Appendix C:

Klamath River Temperature Modeling Scenarios

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C.1 Introduction

In early 2019, EPA requested that Tetra Tech perform model scenario evaluations to support the revision of the Klamath and Lost Subbasins Temperature TMDLs. The existing Klamath River model and multiple scenarios that were developed and run for the original TMDL (2010) formed the basis of the various scenarios that were re-run for this revision effort. The approach, calibration results, and corroboration results for the Klamath River Model for TMDL development were documented previously and are described in the modeling report "*Model Configuration and Results - Klamath River Model for TMDL Development*" (Tetra Tech, Inc., 2009).

In the original TMDL and modeling, the fully tested and calibrated Klamath River Model was applied to evaluate a series of scenarios to support TMDL development. The document "*Modeling Scenarios Klamath River Model for TMDL Development*" (Tetra Tech, Inc., 2009) summarizes the details of how each scenario was configured, along with associated assumptions, and results. Of the original scenarios evaluated for the original TMDL and documented in the noted report, those of interest for the revised TMDL include:

- Natural conditions baseline scenario (T1BSR)
- Oregon allocation scenario (TOD2RN)
- With-dams TMDL scenario (T4BSRN)

The purpose of this report is to document the updates made to the Klamath River scenarios of interest, in-order to evaluate the targeted temperature metric above the applicable criteria and calculate the excess load longitudinally along the entire system.

All model scenarios were evaluated against the following temperature criteria

- Upstream of Keno dam the temperatures were calculated as daily maximums (DM) and were evaluated against the cool water criteria of 28 deg C.
- Downstream of Keno dam the temperatures were calculated as seven-day average daily maximum (7DADM) and were evaluated against the cold-water criteria of 20 deg C plus the human use allowance.
- At Stateline the temperatures were evaluated based on a monthly mean temperature criterion established at the Stateline using the natural condition scenario (monthly mean was calculated based on hourly temperatures from the natural conditions scenario).

Compliance was evaluated using temporal plots along the Klamath River at the Keno Dam outlet and Stateline locations. The temporal plots at Stateline and Keno Dam outlet were evaluated based on the 7DADM and monthly mean metric respectively. Note that for Keno, the outflow was chosen in-order to evaluate the cumulative warming at the Keno outlet rather than upstream since this is the first model segment where the 20 deg C criterion applies and the HUA provision must be achieved. All other locations were evaluated using spatial plots.

Model scenarios for this revision were conducted in three steps. First, Tetra Tech conducted an evaluation of existing condition temperatures. Then, a restored conditions scenario was evaluated and finally, a series of scenarios designed to assess the impacts of point sources (PS), non-point sources (NPS), and dams on compliance with the applicable human use allowance was conducted. This report documents the adjustments made to the original model scenarios and the results.

C.2 Existing Condition Temperature Scenario (S1)

The existing conditions baseline scenario (S1) involved running the calibrated version of the Klamath River Model. The Lake Ewauna portion of the system acts as a reservoir with Keno Dam at the downstream and was modeled using the CE-QUAL-W2 model (in addition to JC Boyle Reservoir which was modeled using the W2 model). The remainder of the river was modeled using RMA-2 and RMA-11. Table C-1 presents the models applied for this scenario.

Table C-1. Model components applied to each Klamath River segment.

Modeling segment	Segment type	Model(s)	Dimensions
Link River	River	RMA-2/RMA-11	1-D
Lake Ewauna-Keno Dam	Reservoir	CE-QUAL-W2	2-D
Keno Reach	River	RMA-2/RMA-11	1-D
JC Boyle Reservoir	Reservoir	CE-QUAL-W2	2-D
Full Flow Reach to OR/CA Stateline	River	RMA-2/RMA-11	1-D

The S1 models were configured to output hourly temperature and flow at all the model segments. The reconfigured models were then re-run in sequence from upstream to downstream. The resulting hourly temperature timeseries were used to calculate the excess DM temperature above Keno and excess 7DADM temperature downstream of Keno (in addition to monthly mean at Stateline), using the timeseries at every model segment/node during the 2000 model period. Excess temperature is defined as the difference between the S1 DM or 7DADM and the applicable criteria. In the reservoirs the hourly W2 temperatures are calculated as a depth average and then used to calculate either the DM or 7DADM timeseries. Similarly, daily mean flow timeseries were also calculated for each of the model segments. The mean daily flow and resulting excess timeseries were then used to calculate the daily excess load in kilocalories per day for every model segment during the 2000 model period. The monthly excess 7DADM and excess heat load statistics at Keno outflow and Stateline can be found in Table C-2 and Table C-3.

Table C-2. S1 - Monthly Temperature Excess (°C) and Excess Heat Load (kcal/day) Statistics at Keno Outflow.

S1						
Keno Outflow	**Excess 7DADM Temperature**			**Excess Load**		
Month	**Min**	**Median**	**Max**	**Min**	**Median**	**Max**
January	0.00	0.00	0.00	0.00E+00	0.00E+00	0.00E+00
February	0.00	0.00	0.00	0.00E+00	0.00E+00	0.00E+00
March	0.00	0.00	0.00	0.00E+00	0.00E+00	0.00E+00
April	0.00	0.00	0.00	0.00E+00	0.00E+00	0.00E+00
May	0.00	0.00	0.00	0.00E+00	0.00E+00	0.00E+00
June	0.00	0.00	4.30	0.00E+00	0.00E+00	9.14E+09
July	0.44	3.22	4.56	7.88E+08	6.55E+09	9.80E+09
August	1.04	2.67	4.34	1.91E+09	5.30E+09	9.25E+09
September	0.00	0.00	0.83	0.00E+00	0.00E+00	1.51E+09

October	0.00	0.00	0.00	0.00E+00	0.00E+00	0.00E+00
November	0.00	0.00	0.00	0.00E+00	0.00E+00	0.00E+00
December	0.00	0.00	0.00	0.00E+00	0.00E+00	0.00E+00

Table C-3. S1 - Monthly Temperature Excess (°C) and Excess Heat Load (kcal/day) Statistics at Stateline.

Stateline	Excess 7DADM Temperature			Excess Load			Excess above CA criteria
Month	Min	Median	Max	Min	Median	Max	
January	0.00	0.00	0.00	0.00E+00	0.00E+00	0.00E+00	0.00
February	0.00	0.00	0.00	0.00E+00	0.00E+00	0.00E+00	0.00
March	0.00	0.00	0.00	0.00E+00	0.00E+00	0.00E+00	0.00
April	0.00	0.00	0.00	0.00E+00	0.00E+00	0.00E+00	0.15
May	0.18	0.20	0.27	6.23E+08	7.86E+08	1.01E+09	0.11
June	0.22	3.16	4.10	6.29E+08	6.87E+09	1.12E+10	0.00
July	0.67	2.98	4.15	1.43E+09	5.92E+09	1.15E+10	0.00
August	0.49	2.25	4.29	9.32E+08	5.45E+09	1.18E+10	0.00
September	0.46	0.46	0.46	9.29E+08	9.29E+08	9.29E+08	0.26
October	0.00	0.00	0.00	0.00E+00	0.00E+00	0.00E+00	0.07
November	0.00	0.00	0.00	0.00E+00	0.00E+00	0.00E+00	0.19
December	0.00	0.00	0.00	0.00E+00	0.00E+00	0.00E+00	0.00

Section C5 includes the longitudinal plots by river kilometer (RKM) of the excess temperature and the excess load showing the min/max/median for each of the modeling segments. Finally, a summary table that shows the summary statistics of the of the min, median, and maximum monthly excess temperature and the corresponding maximum monthly excess load are also included. Table C-4 shows the location in river kilometer where the maximum temperature occurs.

Table C-4. Location where maximum temperature occurs – S1.

Modeling segment	Segment Type	Location of Max Excess Temperature RKM [Segment/Node ID]	Location of Max Excess heat load Location RKM [Segment/Node ID]
Link River	River	NA	NA
Lake Ewauna-Keno Dam	Reservoir	NA	NA
Keno Reach	River	8.66 [117]	8.59 [115]
JC Boyle Reservoir	Reservoir	0.95 [5]	0.95 [5]
Full Flow Reach to OR/CA Stateline	River	1.4 [20]	20.55 [279]

C.3 Updated Restored Condition Scenario (T1BSR2)

This scenario (referenced here as T1BSR2) is based on an update to the T1BSR model and calculates the warming contributed by background sources on the Klamath River. Differences between BBNC and output from the T1BSR2 longitudinal profile can be attributed to be the background reduction.

This scenario uses the same model setup as described in the Modeling Scenario Memo from December 2009 for T1BSR with minor updates to tributary inflow temperatures. This scenario involved running a version of the Klamath River Model that includes no dams, with the exception of Link Dam at the upper boundary to the model. The Lake Ewauna portion of the system was modeled using CE-QUAL-W2 due to the historical presence of the Keno Reef. The remainder of the river was modeled using RMA-2 and RMA-11. Table C-5 presents the models applied for this scenario.

Table C-5. Model components applied to each Klamath River segment.

Modeling segment	Segment type	Model(s)	Dimensions
Link River	River	RMA-2/RMA-11	1-D
Lake Ewauna-Keno Reef	Reservoir	CE-QUAL-W2	2-D
Keno Reef to OR/CA Stateline	River	RMA-2/RMA-11	1-D

The overall approach to restored condition scenario included setting boundary conditions at Upper Klamath Lake (UKL) based on the existing UKL Drainage TMDLs (ODEQ, 2002), removing point source inputs, keeping Lost River Diversion Channel (LRDC) and Klamath Straits Drain (KSD) flows, and assigning natural or TMDL conditions for tributaries. UKL flow was set to be the same as the calibrated Klamath River Model (Appendix B), but the temperature were based on 1995 UKL TMDL model conditions. The year 1995 represents the median condition occurring in UKL (based on implementation of the UKL TMDL).

Assumptions and Configuration

The following list presents key assumptions associated with configuration of the restored condition scenario:

- All the point sources and derived accretion/depletion flows for flow balance in the existing model were removed. Over the course of the year, the accretion/depletion flows average to near zero, so they likely do not represent an ungaged groundwater input. On shorter time scales, the accretion flows can be significant enough to alter the instream concentrations depending on assumptions about their concentrations. Out of concern that the accretion flows might influence allocations to point and discrete nonpoint sources, they were removed in the scenarios.
- The downstream boundary condition was configured to represent the Keno Reef based on the rating curve information provided by the U.S. Bureau of Reclamation – Klamath Basin Area Office (USBR). Implementation of the reef into the model represented conditions prior to the creation of Keno Dam (1905-1909 period). Based on information provided by the USBR, a version of the CEQUAL- W2 model for Lake Ewauna-Keno Dam was developed to

represent the historical presence of Keno Reef (McGlashan and Dean 1913). The rating curve was derived by the USBR hydrologist using historical data and was as follows:

$$Q=101.265(H-1244.5)^2-15.030(H-1244.5)+12.35$$

where Q is the flow rate over the Keno Reef (cms); H is the water surface elevation (m); and 1244.5 m is the Keno Reef datum.

- The flows from LRDC and KSD were kept the same as in the Klamath River Model. LRDC and KSD flows were kept the same as in the Klamath River Model to make it possible to evaluate dam impacts directly (i.e., by representing a similar flow condition between the with-dam and without-dam conditions). The tempeartures for LRDC and KSD were configured a little differently from what was done last time and is discussed in the following paragraph.

In this scenario updates were made to the T1BSR tributary inflow temperature files for the LRDC and KSD in the Lake Ewauna W2 model. While KSD and LRDC are essentially constructed canals, they take advantage and were constructed where water naturally used to flow. Given the modifications that have occurred it is difficult to establish the natural temperature of these waterbodies. The T1BSR scenario had the natural scenario boundary temperatures for both KSD and LRDC set to be the same as the Upper Klamath Lake (UKL). Since historically both KSD and LRDC used to mix with Klamath River water, the temperatures for both were set to be the same as the Klamath River one segment upstream. In the updated T1BSR scenario now renamed as T1BSR2 scenario, the boundary temperature data were set such that they match the hourly temperature of the upstream segments. Specifically, in the Lake Ewauna W2 model, temperatures from segment 19 and segment 71 were used to configure LRDC and KSD respectively. This has the same effect of eliminating the LRDC and KSD impact without disrupting the complicated flow patterns.
The Lake Ewauna model was run twice to establish the boundaries for LRDC and KSD, since both tributaries input at different locations. The LRDC boundaries were first configured using the temperatures from segment 19 and then the model was run using the updated LRDC boundaries. The model was then re-run with the updated LRDC boundaries to extract the temperatures from segment 71 for KSD, which is located downstream of LRDC. Finally, the model was run again with the updated boundaries for LRDC and KSD. The updated LRDC and KSD temperature time series used in the T1BSR2 scenario along with the UKL temperature time series used previously to configure the model are shown below in Figure C-1.

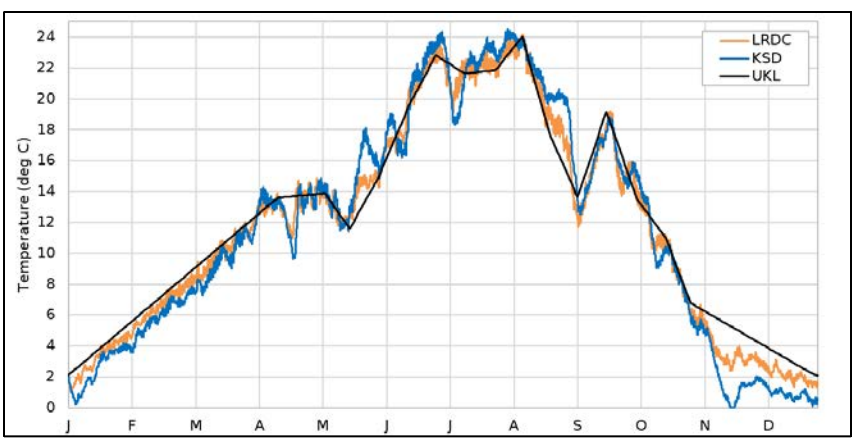


Figure C-1. Updated LRDC and KSD temperature time series used in T1BSR2.

The updated T1BSR2 models were configured to output hourly temperature and flow at all the model segments. The reconfigured models were then re-run in sequence from upstream to downstream. The resulting hourly temperature timeseries were used to calculate the excess DM temperature above Keno and excess 7DADM temperature downstream of Keno, using the timeseries at every model segment/node during the 2000 model period. Excess temperature is defined as the difference between the T1BSR2 DM or 7DADM and the applicable criteria. In the reservoirs the hourly W2 temperatures are calculated as a depth average and then used to calculate either the DM or 7DADM timeseries. Similarly, daily mean flow timeseries were also calculated for each of the model segments. The mean daily flow and resulting excess timeseries were then used to calculate the daily excess load in kilocalories per day for every model segment during the 2000 model period. The monthly excess 7DADM and excess heat load statistics at Keno outflow and Stateline can be found in Table C-6 and Table C-7.

Table C-6. T1BSR2 - Monthly Temperature Excess (°C) and Excess Heat Load (kcal/day) Statistics at Keno Outflow.

T1BSR2						
Keno Outflow	**Excess 7DADM Temperature**			**Excess Load**		
Month	**Min**	**Median**	**Max**	**Min**	**Median**	**Max**
January	0.00	0.00	0.00	0.00E+00	0.00E+00	0.00E+00
February	0.00	0.00	0.00	0.00E+00	0.00E+00	0.00E+00
March	0.00	0.00	0.00	0.00E+00	0.00E+00	0.00E+00
April	0.00	0.00	0.00	0.00E+00	0.00E+00	0.00E+00
May	0.00	0.00	0.00	0.00E+00	0.00E+00	0.00E+00
June	0.00	0.00	4.46	0.00E+00	0.00E+00	8.80E+09
July	0.51	3.37	4.57	8.33E+08	5.26E+09	8.19E+09
August	1.25	3.13	4.86	1.92E+09	5.61E+09	1.05E+10
September	0.00	0.00	1.05	0.00E+00	0.00E+00	1.93E+09
October	0.00	0.00	0.00	0.00E+00	0.00E+00	0.00E+00
November	0.00	0.00	0.00	0.00E+00	0.00E+00	0.00E+00
December	0.00	0.00	0.00	0.00E+00	0.00E+00	0.00E+00

Table C-7. T1BSR2 - Monthly Temperature Excess (°C) and Excess Heat Load (kcal/day) Statistics at Stateline.

Stateline	**Excess 7DADM Temperature**			**Excess Load**			**Monthly Mean**
Month	**Min**	**Median**	**Max**	**Min**	**Median**	**Max**	
January	0.00	0.00	0.00	0.00E+00	0.00E+00	0.00E+00	2.92
February	0.00	0.00	0.00	0.00E+00	0.00E+00	0.00E+00	5.90
March	0.00	0.00	0.00	0.00E+00	0.00E+00	0.00E+00	9.30
April	0.00	0.00	0.00	0.00E+00	0.00E+00	0.00E+00	11.92
May	0.00	0.00	0.00	0.00E+00	0.00E+00	0.00E+00	14.54
June	0.33	2.83	3.16	7.70E+08	6.45E+09	8.59E+09	18.22
July	0.29	1.97	3.13	5.01E+08	4.14E+09	7.38E+09	19.15
August	0.01	1.48	3.60	1.96E+07	3.25E+09	7.57E+09	18.90
September	0.00	0.00	0.00	0.00E+00	0.00E+00	0.00E+00	15.03
October	0.00	0.00	0.00	0.00E+00	0.00E+00	0.00E+00	10.38

November	0.00	0.00	0.00	0.00E+00	0.00E+00	0.00E+00	3.52
December	0.00	0.00	0.00	0.00E+00	0.00E+00	0.00E+00	2.23

Section C.6 includes the longitudinal plots by RKM of the excess temperature and the excess load showing the min/max/median for each of the modeling segments. Finally, a summary table that shows the summary statistics of the of the min, median, and maximum monthly excess temperature and the corresponding maximum monthly excess load are also included. Table C-8 shows the location in river kilometer where the maximum temperature occurs.

Table C-8. Location where maximum temperature occurs – T1BSR2.

Modeling segment	Segment Type	Location of Max Excess Temperature RKM [Segment/Node ID]	Location of Max Excess heat load Location RKM [Segment/Node ID]
Link River	River	NA	NA
Lake Ewauna-Keno Reef	Reservoir	NA	NA
Keno Reef to OR/CA Stateline	River	10.91 [132]	13.45 [149]

C.4 Attainment Scenarios

A series of attainment model runs (in which sources are represented at TMDL allocations) were used to evaluate the impacts of point sources (PS), non-point sources (NPS), and dams on the water temperature in the Klamath River and to ensure that none of the allocated loads exceeds the allowable human use allowance (HUA).

C.4.1 Evaluating Cumulative Warming by Point Sources (TOD2RN2)

This scenario was used to evaluate the impact of solely from PS waste load allocations on water temperatures in the Klamath River. The previous TOD2RN scenario was used as the basis to configure this scenario and was renamed to TOD2RN2. The models applied for this scenario are shown in Table C-5. The Lake Ewauna portion of the system was modeled using CE-QUAL-W2 due to the historical presence of the Keno Reef.

The previous TOD2RN scenario involved running the Klamath River Model with no dams (except for Link Dam), setting boundary conditions at UKL based on the existing UKL TMDL, including point source inputs, assigning natural or TMDL conditions for tributaries and keeping LRDC and KSD flows the same as existing condition. The temperatures for LRDC and KSD were set to be the same as described in the revised natural condition scenario (T1BSR2) scenario described in the previous section. Upper Klamath Lake flow was set to be the same as the existing condition, but the temperatures were based on that of T1BSR2. The modeling analysis was performed for the year 2000.

The following changes were made to configure the TOD2RN2 model:

- Collins Product flow was updated to reflect current discharge which was zero. Collins Products reports a zero discharge, but they have a stormwater permit that may have intermittent discharge in addition to a lagoon that may be unlined with some leakage via the ground to the Klamath River. To represent the current situation, the outfall 001 was set to zero, whereas the discharge from outfall 002 remained unchanged.
- There are four PSs along the Klamath River, all of which are located in the Lake Ewauna model. The PS reflect the temperatures allowed under their waste load allocation (WLA). PS temperature inputs were calculated based on the WLA. Figure C-2 shows the WLA timeseries for the PS (note that Collins Products outfall 001 is not shown as it is set to zero).
- The NPS tributaries LRDC and KSD were kept the same as that in scenario T1BSR2 (restored conditions).

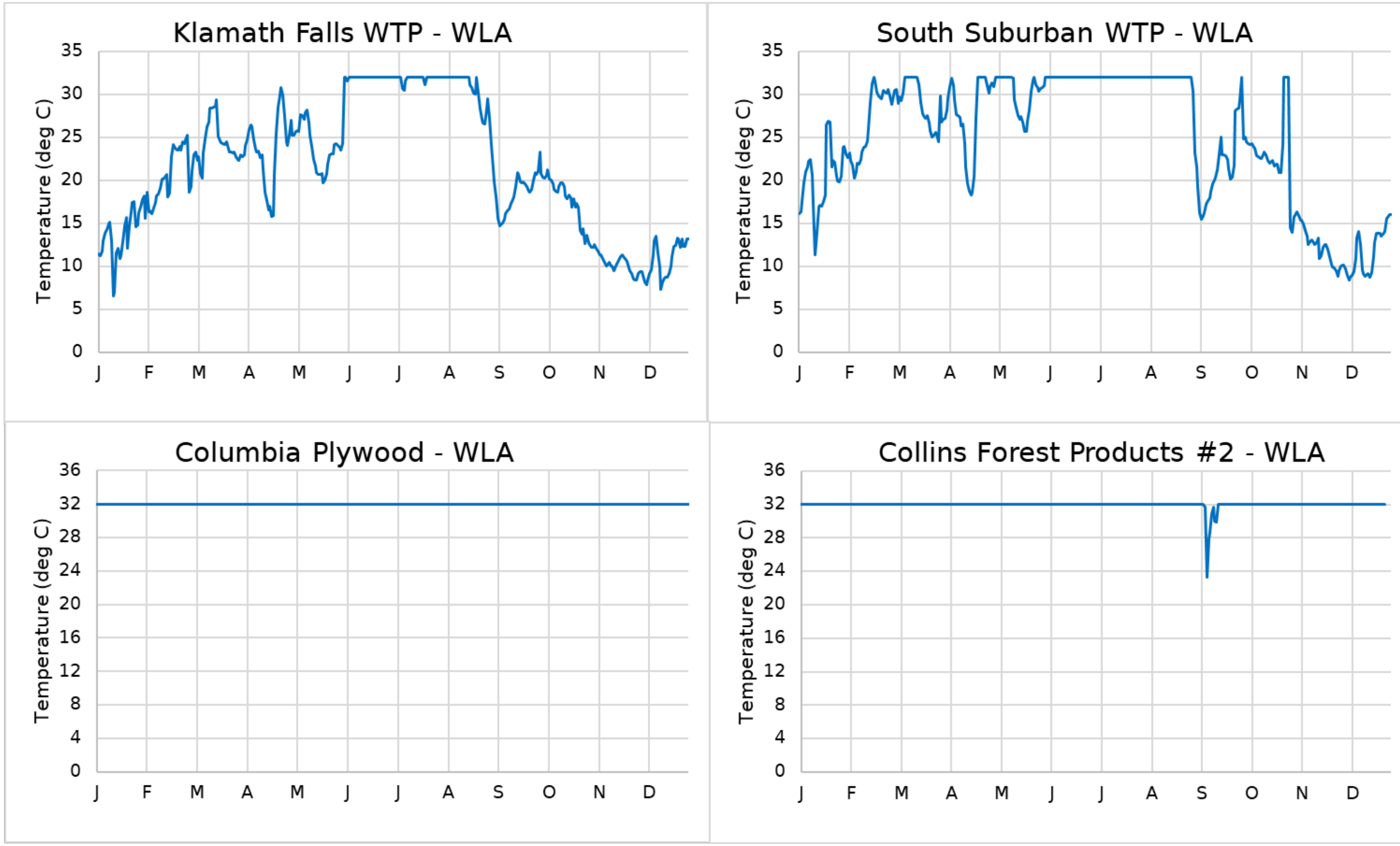


Figure C-2. Point sources effluent temperature at WLA specified in the model.

The updated TOD2RN2 models were configured to output hourly temperature and flow at all the model segments. The reconfigured models were then re-run in sequence from upstream to downstream. The resulting hourly temperature timeseries were used to calculate the excess DM temperature above Keno and excess 7DADM temperature downstream of Keno, using the timeseries at every model segment/node during the 2000 model period. Warming from PS at allocations is calculated as the difference between the DM or 7DADM of TOD2RN2 and T1BSR2. At the Oregon/California border, the warming is calculated as the difference between the monthly averages. Excess temperature is defined as the difference between the TOD2RN2 DM or 7DADM and the applicable criteria. In the reservoirs the hourly W2 temperatures are calculated as a depth average and then used to calculate either the DM or 7DADM timeseries. Similarly, daily mean flow timeseries were also calculated for each of the model segments. The mean daily flow and resulting excess timeseries were then used to calculate the daily excess load in kilocalories per day for every model segment during the 2000 model period. The monthly excess 7DADM and excess heat load statistics at Keno outflow and Stateline can be found in Table C-9 and Table C-10.

Table C-9. TOD2RN2 – Monthly Temperature Excess (°C) and Excess Heat Load (kcal/day) Statistics at Keno Outflow.

TOD2RN2						
Keno Outflow	**Excess 7DADM Temperature**			**Excess Load**		
Month	**Min**	**Median**	**Max**	**Min**	**Median**	**Max**
January	0.00	0.00	0.00	0.00E+00	0.00E+00	0.00E+00
February	0.00	0.00	0.00	0.00E+00	0.00E+00	0.00E+00
March	0.00	0.00	0.00	0.00E+00	0.00E+00	0.00E+00
April	0.00	0.00	0.00	0.00E+00	0.00E+00	0.00E+00
May	0.00	0.00	0.00	0.00E+00	0.00E+00	0.00E+00
June	0.00	0.00	4.48	0.00E+00	0.00E+00	9.70E+09
July	0.54	3.40	4.59	9.84E+08	6.90E+09	9.88E+09
August	1.28	3.15	4.88	2.31E+09	6.25E+09	1.06E+10
September	0.00	0.00	1.08	0.00E+00	0.00E+00	1.89E+09
October	0.00	0.00	0.00	0.00E+00	0.00E+00	0.00E+00
November	0.00	0.00	0.00	0.00E+00	0.00E+00	0.00E+00
December	0.00	0.00	0.00	0.00E+00	0.00E+00	0.00E+00

Table C-10. TOD2RN2 - Monthly Temperature Excess (°C) and Excess Heat Load (kcal/day) Statistics at Stateline.

Stateline	**Excess 7DADM Temperature**			**Excess Load**			**Excess above CA criteria**
Month	**Min**	**Median**	**Max**	**Min**	**Median**	**Max**	
January	0.00	0.00	0.00	0.00E+00	0.00E+00	0.00E+00	0.02
February	0.00	0.00	0.00	0.00E+00	0.00E+00	0.00E+00	0.04
March	0.00	0.00	0.00	0.00E+00	0.00E+00	0.00E+00	0.03
April	0.00	0.00	0.00	0.00E+00	0.00E+00	0.00E+00	0.03
May	0.00	0.00	0.00	0.00E+00	0.00E+00	0.00E+00	0.02
June	0.34	2.84	3.16	8.03E+08	6.46E+09	8.60E+09	0.02
July	0.31	1.98	3.15	5.28E+08	4.17E+09	7.39E+09	0.03
August	0.02	1.50	3.61	5.01E+07	3.28E+09	7.59E+09	0.03
September	0.00	0.00	0.00	0.00E+00	0.00E+00	0.00E+00	0.02
October	0.00	0.00	0.00	0.00E+00	0.00E+00	0.00E+00	0.02
November	0.00	0.00	0.00	0.00E+00	0.00E+00	0.00E+00	0.01
December	0.00	0.00	0.00	0.00E+00	0.00E+00	0.00E+00	0.01

Section C.7 includes the longitudinal plots by RKM of the excess DM or 7DADM and the excess load showing the min/max/median for each of the modeling segments. Finally, a summary table that shows the summary statistics of the of the min, median, and maximum monthly excess 7DADM and the corresponding maximum monthly excess 7DADM are also included. Table C-11shows the location in river kilometer where the maximum temperature occurs.

Table C-11. Location where maximum temperature occurs – TOD2RN2.

Modeling segment	Segment Type	Location of Max Excess Temperature RKM [Segment/Node ID]	Location of Max Excess heat load Location RKM [Segment/Node ID]
Link River (Link Dam (RKM 0) to Lake Ewauna)	River	NA	NA
Lake Ewauna (RKM 0) to Keno Reef	Reservoir	NA	NA
Keno Reef (RKM 0) to OR/CA Stateline	River	10.91 [132]	13.45 [149]

The warming impact due to point sources alone was evaluated based on the difference between the TOD2RN2 (allocation conditions) and T1BSR2 (restored conditions) scenario. The warming impact was evaluated at two compliance locations (i) Keno Dam Outflow and (ii) Stateline.

The warming impact attributed to point sources ranged from 0.01 to 0.07 deg C at Keno outlet based on the difference between TOD2RN2 and T1BSR2 scenario (Figure C-3). Note that maximum 7DADM difference of 0.07 deg C was seen during late November and occurs when the TOD2RN2 7DADM is below 20 deg C.

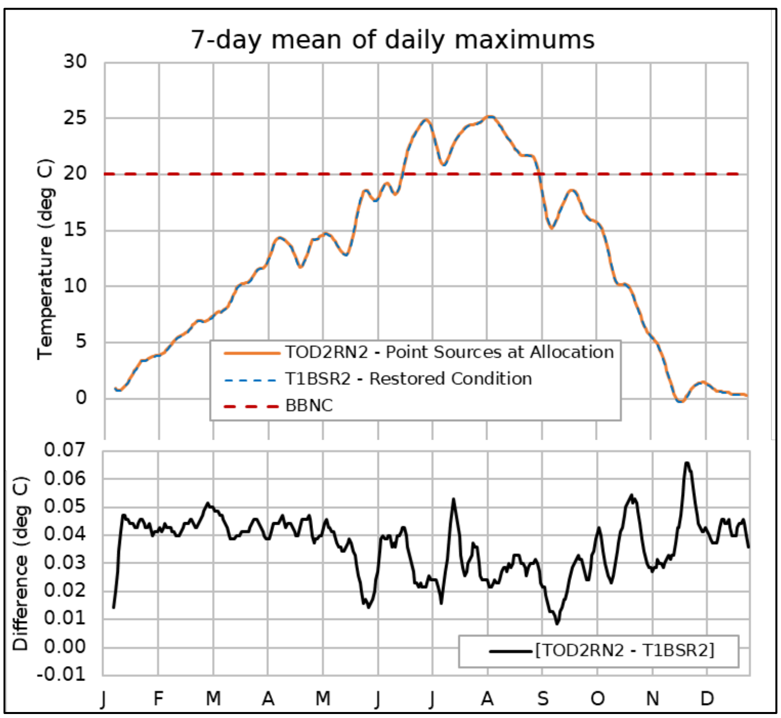


Figure C-3. Klamath River at Keno Dam outflow–TOD2RN2 and T1BSR2.

At the Stateline the monthly means of the differences calculated from the natural baseline condition using T1BSR2 showed a maximum difference of 0.035 deg C in February (Figure C-4).

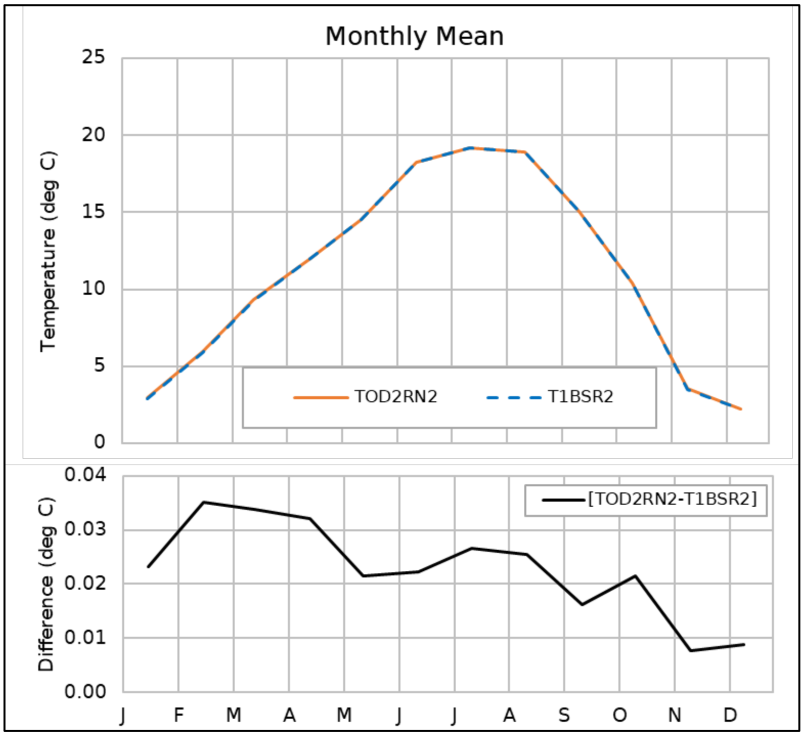


Figure C-4. Klamath River at Stateline–TOD2RN2 and T1BSR2.

C.4.2 Evaluating the Cumulative Impact Due to Point Sources, the Non-Point Tributaries Klamath Straits Drain (KSD), and the Lost River Diversion Channel (LRDC) (TOD2RN3)

This scenario was used to evaluate the impact of PS and NPS tributaries on water temperatures in the Klamath River. The TOD2RN2 scenario was used as the basis to configure this scenario which is referred to as TOD2RN3. For this scenario in addition to having all PS temperatures at WLA (Figure C-2), the temperature inputs for KSD and LRDC were also specified to reflect the temperatures allowed under the load allocation (LA). Figure C-5 shows the LA timeseries for LRDC and KSD.

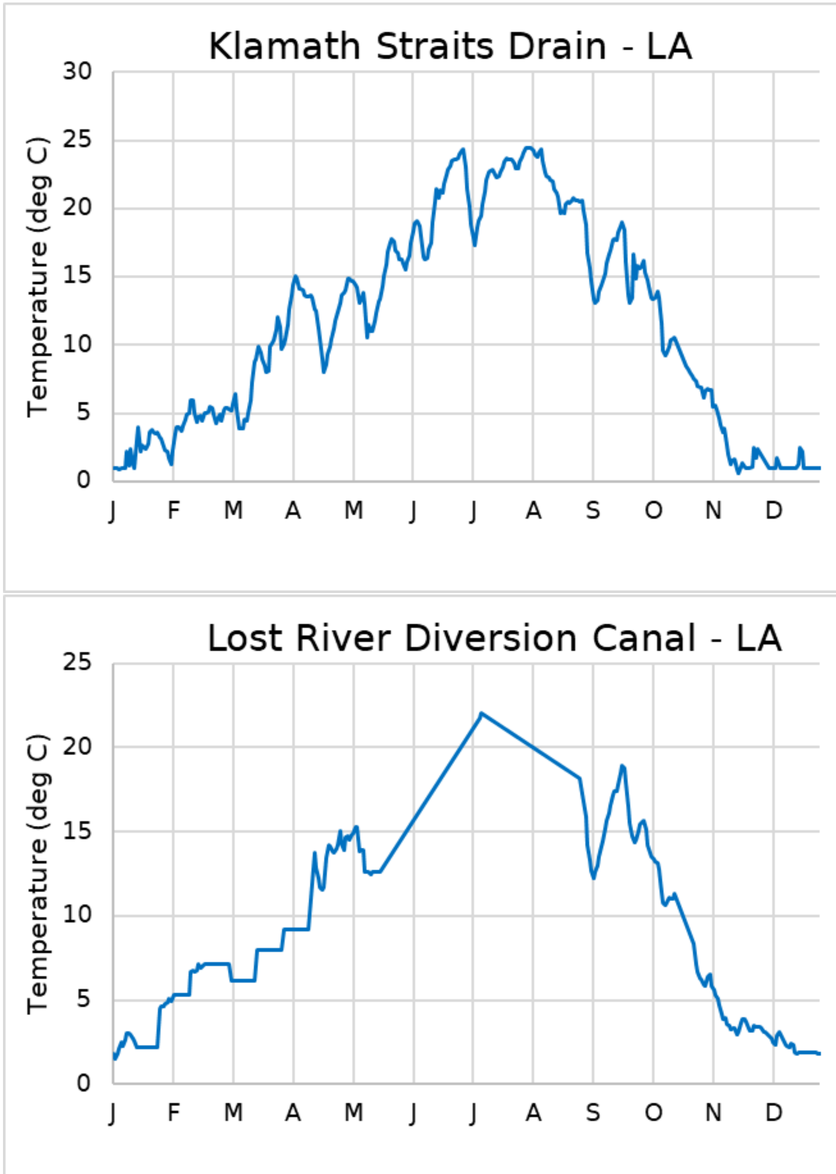


Figure C-5. Point sources at WLA specified in the model.

The updated TOD2RN3 models were configured to output hourly temperature and flow at all the model segments. The reconfigured models were then re-run in sequence from upstream to downstream. The resulting hourly temperature timeseries were used to calculate the excess DM temperature above Keno and excess 7DADM temperature downstream of Keno, using the timeseries at every model segment/node during the 2000 model period. Warming from PS and NPS at allocations is calculated as the difference between the DM or 7DADM of TOD2RN3 and T1BSR2. At the Oregon/California border, the warming is calculated as the difference between the monthly averages. Excess temperature is defined as the difference between the TOD2RN3 DM or 7DADM and the applicable criteria. In the reservoirs the hourly W2 temperatures are calculated as a depth average and then used to calculate either the DM or 7DADM timeseries. Similarly, daily mean flow timeseries were also calculated for each of the model segments. The mean daily flow and resulting excess timeseries were then used to calculate the daily excess load in kilocalories per day for every model segment during the 2000 model period. The monthly excess 7DADM and excess heat load statistics at Keno outflow and Stateline can be found in Table C-12 and Table C-13.

Table C-12. TOD2RN3 - Monthly Temperature Excess (°C) and Excess Heat Load (kcal/day) Statistics at Keno Outflow.

TOD2RN3						
Keno Outflow	**Excess 7DADM Temperature**			**Excess Load**		
Month	**Min**	**Median**	**Max**	**Min**	**Median**	**Max**
January	0.00	0.00	0.00	0.00E+00	0.00E+00	0.00E+00
February	0.00	0.00	0.00	0.00E+00	0.00E+00	0.00E+00
March	0.00	0.00	0.00	0.00E+00	0.00E+00	0.00E+00
April	0.00	0.00	0.00	0.00E+00	0.00E+00	0.00E+00
May	0.00	0.00	0.00	0.00E+00	0.00E+00	0.00E+00
June	0.00	0.00	4.54	0.00E+00	0.00E+00	9.71E+09
July	0.41	3.48	4.65	7.32E+08	7.11E+09	1.00E+10
August	1.31	3.17	4.94	2.44E+09	6.41E+09	1.07E+10
September	0.00	0.00	1.11	0.00E+00	0.00E+00	2.05E+09
October	0.00	0.00	0.00	0.00E+00	0.00E+00	0.00E+00
November	0.00	0.00	0.00	0.00E+00	0.00E+00	0.00E+00
December	0.00	0.00	0.00	0.00E+00	0.00E+00	0.00E+00

Table C-13. TOD2RN3 - Monthly Temperature Excess (°C) and Excess Heat Load (kcal/day) Statistics at Stateline.

Stateline	**Excess 7DADM Temperature**			**Excess Load**			**Excess above CA criteria**
Month	**Min**	**Median**	**Max**	**Min**	**Median**	**Max**	
January	0.00	0.00	0.00	0.00E+00	0.00E+00	0.00E+00	0.00
February	0.00	0.00	0.00	0.00E+00	0.00E+00	0.00E+00	0.00
March	0.00	0.00	0.00	0.00E+00	0.00E+00	0.00E+00	0.00
April	0.00	0.00	0.00	0.00E+00	0.00E+00	0.00E+00	0.00
May	0.00	0.00	0.00	0.00E+00	0.00E+00	0.00E+00	0.04
June	0.37	2.86	3.18	8.63E+08	6.49E+09	8.65E+09	0.04
July	0.31	2.01	3.16	5.30E+08	4.21E+09	7.43E+09	0.03
August	0.02	1.51	3.62	3.75E+07	3.30E+09	7.63E+09	0.03
September	0.00	0.00	0.00	0.00E+00	0.00E+00	0.00E+00	0.04
October	0.00	0.00	0.00	0.00E+00	0.00E+00	0.00E+00	0.03
November	0.00	0.00	0.00	0.00E+00	0.00E+00	0.00E+00	0.02
December	0.00	0.00	0.00	0.00E+00	0.00E+00	0.00E+00	0.02

Section C-8 includes the longitudinal plots by RKM of the excess DM or 7DADM and the excess load showing the min/max/median for each of the modeling segments. Finally, a summary table that shows the summary statistics of the of the min, median, and maximum monthly excess 7DADM and the corresponding maximum monthly excess 7DADM are also included. Table C-14 shows the location in river kilometer where the maximum temperature occurs.

Table C-14. Location where maximum temperature occurs – TOD2RN3.

Modeling segment	Segment Type	Location of Max Excess Temperature RKM [Segment/Node ID]	Location of Max Excess heat load Location RKM [Segment/Node ID]
Link River (Link Dam (RKM 0) to Lake Ewauna)	River	NA	NA
Lake Ewauna (RKM 0) to Keno Reef	Reservoir	NA	NA
Keno Reef (RKM 0) to OR/CA Stateline	River	10.91 [132]	13.45 [149]

Demonstration of attainment of the HUA by point sources, KSD, and LRDC was based on the difference between TOD2RN3 and T1BSR2 scenario. The warming impact was evaluated at two compliance locations (i) Keno Dam Outflow and (ii) Stateline is discussed below:

Keno Dam Outflow: The cumulative HUA warming requirement at Keno Outlet was 0.1 deg C (from June through September) due to PS, LRDC, and KSD. This meant that the difference between T1BSR2 and TOD2RN3 scenario should be less than 0.1 deg C to attain the HUA at Keno Outlet. As can be seen in Figure C3 below the difference between TOD2RN3 and T1BSR2 was always less than 0.1 deg C when the 7DADM was greater 20 deg C. Note that the 7DADM at Keno is below 20 deg C in May and September when the difference was greater than 0.1 deg C.

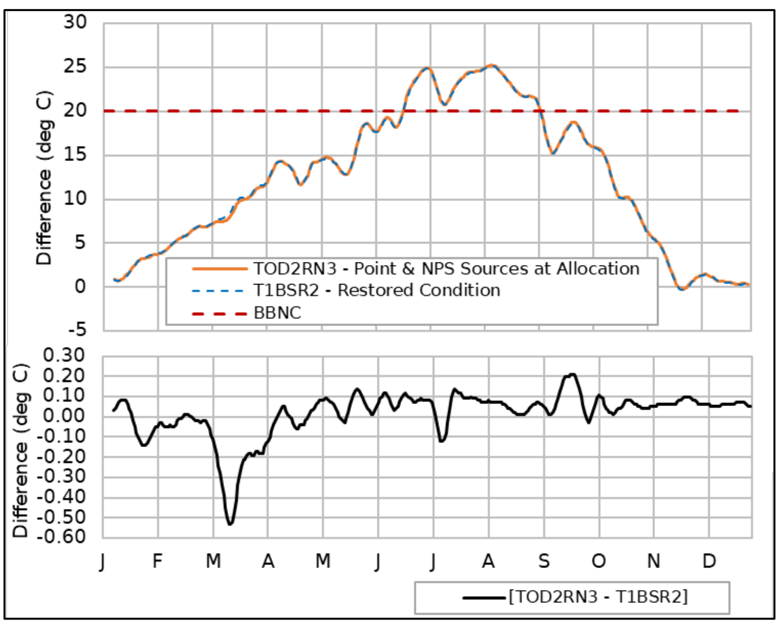


Figure C-6. Klamath River at Keno Dam outflow–TOD2RN3 and T1BSR2.

Stateline: At Stateline the compliance requirement is set such that the TOD2RN3 scenario should result in no warming (defined as <0.04 deg C) above the monthly means calculated from the natural baseline condition using T1BSR2. Figure C-7 shows the monthly means and the difference between TOD2RN3 and T1BSR2.

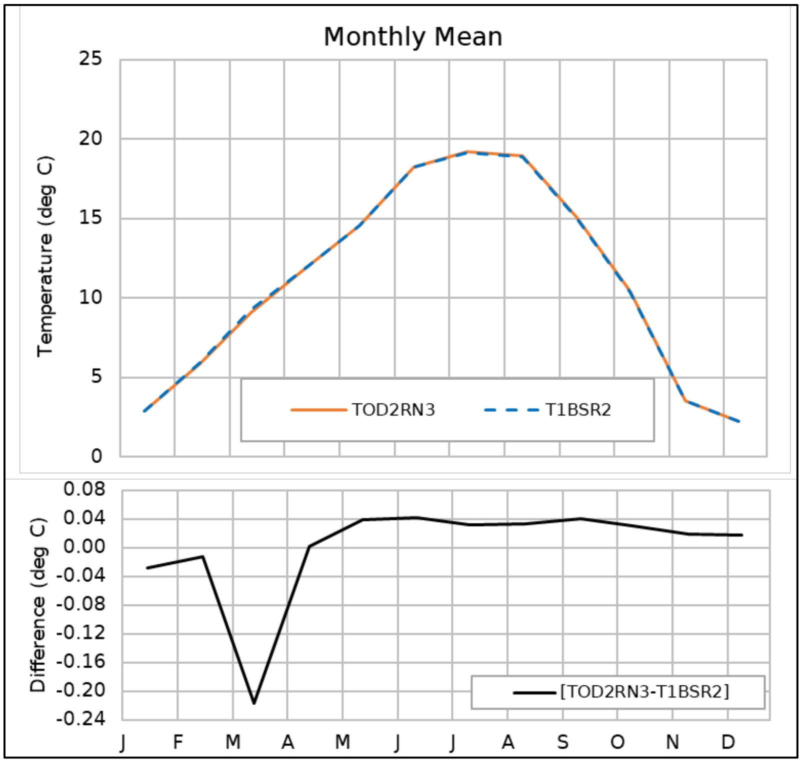


Figure C-7. Klamath River at Stateline–TOD2RN3 and T1BSR2.

C.4.3 Evaluating the Impact of Dams (J.C. Boyle and Keno)

This scenario involved running the Klamath River Model with all dams in place. Boundary temperature inputs were based on the final compliance scenario for Oregon (TOD2RN3). The objective of the simulation was to provide a means of quantifying the impacts of the dams and appropriate allocations. This scenario was configured to include the impact of PS and NPS tributaries on water temperatures in the Klamath River with dams in place. The T4BSRN was configured to include all the boundary condition changes incorporated in TOD2RN3 i.e. PS and NPS at their allocated temperatures and the updated flow for Collins Product outfall 001. Table C-1 presents the models applied for this scenario.

Assumptions and Configuration

The T4BSRN model was configured and implemented in a piece-wise manner from upstream to downstream. The existing condition model (S1) was used as the basis for T4BSRN in terms of physical configuration only (alternating CE-QUAL-W2 and RMA models for the reservoirs and riverine segments). Boundary water temperature conditions were the same as the allocation scenarios (TOD2RN3). Configuration details are as follows:

- All the dams are present, therefore the model is divided into 5 domains (2 reservoirs, 3 riverine reaches as noted in Table C-1).

- For the Upper Klamath Lake boundary condition, flow is the same as in the current conditions model depiction and TOD2RN. Water temperature boundary conditions are the same as in TOD2RN.
- For the Lake Ewauna/Keno Reservoir segment, all inputs from TOD2RN3 are the same.
- Downstream of Keno Dam, all the tributary flow boundary conditions in Oregon are set the same as in TOD2RN3.
- All other water quality parameters are consistent with the compliance runs.

The updated T4BSRN2 models were configured to output hourly temperature and flow at all the model segments. The reconfigured models were then re-run in sequence from upstream to downstream. The resulting hourly temperature timeseries were used to calculate the excess DM temperature above Keno and excess 7DADM temperature downstream of Keno, using the timeseries at every model segment/node during the 2000 model period. Warming from Dams is calculated as the difference between the DM or 7DADM of TOD2RN3 and T4BSRN2. At the Oregon/California border, the warming is calculated as the difference between the monthly averages. Excess temperature is defined as the difference between the T4BSRN2 DM or 7DADM and the applicable criteria. In the reservoirs the hourly W2 temperatures are calculated as a depth average and then used to calculate either the DM or 7DADM timeseries. Similarly, daily mean flow timeseries were also calculated for each of the model segments. The mean daily flow and resulting excess timeseries were then used to calculate the daily excess load in kilocalories per day for every model segment during the 2000 model period. The monthly excess 7DADM and excess heat load statistics at Keno outflow and Stateline can be found in Table C-15 and Table C-16.

Table C-15. T4BSRN2 - Monthly Temperature Excess (°C) and Excess Heat Load (kcal/day) Statistics at Keno Outflow.

T4BSRN2						
Keno Outflow	**Excess 7DADM Temperature**			**Excess Load**		
Month	**Min**	**Median**	**Max**	**Min**	**Median**	**Max**
January	0.00	0.00	0.00	0.00E+00	0.00E+00	0.00E+00
February	0.00	0.00	0.00	0.00E+00	0.00E+00	0.00E+00
March	0.00	0.00	0.00	0.00E+00	0.00E+00	0.00E+00
April	0.00	0.00	0.00	0.00E+00	0.00E+00	0.00E+00
May	0.00	0.00	0.00	0.00E+00	0.00E+00	0.00E+00
June	0.00	0.00	4.46	0.00E+00	0.00E+00	8.83E+09
July	1.02	3.46	4.62	1.68E+09	5.51E+09	8.52E+09
August	1.41	3.21	4.86	2.19E+09	5.79E+09	1.06E+10
September	0.00	0.00	1.26	0.00E+00	0.00E+00	2.35E+09
October	0.00	0.00	0.00	0.00E+00	0.00E+00	0.00E+00
November	0.00	0.00	0.00	0.00E+00	0.00E+00	0.00E+00
December	0.00	0.00	0.00	0.00E+00	0.00E+00	0.00E+00

Table C-16. T4BSRN2 - Monthly Temperature Excess (°C) and Excess Heat Load (kcal/day) Statistics at Stateline.

Stateline	Excess 7DADM Temperature			Excess Load			Excess above CA criteria
Month	Min	Median	Max	Min	Median	Max	
January	0.00	0.00	0.00	0.00E+00	0.00E+00	0.00E+00	0.00
February	0.00	0.00	0.00	0.00E+00	0.00E+00	0.00E+00	0.00
March	0.00	0.00	0.00	0.00E+00	0.00E+00	0.00E+00	0.00
April	0.00	0.00	0.00	0.00E+00	0.00E+00	0.00E+00	0.10
May	0.00	0.00	0.00	0.00E+00	0.00E+00	0.00E+00	0.00
June	0.44	3.86	4.78	1.25E+09	8.38E+09	1.32E+10	0.00
July	1.64	3.44	4.81	2.95E+09	6.70E+09	1.38E+10	0.18
August	1.30	3.08	4.72	2.48E+09	7.02E+09	1.35E+10	0.27
September	0.49	0.78	1.08	1.15E+09	1.68E+09	2.20E+09	0.16
October	0.00	0.00	0.00	0.00E+00	0.00E+00	0.00E+00	0.01
November	0.00	0.00	0.00	0.00E+00	0.00E+00	0.00E+00	0.13
December	0.00	0.00	0.00	0.00E+00	0.00E+00	0.00E+00	0.00

Section C-9 includes the longitudinal plots by RKM of the excess DM or 7DADM and the excess load showing the min/max/median for each of the modeling segments. Finally, a summary table that shows the summary statistics of the of the min, median, and maximum monthly excess 7DADM and the corresponding maximum monthly excess 7DADM are also included. Table C-17 shows the location in river kilometer where the maximum temperature occurs.

Table C-17. Location where maximum temperature occurs - T4BSRN2.

Modeling segment	Segment Type	Location of Max Excess Temperature RKM [Segment/Node ID]	Location of Max Excess heat load Location RKM [Segment/Node ID]
Link River (Link Dam (RKM 0) to Lake Ewauna)	River	NA	NA
Lake Ewauna (RKM 0) to Keno Dam	Reservoir	NA	NA
Keno Reach - Keno Dam (RKM 0) to upstream of JC Boyle	River	8.66 [117]	8.59 [115]
JC Boyle Reservoir (u/s RKM 0) to JC Boyle Dam	Reservoir	0.14 [2]	0.14 [2]
Full Flow Reach-JC Boyle Dam (RKM 0) to OR/CA Stateline	River	1.4 [20]	20.55 [279]

Impact from the dams was calculated as the change in the temperature metric between two model scenarios: TOD2RN3 where dams are excluded (except Link) and the modified version of T4BSRN (referenced as T4BSRN2) where dams are included. Demonstrating attainment of the HUA by dams was accomplished by evaluating the change in the temperature metric from dams and requiring the appropriate reduction to achieve the HUA. The impact due to the dams was evaluated at two compliance locations (i) Keno Dam Outflow and (ii) Stateline is discussed below:

Keno Dam Outflow: The impact from Keno Dam was evaluated using the Keno outflow and was calculated as the change in the 7DADM temperature between TOD2RN3 and T4BSRN2 (calculated on a daily basis). Figure C-8 show the warming due to Keno Dam.

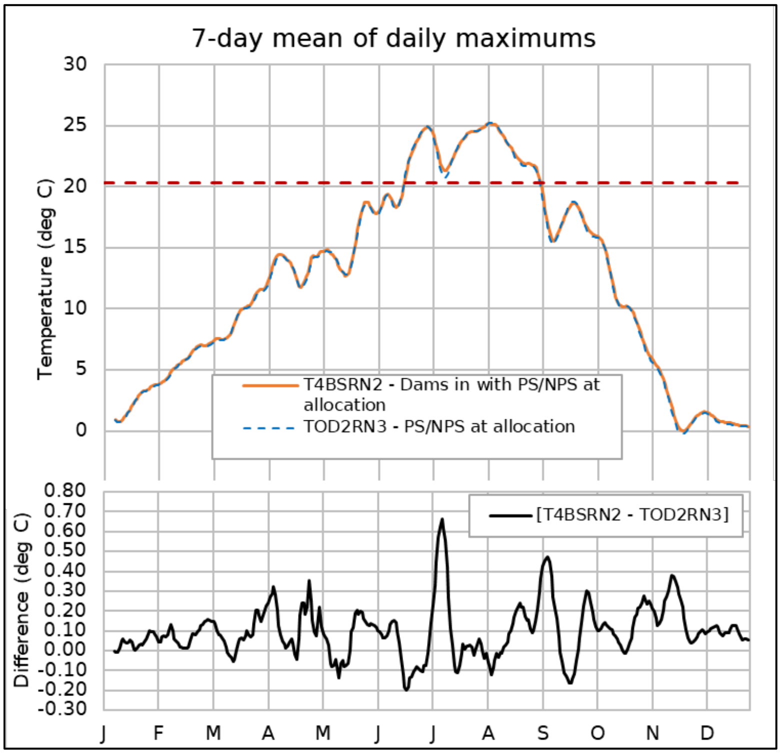


Figure C-8. Klamath River at Keno Dam outflow–T4BSRN2 and TOD2RN2.

The excess change from the HUA represented the appropriate reduction and is calculated on a monthly basis as the delta between the difference and HUA shown in Table C-18 below. Note that the cumulative HUA at Keno Dam outlet due to Keno Dam and Reservoir was assigned as 0.08 deg C (applicable from June 1 to September 30). The HUA was greater than 0.08 deg C for 31 days when 7DADM of 20 deg C was exceeded by T4BSRN2.

Table C-18. Maximum Monthly difference due to warming from Keno Dam and associated reduction required.

Month	Max 7DADM Difference [T4BSRN2 - TOD2RN3] (deg C)	Keno Outlet Reduction-delta (deg C)
6	0.15	0.07
7	0.67	0.59
8	0.24	0.16
9	0.47	0.39

Stateline: The impact due to Keno Dam and JC Boyle Dam was calculated as the change in the monthly mean temperature between TOD2RN3 and T4BSRN2 at Stateline (Figure C-9). The monthly mean deltas are shown below in Table C-19. No cumulative warming due to anthropogenic sources is allowed at Stateline. The positive delta of the monthly mean values at Stateline represents the warming due to Keno Dam and JC Boyle Dam.

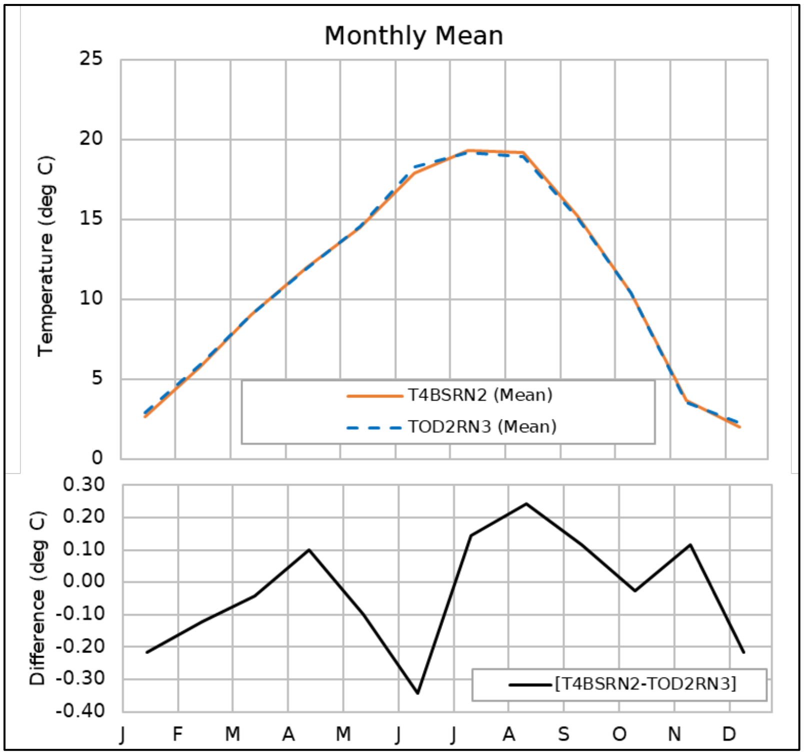


Figure C-9. Klamath River at Stateline–T4BSRN2 and TOD2RN3.

Table C-19. Maximum Monthly difference due to warming from Keno Dam and associated reduction required.

Month	Monthly Mean [T4BSRN2-TOD2RN3] (deg C)	Impact at Stateline due to dams delta (deg C)
1	-0.22	0
2	-0.12	0
3	-0.04	0
4	0.10	0.1
5	-0.10	0
6	-0.34	0
7	0.15	0.15
8	0.24	0.24
9	0.12	0.12
10	-0.03	0
11	0.12	0
12	-0.22	0

C.4.4 Evaluating the Impact of Keno Dam Only

For this scenario run the T4BSRN2 flow and temperature output from the Lake Ewuana to Keno CE-QUAL-W2 model was used as the input into the no dams RMA model from Keno to Iron Gate. The combination of these models represents the new T4BSRN3. The impacts from Keno dam only is defined as the change in 7DADM between two model scenarios: TOD2RN3 where dams are excluded (except Link and Keno Reef in place) and a modified version of T4BSRN2 (referenced here as T4BSRN3) where only Keno dam is included. This scenario was used to evaluate the impact of PS and NPS tributaries at their allocated temperatures (calculated based on 0.015 C of allowed warming). The calculated monthly excess 7DADM and excess load based on temperature excess from 20.3 deg C at both Keno Outflow and at Stateline can be found in Table C-20 and Table C-21.

Table C-20. T4BSRN3 - Monthly Temperature Excess (°C) and Excess Heat Load (kcal/day) Statistics at Keno Outflow

T4BSRN3						
Keno Outflow	Excess 7DADM Temperature			Excess Load		
Month	Min	Median	Max	Min	Median	Max
January	0.00	0.00	0.00	0.00E+00	0.00E+00	0.00E+00
February	0.00	0.00	0.00	0.00E+00	0.00E+00	0.00E+00
March	0.00	0.00	0.00	0.00E+00	0.00E+00	0.00E+00
April	0.00	0.00	0.00	0.00E+00	0.00E+00	0.00E+00
May	0.00	0.00	0.00	0.00E+00	0.00E+00	0.00E+00
June	0.00	0.00	4.46	0.00E+00	0.00E+00	8.83E+09
July	1.02	3.46	4.62	1.68E+09	5.51E+09	8.52E+09
August	1.41	3.21	4.86	2.19E+09	5.79E+09	1.06E+10
September	0.00	0.00	1.26	0.00E+00	0.00E+00	2.35E+09
October	0.00	0.00	0.00	0.00E+00	0.00E+00	0.00E+00
November	0.00	0.00	0.00	0.00E+00	0.00E+00	0.00E+00
December	0.00	0.00	0.00	0.00E+00	0.00E+00	0.00E+00

Table C-21. T4BSRN3 - Monthly Temperature Excess (°C) and Excess Heat Load (kcal/day) Statistics at Stateline

Stateline	Excess 7DADM Temperature			Excess Load			Excess above CA criteria
Month	Min	Median	Max	Min	Median	Max	
January	0.00	0.00	0.00	0.00E+00	0.00E+00	0.00E+00	0.00
February	0.00	0.00	0.00	0.00E+00	0.00E+00	0.00E+00	0.00
March	0.00	0.00	0.00	0.00E+00	0.00E+00	0.00E+00	0.00
April	0.00	0.00	0.00	0.00E+00	0.00E+00	0.00E+00	0.00

Stateline	Excess 7DADM Temperature			Excess Load			Excess above CA criteria
May	0.00	0.00	0.00	0.00E+00	0.00E+00	0.00E+00	0.05
June	0.44	2.94	3.23	1.07E+09	6.21E+09	7.94E+09	0.00
July	0.22	1.99	3.22	4.62E+08	4.13E+09	8.93E+09	0.13
August	0.06	1.46	3.64	1.38E+08	3.46E+09	9.06E+09	0.01
September	0.00	0.00	0.00	0.00E+00	0.00E+00	0.00E+00	0.11
October	0.00	0.00	0.00	0.00E+00	0.00E+00	0.00E+00	0.11
November	0.00	0.00	0.00	0.00E+00	0.00E+00	0.00E+00	0.08
December	0.00	0.00	0.00	0.00E+00	0.00E+00	0.00E+00	0.10

Section C-10 includes the longitudinal plots by RKM of the excess DM or 7DADM and the excess load showing the min/max/median for each of the modeling segments. Table C-22 shows the location in river kilometer where the maximum temperature occurs.

Table C-22. Location where maximum temperature occurs - T4BSRN3.

Modeling segment	Segment Type	Location of Max Excess Temperature RKM [Segment/Node ID]	Location of Max Excess heat load Location RKM [Segment/Node ID]
Link River (Link Dam (RKM 0) to Lake Ewauna)	River	NA	NA
Lake Ewauna (RKM 0) to Keno Dam	Reservoir	NA	NA
Keno Dam (RKM 0) to OR/CA Stateline	River	10.90 [132]	13.45 [149]

Impact from the dams was calculated as the change in the temperature metric between two model scenarios: TOD2RN3 where dams are excluded (except Link) and the modified version of T4BSRN (referenced as T4BSRN3) where only Keno Dam is included. Demonstrating attainment of the HUA by dams requires evaluating the change in the temperature metric from dams and the appropriate reduction to achieve the HUA. The impact due to the dams was evaluated at two compliance locations (i) Keno Dam Outflow and (ii) Stateline is discussed below:

Keno Dam Outflow: The impact from Keno Dam was evaluated using the Keno outflow and was calculated as the change in the 7DADM temperature between TOD2RN3 and T4BSRN3 (calculated on a daily basis). Figure C-10 shows the warming due to Keno Dam.

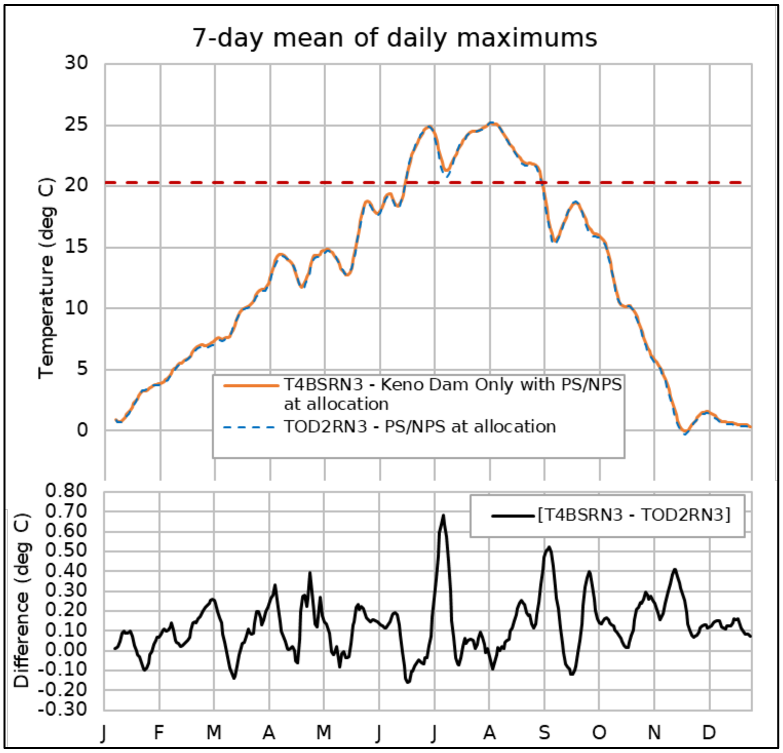


Figure C-10. Klamath River at Keno Dam outflow–T4BSRN3 and TOD2RN2

The excess change from the HUA represented the appropriate reduction and is calculated on a monthly basis as the delta between the difference and HUA shown in Table C-22 below. The cumulative HUA at Keno Dam outlet due to Keno Dam was assigned as 0.08 deg C (from June 1 to September 30). The HUA was greater than 0.08 deg C for 31 days when 7DADM of 20 deg C was exceeded by T4BSRN3.

Table C-23 Maximum Monthly difference due to warming from Keno Dam and associated reduction required

.

Month	Max 7DADM Difference [T4BSRN2 - TOD2RN3] (deg C)	Keno Outlet Reduction-delta (deg C)
6	0.15	0.07
7	0.67	0.59
8	0.24	0.16
9	0.47	0.39

Stateline: The impact due to Keno Dam was calculated as the change in the daily 7DADM and monthly mean temperature between TOD2RN3 and T4BSRN3 at Stateline(Figure C-11 and Figure C-12). The monthly mean deltas are shown below in Table C-23. No cumulative warming due to anthropogenic sources is allowed at Stateline. The positive delta of the monthly mean values at Stateline represents the warming due to Keno Dam only.

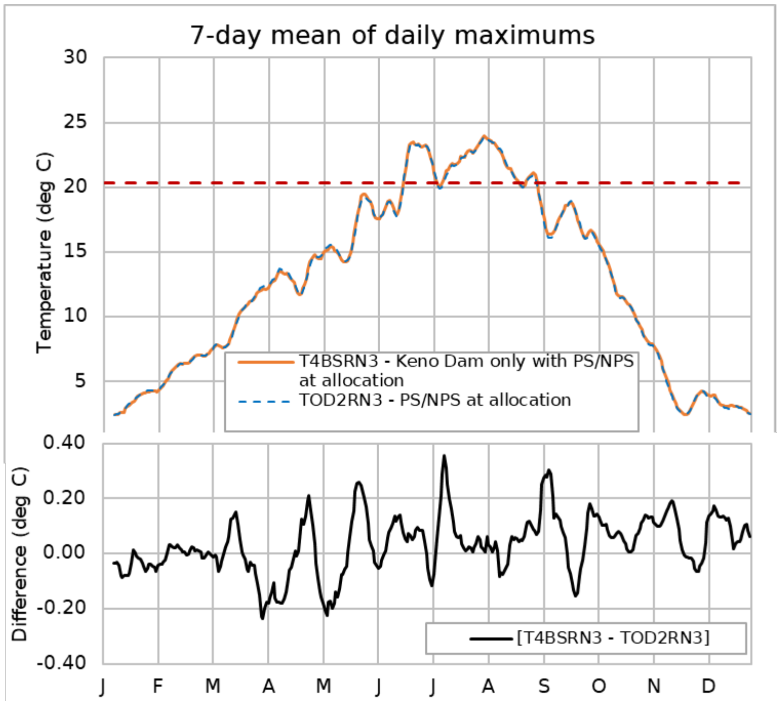


Figure C-11. 7DADM temperatures Klamath River at Stateline–T4BSRN3 and TOD2RN2

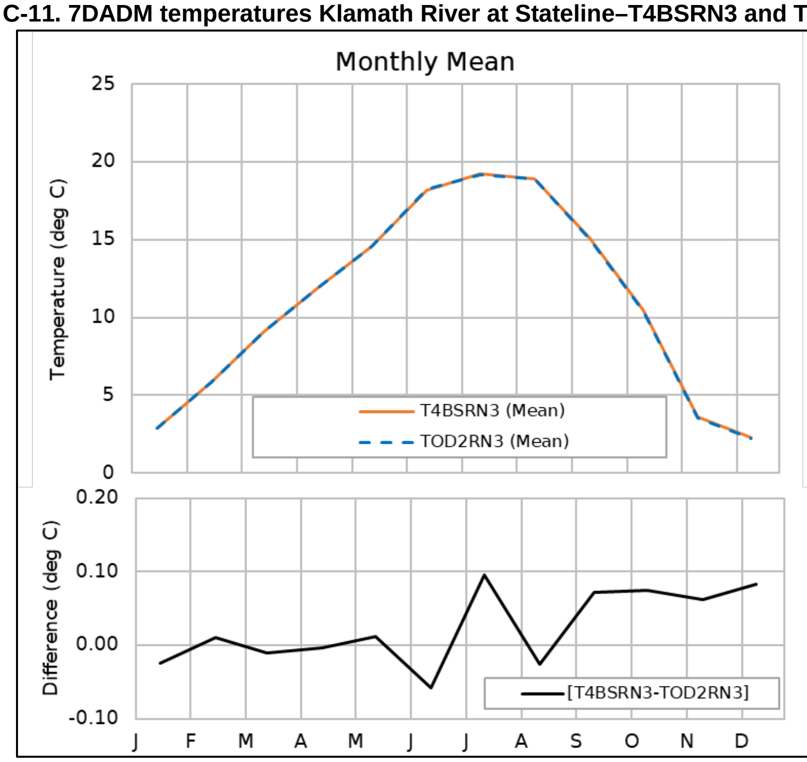


Figure C-12. Klamath River at Stateline Mean Monthly–T4BSRN3 and TOD2RN3

Table C-24. Maximum Monthly difference due to warming from Keno Dam and associated reduction required

Month	Monthly Mean [T4BSRN3-TOD2RN3] (deg C)	Impact at Stateline due to Keno dam only delta (deg C)
1	-0.02	0
2	0.01	0.01

Month	Monthly Mean [T4BSRN3-TOD2RN3] (deg C)	Impact at Stateline due to Keno dam only delta (deg C)
3	-0.01	0
4	0.00	0
5	0.01	0.01
6	-0.06	0
7	0.10	0.10
8	-0.03	0
9	0.07	0.07
10	0.08	0.08
11	0.06	0.06
12	0.08	0.08

In summary, this report documents the results of a number of modeling scenarios to support the revision of the Klamath River Temperature TMDL originally developed in 2010. For this revision, several of the original model scenarios were adapted and rerun to evaluate temperature loading from multiple sources in the Klamath River. Table C-24 summarizes the original model scenarios used and the newly created scenarios used for this revision.

Table C-25. Summary of Model Scenarios

Scenario	Base Model (2010)	Adapted Model (2019)	Description	PS Representation	NPS Representation	Dams
Existing Condition	S1	S1	Existing Condition Model. All inputs based on year 2000	Existing	Existing	Yes
Restored Condition	T1BSR	T1BSR2	Modified version of the T1BSR - Includes the Keno Reef d/s of Lake Ewuana. • Updated the T1BSR tributary inflow temperature files (TTR) for KSD and LRCD. The temperatures are taken from one segment above where KSD and LRDC input into the Klamath River. Temperatures from segment 71 for KSD and segment 19 for LRDC were taken as input for KSD and LRDC respectively.	Not included	Flow same as Existing Condtion S1. Temperatures set same as Klamath River Temperaures.	Not included
PS warming only scenario (PS at WLA)	TOD2RN	TOD2RN2	Modified version of the TOD2RN scenario from the previous round TMDL. Includes Keno Reef at d/s of Lake Ewuana	• Temperatures at WLA • Collins Product flow rate file updated to reflect current discharge	Temperatures same as T1BSR2	Not included
PS and NPS warming scenario (PS at WLA and NPS at LA)	TOD2RN2	TOD2RN3	Updated version of TOD2RN2. Includes Keno Reef at d/s of Lake Ewuana.	• Temperatures at WLA • Collins Product flow rate file updated to reflect current discharge	Temperatures at LA	Not included

Scenario	Base Model (2010)	Adapted Model (2019)	Description	PS Representation	NPS Representation	Dams
Dams In with PS and NPS warming scenario (PS at WLA and NPS at LA)	T4BSRN, TOD2RN3	T4BSRN2	Updated version of TOD2RN3 but with Dams added in at d/s of Lake Ewuana and JC Boyle	• Temperatures at WLA • Collins Product flow rate file updated to reflect current discharge	Temperatures at LA	Yes
Evaluation of the impact due to Keno Dam only no JC Boyle.	T4BSRN2, TOD2RN3	T4BSRN3	Combination of T4BSRN2 and TOD2RN3. Upstream of Keno Dam was evaluated using T4BSRN2. T4BSRN2 flow and temperature output from the Lake Ewuana to Keno CE-QUAL-W2 model was used as the input into the no dams RMA model from Keno to Iron Gate (TOD2RN3)	• Temperatures at WLA • Collins Product flow rate file updated to reflect current discharge	Temperatures at LA	Only Keno Dam (no JC Boyle)

C.5 Existing Condition (S1).

Note for all Figures:
-Top plot shows the Daily Maximum or 7DADM Temperature (min/max/median calculated for each segment along the reach from May through September 15, 2000)
-Middle plot shows the Excess of Daily Maximum or Excess of 7DADM temperatures calculated annually (2000) for each segment along the reach.
-Bottom plot shows the Excess of Daily Maximum or Excess of 7DADM heat load calculated annually for each segment along the reach.

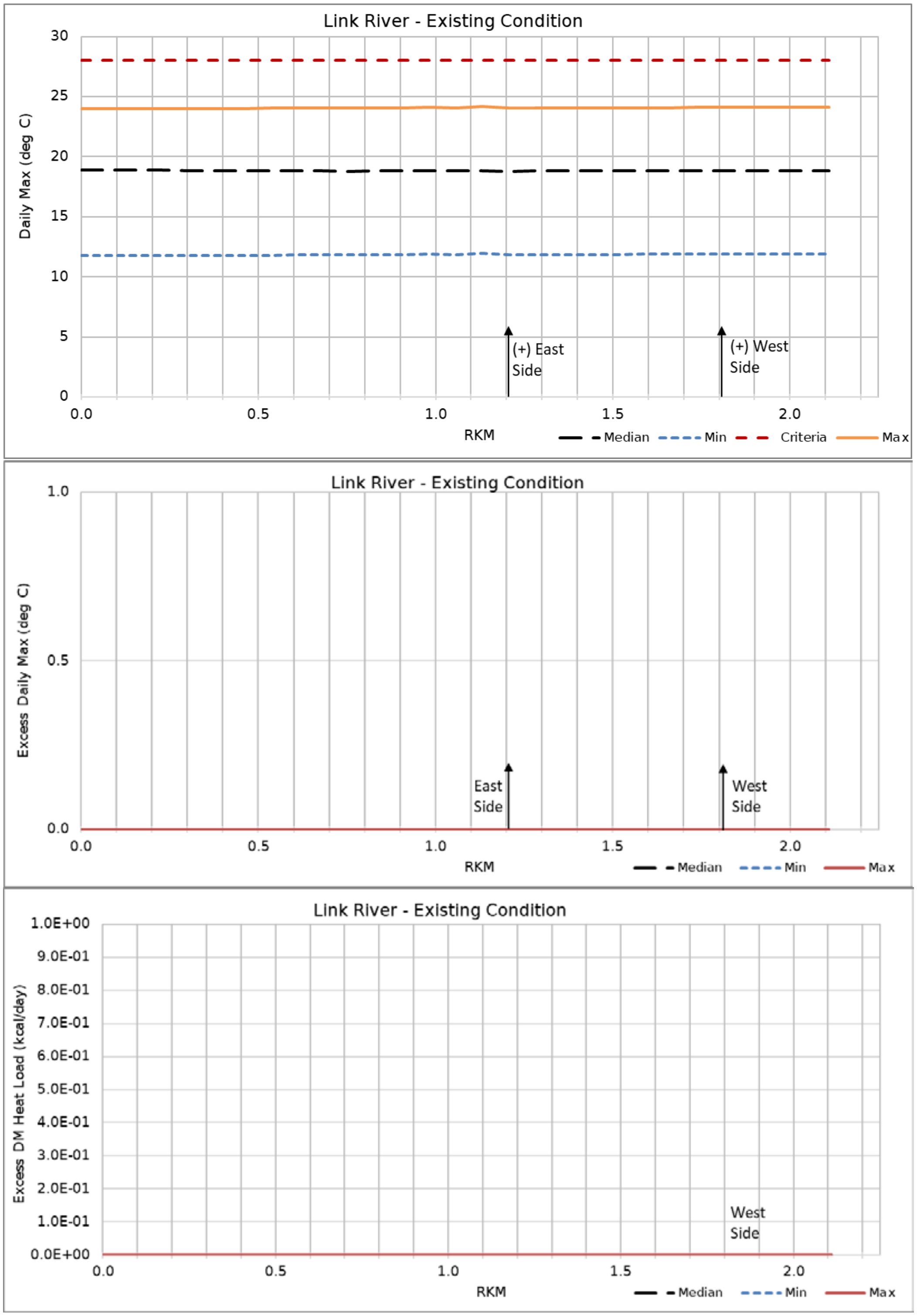
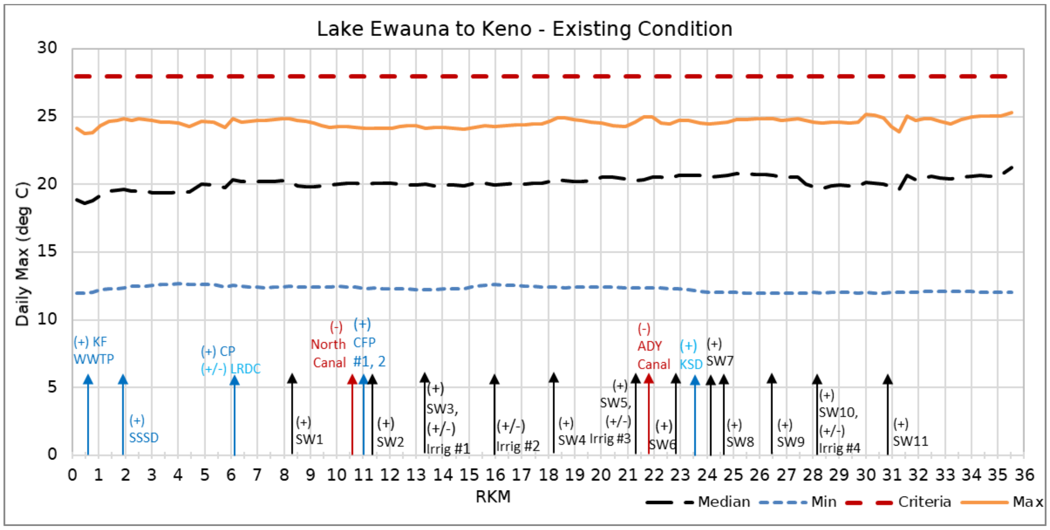
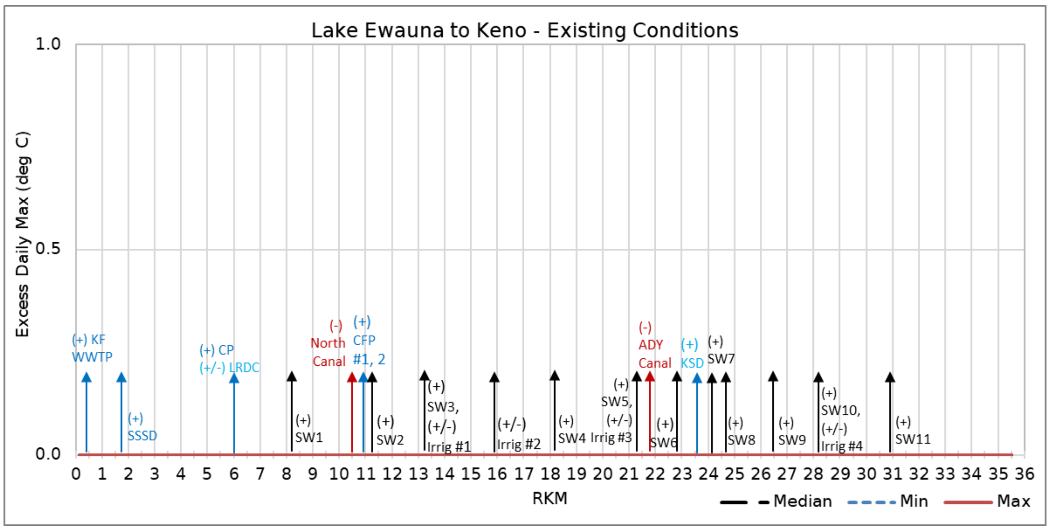


Figure C-13. Link River (Link Dam (RKM 0) to Lake Ewauna).





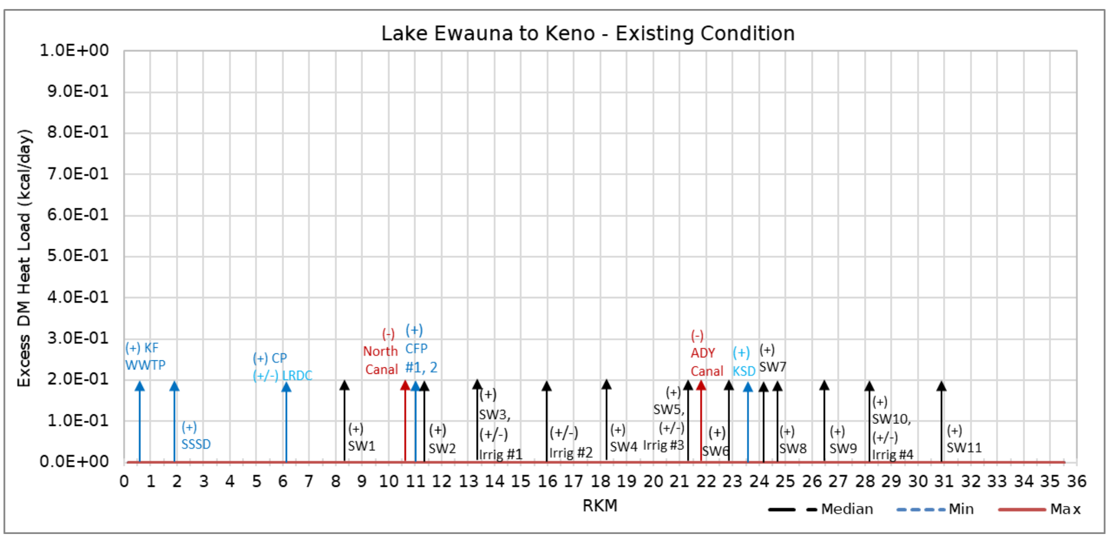


Figure C-14. Lake Ewauna (RKM 0) to Keno Dam.

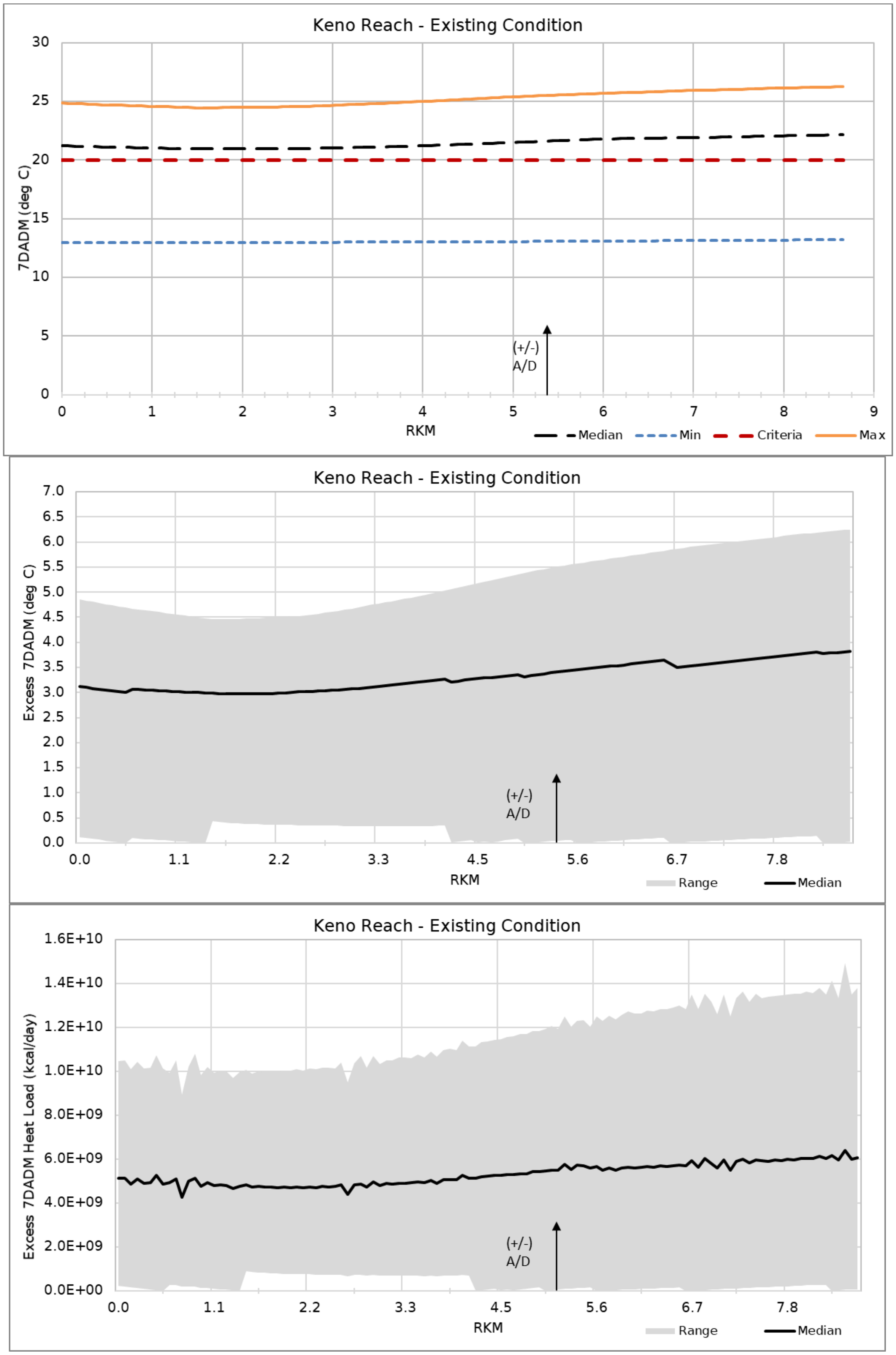


Figure C-15. Keno Reach - Keno Dam (RKM 0) to upstream of JC Boyle

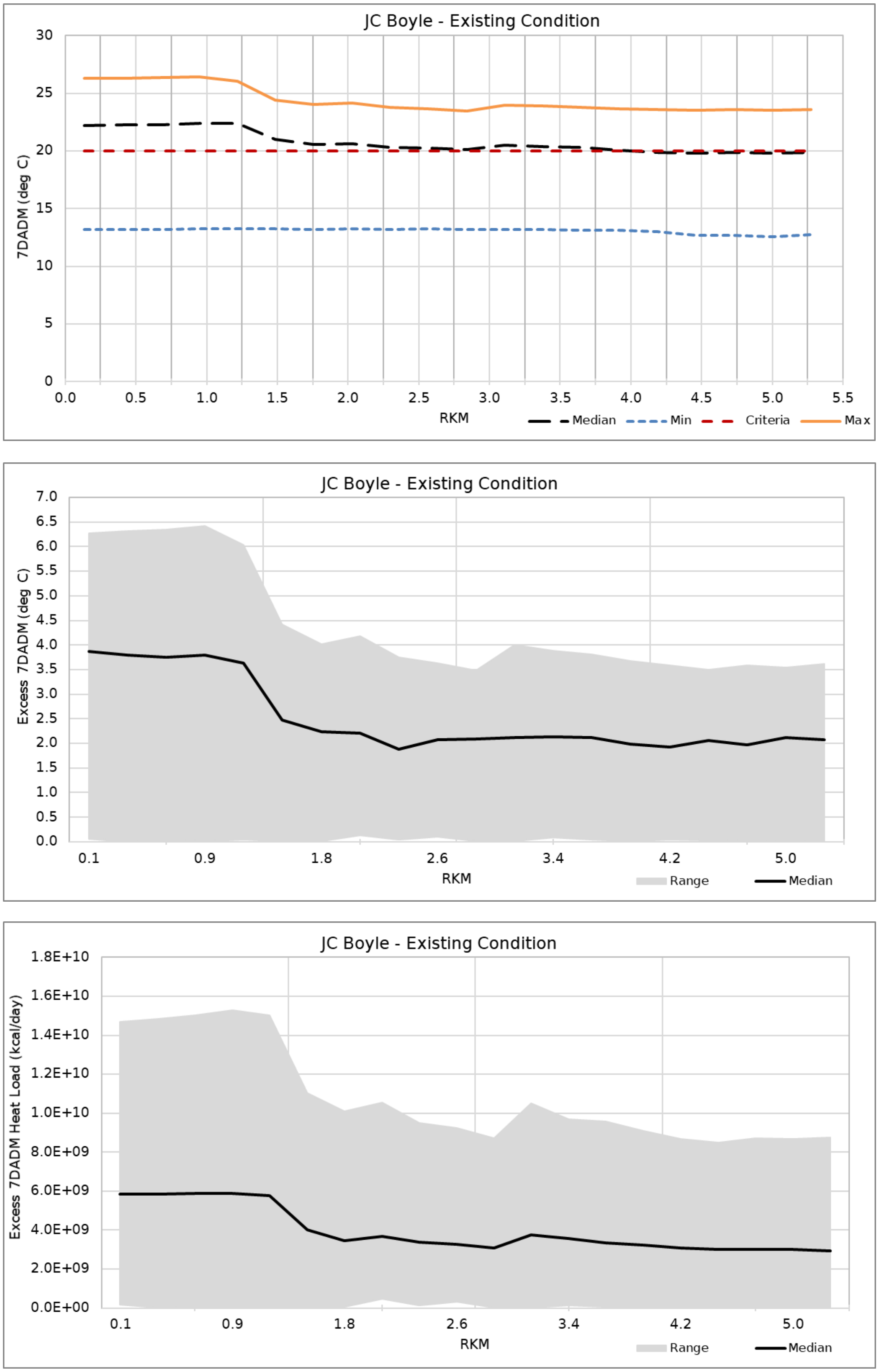


Figure C-16. JC Boyle Resevoir (u/s RKM 0) to JC Boyle Dam

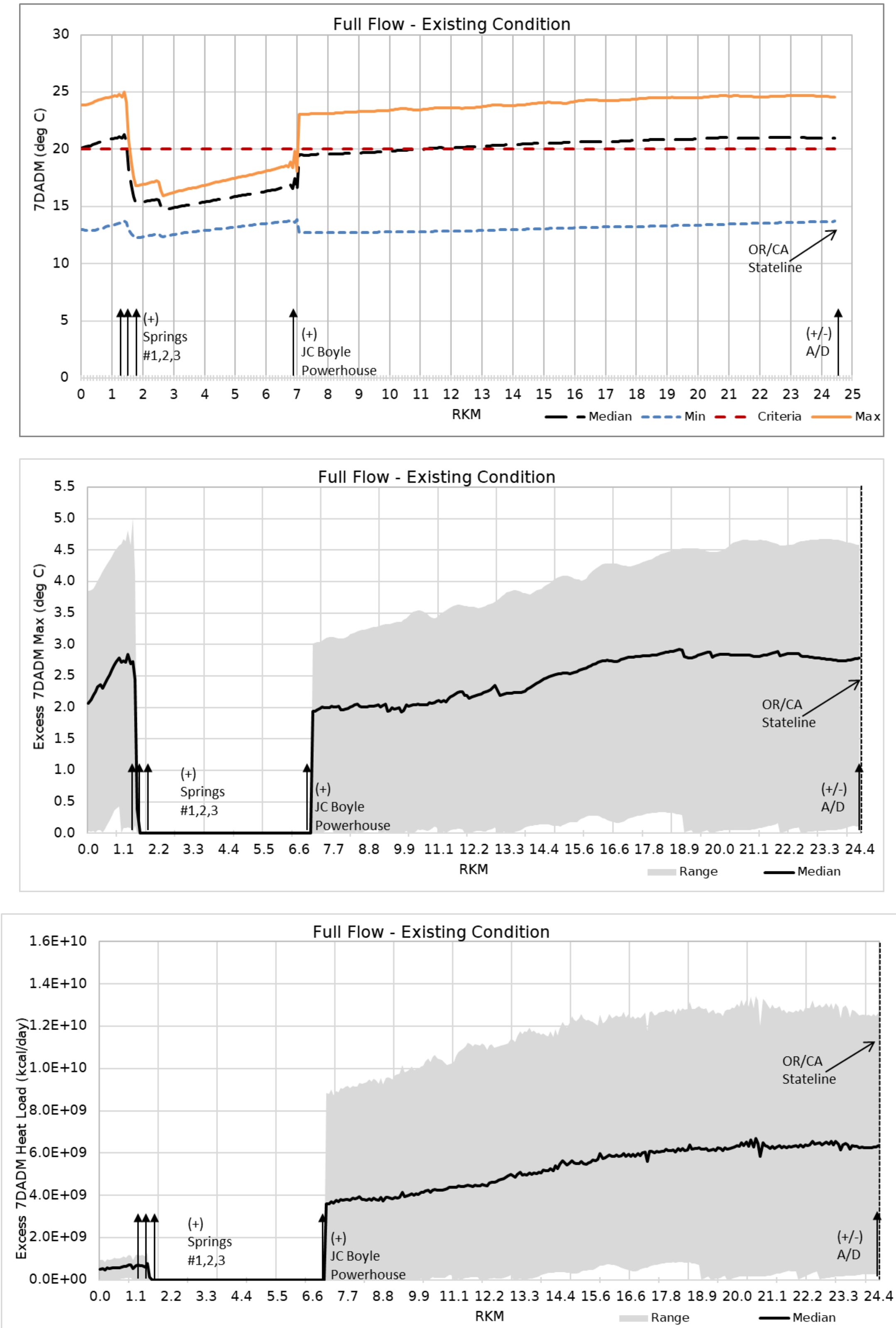


Figure C-17. Full Flow Reach - JC Boyle Dam (RKM 0) to OR/CA Stateline

C.6 Restored Condition (T1BSR2).

Please refer to Section C.5 for Link River plots/summaries.
Note for all Figures:
-Top plot shows the Daily Maximum or 7DADM Temperature (min/max/median calculated for each segment along the reach from May through September 15)
-Middle plot shows the Excess of Daily Maximum or Excess of 7DADM temperatures calculated annually for each segment along the reach.
-Bottom plot shows the Excess of Daily Maximum or Excess of 7DADM heat load calculated annually for each segment along the reach.

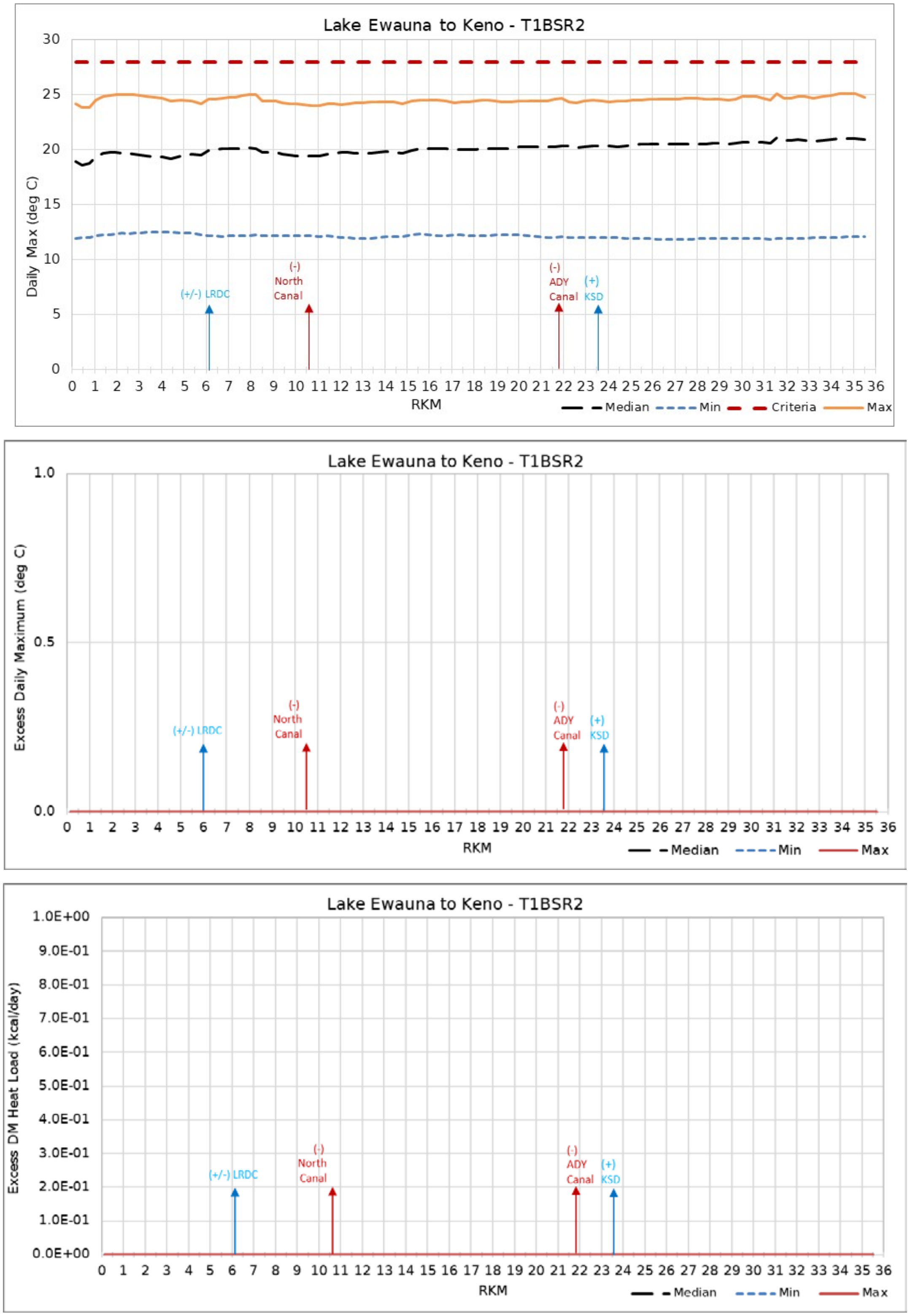


Figure C-18. Lake Ewauna (RKM 0) to Keno Reef.

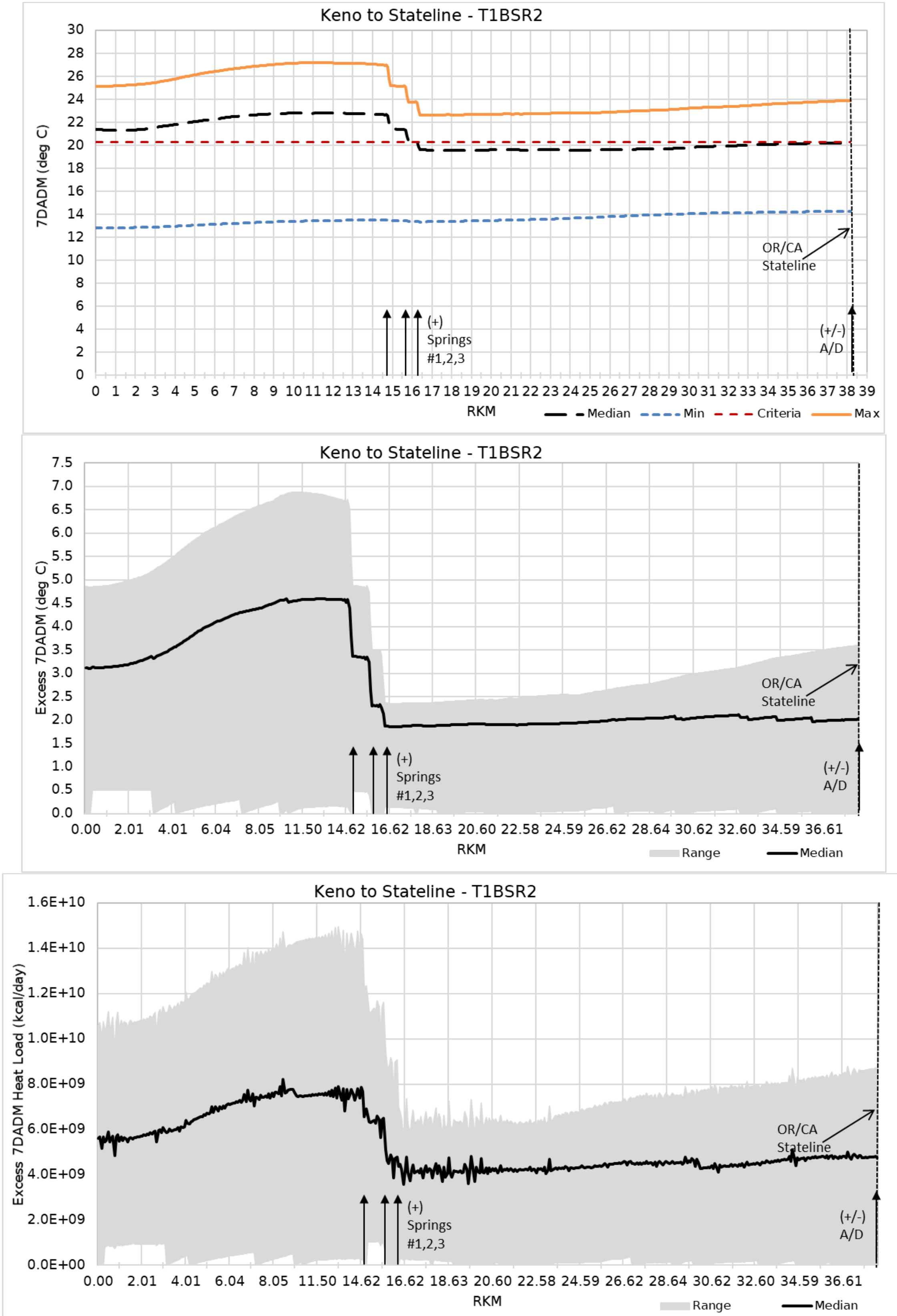


Figure C-19. Keno Reef (RKM 0) to OR/CA Stateline

C.7 Point Sources at Allocation (TOD2RN2).

Note: Please refer to C.5 for Link River plots/summaries.

Note for all Figures:
-Top plot shows the Daily Maximum or 7DADM Temperature (min/max/median calculated for each segment along the reach from May through September 15)
-Middle plot shows the Excess of Daily Maximum or Excess of 7DADM temperatures calculated annually for each segment along the reach.
-Bottom plot shows the Excess of Daily Maximum or Excess of 7DADM heat load calculated annually for each segment along the reach.

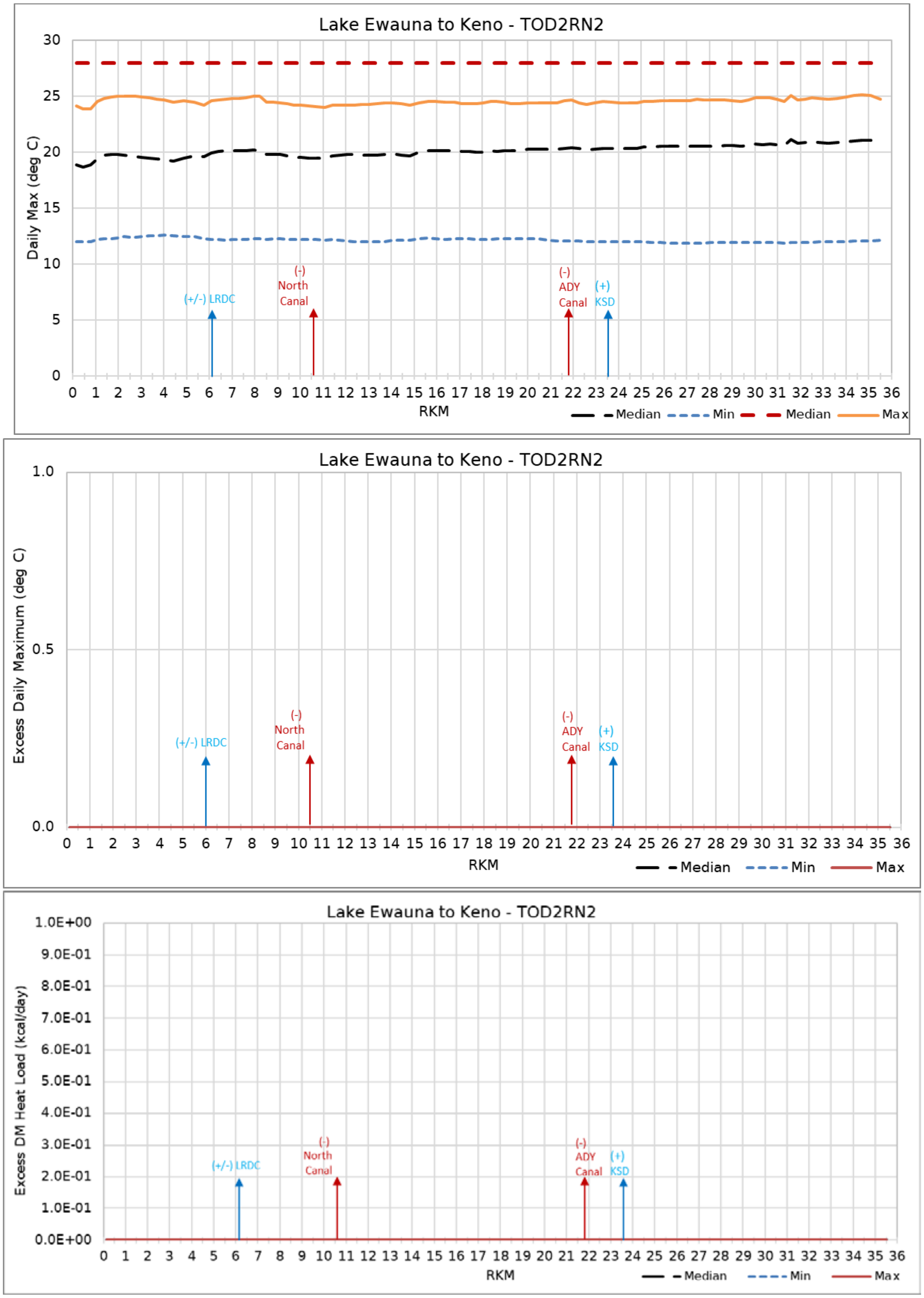


Figure C-20. Lake Ewauna (RKM 0) to Keno Reef.

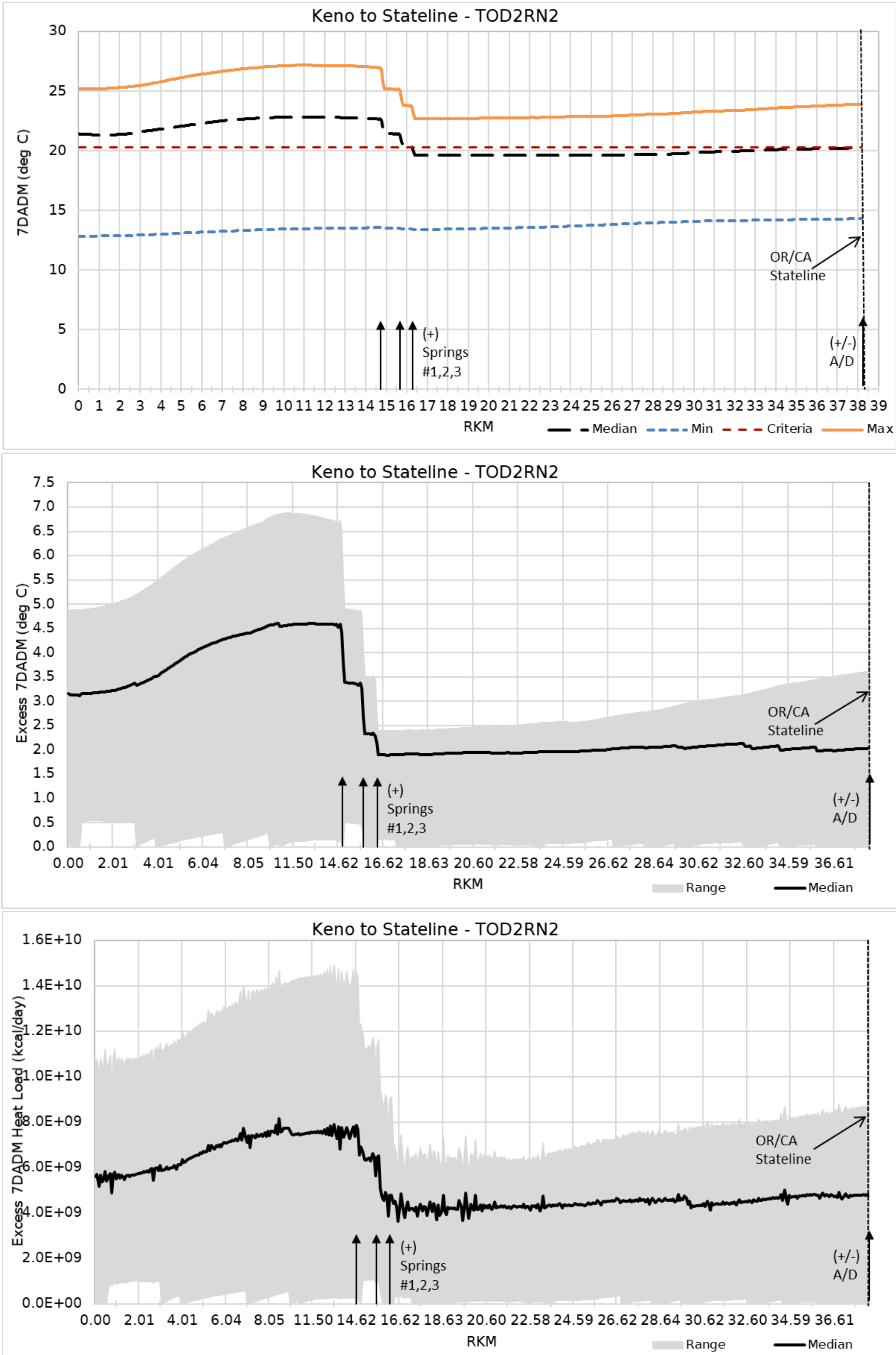


Figure C-21. Keno Reef (RKM 0) to OR/CA Stateline

C.8 Point Sources and Non-Point Source Tributaries at Allocation (TOD2RN3).

Note: Please refer to Section C.5 for Link River plots/summaries.

Note for all Figures:
-Top plot shows the Daily Maximum or 7DADM Temperature (min/max/median calculated for each segment along the reach from May through September 15)
-Middle plot shows the Excess of Daily Maximum or Excess of 7DADM temperatures calculated annually for each segment along the reach.
-Bottom plot shows the Excess of Daily Maximum or Excess of 7DADM heat load calculated annually for each segment along the reach.

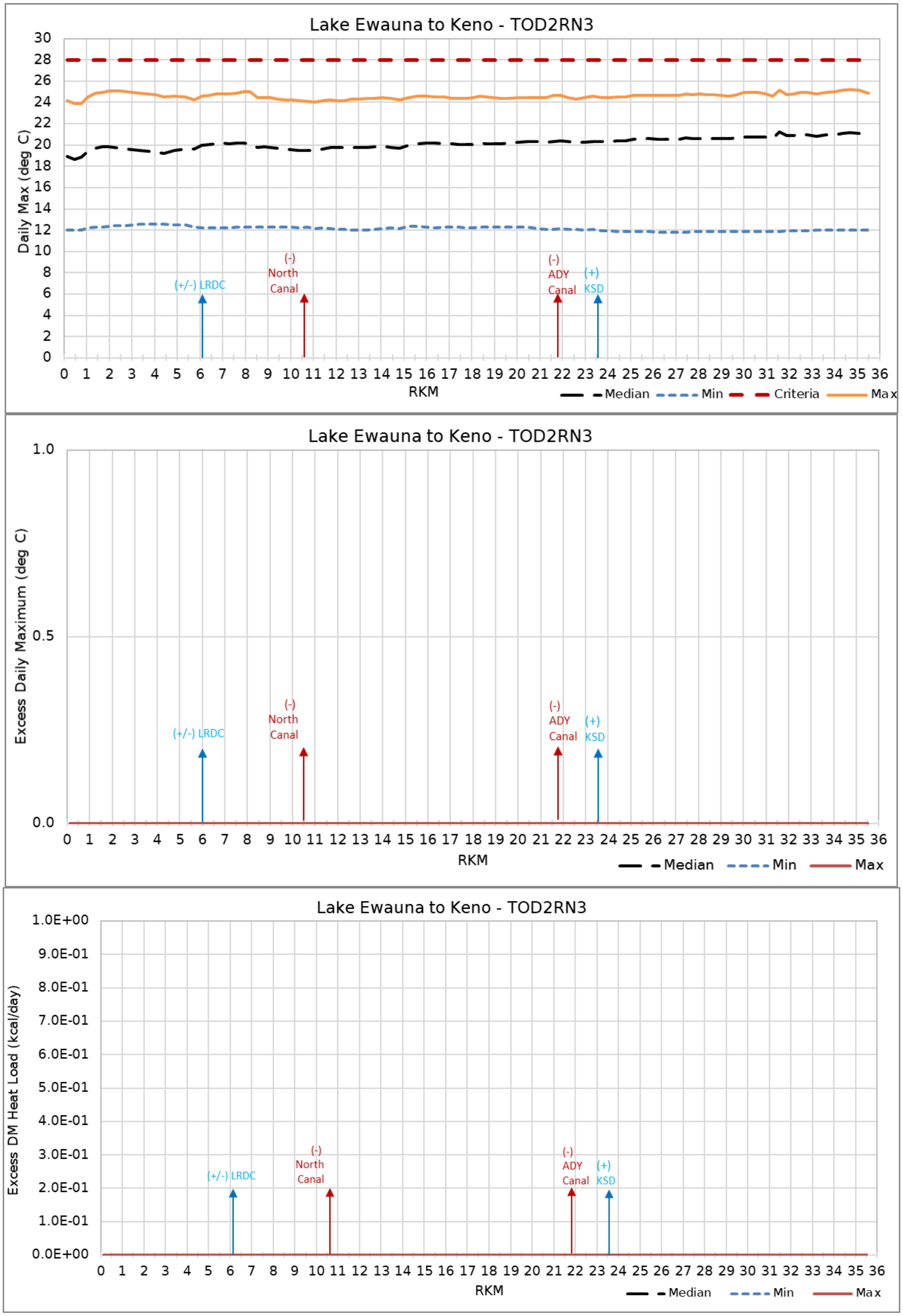


Figure C-22. Lake Ewauna (RKM 0) to Keno Reef.

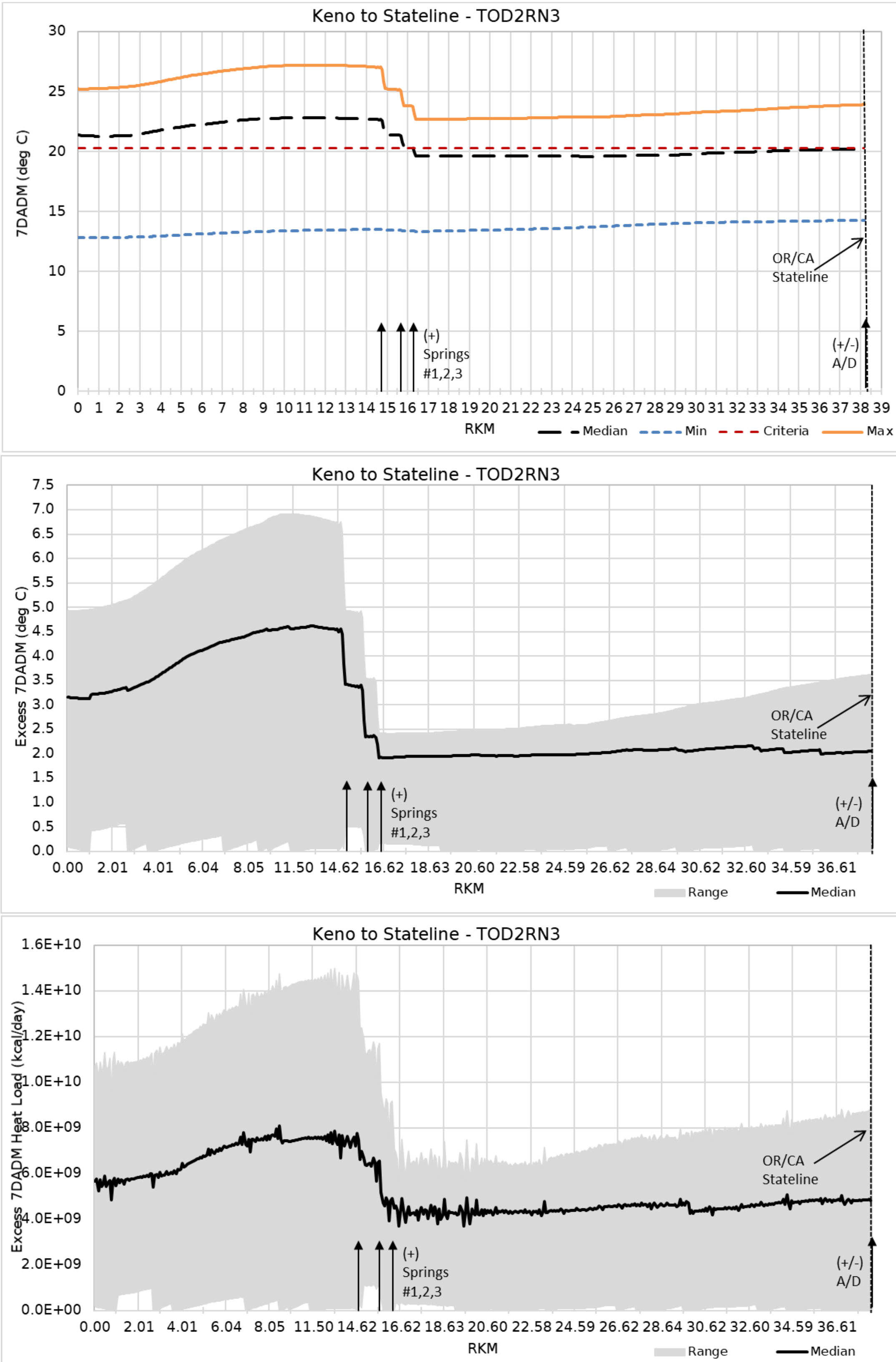


Figure C-23. Keno Reef (RKM 0) to OR/CA Stateline

C.9 PS Sources and NPS Tributaries at Allocation with Dam In (T4BSRN2).

Note: Please refer to Section C.5 for Link River plots/summaries.

Note for all Figures:
-Top plot shows the Daily Maximum or 7DADM Temperature (min/max/median calculated for each segment along the reach from May through September 15)
-Middle plot shows the Excess of Daily Maximum or Excess of 7DADM temperatures calculated annually for each segment along the reach.
-Bottom plot shows the Excess of Daily Maximum or Excess of 7DADM heat load calculated annually for each segment along the reach.

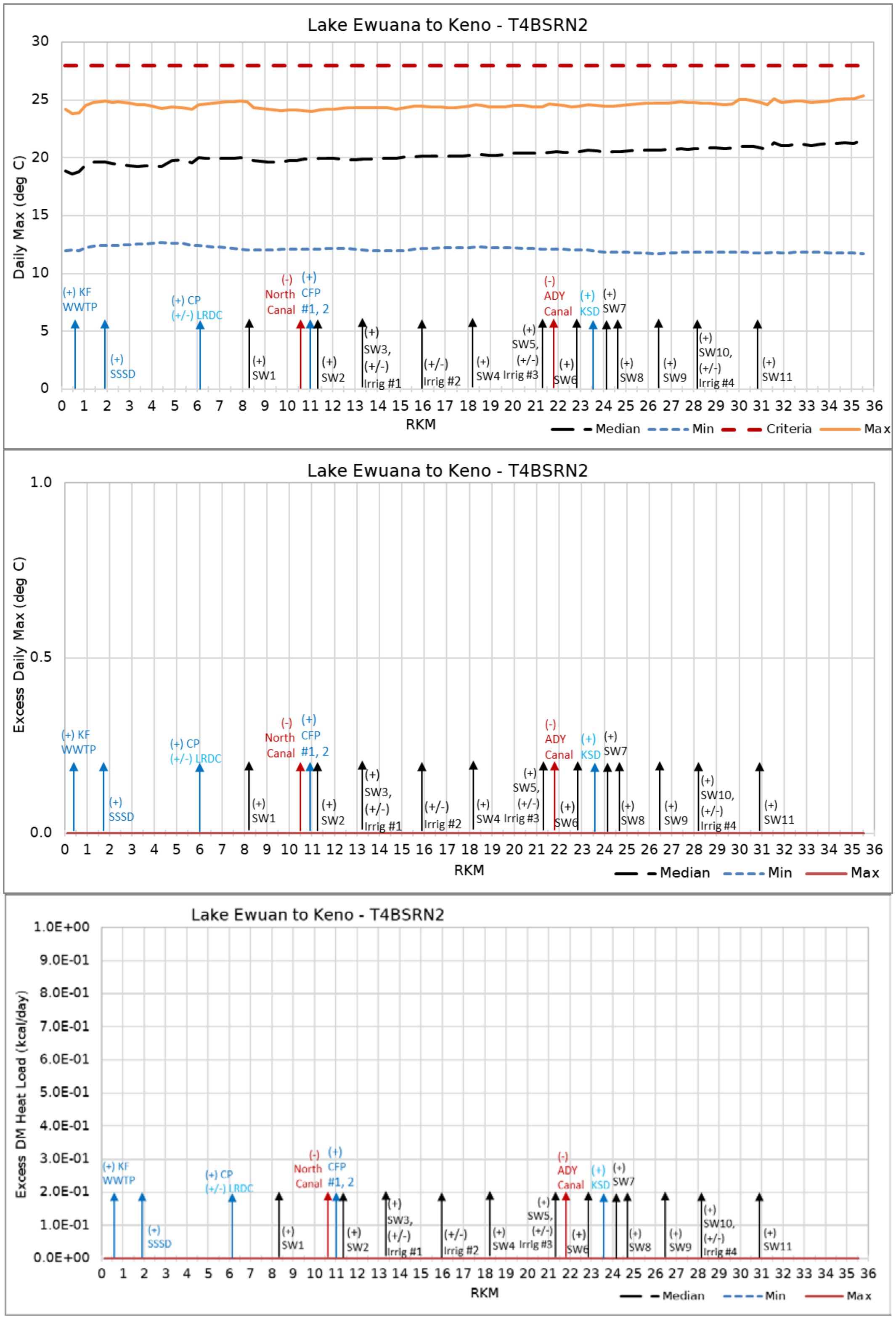


Figure C-24. Lake Ewauna (RKM 0) to Keno Dam.

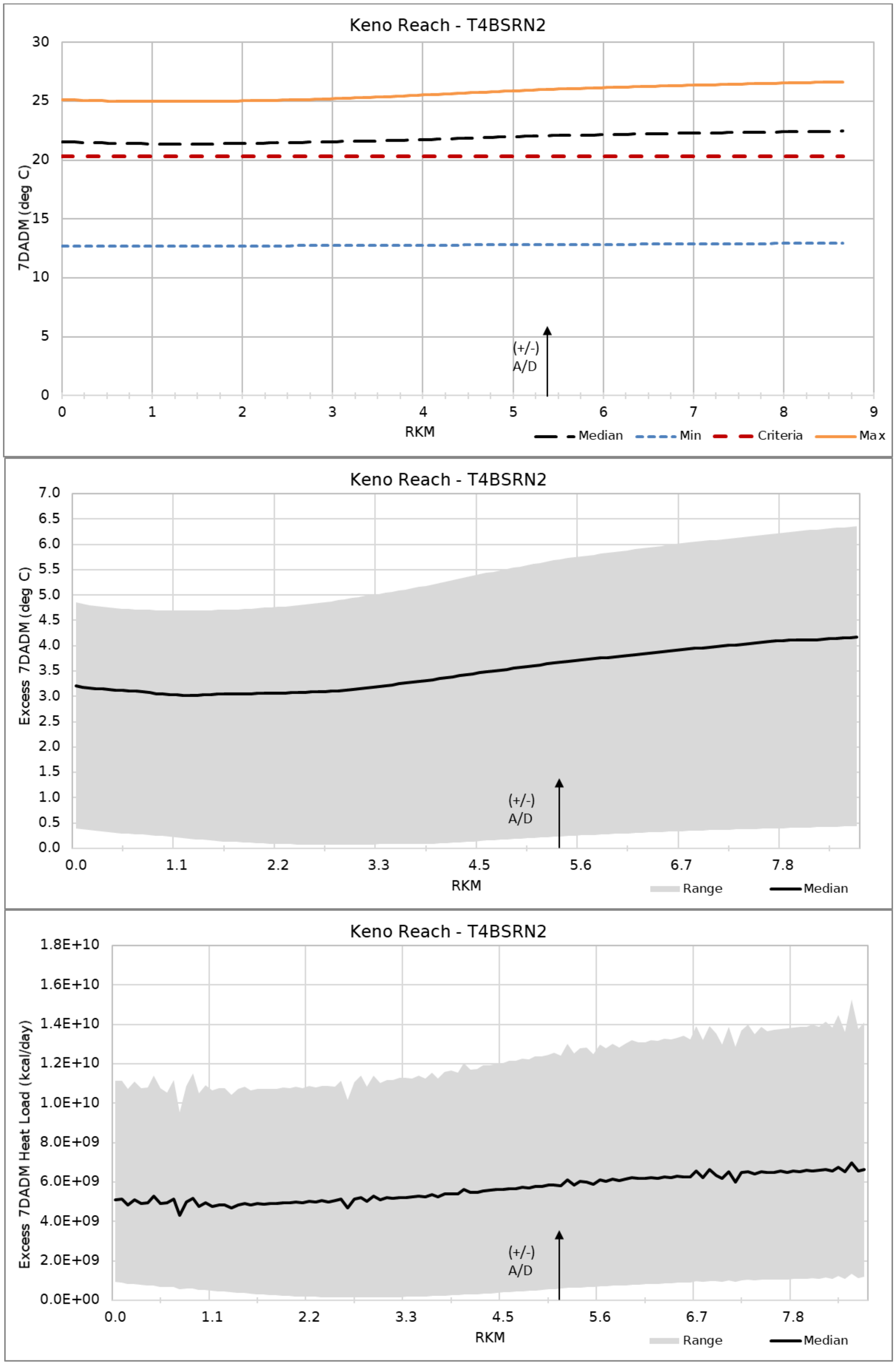


Figure C-25. Keno Reach - Keno Dam (RKM 0) to upstream of JC Boyle

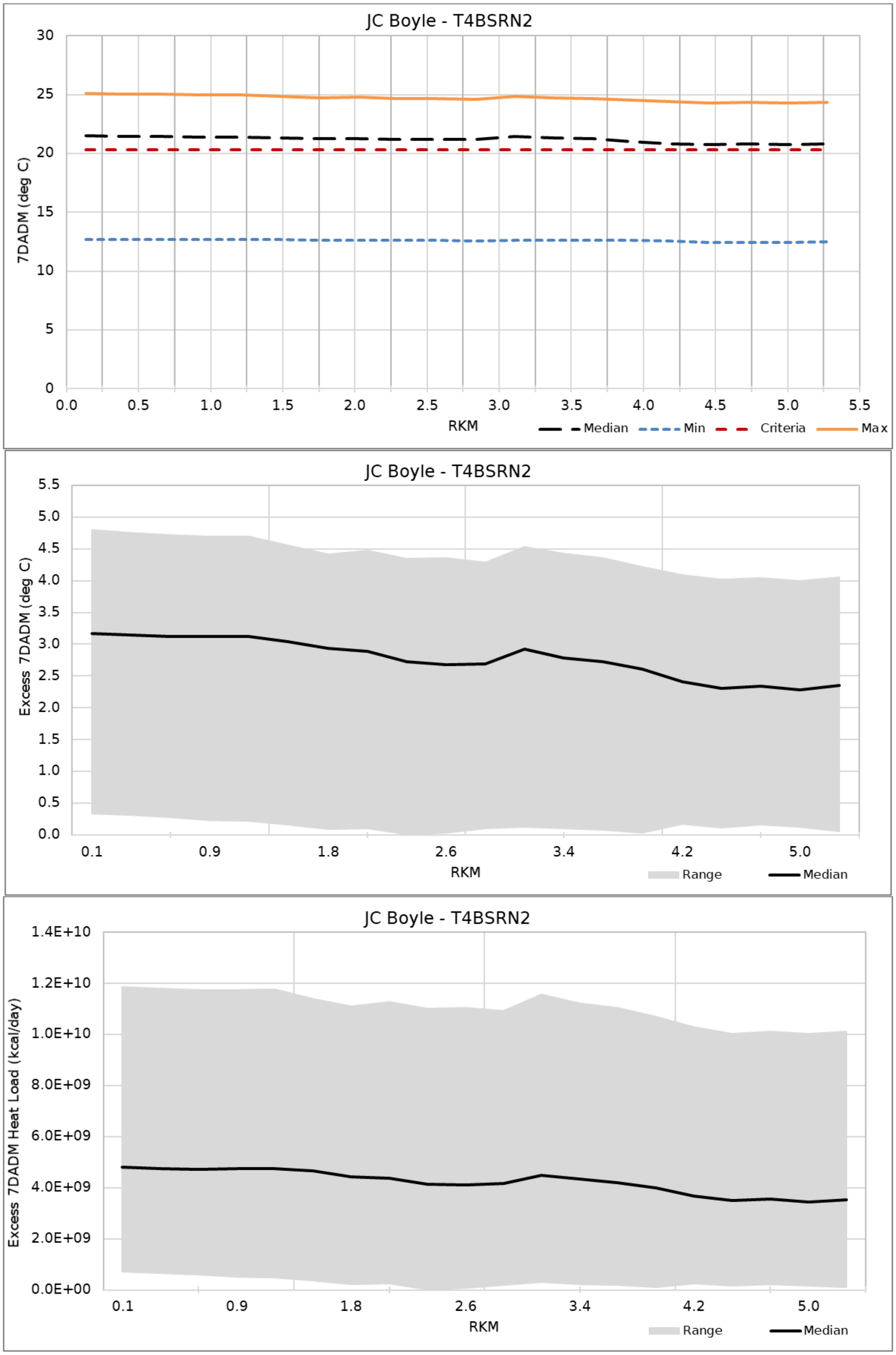


Figure C-26. JC Boyle Resevoir (u/s RKM 0) to JC Boyle Dam

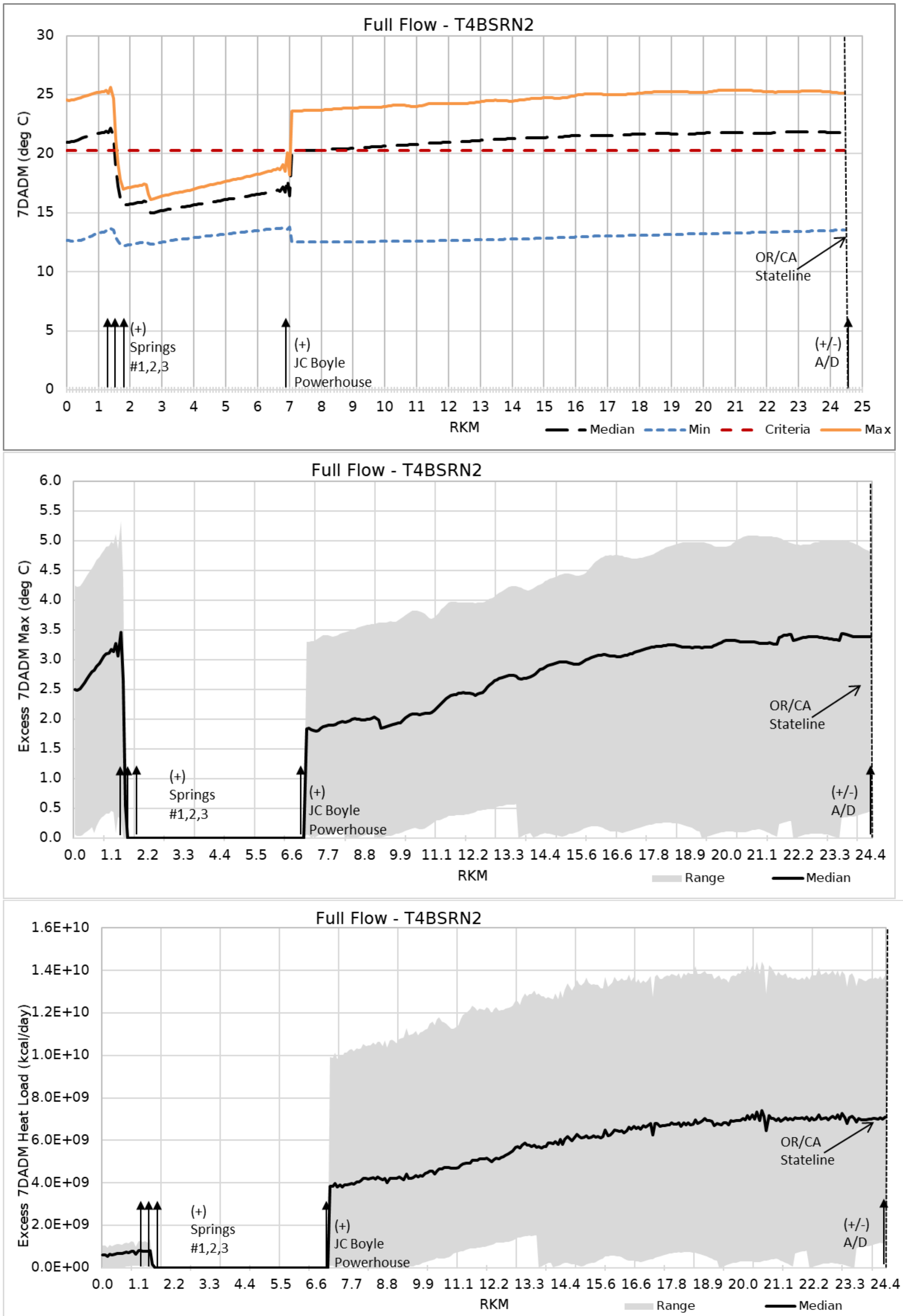


Figure C-27. Full Flow Reach- JC Boyle Dam (RKM 0) to OR/CA Stateline.

C.10 Impact due to Keno Only (T4BSRN3).

Note: (i) refer to Section C.5 for Link River plots/summaries.

(ii) refer to Section C.9 for Lake Ewuana to Keno plots/summaries for scenario T4BSRN2

Note for all Figures:
-Top plot shows the Daily Maximum or 7DADM Temperature (min/max/median calculated for each segment along the reach from May through September 15)
-Middle plot shows the Excess of Daily Maximum or Excess of 7DADM temperatures calculated annually for each segment along the reach.
-Bottom plot shows the Excess of Daily Maximum or Excess of 7DADM heat load calculated annually for each segment along the reach.

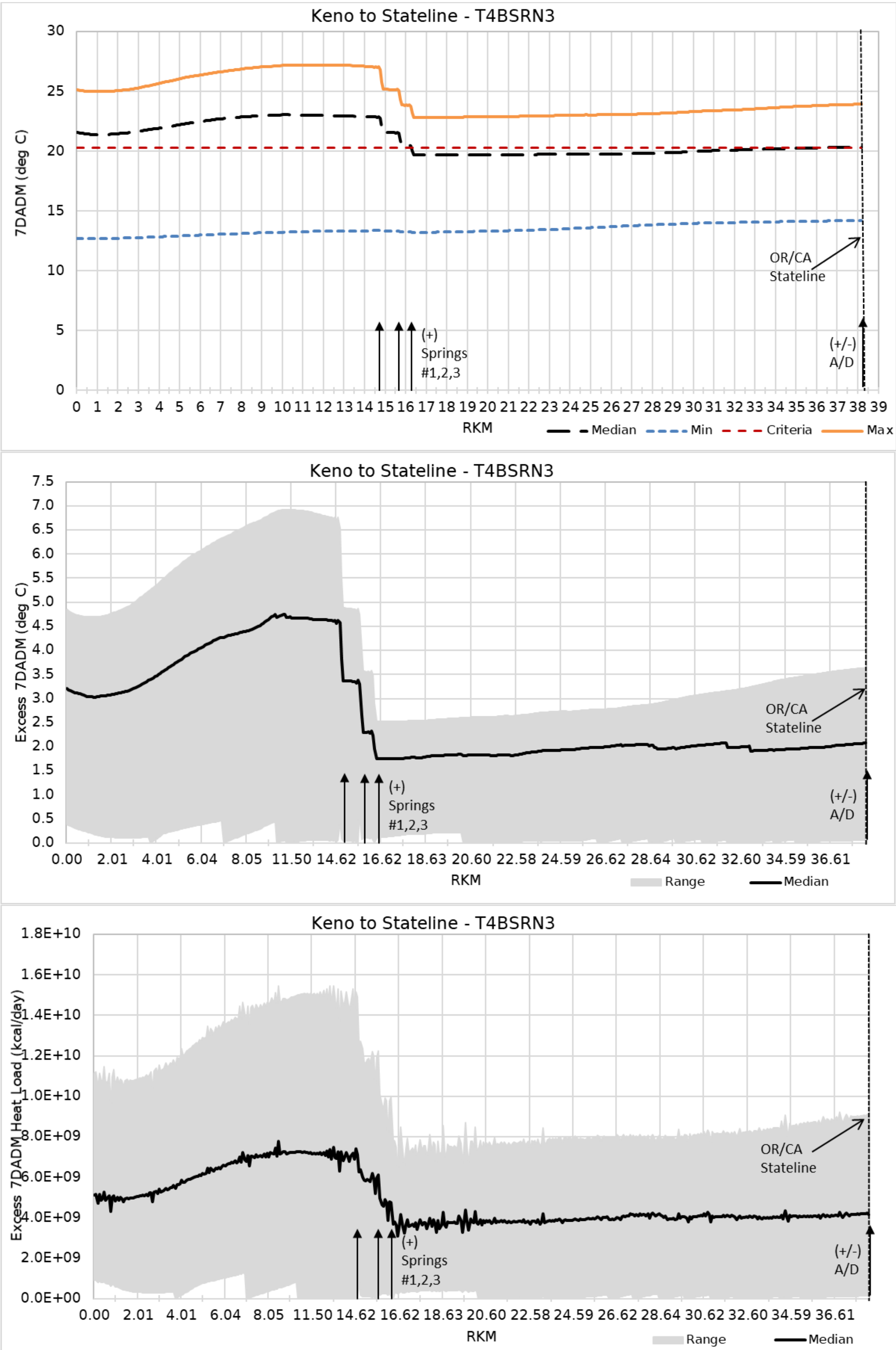


Figure C-28. Keno Dam (RKM 0) to OR/CA Stateline

C.11 References

Tetra Tech 2009. Model Configuration and Results - Klamath River Model for TMDL Development.

Tetra Tech 2009. Modeling Scenarios Klamath River Model for TMDL Development.

McGlashan, H.D. and H.J. Dean. 1913. *Surface Water Supply of the United States 1913, Part XI, Pacific Slope Basins in California*. USGS Water Supply Paper 300. Washington: Government Printing Office. 948 pp.

Oregon Department of Environmental Quality. 2002. Upper Klamath Lake Drainage Total Maximum Daily Load (TMDL) and Water Quality Management Plan.