0.194	0.090	0.350	0.027	0.027	0.023	0.163
27	0.141	0.123	-0.013	0.301	0.001	0.031	-0.048	0.090
28	0.008	0.099	-0.037	0.174	0.018	0.031	0.044	0.047
29	-0.058	0.107	0.179	0.222	0.002	0.037	0.010	0.100
30	-0.041	0.172	-0.162	0.245	-0.037	0.042	-0.069	0.064
31	0.038	0.033	-0.101	0.037	0.062	0.051	-0.055	0.019
32	-0.122	0.183	-0.114	0.124	-0.004	0.053	-0.010	0.095
33	0.020	0.206	0.049	0.024	-0.003	0.035	0.018	0.046
34	0.164	0.203	0.179	0.188	0.002	0.050	0.069	0.047
35	0.018	0.150	-0.057	0.052	0.036	0.026	-0.093	0.116
36	-0.014	0.203	-0.084	0.119	-0.004	0.017	0.077	0.112

	d1pcta			d91pcta			d11pcta			d12apcta	
Period	mean	Sd		Mean	sd		mean	sd		mean	sd
37	0.093	0.112		0.047	0.103		0.023	0.047		-0.021	0.025
38	0.095	0.079		0.088	0.117		0.021	0.053		0.088	0.068
39	-0.178	0.061		-0.107	0.109		0.007	0.048		0.066	0.145
40	-0.005	0.110		0.105	0.206		0.002	0.016		0.028	0.016
41	0.118	0.036		0.056	0.124		-0.028	0.034		0.042	0.138
42	0.104	0.078		-0.057	0.022		0.004	0.004		0.015	0.132
43	0.061	0.053		0.040	0.069		0.018	0.068		-0.018	0.045
44	0.033	0.015		0.063	0.122		0.008	0.038		0.066	0.052
45	-0.121	0.188		0.056	0.081		-0.005	0.065		-0.003	0.077
46	-0.040	0.466		0.098	0.098		-0.015	0.040		0.057	0.043
47	-0.080	0.172		-0.170	0.121		-0.043	0.016		-0.047	0.105
48	-0.002	0.000		-0.008	0.050		0.013	0.034		0.011	0.107
49	0.000	0.001		-0.037	0.027		-0.019	0.056		0.008	0.085
50				-0.025	0.098						
51				0.011	0.028						
52				-0.017	0.030						

The discussion of how the selected formulas were used in the KBPM to simulate Agricultural deliveries is found in Section A.4.4.3 following the several tables below that provide the details of model ranking and error analysis used to select the formulas and coefficients for the four model arcs, D1, D91, D11, and D12a, shown above with the graphed results.

As expected, relative performance of models varied across 5-day periods (Tables A.4.4.4.2.1 and A.4.4.4.2.2), as determined by the relative magnitudes of the $\Delta_m$values. In both tables, results are sorted within each period by the $\Delta_m$values, so that the best performing model (lowest $AICc$) is first and the worst performing model is last. While the results in these tables provide insight into the seasonal influence of climatic and water availability factors, discussion in this regard is deferred to any potential future consideration of modifying this model approach for use in operations. For the present purpose of depicting the pattern of water deliveries in the KBPM, it is useful to note that multimodel-averaging allowed for the weighted (using w_m) influence of different regressors to affect the predicted diversion patterns in a manner that varied across diversion arcs and periods.

The end result of this process was a diversion arc-specific table of model-averaged coefficients for each variable in the model set and for each 5-day period. In any given period, regressors in models with relatively high Akaike weights (that is, w_m near 1) strongly influenced the $\hat{\bar{\beta}}_p$ coefficients in the final averaged model, whereas those with weights near zero had little or no influence on the coefficients (Tables A.4.4.4.2.3 through A.4.4.4.2.7. Each table was used in the KBPM as a lookup table, from which the coefficients corresponding to the appropriate diversion arc, predictor variable, and 5-day period were obtained to compute the percentage of Total A deliveries for each 5-day period.

Table A.4.4.4.2.2. Model ranking and Akaike weights of 5-day period specific for OLS models predicting percent of Total A deliveries through diversion arcs D1 and D91. Within each 5-day period, models are sorted by Δ_m (from "best" to "worst"). In the table below, P = 5-day period of the irrigation water year; M = model number; K = number of estimable parameters of the model; MLL = maximized log-likelihood of the model obtained from OLS output; AIC_c = corrected Akaike Information Criterion; Δ_m = difference between the AIC_c of the model with the minimum AIC_c (the best model) and the AIC_c of model *m*; w_m = Akaike weight for model *m.*

	D1pcta							D91pcta					
P	**M**	**K**	**MLL**	**AIC_c**	**Δ_m**	**w_m**		**M**	**K**	**MLL**	**AIC_c**	**Δ_m**	**w_m**
1								7	4	100.22	-190.78	0.00	0.29
1								10	4	100.05	-190.44	0.34	0.25
1								8	4	100.01	-190.35	0.43	0.24
1								9	4	99.97	-190.27	0.51	0.23
2								1	3	69.85	-132.78	0.00	0.31
2								3	4	70.95	-132.29	0.48	0.24
2								4	4	70.79	-131.99	0.79	0.21
2								5	4	70.14	-130.68	2.09	0.11
2								2	4	70.11	-130.62	2.16	0.11
2								6	4	68.78	-127.89	4.89	0.03
3								3	4	36.01	-62.42	0.00	0.41
3								5	4	35.35	-61.10	1.32	0.21
3								4	4	35.34	-61.07	1.35	0.21
3								1	3	33.35	-59.78	2.64	0.11
3								2	4	33.74	-57.88	4.54	0.04
3								6	4	32.20	-54.73	7.69	0.01
4								4	4	53.00	-96.41	0.00	0.30
4								2	4	52.97	-96.35	0.06	0.30
4								1	3	51.25	-95.58	0.83	0.20
4								3	4	51.96	-94.33	2.08	0.11
4								5	4	51.64	-93.68	2.73	0.08
4								6	4	49.97	-90.27	6.14	0.01
5								4	4	52.18	-94.75	0.00	0.48
5								2	4	51.34	-93.09	1.67	0.21
5								3	4	50.93	-92.27	2.48	0.14

	D1pcta							D91pcta					
P	M	K	MLL	AIC_c	Δ_m	w_m		M	K	MLL	AIC_c	Δ_m	w_m
5								5	4	50.85	-92.09	2.66	0.13
5								1	3	48.35	-89.79	4.97	0.04
5								6	4	46.34	-83.02	11.74	0.00
6	9	4	83.49	-157.31	0.00	0.36		4	4	27.21	-44.82	0.00	0.40
6	8	4	83.38	-157.10	0.21	0.32		2	4	26.56	-43.51	1.31	0.21
6	10	4	82.72	-155.77	1.54	0.17		1	3	25.02	-43.11	1.70	0.17
6	7	4	82.62	-155.58	1.74	0.15		3	4	26.29	-42.98	1.84	0.16
6								5	4	25.03	-40.45	4.37	0.04
6								6	4	24.55	-39.43	5.39	0.03
7	1	3	35.17	-63.41	0.00	0.43		3	4	12.28	-14.96	0.00	0.67
7	5	4	35.63	-61.65	1.76	0.18		5	4	10.49	-11.38	3.58	0.11
7	3	4	35.22	-60.84	2.57	0.12		1	3	9.04	-11.15	3.80	0.10
7	4	4	35.19	-60.78	2.64	0.12		4	4	10.10	-10.61	4.35	0.08
7	2	4	35.17	-60.74	2.67	0.11		2	4	9.12	-8.64	6.32	0.03
7	6	4	34.18	-58.69	4.72	0.04		6	4	8.65	-7.64	7.32	0.02
8	2	4	26.47	-43.35	0.00	0.53		1	3	11.50	-16.07	0.00	0.38
8	4	4	25.99	-42.39	0.96	0.33		5	4	12.26	-14.92	1.15	0.21
8	1	3	23.01	-39.11	4.24	0.06		4	4	11.72	-13.83	2.24	0.12
8	3	4	23.94	-38.29	5.06	0.04		2	4	11.69	-13.79	2.29	0.12
8	5	4	23.02	-36.44	6.90	0.02		3	4	11.61	-13.63	2.44	0.11
8	6	4	22.62	-35.58	7.77	0.01		6	4	11.03	-12.39	3.68	0.06
9	4	4	11.50	-13.41	0.00	0.39		6	4	14.62	-19.57	0.00	0.37
9	2	4	10.91	-12.22	1.19	0.21		1	3	12.61	-18.31	1.27	0.20
9	3	4	10.61	-11.62	1.79	0.16		3	4	13.68	-17.77	1.81	0.15
9	1	3	9.00	-11.07	2.33	0.12		4	4	13.62	-17.64	1.93	0.14
9	6	4	9.98	-10.29	3.12	0.08		2	4	13.05	-16.50	3.07	0.08
9	5	4	9.28	-8.96	4.44	0.04		5	4	12.84	-16.09	3.48	0.06
10	2	4	9.20	-8.81	0.00	0.54		1	3	24.96	-43.00	0.00	0.29
10	6	4	7.91	-6.15	2.66	0.14		2	4	26.11	-42.63	0.38	0.24

	D1pcta							D91pcta					
P	M	K	MLL	AIC_c	Δ_m	w_m		M	K	MLL	AIC_c	Δ_m	w_m
10	4	4	7.84	-6.08	2.72	0.14		3	4	26.01	-42.41	0.59	0.21
10	1	3	6.26	-5.59	3.21	0.11		5	4	25.72	-41.84	1.17	0.16
10	5	4	6.54	-3.48	5.33	0.04		4	4	24.98	-40.36	2.64	0.08
10	3	4	6.27	-2.95	5.86	0.03		6	4	23.79	-37.91	5.09	0.02
11	2	4	8.70	-7.80	0.00	0.69		3	4	21.05	-32.51	0.00	0.65
11	4	4	7.32	-5.03	2.77	0.17		1	3	18.15	-29.38	3.13	0.14
11	6	4	6.11	-2.55	5.26	0.05		4	4	19.02	-28.45	4.06	0.09
11	1	3	4.63	-2.34	5.47	0.04		5	4	18.88	-28.17	4.34	0.07
11	3	4	5.46	-1.31	6.49	0.03		2	4	18.36	-27.13	5.38	0.04
11	5	4	4.76	0.07	7.88	0.01		6	4	17.14	-24.62	7.89	0.01
12	2	4	5.46	-1.33	0.00	0.79		2	4	24.40	-39.20	0.00	0.90
12	4	4	3.96	1.68	3.01	0.18		4	4	21.46	-33.32	5.89	0.05
12	5	4	1.14	7.32	8.65	0.01		1	3	19.52	-32.11	7.09	0.03
12	1	3	-0.25	7.42	8.75	0.01		5	4	20.05	-30.50	8.71	0.01
12	3	4	0.52	8.57	9.90	0.01		6	4	19.56	-29.46	9.75	0.01
12	6	4	0.04	9.59	10.92	0.00		3	4	19.53	-29.45	9.75	0.01
13	4	4	5.89	-2.18	0.00	0.75		4	4	17.91	-26.21	0.00	0.31
13	2	4	4.51	0.58	2.76	0.19		1	3	16.43	-25.93	0.28	0.27
13	6	4	2.29	5.08	7.26	0.02		2	4	17.31	-25.02	1.19	0.17
13	3	4	2.25	5.09	7.28	0.02		3	4	17.13	-24.67	1.54	0.14
13	1	3	0.55	5.83	8.01	0.01		5	4	16.47	-23.33	2.88	0.07
13	5	4	0.60	8.40	10.58	0.00		6	4	15.56	-21.45	4.76	0.03
14	4	4	2.96	3.68	0.00	0.70		1	3	10.01	-13.09	0.00	0.35
14	2	4	2.07	5.47	1.79	0.29		2	4	10.84	-12.07	1.02	0.21
14	3	4	-1.39	12.39	8.71	0.01		4	4	10.64	-11.69	1.41	0.18
14	1	3	-5.70	18.33	14.65	0.00		3	4	10.20	-10.79	2.30	0.11
14	6	4	-5.13	19.94	16.26	0.00		5	4	10.01	-10.42	2.67	0.09
14	5	4	-5.26	20.11	16.43	0.00		6	4	9.47	-9.27	3.82	0.05
15	5	4	5.84	-2.08	0.00	0.82		5	4	9.68	-9.75	0.00	0.62

	D1pcta							D91pcta					
P	M	K	MLL	AIC_c	Δ_m	w_m		M	K	MLL	AIC_c	Δ_m	w_m
15	2	4	3.97	1.66	3.74	0.13		2	4	8.17	-6.74	3.01	0.14
15	4	4	2.61	4.39	6.47	0.03		1	3	6.71	-6.50	3.25	0.12
15	6	4	1.84	5.99	8.08	0.01		3	4	7.06	-4.52	5.24	0.04
15	1	3	-0.96	8.85	10.93	0.00		4	4	7.01	-4.43	5.33	0.04
15	3	4	-0.85	11.30	13.39	0.00		6	4	6.94	-4.21	5.54	0.04
16	2	4	10.39	-11.18	0.00	0.91		1	3	15.42	-23.92	0.00	0.35
16	4	4	7.84	-6.08	5.11	0.07		2	4	16.37	-23.13	0.78	0.24
16	1	3	4.11	-1.30	9.88	0.01		3	4	15.90	-22.20	1.72	0.15
16	6	4	4.90	-0.13	11.06	0.00		5	4	15.54	-21.48	2.44	0.10
16	5	4	4.85	-0.10	11.09	0.00		4	4	15.47	-21.35	2.57	0.10
16	3	4	4.40	0.81	11.99	0.00		6	4	15.06	-20.46	3.46	0.06
17	2	4	6.18	-2.76	0.00	0.97		2	4	5.79	-1.97	0.00	0.77
17	4	4	2.74	4.11	6.87	0.03		4	4	3.85	1.89	3.87	0.11
17	3	4	-3.32	16.24	19.00	0.00		1	3	1.93	3.05	5.03	0.06
17	6	4	-3.38	16.43	19.18	0.00		6	4	2.20	5.27	7.25	0.02
17	1	3	-5.13	17.19	19.95	0.00		3	4	2.00	5.60	7.57	0.02
17	5	4	-4.99	19.59	22.34	0.00		5	4	1.96	5.68	7.65	0.02
18	3	4	2.74	4.12	0.00	0.78		3	4	9.47	-9.35	0.00	0.76
18	4	4	1.45	6.70	2.59	0.21		4	4	8.16	-6.71	2.63	0.20
18	2	4	-2.00	13.60	9.48	0.01		2	4	5.74	-1.89	7.46	0.02
18	1	3	-5.05	17.03	12.91	0.00		1	3	4.30	-1.67	7.68	0.02
18	5	4	-4.60	18.80	14.69	0.00		5	4	4.30	0.99	10.34	0.00
18	6	4	-5.25	20.16	16.04	0.00		6	4	4.06	1.54	10.89	0.00
19	2	4	5.91	-2.21	0.00	0.95		2	4	5.53	-1.45	0.00	0.58
19	4	4	3.06	3.49	5.70	0.05		4	4	5.18	-0.76	0.69	0.41
19	3	4	-2.72	15.05	17.26	0.00		3	4	0.95	7.69	9.15	0.01
19	1	3	-5.83	18.59	20.80	0.00		1	3	-1.92	10.77	12.22	0.00
19	5	4	-5.18	19.96	22.17	0.00		5	4	-0.66	10.92	12.37	0.00
20	2	4	9.55	-9.49	0.00	1.00		2	4	6.17	-2.73	0.00	0.91

	D1pcta							D91pcta					
P	M	K	MLL	AIC_c	Δ_m	w_m		M	K	MLL	AIC_c	Δ_m	w_m
20	4	4	3.33	2.95	12.44	0.00		4	4	3.58	2.44	5.18	0.07
20	1	3	1.25	4.42	13.91	0.00		1	3	0.76	5.39	8.13	0.02
20	3	4	1.34	6.93	16.42	0.00		5	4	1.28	7.04	9.78	0.01
20	5	4	1.27	7.05	16.55	0.00		3	4	0.78	8.03	10.77	0.00
21	2	4	12.84	-16.09	0.00	0.91		2	4	6.83	-4.05	0.00	0.86
21	4	4	10.45	-11.30	4.79	0.08		4	4	5.01	-0.43	3.62	0.14
21	1	3	5.72	-4.52	11.56	0.00		1	3	-0.44	7.81	11.86	0.00
21	3	4	6.82	-4.04	12.05	0.00		3	4	0.70	8.19	12.25	0.00
21	5	4	5.84	-2.09	14.00	0.00		5	4	-0.44	10.49	14.54	0.00
22	2	4	9.29	-8.99	0.00	0.75		5	4	2.75	4.10	0.00	0.97
22	5	4	7.76	-5.92	3.06	0.16		2	4	-1.56	12.72	8.61	0.01
22	4	4	6.63	-3.66	5.33	0.05		1	3	-3.32	13.56	9.46	0.01
22	1	3	4.66	-2.41	6.58	0.03		4	4	-2.99	15.58	11.48	0.00
22	3	4	4.82	-0.04	8.95	0.01		3	4	-3.30	16.19	12.09	0.00
23	2	4	20.32	-31.04	0.00	0.96		2	4	5.33	-1.07	0.00	0.67
23	4	4	17.07	-24.54	6.50	0.04		4	4	4.26	1.08	2.15	0.23
23	3	4	13.58	-17.57	13.47	0.00		1	3	1.35	4.22	5.29	0.05
23	1	3	11.65	-16.38	14.66	0.00		3	4	2.68	4.24	5.31	0.05
23	5	4	12.68	-15.76	15.27	0.00		5	4	1.45	6.71	7.78	0.01
24	2	4	11.87	-14.13	0.00	0.27		2	4	6.28	-2.96	0.00	0.85
24	1	3	10.52	-14.12	0.01	0.27		4	4	4.49	0.62	3.57	0.14
24	5	4	11.61	-13.62	0.52	0.21		1	3	-0.28	7.49	10.45	0.00
24	4	4	11.37	-13.13	1.00	0.17		5	4	1.03	7.55	10.50	0.00
24	3	4	10.63	-11.67	2.47	0.08		3	4	0.25	9.11	12.07	0.00
25	4	4	13.34	-17.09	0.00	0.38		1	3	0.30	6.32	0.00	0.48
25	2	4	13.00	-16.40	0.68	0.27		3	4	0.41	8.77	2.45	0.14
25	3	4	12.63	-15.65	1.43	0.19		4	4	0.35	8.90	2.58	0.13
25	1	3	10.85	-14.78	2.31	0.12		5	4	0.32	8.95	2.64	0.13
25	5	4	10.85	-12.10	4.98	0.03		2	4	0.30	8.99	2.68	0.13

	D1pcta							D91pcta					
P	M	K	MLL	AIC_c	Δ_m	w_m		M	K	MLL	AIC_c	Δ_m	w_m
26	2	4	16.55	-23.50	0.00	0.91		2	4	16.18	-22.77	0.00	0.40
26	4	4	14.25	-18.90	4.60	0.09		1	3	14.63	-22.33	0.44	0.32
26	3	4	10.57	-11.54	11.96	0.00		3	4	14.91	-20.22	2.55	0.11
26	1	3	7.59	-8.26	15.24	0.00		4	4	14.64	-19.68	3.08	0.09
26	5	4	7.65	-5.71	17.79	0.00		5	4	14.63	-19.65	3.11	0.08
27	1	3	14.79	-22.66	0.00	0.41		1	3	7.83	-8.73	0.00	0.36
27	5	4	15.41	-21.22	1.44	0.20		3	4	8.75	-7.90	0.83	0.24
27	2	4	15.21	-20.83	1.83	0.16		5	4	8.36	-7.12	1.61	0.16
27	3	4	14.97	-20.34	2.32	0.13		2	4	8.09	-6.58	2.15	0.12
27	4	4	14.79	-19.98	2.67	0.11		4	4	7.98	-6.35	2.38	0.11
28	1	3	15.92	-24.92	0.00	0.34		1	3	9.20	-11.49	0.00	0.33
28	3	4	17.13	-24.66	0.26	0.30		3	4	10.46	-11.32	0.16	0.30
28	4	4	16.57	-23.55	1.37	0.17		4	4	9.97	-10.33	1.15	0.19
28	2	4	15.99	-22.38	2.54	0.10		5	4	9.27	-8.94	2.55	0.09
28	5	4	15.95	-22.30	2.62	0.09		2	4	9.22	-8.83	2.65	0.09
29	2	4	19.05	-28.49	0.00	1.00		2	4	10.69	-11.77	0.00	0.57
29	4	4	12.72	-15.84	12.65	0.00		4	4	10.29	-10.97	0.80	0.38
29	1	3	8.73	-10.53	17.96	0.00		5	4	7.52	-5.43	6.34	0.02
29	5	4	9.73	-9.85	18.64	0.00		3	4	6.57	-3.55	8.23	0.01
29	3	4	8.84	-8.08	20.42	0.00		1	3	5.19	-3.46	8.31	0.01
30	5	4	22.12	-34.65	0.00	0.64		1	3	25.58	-44.23	0.00	0.38
30	2	4	20.72	-31.84	2.81	0.16		2	4	26.60	-43.61	0.62	0.28
30	1	3	19.04	-31.15	3.50	0.11		4	4	25.81	-42.01	2.22	0.12
30	4	4	19.79	-29.98	4.67	0.06		5	4	25.74	-41.89	2.34	0.12
30	3	4	19.10	-28.59	6.05	0.03		3	4	25.60	-41.61	2.62	0.10
31	3	4	20.04	-30.48	0.00	0.32		3	4	14.41	-19.21	0.00	0.32
31	4	4	20.02	-30.43	0.05	0.31		4	4	14.18	-18.76	0.45	0.26
31	1	3	18.36	-29.79	0.69	0.23		1	3	12.79	-18.66	0.55	0.25
31	5	4	18.77	-27.94	2.54	0.09		2	4	13.24	-16.88	2.33	0.10

	D1pcta							D91pcta					
P	M	K	MLL	AIC$_c$	Δ_m	w_m		M	K	MLL	AIC$_c$	Δ_m	w_m
31	2	4	18.36	-27.12	3.36	0.06		5	4	12.91	-16.21	3.00	0.07
32	1	3	29.03	-51.13	0.00	0.39		1	3	19.32	-31.73	0.00	0.35
32	2	4	29.87	-50.14	0.99	0.24		5	4	20.44	-31.28	0.45	0.28
32	3	4	29.37	-49.13	2.00	0.14		4	4	19.71	-29.81	1.91	0.13
32	5	4	29.16	-48.73	2.40	0.12		3	4	19.63	-29.66	2.06	0.12
32	4	4	29.05	-48.50	2.63	0.11		2	4	19.57	-29.53	2.19	0.12
33	2	4	25.20	-40.80	0.00	0.86		2	4	17.65	-25.70	0.00	0.72
33	4	4	22.98	-36.37	4.43	0.09		4	4	16.47	-23.35	2.36	0.22
33	1	3	20.56	-34.19	6.61	0.03		1	3	13.13	-19.33	6.38	0.03
33	3	4	20.78	-31.96	8.85	0.01		3	4	13.82	-18.03	7.67	0.02
33	5	4	20.59	-31.59	9.22	0.01		5	4	13.14	-16.68	9.02	0.01
34	2	4	34.81	-60.02	0.00	0.72		1	3	16.44	-25.95	0.00	0.32
34	1	3	31.85	-56.78	3.24	0.14		2	4	17.77	-25.93	0.02	0.32
34	4	4	32.44	-55.29	4.73	0.07		4	4	17.01	-24.42	1.53	0.15
34	3	4	31.88	-54.16	5.86	0.04		5	4	16.87	-24.14	1.81	0.13
34	5	4	31.88	-54.15	5.87	0.04		3	4	16.47	-23.34	2.61	0.09
35	2	4	22.71	-35.81	0.00	0.80		2	4	14.42	-19.24	0.00	0.96
35	1	3	19.28	-31.64	4.17	0.10		1	3	8.94	-10.97	8.27	0.02
35	3	4	19.82	-30.03	5.78	0.04		4	4	10.08	-10.57	8.67	0.01
35	4	4	19.39	-29.19	6.62	0.03		5	4	9.07	-8.54	10.70	0.00
35	5	4	19.38	-29.15	6.66	0.03		3	4	8.95	-8.29	10.95	0.00
36	2	4	11.39	-13.18	0.00	0.81		2	4	14.53	-19.46	0.00	0.52
36	4	4	9.44	-9.28	3.90	0.12		1	3	12.36	-17.79	1.67	0.22
36	1	3	7.11	-7.30	5.88	0.04		4	4	13.22	-16.84	2.62	0.14
36	3	4	7.53	-5.46	7.72	0.02		5	4	12.38	-15.16	4.30	0.06
36	5	4	7.13	-4.66	8.52	0.01		3	4	12.38	-15.15	4.31	0.06
37	1	3	22.09	-37.26	0.00	0.29		3	4	23.78	-37.97	0.00	0.38
37	4	4	23.29	-36.97	0.28	0.25		4	4	23.56	-37.51	0.46	0.30
37	3	4	23.15	-36.70	0.56	0.22		1	3	21.70	-36.47	1.50	0.18

	D1pcta							D91pcta					
P	M	K	MLL	AIC_c	Δ_m	w_m		M	K	MLL	AIC_c	Δ_m	w_m
37	2	4	22.78	-35.96	1.30	0.15		2	4	22.26	-34.92	3.05	0.08
37	5	4	22.19	-34.79	2.47	0.08		5	4	21.71	-33.81	4.15	0.05
38	2	4	20.43	-31.26	0.00	1.00		2	4	17.04	-24.47	0.00	0.63
38	4	4	14.35	-19.09	12.16	0.00		1	3	14.30	-21.68	2.79	0.16
38	1	3	12.07	-17.21	14.04	0.00		5	4	14.97	-20.35	4.12	0.08
38	3	4	12.24	-14.87	16.38	0.00		4	4	14.92	-20.23	4.24	0.08
38	5	4	12.14	-14.67	16.59	0.00		3	4	14.53	-19.46	5.02	0.05
39	2	4	21.48	-33.36	0.00	0.61		1	3	17.06	-27.20	0.00	0.46
39	4	4	20.98	-32.37	0.99	0.37		4	4	17.21	-24.83	2.37	0.14
39	3	4	17.93	-26.27	7.10	0.02		3	4	17.19	-24.79	2.41	0.14
39	1	3	14.56	-22.19	11.17	0.00		2	4	17.18	-24.77	2.43	0.14
39	5	4	14.60	-19.59	13.77	0.00		5	4	17.06	-24.52	2.68	0.12
40	2	4	13.85	-18.10	0.00	0.68		3	4	29.81	-50.01	0.00	0.40
40	4	4	12.75	-15.89	2.20	0.23		4	4	29.29	-48.98	1.04	0.24
40	3	4	11.05	-12.50	5.60	0.04		1	3	27.81	-48.69	1.33	0.20
40	1	3	9.62	-12.31	5.79	0.04		2	4	28.48	-47.36	2.65	0.11
40	5	4	9.62	-9.64	8.46	0.01		5	4	27.86	-46.13	3.89	0.06
41	4	4	20.21	-30.82	0.00	0.49		3	4	43.71	-77.81	0.00	0.35
41	3	4	20.13	-30.66	0.17	0.45		4	4	43.29	-76.98	0.84	0.23
41	2	4	17.72	-25.85	4.97	0.04		1	3	41.83	-76.73	1.09	0.21
41	1	3	15.34	-23.75	7.07	0.01		5	4	42.59	-75.58	2.24	0.12
41	5	4	15.56	-21.53	9.29	0.00		2	4	42.33	-75.07	2.75	0.09
42	2	4	19.10	-28.59	0.00	0.96		3	4	63.29	-116.97	0.00	0.38
42	4	4	15.78	-21.97	6.63	0.03		4	4	62.81	-116.01	0.96	0.23
42	1	3	11.70	-16.47	12.12	0.00		1	3	61.45	-115.98	0.99	0.23
42	3	4	12.57	-15.55	13.05	0.00		2	4	61.94	-114.28	2.69	0.10
42	5	4	12.41	-15.22	13.37	0.00		5	4	61.45	-113.31	3.66	0.06
43	4	4	24.22	-38.83	0.00	0.60		1	3	50.47	-94.01	0.00	0.28
43	2	4	23.63	-37.67	1.17	0.33		4	4	51.56	-93.51	0.50	0.22

	D1pcta							D91pcta					
P	M	K	MLL	AIC_c	Δ_m	w_m		M	K	MLL	AIC_c	Δ_m	w_m
43	3	4	21.94	-34.27	4.56	0.06		3	4	51.52	-93.45	0.57	0.21
43	1	3	18.38	-29.84	9.00	0.01		5	4	51.23	-92.86	1.15	0.16
43	5	4	18.40	-27.20	11.63	0.00		2	4	51.08	-92.57	1.44	0.14
44	2	4	29.85	-50.09	0.00	0.35		1	3	44.09	-81.25	0.00	0.47
44	4	4	29.75	-49.91	0.19	0.32		3	4	44.22	-78.83	2.42	0.14
44	1	3	27.84	-48.77	1.33	0.18		4	4	44.16	-78.73	2.53	0.13
44	3	4	28.56	-47.52	2.58	0.10		5	4	44.11	-78.62	2.63	0.13
44	5	4	28.05	-46.51	3.58	0.06		2	4	44.10	-78.60	2.65	0.13
45	2	4	21.41	-33.21	0.00	0.84		2	4	65.47	-121.34	0.00	0.32
45	4	4	19.57	-29.53	3.68	0.13		1	3	64.08	-121.23	0.11	0.30
45	1	3	15.77	-24.62	8.60	0.01		4	4	65.02	-120.45	0.89	0.20
45	3	4	16.89	-24.18	9.04	0.01		3	4	64.27	-118.94	2.40	0.10
45	5	4	15.77	-21.95	11.27	0.00		5	4	64.08	-118.57	2.77	0.08
46	1	3	6.48	-6.04	0.00	0.41		1	3	75.89	-144.86	0.00	0.41
46	3	4	7.01	-4.42	1.62	0.18		3	4	76.38	-143.15	1.70	0.17
46	4	4	6.96	-4.32	1.72	0.17		5	4	76.34	-143.08	1.77	0.17
46	2	4	6.65	-3.71	2.34	0.13		4	4	76.14	-142.68	2.17	0.14
46	5	4	6.49	-3.39	2.66	0.11		2	4	75.92	-142.23	2.62	0.11
47	1	3	20.77	-34.61	0.00	0.47		1	3	38.76	-70.59	0.00	0.48
47	2	4	20.91	-32.22	2.40	0.14		4	4	38.81	-68.01	2.57	0.13
47	4	4	20.82	-32.03	2.58	0.13		2	4	38.79	-67.99	2.60	0.13
47	5	4	20.81	-32.02	2.60	0.13		3	4	38.78	-67.97	2.62	0.13
47	3	4	20.77	-31.94	2.68	0.12		5	4	38.76	-67.91	2.68	0.13
48	1	3	102.51	-198.10	0.00	0.47		1	3	46.97	-87.02	0.00	0.33
48	5	4	102.69	-195.79	2.31	0.15		4	4	47.90	-86.19	0.83	0.22
48	3	4	102.57	-195.53	2.56	0.13		3	4	47.80	-85.99	1.03	0.19
48	4	4	102.55	-195.51	2.59	0.13		2	4	47.67	-85.74	1.29	0.17
48	2	4	102.53	-195.46	2.64	0.13		5	4	47.05	-84.51	2.52	0.09
49	2	4	146.32	-283.04	0.00	0.70		3	4	28.78	-47.95	0.00	0.37

	D1pcta							D91pcta					
P	M	K	MLL	AIC_c	Δ_m	w_m		M	K	MLL	AIC_c	Δ_m	w_m
49	4	4	145.16	-280.71	2.33	0.22		4	4	28.48	-47.36	0.59	0.27
49	3	4	143.59	-277.58	5.46	0.05		1	3	26.46	-46.01	1.95	0.14
49	1	3	141.79	-276.66	6.38	0.03		2	4	27.58	-45.57	2.39	0.11
49	5	4	141.85	-274.09	8.95	0.01		5	4	27.56	-45.52	2.43	0.11
50								1	3	47.02	-87.11	0.00	0.38
50								5	4	47.65	-85.70	1.41	0.19
50								2	4	47.58	-85.56	1.55	0.17
50								4	4	47.45	-85.30	1.82	0.15
50								3	4	47.13	-84.66	2.45	0.11
51								2	4	53.91	-98.22	0.00	0.38
51								4	4	53.60	-97.59	0.63	0.28
51								1	3	51.94	-96.96	1.26	0.20
51								3	4	52.48	-95.35	2.87	0.09
51								5	4	52.02	-94.44	3.77	0.06
52								1	3	66.60	-126.27	0.00	0.47
52								5	4	66.75	-123.90	2.37	0.14
52								3	4	66.67	-123.75	2.52	0.13
52								2	4	66.65	-123.70	2.57	0.13
52								4	4	66.60	-123.60	2.67	0.12

Table A.4.4.4.4.2.3. Model ranking and Akaike weights of 5-day period specific for OLS models predicting percent of Total A deliveries through diversion arcs D11 and D12A. Within each 5-day period, models are sorted by Δ_m (from "best" to "worst"). In the table below, P = 5-day period of the irrigation water year; M = model number; K = number of estimable parameters of the model; MLL = maximized log-likelihood of the model obtained from OLS output; AIC_c = corrected Akaike Information Criterion; Δ_m = difference between the AIC_c of the model with the minimum AIC_c (the best model) and the AIC_c of model *m*; w_m = Akaike weight for model *m.*

	D11pcta							D12Apcta					
P	M	K	MLL	AIC_c	Δ_m	w_m		M	K	MLL	AIC_c	Δ_m	w_m
1	12	3	67.45	-127.98	0.00	0.86		12	3	22.56	-38.20	0.00	0.45
1	9	4	66.60	-123.53	4.45	0.09		9	4	23.31	-36.96	1.24	0.24
1	11	4	65.25	-120.83	7.14	0.02		11	4	23.09	-36.51	1.69	0.19
1	10	4	65.09	-120.50	7.47	0.02		10	4	22.54	-35.41	2.79	0.11
2	1	3	46.37	-85.81	0.00	0.37		3	4	35.46	-61.33	0.00	0.59
2	5	4	47.35	-85.10	0.71	0.26		4	4	34.19	-58.77	2.55	0.17
2	3	4	46.65	-83.71	2.10	0.13		1	3	32.60	-58.27	3.06	0.13
2	4	4	46.44	-83.29	2.53	0.10		5	4	32.89	-56.17	5.15	0.04
2	2	4	46.37	-83.15	2.66	0.10		2	4	32.70	-55.80	5.53	0.04
2	8	4	44.78	-79.89	5.92	0.02		8	4	31.51	-53.36	7.97	0.01
2	6	4	44.59	-79.51	6.30	0.02		7	4	31.49	-53.32	8.01	0.01
2	7	4	44.46	-79.25	6.56	0.01		6	4	31.44	-53.22	8.11	0.01
3	2	4	51.63	-93.67	0.00	0.36		1	3	26.65	-46.38	0.00	0.25
3	1	3	49.88	-92.85	0.82	0.24		5	4	27.98	-46.36	0.01	0.25
3	4	4	51.16	-92.71	0.95	0.22		7	4	27.58	-45.49	0.89	0.16
3	3	4	50.03	-90.46	3.20	0.07		3	4	27.20	-44.80	1.58	0.11
3	5	4	49.96	-90.32	3.34	0.07		2	4	27.01	-44.41	1.96	0.09
3	8	4	48.69	-87.72	5.95	0.02		4	4	26.66	-43.72	2.66	0.07
3	7	4	48.59	-87.51	6.16	0.02		8	4	26.18	-42.69	3.69	0.04
3	6	4	47.96	-86.25	7.42	0.01		6	4	25.79	-41.91	4.46	0.03
4	4	4	71.31	-133.03	0.00	0.34		1	3	39.72	-72.51	0.00	0.39
4	2	4	70.94	-132.29	0.74	0.23		5	4	40.24	-70.89	1.63	0.17
4	1	3	69.46	-132.00	1.03	0.20		2	4	40.04	-70.48	2.03	0.14
4	3	4	70.50	-131.39	1.63	0.15		4	4	39.80	-70.01	2.51	0.11
4	5	4	69.69	-129.77	3.25	0.07		3	4	39.74	-69.88	2.63	0.10

	D11pcta							D12Apcta					
P	M	K	MLL	AIC$_c$	Δ_m	w_m		M	K	MLL	AIC$_c$	Δ_m	w_m
4	7	4	67.63	-125.60	7.43	0.01		8	4	38.60	-67.53	4.98	0.03
4	6	4	67.13	-124.58	8.44	0.00		6	4	38.49	-67.32	5.20	0.03
4	8	4	66.76	-123.85	9.18	0.00		7	4	38.19	-66.72	5.80	0.02
5	3	4	68.19	-126.79	0.00	0.46		5	4	37.93	-66.26	0.00	0.47
5	4	4	67.38	-125.15	1.64	0.20		1	3	35.72	-64.52	1.74	0.20
5	1	3	65.72	-124.51	2.28	0.15		3	4	36.80	-64.01	2.25	0.15
5	5	4	66.60	-123.60	3.19	0.09		4	4	35.91	-62.22	4.04	0.06
5	2	4	66.11	-122.63	4.16	0.06		2	4	35.82	-62.04	4.22	0.06
5	6	4	65.24	-120.82	5.97	0.02		6	4	35.33	-61.00	5.26	0.03
5	8	4	63.94	-118.21	8.58	0.01		8	4	34.71	-59.75	6.51	0.02
5	7	4	63.37	-117.08	9.71	0.00		7	4	34.28	-58.89	7.38	0.01
6	2	4	71.80	-133.99	0.00	0.61		5	4	33.84	-58.08	0.00	0.26
6	1	3	69.16	-131.40	2.59	0.17		1	3	32.46	-58.00	0.09	0.25
6	3	4	70.01	-130.41	3.58	0.10		6	4	33.80	-57.93	0.15	0.24
6	5	4	69.60	-129.59	4.40	0.07		2	4	32.50	-55.41	2.67	0.07
6	4	4	69.27	-128.94	5.05	0.05		3	4	32.49	-55.37	2.71	0.07
6	8	4	66.62	-123.57	10.43	0.00		4	4	32.46	-55.32	2.76	0.06
6	7	4	66.48	-123.29	10.71	0.00		8	4	31.98	-54.30	3.78	0.04
6	6	4	66.47	-123.28	10.71	0.00		7	4	31.06	-52.46	5.63	0.02
7	1	3	61.12	-115.31	0.00	0.42		4	4	42.89	-76.19	0.00	0.31
7	5	4	61.54	-113.48	1.83	0.17		2	4	42.62	-75.63	0.55	0.23
7	2	4	61.42	-113.24	2.08	0.15		1	3	41.06	-75.19	1.00	0.19
7	4	4	61.24	-112.87	2.44	0.12		3	4	42.33	-75.05	1.13	0.18
7	3	4	61.12	-112.64	2.68	0.11		5	4	41.16	-72.72	3.47	0.05
7	7	4	58.72	-107.76	7.55	0.01		7	4	40.10	-70.54	5.65	0.02
7	6	4	58.68	-107.70	7.61	0.01		6	4	39.54	-69.42	6.76	0.01
7	8	4	58.60	-107.54	7.78	0.01		8	4	39.36	-69.05	7.14	0.01
8	3	4	61.97	-114.34	0.00	0.33		3	4	33.19	-56.78	0.00	0.30
8	4	4	61.66	-113.71	0.63	0.24		4	4	32.93	-56.25	0.53	0.23

	D11pcta							D12Apcta					
P	M	K	MLL	AIC_c	Δ_m	w_m		M	K	MLL	AIC_c	Δ_m	w_m
8	1	3	60.19	-113.46	0.88	0.21		1	3	31.51	-56.09	0.69	0.22
8	2	4	60.81	-112.01	2.33	0.10		2	4	32.10	-54.59	2.18	0.10
8	5	4	60.22	-110.84	3.50	0.06		5	4	32.05	-54.50	2.28	0.10
8	7	4	59.91	-110.15	4.19	0.04		7	4	30.41	-51.15	5.63	0.02
8	8	4	58.83	-108.00	6.34	0.01		8	4	30.25	-50.83	5.95	0.02
8	6	4	58.09	-106.51	7.84	0.01		6	4	30.07	-50.48	6.30	0.01
9	1	3	63.92	-120.92	0.00	0.29		1	3	33.81	-60.69	0.00	0.30
9	4	4	64.89	-120.19	0.73	0.20		5	4	34.99	-60.38	0.30	0.26
9	3	4	64.83	-120.05	0.87	0.19		3	4	34.39	-59.18	1.50	0.14
9	5	4	64.74	-119.88	1.04	0.17		4	4	34.29	-58.98	1.71	0.13
9	2	4	64.41	-119.23	1.69	0.12		2	4	33.98	-58.37	2.32	0.09
9	6	4	61.61	-113.55	7.37	0.01		8	4	33.18	-56.70	3.99	0.04
9	7	4	61.53	-113.40	7.52	0.01		7	4	32.71	-55.75	4.94	0.03
9	8	4	61.45	-113.24	7.68	0.01		6	4	32.49	-55.32	5.37	0.02
10	2	4	66.51	-123.42	0.00	0.36		5	4	32.23	-54.87	0.00	0.27
10	1	3	64.82	-122.71	0.71	0.25		1	3	30.76	-54.59	0.28	0.24
10	4	4	65.98	-122.37	1.05	0.21		2	4	32.05	-54.50	0.37	0.23
10	5	4	64.92	-120.24	3.18	0.07		4	4	31.58	-53.55	1.32	0.14
10	3	4	64.89	-120.17	3.25	0.07		3	4	30.78	-51.97	2.90	0.06
10	7	4	62.96	-116.24	7.18	0.01		7	4	29.75	-49.83	5.04	0.02
10	8	4	62.92	-116.17	7.25	0.01		6	4	29.69	-49.72	5.15	0.02
10	6	4	62.49	-115.30	8.12	0.01		8	4	29.45	-49.24	5.63	0.02
11	2	4	61.69	-113.78	0.00	0.41		1	3	39.81	-72.70	0.00	0.26
11	1	3	59.83	-112.74	1.04	0.25		7	4	40.83	-71.99	0.71	0.18
11	8	4	60.15	-110.64	3.14	0.09		2	4	40.67	-71.74	0.95	0.16
11	3	4	60.01	-110.42	3.36	0.08		4	4	40.59	-71.57	1.13	0.15
11	5	4	59.95	-110.31	3.47	0.07		3	4	40.12	-70.65	2.05	0.09
11	4	4	59.95	-110.30	3.48	0.07		5	4	39.81	-70.02	2.68	0.07
11	7	4	58.91	-108.15	5.63	0.02		6	4	39.83	-70.00	2.70	0.07

	D11pcta							D12Apcta					
P	M	K	MLL	AIC_c	Δ_m	w_m		M	K	MLL	AIC_c	Δ_m	w_m
11	6	4	57.72	-105.77	8.01	0.01		8	4	38.18	-66.69	6.01	0.01
12	4	4	63.27	-116.95	0.00	0.61		3	4	37.35	-65.09	0.00	0.64
12	3	4	62.63	-115.66	1.28	0.32		4	4	35.86	-62.13	2.97	0.15
12	2	4	60.77	-111.93	5.01	0.05		1	3	34.18	-61.45	3.65	0.10
12	1	3	58.34	-109.76	7.18	0.02		5	4	34.87	-60.13	4.96	0.05
12	5	4	58.81	-108.01	8.93	0.01		2	4	34.47	-59.35	5.74	0.04
12	8	4	55.92	-102.17	14.78	0.00		7	4	32.90	-56.13	8.96	0.01
12	6	4	55.91	-102.16	14.78	0.00		8	4	32.86	-56.05	9.04	0.01
12	7	4	55.91	-102.16	14.79	0.00		6	4	32.58	-55.50	9.60	0.01
13	1	3	50.45	-93.97	0.00	0.38		7	4	38.80	-67.93	0.00	0.31
13	5	4	50.90	-92.20	1.78	0.16		1	3	37.24	-67.56	0.37	0.26
13	2	4	50.61	-91.62	2.35	0.12		3	4	37.81	-66.01	1.92	0.12
13	4	4	50.61	-91.62	2.35	0.12		4	4	37.58	-65.56	2.37	0.09
13	3	4	50.50	-91.40	2.57	0.11		5	4	37.42	-65.24	2.69	0.08
13	8	4	50.18	-90.69	3.29	0.07		2	4	37.25	-64.91	3.02	0.07
13	7	4	48.90	-88.13	5.84	0.02		6	4	36.87	-64.06	3.87	0.04
13	6	4	48.85	-88.02	5.95	0.02		8	4	36.37	-63.07	4.86	0.03
14	6	4	67.21	-124.76	0.00	0.62		6	4	29.07	-48.47	0.00	0.60
14	5	4	65.90	-122.20	2.56	0.17		1	3	26.16	-45.39	3.08	0.13
14	2	4	64.98	-120.35	4.41	0.07		8	4	26.75	-43.83	4.64	0.06
14	7	4	64.97	-120.26	4.50	0.07		4	4	26.71	-43.83	4.64	0.06
14	1	3	63.01	-119.10	5.66	0.04		2	4	26.63	-43.65	4.82	0.05
14	4	4	63.73	-117.85	6.91	0.02		3	4	26.57	-43.54	4.93	0.05
14	3	4	63.02	-116.44	8.32	0.01		5	4	26.46	-43.33	5.14	0.05
14	8	4	60.75	-111.83	12.94	0.00		7	4	24.99	-40.31	8.16	0.01
15	1	3	60.82	-114.71	0.00	0.41		1	3	32.39	-57.86	0.00	0.32
15	4	4	61.27	-112.94	1.77	0.17		6	4	33.13	-56.59	1.27	0.17
15	3	4	61.16	-112.72	1.99	0.15		2	4	32.97	-56.34	1.52	0.15
15	2	4	60.94	-112.28	2.43	0.12		4	4	32.79	-55.99	1.87	0.13

	D11pcta						D12Apcta					
P	**M**	**K**	**MLL**	**AIC_c**	**Δ_m**	**w_m**	**M**	**K**	**MLL**	**AIC_c**	**Δ_m**	**w_m**
15	5	4	60.88	-112.16	2.56	0.11	3	4	32.43	-55.26	2.60	0.09
15	7	4	59.24	-108.82	5.90	0.02	5	4	32.39	-55.19	2.67	0.08
15	8	4	58.77	-107.88	6.83	0.01	7	4	31.72	-53.78	4.08	0.04
15	6	4	58.44	-107.21	7.51	0.01	8	4	31.11	-52.55	5.31	0.02
16	2	4	58.56	-107.51	0.00	0.75	2	4	32.09	-54.57	0.00	0.30
16	4	4	56.54	-103.47	4.04	0.10	5	4	31.81	-54.03	0.54	0.23
16	1	3	55.08	-103.24	4.27	0.09	1	3	30.32	-53.72	0.85	0.20
16	5	4	55.33	-101.07	6.45	0.03	4	4	31.40	-53.19	1.38	0.15
16	3	4	55.08	-100.57	6.95	0.02	3	4	30.43	-51.25	3.32	0.06
16	7	4	53.70	-97.73	9.78	0.01	7	4	29.62	-49.58	5.00	0.02
16	8	4	53.37	-97.07	10.44	0.00	6	4	29.60	-49.54	5.04	0.02
16	6	4	53.10	-96.53	10.99	0.00	8	4	29.10	-48.54	6.03	0.01
17	1	3	61.86	-116.80	0.00	0.44	1	3	37.29	-67.65	0.00	0.26
17	5	4	62.09	-114.58	2.22	0.15	4	4	38.54	-67.49	0.16	0.24
17	3	4	61.98	-114.36	2.44	0.13	2	4	38.29	-66.98	0.68	0.19
17	4	4	61.91	-114.22	2.58	0.12	3	4	38.21	-66.82	0.83	0.17
17	2	4	61.86	-114.13	2.67	0.12	5	4	37.30	-64.99	2.66	0.07
17	7	4	60.05	-110.42	6.37	0.02	6	4	36.43	-63.19	4.46	0.03
17	8	4	59.70	-109.74	7.06	0.01	7	4	36.01	-62.35	5.30	0.02
17	6	4	59.58	-109.50	7.30	0.01	8	4	35.73	-61.80	5.85	0.01
18	2	4	57.22	-104.83	0.00	0.59	1	3	36.43	-65.95	0.00	0.36
18	4	4	56.55	-103.51	1.32	0.31	5	4	36.84	-64.08	1.86	0.14
18	3	4	54.56	-99.52	5.31	0.04	3	4	36.59	-63.59	2.36	0.11
18	1	3	53.18	-99.45	5.38	0.04	4	4	36.47	-63.33	2.61	0.10
18	5	4	53.47	-97.35	7.48	0.01	2	4	36.44	-63.28	2.67	0.09
18	7	4	52.20	-94.74	10.09	0.00	8	4	36.46	-63.25	2.70	0.09
18	8	4	51.62	-93.58	11.25	0.00	6	4	36.24	-62.81	3.13	0.08
18	6	4	51.20	-92.74	12.09	0.00	7	4	35.16	-60.66	5.29	0.03
19	4	4	58.66	-107.72	0.00	0.54	5	4	26.89	-44.19	0.00	0.57

	D11pcta							D12Apcta					
P	M	K	MLL	AIC_c	Δ_m	w_m		M	K	MLL	AIC_c	Δ_m	w_m
19	3	4	58.07	-106.55	1.17	0.30		1	3	24.70	-42.47	1.71	0.24
19	2	4	56.98	-104.37	3.36	0.10		2	4	24.75	-39.90	4.29	0.07
19	1	3	54.59	-102.27	5.46	0.04		3	4	24.72	-39.84	4.35	0.06
19	5	4	55.05	-100.50	7.22	0.01		4	4	24.70	-39.80	4.39	0.06
20	2	4	55.85	-102.10	0.00	0.76		5	4	36.20	-62.80	0.00	0.78
20	4	4	54.51	-99.43	2.67	0.20		1	3	33.01	-59.09	3.71	0.12
20	1	3	50.96	-95.01	7.09	0.02		2	4	33.05	-56.49	6.31	0.03
20	3	4	51.69	-93.77	8.32	0.01		4	4	33.02	-56.45	6.35	0.03
20	5	4	51.47	-93.34	8.75	0.01		3	4	33.01	-56.42	6.38	0.03
21	5	4	56.15	-102.69	0.00	0.43		5	4	37.60	-65.61	0.00	0.61
21	1	3	54.15	-101.38	1.31	0.22		1	3	35.14	-63.35	2.26	0.20
21	4	4	54.97	-100.34	2.36	0.13		2	4	35.60	-61.60	4.01	0.08
21	2	4	54.81	-100.02	2.67	0.11		4	4	35.28	-60.96	4.65	0.06
21	3	4	54.74	-99.89	2.80	0.11		3	4	35.14	-60.68	4.93	0.05
22	1	3	49.77	-92.61	0.00	0.37		1	3	27.45	-47.98	0.00	0.46
22	2	4	50.84	-92.07	0.54	0.28		5	4	27.79	-45.98	2.00	0.17
22	4	4	50.22	-90.83	1.78	0.15		3	4	27.54	-45.48	2.50	0.13
22	3	4	49.81	-90.02	2.59	0.10		4	4	27.51	-45.41	2.57	0.13
22	5	4	49.77	-89.94	2.67	0.10		2	4	27.45	-45.31	2.68	0.12
23	2	4	47.94	-86.28	0.00	0.29		1	3	27.71	-48.49	0.00	0.35
23	4	4	47.78	-85.96	0.33	0.24		2	4	28.81	-48.02	0.48	0.28
23	1	3	46.31	-85.70	0.59	0.21		5	4	28.19	-46.78	1.71	0.15
23	3	4	47.24	-84.88	1.41	0.14		4	4	28.06	-46.51	1.98	0.13
23	5	4	47.05	-84.50	1.78	0.12		3	4	27.72	-45.83	2.66	0.09
24	4	4	62.26	-114.93	0.00	0.57		4	4	42.17	-74.74	0.00	0.55
24	3	4	61.08	-112.56	2.37	0.18		3	4	41.70	-73.79	0.94	0.34
24	5	4	60.87	-112.13	2.79	0.14		5	4	39.65	-69.70	5.03	0.04
24	2	4	59.98	-110.35	4.57	0.06		1	3	37.93	-68.93	5.81	0.03
24	1	3	58.53	-110.14	4.79	0.05		2	4	39.21	-68.81	5.93	0.03

	D11pcta							D12Apcta					
P	M	K	MLL	AIC_c	Δ_m	w_m		M	K	MLL	AIC_c	Δ_m	w_m
25	1	3	45.99	-85.05	0.00	0.37		1	3	36.51	-66.09	0.00	0.32
25	5	4	46.84	-84.09	0.97	0.23		2	4	37.42	-65.24	0.85	0.21
25	4	4	46.37	-83.14	1.91	0.14		5	4	37.40	-65.20	0.89	0.21
25	3	4	46.33	-83.05	2.00	0.14		4	4	37.15	-64.71	1.38	0.16
25	2	4	46.27	-82.95	2.10	0.13		3	4	36.71	-63.83	2.26	0.10
26	2	4	52.37	-95.15	0.00	0.50		4	4	37.68	-65.76	0.00	0.31
26	4	4	51.98	-94.35	0.80	0.34		2	4	37.32	-65.03	0.73	0.22
26	3	4	50.49	-91.39	3.76	0.08		1	3	35.89	-64.85	0.91	0.20
26	1	3	48.97	-91.01	4.14	0.06		3	4	37.21	-64.82	0.94	0.20
26	5	4	48.97	-88.33	6.82	0.02		5	4	36.21	-62.82	2.93	0.07
27	1	3	56.51	-106.09	0.00	0.32		1	3	42.66	-78.39	0.00	0.46
27	2	4	57.47	-105.35	0.74	0.22		5	4	42.97	-76.35	2.04	0.17
27	4	4	57.39	-105.18	0.91	0.21		2	4	42.71	-75.83	2.56	0.13
27	3	4	57.02	-104.44	1.65	0.14		4	4	42.67	-75.73	2.66	0.12
27	5	4	56.72	-103.85	2.25	0.11		3	4	42.66	-75.71	2.68	0.12
28	2	4	60.24	-110.89	0.00	0.60		1	3	37.80	-68.68	0.00	0.35
28	5	4	59.74	-109.88	1.00	0.36		2	4	38.62	-67.64	1.04	0.21
28	1	3	55.39	-103.85	7.03	0.02		5	4	38.49	-67.37	1.31	0.18
28	4	4	56.18	-102.76	8.13	0.01		4	4	38.30	-67.00	1.68	0.15
28	3	4	55.47	-101.33	9.56	0.01		3	4	38.08	-66.55	2.13	0.12
29	1	3	44.30	-81.68	0.00	0.40		1	3	40.35	-73.78	0.00	0.41
29	2	4	45.14	-80.68	1.00	0.24		3	4	41.05	-72.50	1.28	0.22
29	4	4	44.50	-79.39	2.28	0.13		4	4	40.70	-71.81	1.98	0.15
29	5	4	44.46	-79.33	2.35	0.12		5	4	40.42	-71.24	2.55	0.11
29	3	4	44.32	-79.03	2.65	0.11		2	4	40.36	-71.11	2.67	0.11
30	5	4	53.74	-97.88	0.00	0.40		4	4	33.24	-56.88	0.00	0.25
30	1	3	52.11	-97.31	0.58	0.30		1	3	31.89	-56.85	0.03	0.25
30	2	4	52.52	-95.43	2.45	0.12		2	4	33.19	-56.78	0.10	0.24
30	4	4	52.38	-95.16	2.72	0.10		3	4	32.79	-55.98	0.91	0.16

	D11pcta							D12Apcta					
P	M	K	MLL	AIC$_c$	Δ_m	w_m		M	K	MLL	AIC$_c$	Δ_m	w_m
30	3	4	52.20	-94.80	3.09	0.08		5	4	32.25	-54.90	1.98	0.09
31	2	4	56.74	-103.88	0.00	0.32		2	4	40.40	-71.21	0.00	0.50
31	1	3	55.08	-103.23	0.64	0.23		1	3	38.23	-69.54	1.67	0.22
31	3	4	56.22	-102.84	1.04	0.19		3	4	38.97	-68.35	2.86	0.12
31	4	4	55.91	-102.22	1.66	0.14		4	4	38.71	-67.81	3.40	0.09
31	5	4	55.81	-102.02	1.85	0.13		5	4	38.54	-67.47	3.73	0.08
32	1	3	55.55	-104.17	0.00	0.40		1	3	34.36	-61.79	0.00	0.36
32	5	4	56.49	-103.38	0.80	0.27		2	4	35.18	-60.76	1.04	0.21
32	3	4	55.59	-101.57	2.60	0.11		4	4	35.09	-60.59	1.21	0.20
32	4	4	55.55	-101.51	2.66	0.11		3	4	34.70	-59.80	1.99	0.13
32	2	4	55.55	-101.50	2.67	0.11		5	4	34.36	-59.12	2.67	0.09
33	5	4	60.96	-112.33	0.00	0.61		5	4	33.58	-57.56	0.00	0.38
33	1	3	58.55	-110.18	2.15	0.21		1	3	31.99	-57.05	0.51	0.30
33	2	4	58.78	-107.95	4.38	0.07		2	4	32.41	-55.22	2.33	0.12
33	4	4	58.69	-107.77	4.56	0.06		4	4	32.37	-55.13	2.42	0.11
33	3	4	58.57	-107.53	4.80	0.06		3	4	32.10	-54.60	2.96	0.09
34	1	3	56.42	-105.92	0.00	0.44		4	4	40.39	-71.17	0.00	0.33
34	3	4	56.83	-104.07	1.85	0.17		1	3	38.73	-70.55	0.63	0.24
34	5	4	56.59	-103.57	2.35	0.14		3	4	39.85	-70.09	1.08	0.19
34	4	4	56.58	-103.56	2.36	0.13		2	4	39.66	-69.73	1.45	0.16
34	2	4	56.43	-103.26	2.66	0.12		5	4	38.91	-68.22	2.96	0.08
35	1	3	58.19	-109.46	0.00	0.40		1	3	35.79	-64.65	0.00	0.47
35	3	4	58.93	-108.26	1.20	0.22		3	4	35.97	-62.33	2.32	0.15
35	4	4	58.59	-107.58	1.88	0.15		2	4	35.86	-62.13	2.52	0.13
35	5	4	58.38	-107.16	2.30	0.13		4	4	35.81	-62.02	2.63	0.13
35	2	4	58.20	-106.80	2.66	0.10		5	4	35.79	-61.98	2.66	0.12
36	1	3	63.04	-119.16	0.00	0.47		1	3	43.92	-80.92	0.00	0.41
36	3	4	63.24	-116.88	2.28	0.15		3	4	44.49	-79.39	1.53	0.19
36	2	4	63.07	-116.53	2.62	0.13		4	4	44.28	-78.97	1.95	0.15

	D11pcta							D12Apcta					
P	M	K	MLL	AIC_c	Δ_m	w_m		M	K	MLL	AIC_c	Δ_m	w_m
36	4	4	63.06	-116.52	2.63	0.13		5	4	44.12	-78.63	2.29	0.13
36	5	4	63.06	-116.52	2.63	0.13		2	4	44.03	-78.47	2.45	0.12
37	4	4	64.03	-118.46	0.00	0.28		1	3	37.41	-67.90	0.00	0.41
37	1	3	62.51	-118.10	0.36	0.24		5	4	38.32	-67.04	0.86	0.27
37	2	4	63.84	-118.08	0.37	0.24		2	4	37.43	-65.26	2.63	0.11
37	3	4	63.54	-117.48	0.98	0.17		3	4	37.43	-65.26	2.64	0.11
37	5	4	62.59	-115.57	2.88	0.07		4	4	37.41	-65.22	2.68	0.11
38	1	3	55.98	-105.04	0.00	0.38		5	4	41.85	-74.11	0.00	0.40
38	3	4	57.03	-104.46	0.58	0.28		1	3	40.28	-73.64	0.47	0.32
38	4	4	56.21	-102.81	2.22	0.12		3	4	40.61	-71.61	2.50	0.11
38	5	4	56.16	-102.72	2.32	0.12		4	4	40.34	-71.07	3.03	0.09
38	2	4	56.02	-102.43	2.60	0.10		2	4	40.31	-71.01	3.10	0.08
39	1	3	53.49	-100.06	0.00	0.44		1	3	31.19	-55.45	0.00	0.31
39	3	4	54.07	-98.54	1.52	0.20		3	4	32.52	-55.44	0.01	0.31
39	4	4	53.59	-97.57	2.49	0.13		4	4	31.92	-54.25	1.21	0.17
39	2	4	53.52	-97.43	2.63	0.12		5	4	31.55	-53.50	1.95	0.12
39	5	4	53.50	-97.40	2.66	0.12		2	4	31.39	-53.19	2.27	0.10
40	3	4	69.55	-129.50	0.00	0.35		1	3	38.97	-71.02	0.00	0.47
40	1	3	67.90	-128.87	0.63	0.25		5	4	39.24	-68.88	2.14	0.16
40	5	4	68.85	-128.09	1.41	0.17		3	4	39.01	-68.43	2.59	0.13
40	4	4	68.74	-127.88	1.62	0.15		2	4	38.98	-68.37	2.65	0.12
40	2	4	68.06	-126.52	2.98	0.08		4	4	38.97	-68.35	2.67	0.12
41	3	4	53.71	-97.83	0.00	0.88		1	3	40.27	-73.61	0.00	0.42
41	4	4	51.52	-93.45	4.38	0.10		2	4	40.72	-71.83	1.77	0.17
41	1	3	47.92	-88.92	8.90	0.01		5	4	40.60	-71.59	2.01	0.15
41	2	4	48.71	-87.82	10.01	0.01		4	4	40.47	-71.35	2.26	0.14
41	5	4	47.95	-86.31	11.52	0.00		3	4	40.28	-70.97	2.64	0.11
42	1	3	55.25	-103.59	0.00	0.46		1	3	36.04	-65.15	0.00	0.42
42	2	4	55.45	-101.29	2.29	0.15		3	4	36.35	-63.09	2.06	0.15

	D11pcta							D12Apcta					
P	M	K	MLL	AIC$_c$	Δ_m	w_m		M	K	MLL	AIC$_c$	Δ_m	w_m
42	4	4	55.39	-101.19	2.40	0.14		4	4	36.34	-63.09	2.06	0.15
42	3	4	55.30	-100.99	2.59	0.13		5	4	36.27	-62.93	2.22	0.14
42	5	4	55.26	-100.92	2.66	0.12		2	4	36.22	-62.84	2.31	0.13
43	1	3	52.64	-98.36	0.00	0.39		1	3	49.92	-92.92	0.00	0.44
43	2	4	53.31	-97.01	1.34	0.20		2	4	50.36	-91.12	1.80	0.18
43	5	4	53.06	-96.51	1.84	0.15		4	4	50.17	-90.75	2.17	0.15
43	4	4	53.02	-96.43	1.92	0.15		3	4	49.98	-90.37	2.55	0.12
43	3	4	52.74	-95.88	2.48	0.11		5	4	49.92	-90.25	2.67	0.12
44	1	3	56.89	-106.86	0.00	0.44		1	3	41.85	-76.78	0.00	0.33
44	3	4	57.29	-104.98	1.89	0.17		3	4	42.86	-76.13	0.65	0.24
44	4	4	57.16	-104.72	2.14	0.15		4	4	42.65	-75.70	1.08	0.19
44	2	4	56.96	-104.32	2.54	0.12		2	4	42.14	-74.69	2.09	0.12
44	5	4	56.90	-104.20	2.66	0.12		5	4	42.12	-74.64	2.14	0.11
45	3	4	58.05	-106.51	0.00	0.38		5	4	42.39	-75.19	0.00	0.51
45	1	3	56.56	-106.21	0.30	0.32		1	3	40.18	-73.44	1.75	0.21
45	2	4	56.91	-104.21	2.29	0.12		2	4	40.87	-72.14	3.04	0.11
45	4	4	56.68	-103.77	2.74	0.10		3	4	40.79	-71.98	3.21	0.10
45	5	4	56.56	-103.53	2.98	0.08		4	4	40.18	-70.77	4.42	0.06
46	1	3	58.11	-109.30	0.00	0.45		1	3	36.01	-65.10	0.00	0.45
46	3	4	58.36	-107.12	2.17	0.15		3	4	36.42	-63.23	1.87	0.18
46	4	4	58.35	-107.09	2.20	0.15		4	4	36.11	-62.61	2.49	0.13
46	2	4	58.21	-106.82	2.47	0.13		5	4	36.07	-62.53	2.57	0.12
46	5	4	58.19	-106.78	2.51	0.13		2	4	36.02	-62.45	2.66	0.12
47	1	3	51.31	-95.70	0.00	0.44		1	3	38.14	-69.36	0.00	0.40
47	5	4	51.63	-93.65	2.05	0.16		4	4	38.68	-67.77	1.60	0.18
47	4	4	51.48	-93.36	2.34	0.14		3	4	38.67	-67.74	1.63	0.18
47	2	4	51.45	-93.31	2.40	0.13		2	4	38.39	-67.19	2.18	0.13
47	3	4	51.40	-93.20	2.50	0.13		5	4	38.16	-66.73	2.63	0.11
48	1	3	65.04	-123.15	0.00	0.40		1	3	48.88	-90.83	0.00	0.44

	D11pcta							D12Apcta					
P	M	K	MLL	AIC_c	Δ_m	w_m		M	K	MLL	AIC_c	Δ_m	w_m
48	5	4	65.96	-122.31	0.84	0.26		3	4	49.33	-89.05	1.78	0.18
48	2	4	65.16	-120.71	2.44	0.12		2	4	49.03	-88.46	2.37	0.14
48	4	4	65.07	-120.55	2.61	0.11		5	4	48.92	-88.23	2.60	0.12
48	3	4	65.04	-120.48	2.68	0.11		4	4	48.90	-88.20	2.63	0.12
49	1	3	51.70	-96.47	0.00	0.47		3	4	50.02	-90.44	0.00	0.46
49	2	4	51.86	-94.12	2.36	0.14		4	4	49.71	-89.83	0.61	0.34
49	4	4	51.77	-93.94	2.54	0.13		2	4	48.41	-87.23	3.21	0.09
49	5	4	51.73	-93.86	2.62	0.13		1	3	46.61	-86.30	4.14	0.06
49	3	4	51.71	-93.83	2.65	0.13		5	4	47.80	-85.99	4.45	0.05

Table A.4.4.4.4.2.4. Model-averaged coefficients for predicting the percent of Total A diversion through arc D1 specific to each 5-day period of the irrigation water year.

Period	$\hat{\hat{\beta}}_{1,p}$ *d1pcta*	$\hat{\hat{\beta}}_{2,p}$ *ppt*	$\hat{\hat{\beta}}_{3,p}$ *tmax*	$\hat{\hat{\beta}}_{4,p}$ *ptdayindex*	$\hat{\hat{\beta}}_{5,p}$ *shortdum*	$\hat{\hat{\beta}}_{6,p}$ *cumpptwint*	$\hat{\hat{\beta}}_{0,p}$ *constant*
6	0.00000	-0.00840	0.00021	-0.00316	-0.00069	0.00129	-0.00534
7	4.89474	0.00307	-0.00008	0.00071	0.00629	-0.00104	0.11349
8	1.25829	-0.67129	0.00015	-0.03989	0.00011	-0.00017	0.21523
9	0.78117	-0.41206	0.00107	-0.05936	0.00276	-0.01330	0.31869
10	1.31826	-1.48578	0.00003	-0.02144	-0.00273	-0.03078	0.15832
11	0.97914	-1.46711	0.00016	-0.03756	0.00070	-0.01120	0.25354
12	0.92898	-2.33513	0.00004	-0.04945	0.00206	-0.00060	0.36677
13	0.78099	-0.48028	0.00023	-0.32691	0.00015	0.00371	0.67261
14	0.56899	-0.93787	0.00023	-0.33477	-0.00003	0.00003	1.03871
15	0.82889	-0.28926	0.00000	-0.01456	-0.33369	0.00265	0.48421
16	0.62921	-3.75767	0.00001	-0.01883	-0.00046	-0.00029	0.81728
17	0.39790	-3.72180	0.00000	-0.01684	0.00000	0.00000	1.30555
18	0.60348	-0.02061	0.02166	-0.08892	0.00007	0.00001	-0.63705
19	0.64032	-4.47995	0.00000	-0.02919	0.00000	0.00000	0.87154
20	0.54326	-3.11626	0.00000	-0.00052	-0.00001	0.00000	0.95772
21	0.59650	-1.98105	0.00001	-0.01891	-0.00004	0.00000	0.89645
22	0.58738	-2.87929	0.00003	-0.01288	-0.03887	0.00000	0.93399
23	0.66797	-1.96561	0.00001	-0.00813	-0.00006	0.00000	0.79649
24	0.58102	-0.44357	0.00019	-0.01942	-0.02756	0.00000	0.97929
25	0.58799	-0.45708	0.00164	-0.06563	-0.00014	0.00000	0.83622
26	0.71910	-2.22443	0.00003	-0.02665	0.00000	0.00000	0.71222
27	0.79748	-0.24014	-0.00041	-0.00047	-0.01612	0.00000	0.57915
28	0.92376	-0.06480	-0.00178	0.01646	0.00162	0.00000	0.33011
29	1.09140	-2.19888	0.00000	-0.00052	0.00001	0.00000	-0.25928
30	0.85001	-0.20516	0.00004	-0.00472	0.09506	0.00000	0.30853
31	0.69106	-0.00190	-0.00276	0.04956	0.00519	0.00000	0.87585
32	0.73936	-0.20258	-0.00041	-0.00096	0.00285	0.00000	0.59554
33	0.69968	-2.95382	0.00003	-0.01589	-0.00014	0.00000	0.65606
34	0.96808	-0.81213	-0.00002	-0.00336	0.00034	0.00000	0.06084
35	0.84424	-1.21464	-0.00018	-0.00091	-0.00079	0.00000	0.31498
36	0.65902	-2.04784	0.00010	-0.02271	0.00021	0.00000	0.65816
37	0.82121	0.18396	-0.00125	0.02239	0.00220	0.00000	0.38635
38	0.92944	-1.85082	0.00000	-0.00051	0.00001	0.00000	0.07401
39	0.83461	-1.45973	0.00020	-0.11440	-0.00001	0.00000	0.26141
40	0.89172	-1.11728	0.00039	-0.05463	-0.00003	0.00000	0.04650
41	0.82994	-0.07436	0.00461	-0.09573	0.00023	0.00000	-0.21816
42	0.80064	-1.64988	0.00001	-0.00689	-0.00011	0.00000	0.19455
43	0.85920	-0.74590	0.00045	-0.10845	-0.00002	0.00000	0.10719
44	0.84725	-0.46204	0.00027	-0.02957	0.00176	0.00000	0.05451

Period	$\hat{\hat{\beta}}_{1,p}$ *d1pcta*	$\hat{\hat{\beta}}_{2,p}$ *ppt*	$\hat{\hat{\beta}}_{3,p}$ *tmax*	$\hat{\hat{\beta}}_{4,p}$ *ptdayindex*	$\hat{\hat{\beta}}_{5,p}$ *shortdum*	$\hat{\hat{\beta}}_{6,p}$ *cumpptwint*	$\hat{\hat{\beta}}_{0,p}$ *constant*
45	0.95137	-2.44737	0.00004	-0.02037	-0.00001	0.00000	-0.00353
46	0.51954	0.07166	-0.00082	0.01570	0.00141	0.00000	0.07901
47	0.30723	-0.03814	0.00000	-0.00264	-0.00218	0.00000	-0.10126
48	-0.00078	0.00057	-0.00001	0.00014	-0.00035	0.00000	0.00247
49	0.06254	0.01281	0.00000	0.00048	0.00000	0.00000	-0.00018

Within the KBPM, these estimated percentages were multiplied by an estimate of Total A diversions to compute the diversion volume for that 5-day period, which was then divided by 5 to compute the delivery volume for each day.

Table A.4.4.4.4.2.5. Model-averaged coefficients for predicting the percent of Total A diversion through arc D91 specific to each 5-day period of the irrigation water year.

Period	$\hat{\hat{\beta}}_{1,p}$ *d91pcta*	$\hat{\hat{\beta}}_{2,p}$ *ppt*	$\hat{\hat{\beta}}_{3,p}$ *tmax*	$\hat{\hat{\beta}}_{4,p}$ *ptdayindex*	$\hat{\hat{\beta}}_{5,p}$ *shortdum*	$\hat{\hat{\beta}}_{6,p}$ *cumpptwint*	$\hat{\hat{\beta}}_{0,p}$ *constant*
1	0.00000	-0.00558	0.00000	-0.00023	-0.00089	-0.00088	0.00336
2	2.36408	-0.00503	0.00027	-0.00363	-0.00096	-0.00057	-0.00163
3	1.33396	-0.00836	0.00205	-0.01564	0.01639	-0.00033	-0.07046
4	1.16868	-0.07956	0.00015	-0.00965	-0.00150	-0.00041	0.02298
5	0.99620	-0.09775	0.00037	-0.02320	-0.00653	-0.00001	0.03511
6	1.30424	-0.18141	0.00075	-0.04323	0.00029	-0.00096	0.05140
7	1.41305	-0.01239	0.00858	-0.00890	0.01628	-0.00109	-0.35941
8	1.10001	-0.05376	0.00020	-0.00583	-0.02111	-0.00378	0.08997
9	0.72463	-0.06870	0.00071	-0.01239	-0.00340	-0.07185	0.08912
10	0.66532	-0.23661	-0.00087	-0.00072	0.01005	-0.00075	0.04811
11	0.66183	-0.01409	-0.00486	0.00728	0.00574	-0.00030	0.26158
12	0.72896	-1.32435	0.00000	-0.00512	0.00075	0.00028	0.14230
13	0.83767	-0.12658	0.00064	-0.04411	-0.00142	0.00118	0.10402
14	0.66323	-0.14848	0.00038	-0.01514	-0.00036	-0.00248	0.14170
15	1.00616	-0.14127	-0.00023	-0.00493	-0.13642	-0.00009	0.11575
16	0.88618	-0.30872	-0.00054	-0.00249	-0.00364	-0.00071	0.18861
17	0.50472	-1.49939	0.00005	-0.02642	-0.00043	-0.00013	0.35678
18	0.44408	-0.03101	0.01581	-0.05887	0.00005	0.00026	-0.68761
19	0.28014	-2.06896	0.00009	-0.19401	0.00024	0.00000	0.69524
20	0.44183	-2.38322	0.00001	-0.02340	0.00081	0.00000	0.45237
21	0.35624	-2.42354	0.00002	-0.04712	0.00000	0.00000	0.74503
22	0.61450	-0.04327	0.00000	-0.00043	-0.41196	0.00000	0.54564
23	0.41989	-1.37446	0.00050	-0.05152	-0.00074	0.00000	0.62263
24	0.34829	-4.21112	0.00002	-0.06080	-0.00088	0.00000	0.81751
25	0.84271	0.00580	-0.00049	0.00549	0.00331	0.00000	0.15713
26	0.62309	-0.49588	-0.00033	-0.00122	0.00011	0.00000	0.37114
27	0.88094	-0.18408	-0.00214	0.00709	-0.01550	0.00000	0.35742
28	0.77504	-0.03044	-0.00233	0.02417	0.00300	0.00000	0.35344

Period	$\widehat{\widehat{\beta}}_{1,p}$ d91pcta	$\widehat{\widehat{\beta}}_{2,p}$ ppt	$\widehat{\widehat{\beta}}_{3,p}$ tmax	$\widehat{\widehat{\beta}}_{4,p}$ ptdayindex	$\widehat{\widehat{\beta}}_{5,p}$ shortdum	$\widehat{\widehat{\beta}}_{6,p}$ cumpptwint	$\widehat{\widehat{\beta}}_{0,p}$ constant
29	0.59289	-1.11812	0.00010	-0.13675	0.00507	0.00000	0.30315
30	0.68944	-0.24293	-0.00007	-0.00444	0.00346	0.00000	0.20350
31	0.56705	-1.20224	-0.00338	0.04650	-0.00273	0.00000	0.52813
32	0.79052	0.07667	-0.00047	0.00745	-0.02537	0.00000	0.16817
33	0.73847	-3.12125	0.00011	-0.05552	-0.00011	0.00000	0.16800
34	0.79208	-0.41364	0.00010	-0.01248	0.00826	0.00000	0.13431
35	0.67852	-2.41290	0.00000	-0.00171	0.00020	0.00000	0.20559
36	0.61753	-0.83238	0.00007	-0.01502	0.00102	0.00000	0.19564
37	0.68822	0.10934	-0.00297	0.03617	0.00042	0.00000	0.34565
38	0.74442	-0.69261	-0.00021	-0.00857	0.00685	0.00000	0.07278
39	0.57384	-0.04460	0.00027	-0.00629	-0.00003	0.00000	0.04300
40	0.42344	-0.03909	0.00215	-0.02054	-0.00093	0.00000	-0.14205
41	0.61921	-0.03202	0.00098	-0.01080	-0.00416	0.00000	-0.10590
42	0.56841	-0.00952	0.00050	-0.00559	0.00002	0.00000	-0.03554
43	0.27155	-0.03828	0.00030	-0.00627	-0.00423	0.00000	-0.00237
44	0.89970	-0.00687	0.00009	-0.00118	0.00078	0.00000	-0.01265
45	0.48782	-0.09624	0.00004	-0.00332	-0.00013	0.00000	0.00068
46	0.44229	-0.00243	0.00007	-0.00086	-0.00151	0.00000	-0.00546
47	1.87684	-0.01012	0.00005	-0.00152	0.00003	0.00000	0.04007
48	1.09058	-0.02965	0.00031	-0.00702	0.00093	0.00000	0.01186
49	0.55530	-0.05143	0.00178	-0.02231	0.00778	0.00000	-0.04411
50	0.98108	-0.03629	0.00007	-0.00316	-0.00523	0.00000	-0.00300
51	0.62378	-0.11767	0.00014	-0.00875	-0.00048	0.00000	0.00340
52	0.40152	-0.00234	-0.00004	0.00016	0.00102	0.00000	0.00036

Table A.4.4.4.2.6. Model-averaged coefficients for predicting the percent of Total A diversion through arc D11 specific to each 5-day period of the irrigation water year.

Period	$\hat{\hat{\beta}}_{1,p}$ *d11pcta*	$\hat{\hat{\beta}}_{2,p}$ *ppt*	$\hat{\hat{\beta}}_{3,p}$ *tmax*	$\hat{\hat{\beta}}_{4,p}$ *ptdayindex*	$\hat{\hat{\beta}}_{5,p}$ *shortdum*	$\hat{\hat{\beta}}_{9,p}$ *d11taf*	$\hat{\hat{\beta}}_{6,p}$ *cumd11wint*	$\hat{\hat{\beta}}_{7,p}$ *cumpptwint*	$\hat{\hat{\beta}}_{8,p}$ *pdindexd11*	$\hat{\hat{\beta}}_{0,p}$ *constant*
1	0.00000	0.00000	0.00000	0.00000	0.00000	0.07301	-0.00034	0.00023	-0.00054	0.01869
2	0.81156	-0.00174	-0.00017	0.00116	0.00932	0.00000	-0.00004	-0.00012	-0.00072	0.02610
3	0.43019	0.08239	-0.00005	0.00771	-0.00059	0.00000	-0.00001	-0.00042	-0.00086	0.01621
4	0.66484	-0.03242	0.00013	-0.00603	0.00052	0.00000	0.00001	-0.00013	-0.00003	0.00668
5	0.19510	-0.00585	0.00073	-0.00399	0.00164	0.00000	0.00010	-0.00004	0.00019	-0.01749
6	0.74089	0.15853	0.00009	0.00029	0.00076	0.00000	0.00000	0.00001	0.00004	0.00484
7	0.68091	-0.02076	0.00000	-0.00080	0.00248	0.00000	0.00001	-0.00007	-0.00001	0.01494
8	0.75170	-0.01502	0.00041	-0.00515	-0.00023	0.00000	0.00001	-0.00125	-0.00047	0.00235
9	1.00361	-0.02075	0.00015	-0.00325	-0.00311	0.00000	-0.00001	0.00004	-0.00002	-0.00228
10	0.32083	-0.11076	0.00002	-0.00414	-0.00046	0.00000	0.00000	-0.00014	-0.00021	0.03806
11	0.63233	-0.09542	-0.00003	-0.00055	-0.00059	0.00000	-0.00001	-0.00072	-0.00533	0.03604
12	0.65594	-0.01430	0.00085	-0.02756	0.00011	0.00000	0.00000	0.00000	0.00000	-0.00164
13	0.79517	-0.01189	0.00004	-0.00166	-0.00329	0.00000	-0.00006	-0.00048	-0.00533	0.02879
14	0.44772	-0.01209	0.00000	-0.00028	-0.00579	0.00000	-0.00468	0.00284	-0.00002	0.07476
15	0.82228	-0.00626	0.00009	-0.00311	0.00066	0.00000	-0.00001	0.00045	0.00035	0.02490
16	0.47569	-0.42237	0.00000	-0.00293	-0.00041	0.00000	0.00000	-0.00012	-0.00010	0.06104
17	0.83949	-0.00093	0.00006	-0.00065	-0.00152	0.00000	-0.00001	0.00028	0.00020	0.02379
18	0.06452	-0.29755	0.00008	-0.01389	0.00022	0.00000	0.00000	-0.00011	-0.00007	0.10816
19	0.41162	-0.03275	0.00066	-0.02807	0.00027	0.00000	0.00000	0.00000	0.00000	0.03074
20	0.72065	-0.32597	0.00002	-0.01170	0.00021	0.00000	0.00000	0.00000	0.00000	0.06758
21	0.60006	-0.01591	0.00009	-0.00247	-0.01668	0.00000	0.00000	0.00000	0.00000	0.06917
22	0.44099	-0.12259	0.00004	-0.00380	0.00011	0.00000	0.00000	0.00000	0.00000	0.08588
23	0.33793	-0.08527	0.00027	-0.00852	-0.00357	0.00000	0.00000	0.00000	0.00000	0.09005
24	0.33401	-0.02003	0.00038	-0.02713	-0.00509	0.00000	0.00000	0.00000	0.00000	0.09773
25	0.23845	-0.02368	0.00016	-0.00288	-0.00829	0.00000	0.00000	0.00000	0.00000	0.12582
26	0.40076	-0.22377	0.00017	-0.01903	-0.00002	0.00000	0.00000	0.00000	0.00000	0.11464
27	0.85083	-0.12250	0.00017	-0.00589	0.00126	0.00000	0.00000	0.00000	0.00000	0.02723

Period	$\hat{\hat{\beta}}_{1,p}$ d11pcta	$\hat{\hat{\beta}}_{2,p}$ ppt	$\hat{\hat{\beta}}_{3,p}$ tmax	$\hat{\hat{\beta}}_{4,p}$ ptdayindex	$\hat{\hat{\beta}}_{5,p}$ shortdum	$\hat{\hat{\beta}}_{9,p}$ d11taf	$\hat{\hat{\beta}}_{6,p}$ cumd11wint	$\hat{\hat{\beta}}_{7,p}$ cumpptwint	$\hat{\hat{\beta}}_{8,p}$ pdindexd11	$\hat{\hat{\beta}}_{0,p}$ constant
28	0.47245	0.85496	0.00000	0.00030	0.01878	0.00000	0.00000	0.00000	0.00000	0.07014
29	0.72650	-0.05503	-0.00003	-0.00270	-0.00205	0.00000	0.00000	0.00000	0.00000	0.05750
30	0.69444	-0.02431	0.00004	-0.00150	0.01467	0.00000	0.00000	0.00000	0.00000	0.02297
31	0.58760	-1.75888	-0.00041	0.00480	0.00298	0.00000	0.00000	0.00000	0.00000	0.08048
32	0.77070	-0.00247	-0.00004	0.00023	-0.00731	0.00000	0.00000	0.00000	0.00000	0.02995
33	0.66535	-0.01554	0.00001	-0.00073	-0.02172	0.00000	0.00000	0.00000	0.00000	0.04518
34	0.53705	-0.00340	-0.00019	0.00148	-0.00144	0.00000	0.00000	0.00000	0.00000	0.06634
35	0.45320	0.00214	-0.00027	0.00239	-0.00134	0.00000	0.00000	0.00000	0.00000	0.07921
36	0.65755	0.00440	0.00010	-0.00041	-0.00038	0.00000	0.00000	0.00000	0.00000	0.03655
37	0.73441	-0.09679	0.00023	-0.00667	-0.00039	0.00000	0.00000	0.00000	0.00000	0.01212
38	0.42220	-0.00349	-0.00064	0.00229	-0.00131	0.00000	0.00000	0.00000	0.00000	0.12308
39	0.54685	0.00488	0.00024	-0.00128	-0.00029	0.00000	0.00000	0.00000	0.00000	0.02126
40	0.54022	-0.00384	0.00048	-0.00279	-0.00287	0.00000	0.00000	0.00000	0.00000	0.00782
41	0.47370	-0.00237	0.00302	-0.00550	-0.00002	0.00000	0.00000	0.00000	0.00000	-0.18044
42	0.47340	-0.01208	0.00003	-0.00144	0.00027	0.00000	0.00000	0.00000	0.00000	0.03649
43	0.62588	-0.05757	0.00005	-0.00244	-0.00288	0.00000	0.00000	0.00000	0.00000	0.02007
44	0.54080	-0.01005	0.00013	-0.00174	0.00027	0.00000	0.00000	0.00000	0.00000	0.01941
45	0.98573	-0.02386	-0.00048	0.00070	-0.00002	0.00000	0.00000	0.00000	0.00000	0.03722
46	0.70021	-0.00987	0.00008	-0.00163	-0.00088	0.00000	0.00000	0.00000	0.00000	0.01247
47	0.71077	-0.01267	0.00006	-0.00186	-0.00269	0.00000	0.00000	0.00000	0.00000	0.00892
48	0.61525	0.00468	0.00000	0.00039	0.00486	0.00000	0.00000	0.00000	0.00000	0.01640
49	0.82883	0.01144	-0.00002	0.00092	-0.00066	0.00000	0.00000	0.00000	0.00000	0.00889

Table A.4.4.4.4.2.7. Model-averaged coefficients for predicting the percent of Total A diversion through arc D12A specific to each 5-day period of the irrigation water year.

Per-iod	$\hat{\hat{\beta}}_{1,p}$ ***d12apcta***	$\hat{\hat{\beta}}_{2,p}$ ***ppt***	$\hat{\hat{\beta}}_{3,p}$ ***tmax***	$\hat{\hat{\beta}}_{4,p}$ ***ptdayindex***	$\hat{\hat{\beta}}_{5,p}$ ***shortdum***	$\hat{\hat{\beta}}_{9,p}$ ***d12ataf***	$\hat{\hat{\beta}}_{6,p}$ ***cumd12awint***	$\hat{\hat{\beta}}_{7,p}$ ***cumpptwint***	$\hat{\hat{\beta}}_{8,p}$ ***pdindexd12a***	$\hat{\hat{\beta}}_{0,p}$ ***constant***
1	0.00000	0.00000	0.00000	0.00000	0.00000	0.18305	-0.00128	-0.00062	-0.01744	0.11927
2	0.81802	-0.00416	0.00356	-0.01294	-0.00141	0.00000	0.00000	0.00015	0.00026	-0.13215
3	0.50800	0.02508	0.00034	-0.00047	0.01952	0.00000	0.00007	-0.01538	-0.00328	0.06648
4	0.74563	-0.02448	-0.00004	-0.00113	0.00581	0.00000	0.00006	0.00026	0.00154	0.03679
5	0.94796	0.00776	0.00041	-0.00108	-0.03660	0.00000	-0.00014	0.00009	-0.00095	-0.03227
6	0.70165	0.00825	0.00004	0.00006	0.01693	0.00000	0.00171	-0.00029	0.00346	-0.01036
7	0.83783	-0.14322	0.00045	-0.01472	-0.00078	0.00000	0.00002	-0.00074	-0.00020	0.01350
8	0.71768	-0.03803	0.00096	-0.01296	-0.00424	0.00000	0.00000	-0.00065	-0.00060	-0.00151
9	0.81116	-0.02466	0.00025	-0.00375	-0.01483	0.00000	-0.00005	-0.00103	-0.00336	0.01049
10	0.47693	-0.19870	0.00003	-0.00749	0.01970	0.00000	0.00005	-0.00077	-0.00008	0.06323
11	0.52394	-0.05049	0.00011	-0.00569	0.00006	0.00000	0.00031	-0.01372	-0.00025	0.03948
12	0.53874	0.00830	-0.00306	0.00861	0.00237	0.00000	0.00000	-0.00027	-0.00032	0.21843
13	0.58993	-0.00289	0.00021	-0.00290	-0.00169	0.00000	-0.00015	0.02536	0.00115	0.04005
14	0.54369	-0.01630	0.00013	-0.00254	0.00176	0.00000	0.00622	-0.00014	0.00830	-0.06316
15	0.77568	-0.04073	0.00005	-0.00561	-0.00025	0.00000	-0.00116	0.00200	-0.00066	0.07246
16	0.36187	-0.28472	0.00006	-0.00882	-0.01675	0.00000	0.00008	-0.00111	-0.00006	0.12564
17	0.69767	-0.05804	0.00040	-0.01241	-0.00033	0.00000	0.00009	-0.00051	0.00020	0.04328
18	0.47018	0.00286	0.00011	-0.00074	0.00456	0.00000	0.00034	0.00058	0.00862	0.06206
19	0.22942	-0.00854	-0.00003	-0.00010	0.05956	0.00000	0.00000	0.00000	0.00000	0.15117
20	1.03382	0.00251	0.00000	0.00023	-0.07933	0.00000	0.00000	0.00000	0.00000	0.05434
21	0.76818	-0.01832	-0.00001	-0.00091	0.04779	0.00000	0.00000	0.00000	0.00000	0.04952
22	0.70908	-0.00292	0.00016	-0.00232	-0.00672	0.00000	0.00000	0.00000	0.00000	0.04407
23	0.46171	-0.12922	0.00003	-0.00435	-0.00685	0.00000	0.00000	0.00000	0.00000	0.14161
24	0.67594	0.02001	-0.00181	0.05507	0.00271	0.00000	0.00000	0.00000	0.00000	0.17308
25	0.61014	0.08799	-0.00014	0.00581	0.00959	0.00000	0.00000	0.00000	0.00000	0.09351
26	0.93549	-0.08750	0.00060	-0.01972	0.00215	0.00000	0.00000	0.00000	0.00000	-0.01883
27	0.81487	0.02788	0.00001	0.00063	0.00394	0.00000	0.00000	0.00000	0.00000	0.00657

Per-iod	$\hat{\hat{\beta}}_{1,p}$ *d12apcta*	$\hat{\hat{\beta}}_{2,p}$ *ppt*	$\hat{\hat{\beta}}_{3,p}$ *tmax*	$\hat{\hat{\beta}}_{4,p}$ *ptdayindex*	$\hat{\hat{\beta}}_{5,p}$ *shortdum*	$\hat{\hat{\beta}}_{9,p}$ *d12ataf*	$\hat{\hat{\beta}}_{6,p}$ *cumd12awint*	$\hat{\hat{\beta}}_{7,p}$ *cumpptwint*	$\hat{\hat{\beta}}_{8,p}$ *pdindexd12a*	$\hat{\hat{\beta}}_{0,p}$ *constant*
28	0.76392	-0.23708	0.00017	-0.00605	-0.00737	0.00000	0.00000	0.00000	0.00000	0.02694
29	0.81036	-0.00158	-0.00052	0.00501	-0.00129	0.00000	0.00000	0.00000	0.00000	0.06148
30	0.83403	0.18065	-0.00048	0.01650	-0.00327	0.00000	0.00000	0.00000	0.00000	0.07737
31	0.62705	5.46917	0.00036	-0.00409	0.00198	0.00000	0.00000	0.00000	0.00000	0.02542
32	0.68780	-0.14152	0.00032	-0.00844	-0.00024	0.00000	0.00000	0.00000	0.00000	0.03492
33	0.77325	0.09220	-0.00014	0.00541	-0.02715	0.00000	0.00000	0.00000	0.00000	0.04019
34	0.53871	0.08192	-0.00060	0.02100	0.00147	0.00000	0.00000	0.00000	0.00000	0.11879
35	1.06332	0.01770	0.00020	-0.00100	-0.00052	0.00000	0.00000	0.00000	0.00000	0.00698
36	0.74104	-0.01487	0.00038	-0.00345	-0.00222	0.00000	0.00000	0.00000	0.00000	0.02980
37	0.73660	0.01336	0.00005	-0.00005	0.01212	0.00000	0.00000	0.00000	0.00000	0.05461
38	0.72754	0.00388	0.00023	-0.00126	-0.02137	0.00000	0.00000	0.00000	0.00000	0.02525
39	0.67850	0.02486	-0.00115	0.01003	0.00418	0.00000	0.00000	0.00000	0.00000	0.12946
40	0.58512	-0.00461	-0.00007	0.00036	0.00380	0.00000	0.00000	0.00000	0.00000	0.04039
41	0.48806	0.06198	-0.00003	0.00252	0.00390	0.00000	0.00000	0.00000	0.00000	0.06385
42	0.85842	0.01809	-0.00018	0.00385	0.00344	0.00000	0.00000	0.00000	0.00000	0.01941
43	0.77617	0.04323	-0.00004	0.00211	0.00025	0.00000	0.00000	0.00000	0.00000	0.01957
44	0.54905	-0.03201	0.00044	-0.00596	-0.00250	0.00000	0.00000	0.00000	0.00000	0.01051
45	0.76631	-0.05339	-0.00015	-0.00012	-0.03242	0.00000	0.00000	0.00000	0.00000	0.04758
46	0.36573	-0.00601	-0.00025	0.00186	-0.00149	0.00000	0.00000	0.00000	0.00000	0.11049
47	0.50002	-0.02650	0.00032	-0.00677	-0.00074	0.00000	0.00000	0.00000	0.00000	0.05247
48	0.83936	0.01029	0.00020	-0.00061	0.00080	0.00000	0.00000	0.00000	0.00000	0.02084
49	0.84612	-0.02674	0.00136	-0.01716	0.00189	0.00000	0.00000	0.00000	0.00000	-0.05438

A.4.4.4.3. Implementing the Agricultural Water Delivery Sub-model in the KBPM

In the KBPM, the sub-model described in preceding sections has been fully implemented. For each 5-day period of the spring/summer irrigation season, the sub-model predicts the percent of Total A diversions to be delivered through each diversion arc. Several additional steps were taken within the KBPM to calculate the daily flow to be delivered through each diversion arc.

An estimate of Total A diversions was necessary in order to compute the daily diversions. Predicated on the assumption that the Project Supply will be fully used in each year, KBPM runs were iterated to obtain estimates of two variables used to estimate Total A diversions. Total seasonal diversion of return flow from the LRDC and pumps F/FF for all diversion arcs (dir_div_acc_est) was calculated from KBPM output. Also, the predicted percentages of Total A diversions from KBPM output were summed across diversion arcs for each irrigation water year, and a simple proportional adjustment (Pct_tota_adjust) was developed to correct for departures of these sums from 100%. Then the estimated Total A diversion (esttota) was calculated as:

esttota = PrjSupply_irr + dir_div_acc_est + Pct_tota_adjust * PrjSupply_irr

where PrjSupply_irr = PrjSupply - RefugeFallSupply

Daily diversions were then computed for each diversion arc by multiplying esttota by the predicted percent of Total A diversion for the appropriate 5-day period, dividing the product by 5 days, and converting the volume to cfs. D1 diversions always were comprised solely of UKL water. The other diversion arcs were split into arcs accounting for diversion of UKL water (Project Supply) as opposed to diversion of return flow.

A.4.4.5. Project Return Flows

Project return flow results from delivered water which could not be fully consumed by the Project land to which it was applied. At some times of year, return flows from irrigation are frequently mixed with runoff from precipitation or snowmelt. Return flows are considered separately for the three different irrigation areas of A1, A2 and the LKNWR (see Figure A.4.3.1.1).

Area A1 returns flow to the Lost River downstream of Harpold Dam. This return flow is accounted for through the time-series input (i.e. historical daily flow measured at LRDC headworks) of the Lost River to the Lost River Diversion Channel, or I91 in the model. Because the area between Harpold Dam and the LRDC headworks is served by D1 (A Canal) diversions, the inflows in the I91 arc were adjusted either up or down to reflect changes in A Canal diversion from what occurred historically. For example, historical I91 flow was zero for extended periods during the irrigation shutoff in 2001, whereas the KBPM simulates substantial A Canal diversion throughout 2001 under the Proposed Action. In this case, I91 flows had to be adjusted upwards to reflect the likely outcome of the Proposed Action in such a year. Conversely, simulated A Canal diversion in 1992 under the Proposed Action were much smaller than the actual diversions in that year, requiring a downward adjustment of I91 flow in the simulation.

Adjustments to LRDC inflow reflecting changed (relative to historical) A Canal diversions were made by first subtracting each 5-day period sum of simulated D1 deliveries from the historical

D1 deliveries. Multiplying this difference by 0.2, subtracting the result from I91, dividing this result by 5 days, and converting the resulting daily volume to cfs completed the adjustment. The 0.2, essentially the expected proportion of A Canal diversion expected to appear as return flow at the LRDC headworks, was selected because it produced simulated LRDC inflows of a reasonable magnitude relative to the base flow periods of other years. As a result of this process, the LRDC inflows now respond dynamically to changes in D1 diversions.

Total Area A2 return flows from the Project and Refuge lands (LKNWR and Area K) through the KSD are represented as C131 in the KBPM. Variable C131 can be further divided into return flows from the Project (return flow arc R131a) and LKNWR (return flow arc R131b), along with local runoff from the surrounding area. The Proposed Action assumes R131b to be zero, a conservative assumption reflecting the likely result of LKNWR supply reductions from the historical condition.

Agricultural return flows in R131a were simulated dynamically by a series of simple models estimating non-Refuge return flows from the F/FF pumps for different time periods throughout the year. Different models were required for different periods because of the manner with which water is managed. In Area A2, the agricultural lands are typically flooded over the winter months, pumped off in the late winter or early spring, and then irrigated through the summer and fall months. More extensive winter flood-up can be expected to incrementally reduce the irrigation demand (and the associated return flow) during the following spring and summer, and vice versa. Winter precipitation contributes to the extent of the winter flood-up, as well as the return flow volume pumped off.

All analyses were done using the 5-day periods of the irrigation water year described in Section 4.4.4.1. The irrigation water year was split into two seasons for the purpose of developing variables for use in modeling F&FF return flows. Periods 50-14 encompass the winter and spring periods when flood-up and pump-off activities are prevalent in Area A2. Periods 15-49 encompass the late spring through early fall period comprising the bulk of the growing season. Average daily precipitation (inches) and average daily maximum temperature (°F) for Area A2 were a subset of those used for the agricultural water delivery sub-model development (see section 4.4.4.1); that is, these data were from the PRISM grids in Area A2 in Figure A.4.4.4.1.1. In order to combine precipitation with diversions, average precipitation depth was converted to precipitation volume (TAF) by multiplying it by the approximate irrigated acreage within KDD (27,000 acres).

Historical daily D11 and D12A diversions into Area A2 were summed and used to quantify daily irrigation diversions into A2. Total agricultural diversion plus precipitation volume was computed for each period (variable cum_KDD_in_5d). Cumulative agricultural diversion plus precipitation volume was computed for periods 50-14 (variable cum_KDD_in_p50to14) and 15-49 (variable cum_KDD_in_p15to49); values for these two variables were held constant after the end period until the next starting period was encountered. These three variables were rescaled to be between 0 and 1 (normalized; see formula in Section A.4.4.4.1), and the prefix “norm_” was appended to each of their variable names.

Historical daily returns from the LKNWR measured at KSD at Stateline Road were subtracted from the historical daily volume pumped into the Klamath River at pumps F/FF, assuming a 1-day travel time within the KSD. These historical daily return flows absent the LKNWR returns were summed by 5-day period (variable FFFagout) and used as the dependent variable in developing the simple models used to simulate R131a in the KBPM.

Various expressions of agricultural return flow in the current period relative to combined ag diversion and precipitation as of the end of the previous period (indicated by the prefix "lag_") were calculated:

cum_KDD_in_5d_prop = (FFFagout + 1) / (lag_cum_KDD_in_5d + 1)

cum_KDD_in_p50to14_prop = (FFFagout + 1) / (lag_cum_KDD_in_p50to14 + 1)

cum_KDD_in_p15to49_prop = (FFFagout + 1) / (lag_cum_KDD_in_p15to49 + 1)

Averages by 5-day period across irrigation water year were calculated for each of these variables, denoted by the prefix "avg_".

A series of potential models estimating FFFagout was developed and evaluated based on error characteristics. For each model, error (simulated FFFagout – actual FFFagout) was summarized by 5-day period as mean error (ME), mean square error (MSE), and mean absolute error (MAE). Only the models selected for use in the KBPM are presented here. The models are:

Model_9 = max(0, avg_cum_KDD_in_5d_prop * (lag_cum_KDD_in_5d + 1) - 1)

Model_10 = max(0, model_9 + (-1 * lag_norm_cum_KDD_in_5d * model_9))

Model_11 = max(0, avg_cum_KDD_in_p50to14_prop * (lag_cum_KDD_in_p50to14 + 1) - 1)

Model_12 = max(0, model_11 + (-1 * lag_norm_cum_KDD_in_p50to14 * model_11))

Model_13 = max(0, avg_cum_KDD_in_p15to49_prop * (lag_cum_KDD_in_p15to49 + 1) - 1)

Model_14 = max(0, model_13 + (-1 * lag_norm_cum_KDD_in_p15to49 * model_13))

Model_17 = (model_11 + model_12) / 2

Model_19 = (model_9 + model_11) / 2

Model_20 = (model_9 + model_10 + model_11 + model_12) / 4

Model_22 = (model_9 + model_10 + model_11 + model_12 + model_13 + model_14) / 6

In the KBPM, R131a is computed using:

Model_11 for periods 1-9 and 62-73;

Model_19 for periods 10-32;
Model_20 for periods 33-50;
Model_22 for periods 51-55; and
Model_17 for periods 56-61.

Daily estimates of R131a were obtained by dividing each model result by the number of days in the period and converting from volume to cfs. Implementation of this logic in the KBPM makes R131a dynamically responsive to past irrigation diversions and precipitation.

Errors associated with simulating R131a (Table A.4.4.5.1) tend to be larger during the winter and early spring, tend towards overestimation during the first half of the irrigation water year, but tend towards underestimation during the last half. Note that this model structure was intended only for use in the KBPM. Real-time operational forecasts of R131a are possible and could be developed if deemed useful to operations.

Table A.4.4.5.1. Error characteristics associated with the models used to simulate R131a in the KBPM. Period is 5-day period of the irrigation water year, which begins on March 1. Error is computed as simulated minus actual FFFagout (units are TAF). ME is mean error; MSE is mean square error; and MAE is mean absolute error.

Period	ME	MSE	MAE		Period	ME	MSE	MAE
1	0.016	1.123	0.850		38	-0.151	0.121	0.285
2	0.039	1.146	0.922		39	-0.150	0.152	0.323
3	0.012	1.039	0.823		40	-0.134	0.097	0.237
4	0.010	1.531	1.008		41	-0.129	0.137	0.291
5	0.029	1.443	0.988		42	-0.089	0.087	0.232
6	0.008	1.047	0.782		43	-0.101	0.119	0.269
7	0.025	0.893	0.709		44	-0.063	0.073	0.196
8	0.015	0.960	0.765		45	-0.066	0.052	0.178
9	0.014	0.464	0.525		46	-0.046	0.031	0.129
10	0.050	0.175	0.322		47	-0.030	0.045	0.170
11	0.074	0.184	0.306		48	-0.028	0.070	0.192
12	0.068	0.211	0.334		49	-0.002	0.040	0.142
13	0.088	0.193	0.301		50	-0.069	0.042	0.141
14	0.072	0.110	0.249		51	-0.024	0.074	0.196
15	0.107	0.253	0.321		52	0.039	0.120	0.255
16	0.066	0.095	0.250		53	-0.032	0.070	0.218
17	0.093	0.160	0.287		54	-0.019	0.077	0.216
18	0.081	0.132	0.295		55	-0.031	0.117	0.220
19	0.066	0.134	0.285		56	-0.057	0.072	0.212
20	0.068	0.124	0.277		57	-0.066	0.093	0.241
21	0.079	0.163	0.332		58	-0.102	0.089	0.220
22	0.069	0.159	0.301		59	-0.096	0.122	0.260
23	0.067	0.154	0.327		60	-0.104	0.100	0.230
24	0.056	0.150	0.318		61	-0.135	0.119	0.263
25	0.050	0.164	0.334		62	0.074	0.179	0.330
26	0.059	0.142	0.291		63	0.048	0.328	0.400
27	0.077	0.154	0.311		64	0.067	0.237	0.361
28	0.075	0.153	0.311		65	0.009	0.224	0.335
29	0.066	0.104	0.262		66	-0.024	0.487	0.467
30	0.063	0.090	0.238		67	-0.021	0.581	0.537
31	0.078	0.187	0.352		68	-0.033	0.494	0.511
32	0.085	0.127	0.297		69	-0.034	0.650	0.637
33	-0.143	0.102	0.246		70	-0.028	0.846	0.735
34	-0.102	0.095	0.215		71	-0.008	0.955	0.766
35	-0.120	0.115	0.270		72	-0.006	1.140	0.886
36	-0.177	0.144	0.281		73	0.006	1.249	0.867
37	-0.199	0.119	0.281					

In past versions of the KBPM (including the original spreadsheet model, KPSIM) a variable called A2 Winter Runoff was included in determining the C131 flow. In reality, this term had little to do with runoff – it has always been an error closure term. In the present KBPM, the name A2 Winter Runoff has been dropped, although the error closure term has been retained. This error closure term, I131, is input to the KBPM as an inflow arc, though it is comprised of both positive and negative terms. It was derived by using the model structure described above to simulate the historical FFFagout, and then subtracting the simulated FFFagout from the historical.

A.4.4.6. EWA Use in Model

The EWA is accounted for through releases for the Klamath River through LRD and releases for flood protection. The flood control releases are further described in Sections A.4.4.8 and A.4.4.10. Regardless of the intent of the release, all LRD releases that are not diverted to the Project or LKNWR are counted against the EWA. Furthermore, during IGD controlled flow conditions (e.g., minimum required flows, IGD targeted flows, ramping flows), contributions to IGD flow from LRDC and F/FF pumping are counted as EWA releases when they result in an equivalent reduction in LRD releases to support Klamath River flows. This does not happen when UKL is in flood control.

Targeted flows from March to September are the sum of a formulated LRD release, Keno Reservoir accretions, and Keno to IGD accretions. These flow targets control IGD operations when they are greater than the required minimum flows. There are two LRD release formulas for EWA use: one that applies March to June, and one that applies July to September. EWA releases in service of IGD flow targets are subject to reduction under the UKL control logic (reduction applies to LRD specifically, as described below). EWA releases in service of disease mitigation/habitat flows (as defined in Section A.4.4.7 and BA, Section 4.3.2.2.2.4), minimum required IGD flows, and IGD ramping flows are not subject to reduction under UKL control logic.

The spring/summer LRD release formulation is based on EWA allocation and UKL control logic from March 1 – September 30, and additionally accounts for UKL net inflow and forecasted March-September UKL net inflow from March 1 – June 30 (but not from July 1 – September 30, as described below). From March 1 – June 30 there is also a correction applied that accelerates EWA release if there was under-release in previous days (e.g., due to UKL control) and decelerates EWA release if there was an over-release in previous days (e.g., due to flood control or surface flushing flows). The following steps are taken to calculate the LRD Release:

1. Calculate **in_pct_Mar50vol**, used to ensure that LRD releases for IGD flows properly reflect both the UKL net inflow from the previous day and an appropriate adjustment to account for NRCS forecast error experienced through the current day. This release adjustment is calculated March through June, relying upon the Mar50vol (March 1 – June 1 monthly NRCS forecast of UKL net inflow, combined with actual net inflow since March 1). Experienced forecast error is added to the Mar50vol in order to ensure that releases are increased or decreased to account for deviations from prior UKL net inflow forecasts. In addition, a further release correction, in the form of a UKLSupply dependent quadratic equation developed from model output, is made to avoid substantial over or underspending of calculated EWA across the season. The in_pct_Mar50vol variable is calculated as follows:

   $$\text{In\_pct\_Mar50vol} = \max(0, I1(-1) / (\text{Mar50vol} + \_\text{fcst\_error}) * (1 - 0.000000029263 * \text{UKLSupply}^2 - 0.000107692714 * \text{UKLSupply} + 0.082201089297))$$

   where: I1(-1) = yesterday's UKL net inflow
   Mar50vol = NRCS forecast of inflow to UKL, March through September
   fcst_error = 0 in March; otherwise, from April to June
   [Last month's 50% exceedance UKL net inflow forecast] –

[Last month's actual UKL net inflow] –
[This month's 50% exceedance UKL net inflow forecast]
UKLSupply = calculated UKL Supply as described in section A.4.4.3

2. Determine **Link_release_ss_diff**, which is the cumulative difference between what was actually released from LRD to support IGD flows yesterday and what was expected to be released to support yesterday's IGD flow target. This variable ensures that actual LRD releases remain in line with what is calculated so that seasonal expenditure of EWA remains on track to utilize the full EWA. Link_release_ss_diff serves as a correction for previous over or under release. The calculation is as follows:

   Link_release_ss_diff = C1_River(-1) – prj_credit_spill_forEWA + prj_acc_addition_to_EWA – Link_release_SS_prep(-1) + Link_release_ss_diff(-1)

   where: C1_River(-1) = yesterday's actual LRD release yesterday's actual LRD release that flows out of IGD
   prj_credit_spill_forEWA = spill of the UKL credit due to flood releases
   prj_acc_addition_to_EWA = Project return flows that supported EWA release, and, therefore, count as EWA release
   Link_release_SS_prep(-1) = yesterday's calculated LRD release for IGD flow
   Link_release_ss_diff(-1) = yesterday's computation of this same variable

3. Calculate the **Link_release_SS_prep**, which is the release of UKL water at LRD to support IGD flows. As mentioned above, this flow is calculated differently through the summer. In March through June, EWA releases are predicated on UKL net inflow and are adjusted to ensure that as much EWA water is being released as is practicable while keeping EWA expenditure on track to avoid substantial over or underspending by the end of the season. This is accomplished using the in_pct_Mar50vol and Link_release_ss_diff variables described above, as well as by reserving an amount of EWA for July through September IGD flows. This reserved volume is approximately the quantity of water needed to be released from LRD to the river from July to September to meet IGD minimum flows when Keno Reservoir and Keno Dam to IGD accretions are at their historical medians (i.e., 130,000 AF). The March through June formulation is as follows:

   Link_release_ss_prep = in_pct_Mar50vol * (EWA_River – 130 TAF – Link_release_ss_diff)

   where: in_pct_Mar50vol = UKL net inflow release adjustment
   EWA_River = calculated EWA allocation
   Link_release_ss_diff = cumulative difference between actual and calculated LRD release for IGD flow

   For July through September, it is no longer necessary to make the adjustments needed in the March through June period. There is a known volume of EWA remaining, and it is all intended to be expended. If more UKL water is needed to support EWA minima in the July through September period than is remaining in the EWA, UKL supports the over expenditure of EWA to ensure minima are met. The July through September formula is as follows:

Link_release_ss_prep = EWA_remain_JulSep / daysinmonth

where: EWA_remain_JulSep = EWA volume remaining, adjusted for each month; July receives 35% of the remaining volume for July – September, August receives 44% of the remaining volume for August – September, and September receives what remains on September 1.

daysinmonth = the number of days in the current month

4. Determine **Link_release_SS** by adjusting Link_release_ss_prep by the appropriate storage difference ratio (UKL control logic).

5. If the formulated LRD release exceeds the maximum possible LRD release (variable Link_max is the maximum LRD release that varies with UKL surface elevation), then the maximum possible release will be made but the actual IGD flows can fall short of the target. Maximum possible releases range from a high of 8,600 cfs when UKL level is 4143.3 ft., to a low of 900 cfs when UKL level is 4137.0 ft.

6. Lookup **IGmin**, which is the minimum flow at the gauge below IGD (minima for other months not shown here). If the IGD flow target is less than the minimum flow required, then the minimum required flow is released at IGD.

Table A.4.4.6.1. Minimum flow below Iron Gate Dam, March through September

Month	IG_MIF (cfs)
March	1000
April	1325
May	1175
June	1025
July	900
August	900
September	1000

7. Set **C1forC15**, the LRD release to support IGD flows. For the spring/summer period, this is equal to Link_release_SS.

8. Calculate **C15_target**, which is the targeted release at IGD. This calculation relies upon operational values from 3 days prior, the operational delay accounted for in the model, and a forecast of accretions from 3 days prior. Operationally, IGD releases may vary from those calculated here due to real-time accretion values and flood control operations. Releases are not allowed to exceed a specified maximum (IG_max) during the July-September period. Values for IG_max vary with EWA_River, ranging from 1000-1500 cfs in July, 1050-1250 cfs in August, and 1100-1350 cfs in September.

C15_target = min(IG_max, C1forC15 + I10(-3) + I15_forecast2(-3))

where: I10 = LRD to Keno Dam (Keno Reservoir) accretions;
I15_forecast2 = forecasted Keno Dam to IGD accretions;
(-3) = operational lag of three days assumed in the model.

A.4.4.7. Surface Flushing Flows

In addition to normal UKL releases to support IGD flows during the spring/summer period, the PA implements a surface flushing flow between March 1 to April 15 based on criteria outlined below. See the Biological Assessment, Section 4.3.2.2.2.4 for additional context regarding Reclamation's proposed implementation of approximately 50,000 AF of EWA in dry years and considerations for real-time operations.

Spring/summer IGD flow targets are determined as described in Section A.4.4.6 on a daily basis. However, between March 1 and April 15, a surface flushing flow may replace the daily formula for a three-day period under certain conditions. Surface flushing flows are forced by the model in years in which calculated EWA on March 1 or April 1 is less than 576,000 AF and certain hydrologic conditions are met. If hydrologic conditions supporting a 6,030 cfs surface flushing flow do not occur in these forced flow years, the model will produce maximum releases from Link River Dam for three days beginning on April 15. In years in which the calculated EWA on March 1 or April 1 is greater than or equal to the 576,000 AF threshold, a surface flushing flow may occur on an opportunistic basis if favorable hydrologic conditions exist. Implemented surface flushing flows are subject to ramping rates (see A.4.4.11). Flows which meet the KBPM criteria of a surface flushing flow, but happen outside of the March 1 to April 15 window, will not satisfy model requirements of a surface flushing flow. All surface flushing flow releases are counted against the EWA.

Model conditions on a surface flushing flow are described below. These releases replace normal IGD minimum flows when they are triggered, effectively forcing the model to produce a three-day, 6,030 cfs flow at IGD with attendant releases from LRD. At the end of the three-day period, normal calculation of Link River release resumes.

1. Determine **Link_max_DG1**, which is a conservative estimate of the maximum release from LRD in the months of March and April. The flow estimate is made conservative via a reduction in yesterday's UKL elevation by 0.3 ft., which has the effect of lowering the maximum assumed release. This is to ensure that there is sufficient head to meet the required flow even as UKL levels are dropping over the three-day release. The reduced UKL elevation is used to select a release value from the table **Link_max.table** in KBPM. Intermediary values are linearly interpolated.

2. Calculate **I15_proj_3day**, an average of forecasted Keno Dam to IGD accretions for the next three days. These accretion values are based on the accretion forecast model described in Section A.4.3.3.6. This variable, along with Link_max_DG1, will be used to determine if hydrologic conditions will exist for the next three-day period that would support a surface flushing flow.

I15_proj_3day = (I15_forecast0 + I15_forecast1 + I15_forecast2) / 3

where: I15_forecast0 = Keno Dam to IGD accretion forecast for today
I15_forecast1 = Keno Dam to IGD accretion forecast for tomorrow
I15_forecast2 = Keno Dam to IGD accretion forecast for 2 days from today

3. Set **DG1_daycount**, a counter that will begin when a surface flushing flow is triggered and ensure that the flow does not exceed the three-day period prescribed in the model.

4. Determine **DG1_supply**, which is a variable that will replace the IG_min if a flushing flow is triggered. The value of this variable is 6,030 cfs, except in the case of a forced flushing flow in which conditions do not allow for release of this magnitude. In this case, maximum LRD releases will be made to create the highest possible IGD flows achievable for three days. Conditions which trigger a flushing flow are as follows:

   a. Forced flushing flow will be implemented if:
      i. Date is between March 1 and April 15;
      ii. EWA <576,000 AF;
      iii. Link_max_DG1 + I15_proj_3day > 6030 cfs; and
      iv. S1yestelev (yesterday's UKL elevation) ≥ 4142.4 ft.

   b. Opportunistic flushing flow will be implemented if:
      i. Date is between March 1 and April 15;
      ii. EWA ≥ 576,000 AF;
      iii. Link_max_DG1 + I15_proj_3day ≥ 6030 cfs;
      iv. S1yestelev (yesterday's UKL elevation) ≥ 4142.4 ft.; and
      v. C15(-1) [yesterday's Iron Gate Dam flow] ≥ 3999 cfs.

   c. If March/April 1 EWA is less than 576,000 AF and no flushing flow has been implemented by April 15, a flushing flow (maximum possible, up to 6,030 cfs, release for 72 hours) is attempted regardless of UKL elevation, maximum LRD capacity, or IGD flow.

5. Once a surface flushing flow has been triggered during the March 1 to April 15 time period in a given water year, the model will not try to produce the surface flushing flow again in that water year.

A.4.4.8. Enhanced May and June Flows

In average to below average water years, additional EWA releases may be made in May and June to enhance IGD flow targets to benefit coho salmon. To accomplish these additional flows, EWA is augmented by 20,000 AF, 10,000 AF of which comes from Project Supply, in years of concern. Criteria for the implementation of these enhanced flows are outlined below. *See* the Revised Proposed Action, Part 4.3.2.2.2.5 for additional information on the use of 20,000 AF of additional EWA and considerations for real-time operations.

EWA allocation is determined on a monthly basis from March 1 through July 1 as described in Section A.4.4.3, and spring/summer IGD flow targets are determined as described in Section

A.4.4.6 on a daily basis. However, when EWA allocation on April 1 is greater than 400,000 AF (407,000 AF in Boat Dance years) and less than 576,000 AF, an additional EWA volume of 20,000 AF is released in the months of May and June to enhance daily IGD flow targets. This process is described below:

1. Determine if a MayJuneAugment is needed. If April 1 EWA_River is greater than 400,000 AF (407,000 AF in Boat Dance years) and less than 576,000 AF, the MayJuneAugment is activated. This triggers the release of an additional 20,000 AF of EWA in addition to IGD flow targets in the months of May and June.

2. Set the **MayJuneAdjust**, a daily flow enhancement volume. In order to expend the full 20,000 AF in May and June, a set volume of water is released each day of each month. In May, 12,000 AF is released at the rate of 195 cfs/day. In June, 8,000 AF is released at the rate of 134 cfs/day.

3. Daily augmentation volumes are added to the C15target or the IG_Min, as applicable. See Section A.4.4.6 for details on the calculation of these variables.

4. Ensure that flow targets are not incrementally decreased by the Link_release_ss_diff. Daily flow augmentation values are subtracted from the calculation of this variable. See Section A.4.4.6 for details on calculation of Link_release_ss_diff.

5. Increase the EWA_River after enhanced May/June flows are completed. In years when the MayJuneAugment is triggered, EWA_River is increased on July 1 by 20,000 AF, ensuring that post-June river flows properly reflect the additional May/June volume.

A.4.4.9. EWA and Flood Control Releases

Flood control releases occur any time UKL elevation exceeds the allowable flood control elevation under normal operations criteria (discussed further in Section A.4.4.10). During the irrigation season, these releases typically occur March through May in average to wet years, but can occur at any time of year depending on the rate of snow melt, fall and winter inflow, and carry over storage in UKL.

When releases are made for flood control, they are counted against the EWA and factored into future EWA releases. In some cases, the flood control releases can be so large that the remaining EWA volume would not be considered adequate to provide acceptable Klamath River fish habitat for the remainder of the spring/summer period.

In order to ensure that sufficient EWA volume remains to complete formulaic IGD releases during the final, or “baseflow,” months of the spring/summer period (July through September), EWA volume may need to be reset to a higher volume to account for high expenditures during March through June. When EWA releases above those needed to meet LRD minimum flows are made, these volumes are tracked cumulatively. If the cumulative volume exceeds a percentage of total EWA, a protective increase in EWA is made to support completion of formulaic flows. This protection is considered whenever the total releases made to support river flows in excess of the minimum LRD release (or excess releases) have exceeded 22% of EWA_River by June 1.

This measure ensures a certain volume of remaining EWA each month according to the following criteria:

1. If the total excess releases that have occurred by June 1 exceed 22% of the EWA on June 1, then the remaining EWA is reset to 25% of the total June 1st EWA.

2. If the total excess releases that have occurred by July 1 exceed 22% of the EWA (as calculated on June 1), then the remaining EWA is reset to 18% of the total EWA.

3. If the total excess releases that have occurred by August 1 exceed 22% of the EWA (as calculated on June 1), then the remaining EWA is reset to 13% of the total EWA.

4. If the total excess releases that have occurred by September 1 exceed 22% of the EWA (as calculated on June 1), then the remaining EWA is reset to 7% of the total EWA.

It is unlikely that spills will continue after June, however the potential for this does occur in very wet years where UKL remains full throughout the spring. The model results show that, when following this management plan, flood control releases do not occur in any year in the period of record after June.

A.4.4.10. LKNWR Operations

Water delivery to LKNWR is modeled in the KBPM in four distinct time periods: April through September delivery of a water right transferred from Upper Klamath National Wildlife Refuge (UKNWR; see the Biological Assessment, Section 4.3.2.2.8 for additional details); June through July delivery of UKL water; August through November delivery of Project Supply (see the Biological Assessment, Section 4.3.2.2.2.2 for additional details); and December through February delivery of winter maintenance flow. Reclamation, USFWS, and Project irrigators are currently undertaking a process to develop a shortage sharing agreement (per the 2017 memo from Deputy Secretary of the Interior Connor) to distribute a portion of Project Supply to LKNWR; as this process is on-going, this Biological Assessment will not include specific information regarding LKNWR deliveries from Project Supply between August and November. See the Biological Assessment, Section 4.3.2.2.2.2 for additional context and details regarding this process.

There is no provision for delivery to LKNWR in the month of March. All modeled delivery of water to LKNWR occurs through the Ady Canal. Additional water may be made available to LKNWR from the D Plant pumps, but this water is not modelled in the KBPM nor considered within the scope of this action. However, it is Reclamation's assumption that D Plant water, if and when delivered, will be utilized on LKNWR, unless the water is necessary to meet other legal obligations of the Project.

1. Delivery of the transferred water right occurs from April 1 through September 30. This water right, transferred from its original place of use at UKNWR, is for a daily flow of up to 30.3 cfs, which is the determined consumptive use volume of the transferred right. This flow is delivered on a daily basis in the model and is not subject to reduction via the UKL control

logic. Delivery of this transferred water right is only available if Sevenmile Creek is not regulated to a senior water right (i.e., the Project); the portion of the original UKNWR water right on the Wood River was not considered here given that the Wood River is often regulated to the Klamath Tribes' Time Immemorial water right and therefore not available for transfer. See the Biological Assessment, Section 4.3.2.2.8 for additional details regarding this transferred water right.

2. Delivery of UKL water to LKNWR in the June 1 through July 31 period is conditioned on the following:

    a. The refuge has no target delivery in June through July if Project Supply is less than 350 TAF, which is considered a full supply in this Proposed Action.

    b. In June through July, if the Project has a full supply and if UKL elevation is above the threshold level denoted in Table A.4.4.9.1, then LKNWR can receive a daily delivery equal to the monthly demand, also in Table A.4.4.9.1, converted to cubic feet/second and divided by the number of days in the month. These deliveries are conditioned on UKL elevation remaining above the threshold for the month; if UKL drops below this threshold, deliveries will cease. Deliveries in these months of UKL water do not count against Project Supply nor do they affect delivery of the aforementioned transferred water right.

Table A.4.4.9.1. Monthly LKNWR demand and UKL elevation threshold which condition LKNWR deliveries.

Month	Refuge Demand (TAF)	UKL Threshold (ft)
June	5.94	4142.5
July	6.93	4141.5

3. The details regarding delivery of Project Supply to LKNWR have not yet been established. As mentioned above, Reclamation, USFWS, and Project irrigators are currently undertaking a process to determine what portion of Project Supply is appropriate for delivery to LKNWR between August 1 and November 30; those details are not yet available. See the Biological Assessment, Section 4.3.2.2.2.2 for additional details regarding this process.

4. A maintenance flow is made available to LKNWR in the months of December through February. This flow is intended to allow LKNWR managers to receive water during a time of decreased demand from other users in order to manage their resources for the Spring-Summer season when demand from other users is highest and less water is made available to the refuge. Flows during this time period are capped at 62 cfs/day, or a total of up to 11,000 AF for the December through February period. These flows are subject to reduction via UKL control logic on a daily basis.

A.4.4.11. Flood Control Operations

Flood control operations are implemented in order to protect the infrastructure surrounding UKL. The modeled flood control operations were developed to mimic realistic flood control operations; however real-time management (i.e., professional judgement) will also be used in order to ensure safety and appropriate water management within UKL. The modeled operations manage the water during winter and early spring in a manner that prevents UKL from filling too early and remaining at or near full pool for several months in wetter years. The modeled flood control operations attempt to balance liability risk with risks associated with diminished water supplies for the Project, LKNWR, and the Klamath River. Actual flood control releases will be made at the discretion of Reclamation and PacifiCorp (the operator of LRD) in coordination with USFWS and National Marine Fisheries Service.

Outline of Flood Control Operations
The general process of flood control consists of spilling water from UKL when necessary to prevent elevations from increasing above flood pool elevations, which change throughout the year in response to inflow forecasts and experienced hydrology. Flood pool elevation is calculated each day to create a smooth UKL operation, allowing UKL to fill by the end of March in drier years and by the end of April in wetter years.

The flood control elevations (termed "threshold" by the model language included below) are determined through the following process:

1. The UKL flood control elevation is set at 4141.4 ft. in September and October and then is steadily increased from 4141.4 ft. to 4141.8 ft. from November 1 through December 31. In most years, there are no flood control releases during these months.

2. From January 1 through April 30, the UKL flood control elevations are determined based on the forecasted inflow and the day of the month. The NRCS UKL net inflow forecast is used to determine the end of month flood control elevation each month (using Table A.4.4.10.1 below) and the daily flood control elevation is linearly interpolated between the current end of month elevation and the previous month's end of month flood control elevation.

    a. The distinction between wet conditions and dry conditions in Table A.4.4.10.1 is made based on the NRCS March through September 50% exceedance probability forecast for UKL net inflow volume issued in January, February and March. The forecast issued in March is used for both March and April. If the forecasted March through September net UKL inflow is greater than 710,000 AF, the year is considered wet; the water year is considered dry if the forecasted net inflow is equal to or less than 710,000 AF.

    b. The daily flood control elevation is calculated using the equation below:

Current Threshold = [Yesterday's threshold value] + ([This month's threshold] – [Last month's threshold]) / [Number of days in the month]
Note: The threshold will not decrease from day to day.

3. The UKL flood control elevations remain at the April 30 level from May 1 through August 31.

Table A.4.4.10.1. UKL flood control elevations for the last day of each month under relatively dry or wet conditions.

Month	Dry Condition Elevation (ft) (Forecast ≤ 710 TAF)	Wet Condition Elevation (ft) (Forecast > 710 TAF)
October	4141.4	4141.4
November	4141.6	4141.6
December	4141.8	4141.8
January	4142.3	4142.0
February	4142.7	4142.4
March	4143.1	4142.8
April	4143.3	4143.3

A.4.4.12. Flow Ramping

Flow ramping at IGD

The target ramp down rates at IGD are as follows:

- When IGD flows are greater than 4,600 cfs: decreases in flows of no more than 2,000 cfs per 24-hour period, and no more than 500 cfs per six-hour period.
- When IGD flows are greater than 3,600 cfs but equal to or less than 4,600 cfs: decreases in flows of 1,000 cfs or less per 24-hour period, and no more than 250 cfs per six-hour period.
- When IGD flows are greater than 3,000 cfs but equal to or less than 3,600 cfs: decreases in flows of 600 cfs or less per 24-hour period, and no more than 150 cfs per six-hour period.
- When IGD flows are above 1,750 cfs but equal to or less than 3,000 cfs: decreases in flows of 300 cfs or less per 24-hour period, and no more than 125 cfs per four-hour period.
- When IGD flows are 1,750 cfs or less: decreases in flows of 150 cfs or less per 24-hour period and no more than 50 cfs per two-hour period.

Upward ramping is not restricted.

The KBPM includes only the very crude representation of PacifiCorp reservoir storage and operations necessary to implement the operations described in this appendix. Therefore, the model is only able to adjust LRD releases to attempt to comply with the ramping rate restrictions assumed. In addition, LRD releases cannot necessarily be adjusted to comply with the ramping rate restrictions if unregulated flows (i.e., flood releases) are present at LRD or IGD.

Table A.4.4.3.1 Elevation storage-area for Upper Klamath Lake

Active Storage (TAF)	Elevation (ft.)	Area (acres)
0.000	4136.0	66,109
6.610	4136.1	66,321
13.255	4136.2	66,461
19.914	4136.3	66,579
26.585	4136.4	66,701
33.255	4136.5	66,824
39.929	4136.6	66,927
46.633	4136.7	67,007
53.344	4136.8	67,082
60.062	4136.9	67,155
66.775	4137.0	67,228
73.488	4137.1	67,299
80.228	4137.2	67,371
86.975	4137.3	67,443
93.730	4137.4	67,514
100.478	4137.5	67,584
107.227	4137.6	67,654
114.002	4137.7	67,725
120.785	4137.8	67,798
127.576	4137.9	67,880
134.367	4138.0	68,080
141.175	4138.1	68,349
148.023	4138.2	68,467
154.882	4138.3	68,572
161.751	4138.4	68,674
168.616	4138.5	68,775
175.486	4138.6	68,877
182.385	4138.7	68,979

Active Storage (TAF)	Elevation (ft.)	Area (acres)
189.295	4138.8	69,083
196.215	4138.9	69,187
203.133	4139.0	69,294
210.054	4139.1	69,404
217.007	4139.2	69,516
223.971	4139.3	69,635
230.998	4139.4	70,809
238.182	4139.5	72,984
245.526	4139.6	74,049
252.971	4139.7	74,672
260.471	4139.8	75,180
268.021	4139.9	75,668
275.608	4140.0	76,225
283.247	4140.1	76,843
290.968	4140.2	77,454
298.756	4140.3	78,156
306.618	4140.4	78,963
314.552	4140.5	79,878
322.574	4140.6	80,890
330.725	4140.7	81,982
338.987	4140.8	83,098
347.359	4140.9	84,174
355.819	4141.0	85,167
364.364	4141.1	86,055
373.018	4141.2	86,839
381.746	4141.3	87,519
390.535	4141.4	88,088
399.359	4141.5	88,549
408.216	4141.6	88,921

Active Storage (TAF)	Elevation (ft.)	Area (acres)
417.133	4141.7	89,231
426.078	4141.8	89,491
435.047	4141.9	89,705
444.018	4142.0	89,880
452.996	4142.1	90,031
462.015	4142.2	90,166
471.047	4142.3	90,292
480.090	4142.4	90,405
489.127	4142.5	90,508
498.165	4142.6	90,607
507.240	4142.7	90,703
516.324	4142.8	90,798
525.417	4142.9	90,891
534.502	4143.0	90,982
543.587	4143.1	91,071
552.707	4143.2	91,164
561.838	4143.3	91,265
570.974	4143.4	91,376
580.110	4143.5	91,486

Section A: Model Variables

Table A.4.3.4.1. Model Variables (note that *cfs_taf or *taf_cfs in a formula denotes conversion to new units; (-1) in formula refers to yesterday's value for a given variable; "Total A" refers to sum of delivery volumes for arcs D1, D11, D12A, and D91 or A Canal, North Canal, Ady Canal for agriculture, and Miller Hill/Station 48, respectively).

Variable Name in Model code	Common Name	Definition	Output Variable Name	Model File of Initial Definition
A2FW	Winter water right for A2 diversions	Winter water right for A2 diversions, set to 28.910 taf.	-	Definitions.wresl
adj_endhi	Variable used to compute adj_uklcentral	Set to 0.5. Used to compute adj_uklcentral.	-	UKLThresholds.wresl
adj_endlow	Variable used to compute adj_uklcentral	Set to -0.5. Used to compute adj_uklcentral.	-	UKLThresholds.wresl
adj_intercept	Variable used to compute adj_uklcentral	Computed as: adj_endhi - norm_inf_hi * adj_slope	adj_intercept_	UKLThresholds.wresl
adj_slope	Variable used to compute adj_uklcentral	Computed as: (adj_endhi - adj_endlow) / (norm_inf_hi - norm_inf_low)	adj_slope_	UKLThresholds.wresl
Apr50	April NRCS forecast	April NRCS 50% exceedence forecast for total April-September UKL net inflow.	-	Definitions.wresl
avg_cum_KDD_in_5d_prop	Average cum_KDD_in_5d_prop	Average cum_KDD_in_5d_prop by 5-day period across irrigation water years.	avg_cum_KDD_in_5d_prop_	AgRefOps.wresl
avg_cum_KDD_in_p15to49_prop	Average cum_KDD_in_p15to49_prop	Average cum_KDD_in_p15to49_prop by 5-day period across irrigation water years.	avg_cum_KDD_in_p15to49_prop_	AgRefOps.wresl
avg_cum_KDD_in_p50to14_prop	Average cum_KDD_in_p50to14_prop	Average cum_KDD_in_p50to14_prop by 5-day period across irrigation water years.	avg_cum_KDD_in_p50to14_prop_	AgRefOps.wresl
C1	Link River Dam Release	Total Link River flow released out of Link River Dam from Upper Klamath Lake.	C1	Channel-table.wresl
C1_AG	Link Ag release	Link release to support Ag and refuge diversions at Station 48, Miller Hill, North Canal and Ady Canal	C1_AG	Channel-table.wresl
C1_EXC	Link excess release	Link release in excess of minimum flow requirement and needs of Ag and refuge diversions. Likely due to UKL flood control spill or Iron Gate flow requirements.	C1_EXC	Channel-table.wresl
c1_EXCcumdv	Cumulative C1_EXC releases	Cumulative volume released through the C1_EXC arc beginning on March 1.	c1_EXCcumdv	SeasonalSupply.wresl

Variable Name in Model code	Common Name	Definition	Output Variable Name	Model File of Initial Definition
C1_MIF	Link MIF requirement	Portion of Link release made to support the Link minimum instream flow requirement.	C1_MIF	Channel-table.wresl
C1_River	Link river release	Portion of Link release that flows out of Iron Gate Dam. This is accounted for as an EWA release from March to September.	C1_River	Channel-table.wresl
C13	Keno Dam Release	Release at Keno Dam on the Klamath River.	C13	Channel-table.wresl
C131	Klamath Straits Drain flow (or Pumping Plant F/FF)	Return flows and runoff from the A2 area and LKNWR that are pumped through pumping plant F/FF.	C131	Channel-table.wresl
C131_IG	F/FF pumping to Iron Gate	F/FF pumping that flows out Iron Gate. This is accounted for as an EWA release from March to September when Iron Gate is under controlled flow (minimum, target, or ramping).	C131_IG	Channel-table.wresl
C131_PRJ	F/FF pumping to project	F/FF pumping that is re-diverted by the project at Station 48, Miller Hill, North Canal or Ady Canal.	C131_PRJ	Channel-table.wresl
C15	Iron Gate Dam flow	Flow downstream of Iron Gate Reservoir on the Klamath River.	C15	Channel-table.wresl
C15_EXC	Iron Gate excess flow	Flow in excess of all requirements (MIF, TARG, and RAMP) caused by UKL and/or Iron Gate reservoir flood spill.	C15_EXC	Channel-table.wresl
C15_MIF	Iron Gate MIF requirement	Portion of Iron Gate flow needed to meet minimum instream flow requirement.	C15_MIF	Channel-table.wresl
C15_RAMP	Iron Gate ramping flow	Increment of Iron Gate flow above MIF and TARG needed to support flow ramping requirements.	C15_RAMP	Channel-table.wresl
C15_TARG	Iron Gate target flow	Increment of Iron Gate flow above minimum required needed to meet Iron Gate target flow.	C15_TARG	Channel-table.wresl
C15target	Daily Iron Gate flow target	Daily Iron Gate flow target.	C15target_	UKLReleases.wresl
C15target_prep1	Variable used to determine whether Iron Gate Reservoir should be filled to spillway	This is a C15 target used to determine whether Iron Gate must be filled to spillway elevation to hit a flow target above 1700 cfs. Computed as: C1forC15dv(-1) + I10(-1) + I15_forecast1(-1).	C15target_prep1_	UKLReleases.wresl

Variable Name in Model code	Common Name	Definition	Output Variable Name	Model File of Initial Definition
C15target_prep2	Variable used to determine whether Iron Gate Reservoir should be filled to spillway	This is a C15 target used to determine whether Iron Gate must be filled to spillway elevation to hit a flow target above 1700 cfs. Computed as: C1forC15dv(-2) + I10(-2) + I15_forecast2(-2).	C15target_prep2_	UKLReleases.wresl
C1forC15	Daily target releases from UKL for setting Iron Gate targets	Daily target releases from UKL for setting Iron Gate targets. During October-February, set equal to Link_WF_target. During March-September, set equal to Link_release_SS.	C1forC15dv	UKLReleases.wresl
C91	Lost River Diversion Channel	LRDC flow to the Klamath River (+) or from the Klamath River (-).	C91	Channel-table.wresl
cum_KDD_in_5d_	Total KDD_indv volume by 5-day period	KDD_indv volume summed within each 5-day period of the irrigation water year.	cum_KDD_in_5d_	AgRefOps.wresl
cum_KDD_in_p15to 49_	Cumulative volume input to KDD for periods 15 through 49	Cumulative volume input (diversion and precipitation) to KDD for periods 15 (May 10) through 49 (October 31).	cum_KDD_in_p15to 49_	AgRefOps.wresl
cum_KDD_in_p50to 14_	Cumulative volume input to KDD for periods 50 through 14	Cumulative volume input (diversion and precipitation) to KDD for periods 50 (November 1) through 14 (May 9).	cum_KDD_in_p50to 14_	AgRefOps.wresl
Cum_Ppt	Cumulative daily Project-area precipitation	Cumulative daily precipitation (in) since March 1 through each 5 day period of the irrigation water year for the Project area	Cum_Ppt_	AgForecast.wresl
Cum_Tmax	Cumulative daily Project-area maximum temperature	Cumulative daily maximum air temperature (°F) since March 1 through each 5 day period of the irrigation water year for the Project area	Cum_Tmax_	AgForecast.wresl
CumAg_ss_Del	Cumulative spring-summer ag diversions from UKL	Cumulative volume of surface water diverted for ag use under spring-summer operations from UKL from March through November.	CumAg_ss_DelDV	SeasonalSupply.wresl
CumAg_ss_Div	Cumulative spring-summer ag diversions from all surface water sources	Cumulative volume of surface water diverted for ag use under spring-summer operations from March through November, including diversion of water from UKL, non-UKL water from LRDC, and F/FF return flow.	CumAg_ss_DivDV	SeasonalSupply.wresl
CumAgLRDC_ss_D el	Cumulative spring-summer ag diversion from LRDC and F/FF returns	Cumulative volume of surface water diverted for ag use under spring-summer operations from March through November, including diversion of non-UKL water from LRDC, and F/FF return flow.	CumAgLRDC_ss_ DelDV	SeasonalSupply.wresl

Variable Name in Model code	Common Name	Definition	Output Variable Name	Model File of Initial Definition
cumd11wint	Prior winter D11 diversions	Cumulative total D11 diversions within each irrigation water year from period 56 (December 1) through period 73 (the end of February).	cumd11wint_	AgForecast.wresl
cumd12awint	Prior winter D12A diversions	Cumulative total D12A diversions within each irrigation water year from period 56 (December 1) through period 73 (the end of February).	cumd12awint_	AgForecast.wresl
cumI15	Cumulative volume of Keno-to-Iron Gate accretions	Cumulative volume (taf) of accretions to the Keno-to-Iron Gate reach of the Klamath River beginning Oct 1.	cumI15_	FallWinterRiverOps. wresl
cumpptwint	Cumulative winter precipitation	Cumulative Prj_Ppt within each irrigation water year from period 56 (December 1) through period 73 (the end of February).	cumpptwint_	AgForecast.wresl
CumRefDeliv_fw_D V	Cumulative fall-winter deliveries to the Refuge from UKL	Cumulative delivery of UKL water through D12B to the Refuge from December-February.	CumRefDeliv_fw_ DV	SeasonalSupply.wresl
CumRefDeliv_ss_D V	Cumulative spring-summer deliveries to the Refuge from UKL	Cumulative delivery of UKL water through D12B to the Refuge from March-November.	CumRefDeliv_ss_ DV	SeasonalSupply.wresl
D1	A Canal Deliveries	A Canal project deliveries to area A1	D1	Delivery-table.wresl
D1_5d_	Daily simulated D1 volume	Simulated volume diverted into D1 on the current day.	D1_5d_	Definitions.wresl
D1_5d_Cum_	Total simulated D1 volume for five_day_period	Total simulated volume diverted into D1 in each five_day_period.	D1_5d_Cum_	Definitions.wresl
D1_act_	Daily actual D1 volume	Historic (actual) volume diverted into D1 on the current day.	D1_act_	Definitions.wresl
D1_act_5d_Cum_	Total actual D1 volume for five_day_period	Total historic (actual) volume diverted into D1 in each five_day_period.	D1_act_5d_Cum_	Definitions.wresl
D1_const	Constant for D1 deliveries as percent of Total A	Model-averaged constant for D1 deliveries as percent of Total A.	-	AgForecast.wresl
D1_cumpptwint	Coefficient for cumpptwint influence on D1 deliveries as percent of Total A	Model-averaged coefficient for the influence of cumpptwint on D1 deliveries as percent of Total A.	-	AgForecast.wresl

Variable Name in Model code	Common Name	Definition	Output Variable Name	Model File of Initial Definition
D1_I1_d1pcta	Coefficient for D1 deliveries as percent of Total A	Model-averaged coefficient for D1 deliveries as percent of Total A from the previous 5-day period.	-	AgForecast.wresl
D1_I1_ppt	Coefficient for Prj_Ppt influence on D1 deliveries as percent of Total A	Model-averaged coefficient for the influence of Prj_Ppt (lagged to the previous 5-day period) on D1 deliveries as percent of Total A.	-	AgForecast.wresl
D1_I1_ptdayindex	Coefficient for ptdayindex influence on D1 deliveries as percent of Total A	Model-averaged coefficient for the influence of ptdayindex (lagged to the previous 5-day period) on D1 deliveries as percent of Total A.	-	AgForecast.wresl
D1_I1_tmax	Coefficient for Mean_Tmax influence on D1 deliveries as percent of Total A	Model-averaged coefficient for the influence of Mean_Tmax (lagged to the previous 5-day period) on D1 deliveries as percent of Total A.	-	AgForecast.wresl
D1_pcta_reg_	Forecasted D1 delivery percent of Total A	Forecasted D1 delivery percent of Total A for the current 5-day period.	D1_pcta_reg_	AgForecast.wresl
D1_RealPCTA	Historical D1 delivery as percent of Total A	Historical daily D1 diversion volume percentage of Total A deliveries (Mar-Oct) summed within each 5-day period of the irrigation water year.	D1_RealPCTA_	AgForecast.wresl
D1_shortdum	Coefficient for shortdum influence on D1 deliveries as percent of Total A	Model-averaged coefficient for the influence of shortdum on D1 deliveries as percent of Total A.	-	AgForecast.wresl
D1_calc	D1 delivery target from ag delivery sub-model	D1 delivery target from ag delivery sub-model, set equal to D1calc_reg during March - November, otherwise is 0.	D1calcdv	AgRefOps.wresl
D1calc_reg	Forecast of daily D1	Forecast of daily delivery (cfs) through the D1 arc.	D1calc_reg_	AgForecast.wresl
D11	North Canal Deliveries	North Canal Project Deliveries to area A2	D11	Delivery-table.wresl
D11_const	Constant for D11 deliveries as percent of Total A	Model-averaged constant for D11 deliveries as percent of Total A.	-	AgForecast.wresl
D11_cumd11wint	Coefficient for cumd11wint influence on D11 deliveries as percent of Total A	Model-averaged coefficient for the influence of cumd11wint on D11 deliveries as percent of Total A.	-	AgForecast.wresl

Variable Name in Model code	Common Name	Definition	Output Variable Name	Model File of Initial Definition
D11_cumpptwint	Coefficient for cumpptwint influence on D11 deliveries as percent of Total A	Model-averaged coefficient for the influence of cumpptwint on D11 deliveries as percent of Total A.	-	AgForecast.wresl
D11_fw_calc	Fall-winter component of D11calc	D11calc for November-February, otherwise 0.	D11_fw_calcdv	AgRefOps.wresl
D11_fw_calc_no_ UKL_ctrl	D11 winter release calculation without UKL control	D11 winter release calculation without UKL control, computed as the minimum of either (200 cfs or KDDReserve * taf_cfs) * pctNorth.	D11_fw_calc_no_ UKL_ctrldv	AgRefOps.wresl
D11_l1_d11pcta	Coefficient for D11 deliveries as percent of Total A	Model-averaged coefficient for D11 deliveries as percent of Total A from the previous 5-day period.	-	AgForecast.wresl
D11_l1_d11taf	Coefficient for prior period D11 delivery volume influence on D11 deliveries as percent of Total A	Model-averaged coefficient for the influence of prior period D11 delivery volume on D11 deliveries as percent of Total A.	-	AgForecast.wresl
D11_l1_ppt	Coefficient for Prj_Ppt influence on D11 deliveries as percent of Total A	Model-averaged coefficient for the influence of Prj_Ppt (lagged to the previous 5-day period) on D11 deliveries as percent of Total A.	-	AgForecast.wresl
D11_l1_ptdayindex	Coefficient for ptdayindex influence on D11 deliveries as percent of Total A	Model-averaged coefficient for the influence of ptdayindex (lagged to the previous 5-day period) on D11 deliveries as percent of Total A.	-	AgForecast.wresl
D11_l1_tmax	Coefficient for Mean_Tmax influence on D11 deliveries as percent of Total A	Model-averaged coefficient for the influence of Mean_Tmax (lagged to the previous 5-day period) on D11 deliveries as percent of Total A.	-	AgForecast.wresl
D11_pcta_reg_	Forecasted D11 delivery percent of Total A	Forecasted D11 delivery percent of Total A for the current 5-day period.	D11_pcta_reg_	AgForecast.wresl
D11_pdindexd11	Coefficient for pdindexd11 influence on D11 deliveries as percent of Total A	Model-averaged coefficient for the influence of pdindexd11 on D11 deliveries as percent of Total A.	-	AgForecast.wresl

Variable Name in Model code	Common Name	Definition	Output Variable Name	Model File of Initial Definition
D11_RealPCTA	Historical D11 delivery as percent of Total A	Historical daily D11 diversion volume percentage of Total A deliveries (Mar-Oct) summed within each 5-day period of the irrigation water year	D11_RealPCTA_	AgForecast.wresl
D11_shortdum	Coefficient for shortdum influence on D11 deliveries as percent of Total A	Model-averaged coefficient for the influence of shortdum on D11 deliveries as percent of Total A.	-	AgForecast.wresl
D11_ss_calc	Spring-summer component of D11calc	D11calc for March-October, otherwise 0.	D11_ss_calcdv	AgRefOps.wresl
D11calc	Diversion target for D11	Diversion target for D11. Set equal to D11calc_reg during March - October. Otherwise computed as: D11_fw_calc_no_UKL_ctrl + stor_diff_ratio5d * D11_fw_calc_no_UKL_ctrl.	D11calcdv	AgRefOps.wresl
D11calc_reg	Forecast of daily D11	Forecast of daily delivery (cfs) through the D11 arc.	D11calc_reg_	AgForecast.wresl
D12	Ady Canal flow	Ady Canal flow to either Area A2 (including the Area K lease lands) or the Lower Klamath National Wildlife Refuge	D12	Delivery-table.wresl
D12A	Ady Canal Ag Flow	Ady Canal flow to project in Area A2	D12A	Delivery-table.wresl
D12a_const	Constant for D12A deliveries as percent of Total A	Model-averaged constant for D12A deliveries as percent of Total A.	-	AgForecast.wresl
D12a_cumd12awint	Coefficient for cumd12awint influence on D12A deliveries as percent of Total A	Model-averaged coefficient for the influence of cumd12awint on D12A deliveries as percent of Total A.	-	AgForecast.wresl
D12a_cumpptwint	Coefficient for cumpptwint influence on D12A deliveries as percent of Total A	Model-averaged coefficient for the influence of cumpptwint on D12A deliveries as percent of Total A.	-	AgForecast.wresl
D12A_fw_calc	Fall-winter component of D12Acalc	D12Acalc for November-February, otherwise 0.	D12a_fw_calcdv	AgRefOps.wresl
D12A_fw_calc_no_UKL_ctrl	D12A winter release calculation without UKL control	D12A winter release calculation without UKL control, computed as the minimum of either (200 cfs or KDDReserve * taf_cfs) * pctAdyag.	D12a_fw_calc_no_UKL_ctrldv	AgRefOps.wresl

Variable Name in Model code	Common Name	Definition	Output Variable Name	Model File of Initial Definition
D12a_l1_d12apcta	Coefficient for D12A deliveries as percent of Total A	Model-averaged coefficient for D12A deliveries as percent of Total A from the previous 5-day period.	-	AgForecast.wresl
D12a_l1_d12ataf	Coefficient for prior period D12A delivery volume influence on D12A deliveries as percent of Total A	Model-averaged coefficient for the influence of prior period D12A delivery volume on D12A deliveries as percent of Total A.	-	AgForecast.wresl
D12a_l1_ppt	Coefficient for Prj_Ppt influence on D12A deliveries as percent of Total A	Model-averaged coefficient for the influence of Prj_Ppt (lagged to the previous 5-day period) on D12A deliveries as percent of Total A.	-	AgForecast.wresl
D12a_l1_ptdayindex	Coefficient for ptdayindex influence on D12A deliveries as percent of Total A	Model-averaged coefficient for the influence of ptdayindex (lagged to the previous 5-day period) on D12A deliveries as percent of Total A.	-	AgForecast.wresl
D12a_l1_tmax	Coefficient for Mean_Tmax influence on D12A deliveries as percent of Total A	Model-averaged coefficient for the influence of Mean_Tmax (lagged to the previous 5-day period) on D12A deliveries as percent of Total A.	-	AgForecast.wresl
D12a_pcta_reg_	Forecasted D12A delivery percent of Total A	Forecasted D12A delivery percent of Total A for the current 5-day period.	D12a_pcta_reg_	AgForecast.wresl
D12a_pdindexd12a	Coefficient for pdindexd12a influence on D12A deliveries as percent of Total A	Model-averaged coefficient for the influence of pdindexd12a on D12A deliveries as percent of Total A.	-	AgForecast.wresl
D12a_RealPCTA	Historical D12A delivery as percent of Total A	Historical daily D12A diversion volume percentage of Total A deliveries (Mar-Oct) summed within each 5-day period of the irrigation water year	D12a_RealPCTA_	AgForecast.wresl
D12a_shortdum	Coefficient for shortdum influence on D12A deliveries as percent of Total A	Model-averaged coefficient for the influence of shortdum on D12A deliveries as percent of Total A.	-	AgForecast.wresl
D12A_ss_calc	Spring-summer component of D12Acalc	D12Acalc for March-October, otherwise 0.	D12a_ss_calcdv	AgRefOps.wresl

Variable Name in Model code	Common Name	Definition	Output Variable Name	Model File of Initial Definition
D12Acalc	Diversion target for D12A	Diversion target for D12A. Set equal to D12Acalc_reg during March - October. Otherwise computed as: D12A_fw_calc_no_UKL_ctrl + stor_diff_ratio5d * D12A_fw_calc_no_UKL_ctrl.	D12acalcdv	AgRefOps.wresl
D12acalc_reg	Forecast of daily D12A	Forecast of daily delivery (cfs) through the D12A arc.	D12acalc_reg_	AgForecast.wresl
D12B	Ady Canal Refuge Flow	Ady Canal flow to the Lower Klamath National Wildlife Refuge	D12B	Delivery-table.wresl
D12Bcalc	Delivery target for D12B (LKNWR)	Delivery target for D12B (LKNWR), computed without UKL control.	D12Bcalcdv	AgRefOps.wresl
D12Bcalc_Supply Table	Component of LKNWR delivery computation	Component of LKNWR delivery computation. Computed as Monthly_RemainRefugeFallSupply * RefugeFallRelDist/daysinmonth * taf_cfs.	D12Bcalc_Supply Table_	AgRefOps.wresl
D12Bcalc_UKL	Deliveries to LKNWR from UKL	Delivery target for D12B (LKNWR), computed with UKL control.	D12Bcalc_UKLdv	AgRefOps.wresl
D91	Station 48/Miller Hill Deliveries	Lost River Diversion Channel Project deliveries through the Station 48 diversion and Miller Hill Pumping Plant	D91	Delivery-table.wresl
D91_const	Constant for D91 deliveries as percent of Total A	Model-averaged constant for D91 deliveries as percent of Total A.	-	AgForecast.wresl
D91_cumpptwint	Coefficient for cumpptwint influence on D91 deliveries as percent of Total A	Model-averaged coefficient for the influence of cumpptwint on D91 deliveries as percent of Total A.	-	AgForecast.wresl
D91_l1_d91pcta	Coefficient for D91 deliveries as percent of Total A	Model-averaged coefficient for D91 deliveries as percent of Total A from the previous 5-day period.	-	AgForecast.wresl
D91_l1_ppt	Coefficient for Prj_Ppt influence on D91 deliveries as percent of Total A	Model-averaged coefficient for the influence of Prj_Ppt (lagged to the previous 5-day period) on D91 deliveries as percent of Total A.	-	AgForecast.wresl
D91_l1_ptdayindex	Coefficient for ptdayindex influence on D91 deliveries as percent of Total A	Model-averaged coefficient for the influence of ptdayindex (lagged to the previous 5-day period) on D91 deliveries as percent of Total A.	-	AgForecast.wresl

Variable Name in Model code	Common Name	Definition	Output Variable Name	Model File of Initial Definition
D91_I1_tmax	Coefficient for Mean_Tmax influence on D91 deliveries as percent of Total A	Model-averaged coefficient for the influence of Mean_Tmax (lagged to the previous 5-day period) on D91 deliveries as percent of Total A.	-	AgForecast.wresl
D91_pcta_reg_	Forecasted D91 delivery percent of Total A	Forecasted D91 delivery percent of Total A for the current 5-day period.	D91_pcta_reg_	AgForecast.wresl
D91_RealPCTA	Historical D91 delivery as percent of Total A	Historical daily D91 diversion volume percentage of Total A deliveries (Mar-Nov 15) summed within each 5-day period of the irrigation water year.	D91_RealPCTA_	AgForecast.wresl
D91_shortdum	Coefficient for shortdum influence on D91 deliveries as percent of Total A	Model-averaged coefficient for the influence of shortdum on D91 deliveries as percent of Total A.	-	AgForecast.wresl
D91calc	D91 delivery target from ag delivery sub-model	D91 delivery target from ag delivery sub-model, set equal to D91calc_reg during March - November, otherwise is 0.	D91calcdv	AgRefOps.wresl
D91calc_reg	Forecast of daily D91	Forecast of daily delivery (cfs) through the D91 arc.	D91calc_reg_	AgForecast.wresl
daynum	Day of water year	Day 1 is October 1, incremented by 1 each day thereafter.	daynumDV	Definitions.wresl
daysinprevmo	Days in previous month	Number of days in the previous month.	-	Definitions.wresl
dg1_compliance	Surface flushing flow compliance	Set to a value of 1 within a year once a surface flushing flow has been implemented and achieved; otherwise set to 0.	dg1_compliance_	Definitions.wresl
DG1_compliance_ threshold	Surface flushing flow compliance threshold	Minimum flow threshold for determination if a surface flushing flow has already occurred during December to April. Set at 5,000 cfs. This is not the flow target for a forced surface flushing flow.	-	Operations_Switches. wresl
DG1_supply	Minimum flow target below Iron Gate Dam to implement surface flushing flow	Minimum flow target below Iron Gate Dam to implement surface flushing flow.	DG1_supply_	FallWinterRiverOps. wresl
DG1_target	Surface flushing flow target	Surface flushing flow target. Set to 6,030 cfs.	-	Operations_Switches. wresl
dir_div_acc_est	Total diversion of return flows	Total seasonal diversion of return flow from the LRDC and pumps F&FF for all diversion arcs.	-	AgForecast.wresl

Variable Name in Model code	Common Name	Definition	Output Variable Name	Model File of Initial Definition
dowy	Day of water year	Day of water year: October 1 is day 1, September 30 is day 365 (366 in leap years).	dowy_	FallWinterRiverOps. wresl
DT	Distribution type	Distribution type of year based on Mar-50. Set to: 1 when Mar50 ≤ 420 taf; 2 when Mar50 is between 420-510 taf; 3 when Mar50 is between 510-690 taf; 4 when Mar50 ≥ 690 taf.	-	Definitions.wresl
EOS_hiinc	September increment above unadjusted UKL central tendency	Maximum allowable increment above the unadjusted UKL central tendency for the end of September.	-	Res_Reqs.wresl
EOS_lowinc	September increment below unadjusted UKL central tendency	Maximum allowable increment below the unadjusted UKL central tendency for the end of September.	-	Res_Reqs.wresl
EOScent_lvl	September unadjusted UKL central tendency	Unadjusted UKL central tendency for the end of September.	-	Res_Reqs.wresl
EOStgt_lvl	End-of-September UKL storage target level	End-of-September UKL storage target level.	EOStgt_lvl_	Res_Reqs.wresl
EOStgtsto	End-of-September UKL storage target volume	End-of-September UKL storage target volume. UKL active storage volume associated with EOStgt_lvl.	EOStgtstodv	Res_Reqs.wresl
esttota	Estimated Total A delivery	Estimated Total A delivery for an irrigation water year, including diversions of UKL water and diversions of return flows.	esttota_	AgForecast.wresl
EWA_remain_Jul Sep	EWA volume for release in each summer month	EWA volume to be released in each month from July-September. In July, this volume is 35% of EWAremain on July 1. In August, it is 44% of EWAremain on August 1. In September, it is remaining EWA volume.	EWA_remain_Jul Sep_	UKLReleases.wresl
EWA_River	Environmental water account	Allocation from UKLSupply for use by the Klamath River.	EWA_Riverdv	SeasonalSupply.wresl
EWA_threshold	surface flushing flow EWA threshold	EWA threshold for mandatory surface flushing flow release. Set to 575 TAF. If EWA is less than this threshold, a surface flushing flow must be released sometime between March 1st and April 15th	-	Operations_Switches. wresl
EWAmin	Minimum EWA	Minimum volume for the Environmental Water Account, set to 400 TAF.	EWAmin_	Definitions.wresl

Variable Name in Model code	Common Name	Definition	Output Variable Name	Model File of Initial Definition
EWARemain	Remaining EWA	Volume of EWA remaining, computed on the first day of each month (starting March 1) as: max(EWARemainMinimum, EWA_River - EWAUseddv(-1)). Its value remains constant throughout the remainder of each month.	EWARemainDV	SeasonalSupply.wresl
EWARemain Minimum	EWA remain minimum	Minimum EWA volume to retain for use in June-September period to ensure that sufficient EWA volume remains to cover summer period in years when flows through C1_EXC arc are above a specifed proportion of the EWA volume. That is, when c1_EXCcumdv(-1)≥(0.22*EWA_River), EWARemainMinimum is computed each month as: 0.25*EWA_River in June; 0.18*EWA_River in July; 0.13*EWA_River in August; and 0.07*EWA_River in September.	EWARemain Minimumdv	SeasonalSupply.wresl
EWAUseddv	EWA used	Volume of Link River Dam releases accounted for as EWA water. Computed as: March 1: C1_MIF*cfs_taf+C1_EXC*cfs_taf After March 1: EWAUsedDV(-1) + C1_MIF*cfs_taf + C1_EXC*cfs_taf - prj_credit_spill_forEWA*cfs_taf + prj_acc_addition_to_EWA*cfs_taf.	EWAUseddv	SeasonalSupply.wresl
excluded_dum	Dummy variable for excluded years	Set to 1 for years when historical diversions were altered from normal seasonal patterns by regulatory action to an extent warranting their removal from model development. Excluded years were 2001, 2010, 2014, and 2015.	excluded_dum_	AgForecast.wresl
Fcst_error	Forecast error	Tracking the approximate real-time forecast error, computed first day of the month April-June. On April 1: Mar50 - (Apr50 + LastMonthInf). On May 1: Apr50 - (May50 + LastMonthInf). On June 1: May50 - (Jun50 + LastMonthInf).	Fcst_error_	Definitions.wresl
Feb50	February NRCS forecast	February NRCS 50% exceedence forecast for total March-September UKL net inflow.	-	Definitions.wresl
fill_target_approx	UKL fill target	Elevation (ft) targeted for filling UKL by February 28. Set to 4143.0 ft, this is a soft target, the system is not forced to hit the target. Used beginning on November 16.	-	FallWinterRiverOps.wresl
fill_target_approx_vol	UKL fill target volume	Active storage volume (TAF) at the elevation of the fill_target_approx.	-	FallWinterRiverOps.wresl

Variable Name in Model code	Common Name	Definition	Output Variable Name	Model File of Initial Definition
five_day_period	Five-day period of the irrigation water year	Five-day periods begining March 1, ending at the end of February. Period 73 has 6 days in leap years.	five_day_period_	Definitions.wresl
Flood50fc	UKL net inflow forecasts used in flood operations	NRCS 50% exceedence forecasts for total Mar-Sep UKL net inflow made in Jan-Mar, and total Apr-Sep UKL net inflow forecast made in April.	-	Res_Reqs.wresl
I1	UKL net inflow - smoothed	Net Inflow into Upper Klamath Lake (calculated as the change in storage plus releases through A Canal and Link River Dam). This input timeseries was smoothed to minimize fluctuations due to wind effects on lake levels.	I1_	Inflow-table.wresl
I1_raw	UKL net inflow - raw data	Net Inflow into Upper Klamath Lake (calculated as the change in storage plus releases through A Canal and Link River Dam). This is added as a raw value and does not smooth out significant fluctuations caused by wind effects on lake level.	I1_raw_	Inflow-table.wresl
I10	Lake Ewauna accretions	Lake Ewauna Accretions - difference between historical flows released out of Link River Dam minus known diversions and the measured flow upstream of Keno Reservoir. Diversions include LRDC which may flow into the Klamath River as an inflow.	I10_	Inflow-table.wresl
I131	Area 2 return flow closure term	Input timeseries that is the difference between actual return flows minus modeled return flows based on actual deliveries, precipitation and temperature.	I131_	Inflow-table.wresl
I15	Keno to Iron Gate accretions	Keno to Iron Gate accretion timeseries developed with historical mass balance from Keno Dam to the flow gage below Iron Gate Dam.	I15_	Inflow-table.wresl
I15_d0d3_total	Total 4-day forecasted Keno-to-Iron Gate accretion volume	Forecasted Keno-to-Iron Gate accretion volume summed across forecasts for day 0 (current day) through day 3.	I15_d0d3_total_	FallWinterRiverOps. wresl
I15_FORECAST0	Iron Gate accretion 0 day forecast	Forecast of today's Keno to Iron Gate accretion.	-	Inflow-table.wresl
I15_FORECAST1	Iron Gate accretion 1 day forecast	Forecast of tomorrow's Keno to Iron Gate accretion.	-	Inflow-table.wresl
I15_FORECAST2	Iron Gate accretion 2 day forecast	Forecast of day after tomorrow's Keno to Iron Gate accretion.	-	Inflow-table.wresl

Variable Name in Model code	Common Name	Definition	Output Variable Name	Model File of Initial Definition
I15_FORECAST3	Iron Gate accretion 3 day forecast	Forecast of Keno to Iron Gate accretions three days from now.	-	Inflow-table.wresl
I15_proj_3day	Projected 3-day average daily volume of Keno-to-Iron Gate accretions	Average daily Keno-to-Iron Gate accretion volume forecasted for days 0-2.	I15_proj_3day_	FallWinterRiverOps.wresl
I15_wyAvgVol	Water year average Keno-to-Iron Gate accretion volume	Average accretion volume (TAF) to the Keno-to-Iron Gate reach of the Klamath River from October 1 to the current day.	I15_wyAvgVol_	FallWinterRiverOps.wresl
I91	LRDC at Wilson	Flow diverted at Wilson Dam into the Lost River Diversion Channel. The flow is a combination of flow from the Lost River (timeseries input) and return flows from Area 1 (dynamically determined from a return flow model).	I91_	Inflow-table.wresl
I91_D1Adjust	Adjusted I91	Historical I91 adjusted by I91_reduce.	I91_D1Adjust_	Definitions.wresl
I91_HIST	Historical flow measured at LRDC headworks	Historical diversion into the LRDC, measured at the headworks at Wilson Dam.	I91_HIST_	Definitions.wresl
I91_IG	LRDC inflow to Iron Gate Dam flow	Flow into the LRDC from Wilson Dam that contributes to Iron Gate flow (not diverted by the project).	I91_IG	Inflow-table.wresl
I91_PRJ	LRDC inflow diverted by project	Flow into the LRDC from Wilson Dam that is diverted by the Klamath Project at Station 48, Miller Hill, North Canal, or Ady Canal.	I91_PRJ	Inflow-table.wresl
I91_reduce	Adjustment for I91	Volume by which the historical I91 arc needs to be adjusted to account for changes in D1 deliveries.	I91_reduce_	Definitions.wresl
IG_max	Maximum Iron Gate flow July-September	Maximum flow target below Iron Gate Dam in July-September. Used to constrain C15_target. IG_max is interpolated based on EWA_River between 320 taf and 1500 taf (IG_max constant below 320 taf or above 1500 taf). IG_max varies between 1000-1500 cfs in July; 1050-1250 cfs in August; and 1100-1350 cfs in September.	IG_max_	UKLReleases.wresl
IG_ramp_flow	Ramped Iron Gate flow	Computed as C15(-1) - IG_ramp_rate.	IG_ramp_flow_	UKLReleases.wresl

Variable Name in Model code	Common Name	Definition	Output Variable Name	Model File of Initial Definition
IG_ramp_rate	Iron Gate ramp rate	Computes down-ramp rates for Iron Gate: If C15(-1) < 1750 cfs + 150 cfs, then IG_ramp_rate = 150 cfs If C15(-1) < 3000 cfs + 300 cfs, then IG_ramp_rate = 300 cfs If C15(-1) < 3600 cfs, then IG_ramp_rate = 600 cfs If C15(-1) ≥ 3600 cfs .and. c15(-1) < 4000, then IG_ramp_rate = c15(-1) - 3000 cfs If C15(-1) ≥ 4000 cfs .and. c15(-1) < 4600, then IG_ramp_rate = 1000 cfs Otherwise IG_ramp_rate = min(2000 cfs, c15(-1) - 3600 cfs)	IG_ramp_rate_	UKLReleases.wresl
IG_spawn	Initial fall spawning flow below Iron Gate Dam	Initial flow specified on Oct 1 for fall spawning flows below Iron Gate Dam. Selected by interpolation between 1000 and 1200 cfs based on norm_uklinf_60avg.	IG_spawn_	FallWinterRiverOps. wresl
IG_spawn_flow	Spawning flow at below Iron Gate Dam	Final flow specified for the fall spawning period (October 1-November 15) below Iron Gate Dam. Computed by adding the appropriate IG_spawn_inc variables to IG_spawn.	IG_spawn_flow_	FallWinterRiverOps. wresl
IG_spawn_inc_ Nov1	Final incremental increase of fall spawning flow at Iron Gate	Flow increment added to fall spawning flows November 1-15 below Iron Gate Dam. Selected by interpolation between 0 and 125 cfs based on norm_uklinf_60avg.	-	FallWinterRiverOps. wresl
IG_spawn_inc_ Oct12	First incremental increase of fall spawning flow at Iron Gate	Flow increment added to fall spawning flows October 12-21 below Iron Gate Dam. Selected by interpolation between 0 and 125 cfs based on norm_uklinf_60avg.	-	FallWinterRiverOps. wresl
IG_spawn_inc_ Oct22	Second incremental increase of fall spawning flow at Iron Gate	Flow increment added to fall spawning flows October 22-31 below Iron Gate Dam. Selected by interpolation between 0 and 125 cfs based on norm_uklinf_60avg.	-	FallWinterRiverOps. wresl
IGmin	Minimum flow below Iron Gate Dam	Establishes the minimum flow required below Iron Gate Dam. When surface flushing flows have been triggered, this is set to the value of the DG1_Supply. When Boat Dance flows have been triggered, this is set to 1700 cfs. Otherwise it is set to the established monthly minimum flows.	IGmin_	FallWinterRiverOps. wresl
in_pct_Mar50vol	UKL net inflow percent of forecasted/realized net inflow	Used to establish Link River Dam release targets during March-June, which are subsequently used to establish targets at Iron Gate.	in_pct_Mar50vol_	UKLReleases.wresl

Variable Name in Model code	Common Name	Definition	Output Variable Name	Model File of Initial Definition
intercept_4dTrigger_mult	Variable used to compute stage1_trigger	Variable involved in computation of stage1_trigger. Computed as: upper_4dTrigger_mult - upper_I15_wyAvg_mult * slope_4dTrigger_mult.	intercept_4dTrigger_mult_	FallWinterRiverOps.wresl
irr_WY	Irrigation water year	The irrigation water year extends from March 1 through the end of February. Its value is the same as that for the calendar year for March - December.	-	AgForecast.wresl
Jan50	January NRCS forecast	January NRCS 50% exceedence forecast for total March-September UKL net inflow.	-	Definitions.wresl
Jun50	June NRCS forecast	June NRCS 50% exceedence forecast for total June-September UKL net inflow.	-	Definitions.wresl
KDD_indv	Input of diversion and precipitation volume into KDD	Daily total volume of D11, D12A, and KDD_ppt_acft, combined.	KDD_indv	AgRefOps.wresl
KDD_ppt	Average daily precipitation in Area A2	Average daily precipitation (in) for 3 PRISM grids in Area A2.	-	AgRefOps.wresl
KDD_ppt_acft	Precipitation volume in KDD area	KDD_ppt converted to a volume (taf), assuming 27,000 acres in KDD.	-	AgRefOps.wresl
KDDOctFebDV	Running total of winter deliveries to KDD	Running total of November - February deliveries through D11 and D12A (does not include October, despite the variable name).	KDDOctFebDV	AgRefOps.wresl
KDDReserve	Amount of KDD winter water right remaining unused	Amount of KDD winter water right remaining unused, computed as A2FW - KDDOctFebDV(-1) during November - February.	KDDResDV	AgRefOps.wresl
Keno_min	Minimum Keno Dam release	Minimum release (cfs) from Keno Dam.	Keno_min_	FallWinterRiverOps.wresl
l_bound	Lower bound of stor_diff_ratio	Lower bound of stor_diff_ratio, set to -0.8.	-	UKLThresholds.wresl
L1_D11taf	Simulated D11 delivery volume total for prior 5-day period	Simulated D11 delivery volume total for prior 5-day period.	L1_D11taf_	AgForecast.wresl
L1_D12ataf	Simulated D12A delivery volume total for prior 5-day period	Simulated D12A delivery volume total for prior 5-day period.	L1_D12ataf_	AgForecast.wresl

Variable Name in Model code	Common Name	Definition	Output Variable Name	Model File of Initial Definition
lag_norm_cum_ KDD_in_5d	Normalized cum_KDD_in_5d_	Normalized cum_KDD_in_5d_, from the previous 5-day period.	lag_norm_cum_KD D_in_5d_	AgRefOps.wresl
lag_norm_cum_ KDD_in_p15to49	Normalized cum_KDD_in_p15to49_	Normalized cum_KDD_in_p15to49_, from the previous 5-day period.	lag_norm_cum_KD D_in_p15to49_	AgRefOps.wresl
lag_norm_cum_ KDD_in_p50to14	Normalized cum_KDD_in_p50to14_	Normalized cum_KDD_in_p50to14_, from the previous 5-day period.	lag_norm_cum_KD D_in_p50to14_	AgRefOps.wresl
LastMonthInf	Last month's UKL net inflow volume	Total volume of UKL net inflow (taf) for previous month.	LastMonthInfdv	Definitions.wresl
Link_max	Maximum acheivable release from Link River Dam	Maximum achievable release from Link River Dam based on a stage-discharge curve, ranging from 900 cfs when UKL elevation is 4137.0 ft to 8600 cfs when UKL elevation is 4143.3 ft.	Link_max_	FallWinterRiverOps. wresl
Link_max_DG1	Maxmimum Link River Dam release used for DG1_supply calculation	Expression of the maximum Link River Dam release for use in calculating the DG1_supply. Computed as the Link_max associated with yesterday's UKL elevation minus 0.3 ft. This 0.3 ft buffer reduces the likelihood of triggering a surface flushing flow that cannot be attained.	Link_max_DG1_	FallWinterRiverOps. wresl
Link_min	Minimum Link River Dam release	Minimum release (cfs) from Link River Dam.	Link_min_	FallWinterRiverOps. wresl
Link_release_FW	Fall-winter flow release target for Link River Dam	Flow release target for Link River Dam for October-February. Computed as Link_release_FW_prep reduced (when appropriate) by the product of the stor_diff_ratio5d and Link_release_FW_prep.	Link_release_FW_	FallWinterRiverOps. wresl
Link_release_FW_ prep	Calculated release target for Link River Dam	Initial flow release target for Link River Dam for October-February. From October - November 15, computed as IG_spawn_flow minus accretions and measured return flows plus diversions. From November 16 through February, computed as yesterday's UKL net inflow minus the Needed_fill_rate multiplied by 1.5.	Link_release_FW_ prep_	FallWinterRiverOps. wresl
Link_release_SS	Link River Dam release target, with UKL control, during spring-summer	Calculated release of UKL water at Link River Dam for March-September, with UKL control.	Link_release_SSdv	UKLReleases.wresl

Variable Name in Model code	Common Name	Definition	Output Variable Name	Model File of Initial Definition
Link_release_ss_diff	Difference between actual and expected Link River Dam releases	Cumulative difference between what was actually released from Link River Dam to support Iron Gate Dam flows yesterday and what was expected to be released to support yesterday's Iron Gate flow target.	Link_release_ss_ diff_	UKLReleases.wresl
Link_release_SS_ prep	Link River Dam release target, without UKL control, during spring-summer	Calculated release of UKL water at Link River Dam for March-September, without UKL control.	Link_release_SS_ prep_	UKLReleases.wresl
Link_WF_target	Target release for Link River Dam during fall-winter period	Link River Dam release target for October - February. Computed as the maximum of either Link_min or Link_release_FW.	Link_WF_target_	FallWinterRiverOps. wresl
LinktoIG_Delay	Iron Gate flow target delay	Delay between scheduling the Iron Gate flow target and implementing the target. Delay is currently set at 3 days.	-	Operations_Switches. wresl
lower_4dTrigger_ mult	Variable used to compute stage1_trigger	Variable involved in computation of stage1_trigger. Set to 2.2.	-	FallWinterRiverOps. wresl
lower_I15_wyAvg_ mult	Variable used to compute stage1_trigger	Variable involved in computation of stage1_trigger. Set to 0.7.	-	FallWinterRiverOps. wresl
Mar1_EWA_	EWA_River on March 1	EWA_River on March 1.	Mar1_EWA_	UKLThresholds.wresl
Mar50	March NRCS forecast	March NRCS 50% exceedence forecast for total March-September UKL net inflow.	-	Definitions.wresl
Mar50vol	Combined forecasted/experienced UKL net inflow	Always applicable to the March-September period, this is the NRCS 50% exceedence forecast for UKL net inflow looking forward plus the experienced UKL net inflow since March 1.	Mar50voldv	Definitions.wresl
May50	May NRCS forecast	May NRCS 50% exceedence forecast for total May-September UKL net inflow.	-	Definitions.wresl
MayJuneAdjust	Daily May/June IGD flow increase	20,000 AF volume released in May and June. 60% release in May at 195 cfs/day, 40% in June at 134 cfs/day.	MayJuneAdjust_	UKLReleases.wresl
MayJuneAugment	Switch determining whether May/June IGD flows should be enhanced	If April 1 EWA_River is greater than 400,000 AF (407,000 AF in Boat Dance years) and less than 576,000 AF, switch is turned on.	MayJuneAugment_	SeasonalSupply.wresl

Variable Name in Model code	Common Name	Definition	Output Variable Name	Model File of Initial Definition
Mean_Tmax	Mean daily Project area maximum temperature	Mean daily Tmax (°F) for the Project area from nine randomly selected PRISM grids, averaged within iwy 5 day periods of the irrigation water year	Mean_Tmax_	AgForecast.wresl
model_10	KDD return flow model 10	KDD return flow model 10.	model_10_	AgRefOps.wresl
model_11	KDD return flow model 11	KDD return flow model 11. S	model_11_	AgRefOps.wresl
model_12	KDD return flow model 12	KDD return flow model 12.	model_12_	AgRefOps.wresl
model_13	KDD return flow model 13	KDD return flow model 13. S	model_13_	AgRefOps.wresl
model_14	KDD return flow model 14	KDD return flow model 14.	model_14_	AgRefOps.wresl
model_17	KDD return flow model 17	KDD return flow model 17.	model_17_	AgRefOps.wresl
model_19	KDD return flow model 19	KDD return flow model 19.	model_19_	AgRefOps.wresl
model_20	KDD return flow model 20	KDD return flow model 20. S	model_20_	AgRefOps.wresl
model_22	KDD return flow model 22	KDD return flow model 22.	model_22_	AgRefOps.wresl
model_9	KDD return flow model 9	KDD return flow model 9.	model_9_	AgRefOps.wresl
Monthly_RemainRefugeFallSupply	RemainRefugeFallSupply on first day of the month	During August - November, RemainRefugeFallSupply on the first day of the month.	Monthly_RemainRefugeFallSupply_	AgRefOps.wresl
Needed_fill_rate	Needed UKL fill rate	For any day between November 16 and February 28, this is the average UKL fill rate needed to reach the fill_target_approx elevation (4143.0 ft) by February 28.	Needed_fill_rate_	FallWinterRiverOps.wresl
norm_inf_hi	Variable used to compute adj_uklcentral	Upper end of the norm_uklinf_60avg, set to 1. Used to compute adj_uklcentral.	-	UKLThresholds.wresl
norm_inf_low	Variable used to compute adj_uklcentral	Lower end of the norm_uklinf_60avg, set to 0. Used to compute adj_uklcentral.	-	UKLThresholds.wresl
norm_uklinf_60avg	Normalized 60-day trailing average of UKL net inflow	60-day trailing average of UKL net inflow re-scaled (normalized) to be between 0 and 1.	norm_uklinf_60avgDV	UKLThresholds.wresl
normcumd11	Normalized cumd11wint	Re-scaled cumd11wint (between 0 and 1).	normcumd11_	AgForecast.wresl
normcumd12a	Normalized cumd12awint	Re-scaled cumd12awint (between 0 and 1).	normcumd12a_	AgForecast.wresl
normcumpptwint	Normalized cumpptwint	Re-scaled cumpptwint (between 0 and 1).	normcumpptwint_	AgForecast.wresl
normMar50vol	Normalized Mar50vol	Normalized (re-scaled to be between 0 and 1) Mar50vol across all months and years in the POR.	normMar50vol_	Res_Reqs.wresl

Variable Name in Model code	Common Name	Definition	Output Variable Name	Model File of Initial Definition
normppt	Normalized Prj_Ppt	Re-scaled Prj_Ppt (between 0 and 1), for use in calculating the ptdayindex.	normppt_	AgForecast.wresl
normpptc	Normalized Cum_Ppt	Re-scaled Cum_Ppt (between 0 and 1), for use in calculating the ptindex.	normpptc_	AgForecast.wresl
normtmax	Normalized Mean_Tmax	Re-scaled Mean_Tmax (between 0 and 1), for use in calculating the ptdayindex. Subtracted from 1 to flip the scale, so that increasingly warm conditions move towards 0.	normtmax_	AgForecast.wresl
normtmaxc	Normalized Cum_Tmax	Re-scaled Cum_Tmax (between 0 and 1), for use in calculating the ptindex. Subtracted from 1 to flip the scale, so that increasingly warm conditions move towards 0.	normtmaxc_	AgForecast.wresl
Pct_tota_adjust	Proportional adjustment for percentage of Total A	An adjustment factor applied to estimates of percentage of Total A summed across all diversion arcs, to ensure that they sum to 1 for each irrigation water year.	-	AgForecast.wresl
pctAdyAg	Historical D12A as percent of Area A2 diversion	Historical D12A delivery as percentage of Area A2 total delivery. Used to compute D12A deliveries during November-February.	-	AgRefOps.wresl
pctNorth	Historical D11 as percent of Area A2 diversion	Historical D11 delivery as percentage of Area A2 total delivery. Used to compute D11 deliveries during November-February.	-	AgRefOps.wresl
pdindexd11	Index of winter precipitation and winter D11 deliveries	Index combining winter precipitation and winter D11 delivery volume: normcumpptwint + normcumd11.	pdindexd11_	AgForecast.wresl
pdindexd12a	Index of winter precipitation and winter D12a deliveries	Index combining winter precipitation and winter D12a delivery volume: normcumpptwint + normcumd12a.	pdindexd12a_	AgForecast.wresl
prj_acc_addition_to _EWA	Combined LRDC and F/FF EWA release contribution	Calculation of yesterday's LRDC accretions and F/FF pumping that counted as an EWA release and therefore adds to the UKL credit.	prj_acc_addition_to _EWA_	Project_IG_release_ credit.wresl
prj_credit_spill_ forEWA	Spill of UKL credit	Yesterday's spill of accumulated UKL credit. This does not count as an EWA release.	prj_credit_spill_forE WA_	Project_IG_release_ credit.wresl
Prj_Ppt	Average daily Project-area precipitation	Mean daily precipitation in inches for the Project area from nine randomly selected PRISM grids, averaged within 5-day periods of the irrigation water year	Prj_Ppt_	AgForecast.wresl

Variable Name in Model code	Common Name	Definition	Output Variable Name	Model File of Initial Definition
prj_UKL_credit	UKL credit	Accumulated credit in UKL due to LRDC accretion and F/FF pumping contribution to EWA release	prj_UKL_credit_	Project_IG_release_ credit.wresl
PrjPpt_max	Maximum Prj_Ppt for period of record	Maximum value of Prj_Ppt for a given 5-day period across all irrigation water years in the period of record. Used to re-scale (normalize) Prj_Ppt to be between 0 and 1, for use in calculating the ptdayindex.	PrjPpt_max_	AgForecast.wresl
PrjPpt_min	Minimum Prj_Ppt for period of record	Minimum value of Prj_Ppt for a given 5-day period across all irrigation water years in the period of record. Used to re-scale (normalize) Prj_Ppt to be between 0 and 1, for use in calculating the ptdayindex.	PrjPpt_min_	AgForecast.wresl
PrjPptCum_max	Maximum Cum_Ppt for period of record	Maximum value of Cum_Ppt for a given 5-day period across all irrigation water years in the period of record. Used to re-scale (normalize) Cum_Ppt to be between 0 and 1, for use in calculating the ptindex.	PrjPptCum_max_	AgForecast.wresl
PrjPptCum_min	Minimum Cum_Ppt for period of record	Minimum value of Cum_Ppt for a given 5-day period across all irrigation water years in the period of record. Used to re-scale (normalize) Cum_Ppt to be between 0 and 1, for use in calculating the ptindex.	PrjPptCum_min_	AgForecast.wresl
PrjSupply	Project supply	Allocation from UKLSupply for use by the Project irrigators.	PrjSupplydv	SeasonalSupply.wresl
PrjSupply_Apr1	Project supply on April 1	Project supply computed on April 1 as min(Projectmax, UKLsupply - EWA_River).	PrjSupply_Apr1_	SeasonalSupply.wresl
PrjSupply_irr	Project supply for irrigation	Allocation from UKLSupply for use by the Project, computed as max(0., PrjSupply - RefugeFallSupply).	PrjSupply_irrdv	SeasonalSupply.wresl
PrjSupply_irr_Apr1 min	Project supply for irrigation on April 1	Allocation from UKLSupply for use by the Project on April 1, computed as max(0., PrjSupply_Apr1 - RefugeFallSupplyApr1min).	PrjSupply_irr_Apr1 mindv	SeasonalSupply.wresl
Proj_full_check	Project full supply check	Set to 1 when Project supply is at its maximum. Set to 1 when either UKLsupply - EWA_River > Projectmax or UKLsupply > 1035; set to zero otherwise.	Proj_full_check_	SeasonalSupply.wresl
projectmax	Maximum allocation of UKL water for Project use	Maximum allocation of UKL water for Project use, set to 350 TAF.	projectmaxdv	Definitions.wresl

Variable Name in Model code	Common Name	Definition	Output Variable Name	Model File of Initial Definition
ptdayindex	Precipitation-temperature index	The sum of normppt and normtmax for a 5-day period of the irrigation water year. Values near zero indicate warm, dry conditions; values near 1 indicate cool, wet conditions.	ptdayindex_	AgForecast.wresl
ptindex	Cumulative precipitation-temperature index	The sum of normpptc and normtmaxc for a 5-day period of the irrigation water year. Values near zero indicate warm, dry conditions; values near 1 indicate cool, wet conditions.	ptindex_	AgForecast.wresl
R131a	Return flow from KDD	Return flow from KDD.	R131a	Return-table.wresl
R131b	Return flow from LKNWR	Return flow from LKNWR. Set to 0.	R131b	Return-table.wresl
RefugeFallCumulDist	Component of LKNWR delivery computation	Variable used to compute D12B deliveries. Set to 1.0 in August, 0.84 in September, 0.60 in October, and 0.20 in November.	RefugeFallCumulDist_	AgRefOps.wresl
RefugeFallRelDist	Component of LKNWR delivery computation	Variable used to compute D12B deliveries. Computed as RefugeFallSupplyDist / RefugeFallCumulDist during August - November.	RefugeFallRelDist_	AgRefOps.wresl
RefugeFallSupply	Refuge Fall Supply		RefugeFallSupply_	SeasonalSupply.wresl
RefugeFallSupplyApr1min	Refuge Fall Supply on April 1	Refuge Fall Supply on April 1.	RefugeFallSupplyApr1min_	SeasonalSupply.wresl
RefugeFallSupplyDist	Component of LKNWR delivery computation	Variable used to compute D12B deliveries. Set to 0.16 in August, 0.25 in September, 0.40 in October, and 0.20 in November.	RefugeFallSupplyDist_	AgRefOps.wresl
RemainRefugeFallSupply	Remaining LKNWR fall supply	Remaining LKNWR fall supply. August - November, it is computed as the RefugeFallSupply on August 1, and as max(0., RemainRefugeFallSupply_(-1) - max(0.,D12b(-1)-transfer_diversion)*cfs_taf) thereafter.	RemainRefugeFallSupply_	AgRefOps.wresl
Rfg_month_dem	Monthly demand volume for LKNWR	Monthly demand volume (TAF) for LKNWR.	-	AgRefOps.wresl
Rfg_PrjSupPct	Refuge percentage of Project supply	Percentage of Project Supply set aside for LKNWR use in August – November.	Rfg_PrjSupPct_	SeasonalSupply.wresl
Rfg_PrjSupPctmin	Refuge percentage of Project supply on April 1	The Rfg_PrjSupPct computed based on PrjSupply_Apr1.	Rfg_PrjSupPctmin_	SeasonalSupply.wresl

Variable Name in Model code	Common Name	Definition	Output Variable Name	Model File of Initial Definition
S1	UKL storage	Storage in UKL as modeled through the mass balance of UKL net inflow, Link releases, and A Canal diversions.	S1	Reservoir-table.wresl
S15	Iron Gate storage	This is a simplistic representation of Iron Gate storage in order to replicate necessary fill to the Iron Gate spillway to make releases greater than 1,700 cfs over the spillway.	S15	Reservoir-table.wresl
S15_proj	Projected storage in Iron Gate Reservoir at end of today	Projected storage in Iron Gate Reservoir at end of today, computed as: min(S15level4, C13_MIF1(-1)*cfs_taf + I15_forecast0*cfs_taf + S15(-1) - max(IGmin, C15target)*cfs_taf).	S15_proj_	UKLReleases.wresl
S15target	Iron Gate Reservoir storage target	Set to 53 TAF (volume at spillway elevation) when C15target > 1700 cfs or when stage1_trigger_ = 1; otherwise set to 51 TAF. Used to fill Iron Gate Reservoir to spillway elevation before C15target flows requiring spill.	S15target_	UKLReleases.wresl
S1yestelev	UKL elevation	Elevation of UKL water surface measured at the end of yesterday. In the model, this is determined using the calculated storage (S1) in the storage-elevation lookup table.	S1yestelevdv	Reservoir-table.wresl
sb	Step-back	Variable used in lag functions to "step-back", or lag, to the last day of the previous five_day_period.	sb_	Definitions.wresl
shortdum	Water-short-year indicator	Dummy variable used in forecasting models to indicate when water supply is substantially less than irrigation demand. When UKLSupply < 836 TAF, this variable is set to 1, indicating water-short conditions. It is zero otherwise.	shortdum_	AgForecast.wresl
slope_4dTrigger_mult	Variable used to compute stage1_trigger	Variable involved in computation of stage1_trigger. Computed as: (upper_4dTrigger_mult - lower_4dTrigger_mult) / (upper_I15_wyAvg_mult - lower_I15_wyAvg_mult).	slope_4dTrigger_mult_	FallWinterRiverOps.wresl
SSdaynum	Day of spring-summer season	Day 1 is March 1, incremented by 1 each day thereafter.	SSdaynumDV	Definitions.wresl
stage1_trigger	Trigger to fill Iron Gate Reservoir to spillway elevation	Triggers the filling of Iron Gate Reservoir to its spillway elevation in anticipation of releases from UKL for a surface flushing flow. It is triggered when (I15_d0d3_total(-1) - (I15_wyAvgVol(-1) * 4.)) ≥ (I15_wyAvgVol(-1) * (slope_4dTrigger_mult * I15_wyAvgVol(-1) + intercept_4dTrigger_mult)	stage1_trigger_	FallWinterRiverOps.wresl

Variable Name in Model code	Common Name	Definition	Output Variable Name	Model File of Initial Definition
stor_diff_ratio	Daily storage difference ratio	Daily expression of the storage difference ratio, which is used in UKL control logic.	stor_diff_ratio_	UKLThresholds.wresl
stor_diff_ratio5d	Storage difference ratio for 5-day period	5-day period expression of the storage difference ratio, which is used in UKL control logic. For each 5-day period, it is set to the value of stor_diff_ratio on day 1 of the 5-day period.	stor_diff_ratio5d_	UKLThresholds.wresl
stor_diff_ratio5d_ag	Storage difference ratio for refuge	The storage difference ratio computed for each 5-day period that is applied to D12B (Refuge) diversions. Despite the name, it is not applied to ag diversions. It is the same as stor_diff_ratio5d but is not allowed to drop below -0.5 or to go above 0.	stor_diff_ratio5d_ag _	SeasonalSupply.wresl
switch_acc_AddToTarget	Iron Gate Target augmentation switch	Conditional variable that equals 1 when LRDC accretions and F/FF pumping augment Iron Gate calculated target. Equals 0 when they do not augment Iron Gate calculated target. In current proposed action this variable equals 1 from October to February and 0 from March to September.	-	Project_IG_release_credit.wresl
Tmax_max	Maximum Mean_Tmax for period of record	Maximum value of Mean_Tmax for a given 5-day period across all irrigation water years in the period of record. Used to re-scale (normalize) Mean_Tmax to be between 0 and 1, for use in calculating the ptdayindex.	Tmax_max_	AgForecast.wresl
Tmax_min	Minimum Mean_Tmax for period of record	Minimum value of Mean_Tmax for a given 5-day period across all irrigation water years in the period of record. Used to re-scale (normalize) Mean_Tmax to be between 0 and 1, for use in calculating the ptdayindex.	Tmax_min_	AgForecast.wresl
TmaxCum_max	Maximum Tmax_Cum for period of record	Maximum value of Tmax_Cum for a given 5-day period across all irrigation water years in the period of record. Used to re-scale (normalize) Tmax_Cum to be between 0 and 1, for use in calculating the ptindex.	TmaxCum_max_	AgForecast.wresl
TmaxCum_min	Minimum Tmax_Cum for period of record	Minimum value of Tmax_Cum for a given 5-day period across all irrigation water years in the period of record. Used to re-scale (normalize) Tmax_Cum to be between 0 and 1, for use in calculating the ptindex.	TmaxCum_min_	AgForecast.wresl
transfer_diversion	Refuge transfer	Input of 11 TAF of transfer from UKL refuge to Lower Klamath Lake refuge uniformly distributed on a daily basis from April through September	refuge_transfer	Operations_Switches.wresl

Variable Name in Model code	Common Name	Definition	Output Variable Name	Model File of Initial Definition
u_bound	Upper bound of stor_diff_ratio	Upper bound of stor_diff_ratio, set to 0.	-	UKLThresholds.wresl
UKL_adj_width	stor_diff_ratio denominator	Specifies the volume in the denominator of the stor_diff_ratio.	-	UKLThresholds.wresl
UKL_flood_lvl	Maximum UKL monthly level	Maximum allowable UKL level for each month. Set to 4143.1 ft for all months except April (4143.2 ft), and May and June (4143.3 ft).	S1_maxL_dv	Res_Reqs.wresl
UKL_flood_sto	Year-round threshold storage for UKL flood releases	Year-round threshold storage for UKL flood releases, set equal to UKL_release_sto during Oct-Apr, otherwise set to UKL_flood_sto1. This is the final determination of the UKL flood release storage threshold in the KBPM.	S1_maxS_dv	Res_Reqs.wresl
UKL_flood_sto1	Maximum UKL monthly storage volume	Maximum allowable UKL level for each month: active storage volume associated with UKL_flood_lvl.	-	Res_Reqs.wresl
UKL_min_lvl	Minimum UKL monthly level	Minimum allowable UKL level for each month. Set to 4137.0 ft in all months.	S1_minL_dv	Res_Reqs.wresl
UKL_min_sto	Minimum UKL monthly storage volume	Minimum allowable UKL storage volume for each month: active storage volume associated with UKL_min_sto.	S1_minS_dv	Res_Reqs.wresl
UKL_release_level_ som_use	UKL flood release level at start of month	Computed as: max(UKL_release_lvl_som, UKL_release_thresh_(-day)), where (-day) is the last day of the previous month.	UKL_rels_lvl_som_ use_	Res_Reqs.wresl
UKL_release_lvl	Year-round threshold level for UKL flood releases	Year-round threshold storage for UKL flood releases. This is the UKL level associated with UKL_flood_sto, and is the final determination of the UKL flood release threshold level in the KBPM.	UKL_release_lvl_dv	Res_Reqs.wresl
UKL_release_lvl_ eom	UKL flood release level at end of month	UKL flood release level at end of month.	UKL_release_lvl_ eom_	Res_Reqs.wresl
UKL_release_lvl_ som	UKL flood release level at start of month	UKL flood release level at start of month.	UKL_release_lvl_ som_	Res_Reqs.wresl
UKL_release_sto	Oct-Apr threshold storage for UKL flood releases	Threshold storage volume for UKL flood releases during Oct-Apr period, when it is set equal to UKL_release_thresh_sto. It set to zero in other months.	-	Res_Reqs.wresl
UKL_release_thresh	UKL flood release threshold level	UKL level above which flood releases occur.	UKL_release_thresh _	Res_Reqs.wresl

Variable Name in Model code	Common Name	Definition	Output Variable Name	Model File of Initial Definition
UKL_release_thresh_sto	UKL flood release threshold storage volume	UKL volume above which flood releases occur. This is the UKL active storage volume associated with UKL_release_thresh.	-	Res_Reqs.wresl
UKL_rfg_up_thresh	UKL refuge upper threshold	During June-July, UKL level thresholds above which the Refuge can receive a daily delivery equal to the monthly demand, if the Project has a full supply. Set to 4142.50 ft in June, and 4141.50 ft in July.	UKL_rfg_up_thresh_	SeasonalSupply.wresl
UKLsupply	UKL supply	Supply identified in UKL as available to meet needs in the river, Refuge, and Project.	UKLSupplydv	SeasonalSupply.wresl
ukltraj_central	UKL central tendency base	Unadjusted UKL central tendency.	ukltraj_central_	UKLThresholds.wresl
ukltraj_high	Upper bound to adjusted UKL central tendency	Upper bound to adjusted UKL central tendency.	ukltraj_high_	UKLThresholds.wresl
ukltraj_low	Lower bound to adjusted UKL central tendency	Lower bound to adjusted UKL central tendency.	ukltraj_low_	UKLThresholds.wresl
upper_4dTrigger_mult	Variable used to compute stage1_trigger	Variable involved in computation of stage1_trigger. Set to 3.	-	FallWinterRiverOps.wresl
upper_I15_wyAvg_mult	Variable used to compute stage1_trigger	Variable involved in computation of stage1_trigger. Set to 1.6.	-	FallWinterRiverOps.wresl

Section B: Proposed Action Model Output Graphs

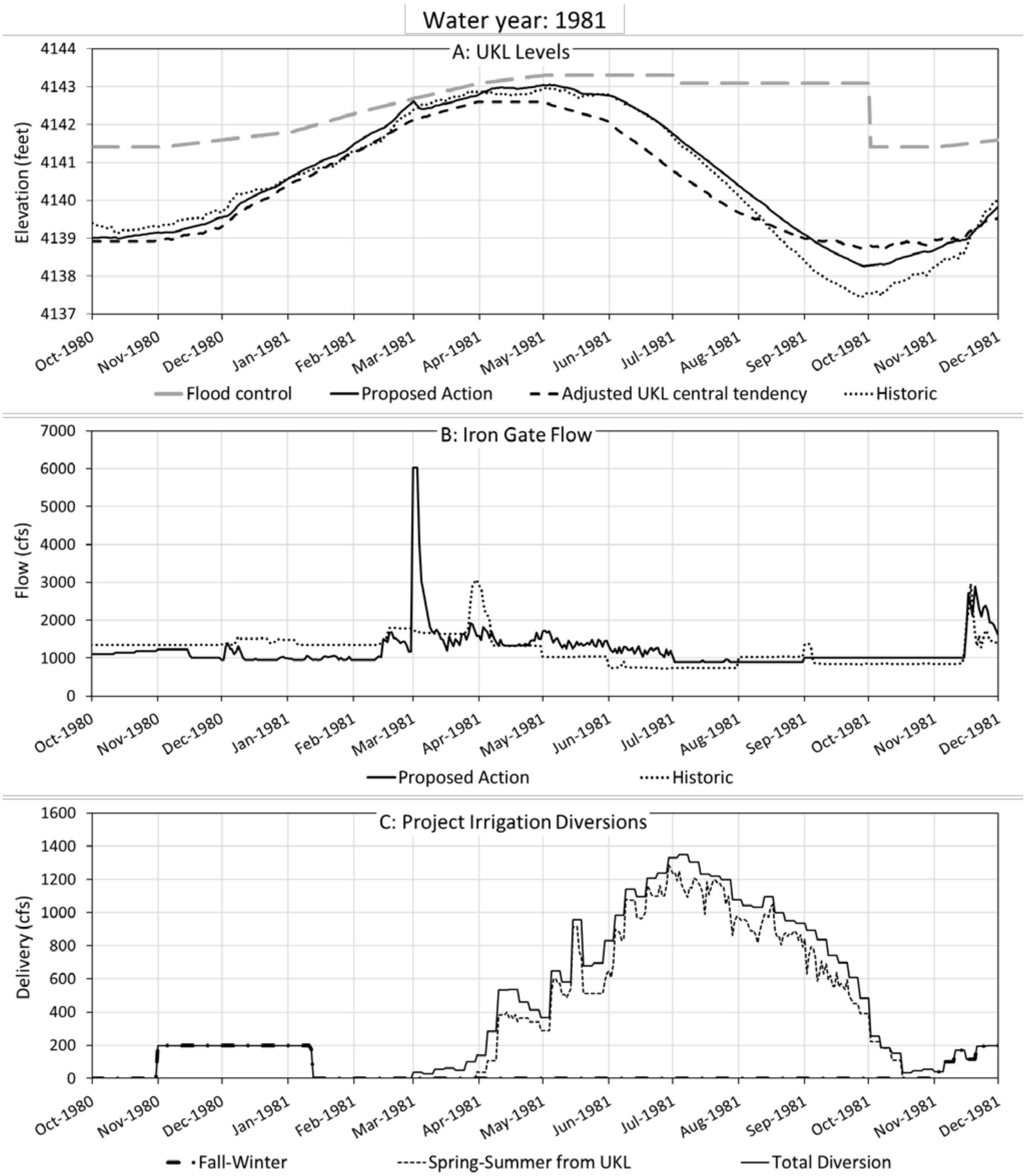

Figure B1. Proposed Action simulation results from the KBPM for Upper Klamath Lake (A), the Klamath River below Iron Gate Dam (B), and Project irrigation diversions (C) for water year 1981.

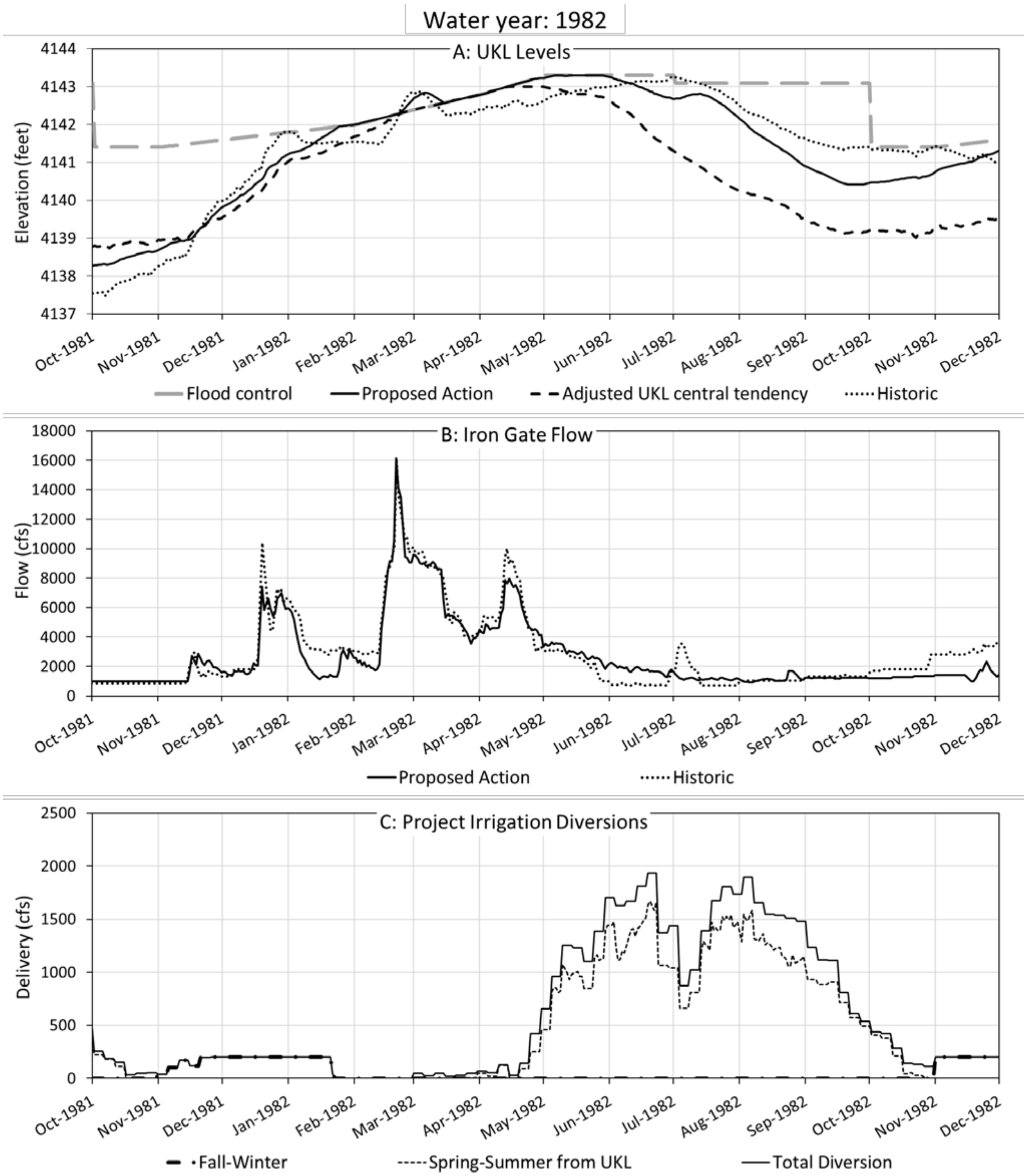

Figure B2. Proposed Action simulation results from the KBPM for Upper Klamath Lake (A), the Klamath River below Iron Gate Dam (B), and Project irrigation diversions (C) for water year 1982.

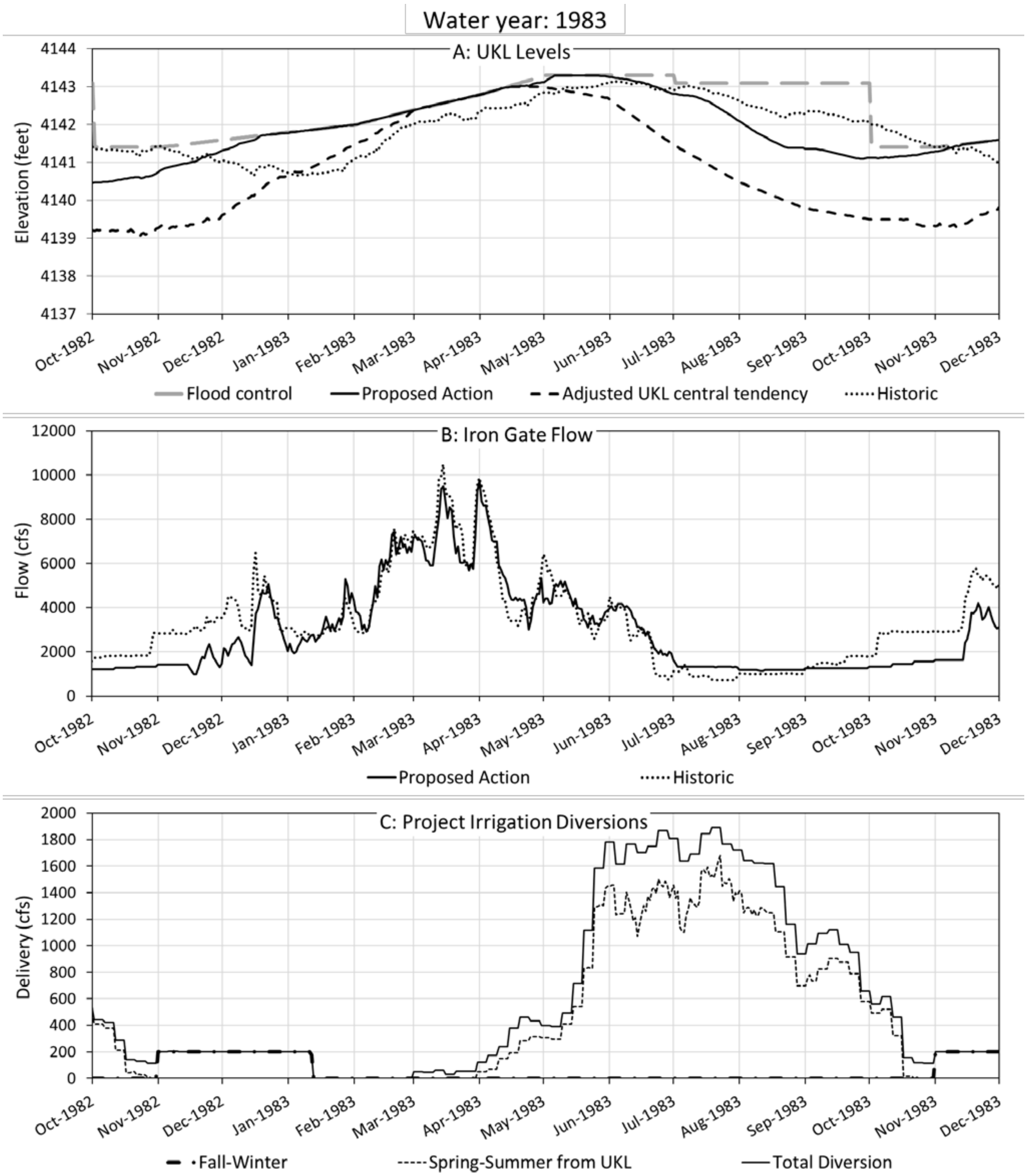

Figure B3. Proposed Action simulation results from the KBPM for Upper Klamath Lake (A), the Klamath River below Iron Gate Dam (B), and Project irrigation diversions (C) for water year 1983.

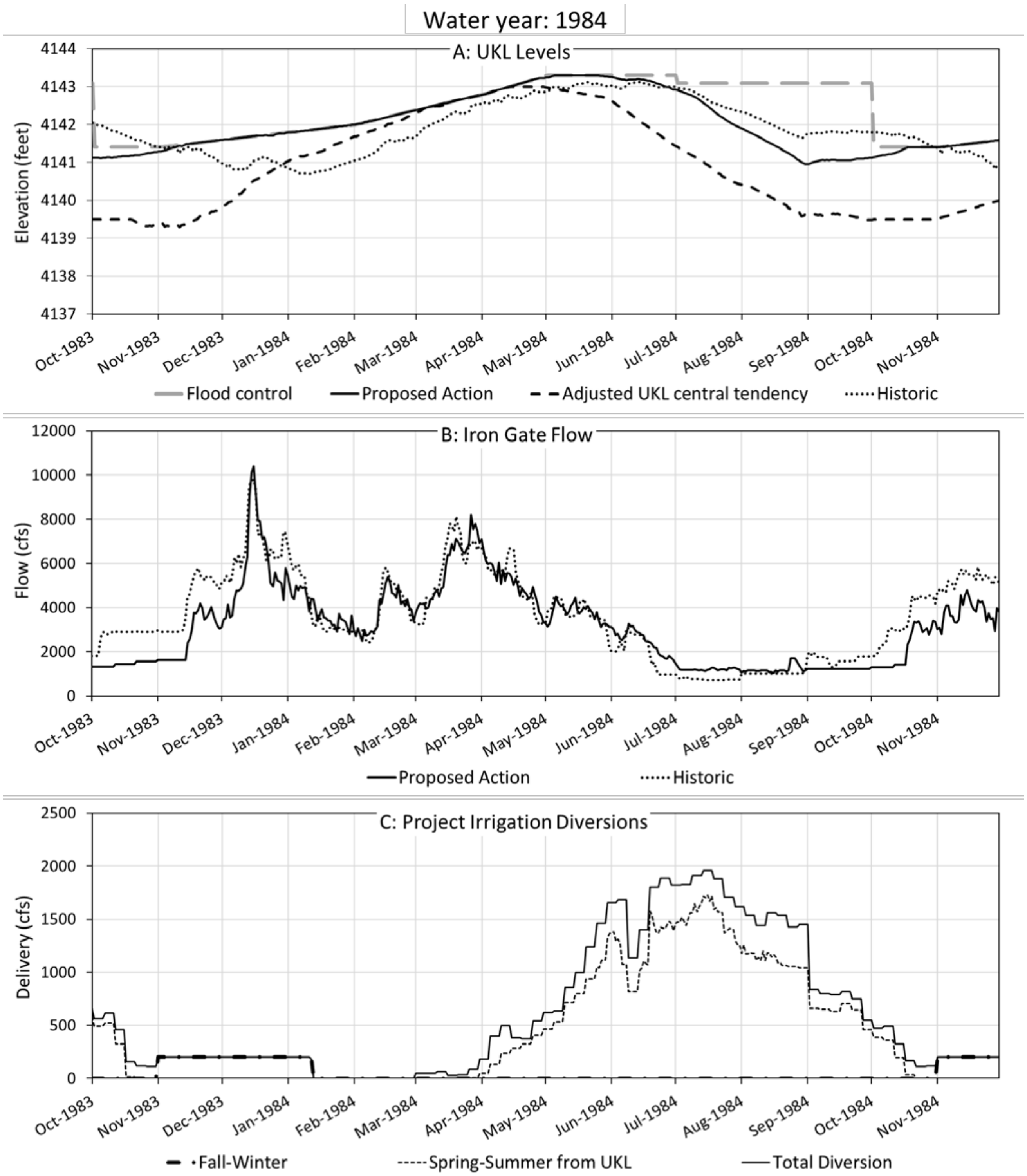

Figure B4. Proposed Action simulation results from the KBPM for Upper Klamath Lake (A), the Klamath River below Iron Gate Dam (B), and Project irrigation diversions (C) for water year 1984.

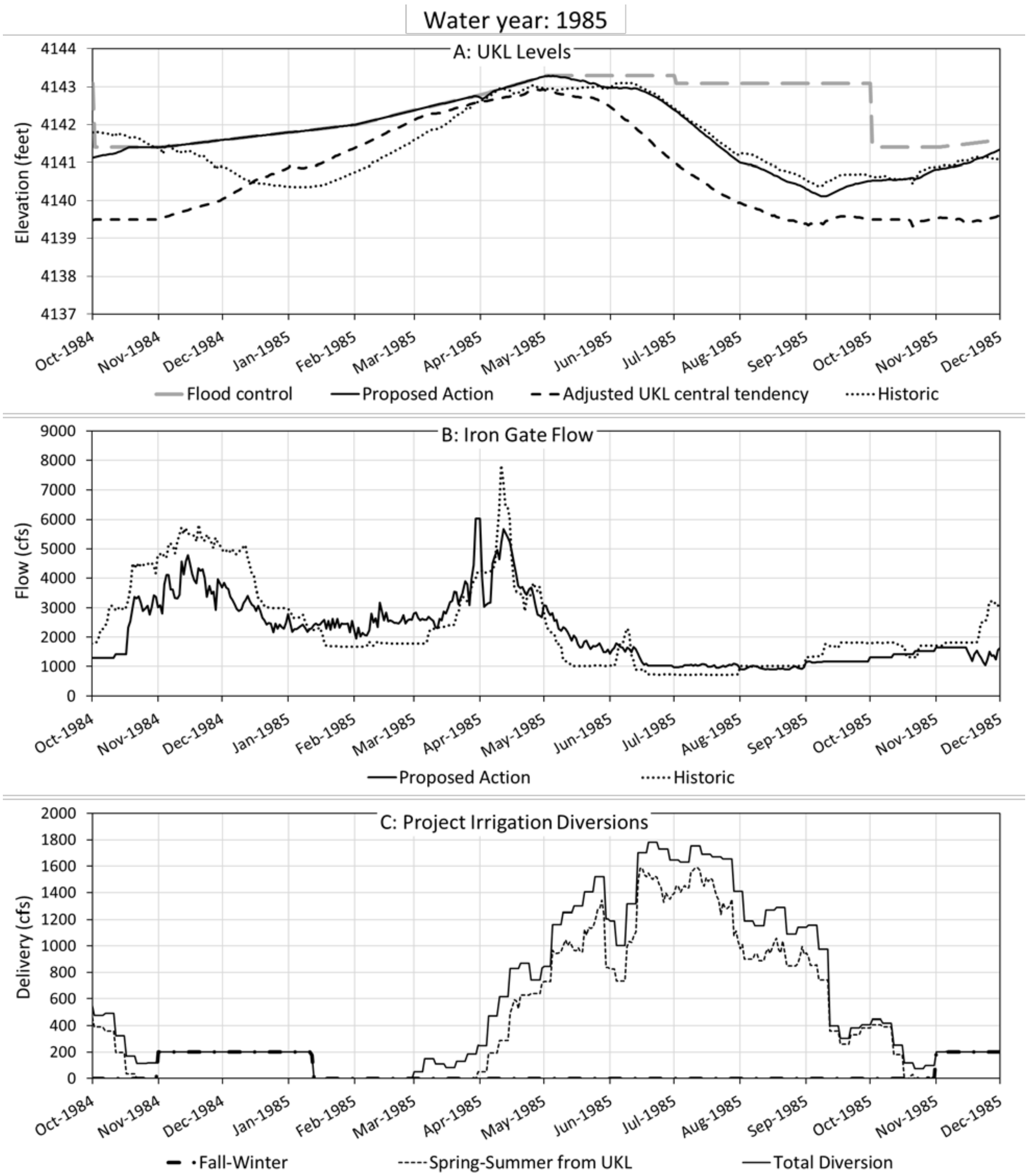

Figure B5. Proposed Action simulation results from the KBPM for Upper Klamath Lake (A), the Klamath River below Iron Gate Dam (B), and Project irrigation diversions (C) for water year 1985.

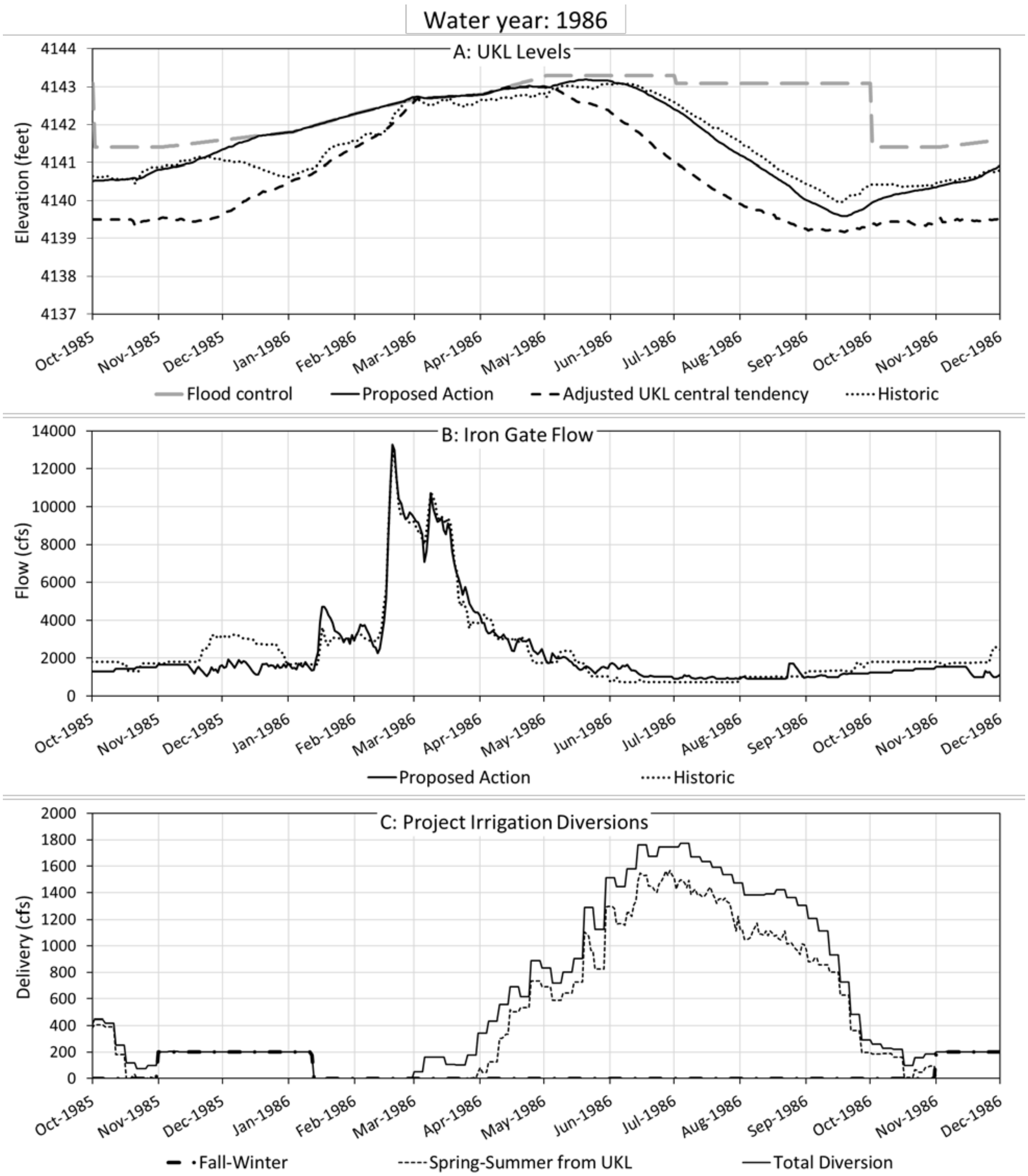

Figure B6. Proposed Action simulation results from the KBPM for Upper Klamath Lake (A), the Klamath River below Iron Gate Dam (B), and Project irrigation diversions (C) for water year 1986.

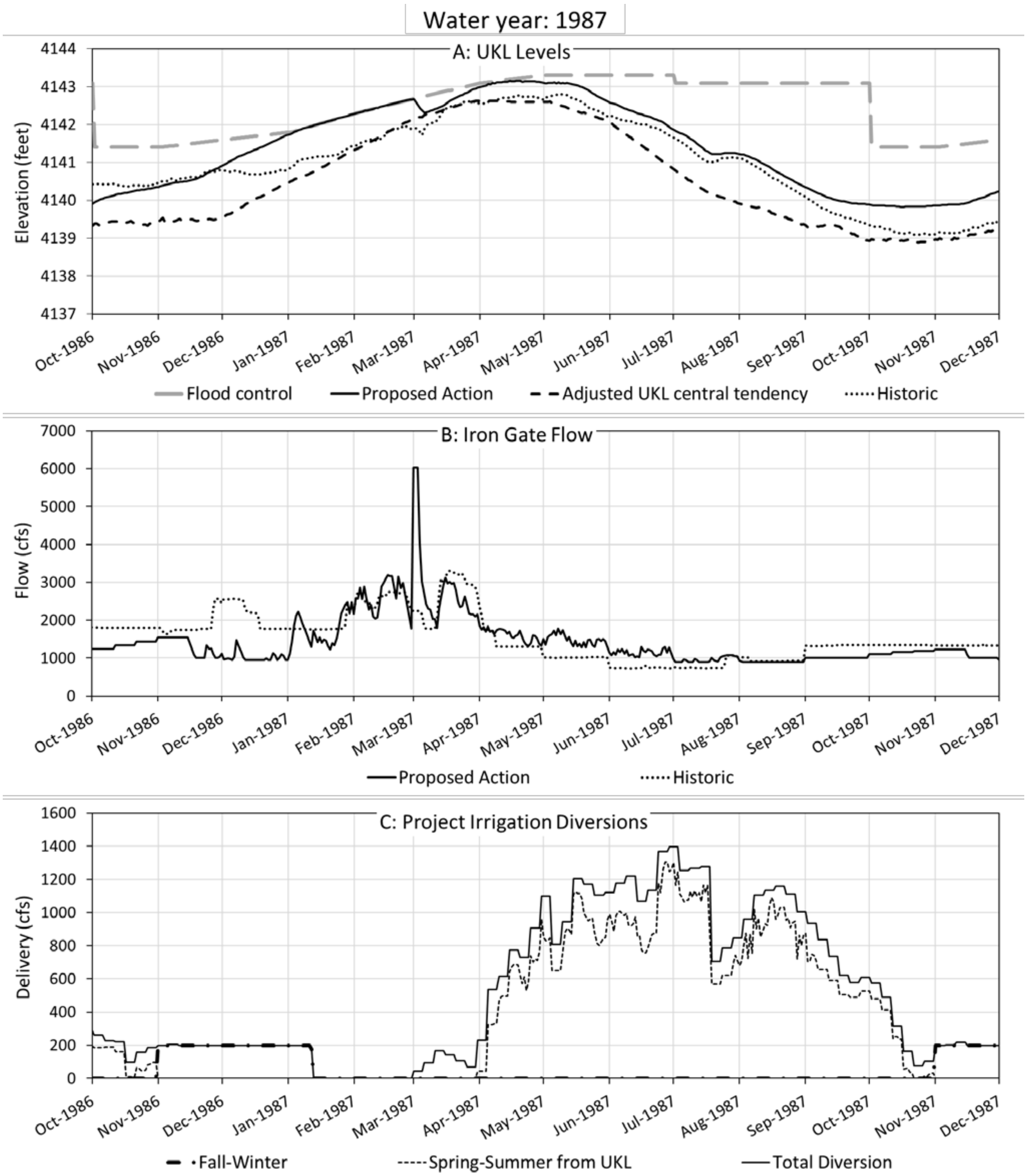

Figure B7. Proposed Action simulation results from the KBPM for Upper Klamath Lake (A), the Klamath River below Iron Gate Dam (B), and Project irrigation diversions (C) for water year 1987.

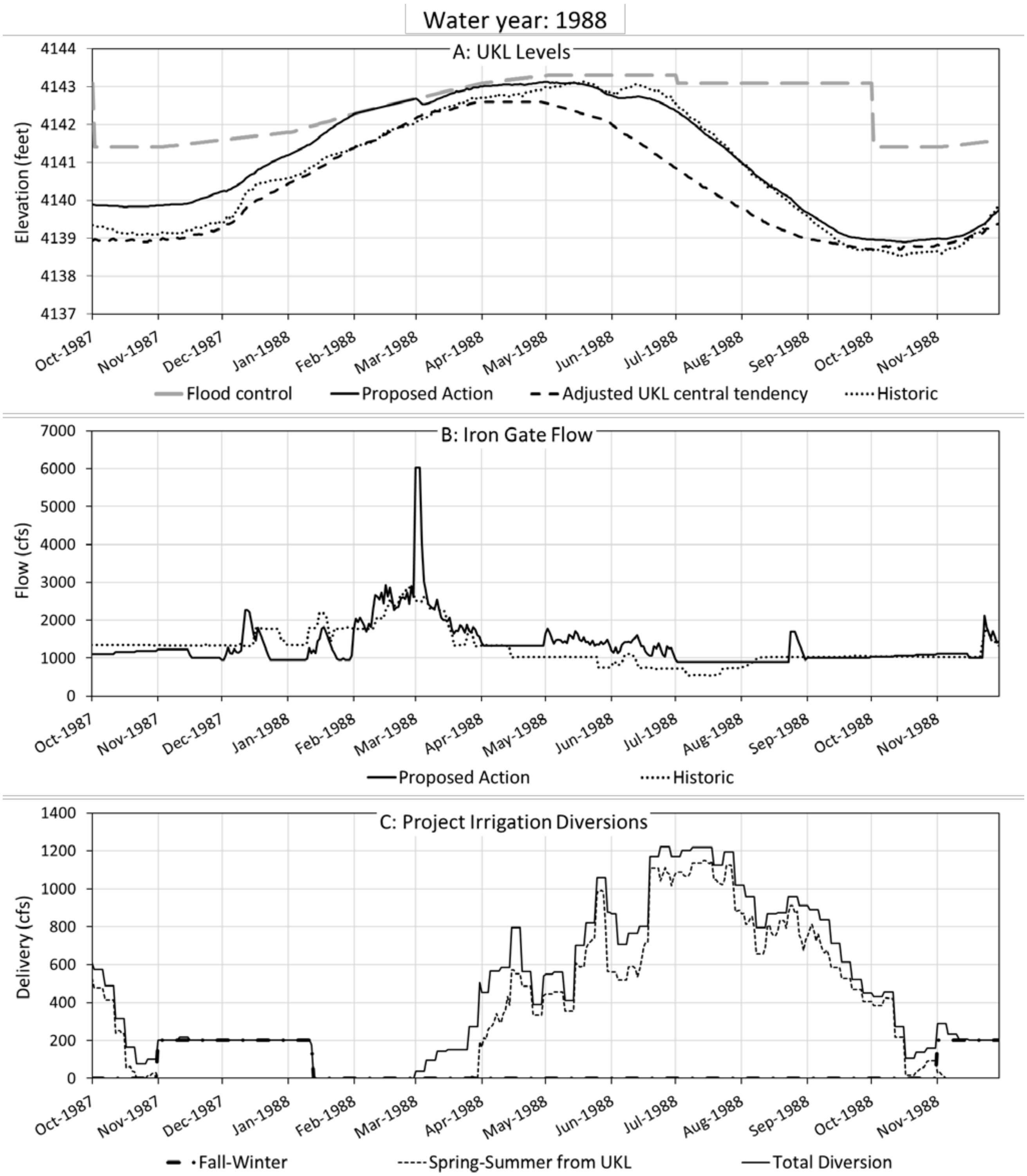

Figure B8. Proposed Action simulation results from the KBPM for Upper Klamath Lake (A), the Klamath River below Iron Gate Dam (B), and Project irrigation diversions (C) for water year 1988.

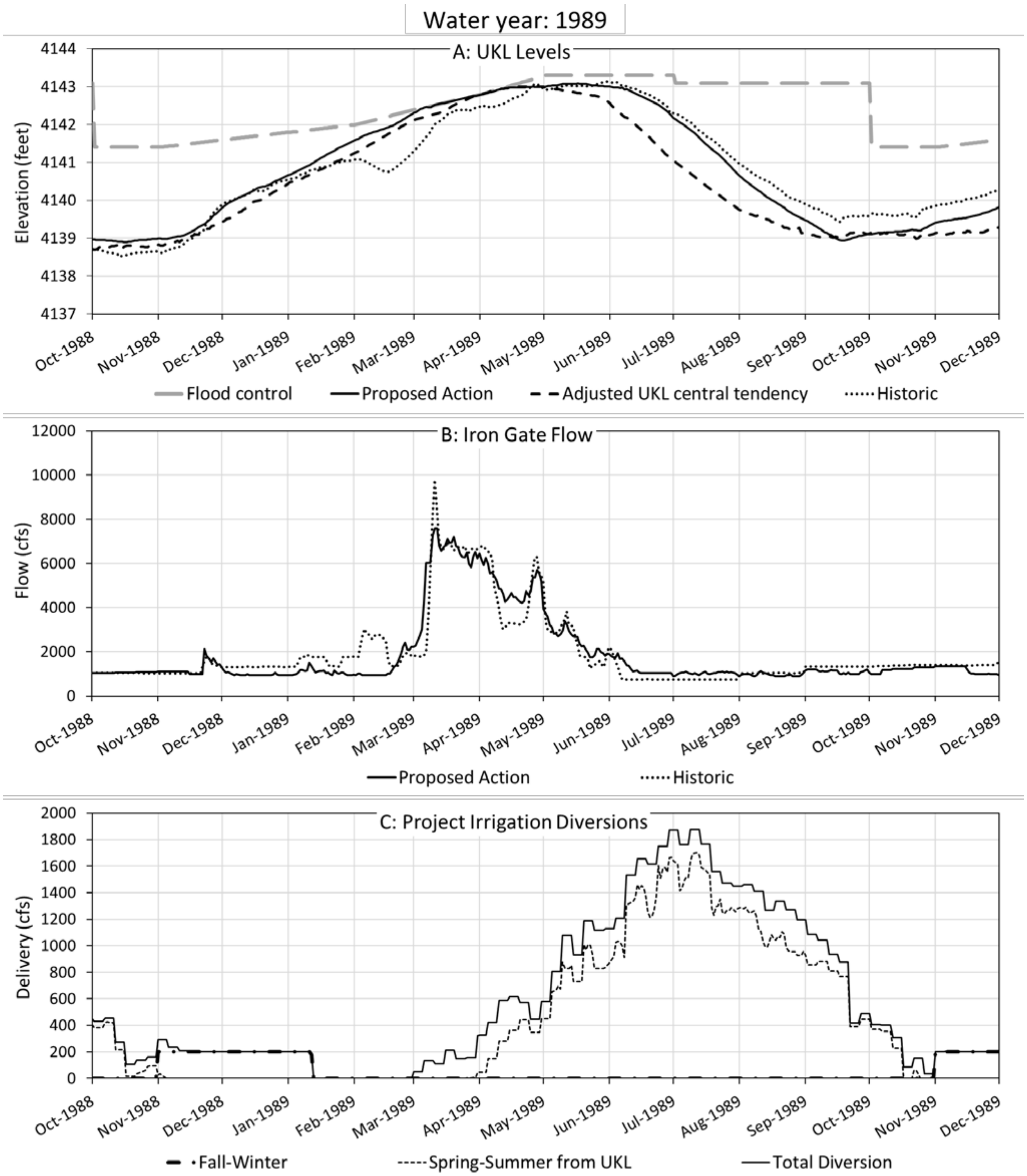

Figure B9. Proposed Action simulation results from the KBPM for Upper Klamath Lake (A), the Klamath River below Iron Gate Dam (B), and Project irrigation diversions (C) for water year 1989.

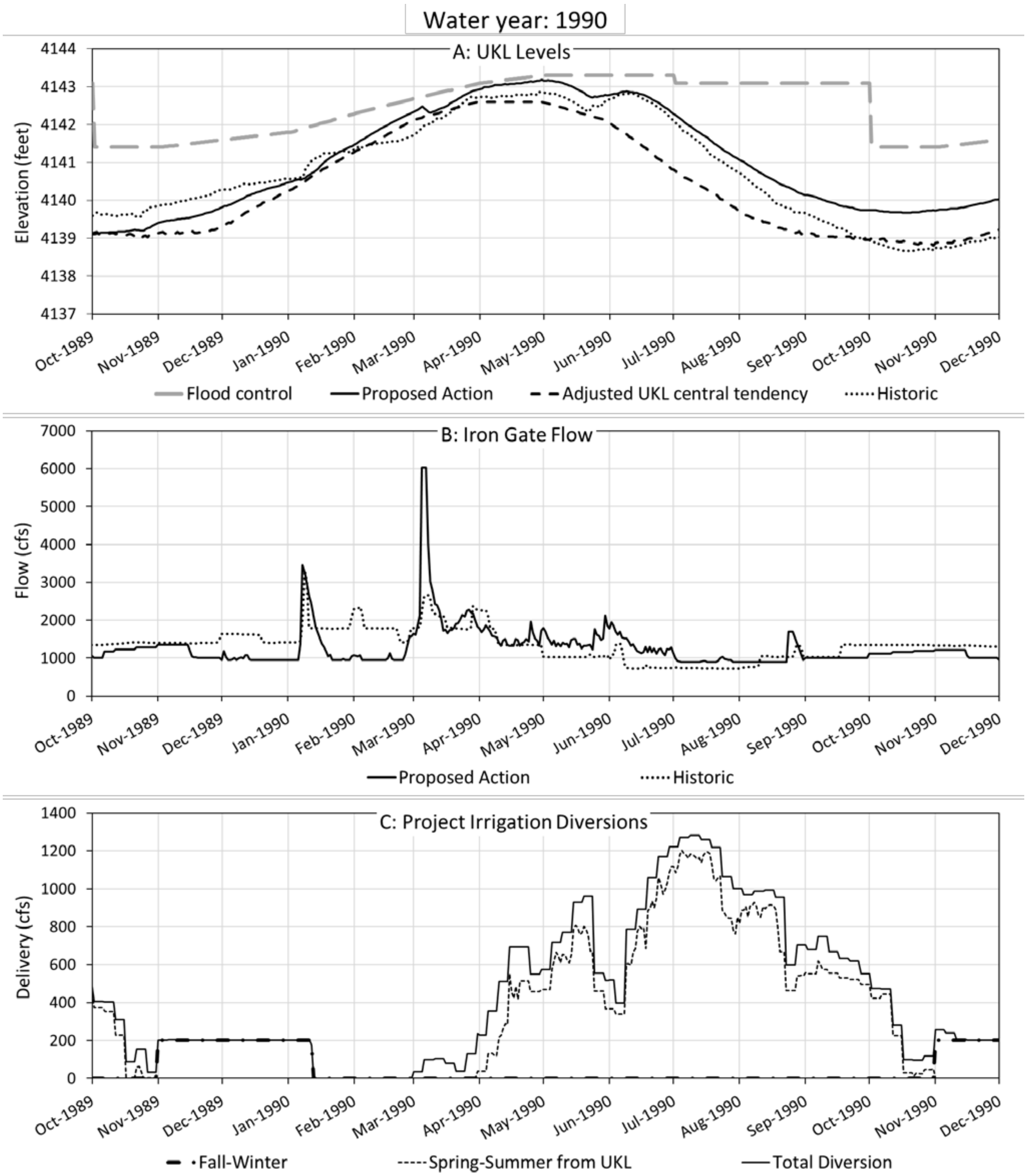

Figure B10. Proposed Action simulation results from the KBPM for Upper Klamath Lake (A), the Klamath River below Iron Gate Dam (B), and Project irrigation diversions (C) for water year 1990.

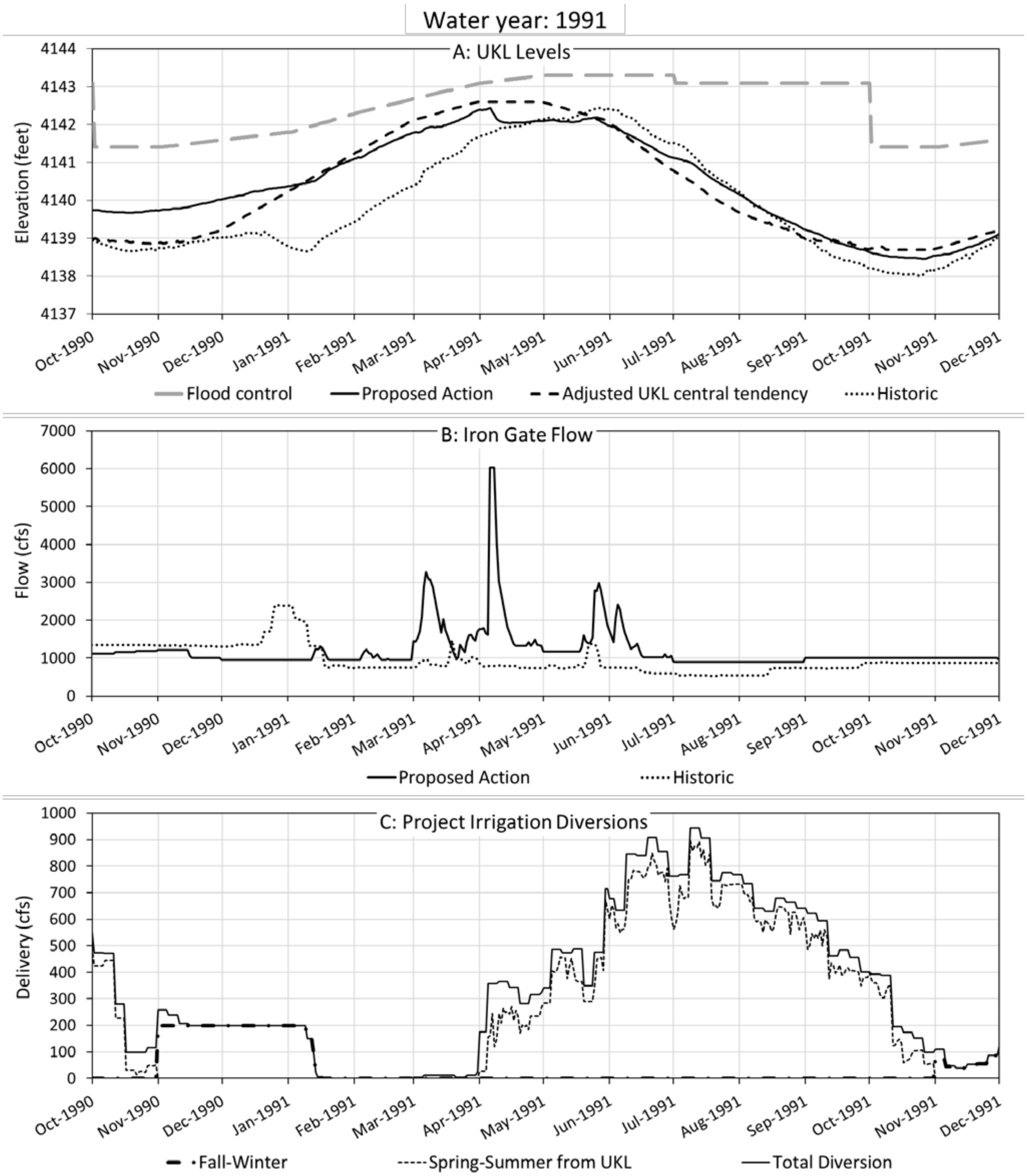

Figure B11. Proposed Action simulation results from the KBPM for Upper Klamath Lake (A), the Klamath River below Iron Gate Dam (B), and Project irrigation diversions (C) for water year 1991.

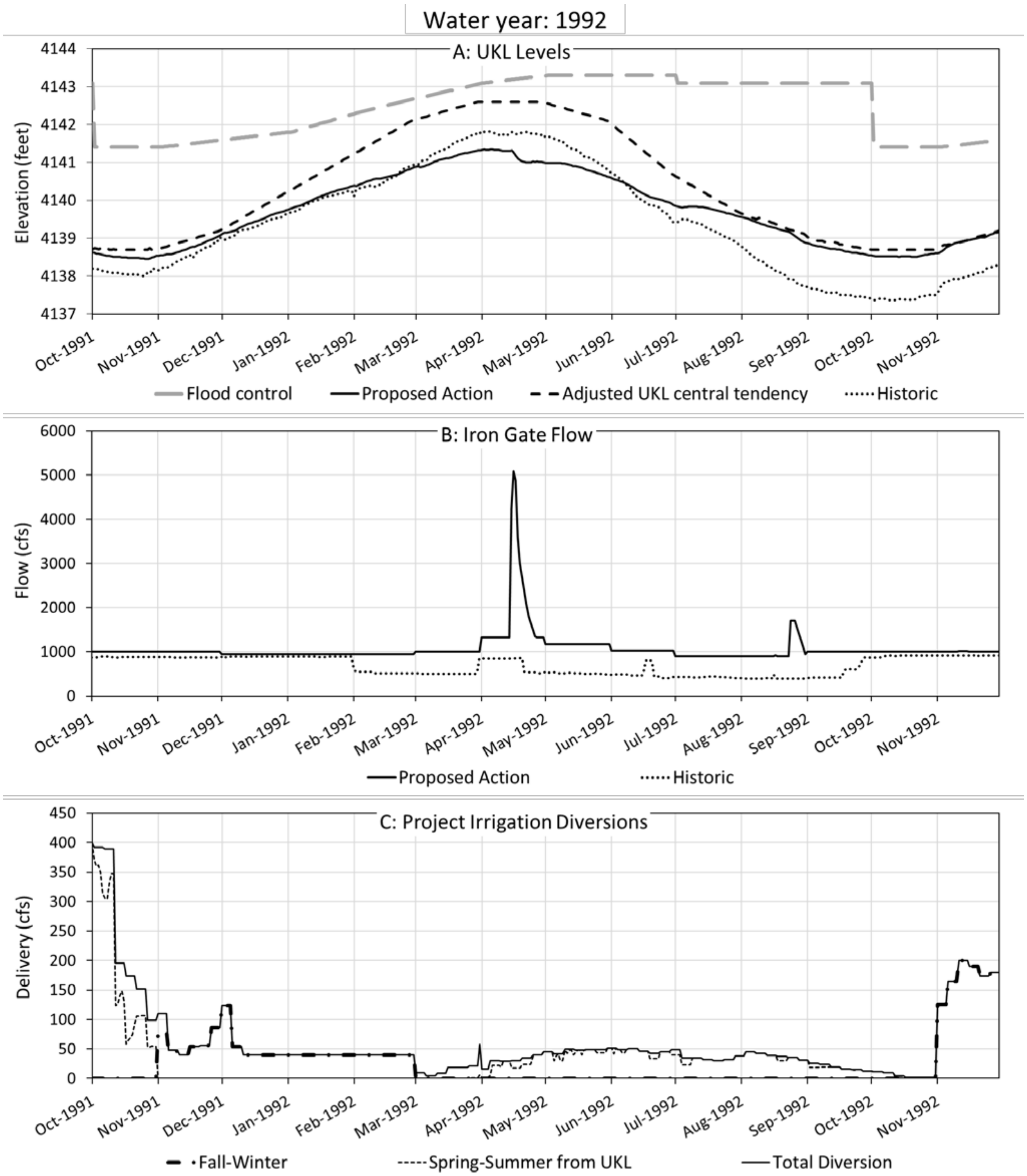

Figure B12. Proposed Action simulation results from the KBPM for Upper Klamath Lake (A), the Klamath River below Iron Gate Dam (B), and Project irrigation diversions (C) for water year 1992.

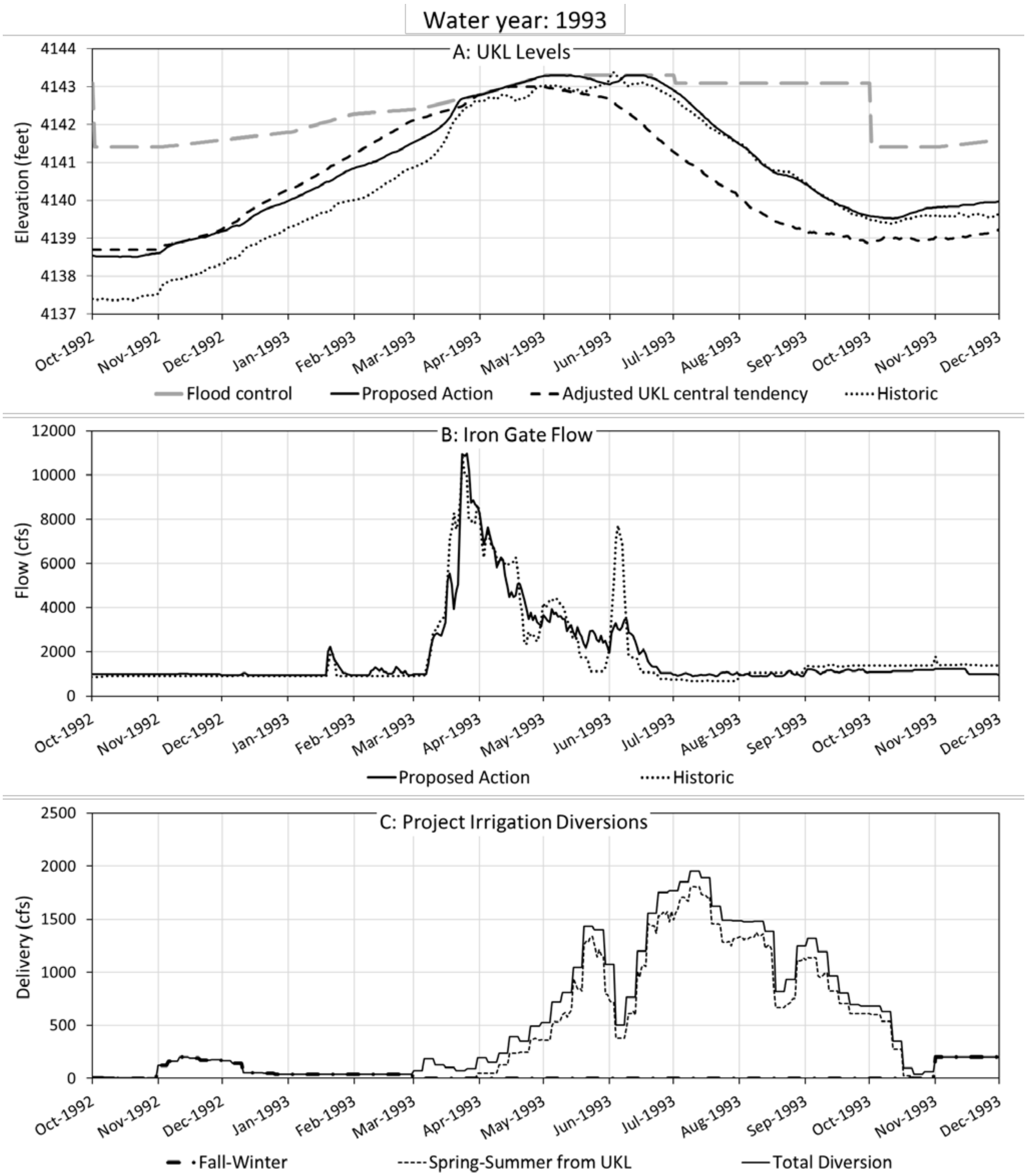

Figure B13. Proposed Action simulation results from the KBPM for Upper Klamath Lake (A), the Klamath River below Iron Gate Dam (B), and Project irrigation diversions (C) for water year 1993.

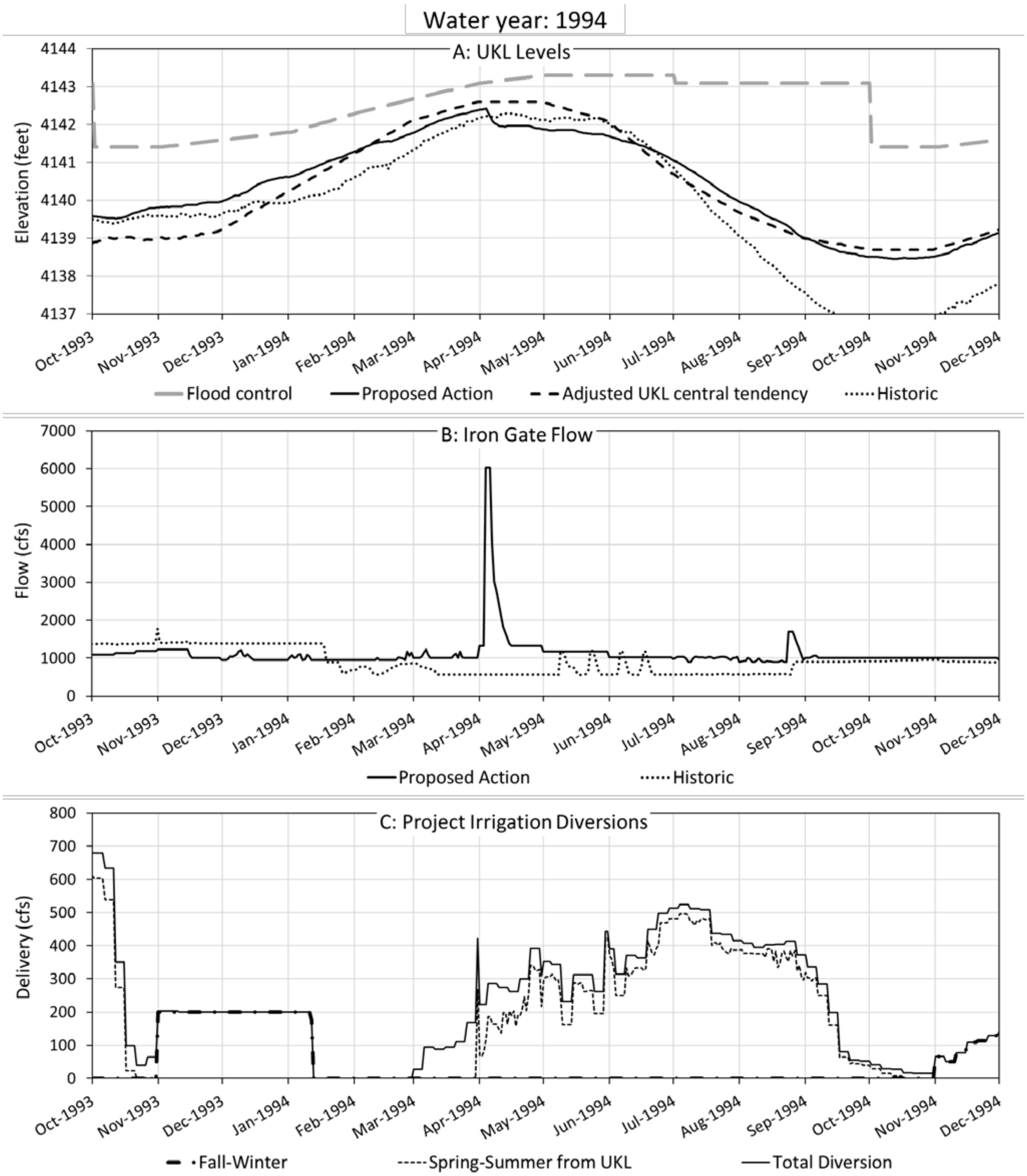

Figure B14. Proposed Action simulation results from the KBPM for Upper Klamath Lake (A), the Klamath River below Iron Gate Dam (B), and Project irrigation diversions (C) for water year 1994.

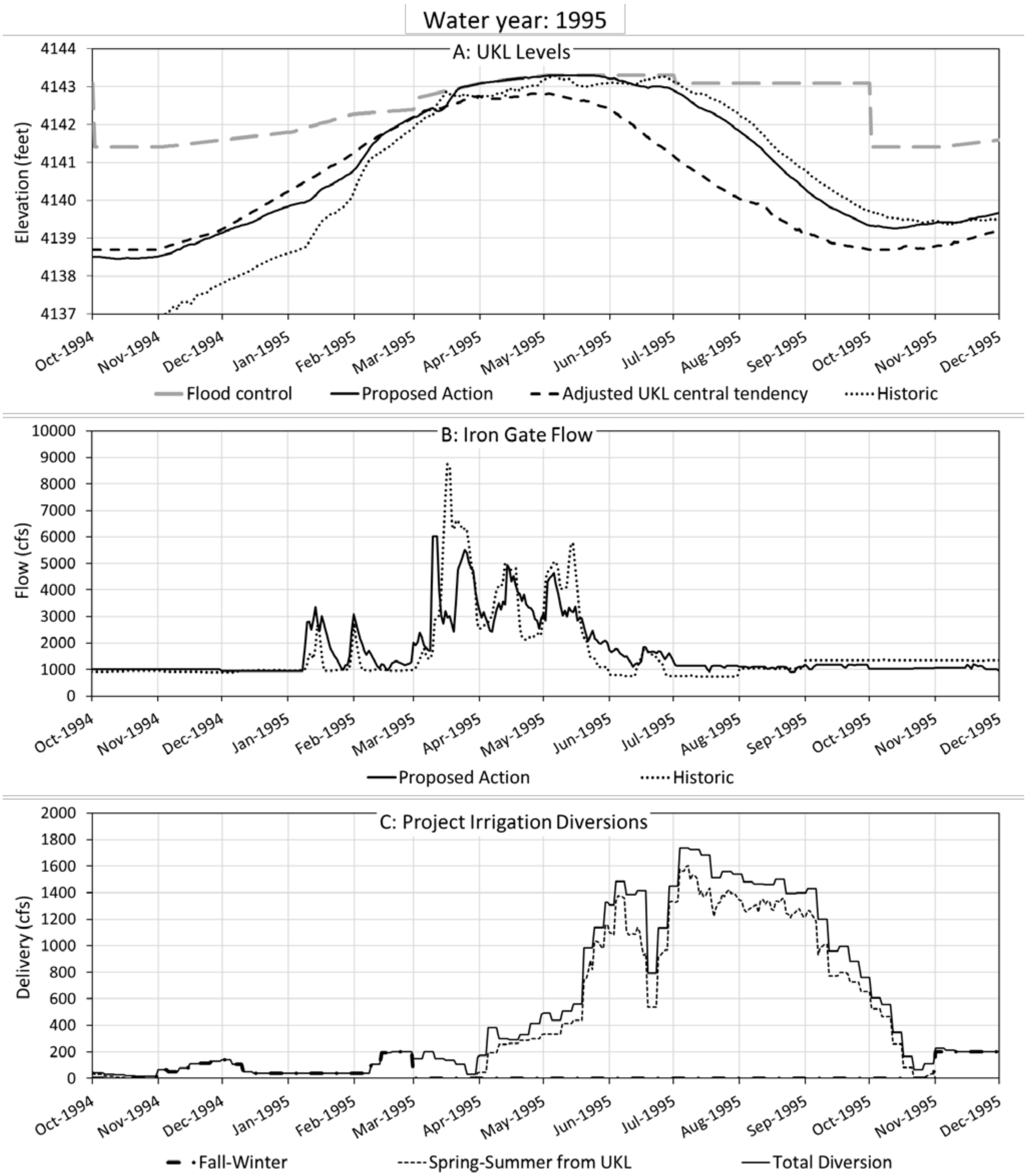

Figure B15. Proposed Action simulation results from the KBPM for Upper Klamath Lake (A), the Klamath River below Iron Gate Dam (B), and Project irrigation diversions (C) for water year 1995.

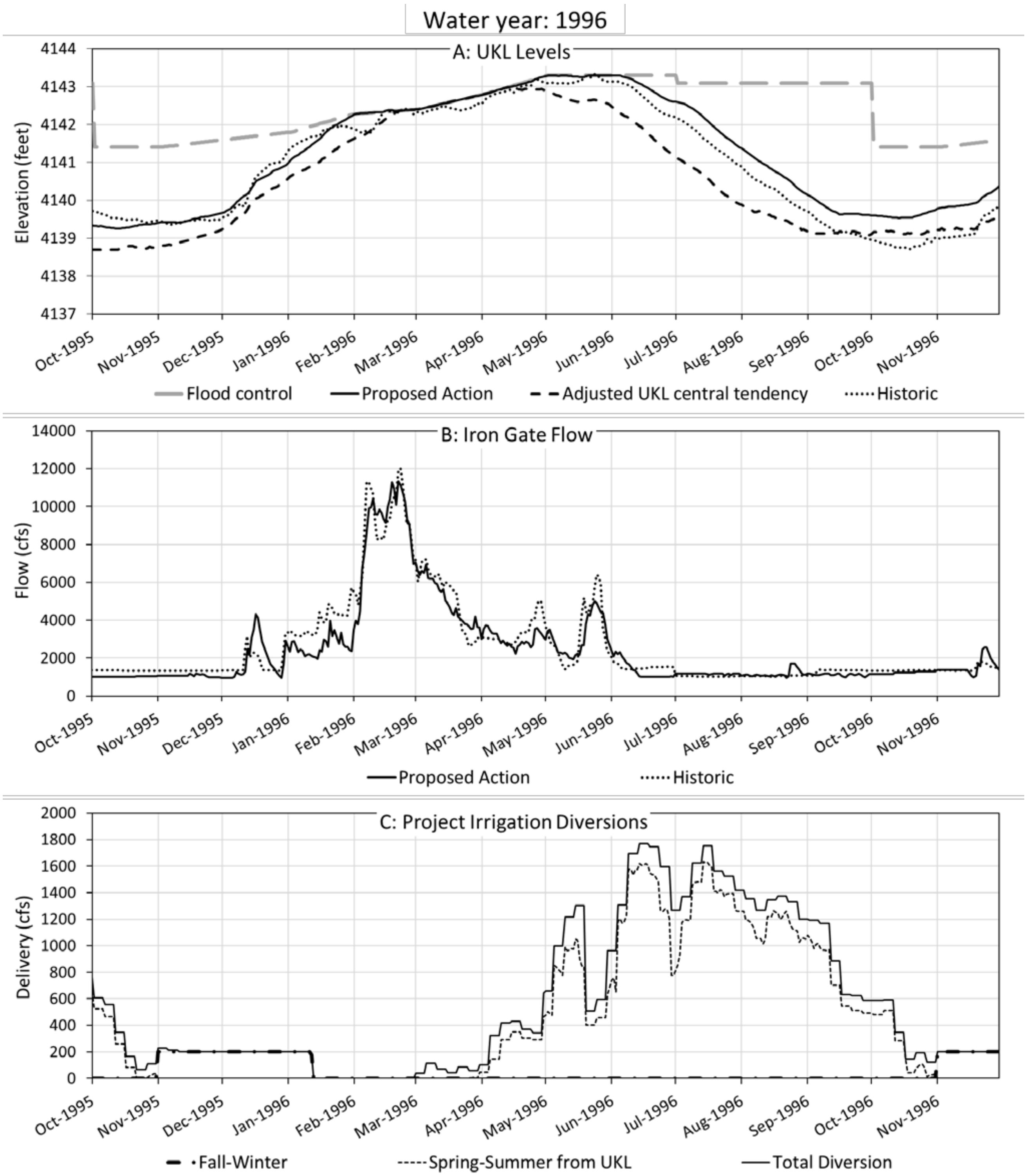

Figure B16. Proposed Action simulation results from the KBPM for Upper Klamath Lake (A), the Klamath River below Iron Gate Dam (B), and Project irrigation diversions (C) for water year 1996.

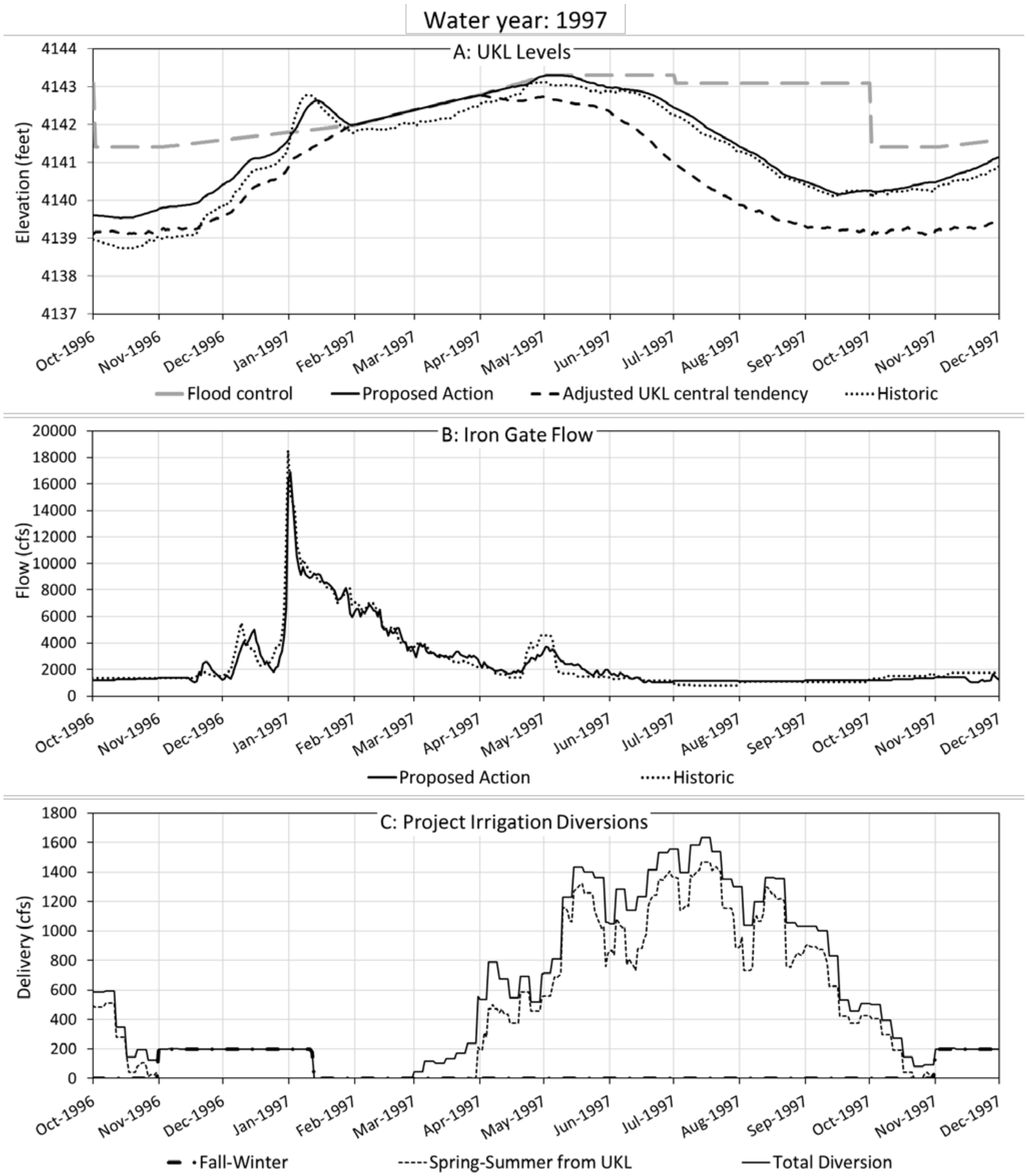

Figure B17. Proposed Action simulation results from the KBPM for Upper Klamath Lake (A), the Klamath River below Iron Gate Dam (B), and Project irrigation diversions (C) for water year 1997.

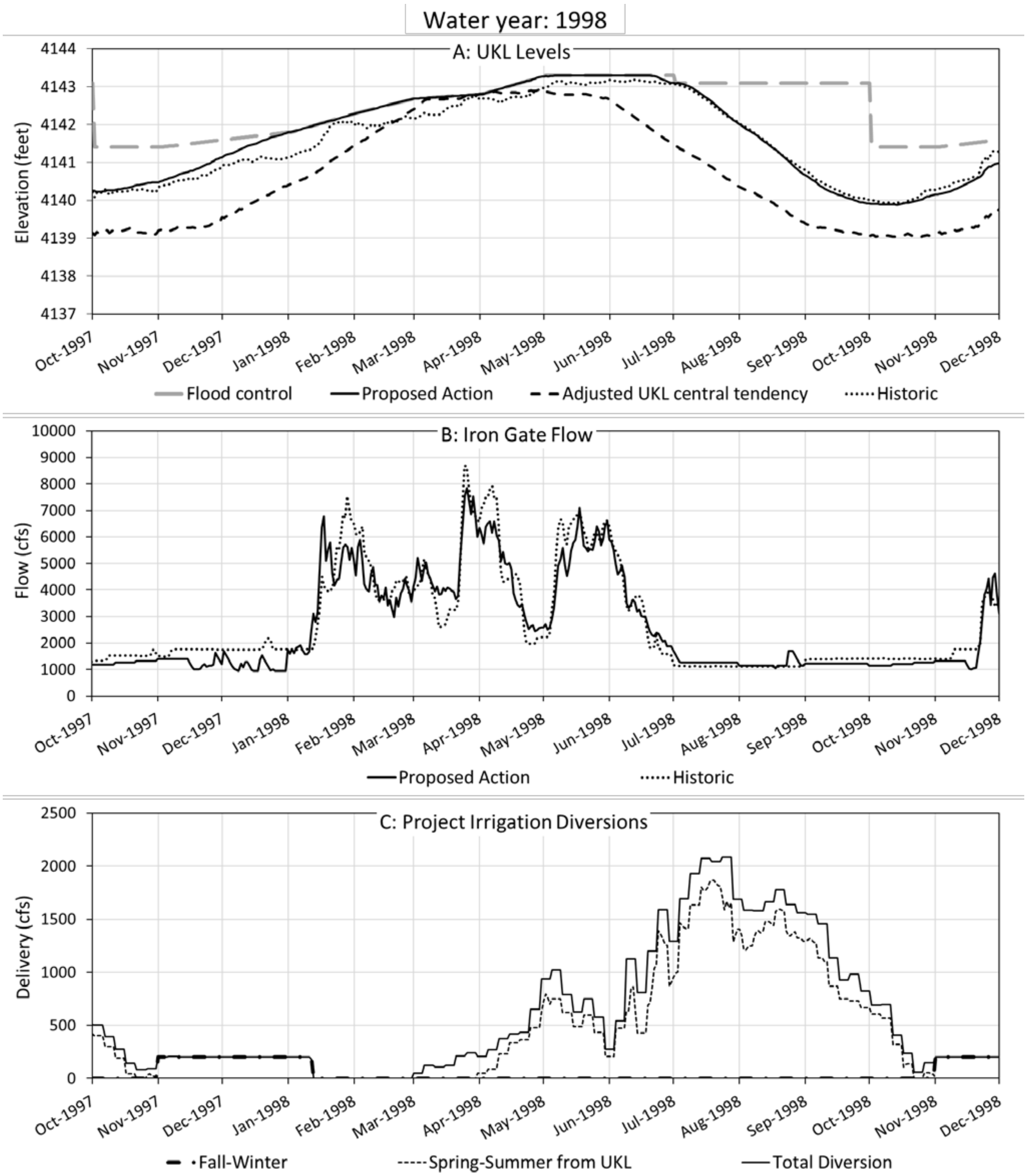

Figure B18. Proposed Action simulation results from the KBPM for Upper Klamath Lake (A), the Klamath River below Iron Gate Dam (B), and Project irrigation diversions (C) for water year 1998.

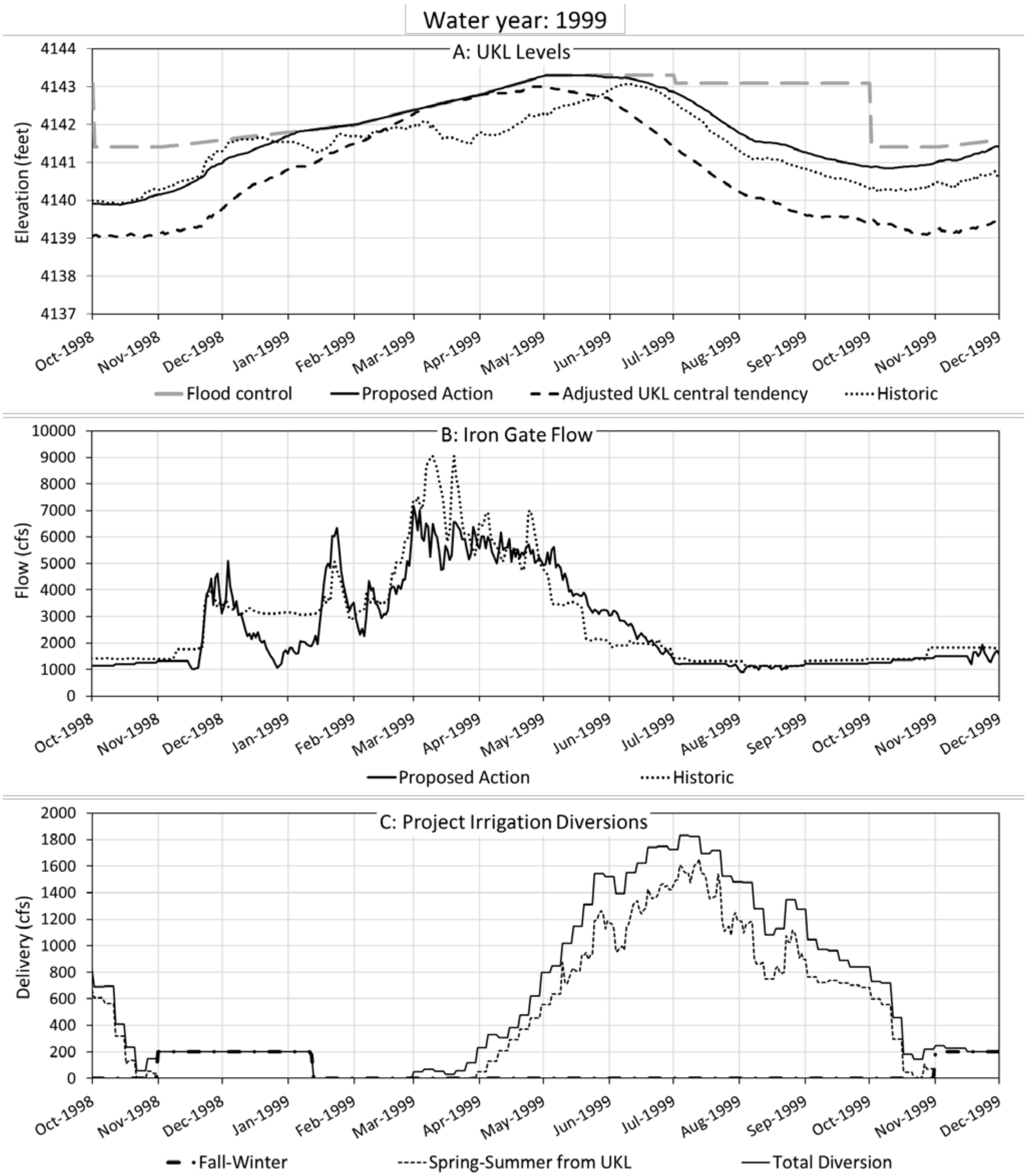

Figure B19. Proposed Action simulation results from the KBPM for Upper Klamath Lake (A), the Klamath River below Iron Gate Dam (B), and Project irrigation diversions (C) for water year 1999.

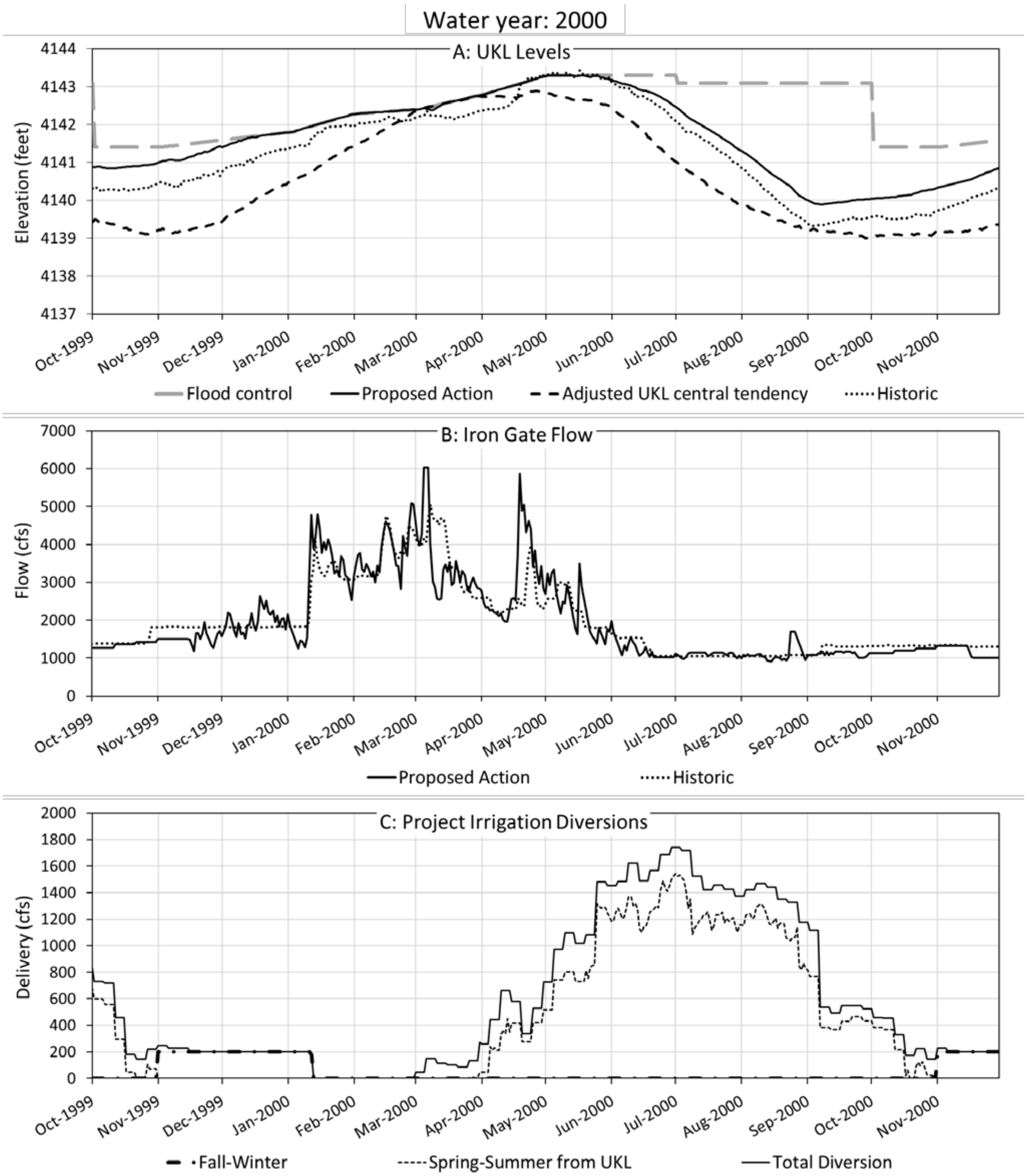

Figure B20. Proposed Action simulation results from the KBPM for Upper Klamath Lake (A), the Klamath River below Iron Gate Dam (B), and Project irrigation diversions (C) for water year 2000.

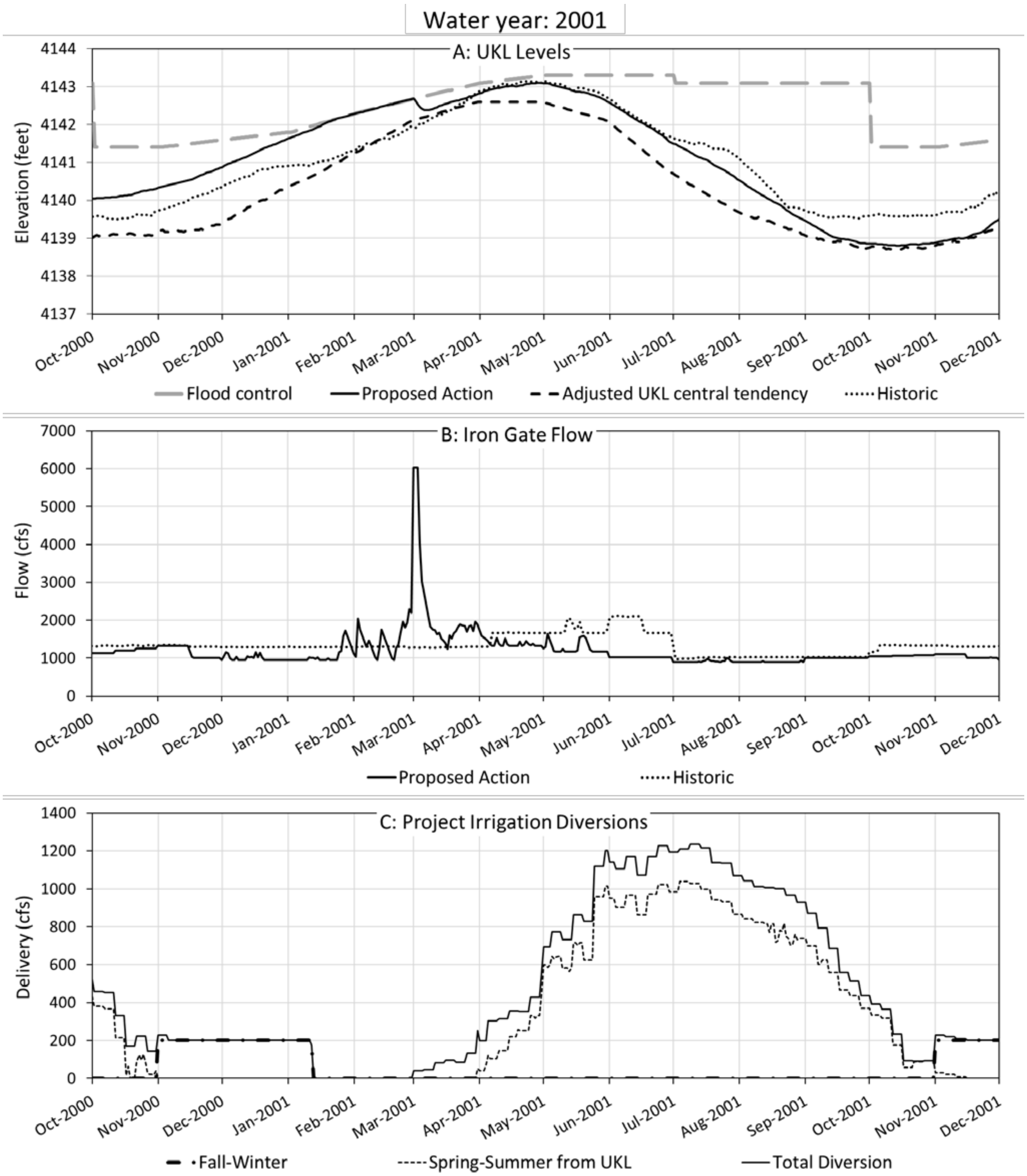

Figure B21. Proposed Action simulation results from the KBPM for Upper Klamath Lake (A), the Klamath River below Iron Gate Dam (B), and Project irrigation diversions (C) for water year 2001.

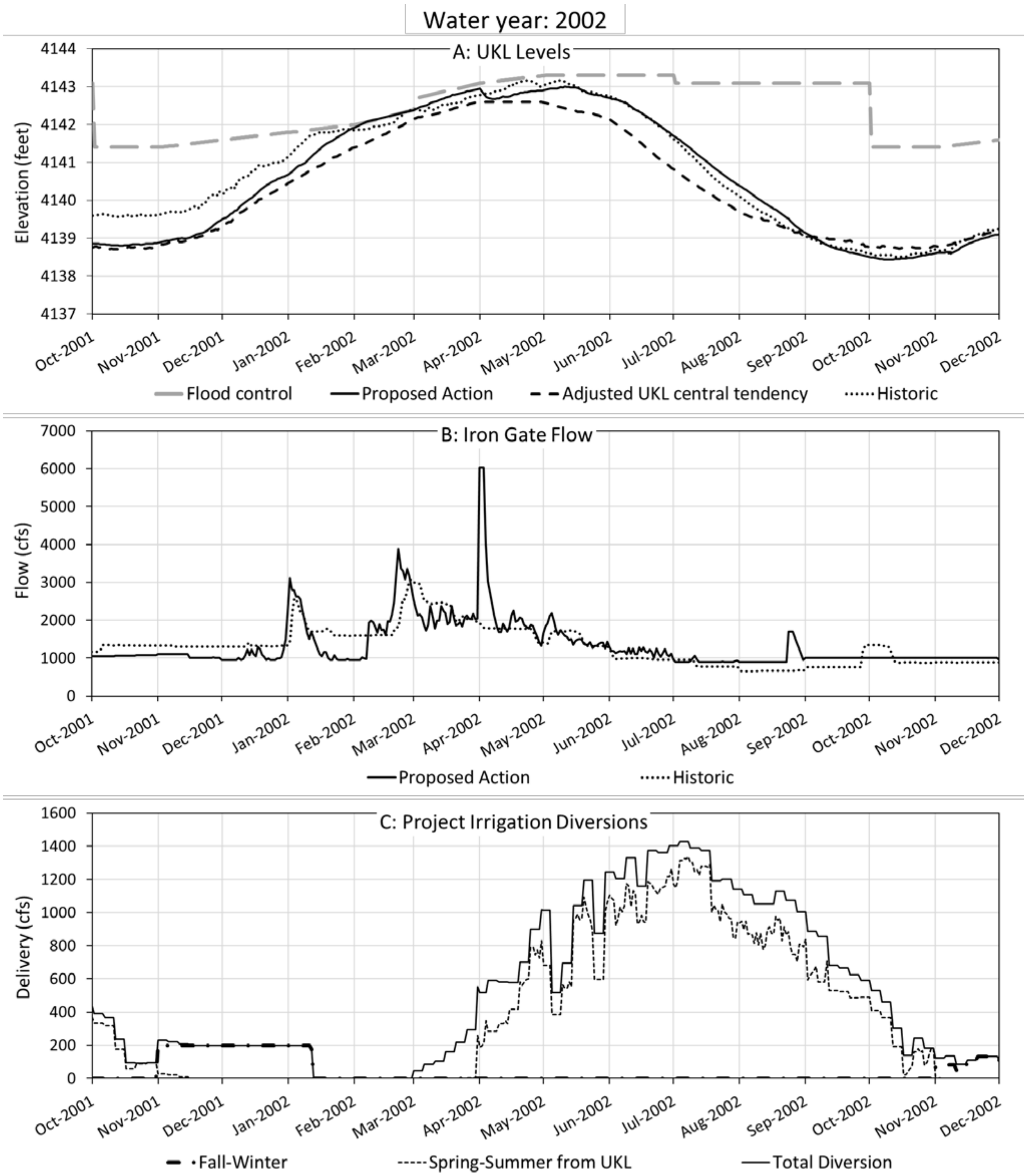

Figure B22. Proposed Action simulation results from the KBPM for Upper Klamath Lake (A), the Klamath River below Iron Gate Dam (B), and Project irrigation diversions (C) for water year 2002.

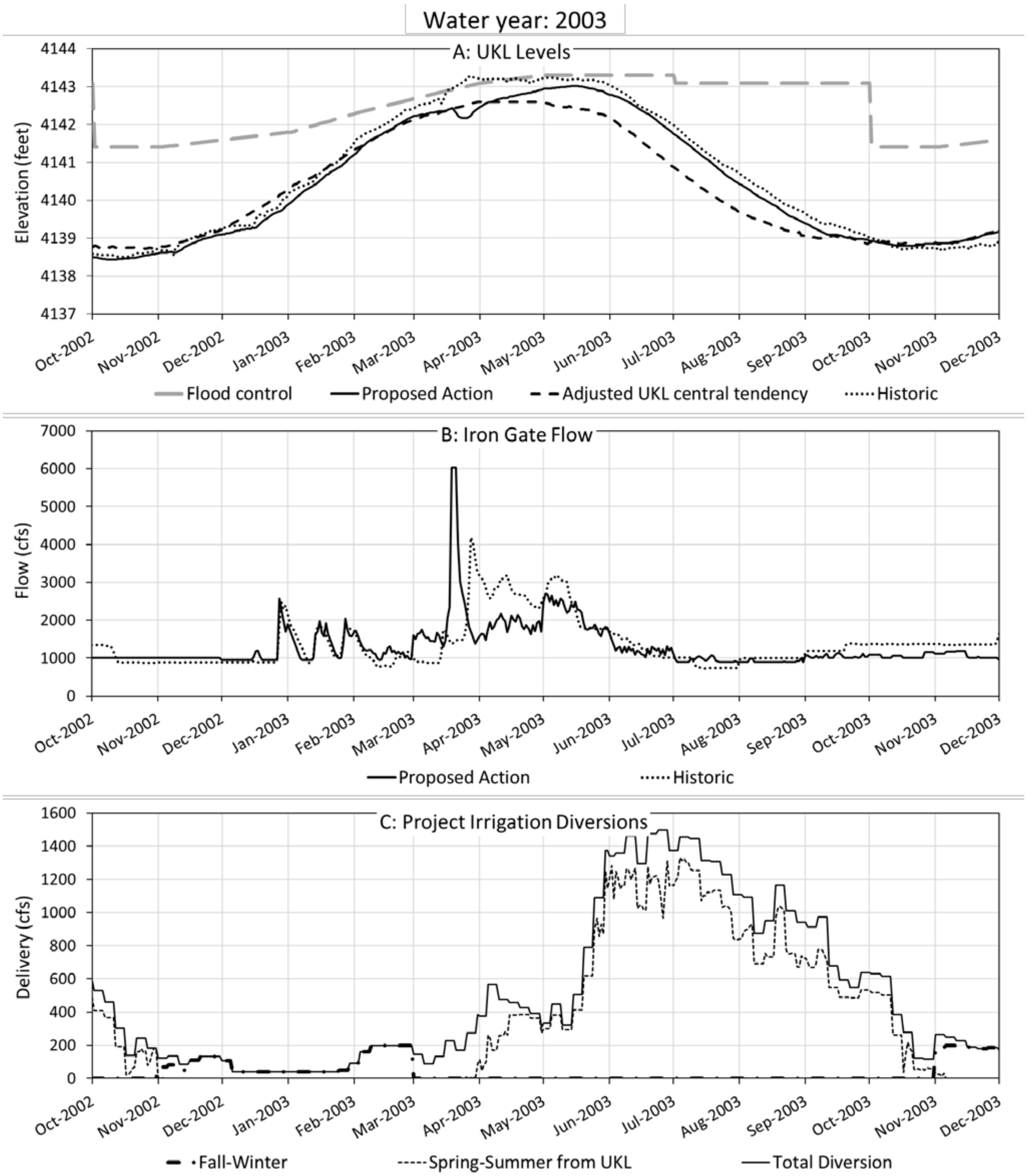

Figure B23. Proposed Action simulation results from the KBPM for Upper Klamath Lake (A), the Klamath River below Iron Gate Dam (B), and Project irrigation diversions (C) for water year 2003.

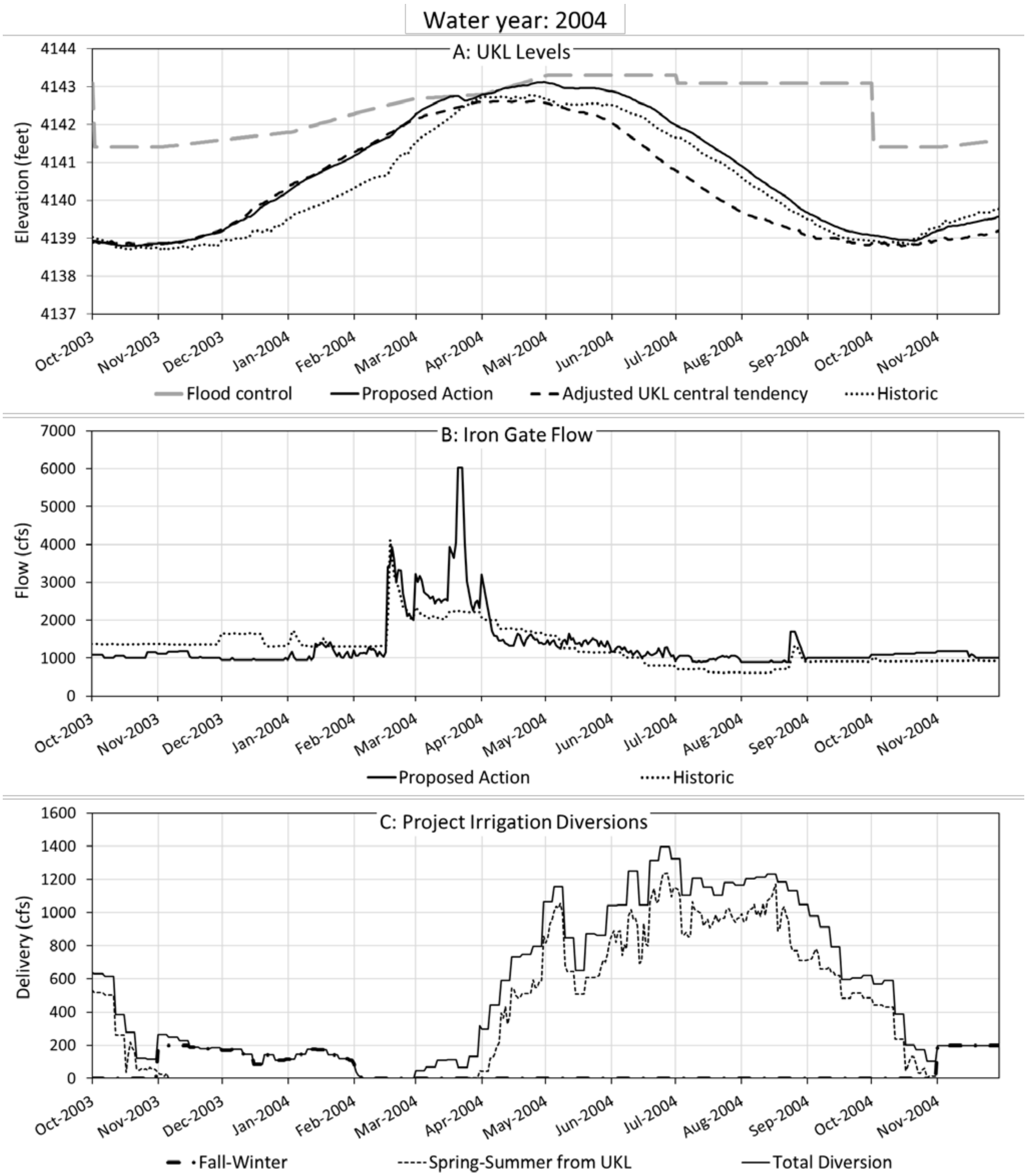

Figure B24. Proposed Action simulation results from the KBPM for Upper Klamath Lake (A), the Klamath River below Iron Gate Dam (B), and Project irrigation diversions (C) for water year 2004.

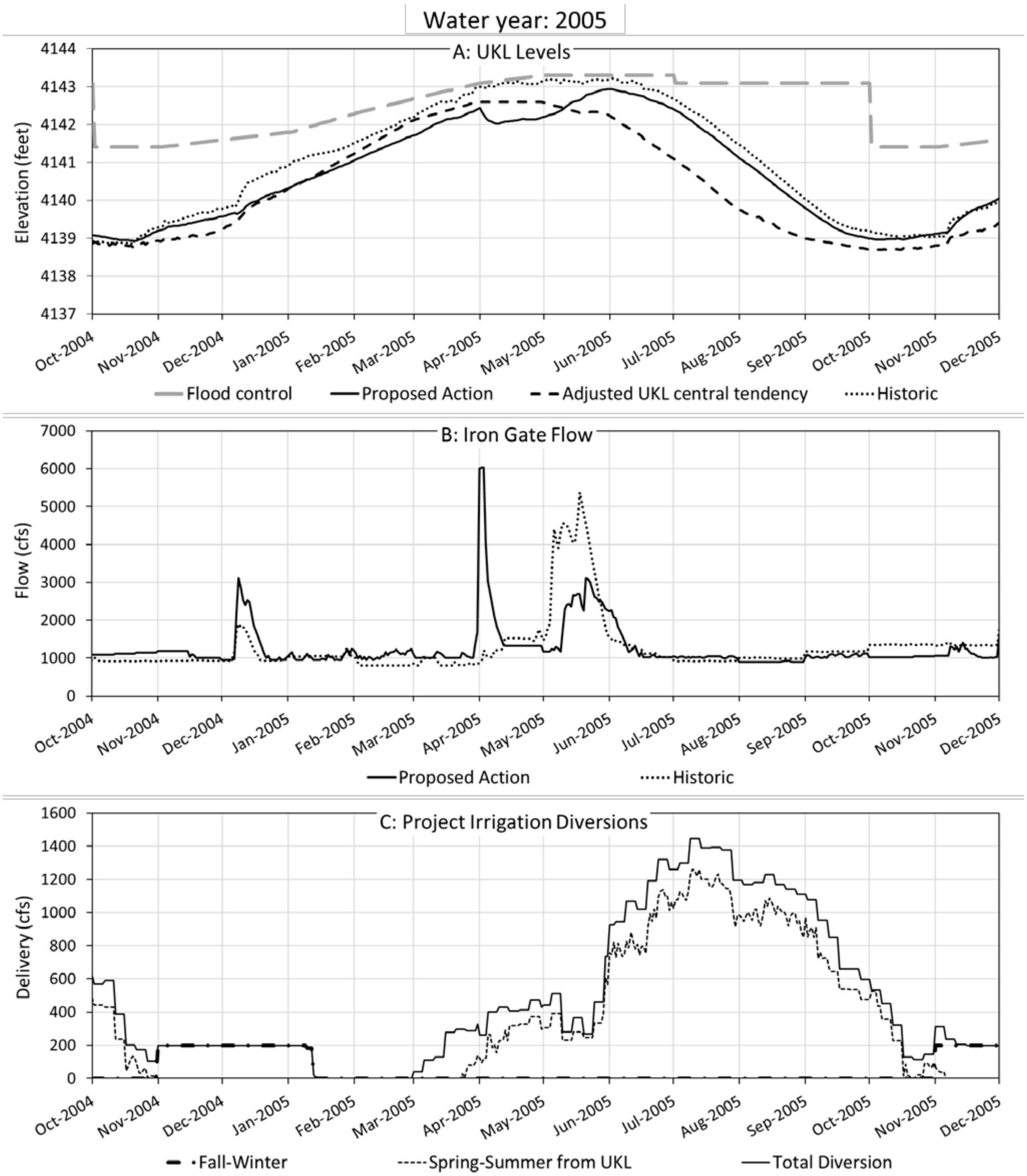

Figure B25. Proposed Action simulation results from the KBPM for Upper Klamath Lake (A), the Klamath River below Iron Gate Dam (B), and Project irrigation diversions (C) for water year 2005.

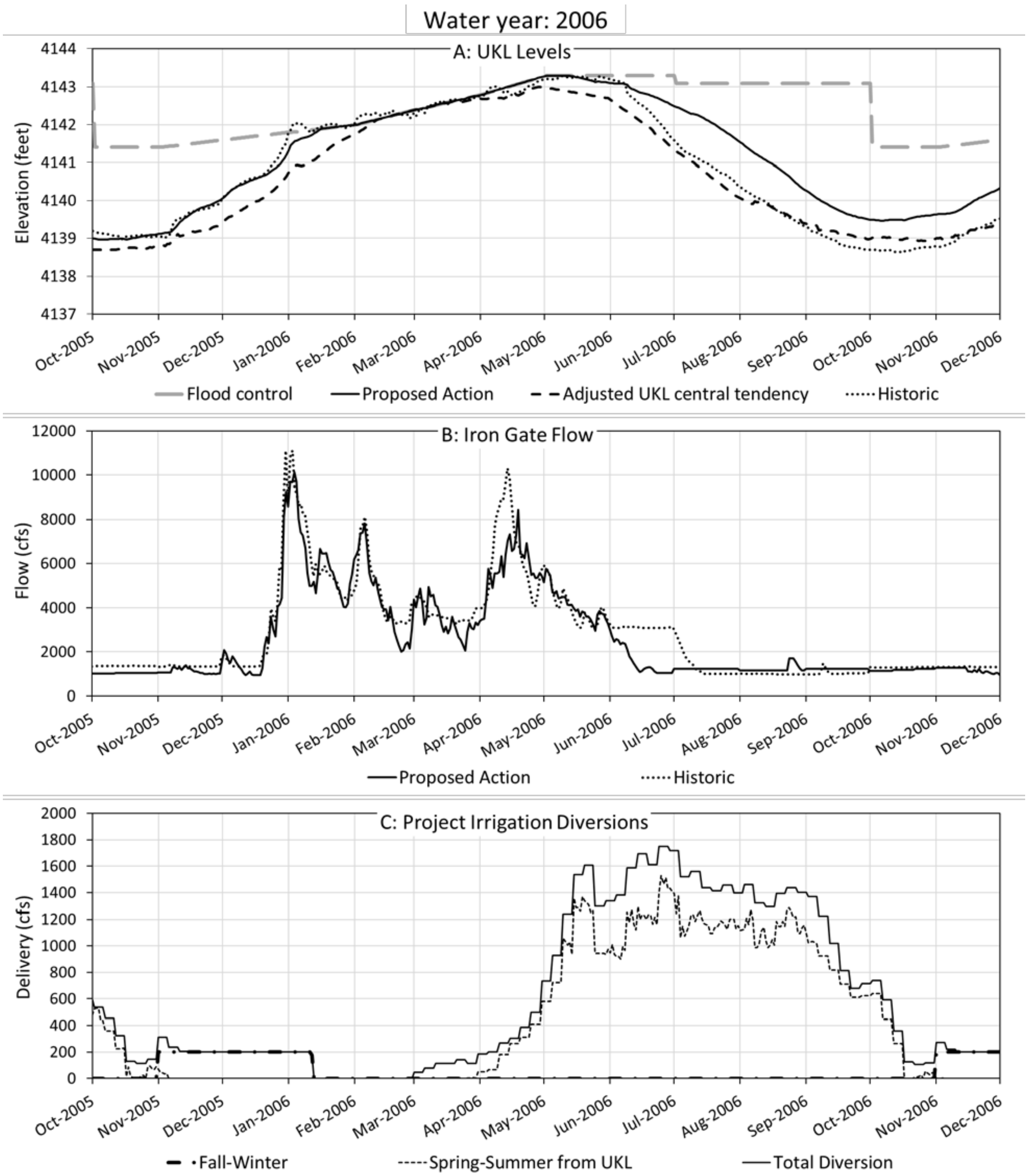

Figure B26. Proposed Action simulation results from the KBPM for Upper Klamath Lake (A), the Klamath River below Iron Gate Dam (B), and Project irrigation diversions (C) for water year 2006.

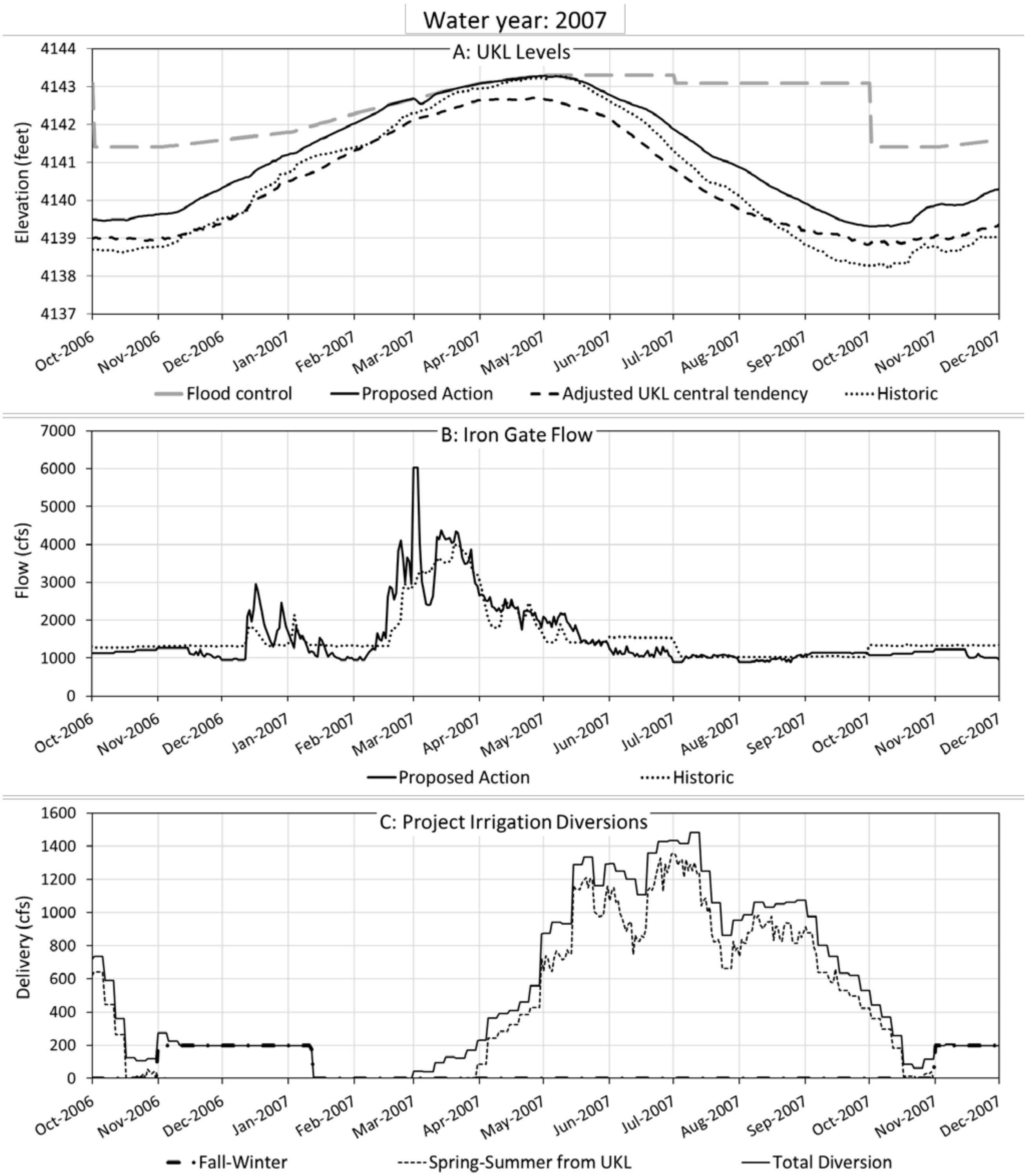

Figure B27. Proposed Action simulation results from the KBPM for Upper Klamath Lake (A), the Klamath River below Iron Gate Dam (B), and Project irrigation diversions (C) for water year 2007.

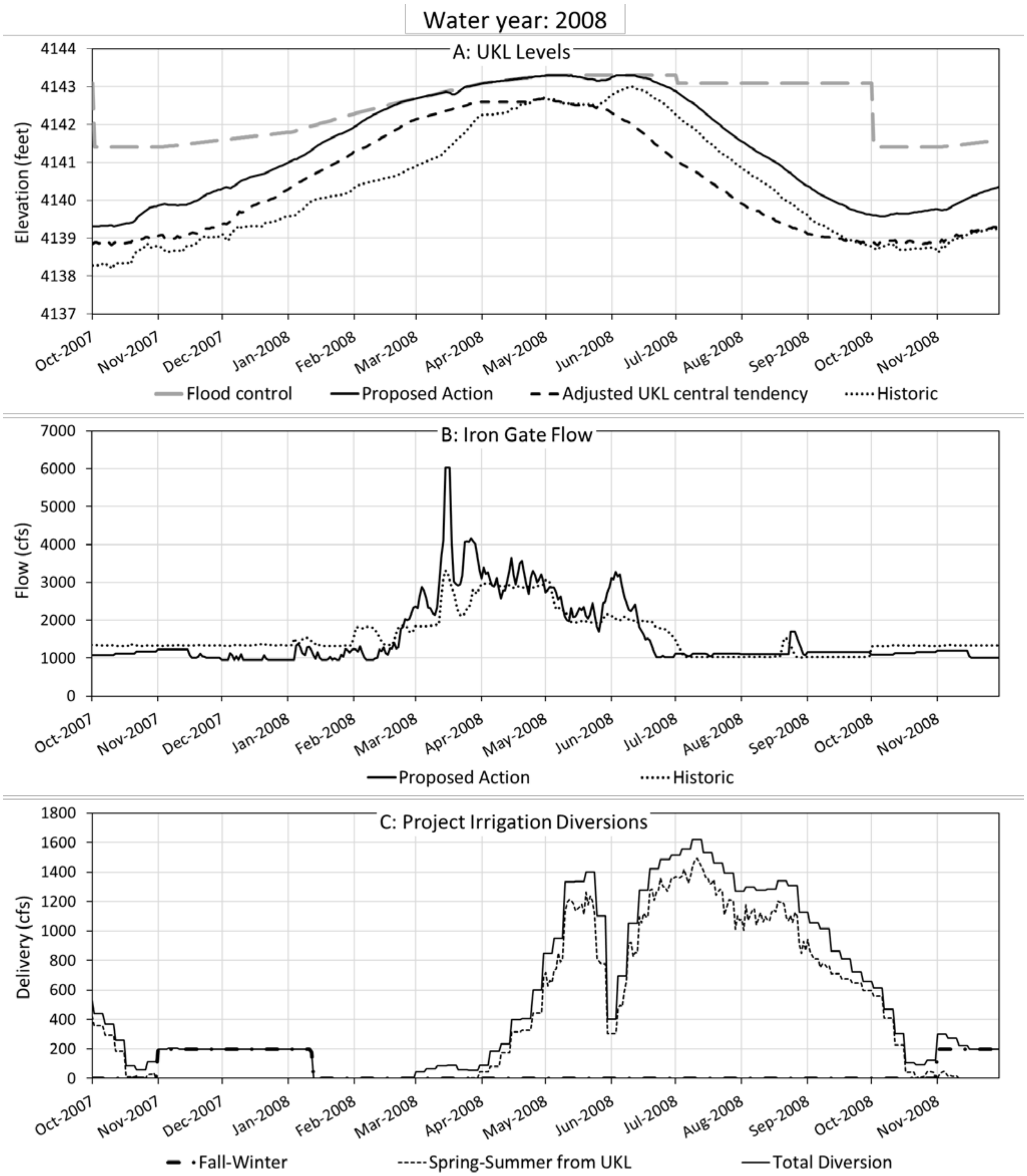

Figure B28. Proposed Action simulation results from the KBPM for Upper Klamath Lake (A), the Klamath River below Iron Gate Dam (B), and Project irrigation diversions (C) for water year 2008.

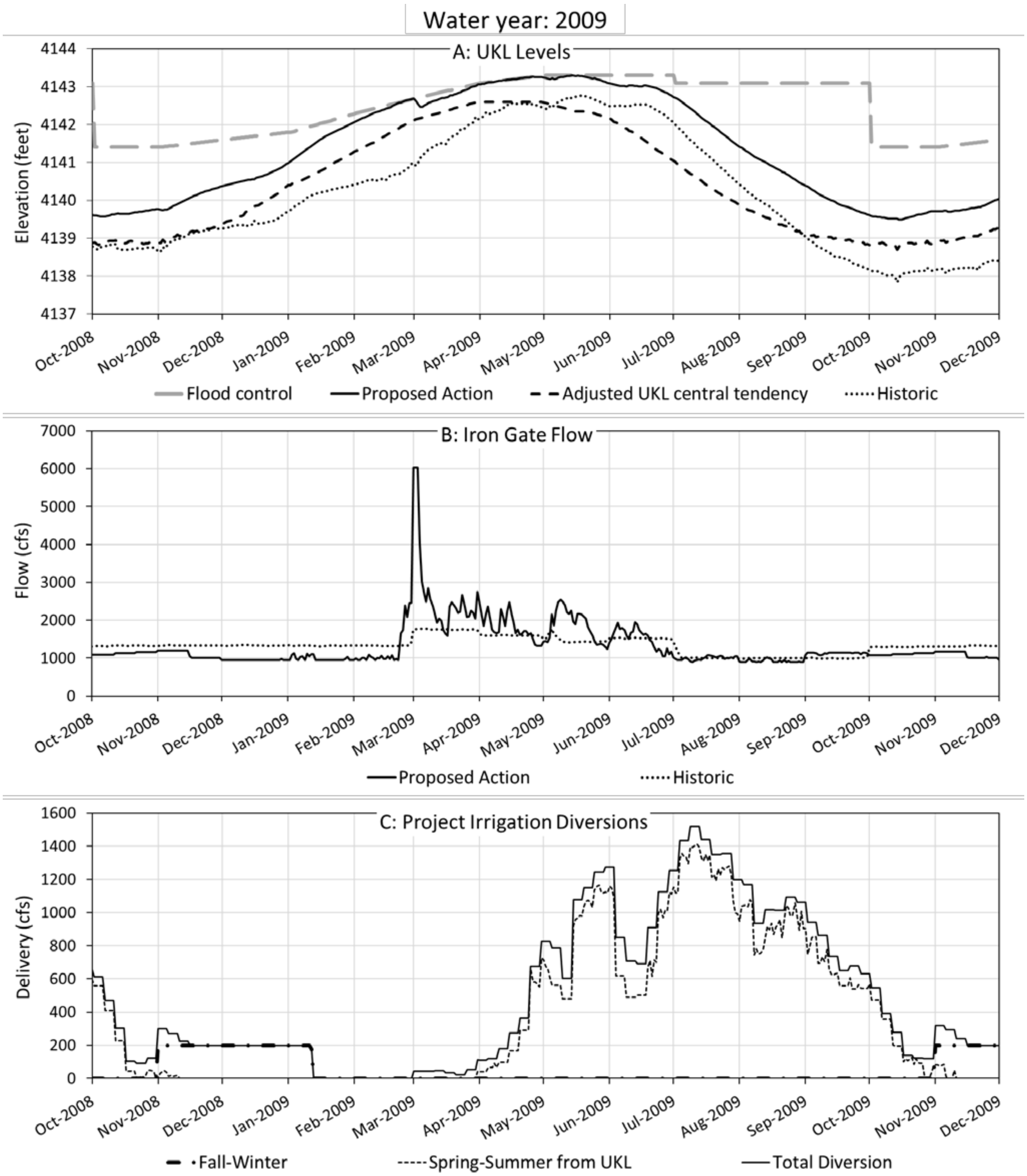

Figure B29. Proposed Action simulation results from the KBPM for Upper Klamath Lake (A), the Klamath River below Iron Gate Dam (B), and Project irrigation diversions (C) for water year 2009.

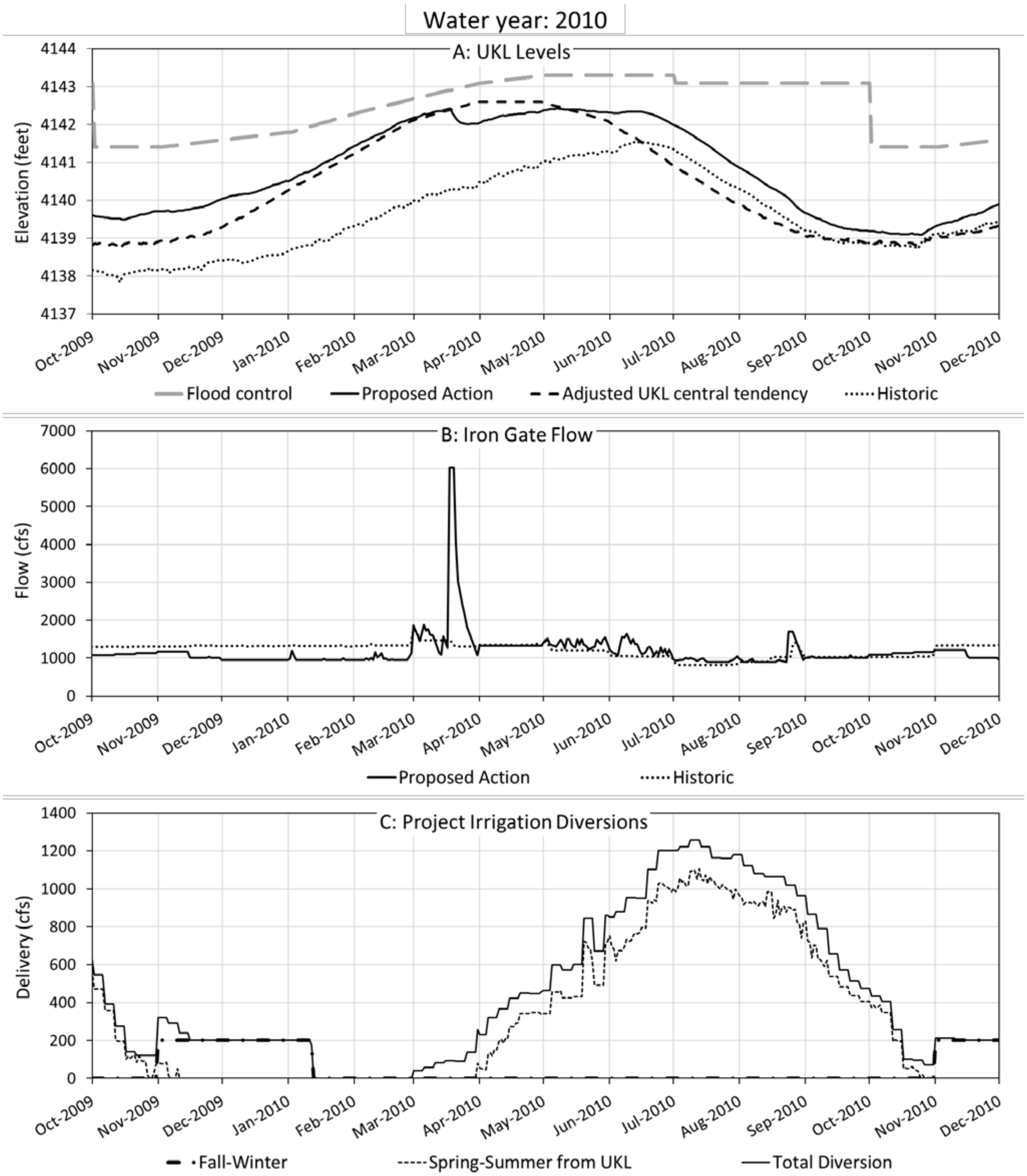

Figure B30. Proposed Action simulation results from the KBPM for Upper Klamath Lake (A), the Klamath River below Iron Gate Dam (B), and Project irrigation diversions (C) for water year 2010.

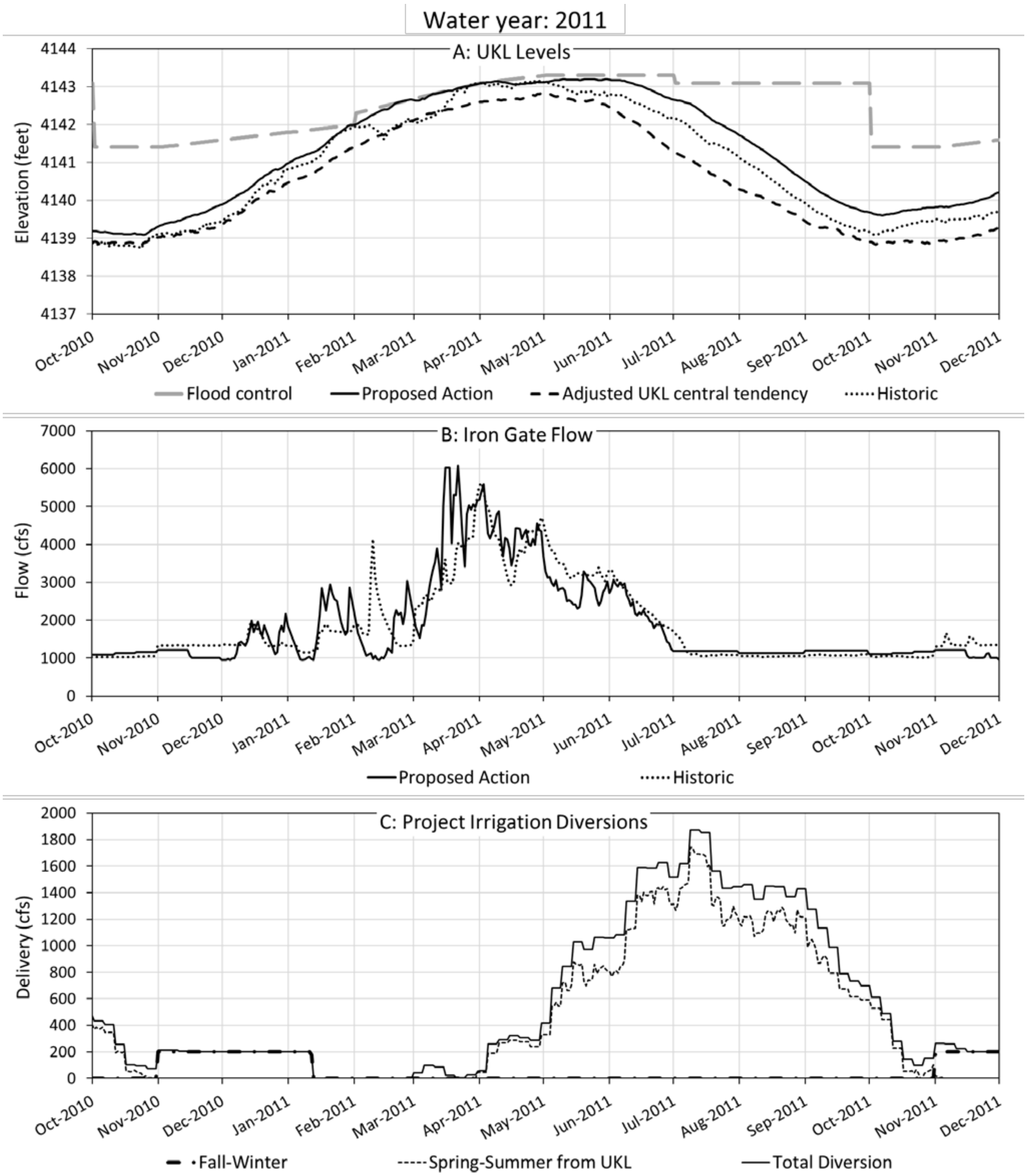

Figure B31. Proposed Action simulation results from the KBPM for Upper Klamath Lake (A), the Klamath River below Iron Gate Dam (B), and Project irrigation diversions (C) for water year 2011.

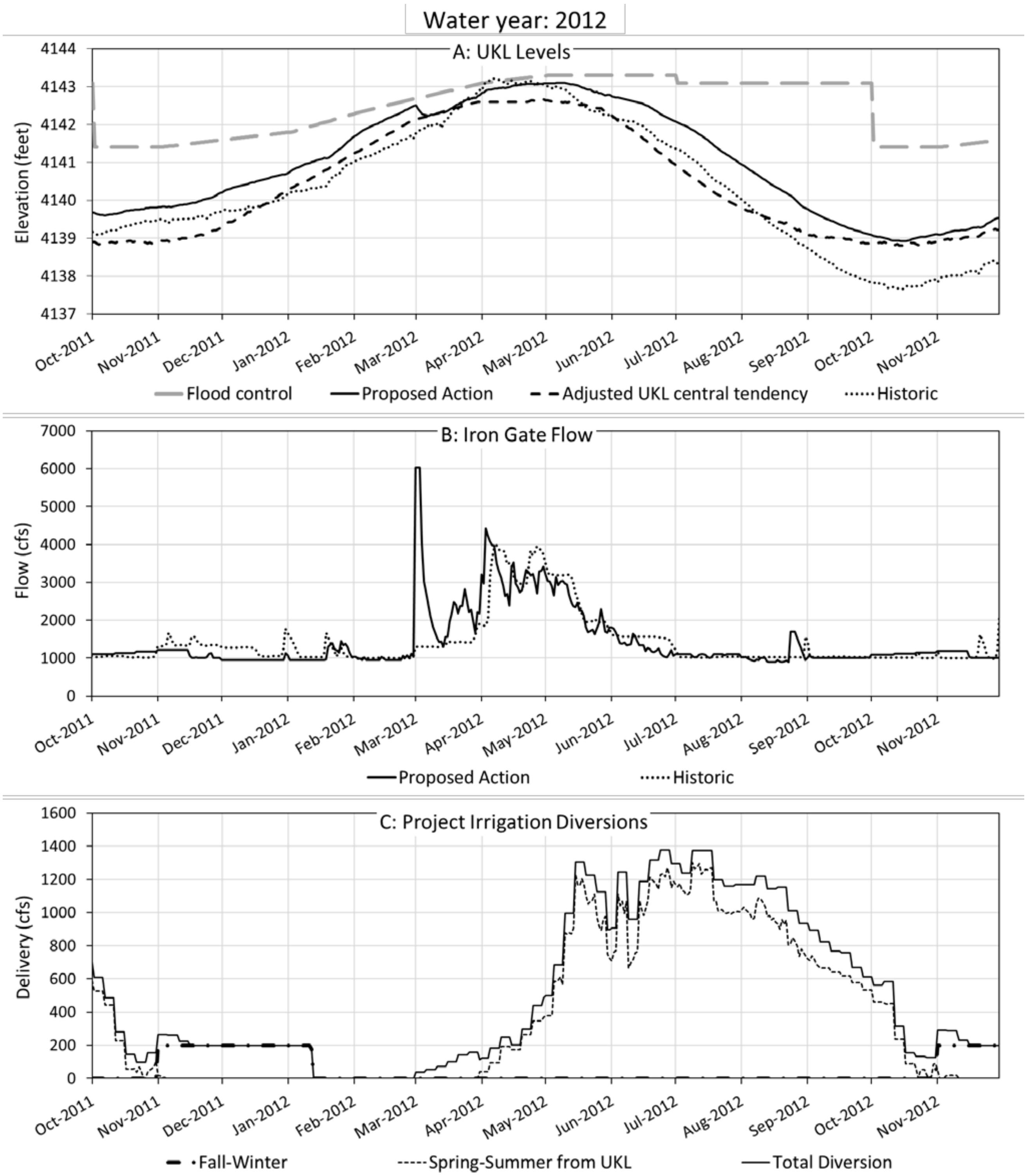

Figure B32. Proposed Action simulation results from the KBPM for Upper Klamath Lake (A), the Klamath River below Iron Gate Dam (B), and Project irrigation diversions (C) for water year 2012.

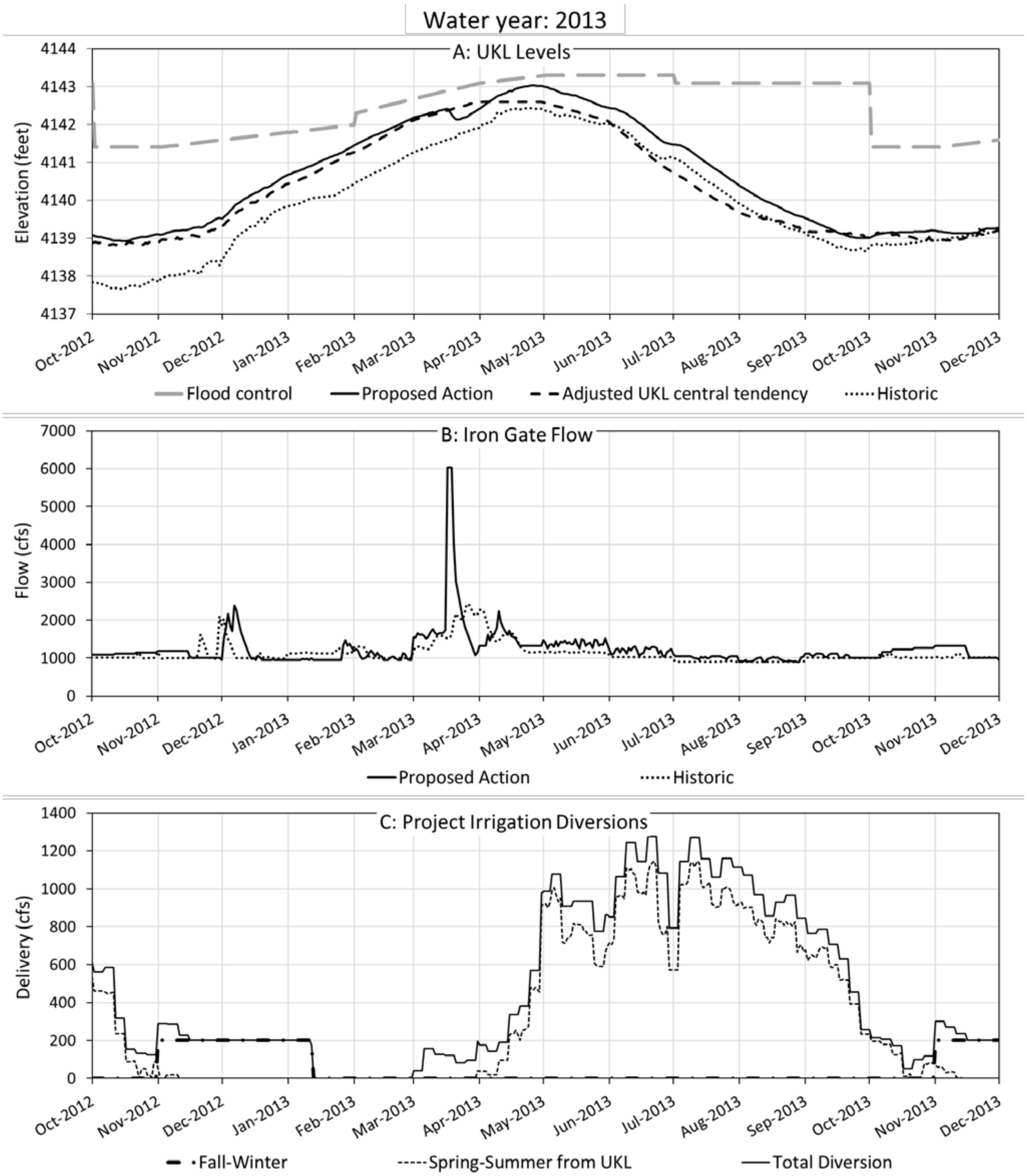

Figure B33. Proposed Action simulation results from the KBPM for Upper Klamath Lake (A), the Klamath River below Iron Gate Dam (B), and Project irrigation diversions (C) for water year 2013.

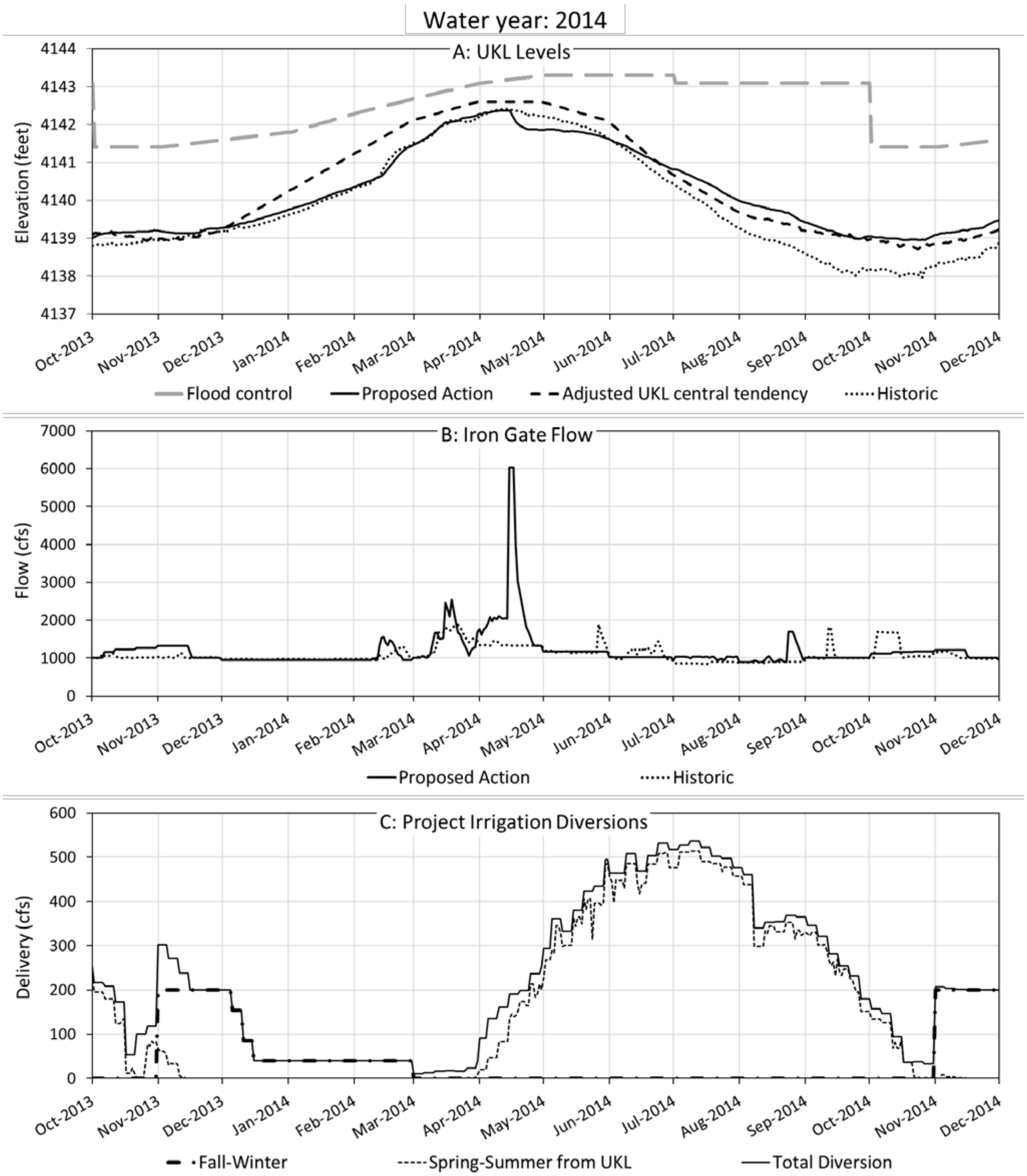

Figure B34. Proposed Action simulation results from the KBPM for Upper Klamath Lake (A), the Klamath River below Iron Gate Dam (B), and Project irrigation diversions (C) for water year 2014.

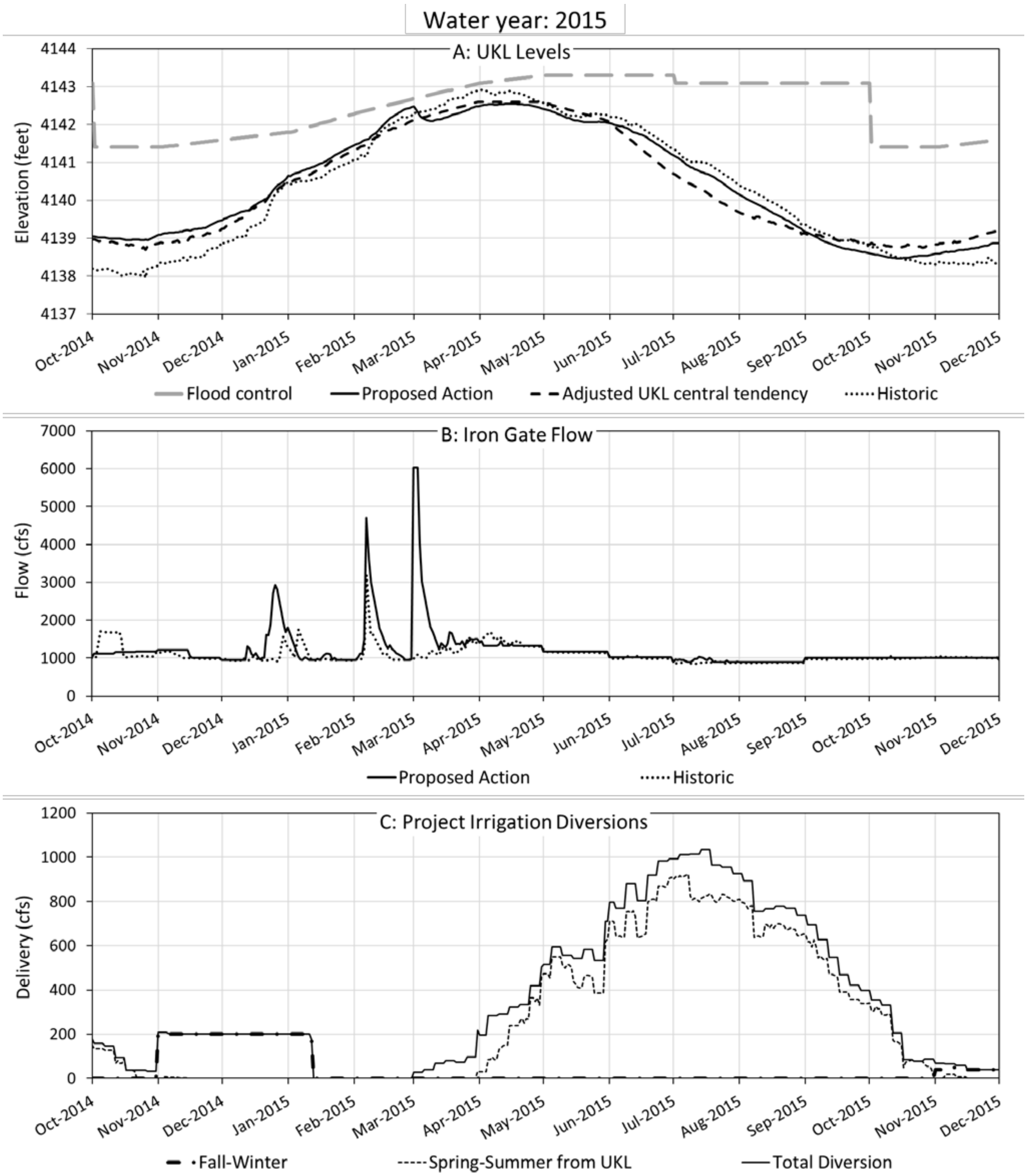

Figure B35. Proposed Action simulation results from the KBPM for Upper Klamath Lake (A), the Klamath River below Iron Gate Dam (B), and Project irrigation diversions (C) for water year 2015.

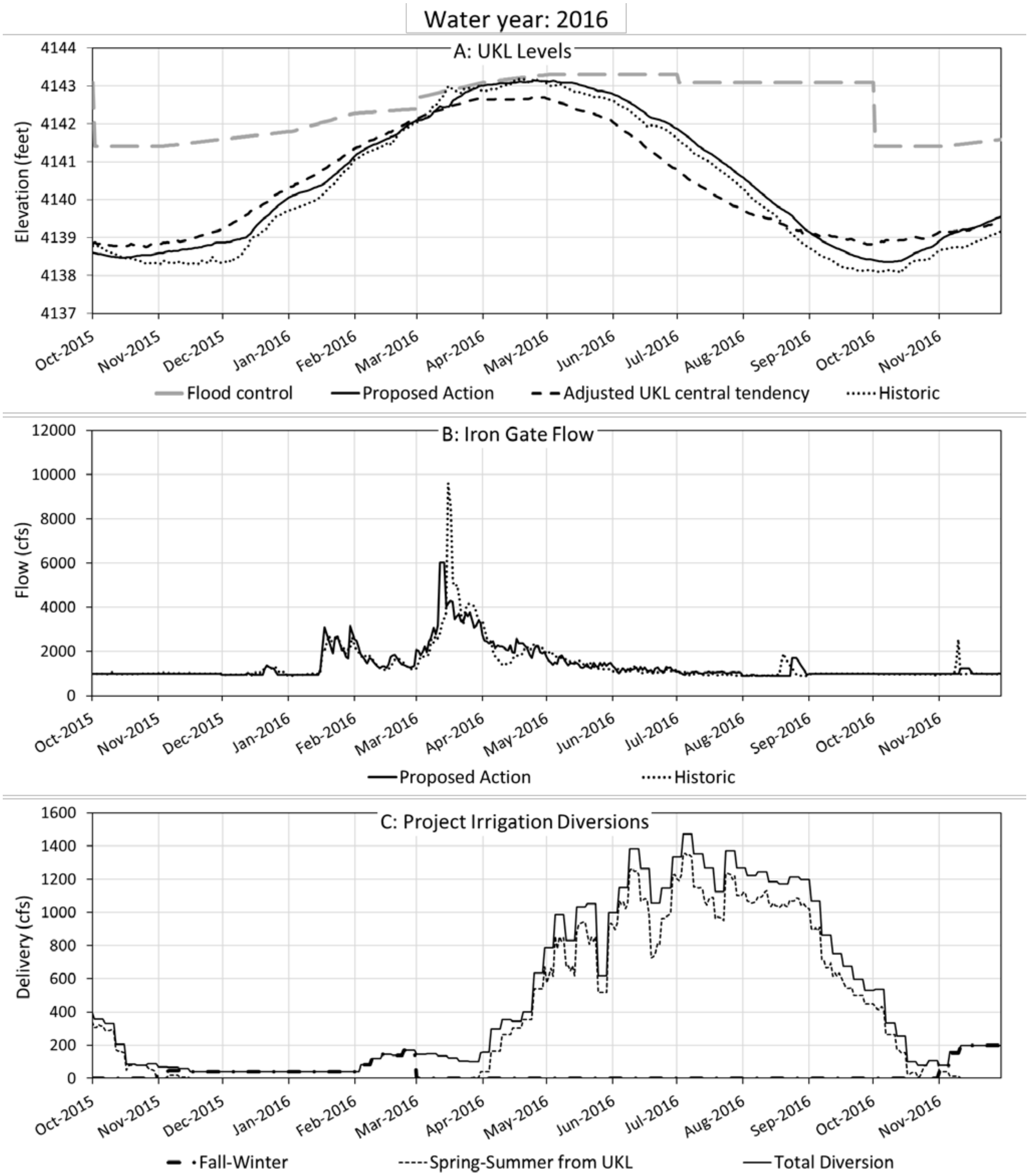

Figure B36. Proposed Action simulation results from the KBPM for Upper Klamath Lake (A), the Klamath River below Iron Gate Dam (B), and Project irrigation diversions (C) for water year 2016.

Section C: LKNWR Historical Deliveries

Table C1. Historical LK NWR Water Deliveries.

Water Year	Ady Canal Deliveries to LKNWR	D Plant Deliveries to LKNWR	Total Deliveries to LKNWR
1981	26.1	68.1	94.2
1982	10.1	120.1	130.2
1983	9.9	111.5	121.4
1984	10.4	120.4	130.8
1985	21.1	103.3	124.4
1986	20.9	104.6	125.5
1987	18.7	96.9	115.6
1988	17.2	93.9	111.1
1989	24.2	100.5	124.7
1990	22.7	95.7	118.4
1991	32.2	76.6	108.8
1992	14.8	41.5	56.3
1993	30.8	88.8	119.6
1994	35.5	49.8	85.3
1995	24.1	86.1	110.2
1996	32.7	115.4	148.1
1997	22.8	89.9	112.7
1998	21.0	97.2	118.2
1999	14.9	113.1	128.0
2000	20.9	79.3	100.2
2001	19.3	23.8	43.1
2002	38.4	77.3	115.7
2003	21.0	61.5	82.5
2004	46.2	51.3	97.5
2005	33.8	65.7	99.5
2006	23.2	112.3	135.5
2007	44.1	32.3	76.4
2008	27.2	54.9	82.1
2009	46.3	33.6	79.9
2010	6.6	10.0	16.6
2011	47.8	20.1	67.9
2012	38.0	10.4	48.4
2013	18.3	24.8	43.1
2014	7.0	12.4	19.4
2015	4.7	13.7	18.4
2016	24.4	22.1	46.5
Average 1981-2016	24.0	68.9	93.2

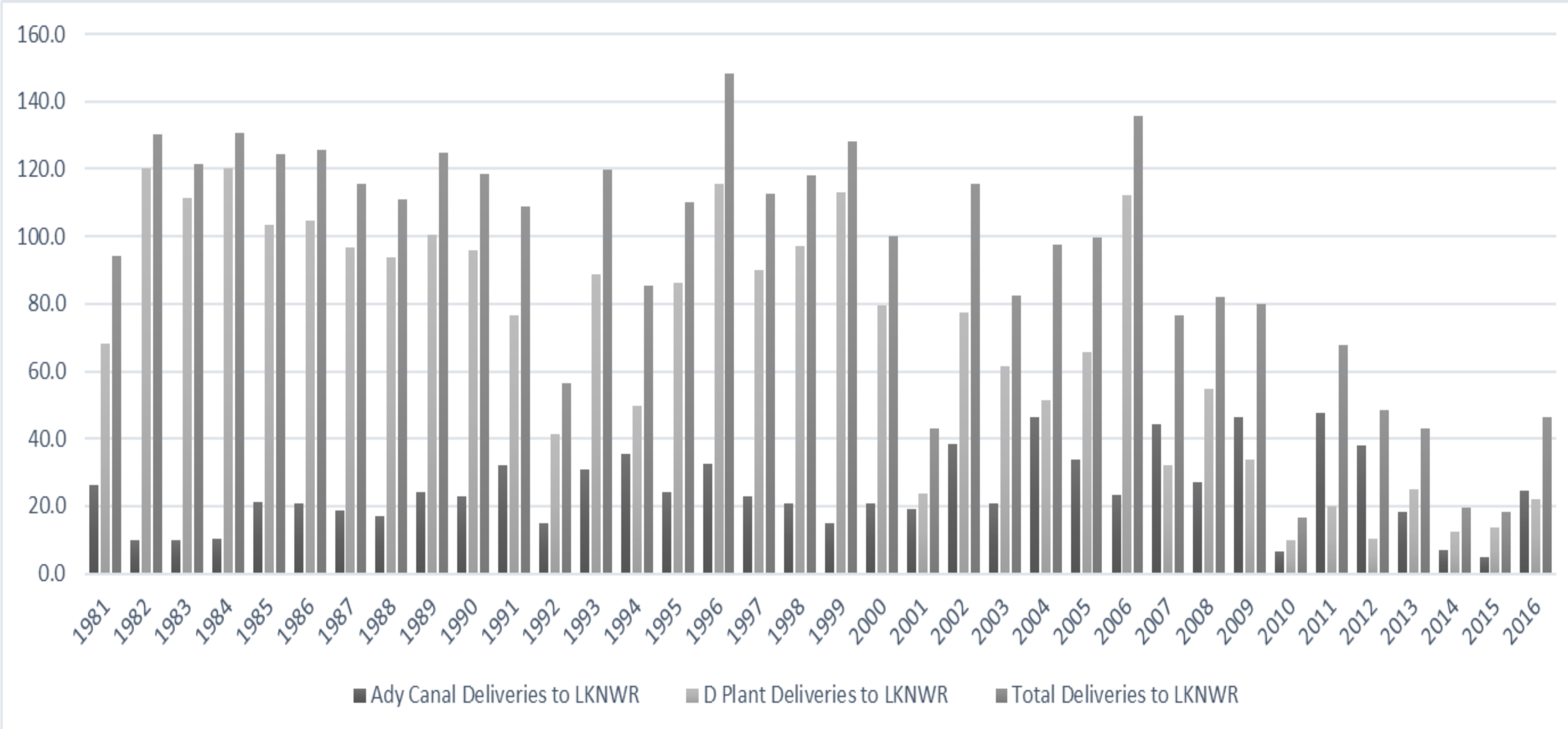

Figure C1. Historical deliveries to LKNWR by water year for the 36-year period of record considered in the Proposed Action. Deliveries are graphed as those delivered through Ady Canal (i.e. direct diversion from the Klamath River), D Plant pumping (i.e. deliveries made from Tule Lake Sumps), and total delivery through both delivery arcs.

Section D: Clear Lake Reservoir and Gerber Reservoir Water Supply Forecast Models

Table D1. Clear Lake Reservoir Operational Forecast Model. Example of the Clear Lake Reservoir operational forecast model from May 2018.

Date	Actual Elevation (Feet)	Actual Volume (Acre-Feet)	Actual Area (Acres)	Projected Inflow (Acre-Feet)	Projected Evaporation and Seepage (Acre-Feet)	Releases (Acre-Feet)	Modeled Volume (Acre-Feet)	Modeled Area (Acres)	Modeled Elevation (Feet)
1-May	4,531.01	228,000	21,640	5	328	125	228,000	21,640	4,531.01
2-May	4,531.00	227,780	21,640	5	328	125	227,780	21,640	4,531.00
3-May	4,530.99	227,560	21,600	5	327	125	227,560	21,600	4,530.99
4-May	4,530.98	227,350	21,600	5	327	125	227,350	21,600	4,530.98
5-May	4,530.97	227,130	21,600	5	327	125	227,130	21,600	4,530.97
6-May	4,530.95	226,700	21,600	5	327	125	226,700	21,600	4,530.95
7-May	4,530.94	226,480	21,600	5	327	165	226,480	21,600	4,530.94
8-May	4,530.92	226,050	21,600	5	327	165	226,050	21,600	4,530.92
9-May	4,530.90	225,620	21,600	5	327	188	225,620	21,600	4,530.90
10-May	4,530.86	224,760	21,560	5	327	188	224,760	21,560	4,530.86
11-May	4,530.86	224,760	21,560	5	327	188	224,760	21,560	4,530.86
12-May	4,530.82	223,900	21,560	5	327	377	223,900	21,560	4,530.82
13-May	4,530.79	223,260	21,510	5	326	377	223,260	21,510	4,530.79
14-May	4,530.77	222,820	21,510	5	326	377	222,820	21,510	4,530.77
15-May	4,530.73	221,960	21,510	5	326	377	221,960	21,510	4,530.73
16-May	4,530.69	221,110	21,460	5	325	377	221,110	21,460	4,530.69
17-May	4,530.67	220,680	21,460	5	325	377	220,680	21,460	4,530.67
18-May	4,530.65	220,250	21,460	5	325	377	220,250	21,460	4,530.65
19-May	4,530.62	219,610	21,460	5	325	377	219,610	21,460	4,530.62
20-May	4,530.60	219,180	21,460	5	325	377	219,180	21,460	4,530.60
21-May	4,530.57	218,540	21,420	5	325	377	218,540	21,420	4,530.57
22-May	4,530.54	217,900	21,420	5	325	377	217,900	21,420	4,530.54
23-May	4,530.51	217,250	21,420	5	325	377	217,250	21,420	4,530.51
24-May	4,530.51	217,250	21,420	5	325	377	217,250	21,420	4,530.51
25-May	4,530.53	217,680	21,420	5	325	198	217,680	21,420	4,530.53
26-May	4,530.58	218,750	21,420	5	325	0	218,750	21,420	4,530.58
27-May	4,530.60	219,180	21,460	5	325	0	219,180	21,460	4,530.60

Table D2. Gerber Reservoir Operational Forecast Model. Example of the Gerber Reservoir operational forecast model from May 2018.

Date	Actual Elevation (Feet)	Actual Volume (Acre-Feet)	Actual Area (Acres)	Projected Inflow (Acre-Feet)	Projected Evaporation and Seepage (Acre-Feet)	Releases (Acre-Feet)	Modeled Volume (Acre-Feet)	Modeled Area (Acres)	Modeled Elevation (Feet)
1-May	4832.89	84,833	3,538	38	54	71	84,833	3,538	4,832.89
2-May	4832.86	84,722	3,535	75	66	71	84,722	3,535	4,832.86
3-May	4832.84	84,648	3,533	75	66	71	84,648	3,533	4,832.84
4-May	4832.81	84,537	3,531	75	66	95	84,537	3,531	4,832.81
5-May	4832.78	84,426	3,528	75	66	143	84,426	3,528	4,832.78
6-May	4832.74	84,278	3,524	75	66	143	84,278	3,524	4,832.74
7-May	4832.68	84,056	3,519	75	66	214	84,056	3,519	4,832.68
8-May	4832.61	83,797	3,512	75	66	214	83,797	3,512	4,832.61
9-May	4832.55	83,575	3,507	75	66	214	83,575	3,507	4,832.55
10-May	4832.48	83,318	3,500	75	65	214	83,318	3,500	4,832.48
11-May	4832.4	83,030	3,493	75	65	214	83,030	3,493	4,832.40
12-May	4832.32	82,734	3,486	75	65	226	82,734	3,486	4,832.32
13-May	4832.24	82,444	3,478	75	65	226	82,444	3,478	4,832.24
14-May	4832.17	82,189	3,472	75	65	262	82,189	3,472	4,832.17
15-May	4832.09	81,894	3,464	75	65	262	81,894	3,464	4,832.09
16-May	4832.01	81,606	3,457	75	65	262	81,606	3,457	4,832.01
17-May	4831.95	81,385	3,451	75	65	262	81,385	3,451	4,831.95
18-May	4831.88	81,128	3,445	75	64	262	81,128	3,445	4,831.88
19-May	4831.79	80,804	3,437	75	64	262	80,804	3,437	4,831.79
20-May	4831.72	80,552	3,430	75	64	262	80,552	3,430	4,831.72
21-May	4831.64	80,264	3,423	75	64	262	80,264	3,423	4,831.64
22-May	4831.57	80,012	3,416	75	64	262	80,012	3,416	4,831.57
23-May	4831.49	79,724	3,409	75	64	262	79,724	3,409	4,831.49
24-May	4831.43	79,508	3,403	75	64	262	79,508	3,403	4,831.43
25-May	4831.44	79,544	3,404	75	64	139	79,544	3,404	4,831.44
26-May	4831.5	79,760	3,410	75	64	0	79,760	3,410	4,831.50
27-May	4831.52	79,832	3,412	75	64	0	79,832	3,412	4,831.52