US Army Corps of Engineers®
Portland District

WILLAMETTE VALLEY SYSTEM OPERATIONS AND MAINTENANCE

DRAFT PROGRAMMATIC ENVIRONMENTAL IMPACT STATEMENT

APPENDIX D: WATER TEMPERATURE AND TOTAL DISSOLVED GAS METHODOLOGY

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

Acronyms and Abbreviations

7-DADM	Seven-Day Moving Average of Daily Maximum
ALBO	Willamette River at Albany
ATU	Average Thermal Units
BCL	Big Cliff Dam
BCLO	Big Cliff Reservoir near Niagara gage
BLU	Blue River Dam
CFS	Cubic Feet per Second (flowrate)
CMS	Cubic Meters per Second (flowrate)
CE-QUAL-W2	A two-dimensional hydrodynamic, temperature and water quality model
CGR	Cougar Dam
CGRO	South Fork McKenzie River near Rainbow
DEXO	Middle Fork Willamette River near Dexter gage
DET	Detroit Dam
FOS	Foster Dam
FSC	Floating Surface Collector
FSS	Floating Screen Structure
FWWS	Foster Warm-Water Supply
GPR	Green Peter Dam
GPRO	Green Peter Reservoir gage
HCR	Hills Creek Dam
HCRO	Middle Fork Willamette River above Salt Creek gage
HEC-RES-SIM	Hydrologic Engineering Center Reservoir System Simulation Model
HIR	High Intake Gate

LIG Low-intake Gate

LOP Lookout Point Dam

LRO Lower Regulating Outlet

ODFW Oregon Department of Fish and Wildlife

NOAA National Oceanic and Atmospheric Administration

RA Resource Agencies (NOAA, USFWS, and ODFW)

ROs Regulating Outlets

SLMO Willamette River at Salem

SSFO South Santiam near Foster gage

SWS Selective Withdrawal Structure

TDG Total Dissolved Gas

TMDL Total Daily Maximum Load

TW Tailwater

URO Upper Regulating Outlet

USACE United States Army Corps of Engineers

USFWS United States Fish and Wildlife Service

USGS United States Geological Survey

WATER Willamette Action Team for Ecosystem Restoration

WTCT Water Temperature Control Tower

WVP Willamette Valley Project

WV EIS Willamette Valley Environmental Impact Statement

CHAPTER 1 - WATER TEMPERATURE ANALYSIS

Resource Name: Water Quality

Preparer's Name: Norm Buccola

Date of Last Revision: 10/24/2022

Water temperature within the WV EIS was assessed through a series of 2-dimensional (longitudinal/vertical) hydrodynamic CE-QUAL-W2 reservoir and river models (Cole and Wells, 2020). This model has been widely used and applied to water bodies around the world (Berger, Annear, and Wells 2002; West Consultants, 2005; Sullivan and Rounds, 2007; Buccola, et al., 2012; Threadgill et al., 2012; Buccola, et al., 2013; Buccola and Stonewall 2016; Buccola, Turner, and Rounds 2016; Buccola, 2018; Sullivan and Rounds, 2021; USACE, 2020c). For a complete list of the model applications, see the W2 website: http://www.ce.pdx.edu/w2/. The water temperature models were driven primarily by outlet gate flows and lake elevations simulated in HEC-RES-SIM (https://www.hec.usace.army.mil/software/hec-ressim/) and are described further in Chapter 3.2 (Effects Analysis – Hydrology and Hydraulics) and Technical Appendix B (Hydrology and Hydraulics). Additional inputs to the temperature models consist of temperature targets and outlet configurations that allow for comparison of temperature management options and are discussed in this Appendix.

1.1 LIMITATIONS, ASSUMPTIONS, AND UNCERTAINTY

- The Willamette River reach downstream of Willamette Falls is not included in the water quality analysis for the Willamette Valley EIS.
- The impact of operations to temperature were quantified using mechanistic models (CE-QUAL-W2). All models are simplifications of the real world and represent the processes that are important to water temperature.
- Daily average flows were used in the RES-SIM, CE-QUAL-W2, and TDG modeling. Sub-daily temperature variation was simulated in the CE-QUAL-W2 modeling but results were summarized as daily mean and maximum values.
- Water temperature was not simulated at Blue River, Fall Creek, Dorena, Cottage Grove, or Fern Ridge lakes due to one or more of the following reasons: negligible difference in operation from Affected Environment, negligible combined heating effect to downstream waters, or lack of a CE-QUAL-W2 model. The simulated water temperature effects of proposed structures (Selective Withdrawal Structure [SWS], Floating Screen Structure [FSS], Floating Surface Collector [FSC]) are based on the most current design (where applicable). The actual functionality and resulting temperatures could vary if plans, specifications, materials, and as-built construction vary from current design.
- Due to extreme low water and resulting CE-QUAL-W2 model instabilities during summer/fall of 2015, a minimum streamflow rule was applied at some locations downstream of the

dams so that model output can be passed downstream to the Willamette River (see Model Configurations).

1.2 MODEL DEVELOPMENT

Previous research has examined the extent to which operational or structural solutions can improve temperature management below WVP dams.

In the North Santiam subbasin, the extent to which a hypothetical temperature control structure at Detroit Dam can control water temperature has been examined in each season (Buccola et.al., 2012; USACE, 2019; Keefer, et.al., 2019). In any given year, the heat absorbed by the lake during summer from solar radiation will be released downstream at some point later in the autumn. As part of the design process for the Detroit SWS (Selective Withdrawal Structure) and FSS (Floating Screen Structure), USACE compared simulated water temperature derived from cooler and warmer spring-summer targets with and without the presence of a temperature control structure at Detroit. These model simulations were shared with University of Idaho to support a study of the trade-offs associated with each scenario and the effects on adult chinook salmon in the North Santiam (Keefer, et.al., 2019). One conclusion of this study was that cooler spring-summer targets lead to warmer autumn temperature, even with the presence of a water temperature control structure at Detroit Dam (see Section 7 and Figures 12-15 in Keefer, et. al., 2019).

Previous water temperature modeling in the South Santiam (Buccola, 2017; Sullivan and Rounds, 2021) and Middle Fork subbasins (Buccola et. al., 2016) has shown how a variety of hypothetical structures and operations can improve temperature control downstream of USACE dams. However, each subbasin is unique in the relative ability to provide cool water temperature downstream of the dams, even with the inclusion of a water temperature control structure in place. For example, Lookout Point and Dexter dams on the Middle Willamette River are relatively lower in their respective sub-basins than Detroit, Green Peter, Cougar, and Hills Creek Dams. This results in longer travel times and warmer temperatures at Lookout Point – Dexter Dams compared to higher dam locations. Previous studies investigating the potential for structural and operational changes to Middle Fork Willamette dams (Buccola, et.al., 2016) resulted in less ideal thermal habitat for ESA-listed Chinook and steelhead associated with those changes than seen in other subbasins.

1.2.1 Calendar year selection

Three representative calendar-years from recent decades were chosen to simulate water temperature in the network of Willamette Basin CE-QUAL-W2 models used in the WV EIS (Figure 1-1). The three years can be described qualitatively and relative to the past two decades as follows: 2011 (high flow, cool temperature), 2015 (extreme low flow, extreme warm temperature), and 2016 (low flow, warm temperature). Annual statistics and exceedance values of Salem Airport McNary Field air temperature (NOAA USW00024232 [NOAA, 2020]; *Slm_AirT(Degrees F)*), unregulated streamflow at Salem (derived from RES-SIM; *SLM_FlowUnreg(Kcfs)*), and unregulated streamflow at Detroit, Oregon (derived from RES-SIM;

DET_FlowUnreg(Kcfs)) for these three years are shown in Figure 1-2 and Table 1-1. More background on the year selection process and environmental conditions can be found in Stratton Garven (2022a).

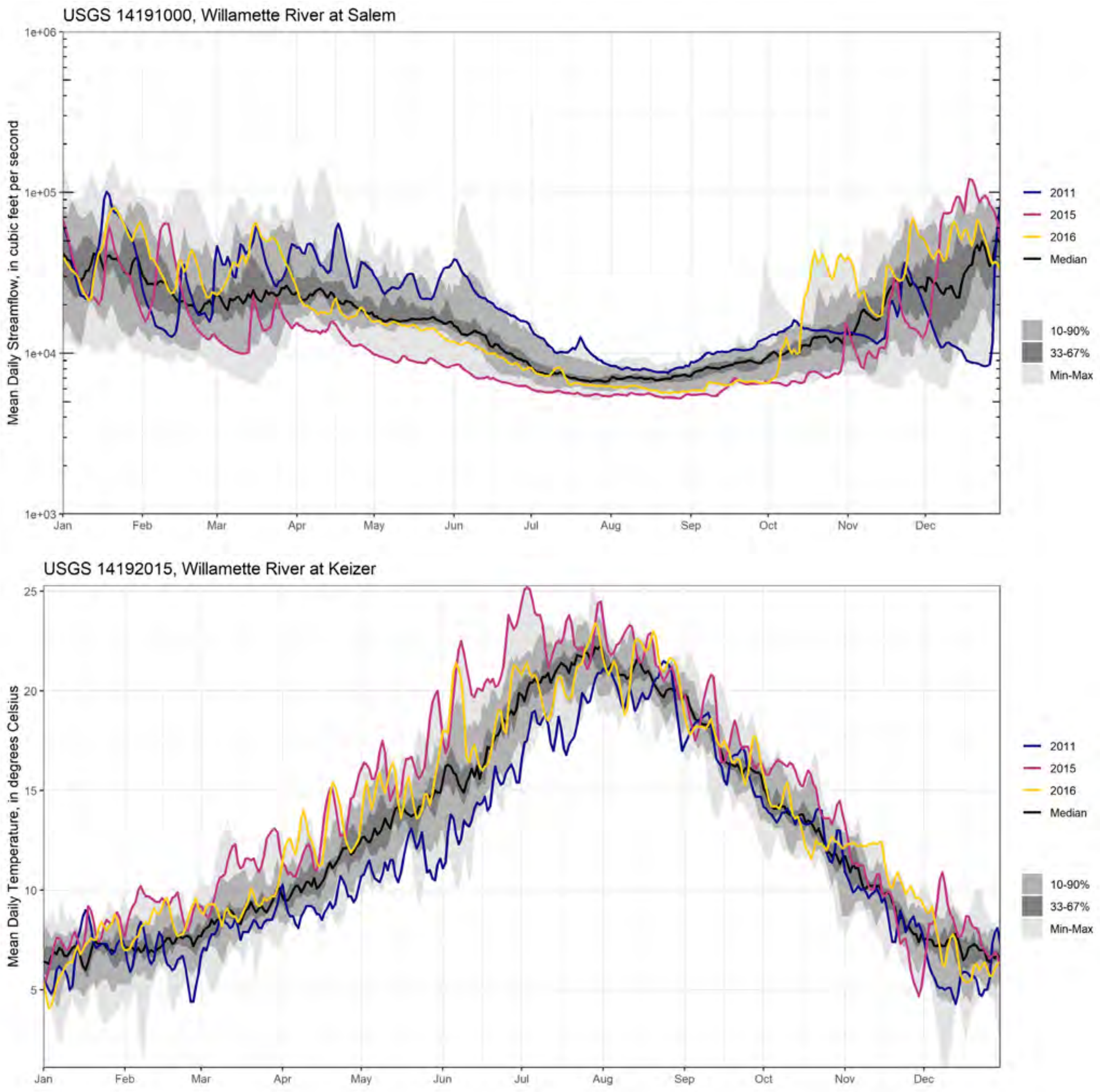

Figure 1-1. Streamflow (top) and water temperature (bottom) at Salem/Keizer, Oregon in 2011, 2015, and 2016 (Reproduced from Stratton Garvin, 2022a).

Table 1-1. Exceedance percentiles for mean annual Salem air temperature (Slm_AirT(Degrees F)), Salem unregulated streamflow (SLM_FlowUnreg), Detroit unregulated streamflow (DET_FlowUnreg) in 1936-2019.

Year	Slm_AirT (Degrees F)	SLM_FlowUnreg(Kcfs)	DET_FlowUnreg (Kcfs)
2000	21	51	61
2001	39	15	12
2002	60	36	86
2003	86	37	26
2004	68	26	33
2005	43	48	32
2006	76	30	44
2007	20	11	13
2008	10	82	100
2009	55	54	69
2010	45	93	65
2011	11	94	81
2012	49	98	80
2013	46	32	40
2014	96	52	37
2015	100	1	1
2016	94	10	4
2017	83	79	62
2018	95	27	20
2019	40	85	50

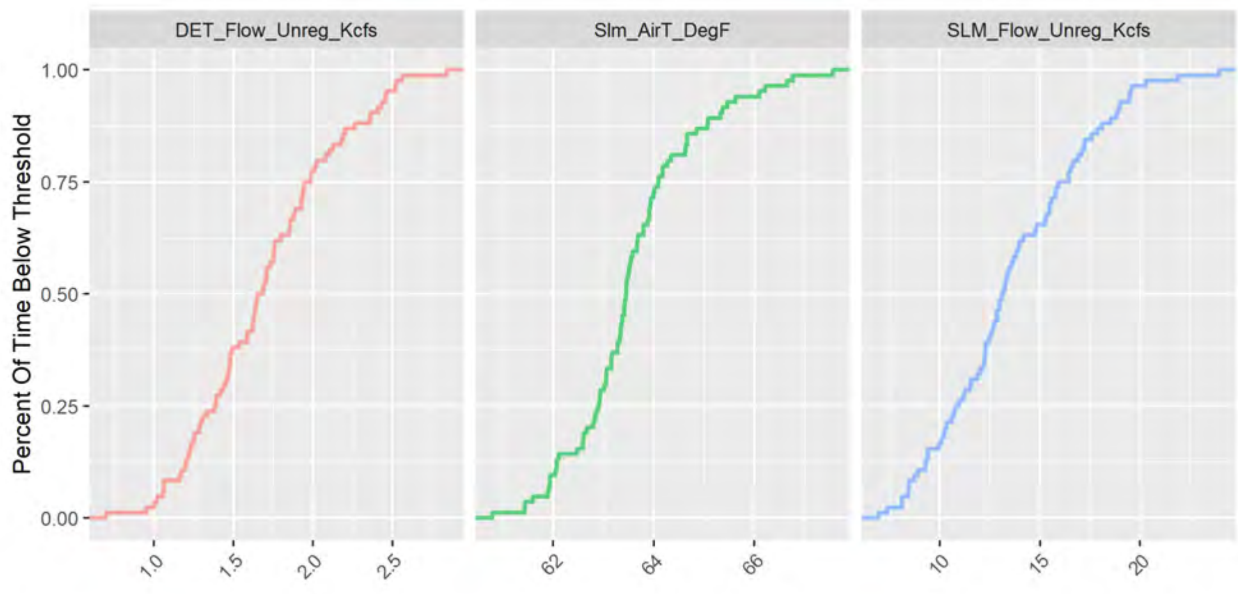

Figure 1-2. Percent exceedance graphs of annual mean unregulated flow at Detroit, Oregon (left), air temperature at Salem, Oregon (middle), and unregulated streamflow at Salem, Oregon (right) over the period of record (1936-2019).

1.2.2 Model Configurations

A network of 7 hydrodynamic CE-QUAL-W2 water temperature models have been developed for the major WVP reservoirs (Cole and Wells, 2020) and are utilized in the WV EIS to examine potential operational and structural measures on USACE-managed projects. Reservoir temperature models were developed for Detroit (Sullivan and Rounds, 2007), Big Cliff (Buccola, et al., 2012), Green Peter-Foster (West Consultants, 2005; Buccola, et al., 2013), Cougar (Threadgill et al., 2012), and the Middle Fork Willamette complex including Hills Creek, Lookout Point, and Dexter Dams (West Consultants Inc, 2004a; West Consultants Inc, 2004b; Buccola, et al., 2013). Since the development of these models, many studies have examined scenarios including hypothetical structures and operations at Detroit Dam (Buccola, et.al, 2016 and 2017; USACE, 2019b), Green Peter-Foster (Buccola, 2018; Sullivan and Rounds, 2021; USACE, 2020c), Cougar (USACE, 2019a), and the Middle Fork Willamette complex of dams (Buccola, et al., 2016). There was no additional model calibration for the WV EIS simulations. However, CE-QUAL-W2 model code was modified to increase model stability and decrease model run-times, especially during deep reservoir drawdowns (Rounds, 2021).

Below the CE-QUAL-W2 reservoir models were a network of CE-QUAL-W2 river models, previously calibrated for the North Santiam (Sullivan and Round, 2004), South Santiam (Bloom, 2016), and other tributaries to the Willamette River (Annear et al., 2004; Berger and others, 2004; Sullivan and Rounds, 2004; Oregon Department of Environmental Quality, 2006). This network of river models has been used to examine Willamette temperature in the absence of dams (Rounds, 2010) and the effect of flow on temperature in the Willamette (Rounds and

Stratton Garvin, 2022b). Further updates to these models and assemblage of boundary conditions for 2011, 2015, and 2016 are documented in Stratton Garvin and others (2021).

While RES-SIM modeling incorporates an 84-year simulation (spanning 1935 – 2019), CE-QUAL-W2 modeling included three calendar years under each alternative (2011: “wet”, 2015: “dry”, 2016: “normal”) due to the level of effort involved in compiling boundary conditions for temperature modeling (Stratton Garvin and others, 2021). Reservoir models were simulated for the January through December period, while river models were simulated April through October. Distributed tributary flows added or withdrawn from the system to ensure lake levels matched intended operations were estimated using a Water Balance Utility available with the CE-QUAL-W2 download.

A simplifying assumption was made in RES-SIM and CE-QUAL-W2 that Big Cliff Dam (a re-regulating reservoir) outflow was equal to Detroit outflow on a daily average basis through each WV EIS alternative (i.e., no tributary inputs to Big Cliff Reservoir were included). Similarly, the re-regulating reservoir of Dexter Lake is relatively shallow and fluctuating generally between 690 and 695 ft lake surface elevation. Residence times in Dexter Lake are on the order of 1 week, which leads to a general warming of the outflow from LOP. For this reason, the combined effect from LOP-DEX was analyzed at the downstream outlet below DEX.

In some instances, total outflow from individual dams as output from RES-SIM was too low for the downstream river models to simulate. In these cases, an iteratively-determined minimum discharge value was applied to the upstream boundary condition for the river model in question. For example, in Alternative 3b outflow from Foster Dam was modeled by RES-SIM to be less than 8 cms (283 cfs) on 63 days of 2016. In these cases, RES-SIM-derived outflow was used to specify outflow from Foster Dam but increased to a minimum of 8 cms (283 cfs) when input to the South Santiam River model. This artificial increase in flow may bias the modeled temperature in the South Santiam (or other rivers where this correction was applied) slightly cooler than the actual alternative specifies, but the effect is likely small and diminishes downstream. These flow changes in CE-QUAL-W2 models below some dams occurred primarily during summer/fall of 2015 and 2016, where minimum streamflow rules were applied as shown in Table 1-2.

Table 1-2. Minimum flow values applied to inflow of river water temperature models below each WVP dam (as floor to RESSIM-provided outflow from project listed).

Model inflow (source)	2011	2015	2016
NAA			
Cottage Grove	NA	1.42	NA
Foster	NA	8	NA
Big Cliff	NA	11	NA
Alt1			
Cottage Grove	NA	1.42	NA

Model inflow (source)	2011	2015	2016
Foster	NA	8	NA
Big Cliff	NA	11	NA
Alt4			
Cottage Grove	NA	1.42	NA
Foster	NA	8	
Big Cliff	NA	11	NA
Alt3a			
Foster	8	8	8
Big Cliff	11	11	15
Alt3b			
Cottage Grove	1.42	1.42	NA
Dexter	NA	NA	NA
Foster	NA	8	8
Big Cliff	NA	11	NA

Existing and proposed outlet properties for CE-QUAL-W2 reservoir temperature models are shown in Table 1-3. These properties are inputs to the model (w2_selective.npt file) for blending between multiple outlets in the attempt to meet a downstream temperature target (Rounds and Buccola, 2015). All elevations are centerline elevations except for spillways and weirs, which are the crest elevation. MAXFLOW values are given to limit the amount flow released from a particular outlet. General configurations at each project are listed below.

- Detroit (DET) has 9 gates. Gates Q1 to Q4 currently exist at the dam, while Q5 to Q9 are proposed gates as part of the SWS and FSS in Measure 105. Note: Further investigation into actual centerline elevations of Upper RO and Lower ROs were found to be 1340' and 1265', respectively. While these changes were not incorporated into WV EIS temperature models, they will be included in further studies as updates to the Detroit Lake CE-QUAL-W2 model.
- Cougar (CGR) has 7 gates. All gates currently exist at the dam, but not all are used as described in the WV EIS: Q2 (RO) includes an internal bifurcation that leads to Q6 (Penstock), which does not currently have a direct connection to the reservoir. Q1, Q3, Q4, and Q5 represent approximate gaps within the existing Water Temperature Control Tower (WTCT). Model calibration has led to an approximation of the weir leakage as 10% of total outflow through each of Q3, Q4, and Q5. The diversion tunnel (Q7: Dtnnl) does not currently exist as a regularly operable outlet but is considered in Measure 479 (see Measure Assumptions) with structural/mechanical modifications for regular operation.
- Foster Dam (FOS) has 7 gates. The primary gates currently in use at the dam are Q2 through Q7. There are three Power intakes: Q3 (*PowerUp*); providing attraction water to the fish ladder side entrance, Q6 (*PowerLow*); supplying the fish facility and fish ladder, and Q5 (*PowerMain*) providing the bulk of the river flow for most of the year. 7.5 % of total outflow

was assumed to flow through both Q3 and Q6, with a maximum of 58.6 cfs through either gate at any time, as a simplification of typical current operations. All gates except Q1: *FWWS* (see Measure Assumptions) currently exist at the dam. Q7 is not used in the WV EIS analysis as it typically discharges negligible flow levels to the fish hatchery during the spring and summer.

- Green Peter (GPR), Lookout Point (LOP), and Hills Creek (HCR) have 3 gates at each project.
- Big Cliff (BCL) and Dexter (DEX) have 2 gates at each project (Power and Spillway)

Table 1-3. Reservoir Model Gate Configurations (abbreviations: URO = Upper Regulating Outlets, LRO = Lower Regulating Outlets, SWS = Selective Withdrawal Structure, CL = Centerline, FSS = Floating Screen Structure, HIW=High Invert Weirs, LIG = Low Intake Gates, * Indicates a Proposed Outlet, ** Indicates Outlet Not Used in WV EIS analysis). Vertical Datums are Specific to As-Built Drawings for Each Site.

Site	Outlet Number	Outlet Name	Elevation (m)	Elevation (ft)
DET	Q1	URO	410.0	1345.0
DET	Q2	Spillway	469.7	1541.0
DET	Q3	Power	427.6	1403.0
DET	Q4	LRO	387.1	1270.0
DET	Q5	SWS_HIW*	429.8	1410.1
DET	Q6	FSS1*	429.8	1410.1
DET	Q7	FSS2*	429.8	1410.1
DET	Q8	FSS3*	429.8	1410.1
DET	Q9	SWS_LIG*	406.0	1332.0
BCL	Q1	Spillway	354.0	1161.5
BCL	Q2	Power	347.5	1140.0
GPR	Q1	Spillway	295.3	968.7
GPR	Q2	Power	246.9	810.0
GPR	Q3	RO	228.6	750.0
FOS	Q1	FWWS*	192.0	630.0
FOS	Q2	Weir	193.1	633.5
FOS	Q3	PowerUp	182.7	599.3
FOS	Q4	Spillway	181.9	596.8
FOS	Q5	PowerMain	179.8	590.0
FOS	Q6	PowerLow	178.1	584.3
FOS	Q7	HatchLow**	175.6	576.0
CGR	Q1	WTC4	512.1	1680.0
CGR	Q2	RO	452.6	1485.0
CGR	Q3	WTC3	500.0	1640.3
CGR	Q4	WTC2	487.9	1600.6
CGR	Q5	WTC1	475.8	1561.0
CGR	Q6	Penstock**	434.3	1424.8
CGR	Q7	DTnnl	396.2	1300.0
HCR	Q1	RO	431.3	1415.0
HCR	Q2	Power	423.7	1390.0
HCR	Q3	Spillway	455.8	1495.5

Site	Outlet Number	Outlet Name	Elevation (m)	Elevation (ft)
LOP	Q1	Spillway	270.5	887.5
LOP	Q2	Power	237.7	780.0
LOP	Q3	RO	222.3	729.3
DEX	Q1	Spillway	201.2	660.0
DEX	Q2	Power	198.2	650.4

1.3 MEASURE ASSUMPTIONS

Measures associated with water temperature are designed to provide more seasonally appropriate temperatures downstream of Willamette Project dams and improve habitat for Spring chinook and winter steelhead fish. Measures are designed to align with fish passage measures and balance other authorized purposes as best as possible. Many structural modifications are assumed and would require detailed design work to be implemented. General measure descriptions are as follows:

- **Measure 105** *Construction of selective withdrawal structures (SWS):* The SWS would be constructed on the face of high-head WVP hydropower dams to allow the release and blending of water at various temperatures (depths) in the reservoir to improve water temperature downstream of the dam. The new structure would send this water through the powerhouse and continue to generate power while meeting downstream water quality targets. These structures could also be attached to or combined with new fish passage facilities (notably Measure 392: construct downstream passage) to meet the requirements of fish passage RPAs (NMFS 2008).
- **Measure 479** *Modify existing outlets to allow releases at varying depths for temperature control:* Outlets exist at some WVP dams would permit enhanced temperature control if such outlets were modified to allow for regular operation at relatively low flows during April-November. This measure would call for modifying existing outlets to allow for routine usage specific to each project to help restore normative temperatures to extent possible using existing outlets.
- **Measure 166** *Operational Temperature Control for Cooler Water:* Use existing outlets to discharge colder water during drawdown operations in fall and winter to reduce water temperatures below dams. Due to the strong stratification that most the valley lakes experience during the spring, summer, and fall (before lake turnover), there is an opportunity at some projects to release relatively cool water from the regulating outlets (below the power intakes). This cooler water (compared to releases through the turbines) can provide a benefit for chinook egg incubation downstream. Projects that include various usable outlet inverts include Detroit, Green Peter, and Lookout Point dams. This measure specifies up to 60% of total release through ROs in the fall. Water temperature simulations assume outlet details and temperature targets align with those used in previous studies (Buccola, et.al, 2016; Buccola, et.al, 2017, USACE, 2019a; USACE 2019b). Simulated mixing between outlets depends on temperature targets imposed in temperature models and may

differ from outlet flow ratios simulated in RES-SIM model. Note: Minimum gate openings are not accounted for in RES-SIM or CE-QUAL-W2.

- **Measure 721** *Operational Temperature Control for Warmer Water:* Use of the spillway in order to improve downstream water temperature management from spring through autumn. By extending the use of the spillway, a larger volume of warm surface water from the reservoir can be released and cold deep water can be reserved for later in the fall/early winter when necessary for fish incubation. In the fall, the deeper ROs can release a limited amount of cooler water at Detroit, Green Peter, Hills Creek, and Lookout Point Dams. Water temperature simulations assume outlet details and temperature targets align with those used in previous studies (Buccola, et.al, 2016; Buccola, et.al, 2017, USACE, 2019a; USACE 2019b). Simulated mix between outlets depend on temperature targets imposed in temperature models and may differ from mix simulated in RES-SIM model. Note: Minimum gate openings are not accounted for in RES-SIM or CE-QUAL-W2.

1.3.1 North Santiam

The following are site-specific measure details applied to the Detroit CE-QUAL-W2 model:

Measures 105, 392 at Detroit Dam contain outlet details and temperature targets similar to those used in previous studies (Buccola, et.al, 2016; Buccola, et.al, 2017, USACE 2019b) with some simplifying assumptions applied to be consistent with WV EIS Measure 392 description. Those modifications are as follows: Rather than multiple floating intakes (simulating a distributed inflow to the FSS), a single floating outlet at 25 feet deep (*Q3 DEPTH* = 7.62 [m] in *w2_selective.npt* file) was used. Maximum outflow from the FSS was assumed to be 4600 cfs (*Q3 MAXFLOW* = 130.26 [cms]).

Measures 166, 721 at Detroit Dam were implemented in RES-SIM as 60% of the total outflow assigned to the spillway from April 15 to Aug 30 and up to 60% of total outflow through the ROs from Sep 1 to Nov 15. However, these flow values were adjusted by the temperature blending routine within the CE-QUAL-W2 model (*Q3 MINFLOW* = 0.4) to meet the downstream temperature target optimally. A 200 ft maximum head restriction was placed on the ROs in NAA to simulate the operational limits of these gates due to structural/mechanical safety concerns. This *MAXHEAD* restriction was removed for Alternative 3a/3b to match the Measure 479 description below. When Measures 721 and 166 were combined with Measure 714 (Alternative 3b), *MINFLOW* values for all outlets were set to 0 which allowed the model optimization to meet downstream temperature target with no restraint. The lower RO (*Q4 PRIORITY = 1*) was allowed to be blended in Alternative 3b during autumn. When Measures 721 and 166 were combined with 720 (operational downstream passage: Alternatives 3a), temperature blending was not used, so that fish passage could be given higher priority.

Measure 479 at Detroit Dam describes the reinforcement and strengthening of regulating outlet (RO) gates and tunnels, which exist at elevations 1340 ft (upper ROs) and 1265 ft (lower ROs). The ROs were not designed to be operated regularly with extreme head pressure. Head pressure limits are not to exceed the spillway crest for the upper ROs and not to exceed 200 feet for the lower ROs *(Q1 MINFRAC = 59.7, Q4 MINFRAC = 61.3)*. This measure describes additional structural reinforcement, lining of the RO tunnels, and strengthening of the gates to provide additional reliability, and limit cavitation/scouring of the dam when head pressure exceeds thresholds described above. This would allow for additional capability to release cooler flows in the late fall (typically November).

1.3.2 South Santiam

The following are site-specific measure details applied to the Green Peter -Foster CE-QUAL-W2 model:

Measures 105, 392 at Green Peter Dam consists of assumptions similar to those used at Detroit Dam with a floating outlet at 25 feet deep (*Q2 DEPTH* = 7.62 [m] in *w2_selective.npt* file). Maximum outflow from the FSS was assumed to be 4000 cfs (*Q2 MAXFLOW* = 113.27 [cms]).

Measure 392 at Foster Dam generalizes a downstream fish passage structure with 500-800 cfs surface spill through a safe and effective route (spillway or screened intake). This structure was simulated in RES-SIM with the assumption of a year-round fish passage of 600 cfs as “Spillway” flow. In CE-QUAL-W2, this surface spill was designated in the Q2 (Weir) outlet with a floating DEPTH value of 1 m (3.3 ft), minimum flow (MINFRAC) value of -16.99 (600 cfs), and the same blending (PRIORITY) group of 1 with the Q5 (*PowerMain*) outlet (designating that both outlets were blended to meet a mutual temperature target). Further, Q5 was designated a minimum flow (MINFRAC) value of -4.2475 (150 cfs).

Measures 166, 721 at Green Peter Dam was implemented in RES-SIM as 60% of the total outflow assigned to the spillway as soon as it is available in May to Aug 30 and up to 60% of total outflow through the ROs from Sep 1 to Nov 15. However, these flow values were adjusted by the temperature blending routine within the CE-QUAL-W2 model (*Q2 MINFLOW* = 0.4) to meet the downstream temperature target optimally. When Measures 721 and 166 were combined with Measure 714 (Alternative 3a), *MINFLOW* values for all outlets were set to 0 which allowed the model to optimize to meet downstream temperature target with no restraint. When Measures 721 and 166 were combined with 720 (operational downstream passage: Alternatives 3a), temperature blending was not used, so that fish passage could be given higher priority.

Measure 479 at Foster Dam is described as the Foster Warm-Water Supply pipe (FWWS) to the existing adult fish ladder at the Foster Fish Facility (USACE, 2020). Currently, the Foster fish ladder is fed by deeper water in Foster Lake via the turbine intakes. This measure would add flexibility to provide more normative temperatures in the fish ladder and attract upstream migrant fish in a more timely manner during the spring. Assumptions for RES-SIM modeling include 144 cfs in May and 72 cfs during June through the FWWS (by-passing the turbines). CE-QUAL-W2 modeling allocates these exact flows through the FWWS outlet (Q1) with a centerline elevation of 630 ft. Post-processing can refine this flowrate and calculate an optimal flow that will meet a separate temperature target for the fish ladder, similar to methods in Foster Fish Ladder Improvements Project Design Documentation Report (USACE, 2020).

1.3.3 South Fork McKenzie

The following are site-specific measure details applied to the Cougar CE-QUAL-W2 model:

Measure 479:

- Cougar Dam: The Cougar Diversion Tunnel is the deepest outlet at Cougar Dam (invert elevation 1290 ft; centerline elevation 1300 ft) and has the potential to release deep, cold water under scenarios in which lake level is below the RO intake (invert elevation 1479 ft; centerline elevation 1485 ft). This measure assumes new structural and mechanical gate improvements have been made to allow for safe remote routine operation of the diversion tunnel. Measure 479 coincides with Measure 720 (spring drawdown) in Alternative 3b, the lake level is below the WTCT, so blending between the RO bypass intake and the diversion tunnel is specified (Q2 and Q7 PRIORITY = 1 in w2_selective.npt file).
- Blue River Dam: Blue River Dam was built with two spillway gates (spillway crest elevation 1321 ft) and a spillway channel, designed for extreme flow events. This measure assumes the current spillway gates and spillway channel could be re-designed to enable low-flow releases when the lake is above spillway crest. This would provide more normative temperatures during the summer through the release of warmer water, saving cooler deeper water for the fall. Water temperatures downstream of Blue River Dam were estimated based on the simulated RES-SIM pool elevation and the average monthly thermocline as measured monthly in 2014 and 2019 (Figure 1-3).

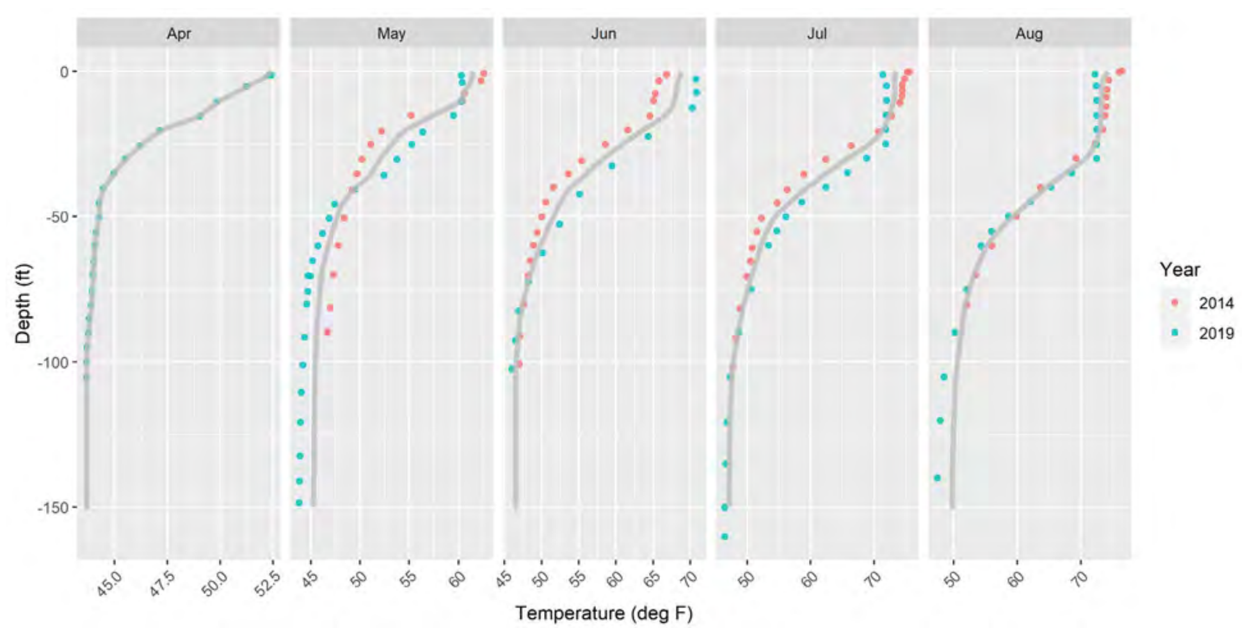

Figure 1-3. Blue River Lake water temperature as measured at monthly intervals in 2014 and 2019. Gray line represents the average of the two years.

Measures 105, 392 outlet details and temperature targets at Cougar Dam are similar to those used in previous studies (USACE, 2019a) with some simplifying assumptions applied to be consistent with WV EIS Measure 392. A single floating outlet at 25 feet deep (*Q3 DEPTH* = 7.62 [m] in *w2_selective.npt* file) was used with maximum outflow from the FSS assumed to be 1000 cfs (*Q1 MAXFLOW* = 28.32 [cms]).

1.3.4 Middle Fork Willamette

The following are site-specific measure details applied to the Hills Creek and Lookout Point-Dexter CE-QUAL-W2 models:

Measures 105, 392:

- Lookout Point Dam consists of assumptions similar to those used at Detroit Dam with a floating outlet at 25 feet deep (*Q2 DEPTH* = 7.62 [m] in *w2_selective.npt* file). Maximum outflow from the FSS was assumed to be 6000 cfs (*Q2 MAXFLOW* = 169.90 [cms]) to be consistent with Measure 392 description for Lookout Point Dam.
- Hills Creek Dam FSS assumptions include a single floating outlet at 25 feet deep (*Q3 DEPTH* = 7.62 [m] in *w2_selective.npt* file) with maximum outflow from the FSS assumed to be 1000 cfs (*Q1 MAXFLOW* = 28.32 [cms]).

Measures 166, 721 at Lookout Point Dam were implemented in RES-SIM as 60% of the total outflow assigned to the spillway from April 15 to Aug 30 and up to 60% of total outflow through the ROs from Sep 1 to Nov 15. However, these flow values were adjusted by the temperature blending routine within the CE-QUAL-W2 model (*Q2 MINFLOW* = 0.4) to meet the downstream temperature target optimally. When Measures 721 and 166 were combined with Measure 714 (Alternative 3b), *MINFLOW* values for all outlets were set to 0 which allowed the model to optimize to meet downstream temperature target with no restraint. When Measures 721 and 166 were combined with 720 (operational downstream passage: Alternatives 3a), temperature blending was not used, so that fish passage could be given higher priority.

Measure 479: Hills Creek Dam was built with 3 spillway gates (spillway crest elevation 1495.5 ft) and a spillway channel, designed for extreme flow events. This measure assumes the current spillway gates and spillway channel could be re-designed to enable low-flow releases when the lake is above spillway crest. This would provide more normative temperatures during the summer through the release of warmer water; saving cooler, deeper water for the fall. When Measures 721 and 166 were combined with Measure 714 (Alternative 3a), *MINFLOW* values for all outlets were set to 0 which allowed the model to optimize to meet downstream temperature target with no restraint. When Measures 721 and 166 were combined with 720 (operational downstream passage: Alternatives 3b), temperature blending was not used, so that fish passage could be given higher priority.

A complete listing of the measures included in each alternative can be found in Chapter 3.

1.4 TEMPERATURE TARGETS

Natural temperature patterns and magnitude immediately downstream of each project are estimated using an 'upstream mix' calculation based on Rounds 2010. The 'upstream mix' is a flow-weighted averaging of upstream temperature and a maximum warming rate of 0.11 degrees C per river mile which is decreased for cooler upstream temperatures. The upstream mix calculations were determined for the period of available data. It is assumed that upstream flow and temperatures are reasonable surrogates for natural conditions given most of the watershed is forested and managed by the USFS.

1.4.1 North Santiam

Two separate temperature targets for Detroit Dam were used in the WV EIS:

1. The current operational temperature target (*DET 2017 Operations Max* in Figure 1-4) was developed through the WATER process and is used to guide interim operational temperature control below Detroit Dam from 2017 to 2020 (Willamette Fish Passage Operations and Maintenance (W-FPOM) Coordination Team, 2017; USACE, 2019c). This target is used in NAA.

2. A target based on the long-term water temperature data record above Detroit dam (*DET Upstream Mix* in Figure 1-4) was developed and used in previous studies to evaluate the system potential for minimizing thermal effects of the dam (Buccola, et al., 2012). This target was used in all alternatives except NAA.

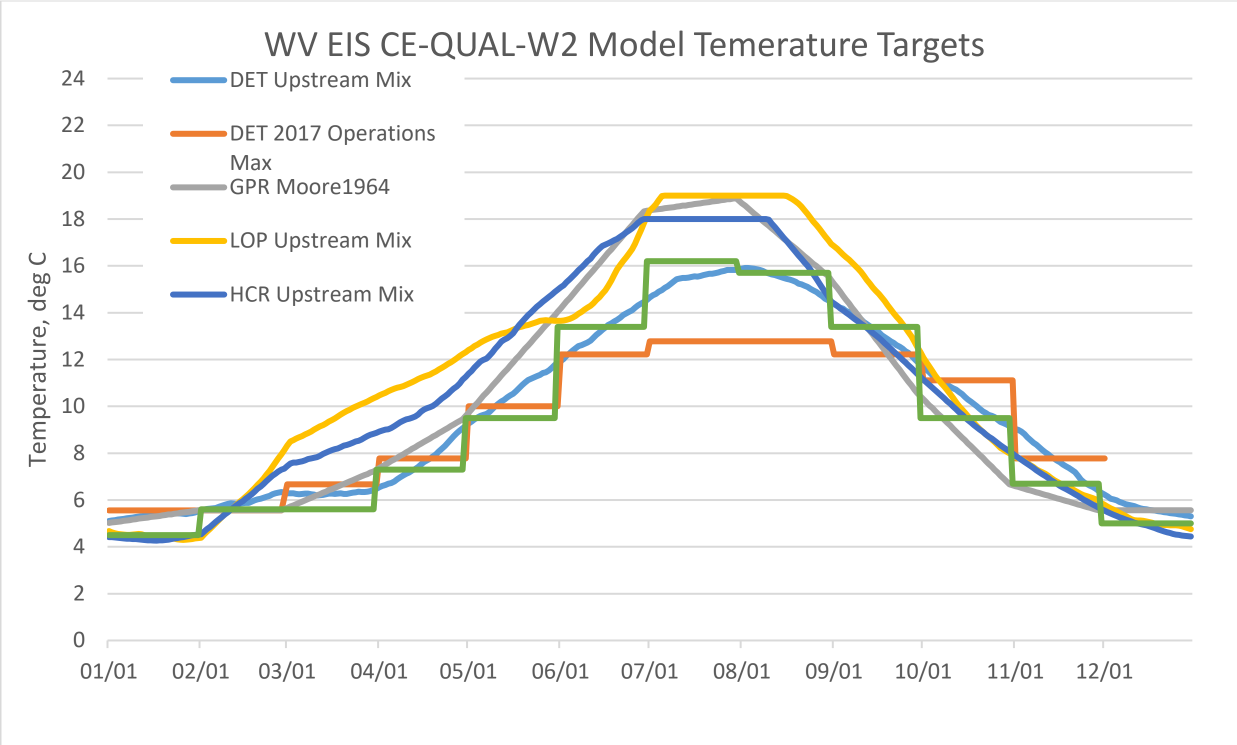

Figure 1-4. Temperature targets used at each CE-QUAL-W2 reservoir temperature model within the WV EIS. Explanation as follows: DET: Detroit, GPR: Green Peter, LOP: Lookout Point, HCR: Hills Creek, CGR: Cougar.

1.4.2 South Santiam

A temperature target based on measured monthly mean temperature 0.7 mi upstream from the mouth of the Middle Santiam River, prior to construction of Green Peter and Foster Dams from 1954 to 1962 (site 14-1865 in Moore, 1964), was developed for both the GPR and FOS models in all WV EIS alternatives (*GPR_Moore1964* in Figure 1-4) (Buccola, 2017). The pre-dam temperature measurements from the Middle Santiam River range from about 5.0 °C (41.0 °F) in winter to a high of near 19.0 °C (66.2 °F) in July.

1.4.3 South Fork McKenzie

Minimum and maximum temperature targets were developed and agreed upon for Cougar Dam by the resource agencies (NOAA, USFWS, and ODFW) in 1984 to benefit the downstream ESA listed anadromous fish (NOAA, 2008). The maximum target is used by the CE-QUAL-W2 model in all WV EIS alternatives to release the maximum volume of warm surface water during the summer, saving cooler deeper water for the fall.

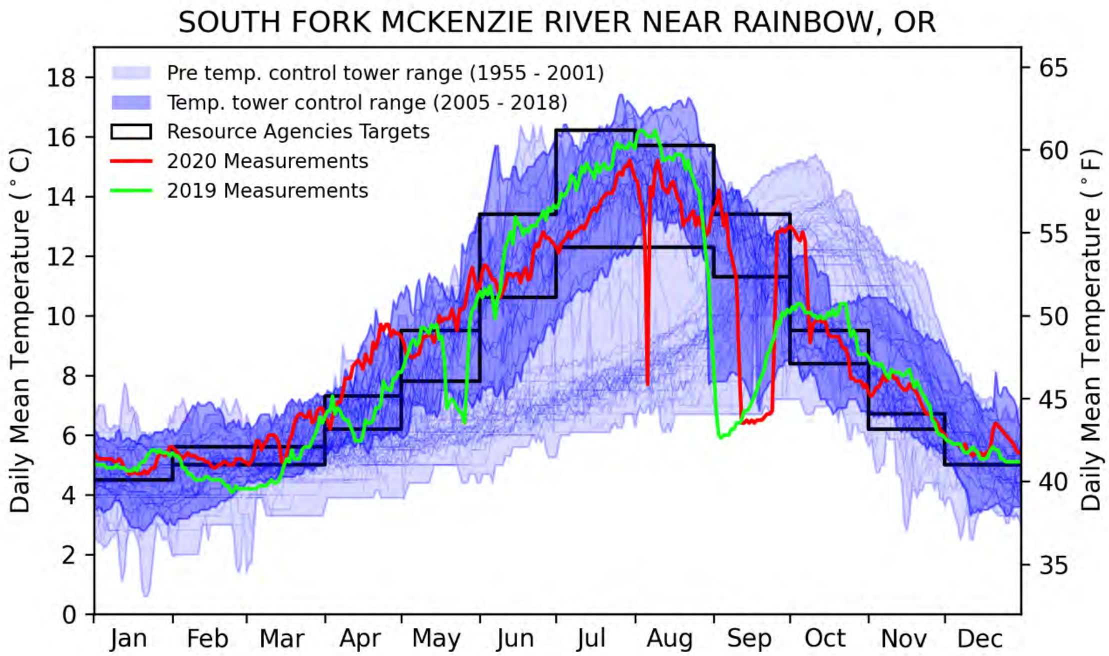

Figure 1-5. Resource Agencies (RA) Targets for South Fork McKenzie River below Cougar Dam. The maximum RA target was used for the Cougar Reservoir CE-QUAL-W2 temperature model in each of the WV EIS alternatives.

1.4.4 Middle Fork Willamette

Temperature targets were developed for Hills Creek and Lookout Point Dams (Buccola, et al., 2016; USACE, 2016) based on upstream temperature and flow data from USGS gages. The Hills Creek temperature target (*HCR Upstream Mix* in Figure 1-4) was based on Middle Fork Willamette River near Oakridge, OR, USGS 14144800 (located 8.0 river miles upstream of the dam) and Hills Creek above Hills Creek Reservoir, USGS 14144900 (located 4.1 river miles upstream of the dam). A flow-weighted average temperature of these two tributaries was calculated using a watershed area estimation method as a surrogate for missing flow data (264 and 52.7 square miles respectively).

The calculations for developing a temperature target downstream of Lookout Point and Dexter Dams (*LOP Upstream Mix* in Figure 1-4) were more complex. Upstream temperature and flow were from North Fork of Middle Fork Willamette River near Oakridge, OR (USGS 14147500, 5.0 river miles upstream of the Lookout Point Reservoir) and the upstream mix temperature and inflow at Hills Creek Reservoir (calculated as described above; 11.5 miles upstream of Lookout Point Reservoir). Little data is available for Salt and Salmon Creeks, tributaries to the Middle Fork downstream of Hills Creek Dam and upstream of Lookout Point Reservoir. Therefore, it was assumed that water temperature at the mouth of these tributaries is similar to the North Fork measurements and Middle Fork upstream mix calculations. It is 18.7 river miles from the head of the Lookout Point Reservoir to the gage downstream of Dexter Dam.

The warmest daily mean outflow temperature from Hills Creek Dam between 1978 and 2014 typically occurs around October 8th and has ranged 13.9 to 17.6 degrees C with a mean of 14.9 degrees C (Figure 1-6). The peak upstream mix temperature between 1956 and 2014 typically occurs on July 27th and has ranged from 13.8 to 20.6 with a mean of 16.6 degrees C. The magnitude and pattern of the upstream mix temperatures is similar to the measurements of the North Fork of the Middle Fork Willamette near its mouth, an unregulated system. The headwaters of both watersheds are in the high Cascades and the Middle Fork watershed area is 392 square miles while the North Fork is 246 square miles. The temperature similarity increases confidence in using the upstream mix calculation as a surrogate for natural temperatures.

The warmest daily mean outflow temperature from Dexter Dam between 1978 and 2014 typically occurs around September 14th and has ranged 14.6 to 19.5 degrees C with a mean of 16.3 degrees C (Figure 1-7). The peak upstream mix daily mean temperature between 2001 and 2013 typically occurs around August 4th and has ranged from 18.0 to 21.1 with a mean of 19.4 degrees C. The magnitude and pattern of the upstream mix calculation is similar to monthly average temperature collected prior to construction of the dams from 1950 – 1953 (Moore 1964). The temperature similarity increases confidence in using the upstream mix calculation as a surrogate for natural temperatures.

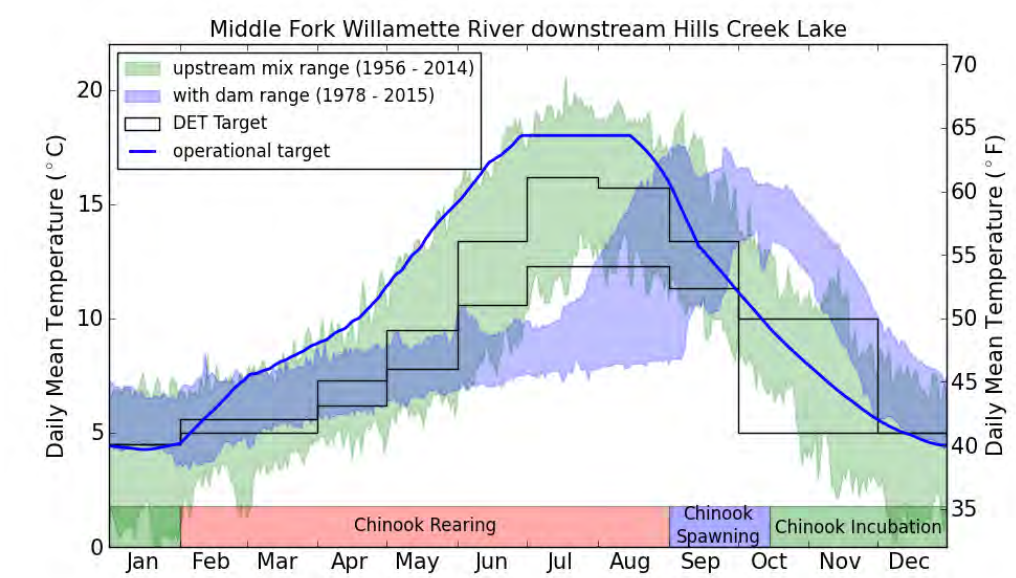

Figure 1-6. Hills Creek Dam operation temperature control target with comparison to relevant temperature ranges, the 2015 Detroit (DET) temperature target and anticipated Chinook salmon life stages.

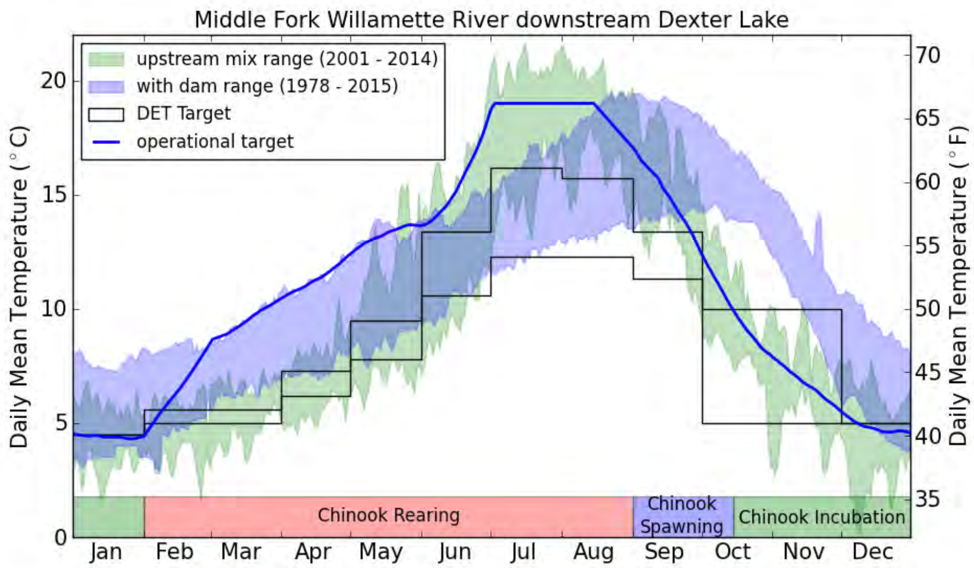

Figure 1-7. Lookout Point Dam operation temperature control target with comparison to relevant temperature ranges, the Detroit (DET) temperature target and anticipated Chinook salmon life stages

1.5 SIMULATED RESULTS

The model CE-QUAL W2 was utilized to simulate water temperatures at all sub-basins and downstream to Salem, except for the Coast Fork and Long Tom sub-basins, for the years 2011, 2015, and 2016. Each year represented a different climatological condition: wet year (2011), dry year (2015), and average year (2016). CE-QUAL-W2 reservoir water temperature model output was analyzed for each of the three calendar years and alternative, aside from Alternative 5 (qualitatively assessed due to time constraints and close resemblance to Alternative 2b). CE-QUAL-W2 water temperature simulations in the reservoirs and downstream were based on inflow discharge, inflow water temperature, air temperature, dew point temperature, wind speed, wind direction, solar radiation, cloud cover, and gate-specific outflow as data inputs for each simulation. Daily average gate-specific outflows and lake elevations were derived from RES-SIM simulations under each alternative. Lake surface elevations in CE-QUAL-W2 reservoirs were forced to match lake levels from RES-SIM through a *water balance* process in which a time-series of distributed tributary inflow values (*QDT*) was added to (or subtracted from) specific to each reservoir, year, and alternative model run. Inflows generated by RES-SIM were occasionally near zero, due to evaporation loss assumptions at each reservoir.

This section will focus on discussion of the water management and water temperature implications generally between April and December each year simulated through CE-QUAL-W2, as this is the time of year that is most impacted by the heat-exchange process occurring in the reservoirs during summer and conveyance of heated water downstream of the dams through autumn. A full description of hydrology and water management operations throughout the entire calendar year can be found in the Hydrology and Hydraulics Appendix B and Chapter 3.2. Please refer to section 3.6 Water Quality Affected Environment for additional discussion of water temperature under the NAA.

1.5.1 No Action Alternative (NAA)

The NAA simulations are based on RES-SIM inflow hydrology (including constant reservoir-specific evaporation rates in each year), gate-specific outflows, and lake surface elevations that are different from those that took place historically. Simulated outflow temperatures depend on lake surface elevations and gate-specific outflow data from RES-SIM rulesets established for the NAA to allow for equivalent assumptions in each year and could differ from measurements in 2011, 2015, and 2016. Differences in lake surface elevation and gate-specific outflows can affect lake surface area, volume, heat content stored in the lake, and the amount of heat released in downstream water in a given year. See the section Comparison of NAA with Measurements for more details comparing simulated RES-SIM operations and simulated NAA temperatures with measurements.

1.5.1.1 NORTH SANTIAM DAMS

The North Santiam sub-basin is represented at BCLO and includes Detroit reservoir interim temperature operations. NAA included up to 60% of total outflow released through the Detroit Dam spillway from June 1 to August 30 (if/when the lake is above the spillway crest) and up to

60% of total outflow released through the Regulating Outlets from October 1st to November 15. The low water year of 2015 (Figure 1-9) resulted in Detroit Lake not filling to the spillway crest (Figure 1-11), which resulted in relatively warmer temperatures compared to 2011 (Figure 1-8) and 2016 (Figure 1-10), especially in July-October. Water temperature under the NAA would be similar to observed values since the issuance of the BiOp and implementation of operational water temperature management (Figure 1-12; Figure 1-13).

1.5.1.1.1. Detroit

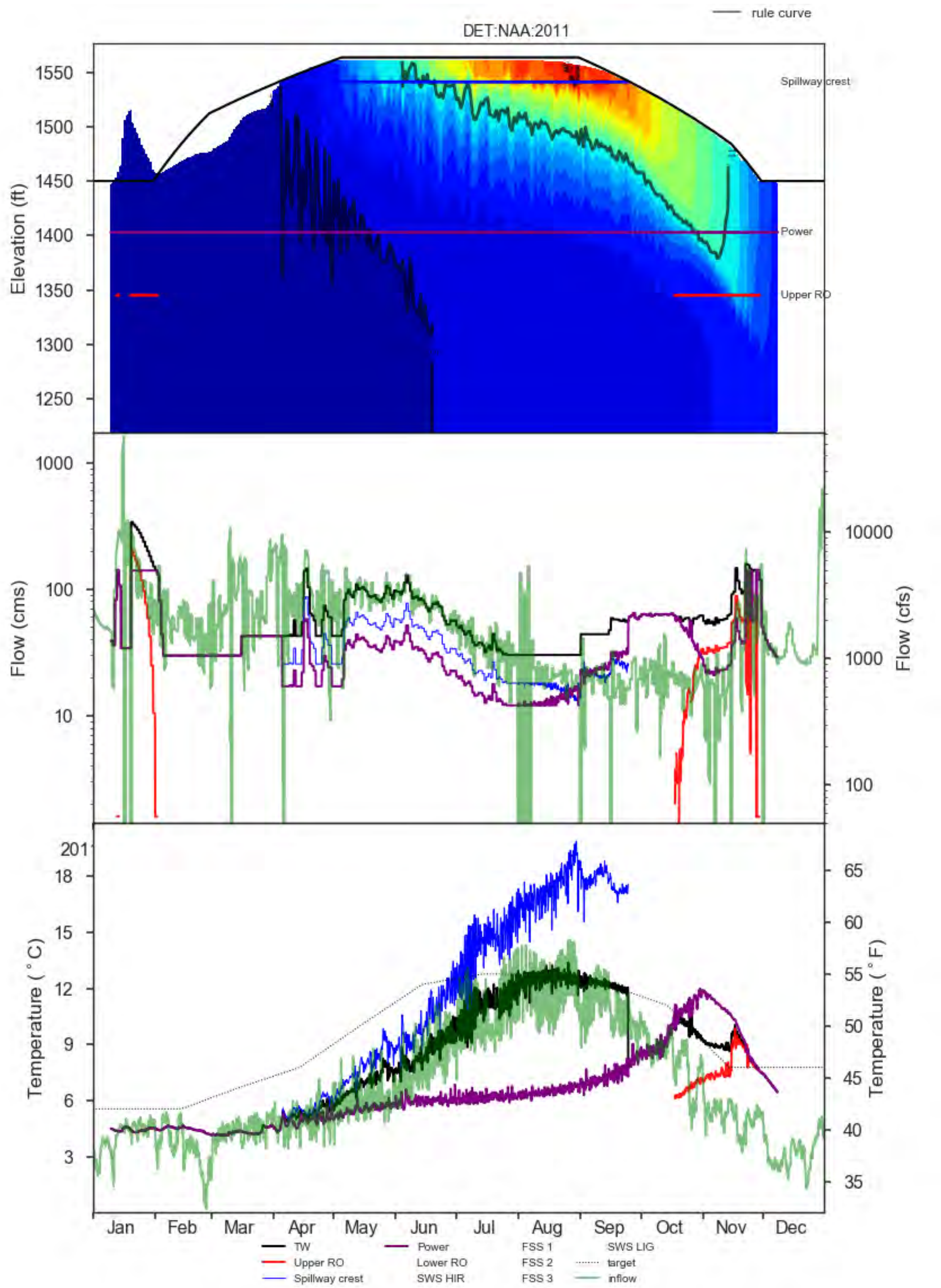

Figure 1-8. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and outflow temperatures (bottom) at Detroit under NAA in 2011.

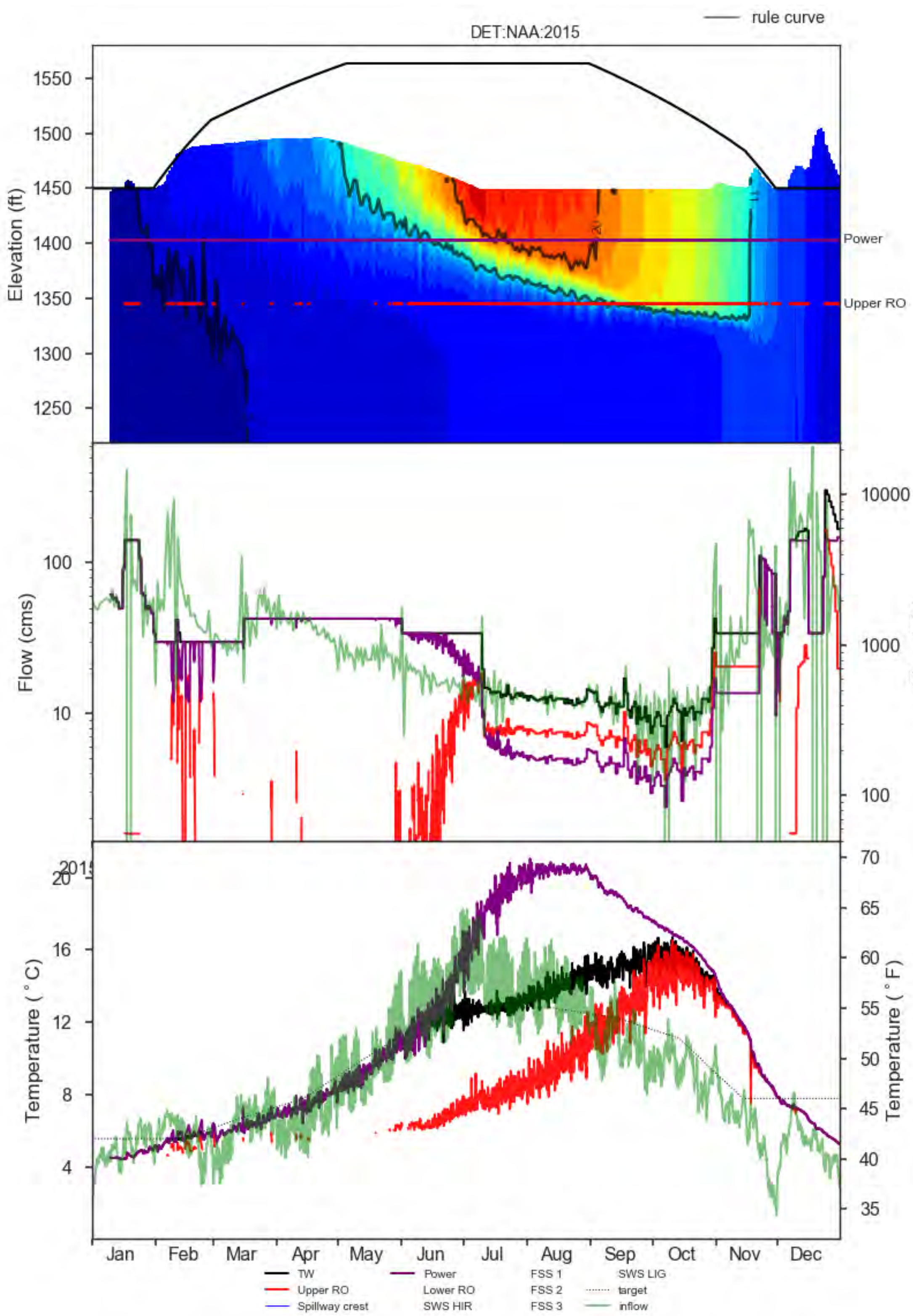

Figure 1-9. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at Detroit Under NAA in 2015.

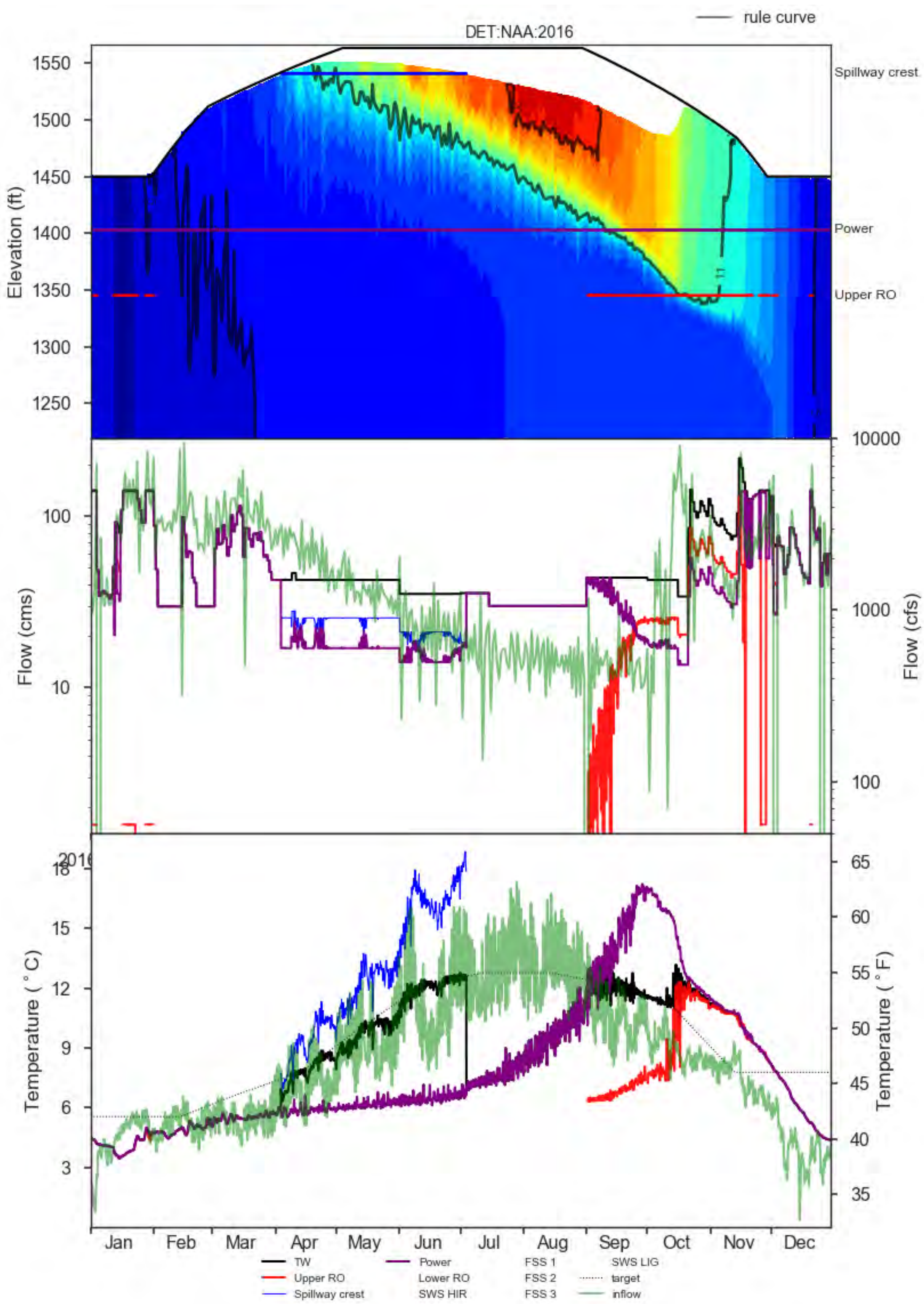

Figure 1-10. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at Detroit Under NAA in 2016.

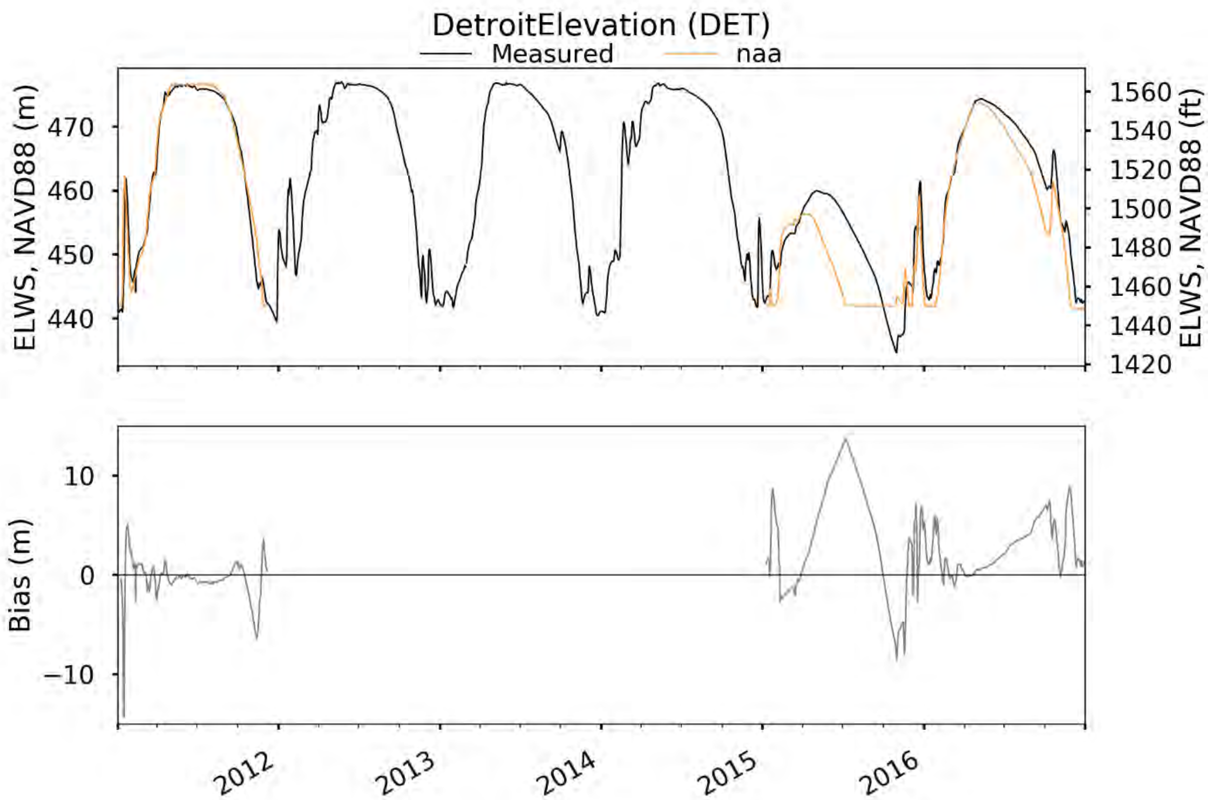

Figure 1-11. Comparison of DET Daily Lake Surface Elevations in NAA vs Measured.

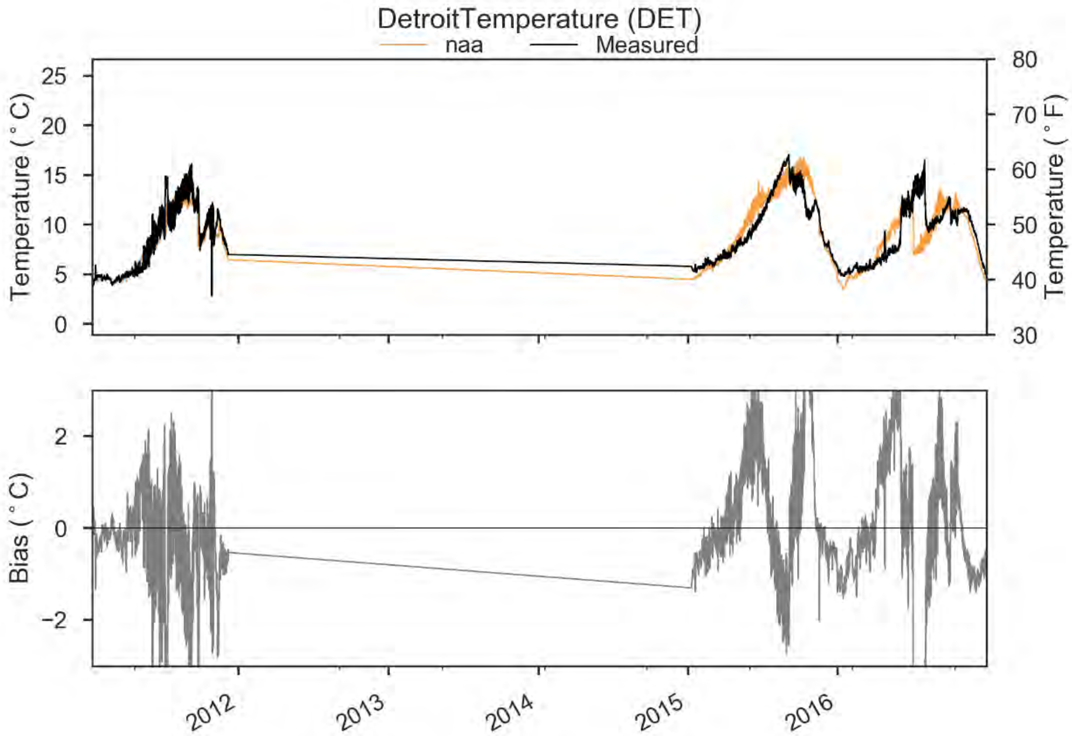

Figure 1-12. Comparison of DET Outflow Temperatures in NAA vs Measured.

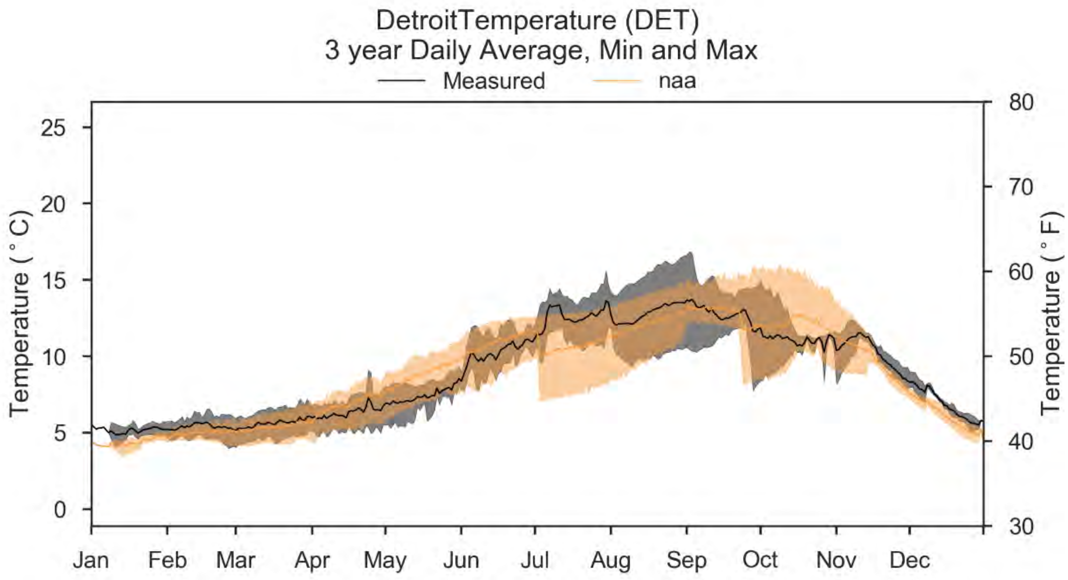

Figure 1-13. Comparison of DET 3-year Average, Min, Max Daily Outflow Temperatures in NAA vs Measured.

1.5.1.2 SOUTH SANTIAM DAMS

1.5.1.2.1 Green Peter

Green Peter operations in NAA are identical to those under the Affected Environment, consisting of relatively deep releases from the Power penstock and ROs year-round (Figure 1-14; Figure 1-15; Figure 1-16). Differences between NAA and measurements in lake levels in the three calendar-year scenarios were relatively minor, aside from 2015 (Figure 1-17), and generally led to differences in outflow tailwater temperatures less than 2 degrees Celsius. Short-term differences between NAA and Measurements in fall of 2016 can be attributed to model sensitivity during fall storms as the lake is drafted and the thermocline depth is affected by upstream inflow temperatures (Figure 1-18; Figure 1-19).

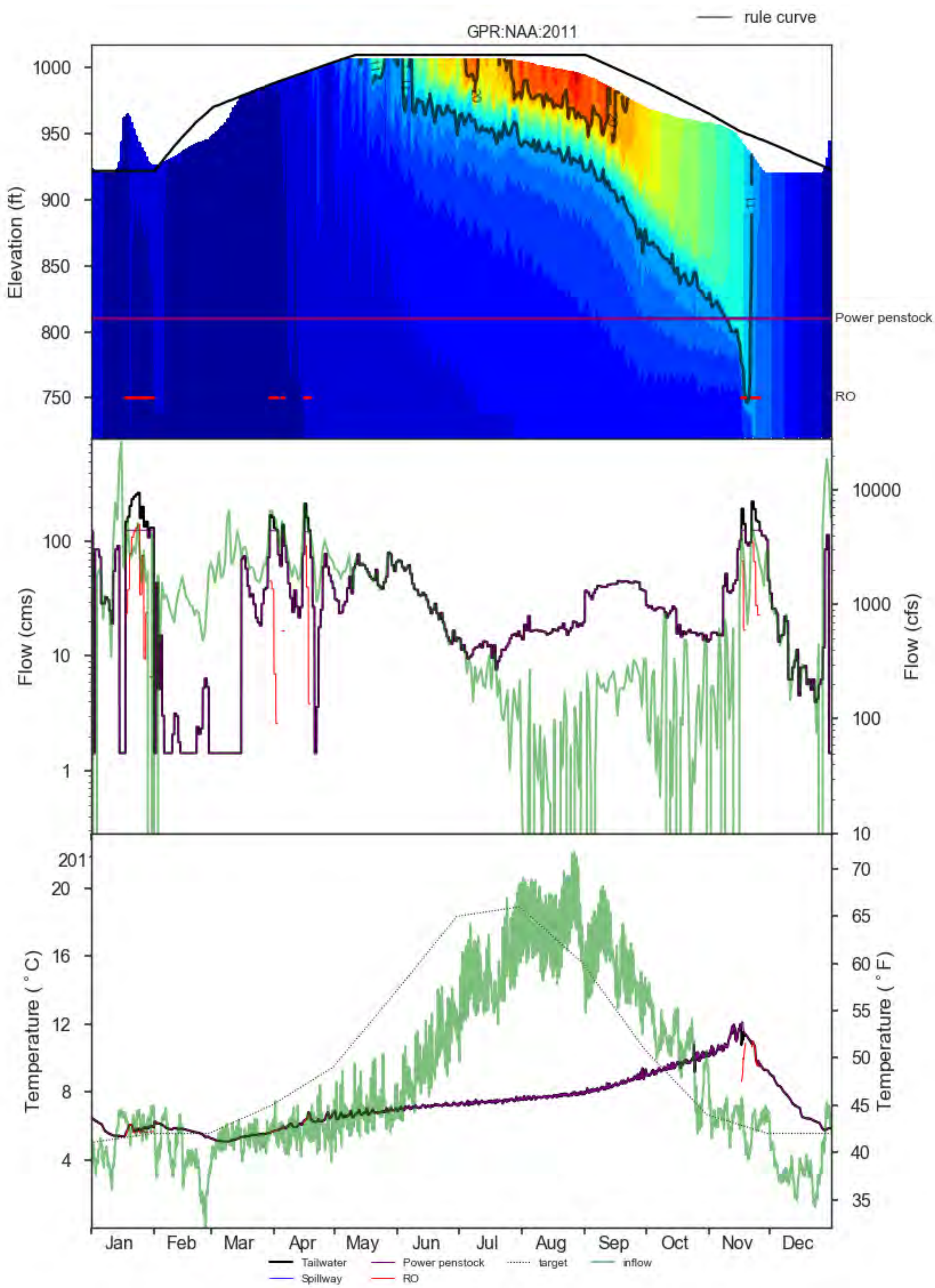

Figure 1-14. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at GPR in 2011.

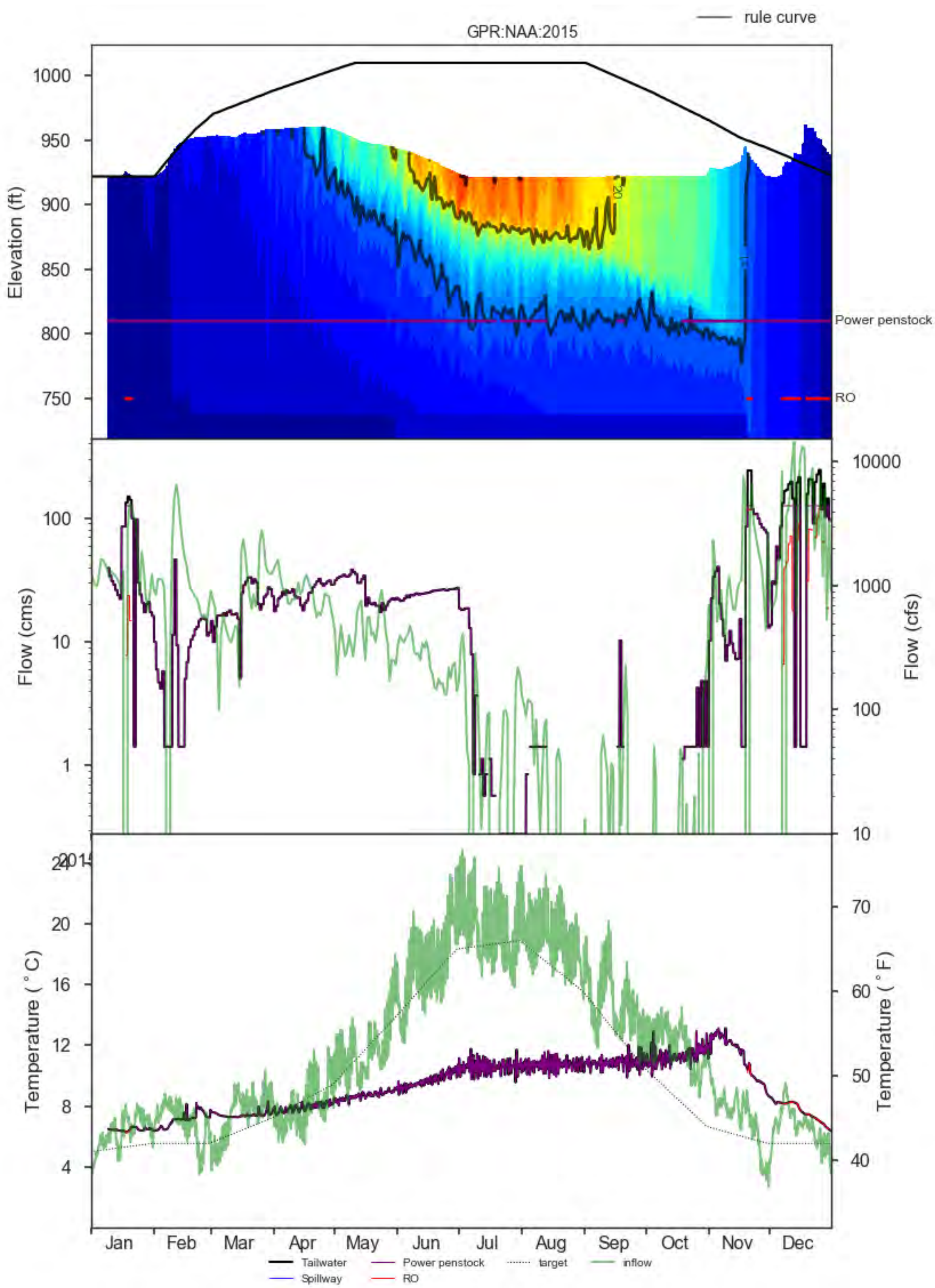

Figure 1-15. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at GPR in 2015.

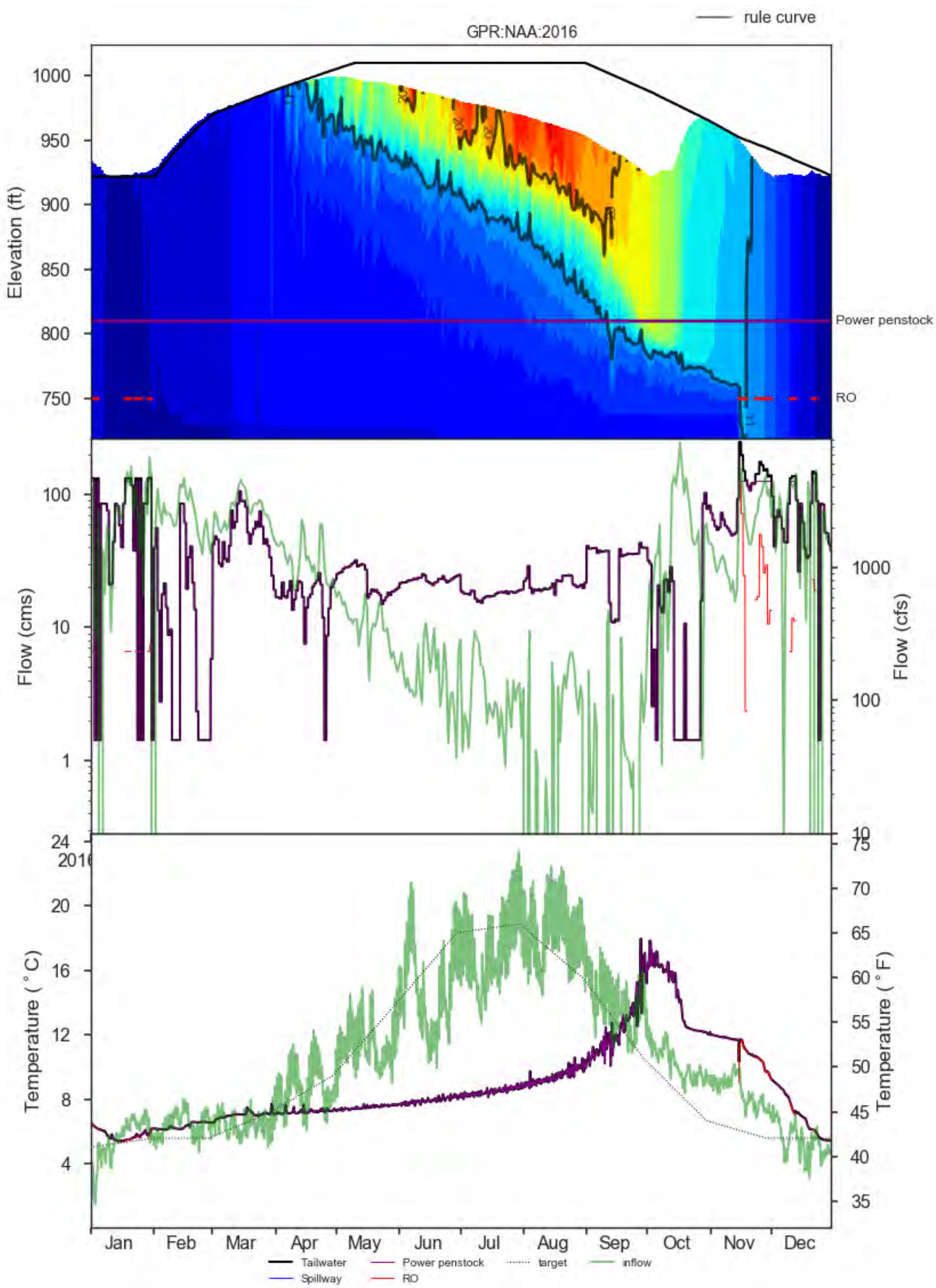

Figure 1-16. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at GPR in 2016.

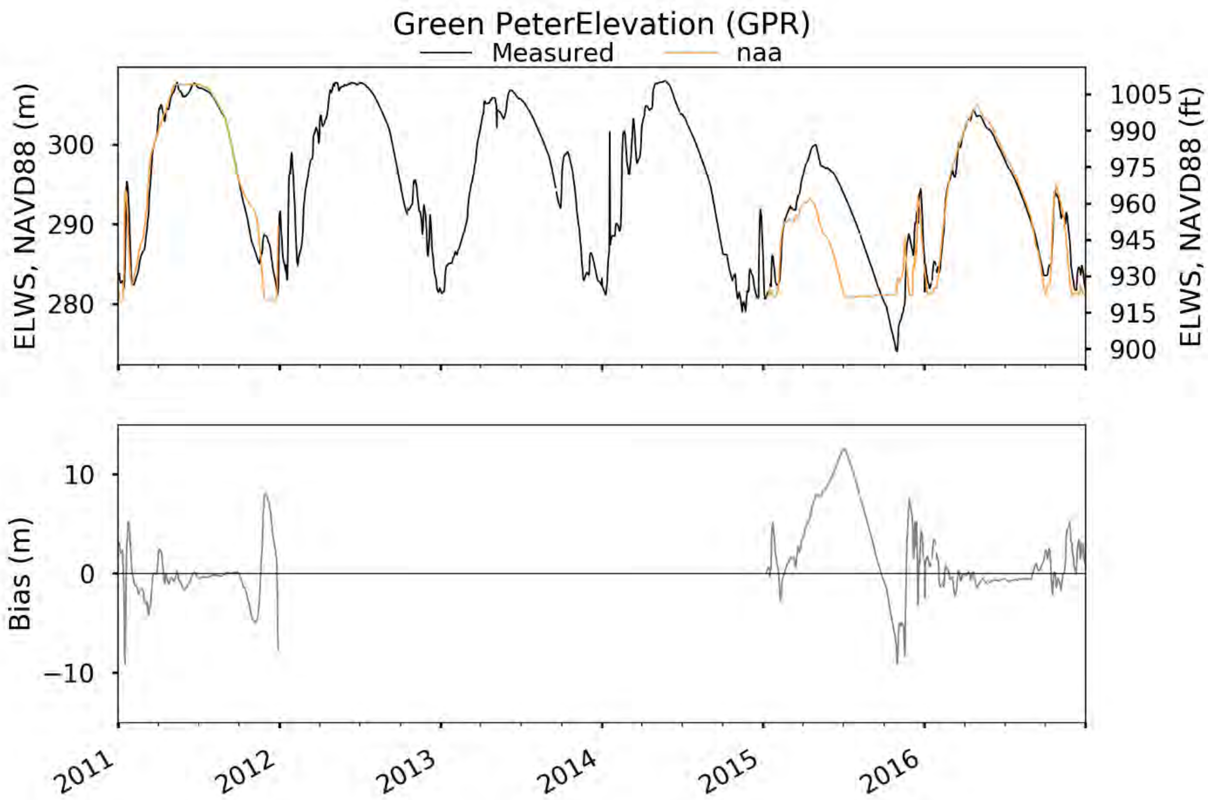

Figure 1-17. Comparison of GPR Daily Lake Surface Elevations in NAA vs Measured.

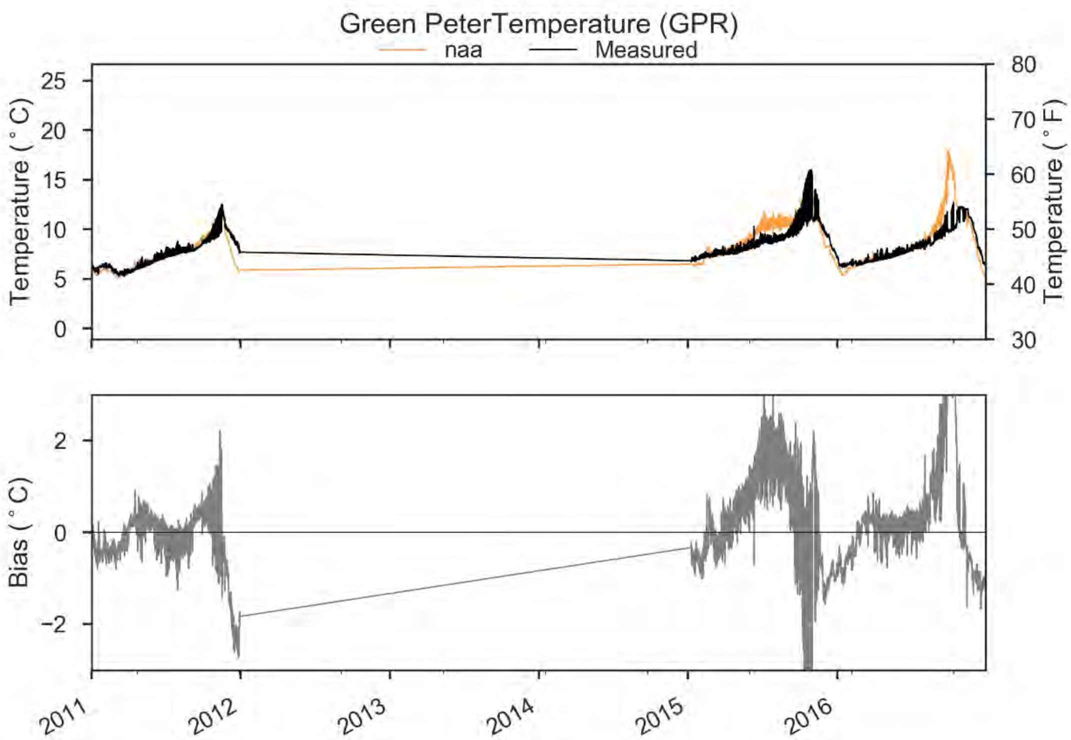

Figure 1-18. Comparison of GPR Outflow Temperatures in NAA vs Measured.

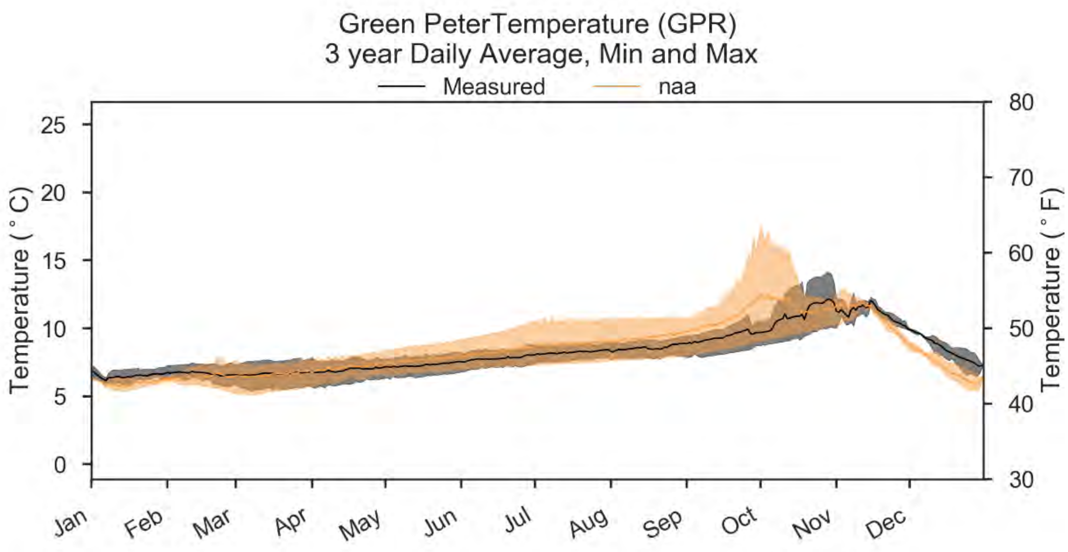

Figure 1-19. Comparison of GPR 3-year average, min, max outflow temperatures in NAA vs Measured.

1.5.1.2.2 Foster

At Foster, temperature operations under the NAA would remain similar to the Affected Environment whereby the Foster fish weir and night-time spill operations of 300 cfs would remain in effect from June 16 until August 15 (Figure 1-20; Figure 1-21; Figure 1-22). As Foster is a reregulating dam for Green Peter, Foster Lake temperature was affected by Green Peter Dam operations release temperatures, generally resulting in travel times through Foster of 10-20 days during summer and a time lag in the temperature pattern (Sullivan and Rounds, 2021). Major differences between NAA and measurements can be linked to operational lake levels (Figure 1-23), especially in 2015 (Figure 1-24), where the time during which the fish weir could be used was reduced. Generally, NAA was warmer in July-October and cooler in December compared to measurements (Figure 1-25).

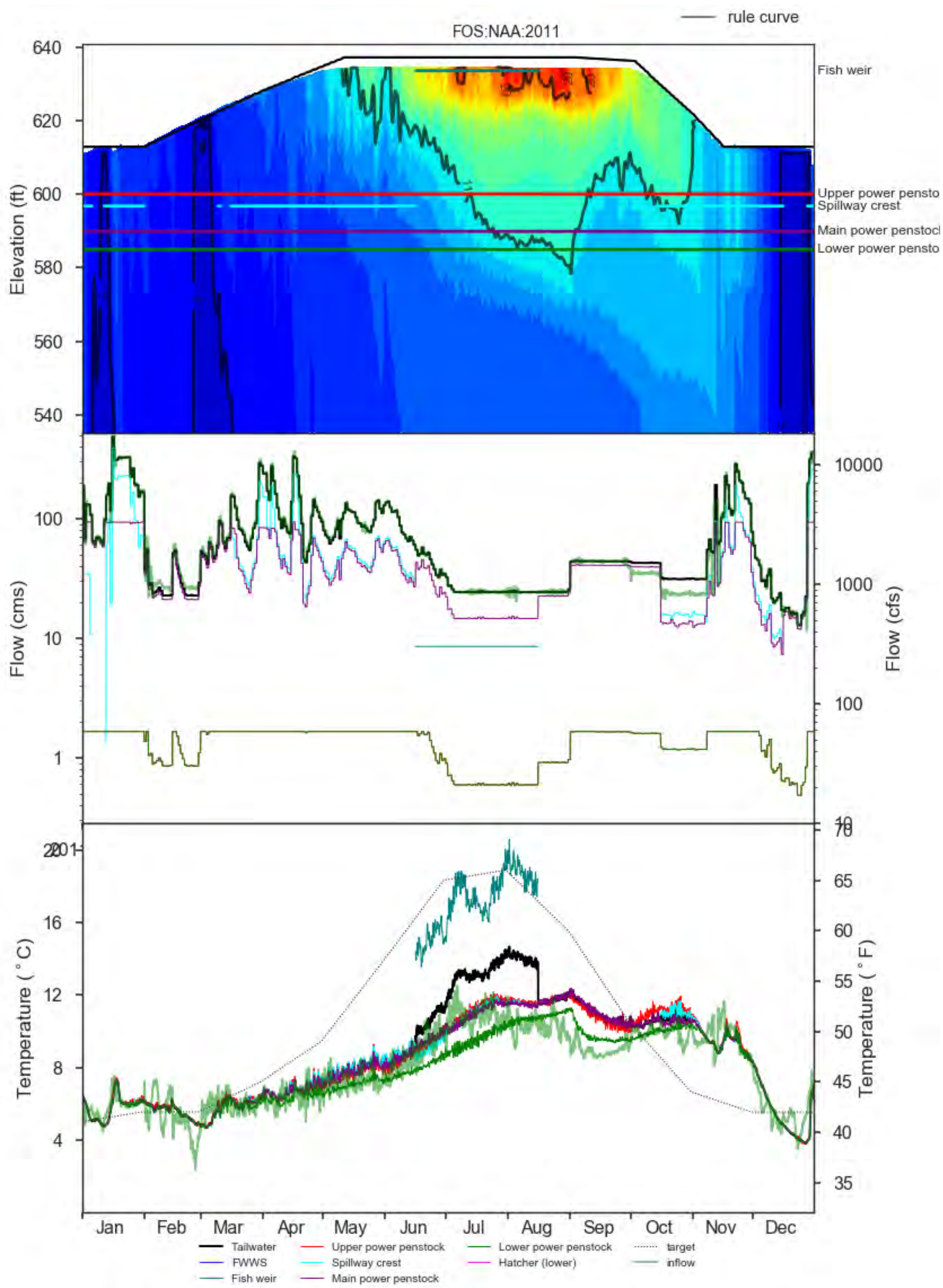

Figure 1-20. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and outflow temperatures (bottom) at FOS in 2011.

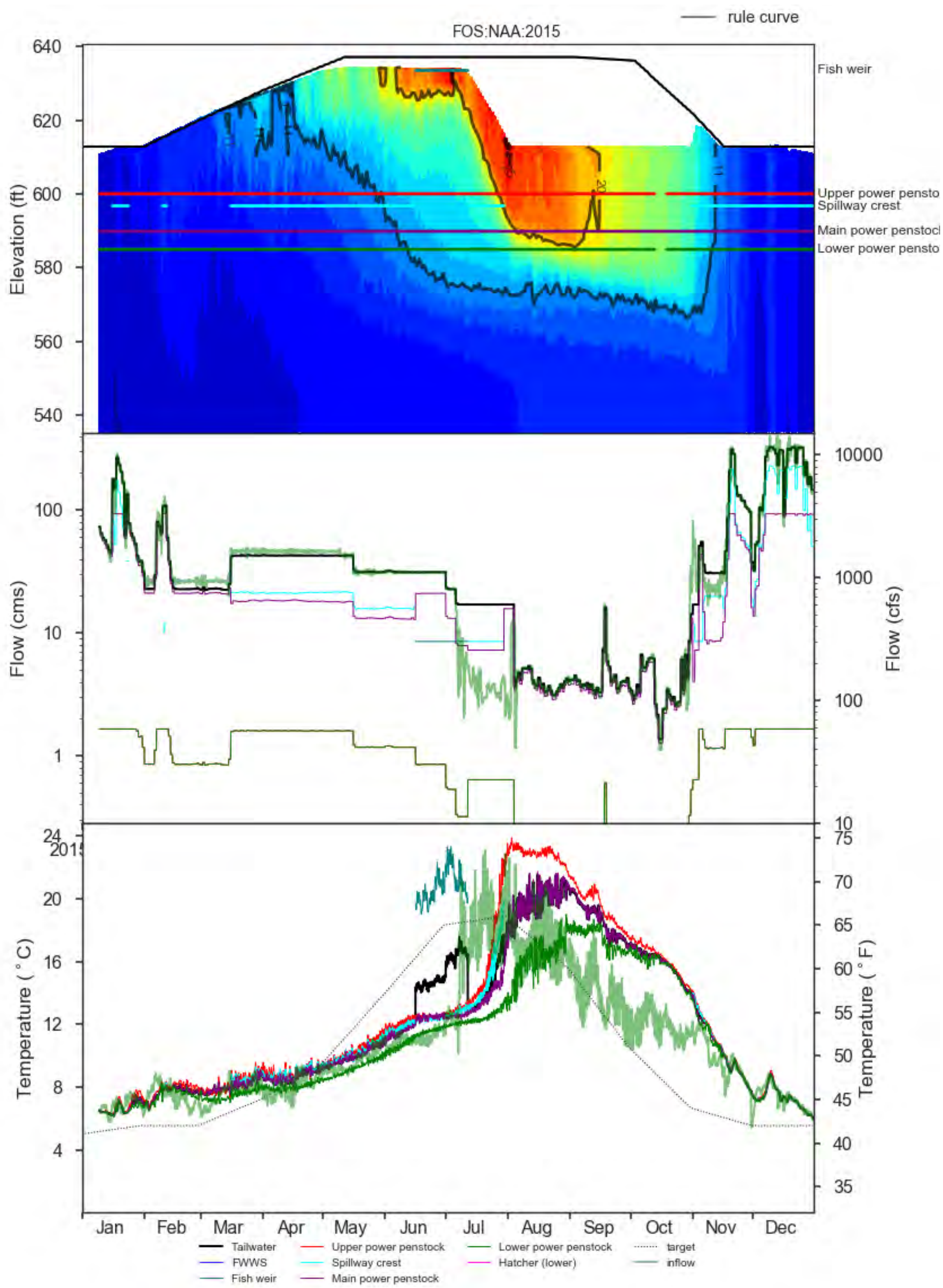

Figure 1-21. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and outflow temperatures (bottom) at FOS in 2015.

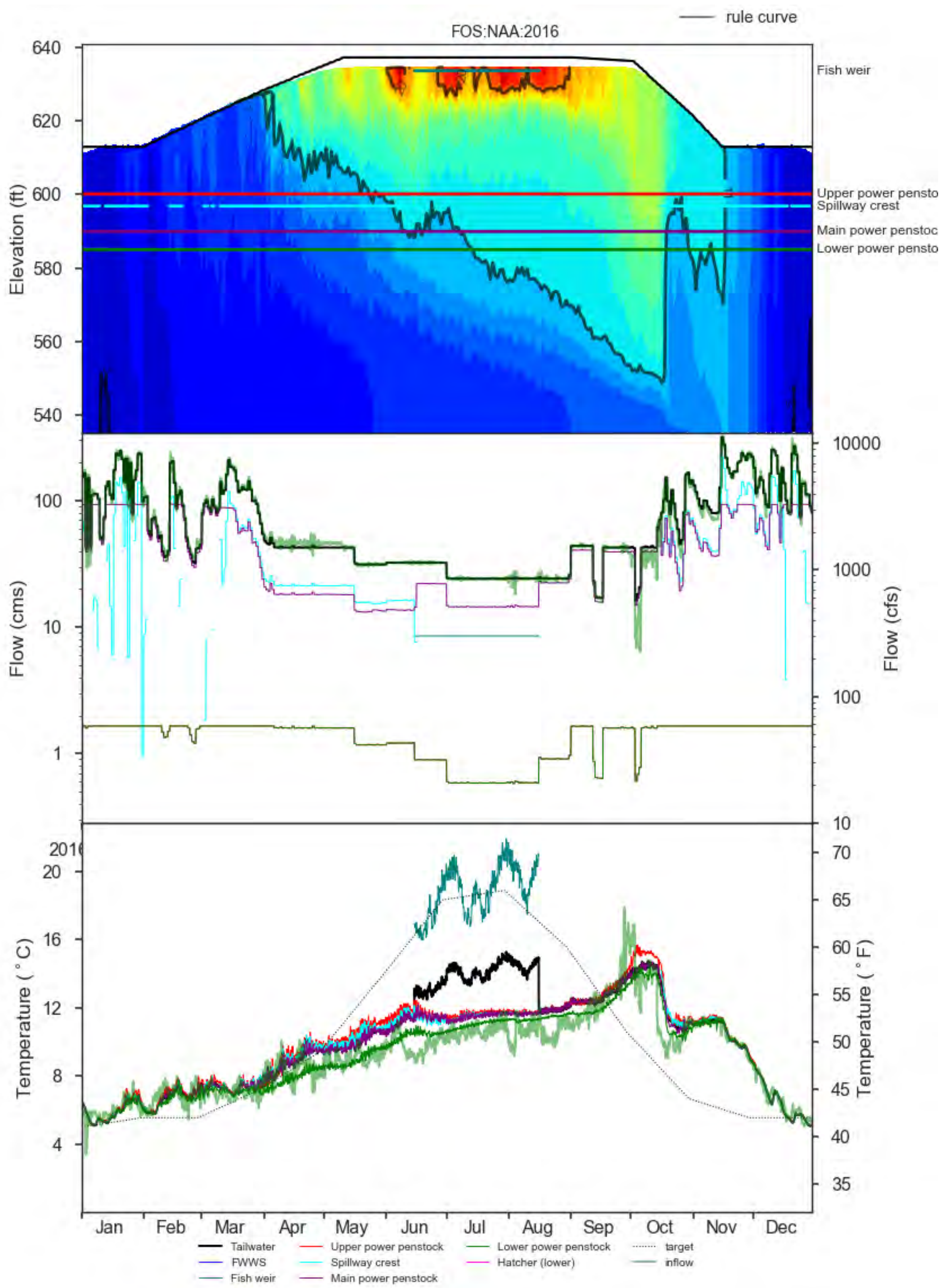

Figure 1-22. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and outflow temperatures (bottom) at FOS in 2016.

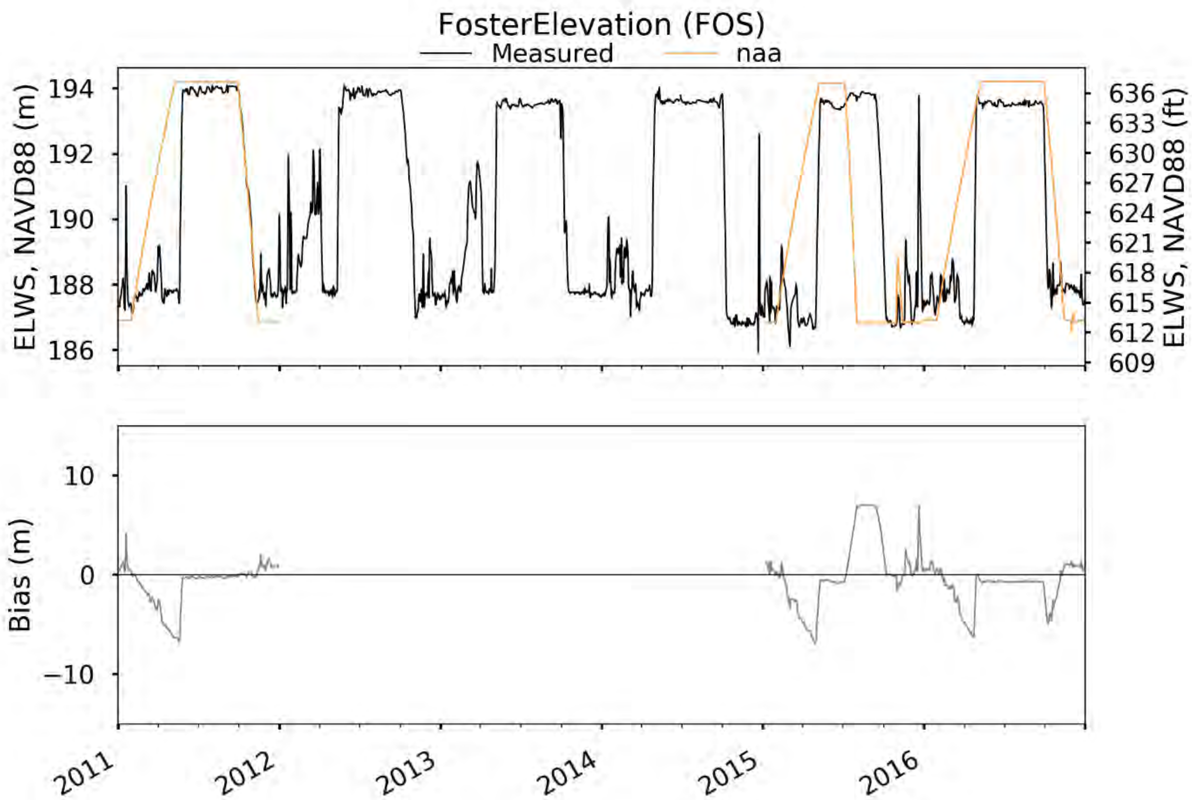

Figure 1-23. Comparison of FOS Daily Lake Surface Elevations in NAA vs Measured.

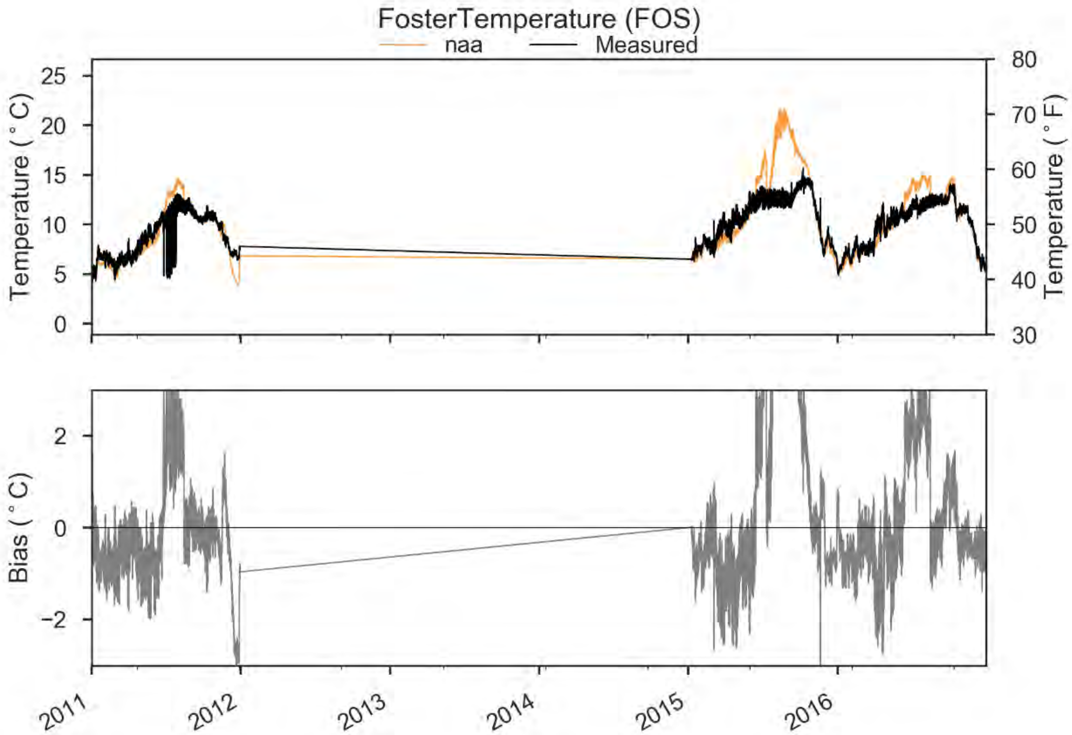

Figure 1-24. Comparison of FOS Outflow Temperatures in NAA vs Measured.

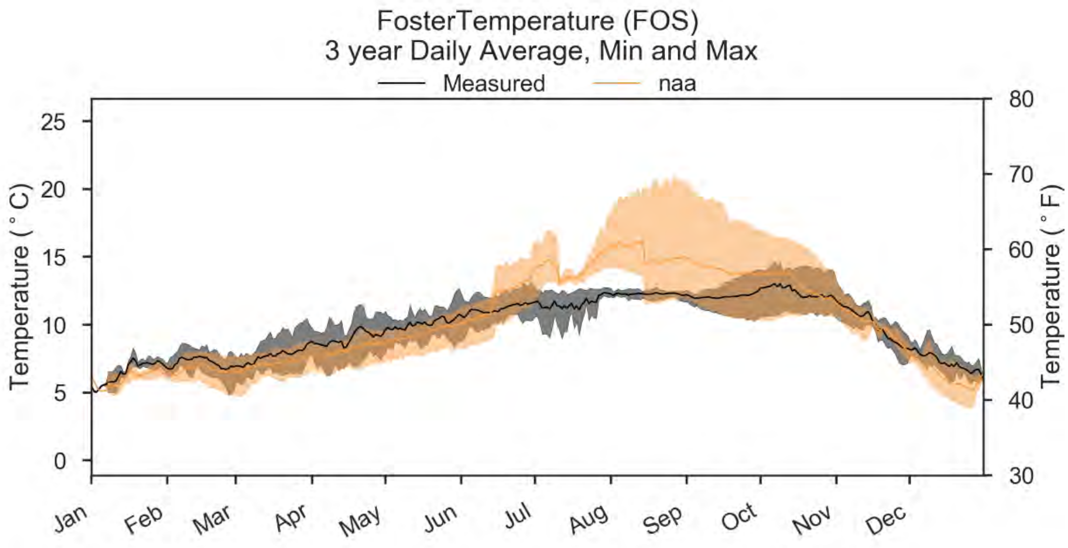

Figure 1-25. Comparison of FOS 3-year average, min, max outflow temperatures in NAA vs Measured.

1.5.1.3 MCKENZIE DAMS

1.5.1.3.1 Cougar

The Cougar water temperature control tower would continue to be operated annually to draft water to 1541 ft elevation by November 15 under NAA. Once water elevation is below 1541 ft there are no temperature control operations (Figure 1-26; Figure 1-27; Figure 1-28). The largest temperature differences between NAA and measurements can be linked to operational lake levels (Figure 1-29), especially in 2016 (Figure 1-30), when a drawdown occurred in the measurement record that resulted in no ability to use the temperature control tower. Generally, NAA was warmer in July and cooler in November-December compared to measurements (Figure 1-31).

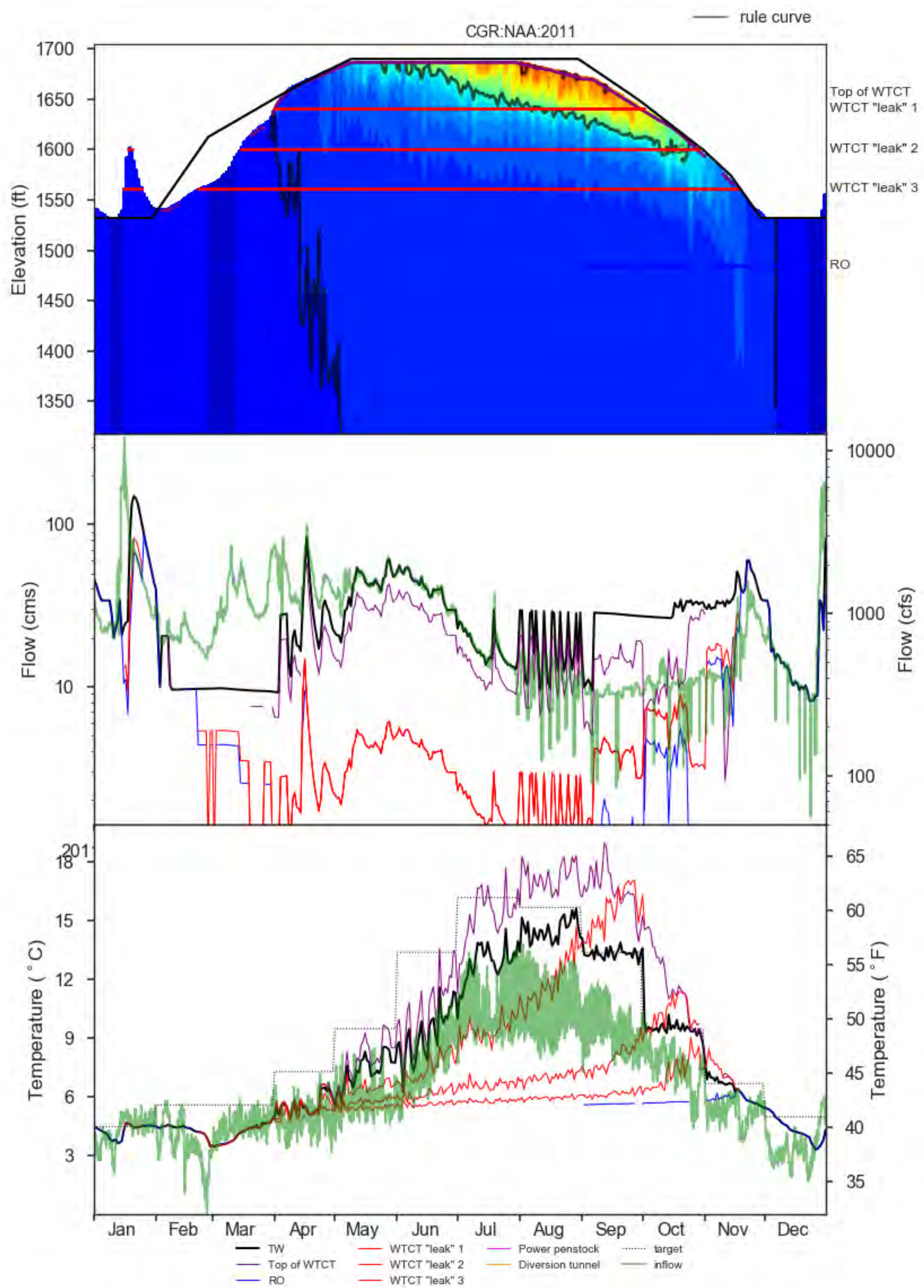

Figure 1-26. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at CGR in 2011.

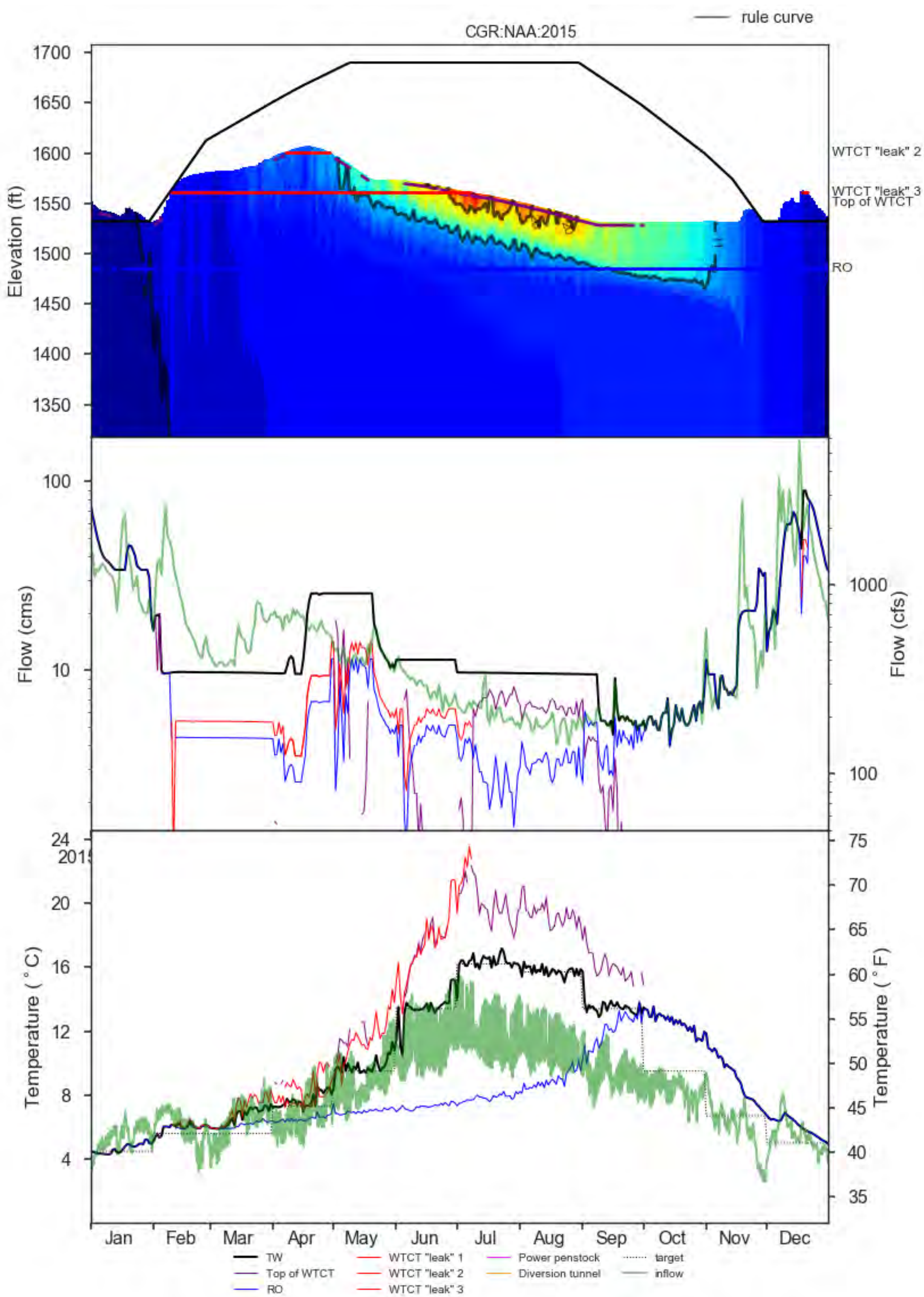

Figure 1-27. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at CGR in 2015.

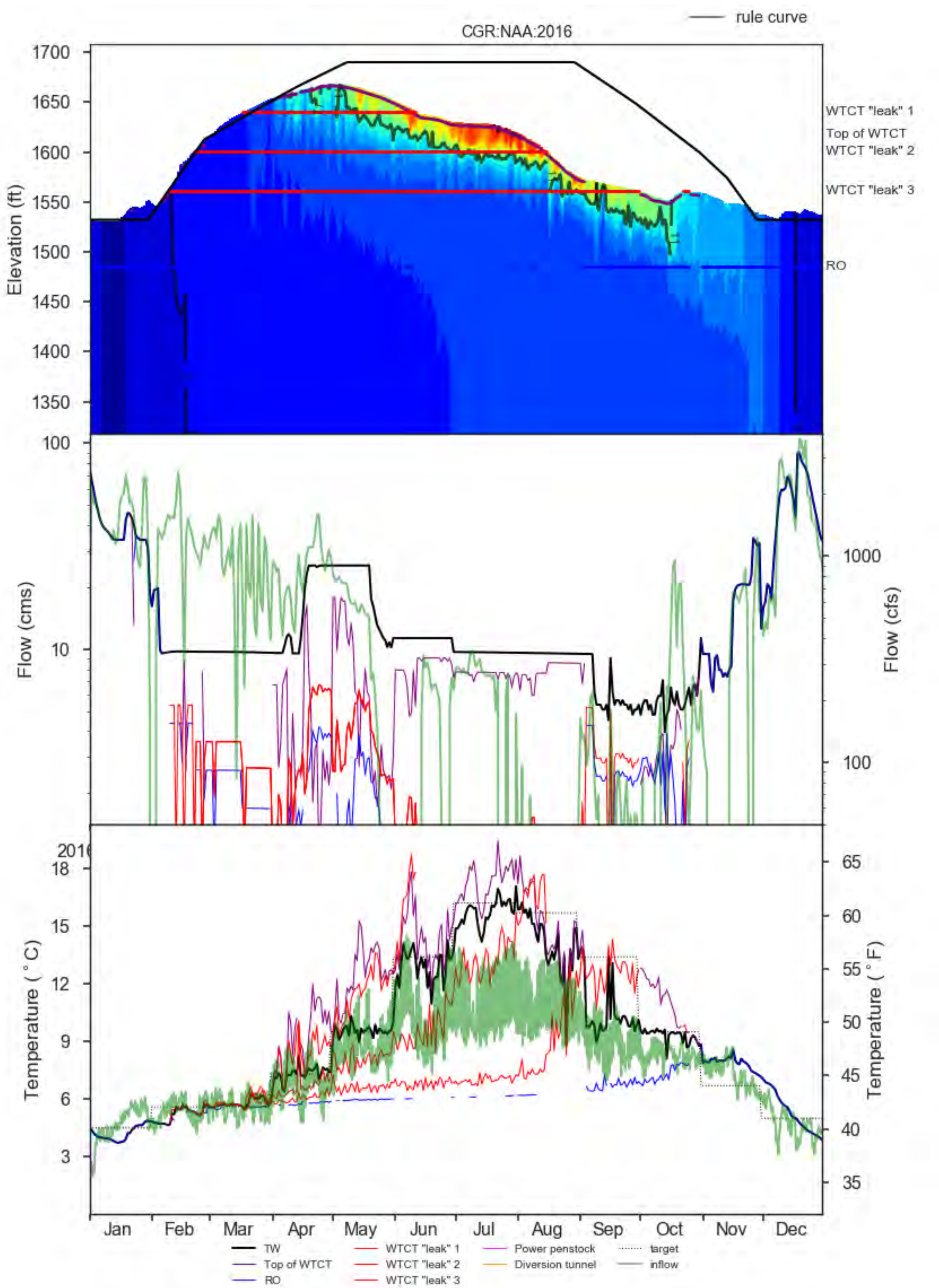

Figure 1-28. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at CGR in 2016.

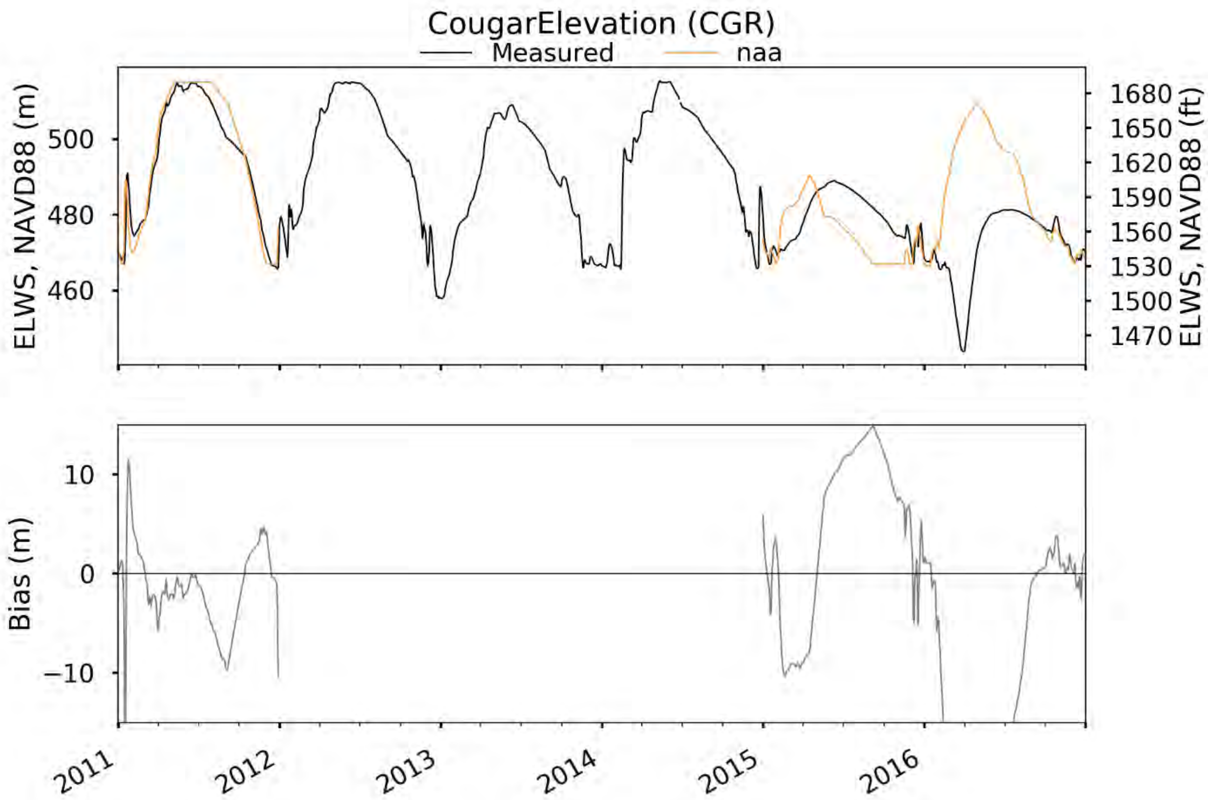

Figure 1-29. Comparison of CGR Daily Lake Surface Elevations in NAA vs Measured.

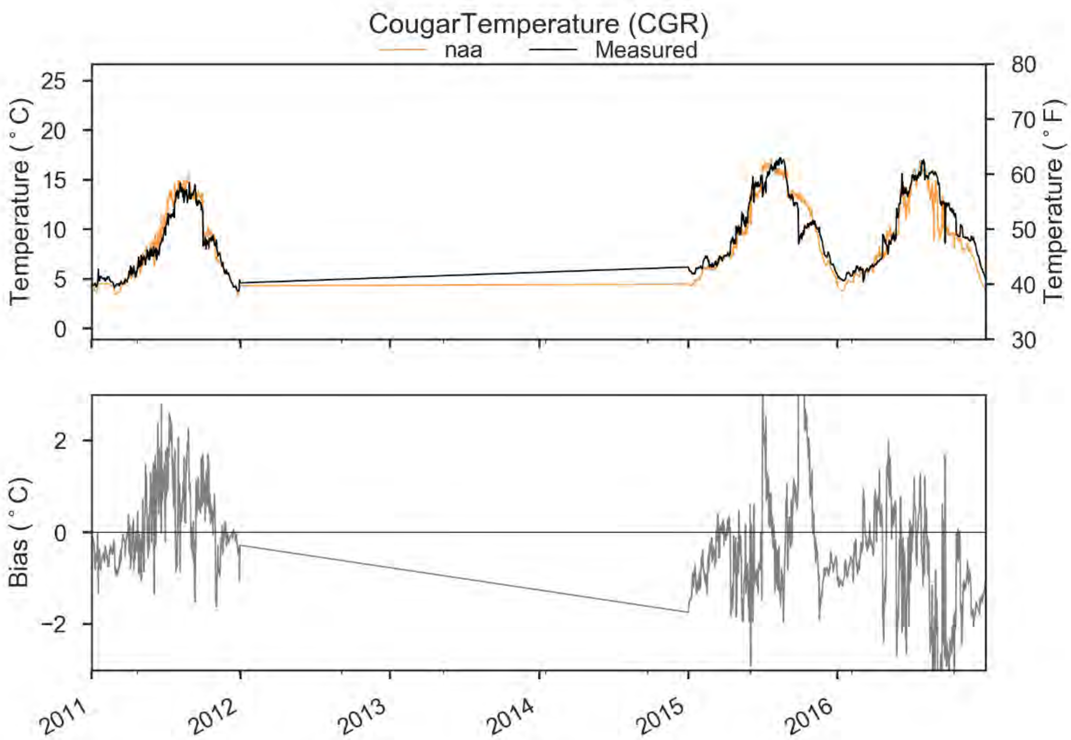

Figure 1-30. Comparison of CGR Outflow Temperatures in NAA vs Measured.

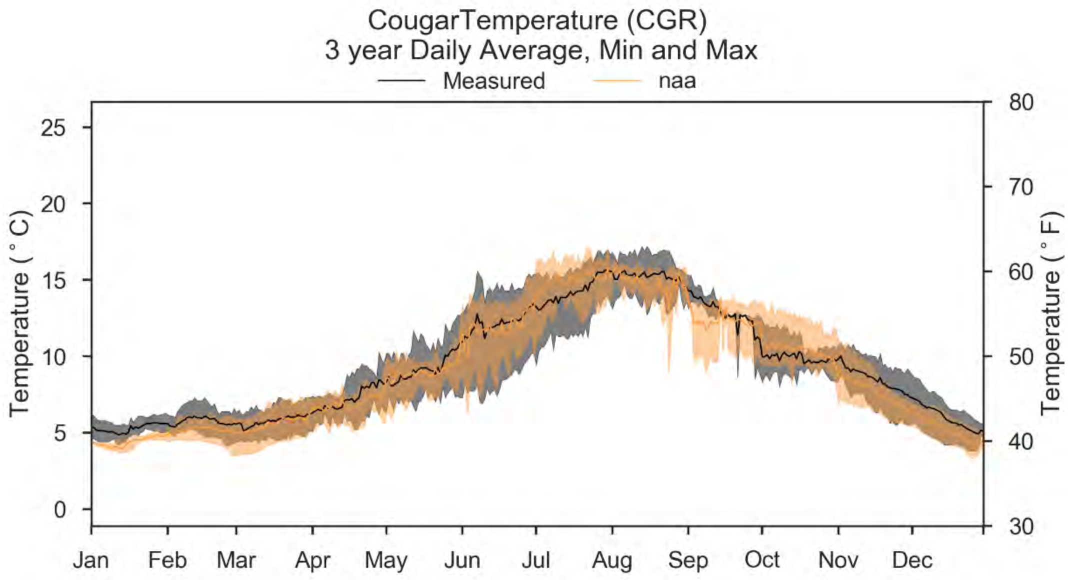

Figure 1-31. Comparison of CGR 3-year average, min, max outflow temperatures in NAA vs Measured.

1.5.1.4 MIDDLE FORK WILLAMETTE DAMS

1.5.1.4.1 Hills Creek

Hills Creek operations in NAA are identical to those under the Affected Environment, consisting of relatively deep releases from the Power penstock and ROs year-round (Figure 1-32; Figure 1-33; Figure 1-34). Differences between NAA and measurements in lake levels in the three calendar-years were relatively minor, aside from 2015 (Figure 1-35), and generally led to differences in outflow tailwater temperatures less than 2 degrees Celsius. Short-term differences between NAA and Measurements in 2015 can be attributed to lower lake levels in NAA (Figure 1-36; Figure 1-37).

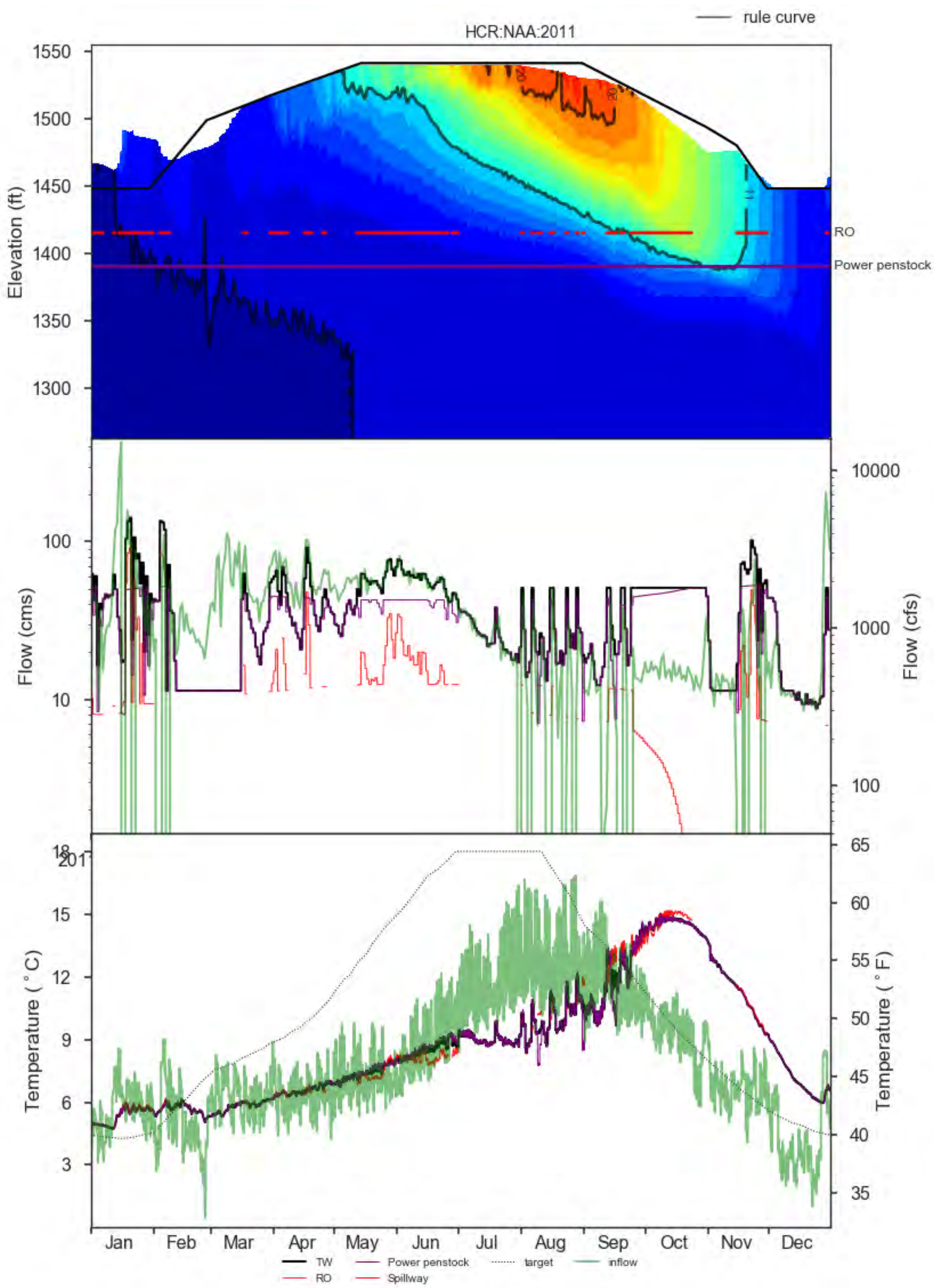

Figure 1-32. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at HCR in 2011.

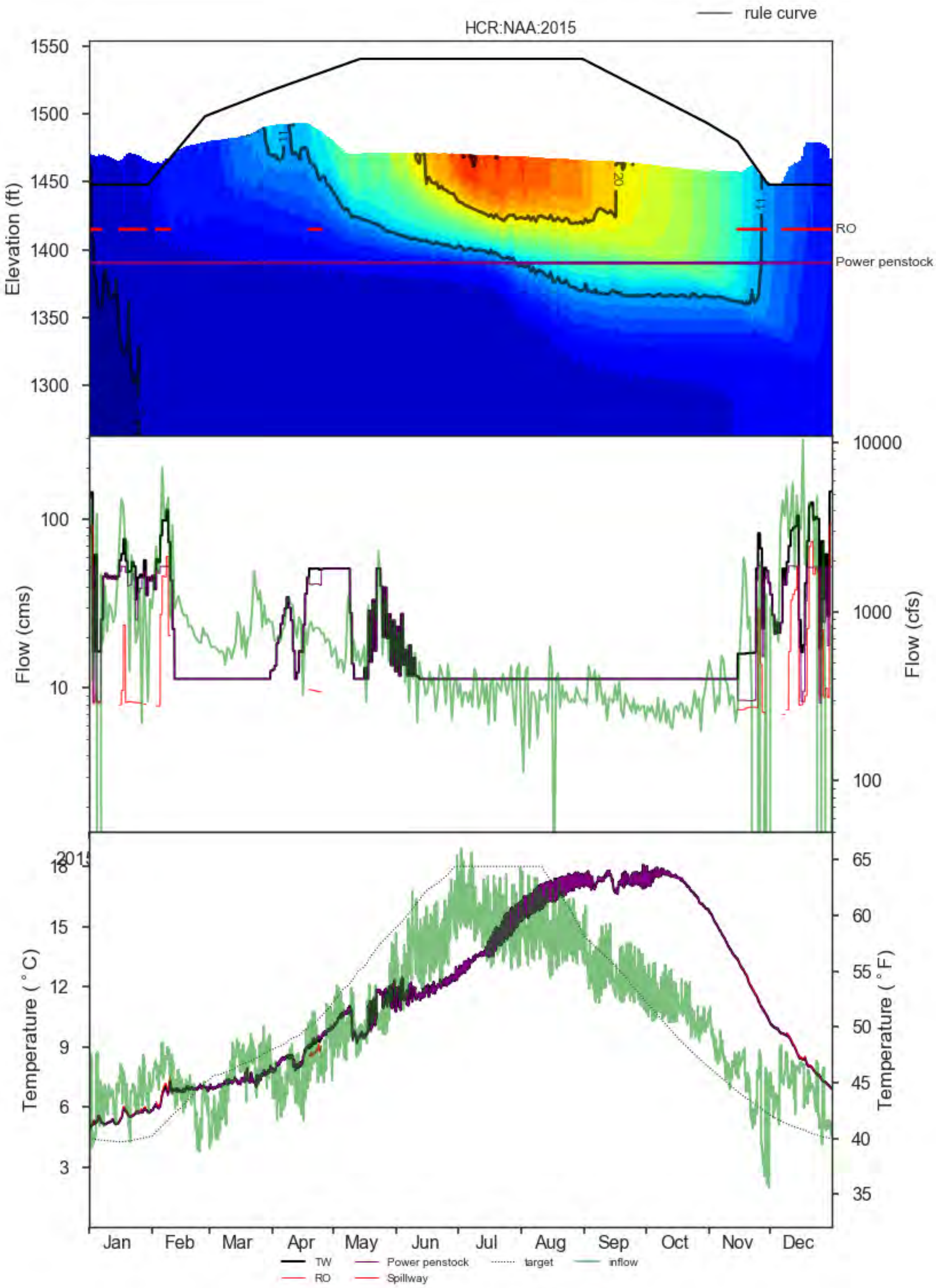

Figure 1-33. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at HCR in 2015.

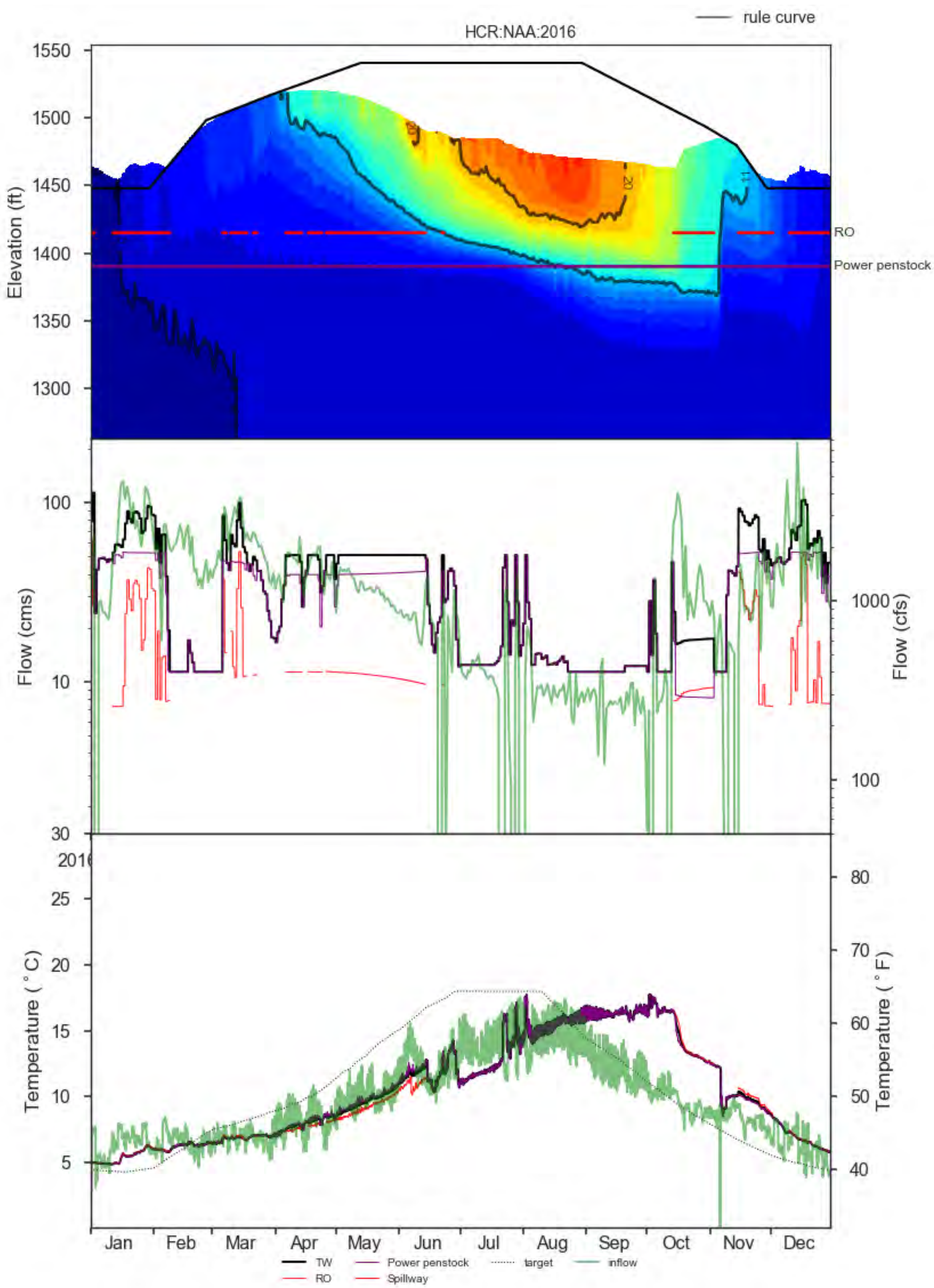

Figure 1-34. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at HCR in 2016.

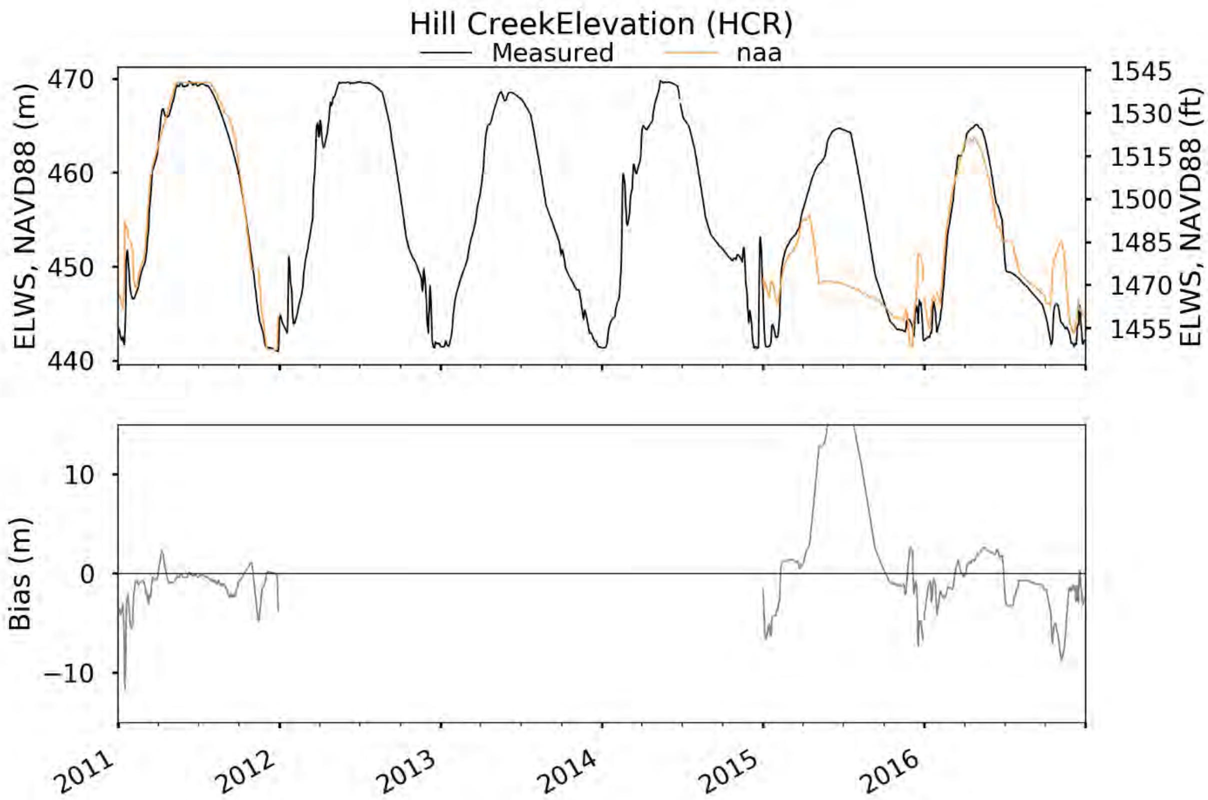

Figure 1-35. Comparison of HCR Daily Lake Surface Elevations in NAA vs Measured.

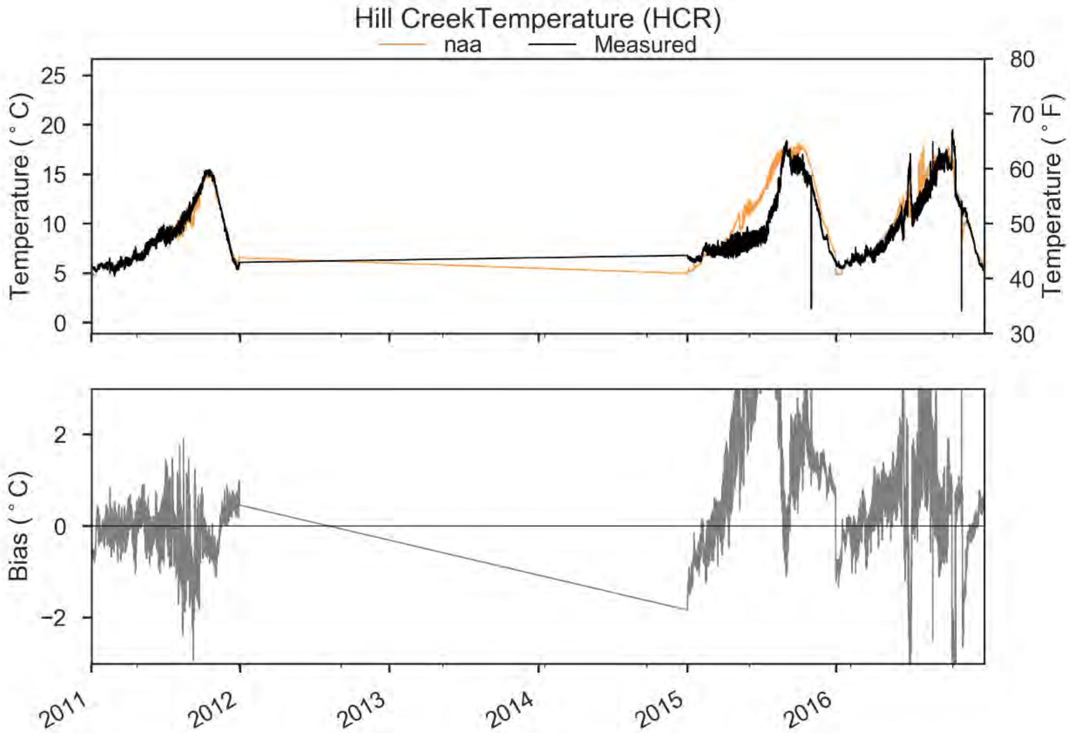

Figure 1-36. Comparison of HCR Outflow Temperatures in NAA vs Measured.

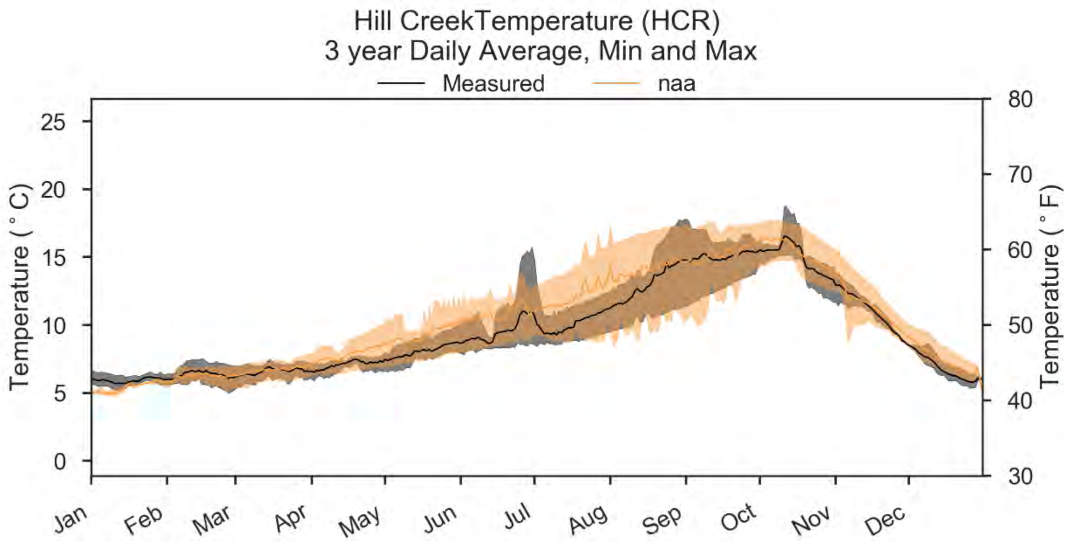

Figure 1-37. Comparison of HCR 3-year daily average, min, max outflow temperatures in NAA vs Measured.

1.5.1.4.2 Lookout Point - Dexter

Lookout Point operations in NAA are identical to those under the Affected Environment, consisting of relatively deep releases from the Power penstock and ROs year-round (Figure 1-38; Figure 1-39; Figure 1-40). Differences between NAA and measurements in lake levels in the three calendar-year scenarios were relatively minor in 2011, aside from 2015 and 2016 (Figure 1-41). Short-term temperature differences between NAA and measurements in 2015 can be attributed to lower lake levels in NAA (Figure 1-42; Figure 1-43) while other differences in outflow tailwater temperatures were less than 2 degrees Celsius.

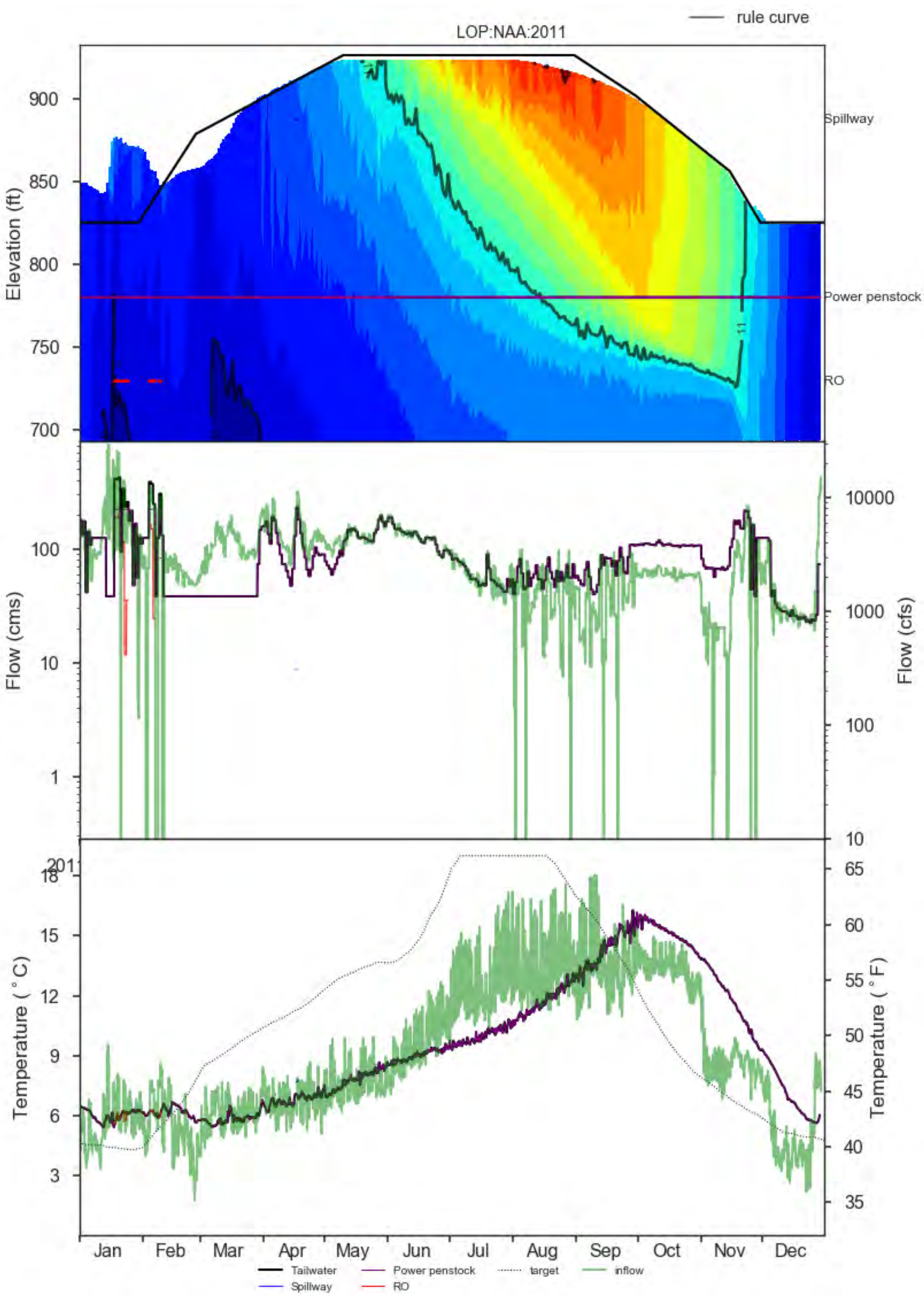

Figure 1-38. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at LOP in 2011.

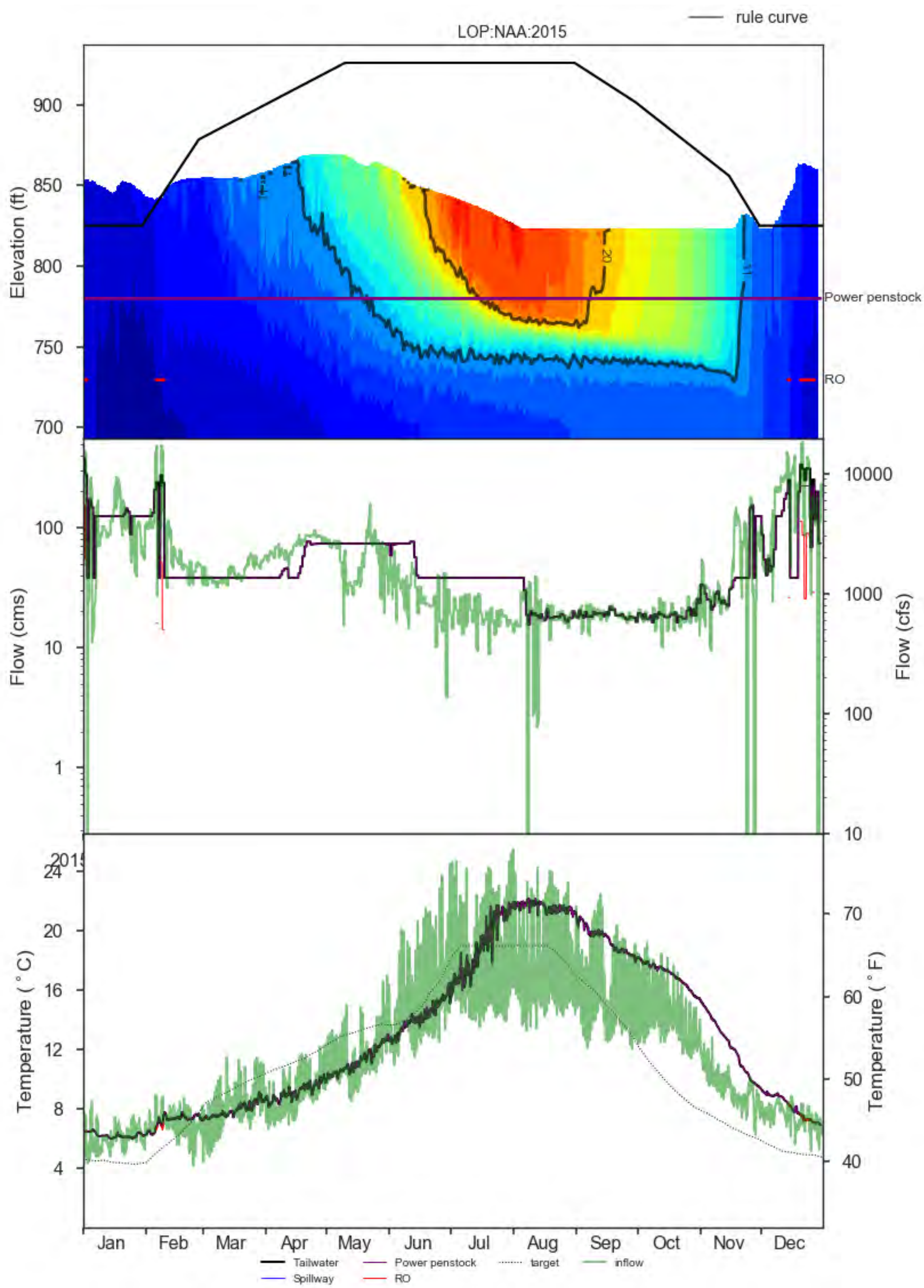

Figure 1-39. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at LOP in 2015.

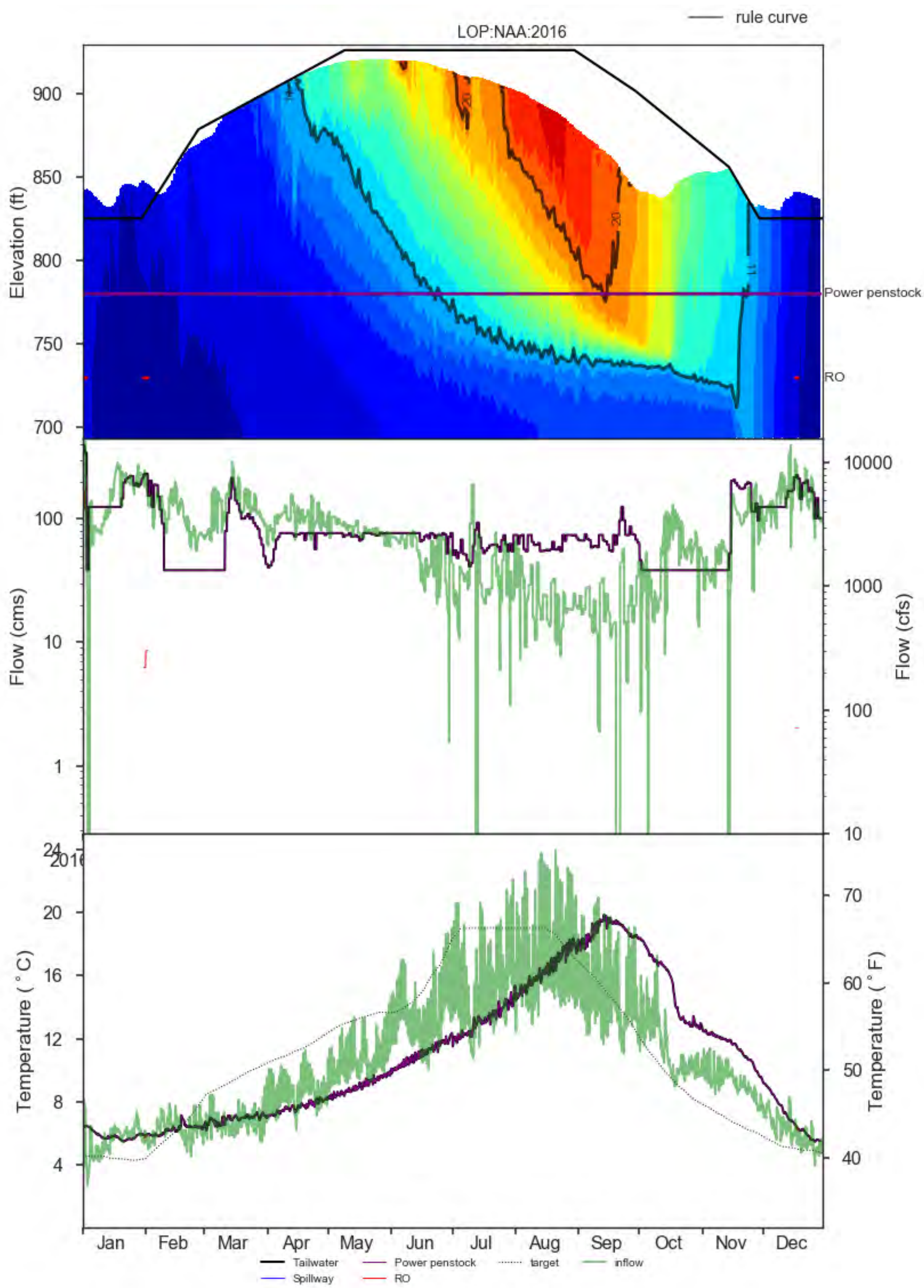

Figure 1-40. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at LOP in 2016.

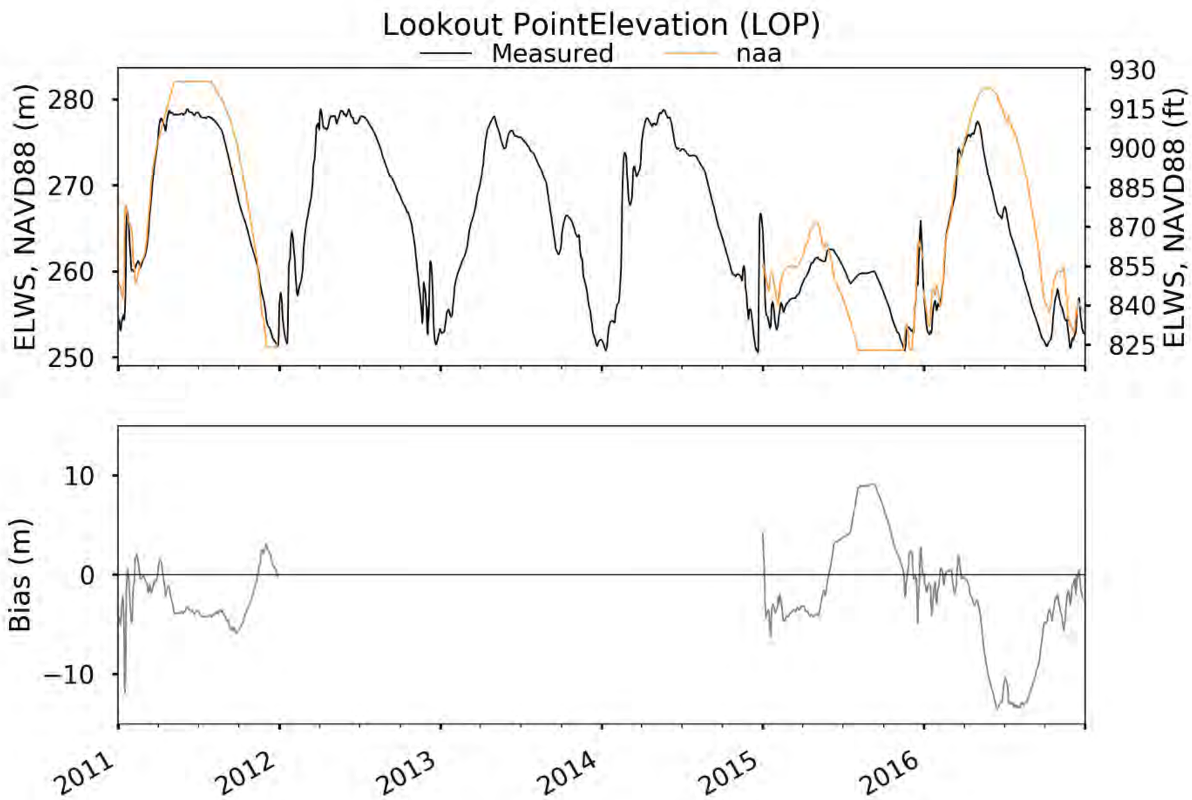

Figure 1-41. Comparison of LOP Daily Lake Surface Elevations in NAA vs Measured.

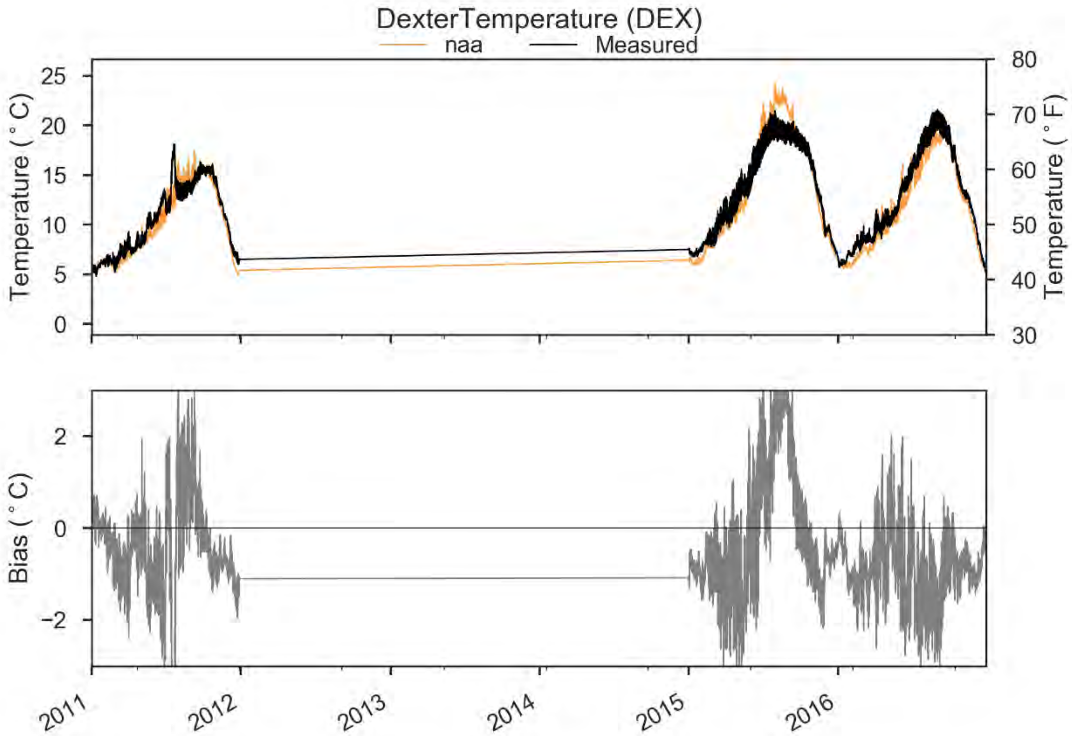

Figure 1-42. Comparison of DEX Outflow Temperatures in NAA and Measured.

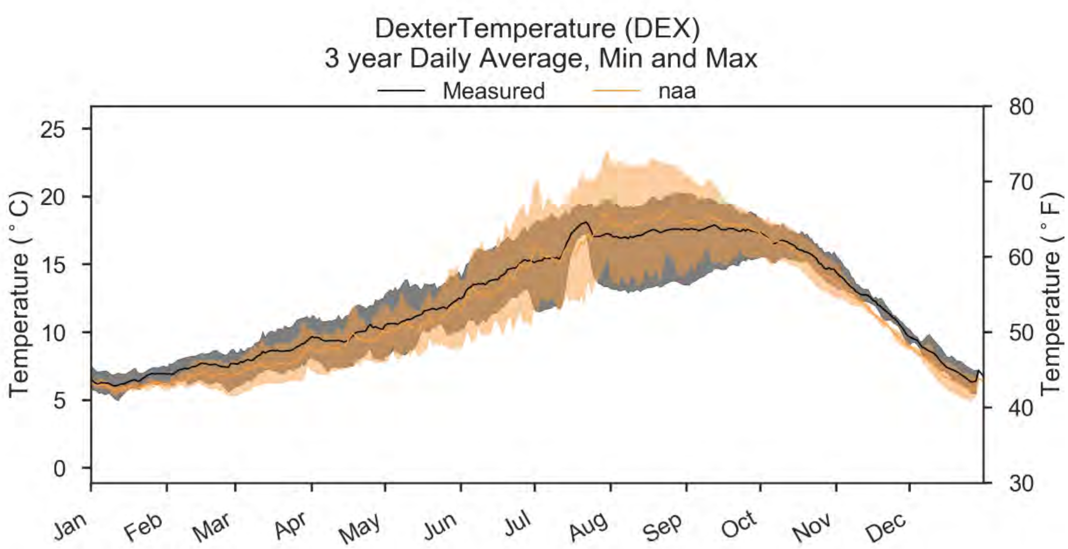

Figure 1-43. Comparison of DEX 3-year daily average, min, max outflow temperatures in NAA and Measured.

1.5.1.5 Mainstem Willamette River

There are no WVS projects located on the Mainstem Willamette River, however water temperatures downstream of the WVS projects can influence temperature regulation on the Willamette River. Heat source tracking in the Willamette has shown the heat content in the Willamette at Salem/Keizer during May-August in 2011, 2015, and 2016 was typically less than 20 percent sourced from upstream dam releases, despite the fact that roughly 50 percent of total streamflow during those months is attributed to upstream dam releases (Rounds and Stratton-Garvin, 2022a). Water temperature in NAA is compared with measurements in each of the three calendar-years for the Willamette River at Salem (SLMO) are shown in Figure 1-44 and Figure 1-45. Overall water temperature differences between NAA and measurements were generally less than 2 degrees Celsius, with the greatest differences occurring in 2015.

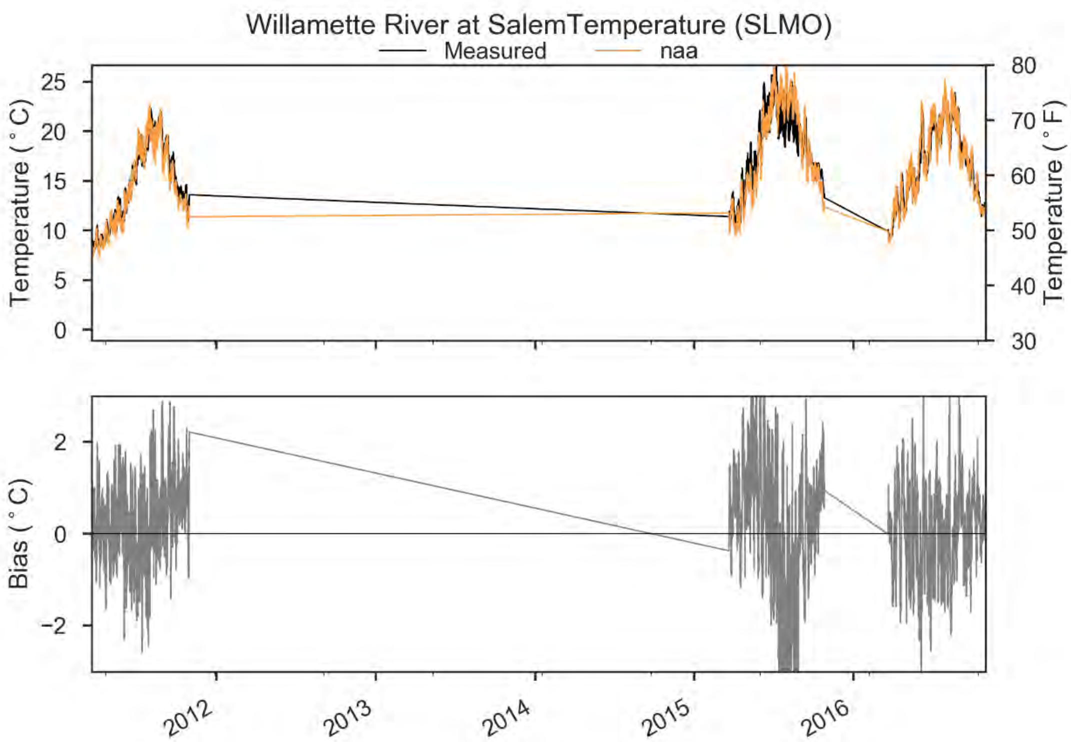

Figure 1-44. Comparison of Willamette River at SLMO Water Temperatures in NAA and Measured.

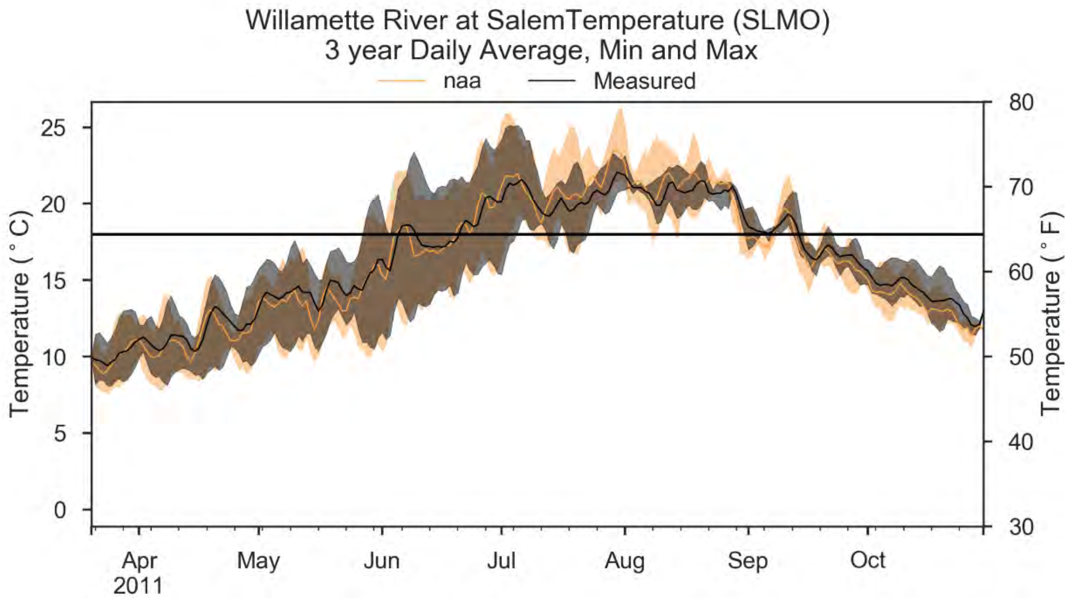

Figure 1-45. Comparison of Willamette River at SLMO 3-year daily average, min, max outflow temperatures in NAA and Measured.

1.5.2 Alternative 1– Project Storage Alternative

Alternative 1 measures that affected operations, lake storage, and water temperature included:

- Structural improvements for water temperature (water temperature control towers or selective water withdrawal structures) at Detroit, Green Peter, and Lookout Point dams.
- Modifications to existing outlets at Foster Dam that would allow releases at varying depths for temperature control by modifying the Facility Warm Water Supply (FWWS) pipe and fish weirs.
- Reduced minimum flow rules (compared to NAA) to congressionally authorized minimum flow rules.
- Flow augmentation by using the power pool or inactive storage.

1.5.2.1 NORTH SANTIAM DAMS

1.5.2.1.1 Detroit

RES-SIM Lake Levels and Outflows

Lake level and storage at Detroit Lake generally increased in Alternative 1 compared to NAA in 2015 and 2016 aside from September-November in 2015 where the power pool was utilized for downstream flow augmentation (Figure 1-46; Figure 1-48). The increased storage coincided with reduced outflows during spring and increased outflows in summer during 2015 and 2016. The proposed SWS and FSS in Alternative 1 allowed all outflow within powerhouse capacity (assumed at 4600 cfs) to be routed from a floating outlet through the Power outlets for temperature management, rather than the Spillway or URO flow for temperature management that was used in NAA (Figure 1-47). 2011 operations were generally similar in Alternative 1 and NAA at Detroit Lake.

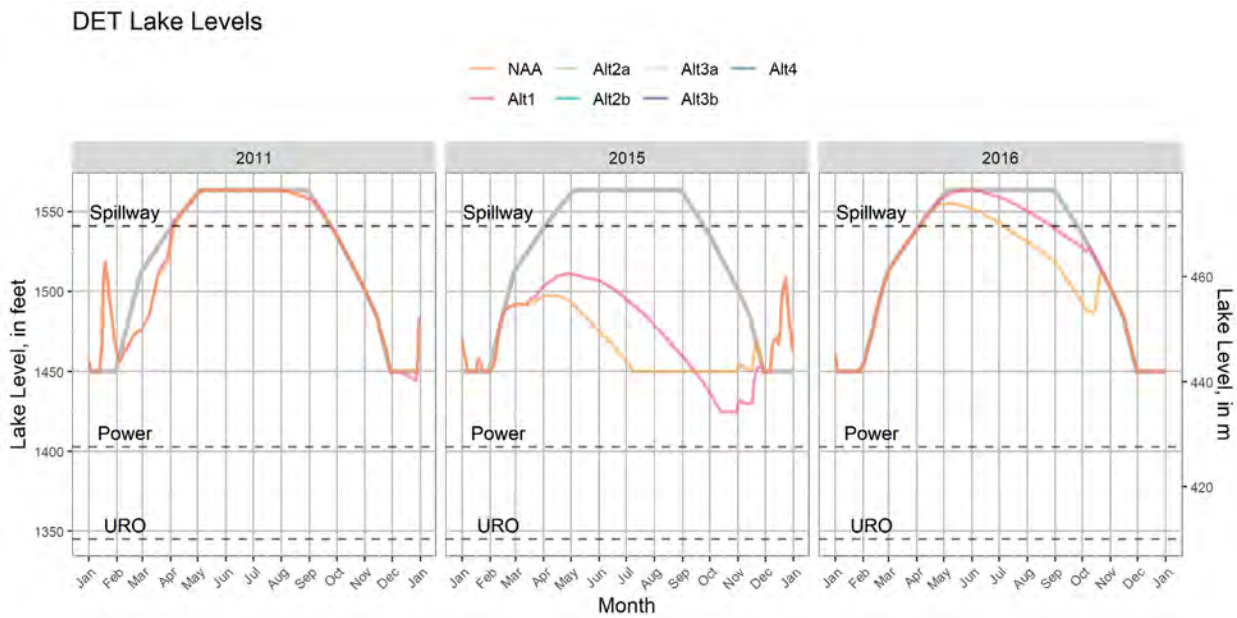

Figure 1-46. WV EIS RES-SIM Detroit Lake Levels in 2011, 2015, and 2016 under Alternative 1 and NAA.

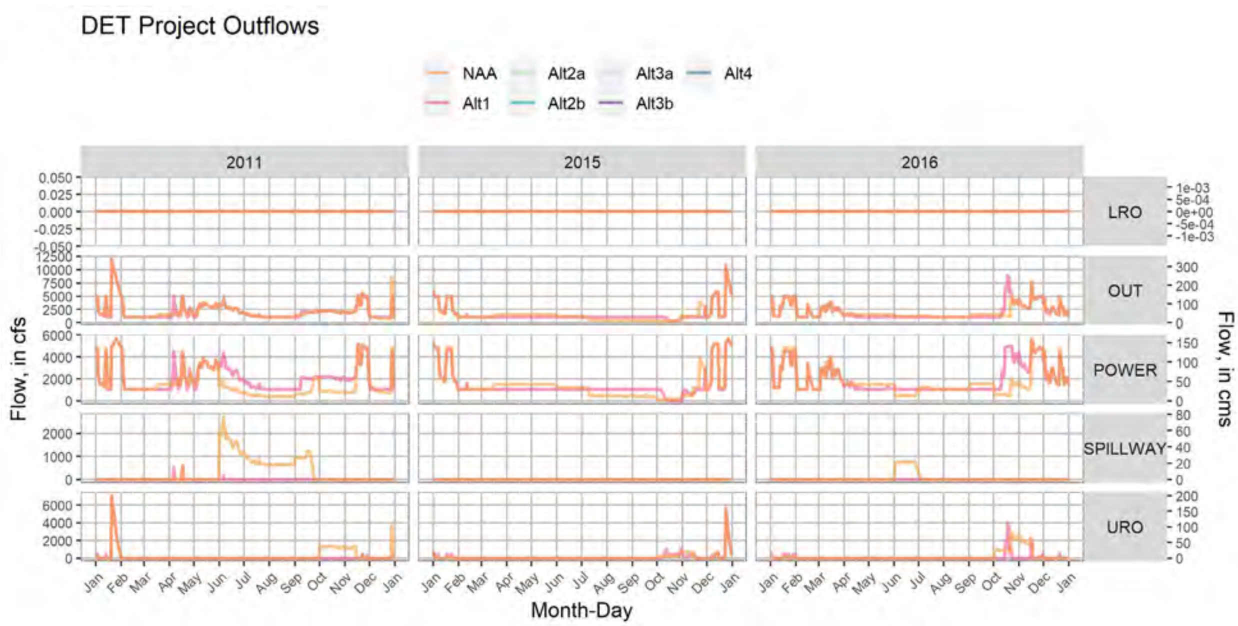

Figure 1-47. WV EIS RES-SIM gate-specific outflows in 2011, 2015, and 2016 under Alternative 1 and NAA.

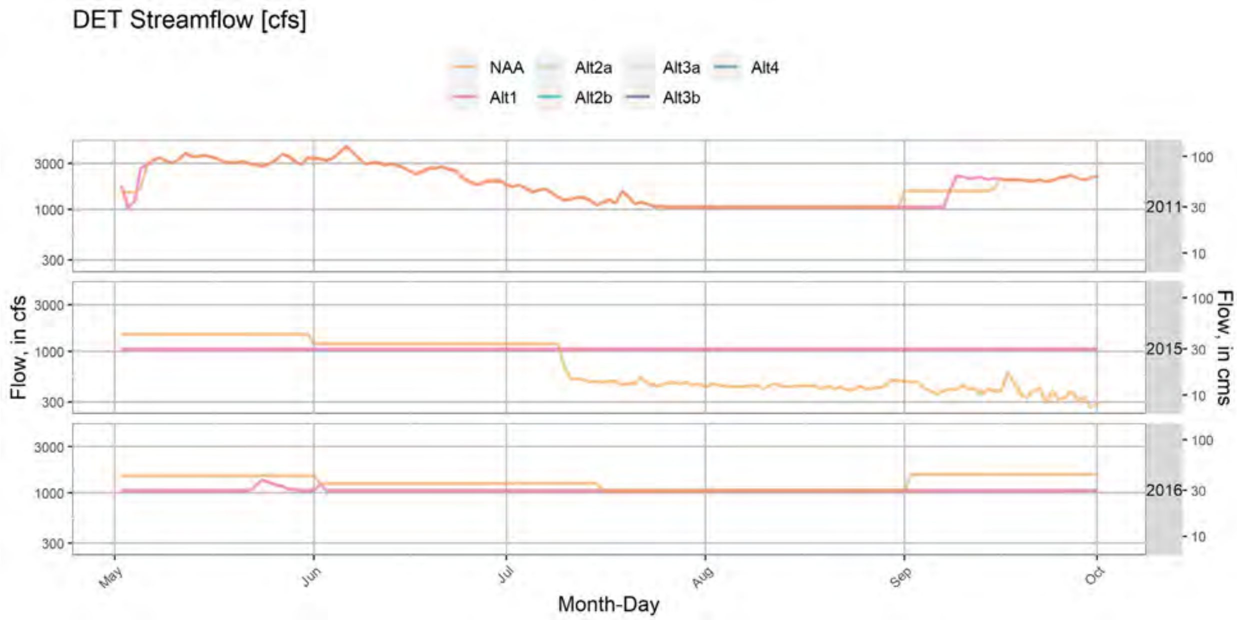

Figure 1-48. WV EIS RES-SIM Detroit Total Outflow in 2011, 2015, and 2016 under Alternative 1 and NAA.

Lake Levels and Temperatures from CE-QUAL-W2

Depth-varying temperature, gate-specific outflows, and outflow temperatures through each calendar year scenario at Detroit Lake are shown in Figure 1-49, Figure 1-50, and Figure 1-51. Temperature tower outflows blended between a floating outlet (25 feet below lake surface) and a deeper outlet at the elevation of the Upper RO. Tailwater release temperatures generally matched the temperature target when sufficient warm or cool water was available. Generally, this structure allowed temperatures to be warmer than NAA in spring/summer and cooler than NAA in autumn (Figure 1-52, Figure 1-53).

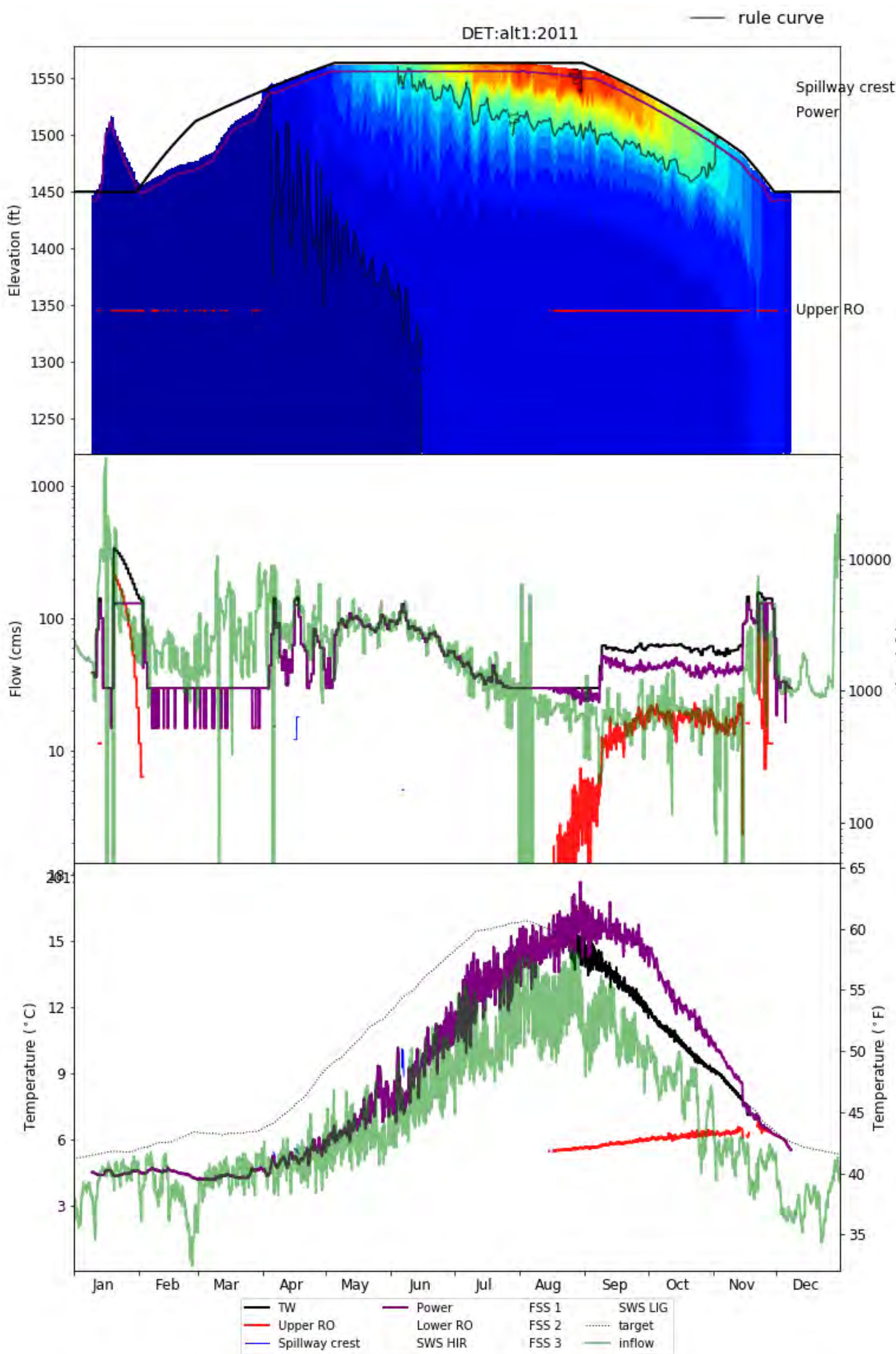

Figure 1-49. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at Detroit Under Alternative 1 in 2011.

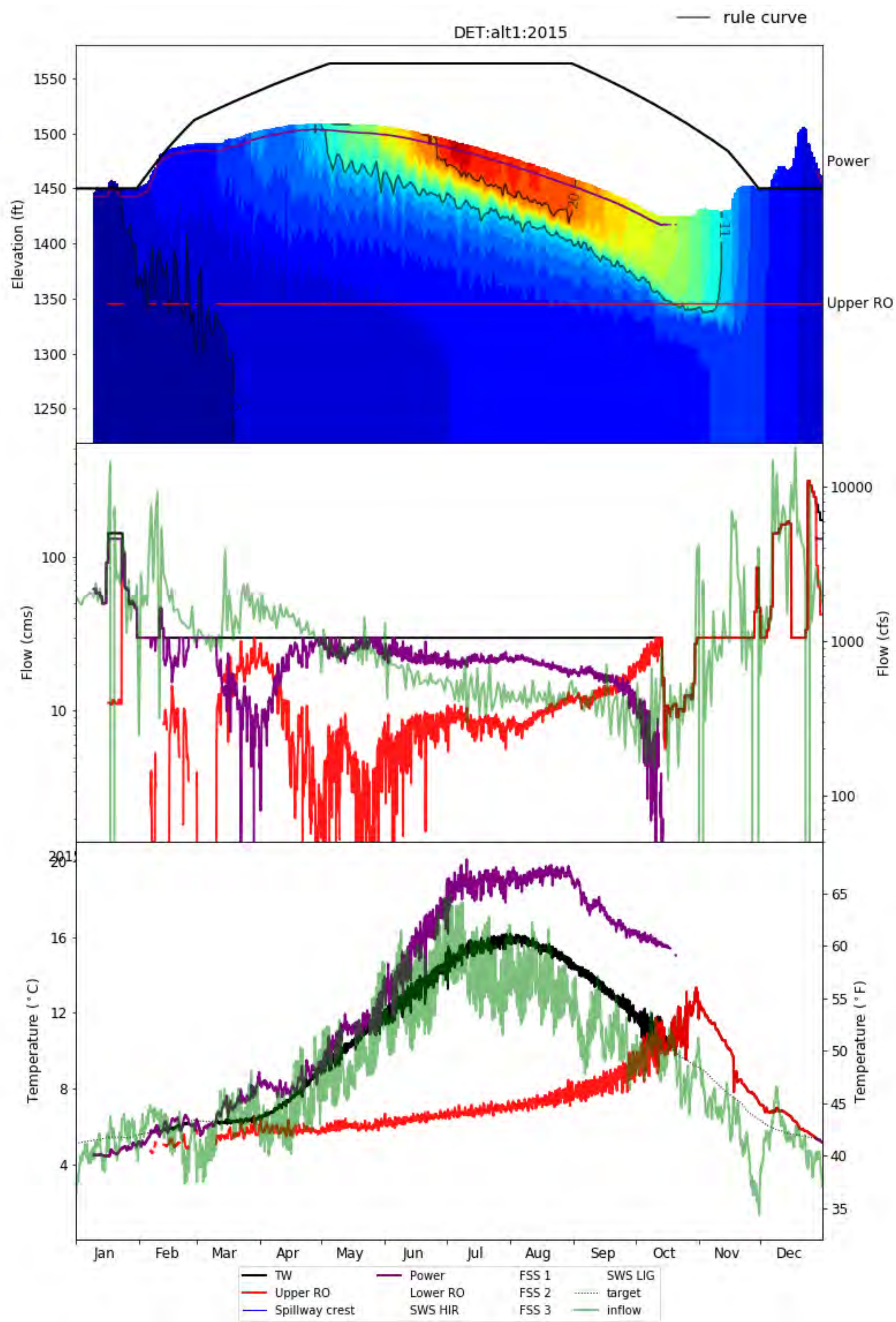

Figure 1-50. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at Detroit Under Alternative 1 in 2015.

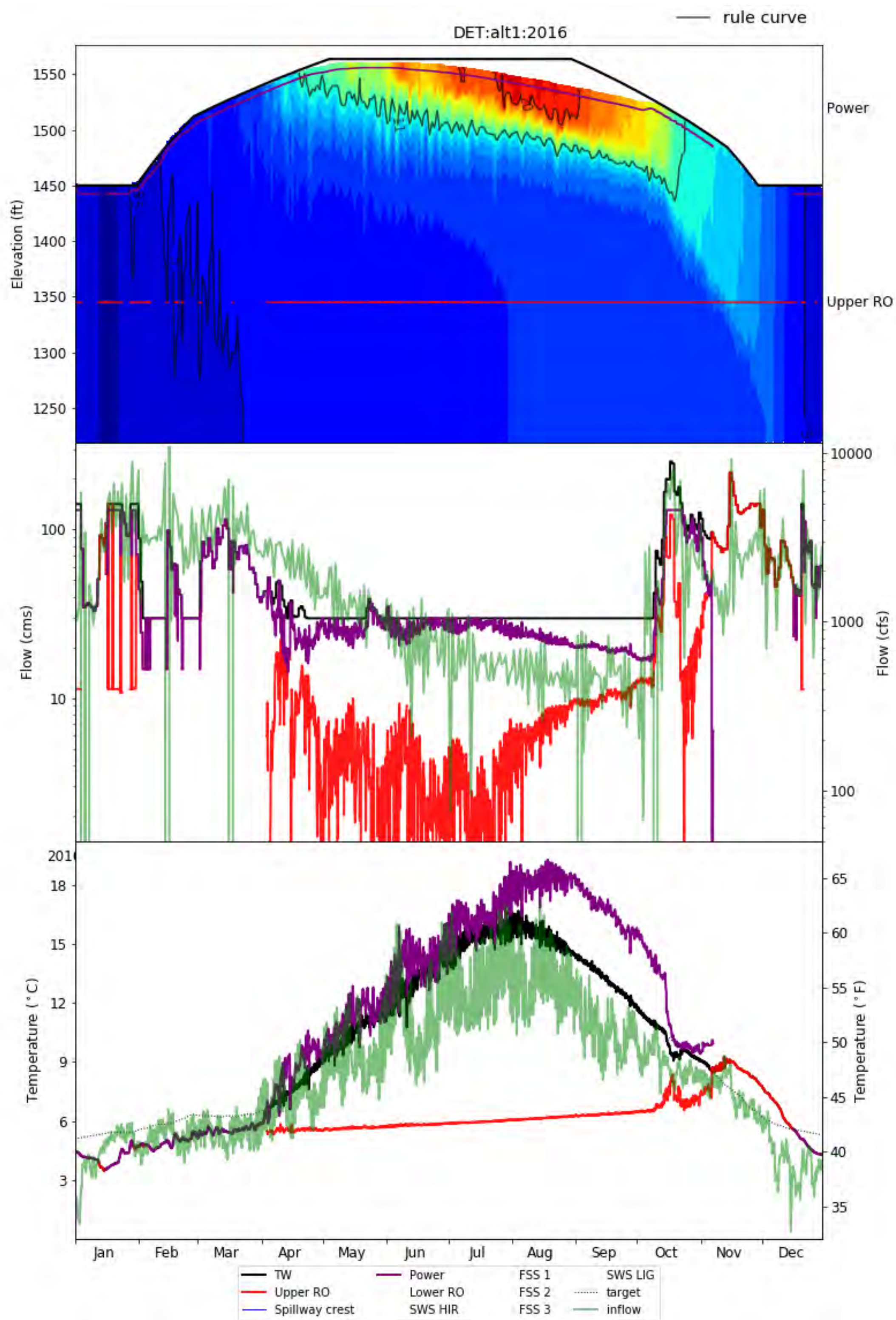

Figure 1-51. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at Detroit Under Alternative 1 in 2016.

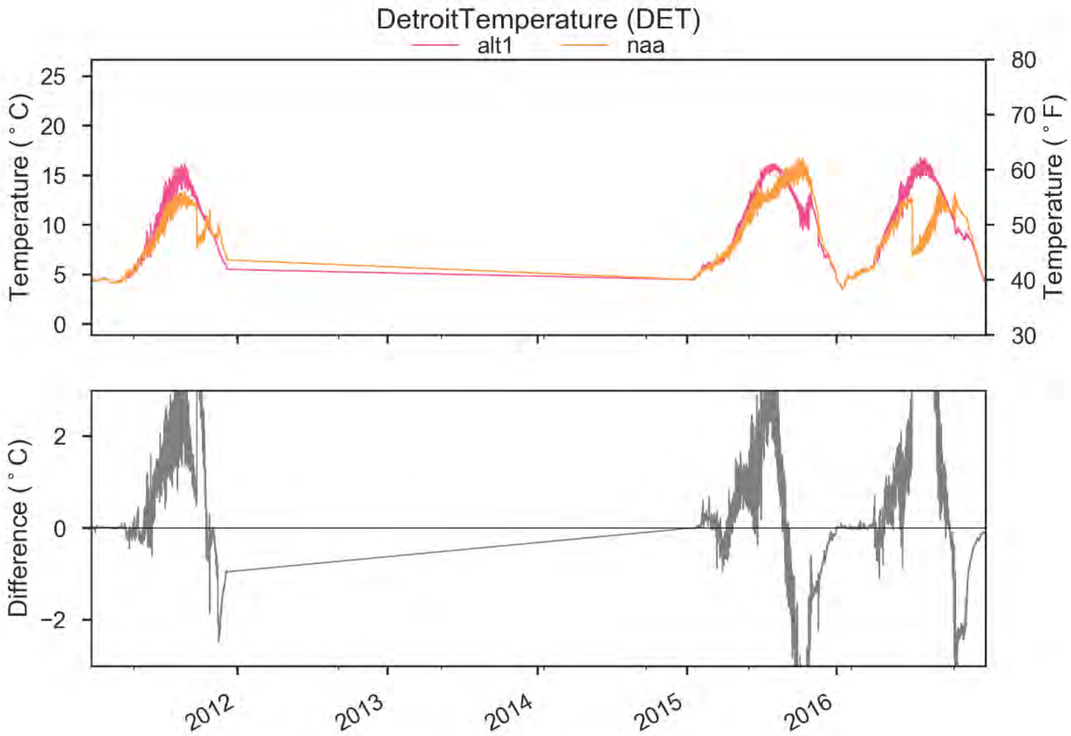

Figure 1-52. Comparison of DET Outflow Temperatures in NAA and Alternative 1.

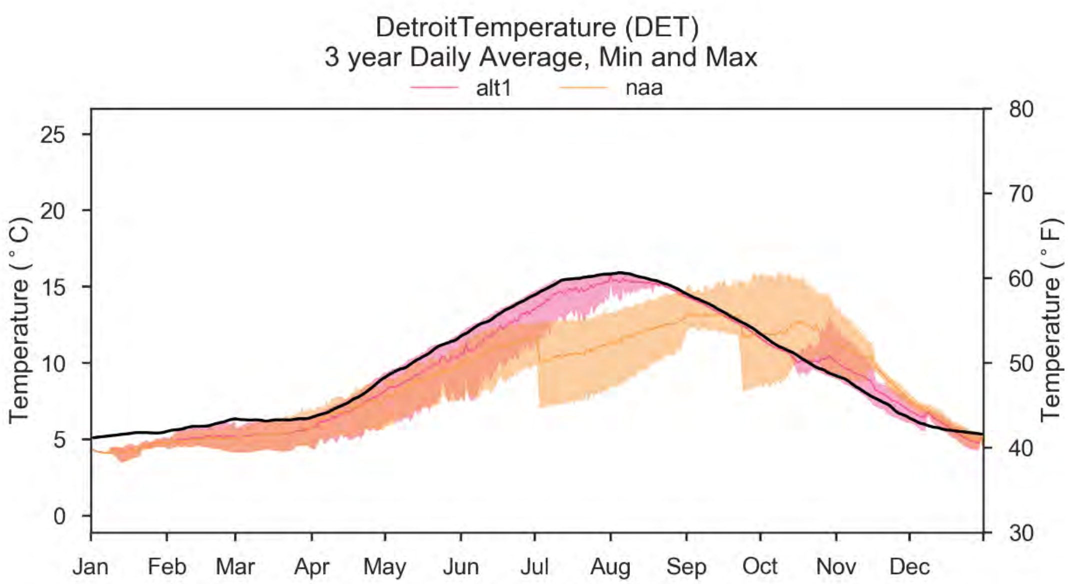

Figure 1-53. Comparison of DET 3-year average, min, max outflow temperatures in NAA and Alternative 1. Black line indicates temperature target.

1.5.2.2 SOUTH SANTIAM DAMS

1.5.2.2.1 Green Peter

RES-SIM Lake Levels and Outflows

Lake level and storage at Green Peter were generally increased in Alternative 1 compared to NAA in 2011, 2015, and 2016 aside from October-November in 2015 where the power pool was utilized for downstream flow augmentation (Figure 1-54, Figure 1-56). The proposed SWS and FSS in Alternative 1 allowed all outflow within powerhouse capacity (assumed at 4000 cfs) to be routed from a floating outlet through the Power outlets for temperature management, which generally matched NAA gate-specific operations related to temperature management (Figure 1-55).

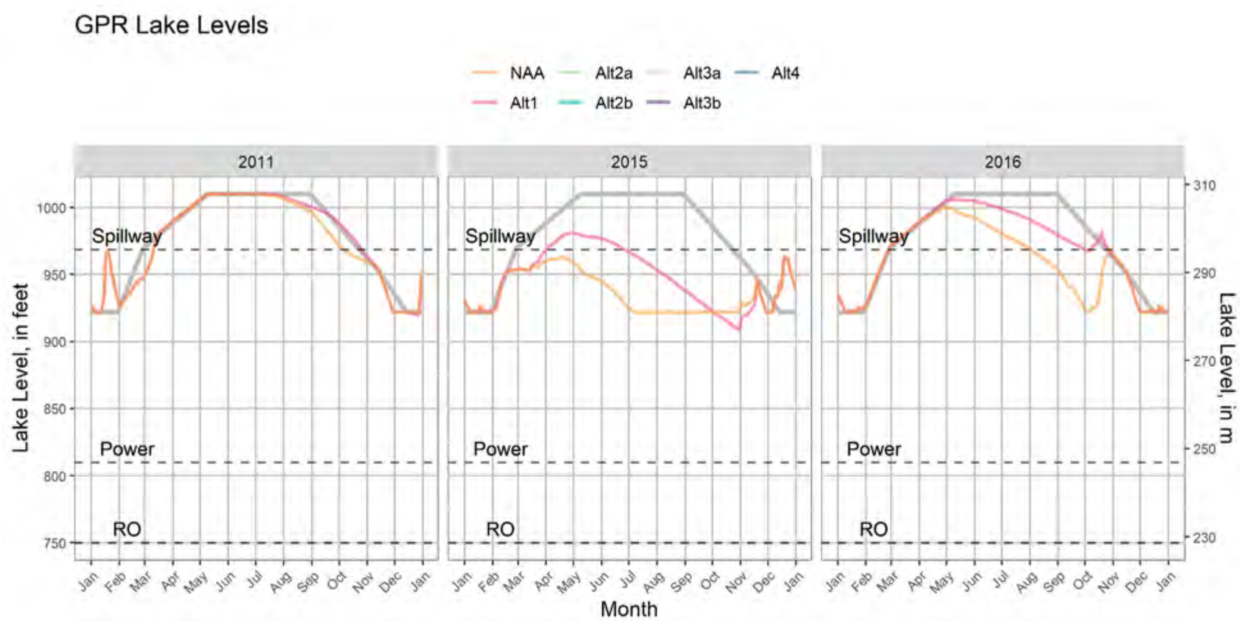

Figure 1-54. WV EIS RES-SIM Green Peter Lake Levels in 2011, 2015, and 2016 Under Alternative 1 and NAA.

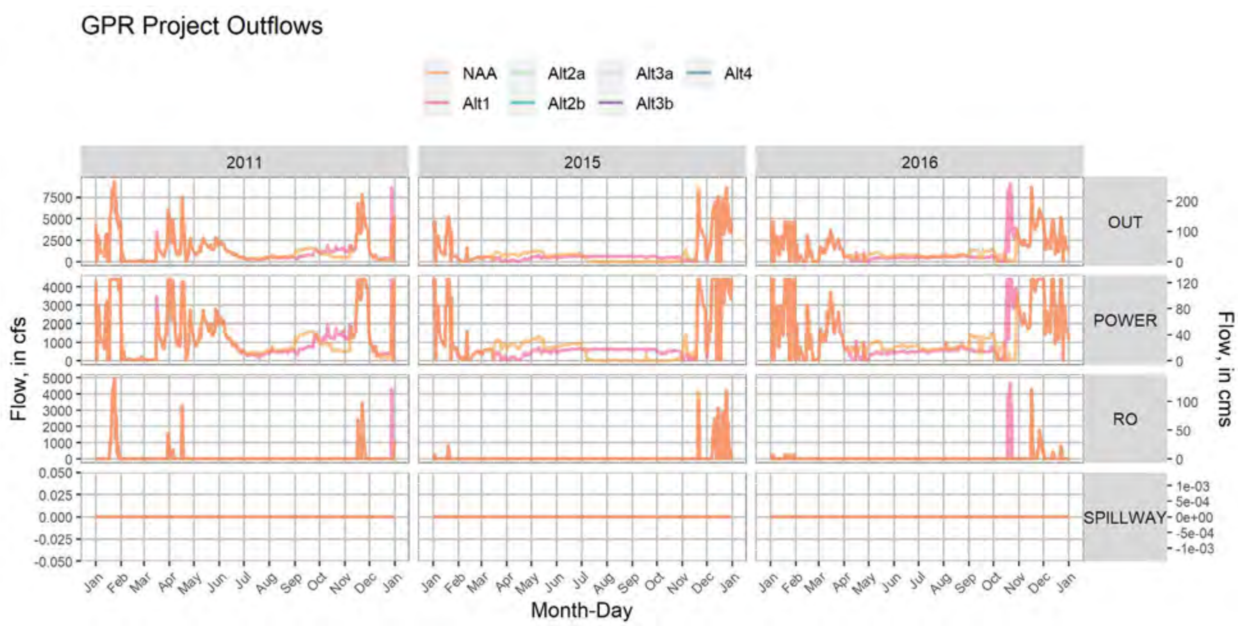

Figure 1-55. WV EIS RES-SIM Green Peter Dam gate-specific Outflows in 2011, 2015, and 2016 Under Alternative 1 and NAA.

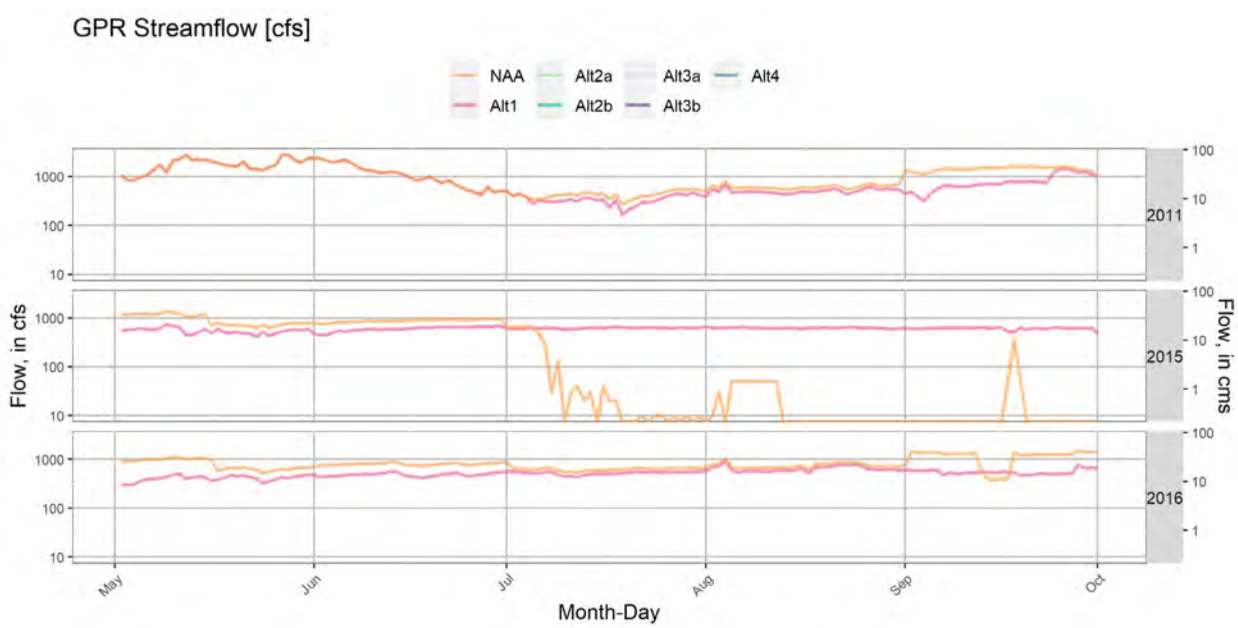

Figure 1-56. WV EIS RES-SIM Green Peter Dam Total Outflow in 2011, 2015, and 2016 Under Alternative 1 and NAA.

Lake Levels and Temperatures from CE-QUAL-W2

Depth-varying temperature, gate-specific outflows, and outflow temperatures through each calendar year scenario at Green Peter Lake are shown in Figure 1-57, Figure 1-58, and Figure 1-59. Temperature tower outflows blended between a floating outlet (25 feet below lake surface) and a deeper outlet at the elevation of the Upper RO. Tailwater release temperatures generally matched the temperature target when sufficient warm or cool water was available. Generally, this structure allowed temperatures to be warmer than NAA in spring/summer and cooler than NAA in autumn (Figure 1-60, Figure 1-61).

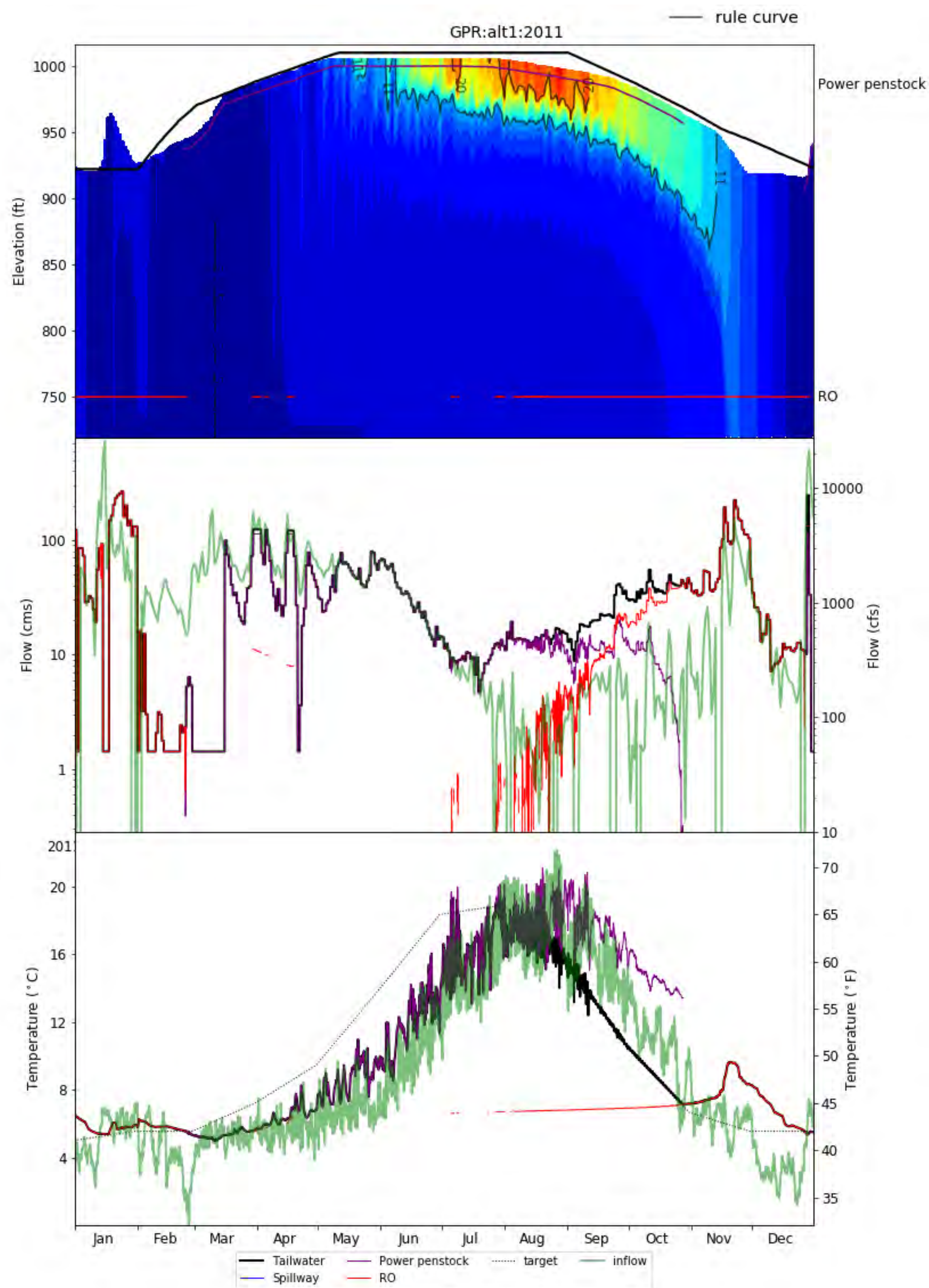

Figure 1-57. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at GPR under Alternative 1 in 2011.

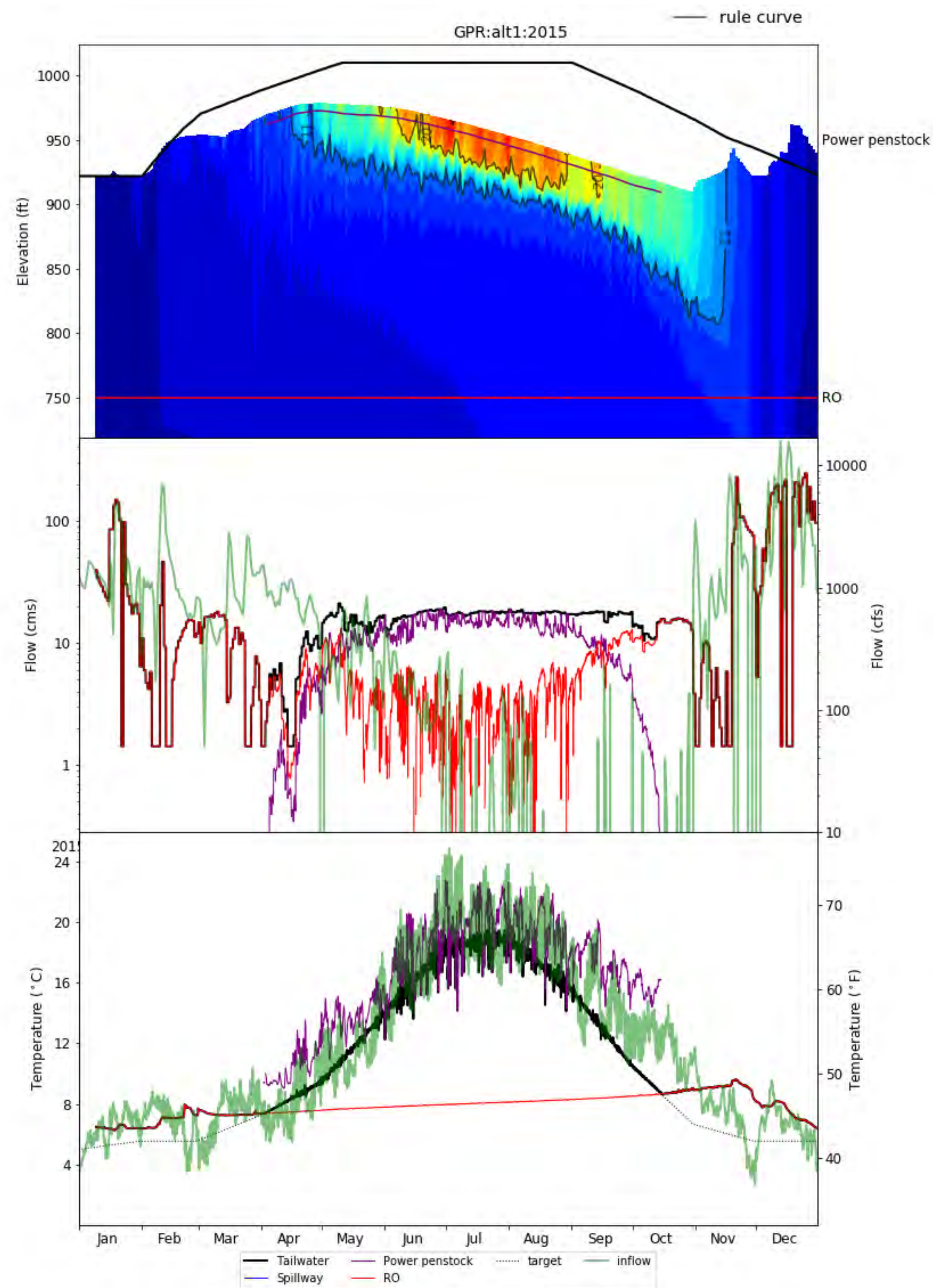

Figure 1-58. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at GPR under Alternative 1 in 2015.

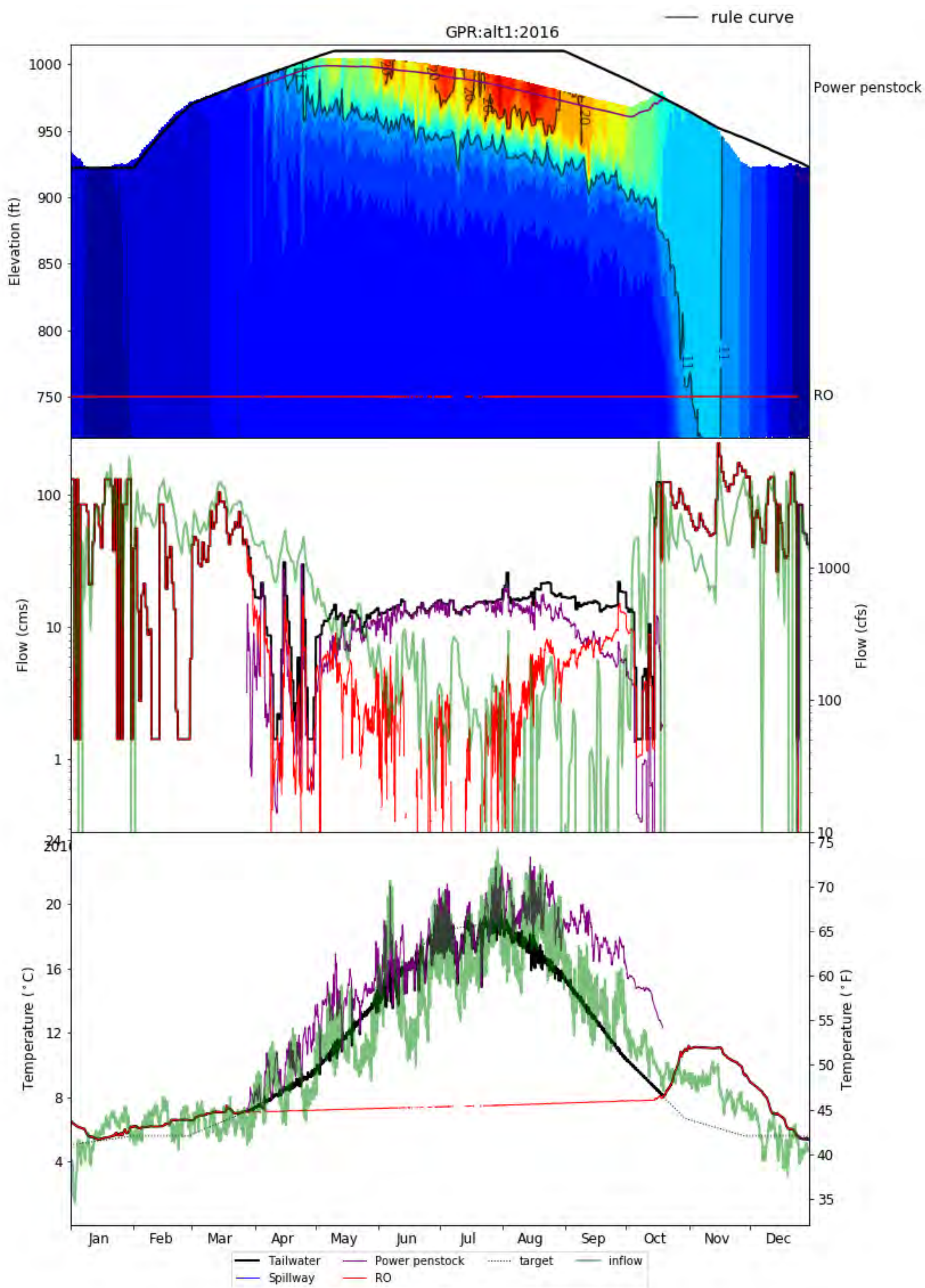

Figure 1-59. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at GPR under Alternative 1 in 2016.

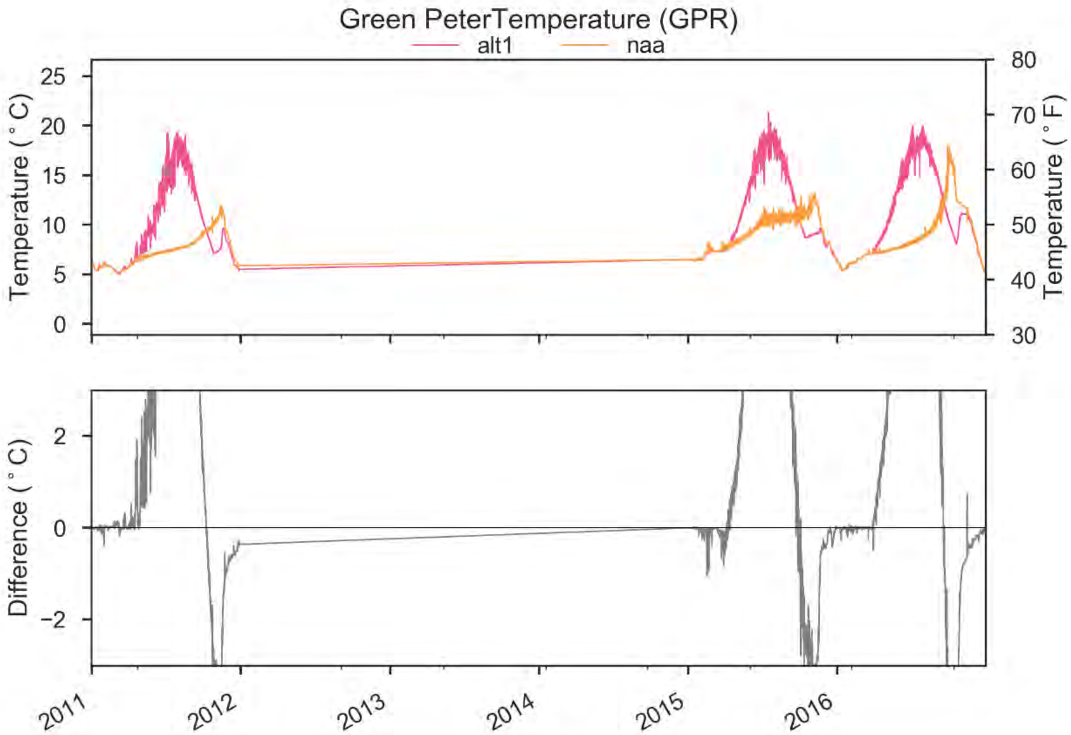

Figure 1-60. Comparison of GPR outflow temperatures in NAA and Alternative 1.

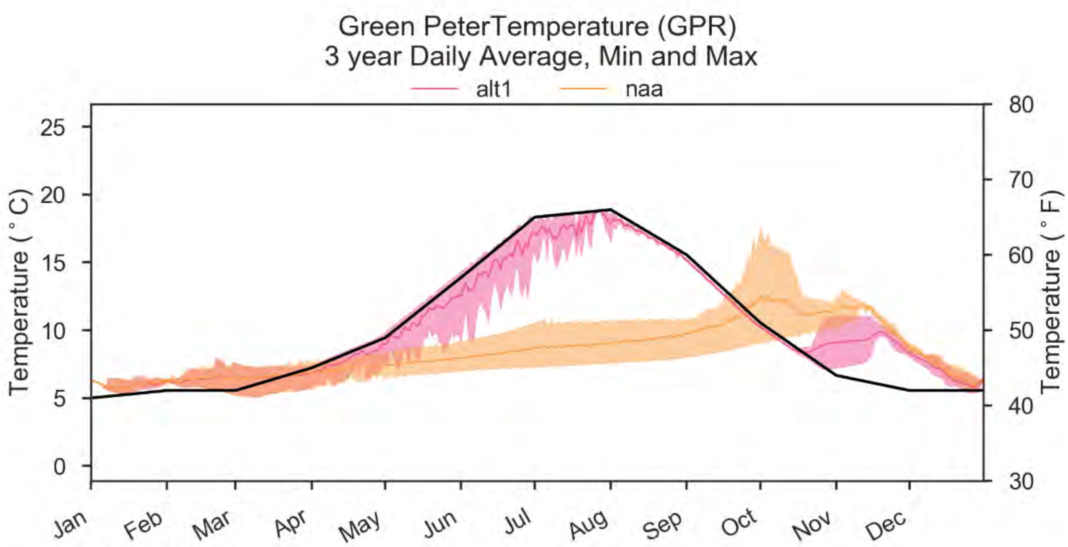

Figure 1-61. Comparison of GPR 3-year Daily Average, Min, Max Outflow Temperatures in NAA and Alternative 1. Black Line Indicates Temperature Target.

1.5.2.2.2 Foster

RES-SIM Lake Levels and Outflows

Lake level and storage at Foster was generally similar in Alternative 1 compared to NAA in 2011 and 2016 but increased in 2015 in Alternative 1 compared to NAA (Figure 1-62, Figure 1-64). Total outflow from Foster Dam was affected by upstream operations at Green Peter Dam. The proposed modifications to the fish weir and FWWS in Alternative 1 resulted in lower outflow routed through the Power outlets for temperature management), especially during spring and summer compared to NAA (Figure 1-63).

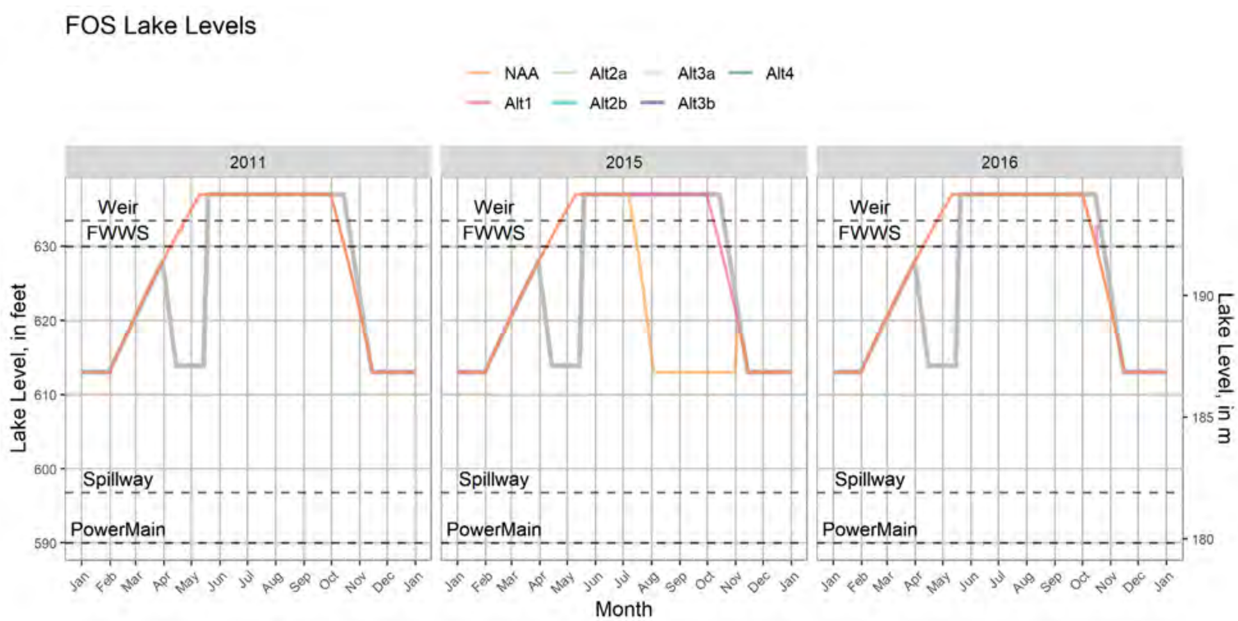

Figure 1-62. WV EIS RES-SIM Foster Lake Levels in 2011, 2015, and 2016 under Alternative 1 and NAA.

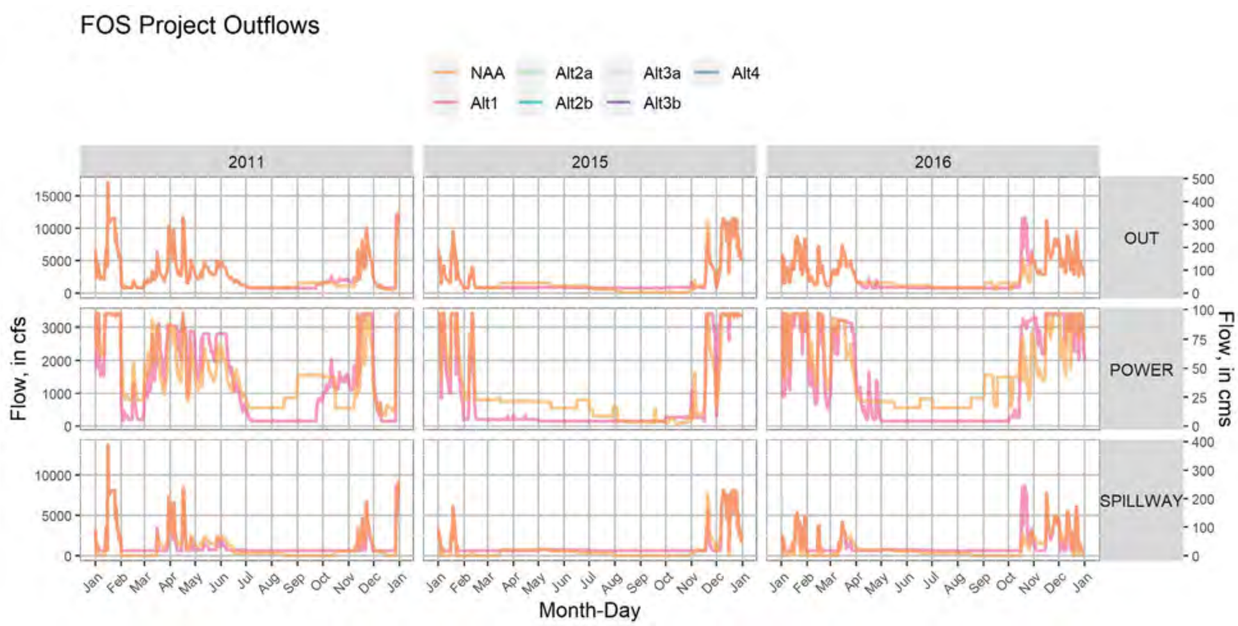

Figure 1-63. WV EIS RES-SIM Foster Dam gate-specific outflows in 2011, 2015, and 2016 under Alternative 1 and NAA.

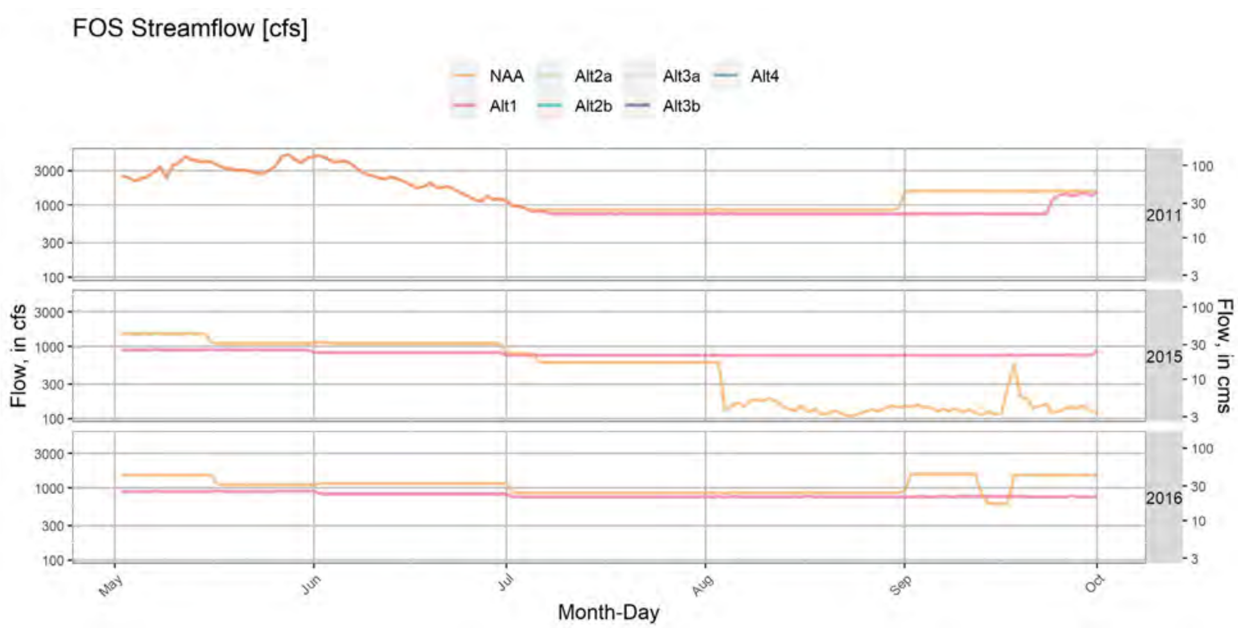

Figure 1-64. WV EIS RES-SIM Foster Dam Total Outflow in 2011, 2015, and 2016 under Alternative 1 and NAA.

Lake Levels and Temperatures from CE-QUAL-W2

Depth-varying temperature, gate-specific outflows, and outflow temperatures through each calendar year scenario at Foster Lake are shown in Figure 1-65, Figure 1-66, and Figure 1-67. Foster Lake temperature was affected by Green Peter Dam operations release temperatures, generally resulting in travel times through Foster of 10-20 days during summer and a time lag in the temperature pattern (Sullivan and Rounds, 2021). Outflows from the proposed fish weir and FWWS resulted in warmer tailwater temperature in spring and summer compared to NAA and cooler than NAA in autumn (Figure 1-68, Figure 1-69).

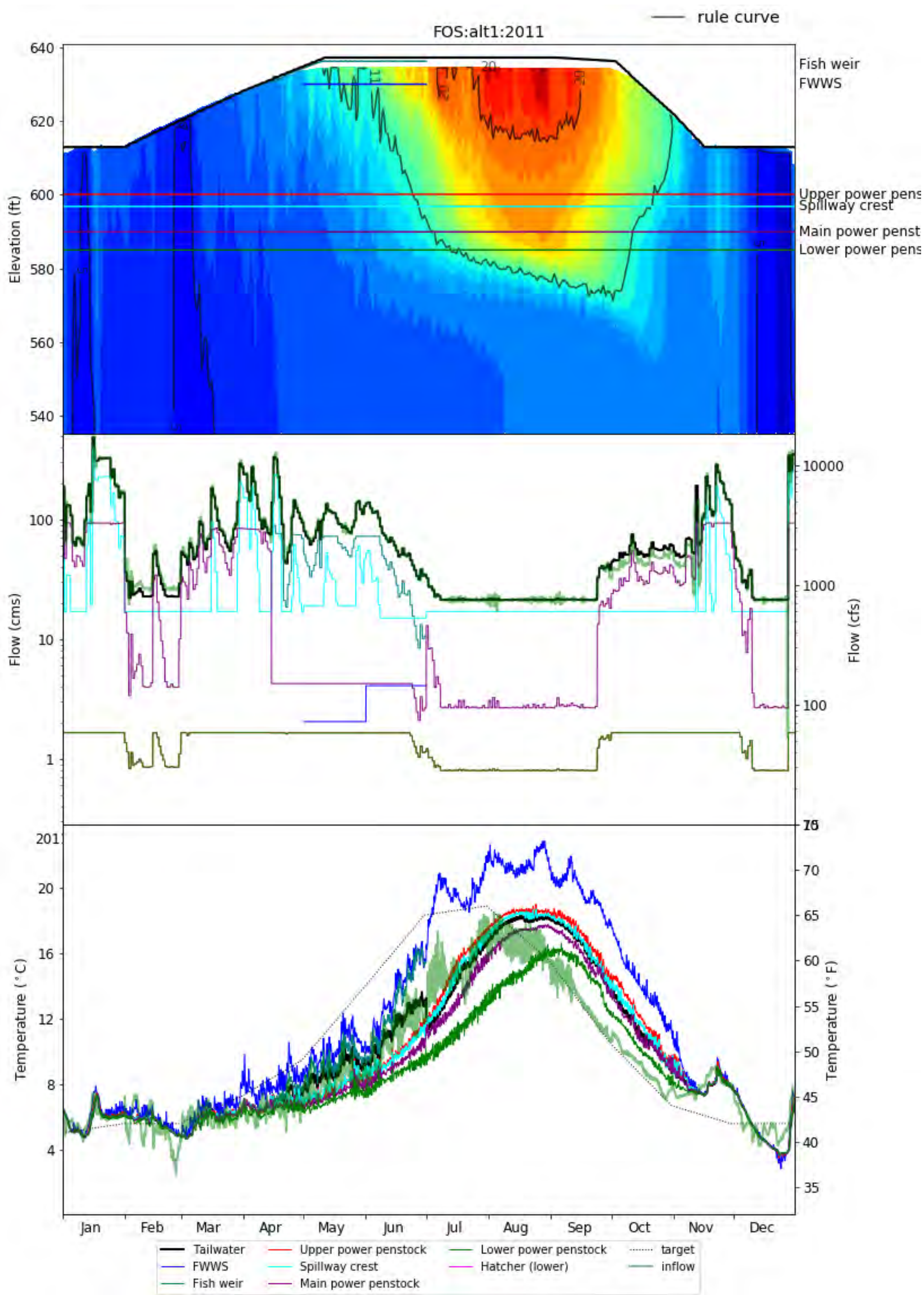

Figure 1-65. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at FOS Under Alternative 1 in 2011.

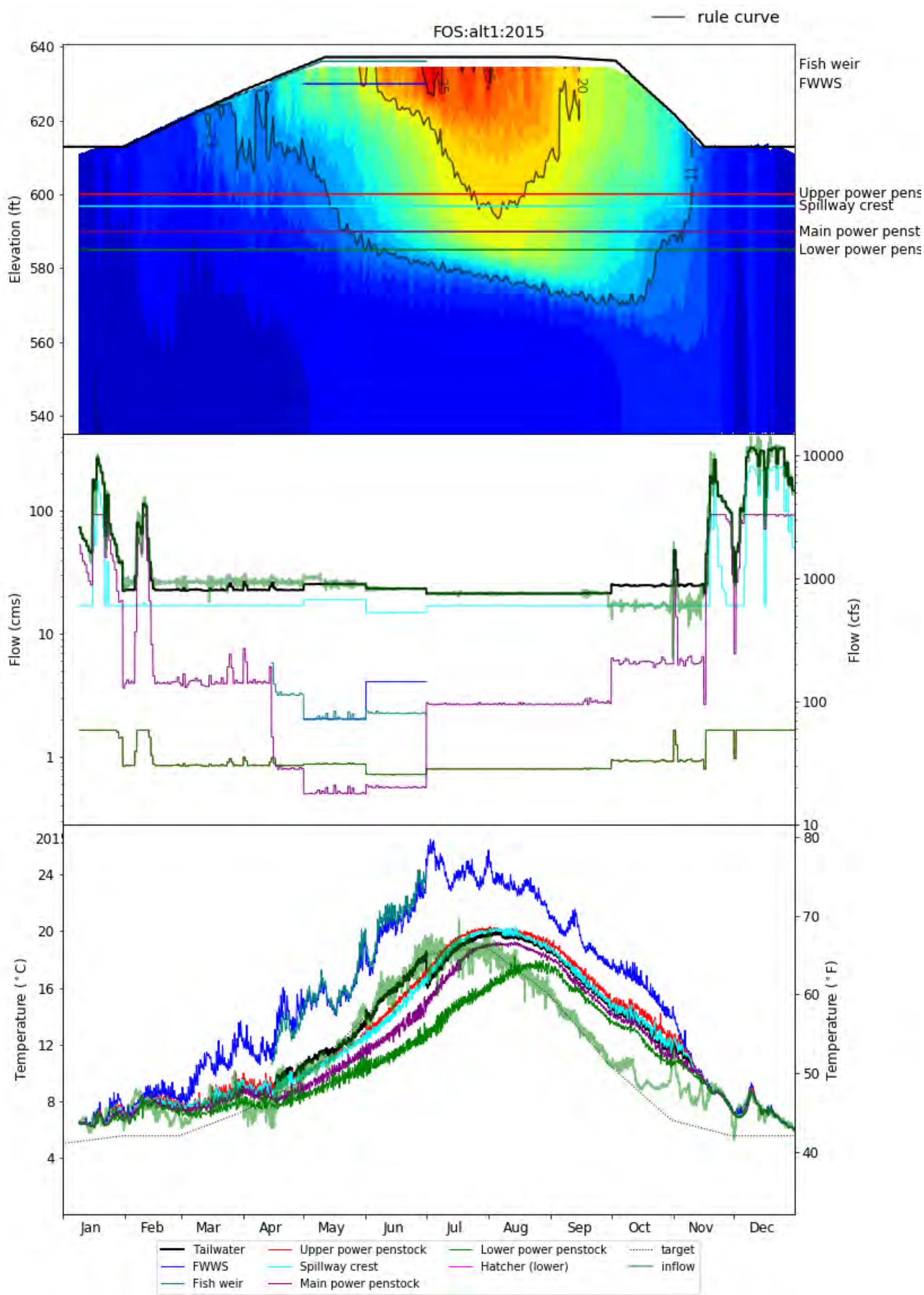

Figure 1-66. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at FOS Under Alternative 1 in 2015.

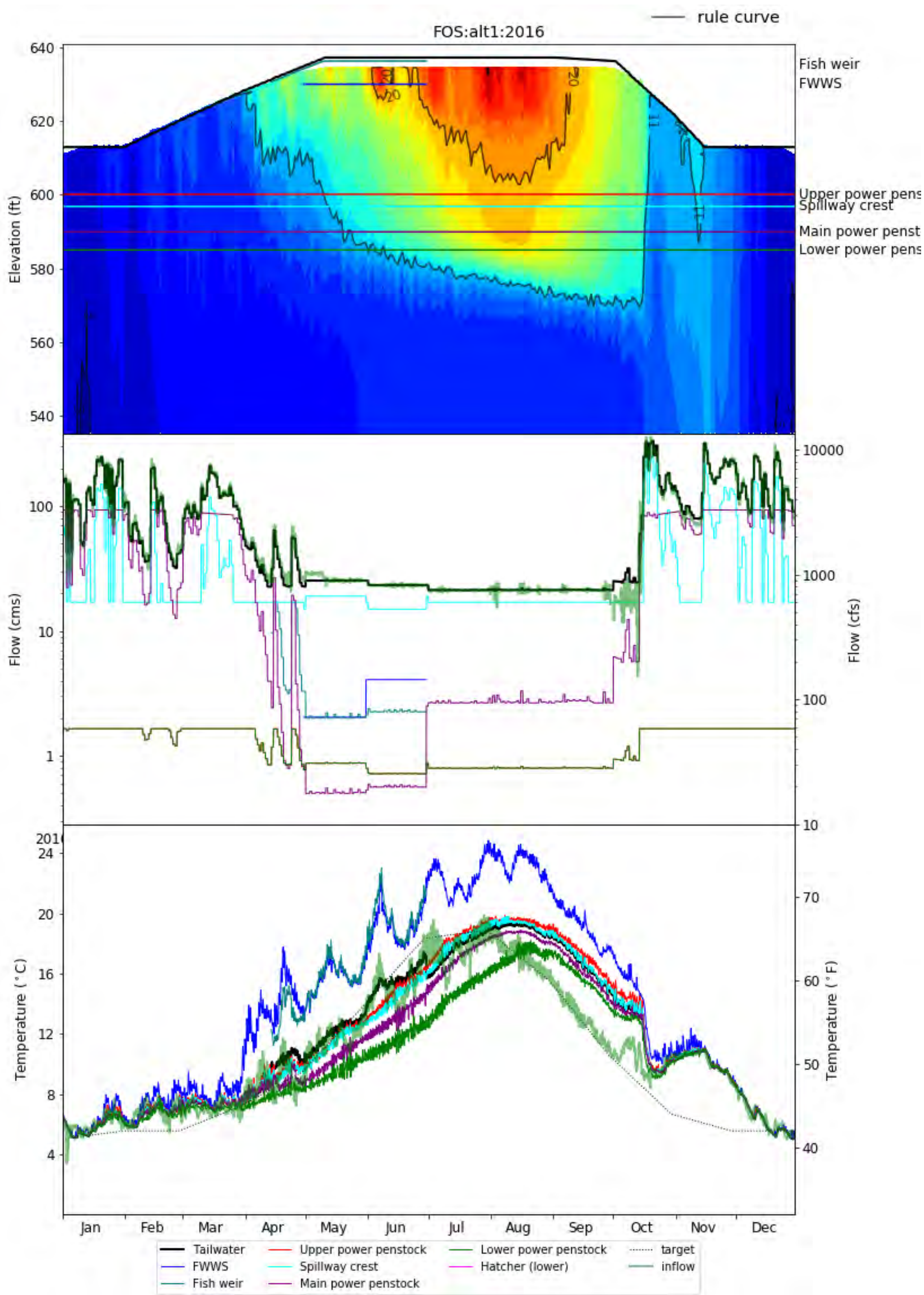

Figure 1-67. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at FOS Under Alternative 1 in 2016.

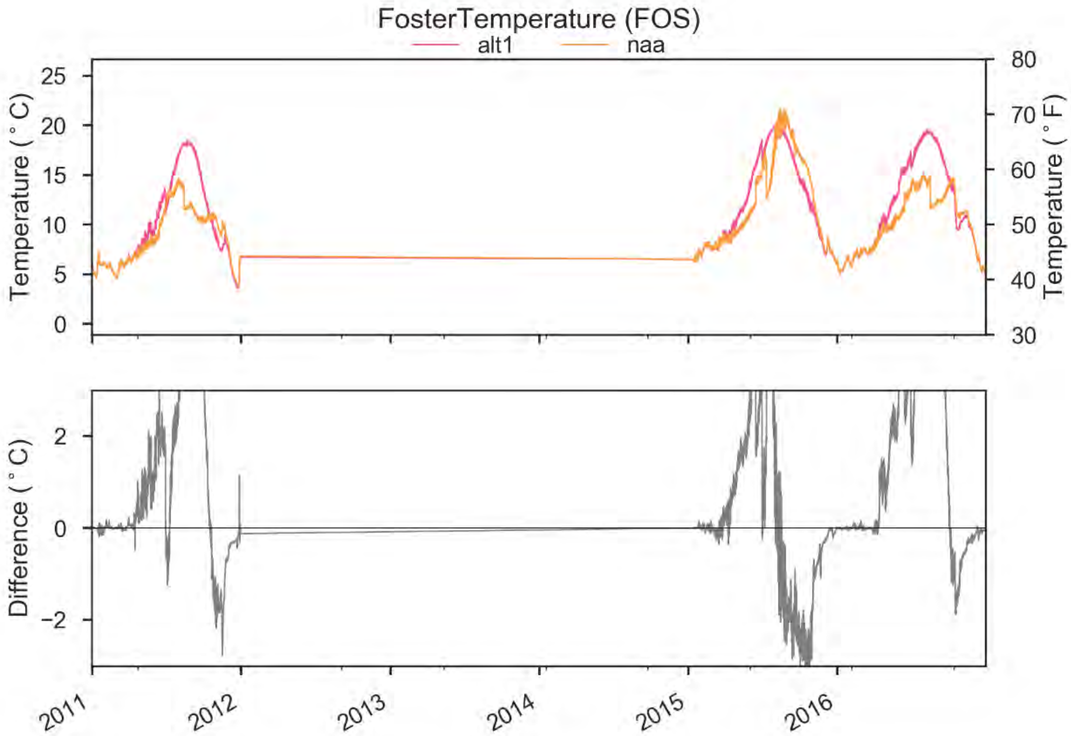

Figure 1-68. Comparison of FOS Outflow Temperatures in NAA and Alternative 1.

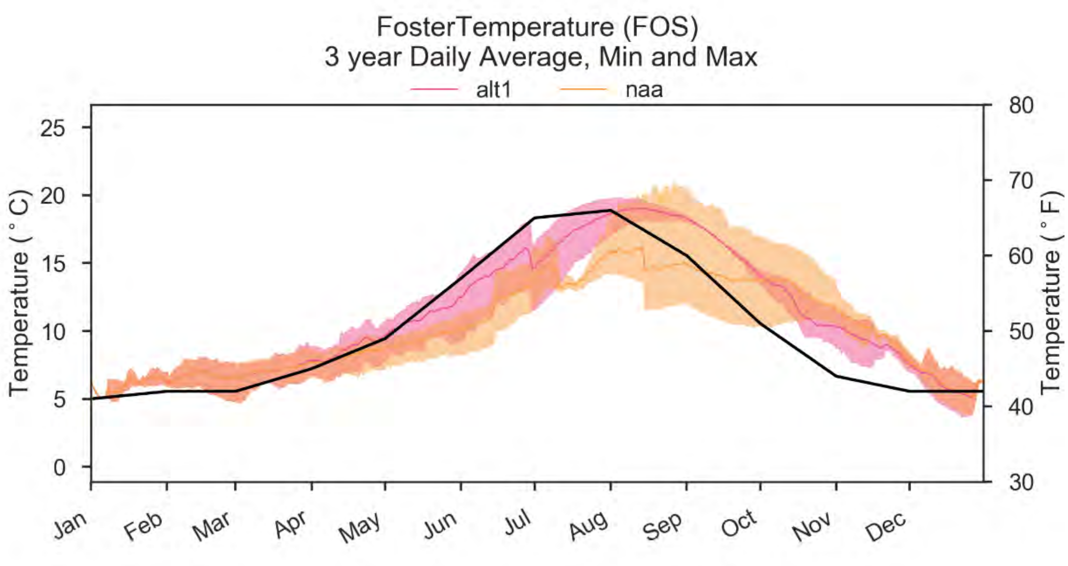

Figure 1-69. Comparison of FOS 3-year Daily Average, Min, Max Outflow Temperatures in NAA and Alternative 1. Black line indicates temperature target.

1.5.2.3 MCKENZIE DAMS

1.5.2.3.1 Cougar

RES-SIM Lake Levels and Outflows

Lake level and storage at Cougar Lake generally increased under Alternative 1 compared to NAA in 2015 and 2016 aside from September-November in 2015 where the power pool was utilized for downstream flow augmentation (Figure 1-70 and Figure 1-71). Increased storage coincided with reduced outflows during spring and increased outflows in summer during 2015 and 2016 (Figure 1-71). 2011 operations were generally similar in Alternative 1 and NAA at Cougar Lake.

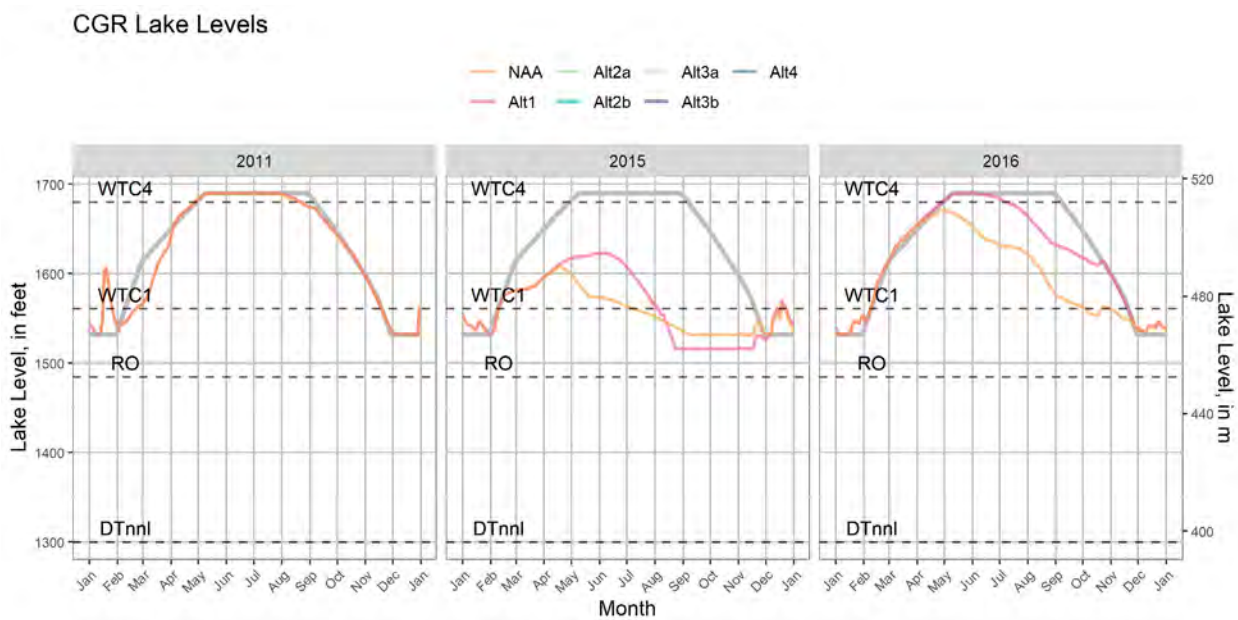

Figure 1-70. WV EIS RES-SIM Cougar Lake Levels in 2011, 2015, and 2016 under Alternative 1 and NAA.

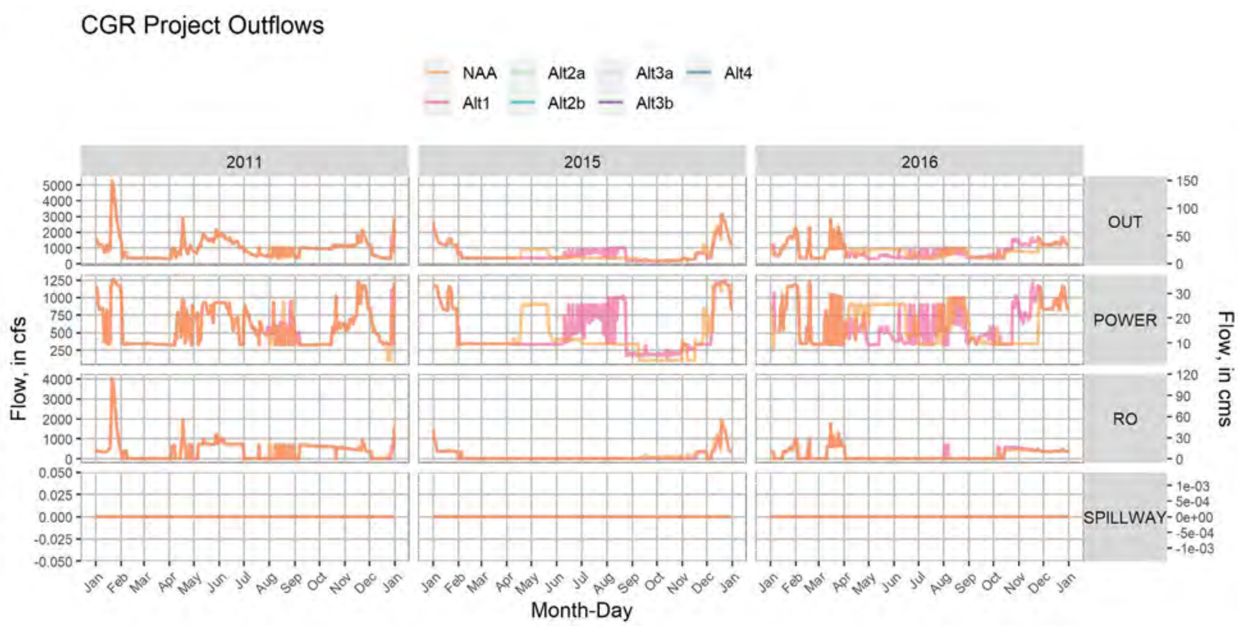

Figure 1-71. WV EIS RES-SIM Cougar Dam gate-specific outflows in 2011, 2015, and 2016 under Alternative 1 and NAA.

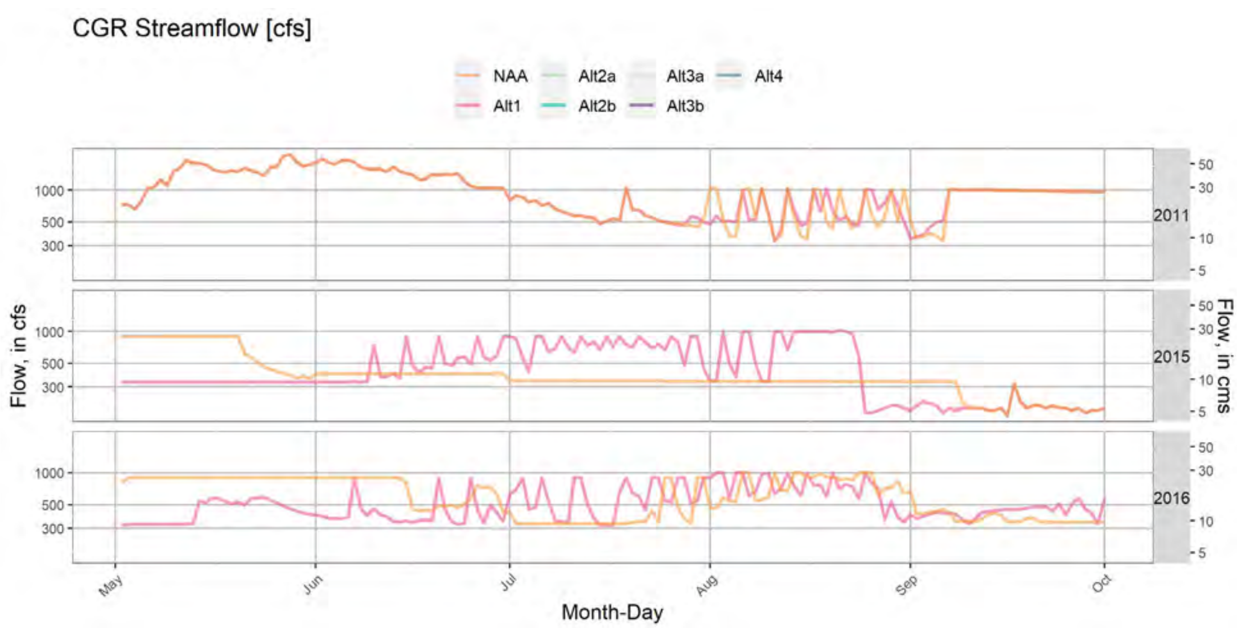

Figure 1-72. WV EIS RES-SIM Cougar Dam Total Outflow in 2011, 2015, and 2016 under Alternative 1 and NAA.

Lake Levels and Temperatures from CE-QUAL-W2

Depth-varying temperature, gate-specific outflows, and outflow temperatures through each calendar year scenario at Cougar Lake are shown in Figure 1-73, Figure 1-74, and Figure 1-75. Outflows from the existing temperature tower and proposed FSS resulted in similar tailwater temperature in Alternative 1 compared to NAA (Figure 1-76, Figure 1-77) aside from minor differences in each calendar year scenario that were likely linked to differences in lake levels. The addition of a FSS structure in Alternative 2a is not expected to have a large effect on the ability of the existing WTCT functionality with respect to temperature management (USACE, 2019a).

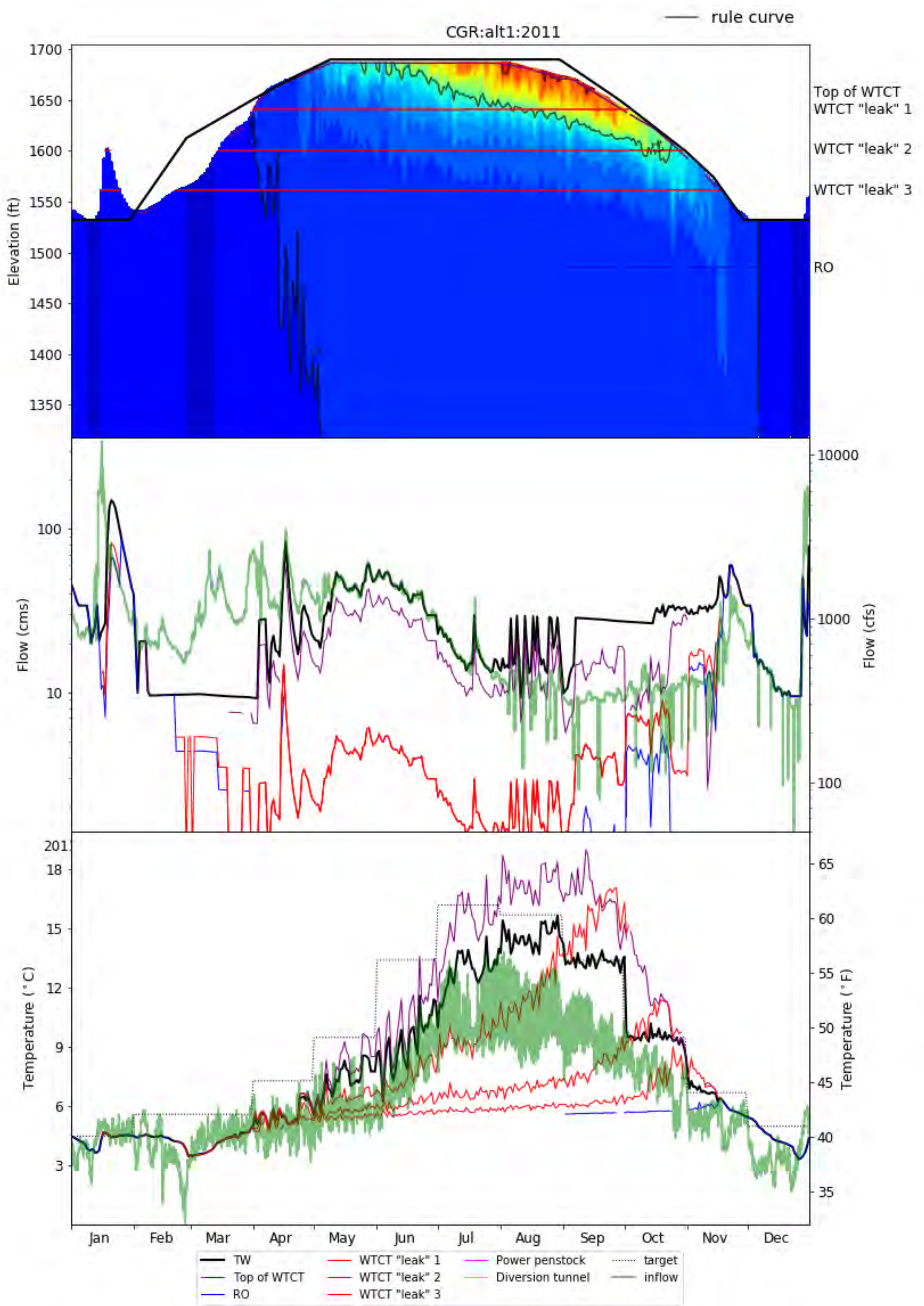

Figure 1-73. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at CGR under Alternative 1 in 2011.

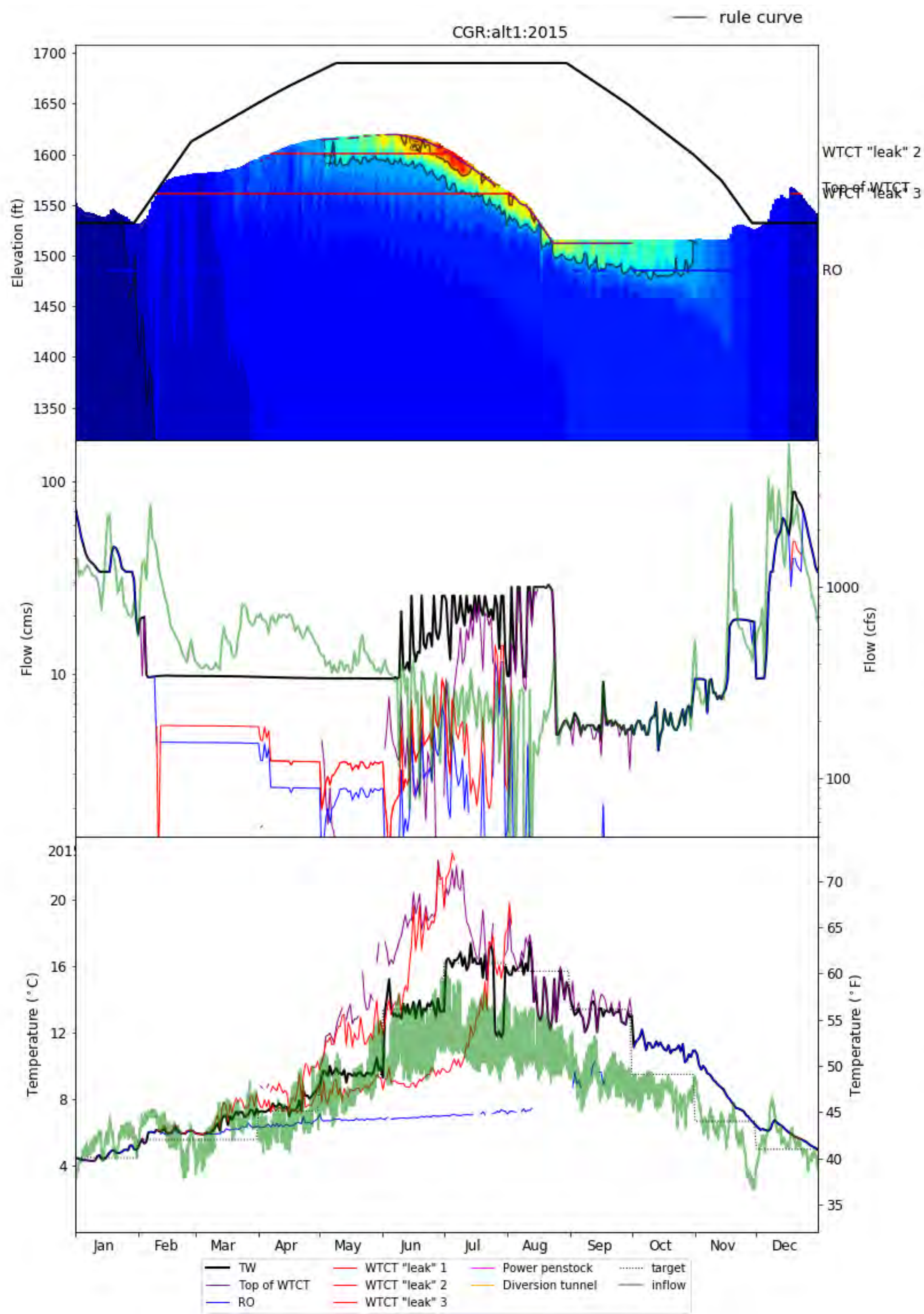

Figure 1-74. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at CGR under Alternative 1 in 2015.

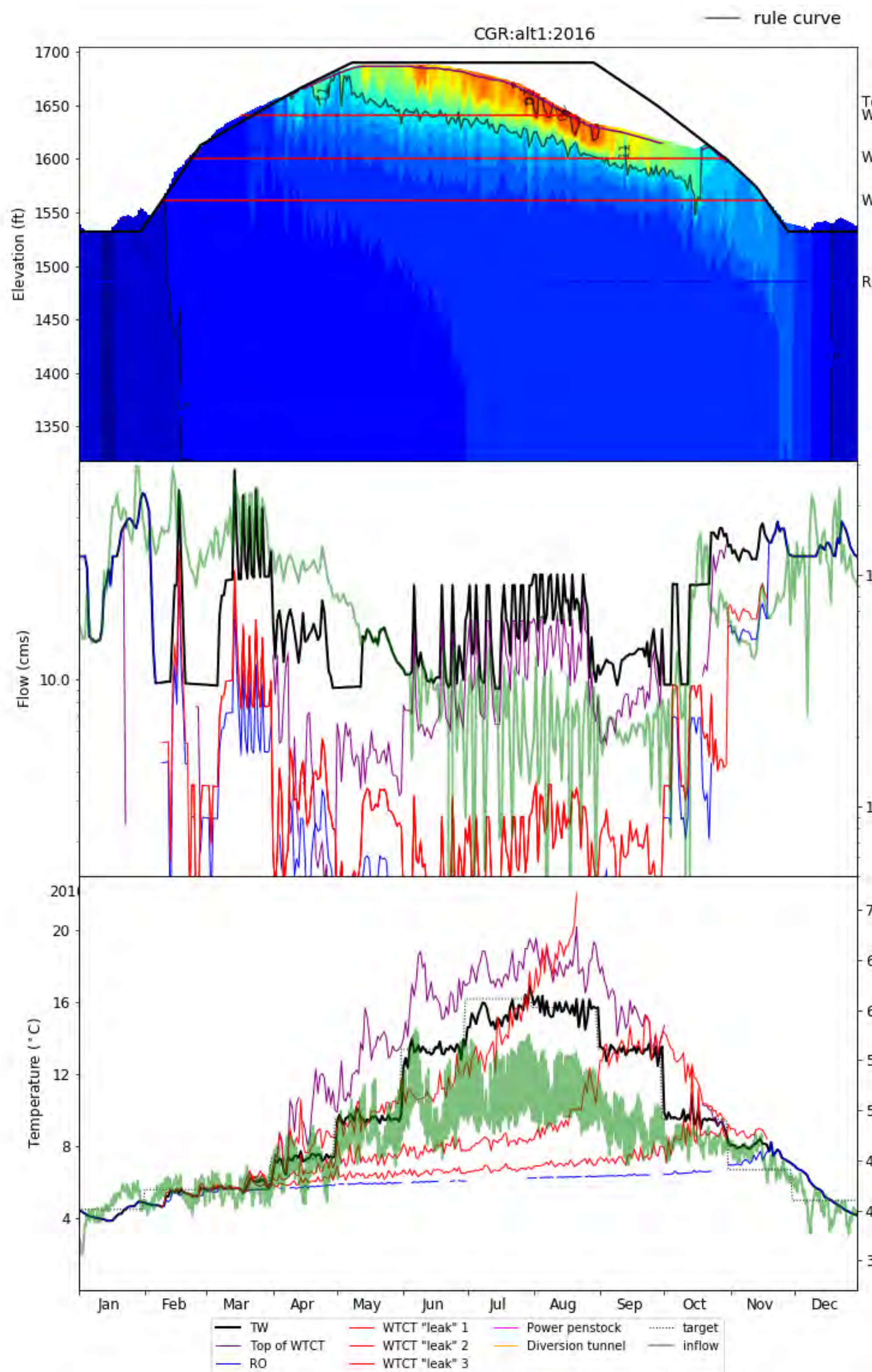

Figure 1-75. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at CGR under Alternative 1 in 2016.

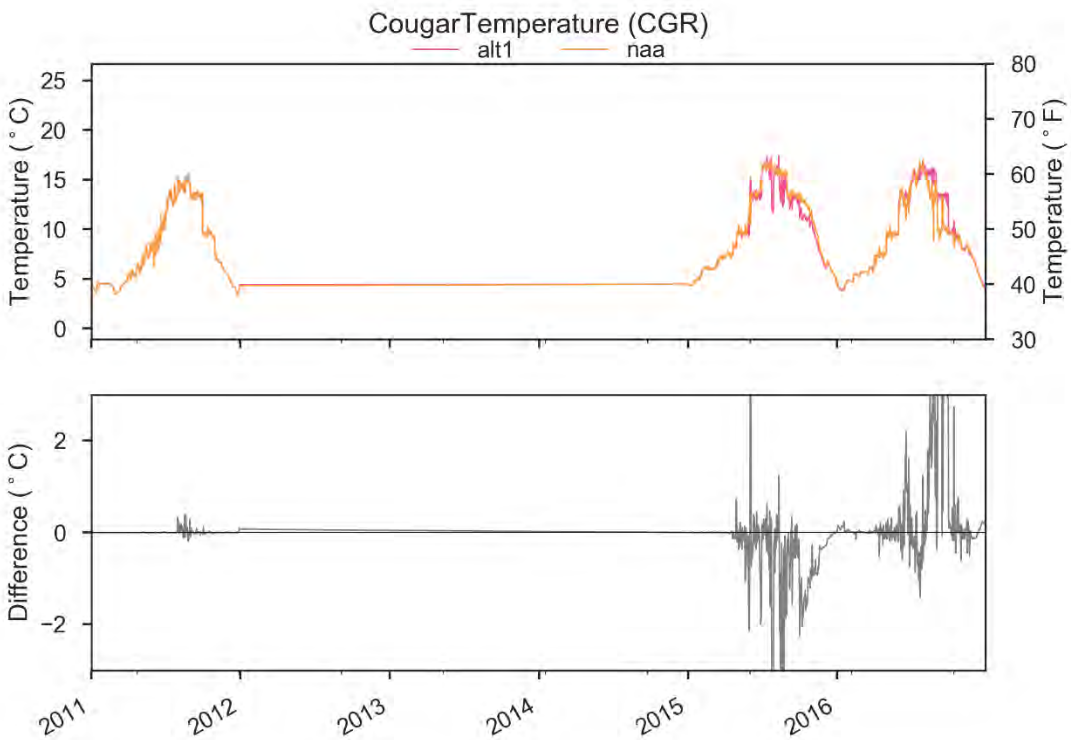

Figure 1-76. Comparison of CGR Outflow Temperatures in NAA and Alternative 1.

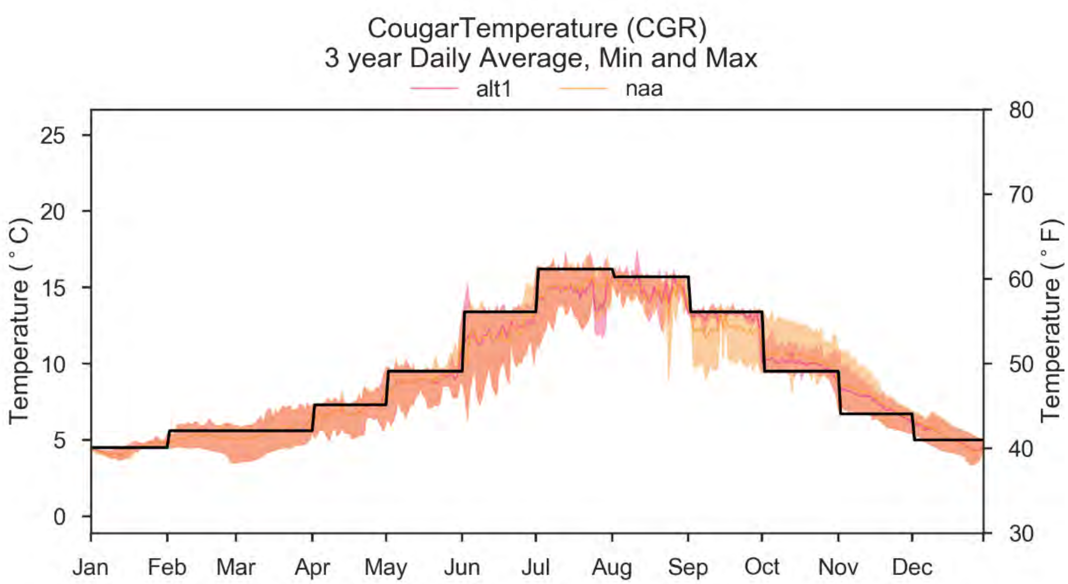

Figure 1-77. Comparison of CGR 3-year Daily Average, Min, Max Outflow Temperatures in NAA and Alternative 1. Black line indicates temperature target.

1.5.2.4 MIDDLE FORK WILLAMETTE DAMS

1.5.2.4.1 Hills Creek

RES-SIM Lake Levels and Outflows

Lake level and storage at Hills Creek Lake generally increased in Alternative 1 compared to NAA in 2015 and 2016 aside from August-November in 2015 where the power pool was utilized for downstream flow augmentation (Figure 1-78; Figure 1-80). The increased storage coincided with reduced outflows during spring and increased outflows in June-July during 2015 and July-October in 2016. (Figure 1-79). 2011 operations were generally similar in Alternative 1 and NAA at Hills Creek Lake.

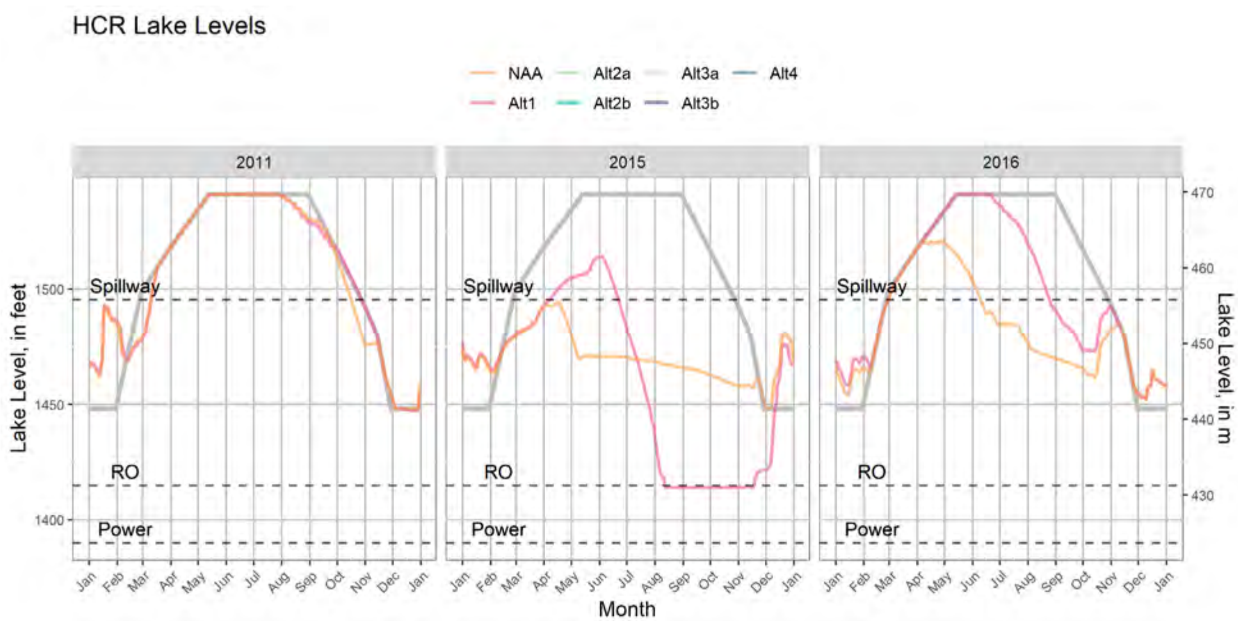

Figure 1-78. WV EIS RES-SIM Hills Creek Lake Levels in 2011, 2015, and 2016 under Alternative 1 and NAA.

Figure 1-79. WV EIS RES-SIM Hills Creek Dam gate-specific outflows in 2011, 2015, and 2016 under Alternative 1 and NAA.

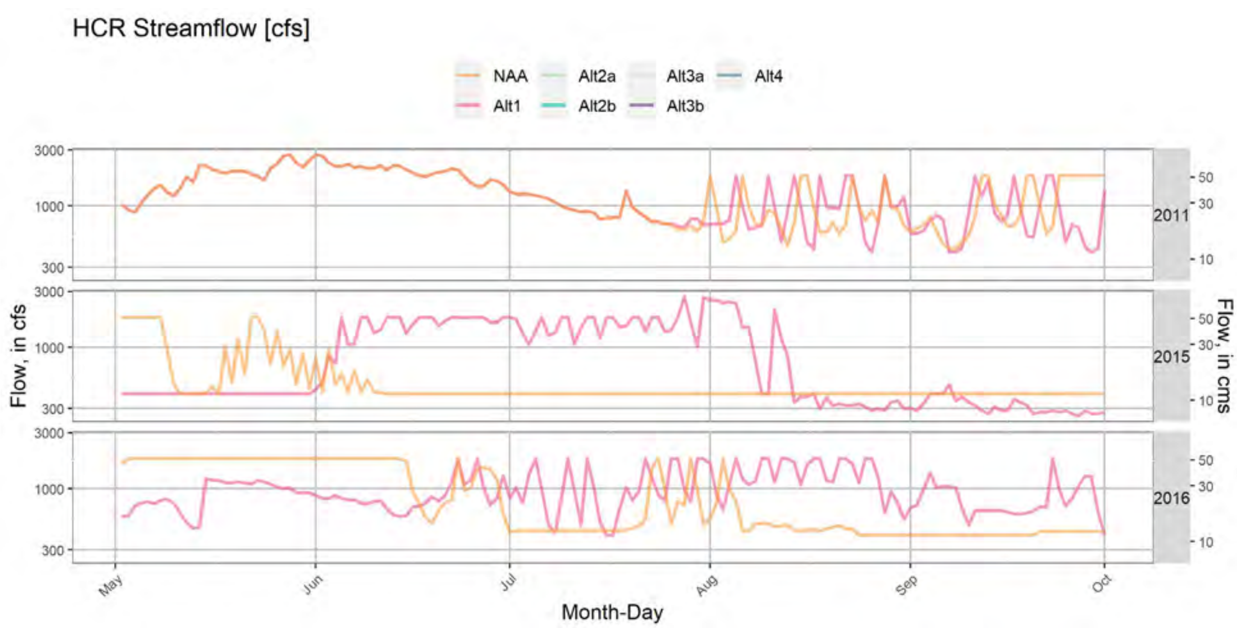

Figure 1-80. WV EIS RES-SIM Hills Creek Dam Total Outflow in 2011, 2015, and 2016 under Alternative 1 and NAA.

Lake Levels and Temperatures from CE-QUAL-W2

Depth-varying temperature, gate-specific outflows, and outflow temperatures through each calendar year scenario in Alternative 1 at Hills Creek Lake are shown in Figure 1-81, Figure 1-82, and Figure 1-83. The timing of the peak seasonal tailwater temperature under Alternative 1 occurred about one month earlier in 2015, which resulted in cooler tailwater temperature during autumn of that year compared to NAA (Figure 1-76, Figure 1-77). 2016 outflow tailwater temperature in Alternative 1 was generally cooler than NAA in spring and summer but similar during autumn.

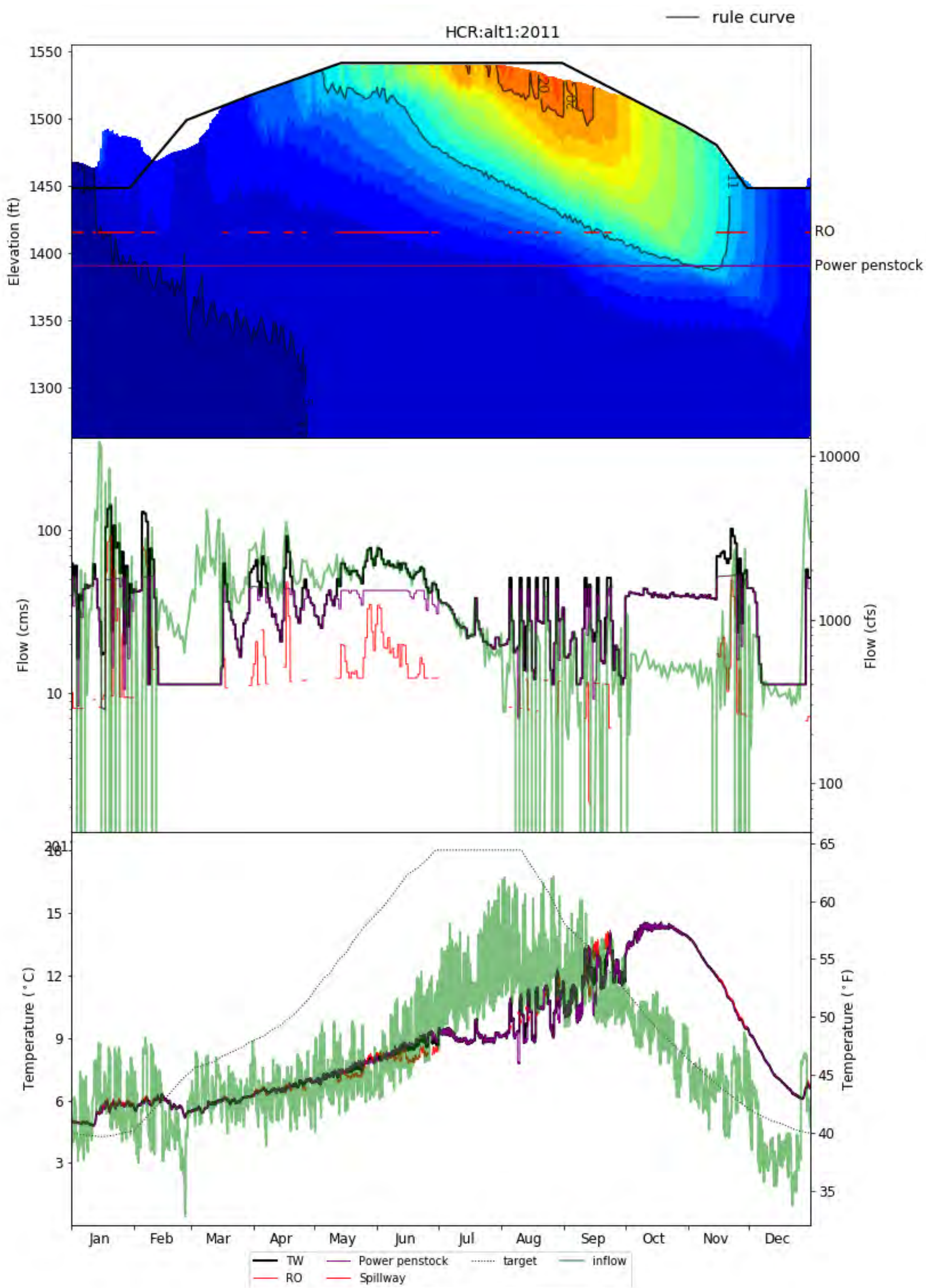

Figure 1-81. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at HCR under Alternative 1 in 2011.

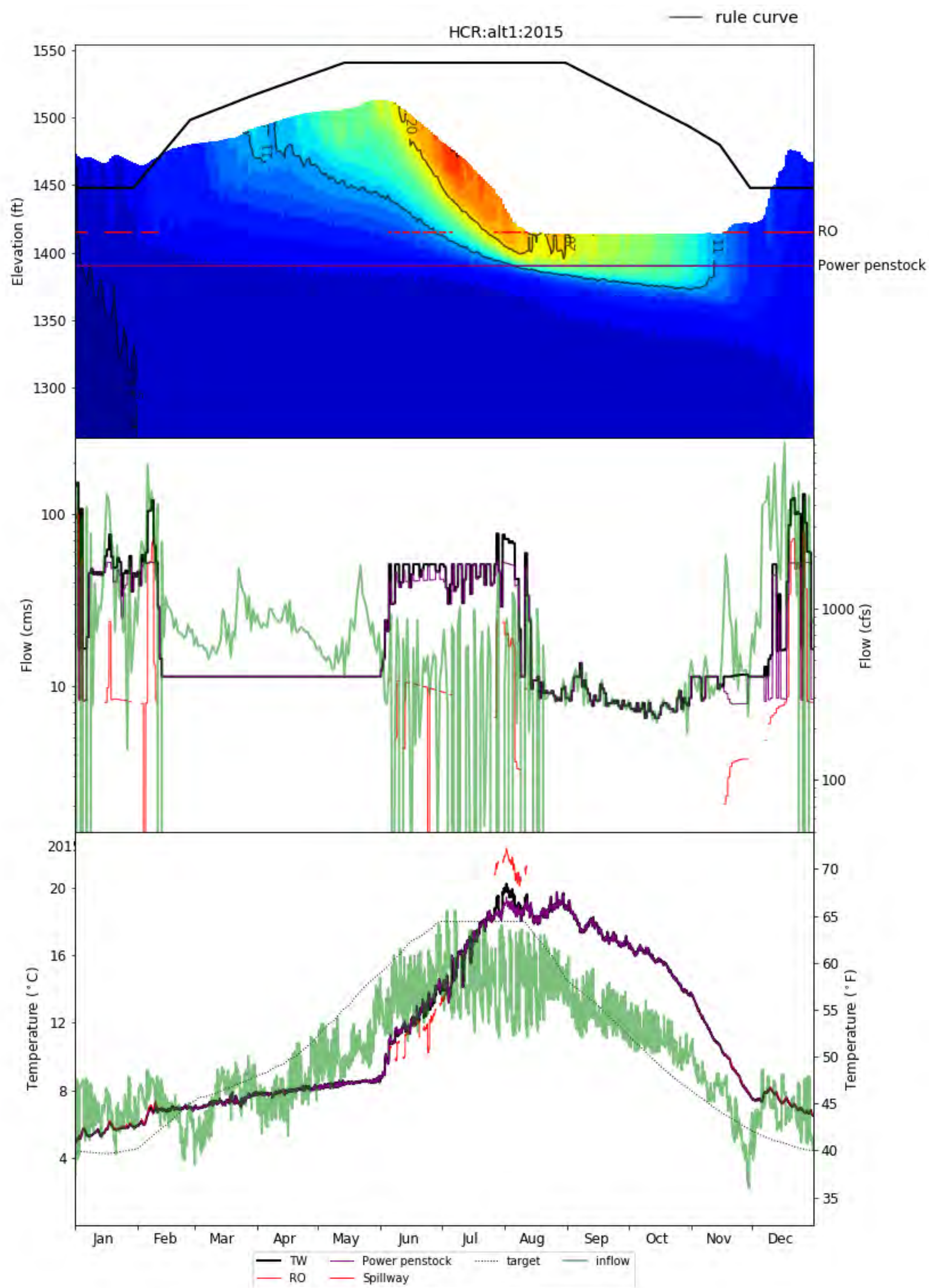

Figure 1-82. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at HCR under Alternative 1 in 2015.

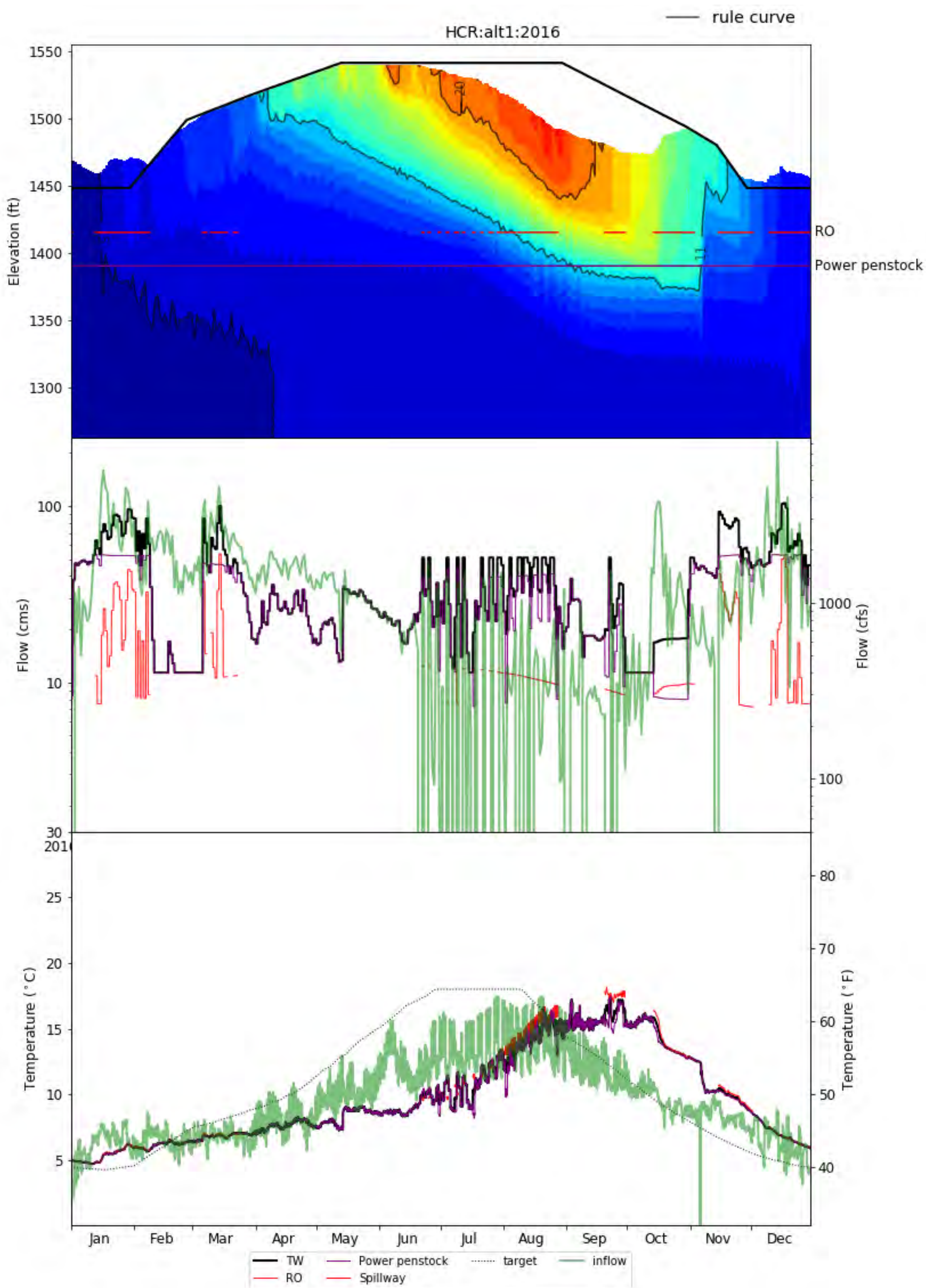

Figure 1-83. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at HCR under Alternative 1 in 2016.

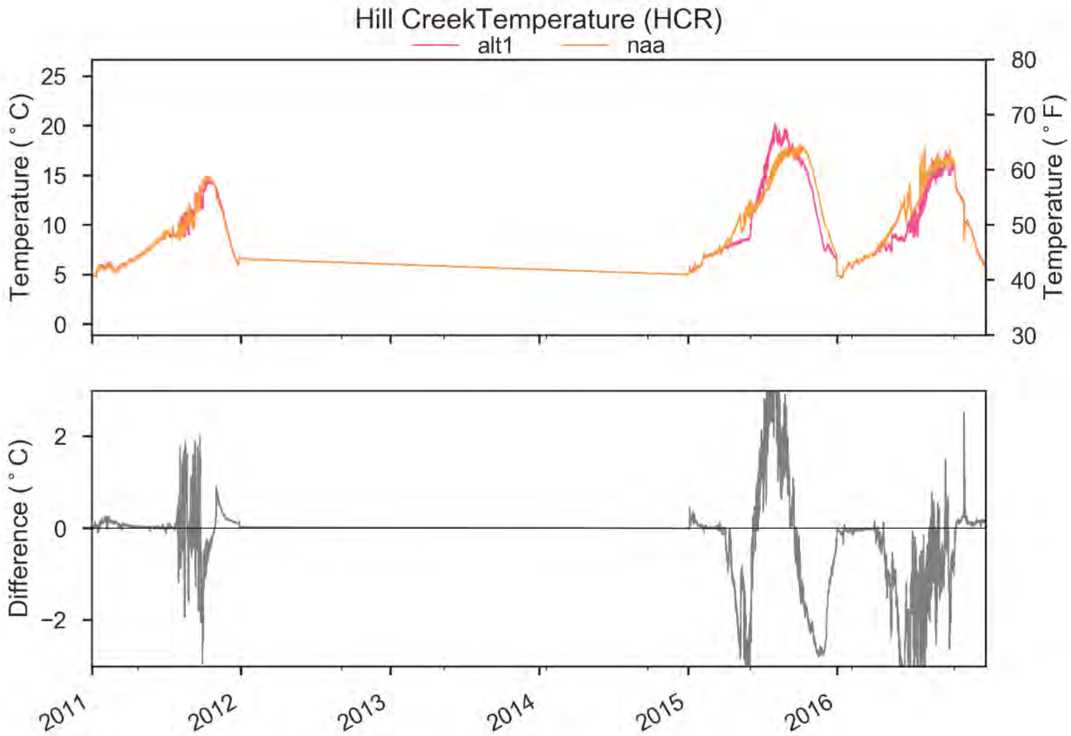

Figure 1-84. Comparison of HCR Outflow Temperatures in NAA and Alternative 1.

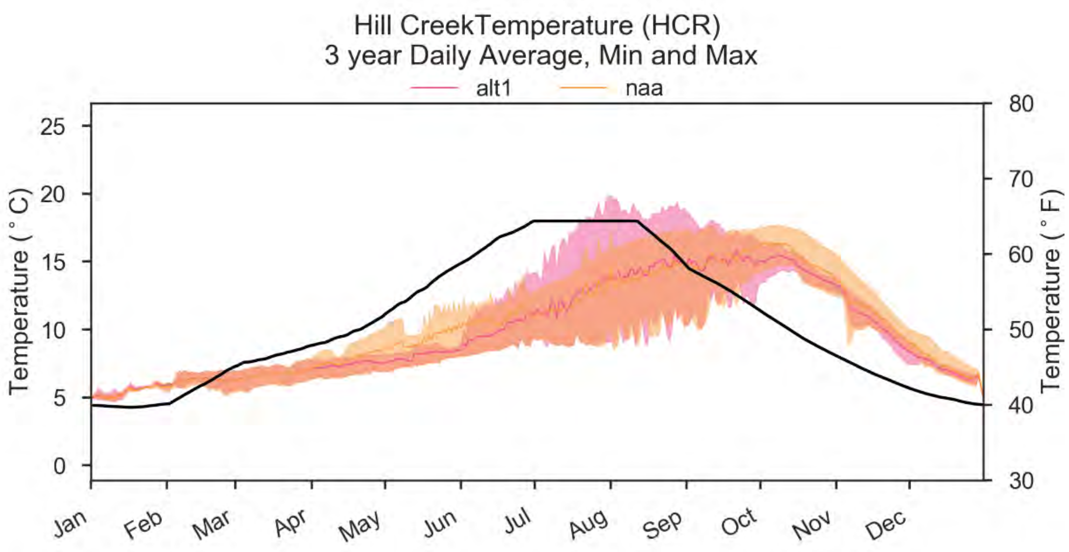

Figure 1-85. Comparison of HCR 3-year Daily Average, Min, Max Outflow Temperatures in NAA and Alternative 1. Black line indicates temperature target.

1.5.2.4.2 Lookout Point

RES-SIM Lake Levels and Outflows

Lake level and storage at Lookout Point Lake were generally similar to NAA in 2011, 2015, and 2016 (Figure 1-86, Figure 1-88) aside from minor differences in timing of refill and release rates that were associated with upstream Hills Creek Dam operations. The proposed SWS and FSS in Alternative 1 allowed all outflow within powerhouse capacity (assumed at 6000 cfs) to be routed from a floating outlet through the Power outlets for temperature management (Figure 1-87).

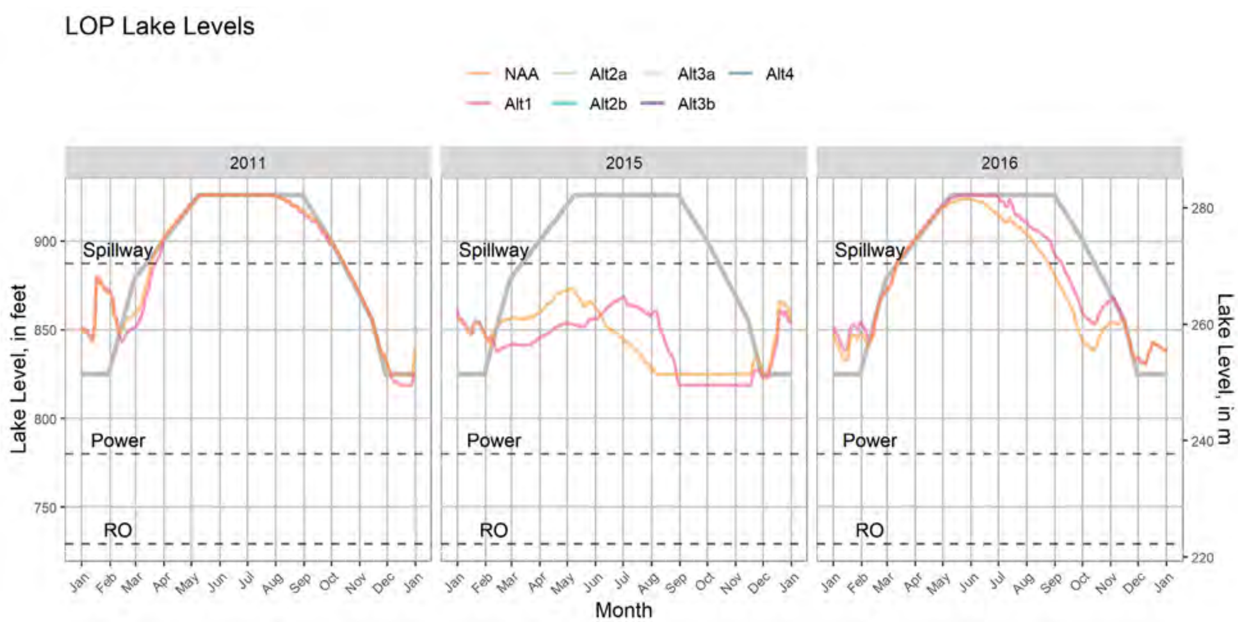

Figure 1-86. WV EIS RES-SIM Lookout Point Lake Levels in 2011, 2015, and 2016 under Alternative 1 and NAA.

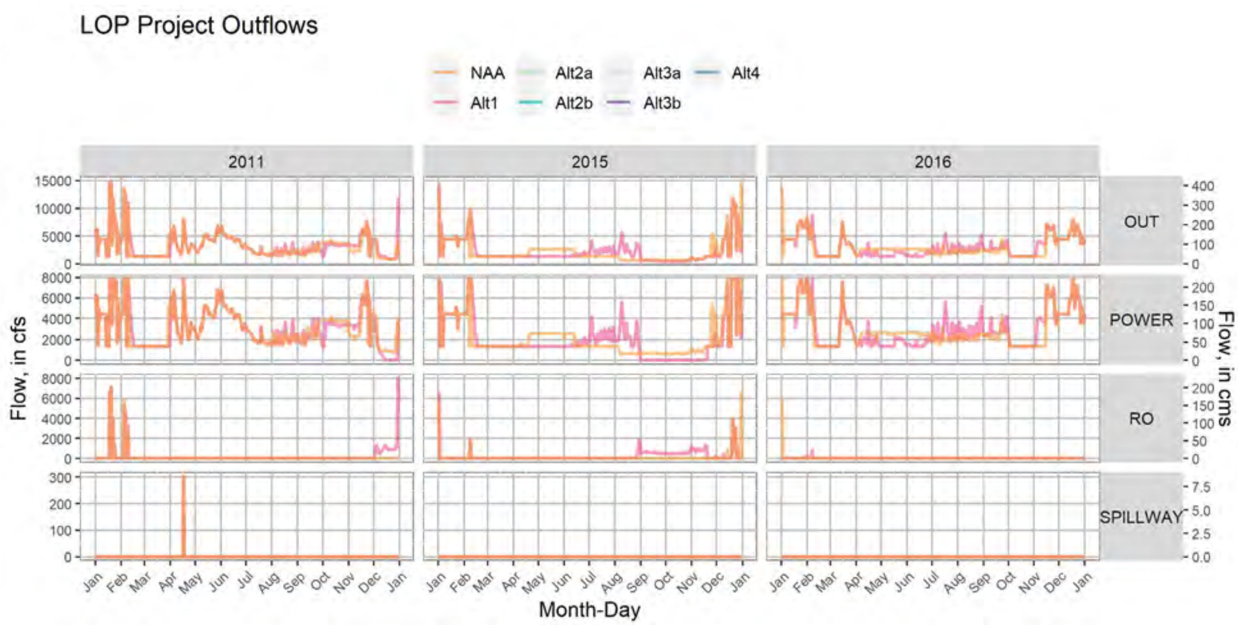

Figure 1-87. WV EIS RES-SIM Lookout Point Dam gate-specific outflows in 2011, 2015, and 2016 under Alternative 1 and NAA.

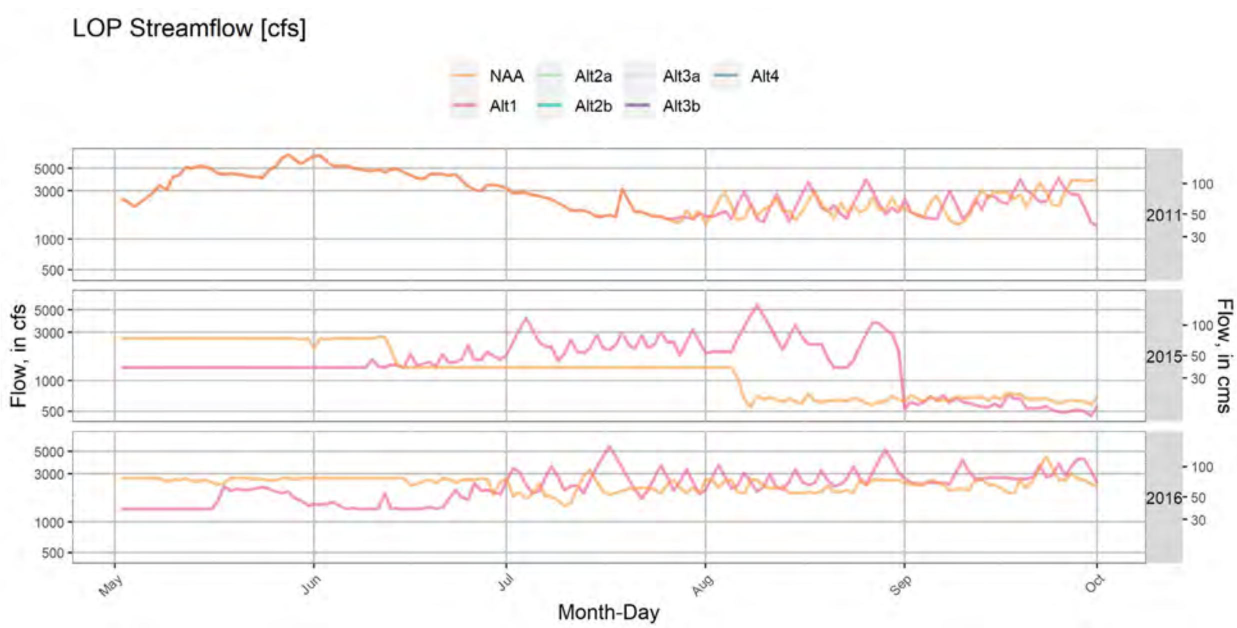

Figure 1-88. WV EIS RES-SIM Lookout Point Dam Total Outflow in 2011, 2015, and 2016 under Alternative 1 and NAA.

Lake Levels and Temperatures from CE-QUAL-W2

Depth-varying temperature, gate-specific outflows, and outflow temperatures through each calendar year at Lookout Point Lake are shown in Figure 1-89, Figure 1-90, and Figure 1-91. Temperature tower outflows blended between a floating outlet (25 feet below lake surface) and a deeper outlet at the elevation of the RO. Tailwater release temperatures generally matched the temperature target when sufficient warm or cool water was available. Generally, these proposed SWS-FSS structures allowed temperatures to be warmer than NAA in spring/summer and cooler than NAA in autumn in 2011, 2015, and 2016 (Figure 1-92, Figure 1-93) as measured below Dexter Dam.

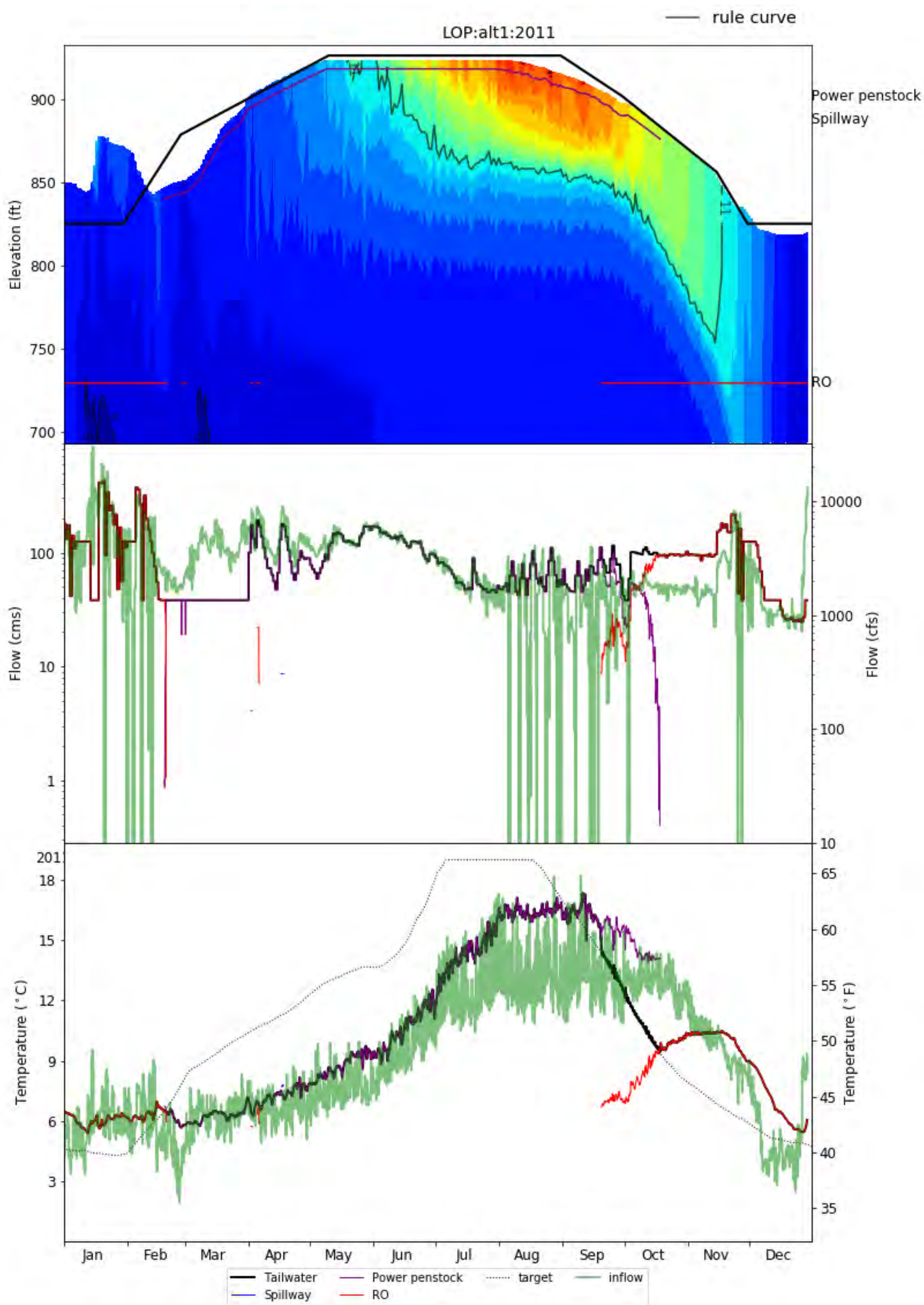

Figure 1-89. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at LOP under Alternative 1 in 2011.

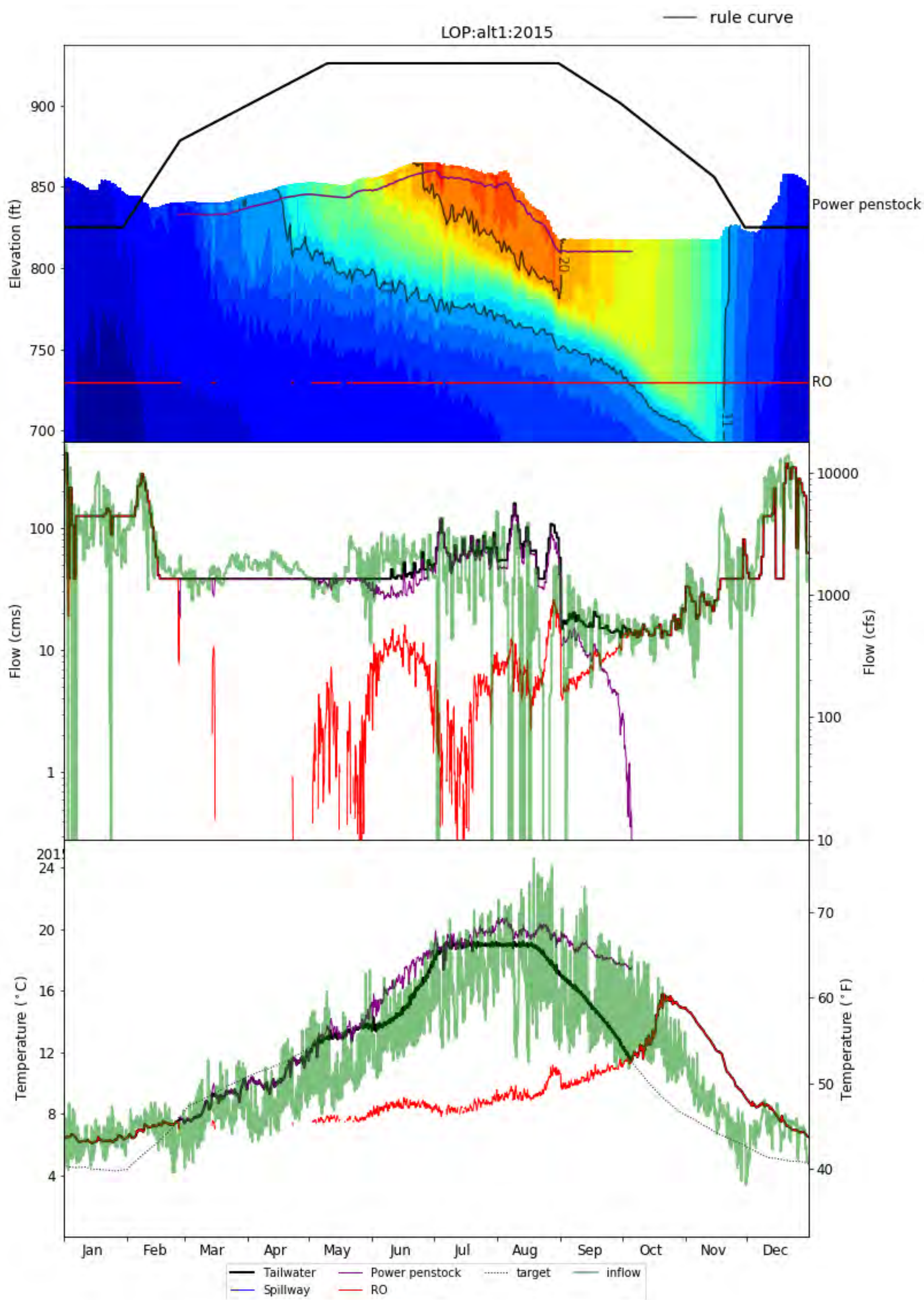

Figure 1-90. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at LOP under Alternative 1 in 2015.

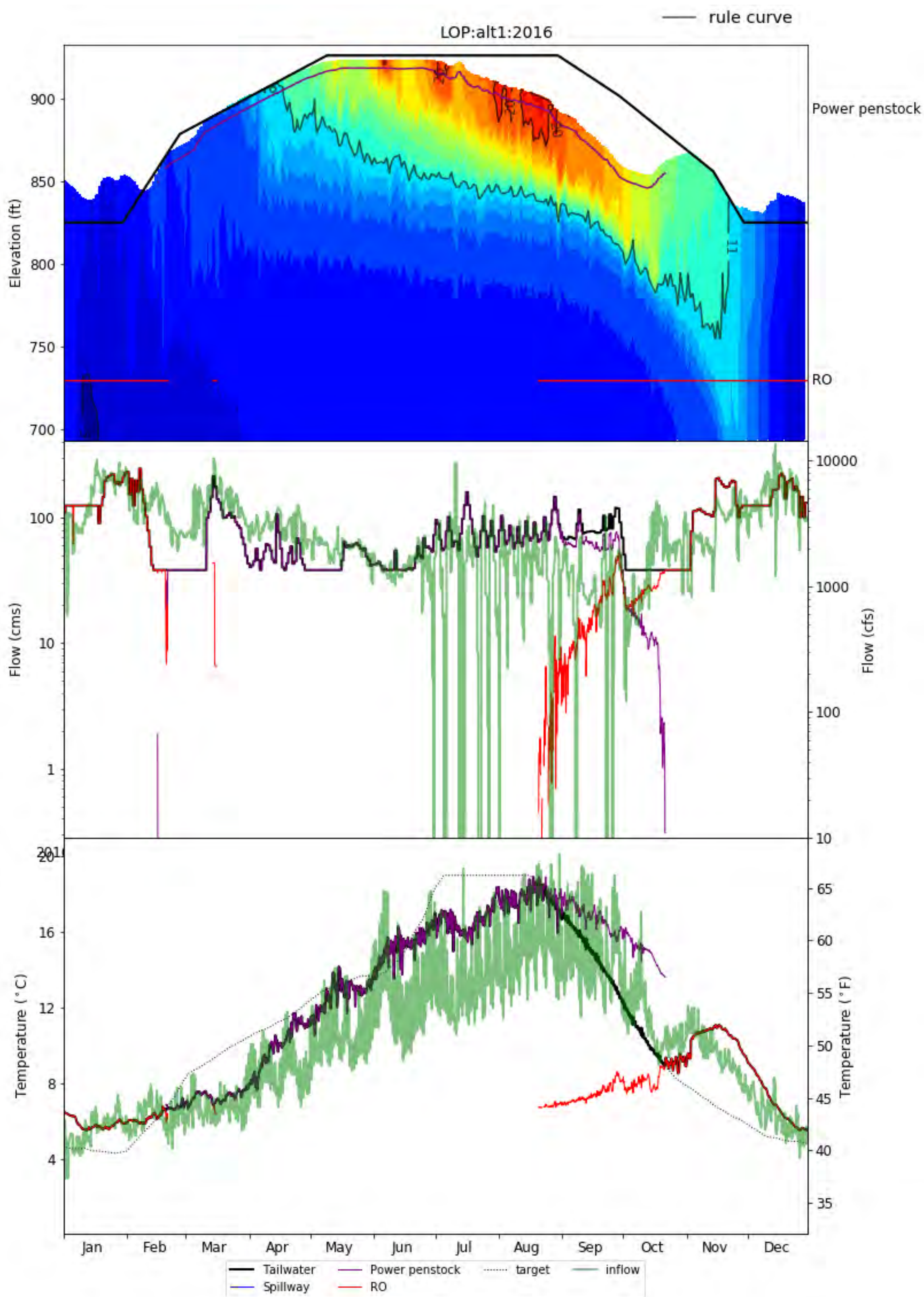

Figure 1-91. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at LOP under Alternative 1 in 2016.

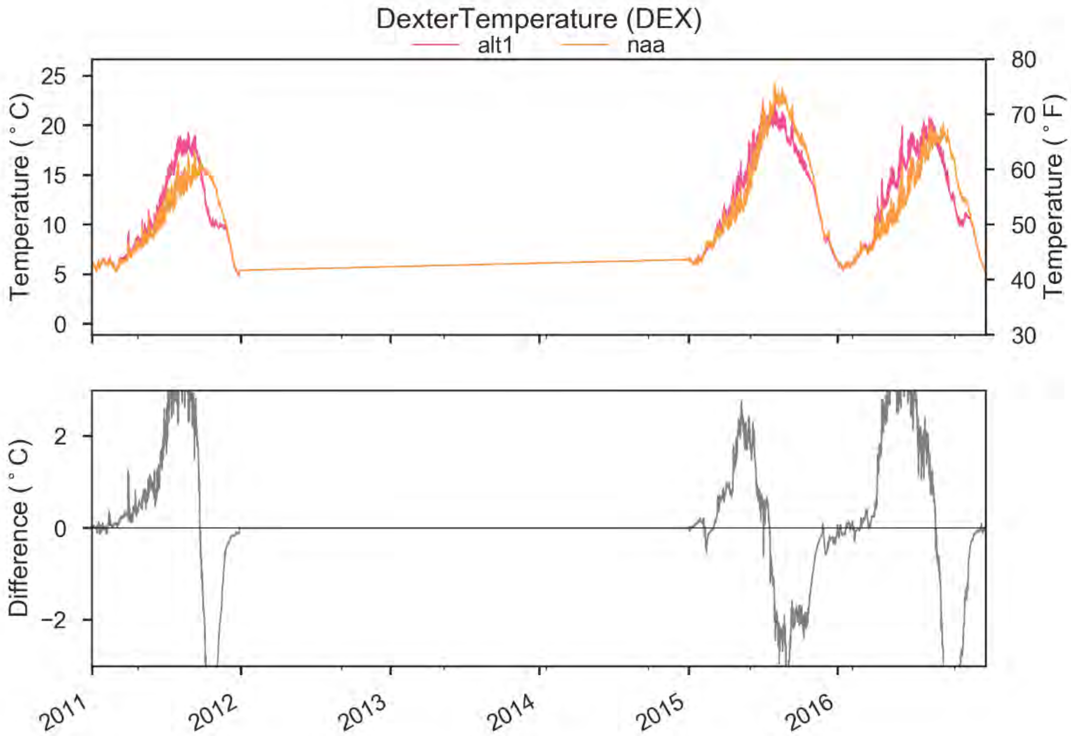

Figure 1-92. Comparison of DEX Outflow Temperatures in NAA and Alternative 1.

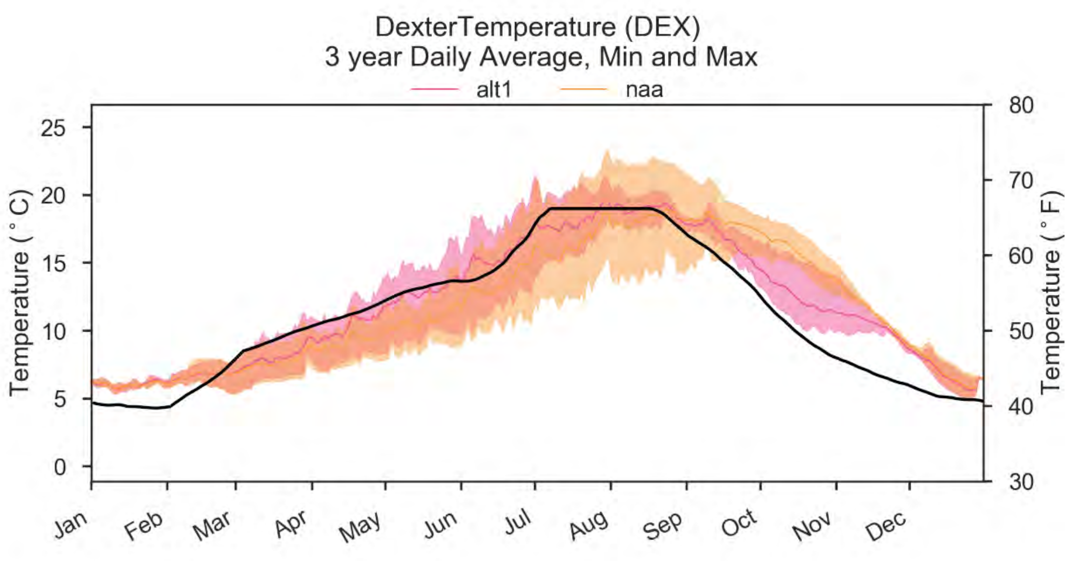

Figure 1-93. Comparison of DEX 3-year Daily Average, Min, Max Outflow Temperatures in NAA and Alternative 1. Black line indicates temperature target.

1.5.2.5 Mainstem Willamette River

Streamflow in the Mainstem Willamette River under Alternative 1 was generally lower from April to mid-June and higher from mid-June to mid-September compared with NAA (Figure 1-94). However, these flow differences were primarily in 2015 and responsive to the flow Measure 30 rules that increase dam outflows in advance of heat wave events (Figure 1-95). These flow changes resulted in warmer water temperatures April to mid-June and cooler water temperatures from mid-June to mid-September compared with NAA in 2015 (Figure 1-96, Figure 1-97). Water temperatures at Salem were also affected by upstream dam operations and proposed SWS-FSS structures, which likely contributed to warmer temperatures seen in 2011 and 2015 comparing Alternative 1 to NAA. Overall water temperature differences between Alternative 1 and NAA were less than 2 degrees Celsius.

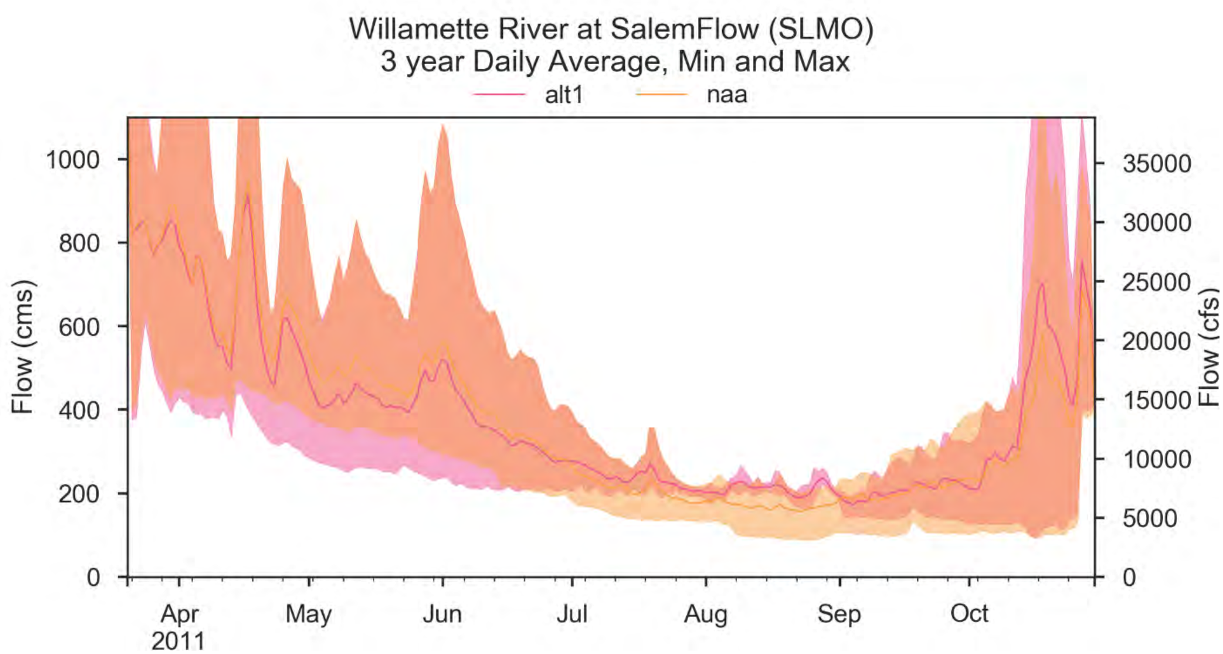

Figure 1-94. Streamflow comparison of Daily Average, Min, Max at Willamette River at SLMO under NAA and Alternative 1 conditions.

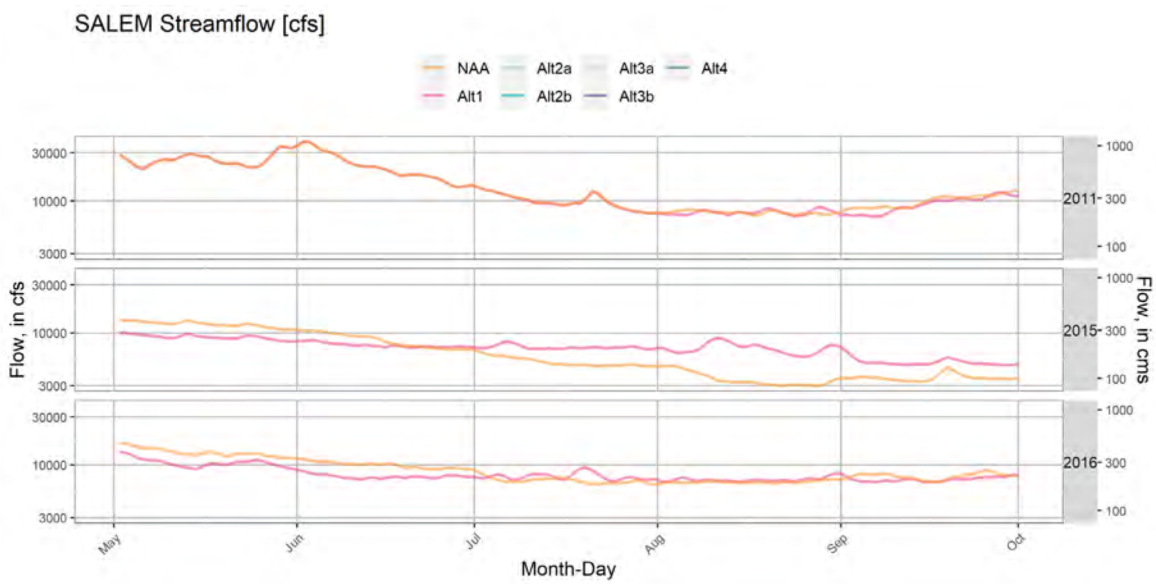

Figure 1-95. Streamflow Comparison Between Alternative 1 and NAA at Willamette River at SLMO.

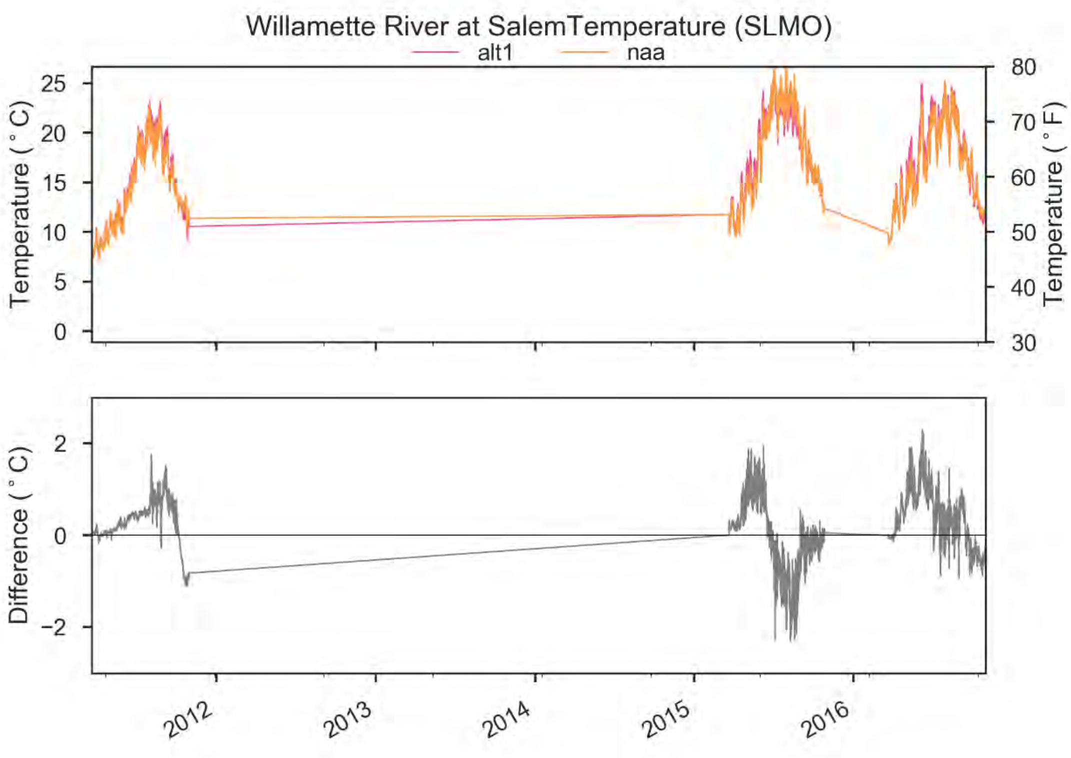

Figure 1-96. Comparison of Willamette River at SLMO Water Temperatures in NAA and Alternative 1.

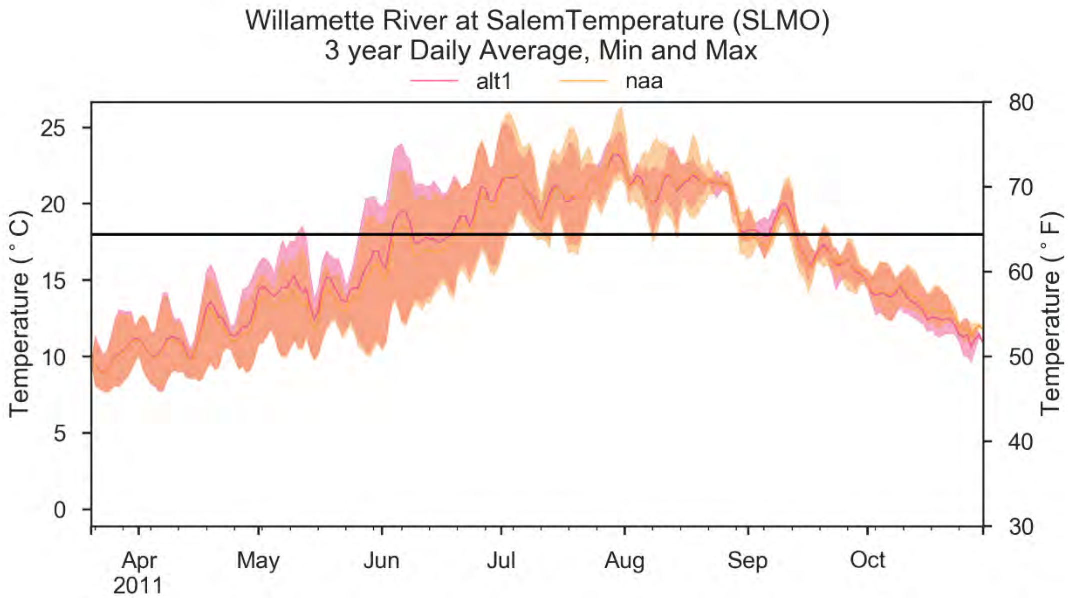

Figure 1-97. Comparison of Willamette River at SLMO 3-year Daily Average, Min, Max Outflow Temperatures in NAA and Alternative 1.

1.5.3 Alternative 2a-- Hybrid Alternative

Alternative 2a measures that affected operations, lake storage, and water temperature included:

- Changes to tributary targets below Foster, Detroit, Lookout Point, and Cougar that are higher than the NAA BiOp targets when those reservoirs are more than 90% full and less than the NAA BiOp when those reservoirs are less than 90% full.
- Changes to baseline mainstem targets at Salem and Albany while adding a Salem flow target tied to forecasted air temperature.
- Construct temperature control structure at Detroit.
- Deep fall drawdown to 35’ over the regulating outlet at Green Peter, use of RO in fall, use spillway for surface spill in spring and summer
- Modifications to existing outlets at Foster Dam that would allow releases at varying depths for temperature control by modifying the Facility Warm Water Supply (FWWS) pipe and fish weirs.

1.5.3.1 NORTH SANTIAM DAMS

1.5.3.1.1 Detroit

RES-SIM Lake Levels and Outflows

Lake level and storage at Detroit Lake generally increased under Alternative 2a compared to NAA in 2015 and 2016 aside from September-November in 2015, where the power pool was utilized for downstream flow augmentation (Figure 1-98, Figure 1-99, Figure 1-100). The increased storage coincided with reduced outflows during spring and increased outflows in summer during 2015 and 2016 comparing Alternative 4 to NAA. Total outflow in 2011 was generally similar in Alternative 2a and NAA at Detroit Lake. The proposed SWS and FSS in Alternative 2a allowed all outflow within powerhouse capacity (assumed at 4600 cfs) to be routed from a floating outlet through the Power outlets for temperature management, rather than the Spillway or URO flow for temperature management that was used in NAA (Figure 1-99).

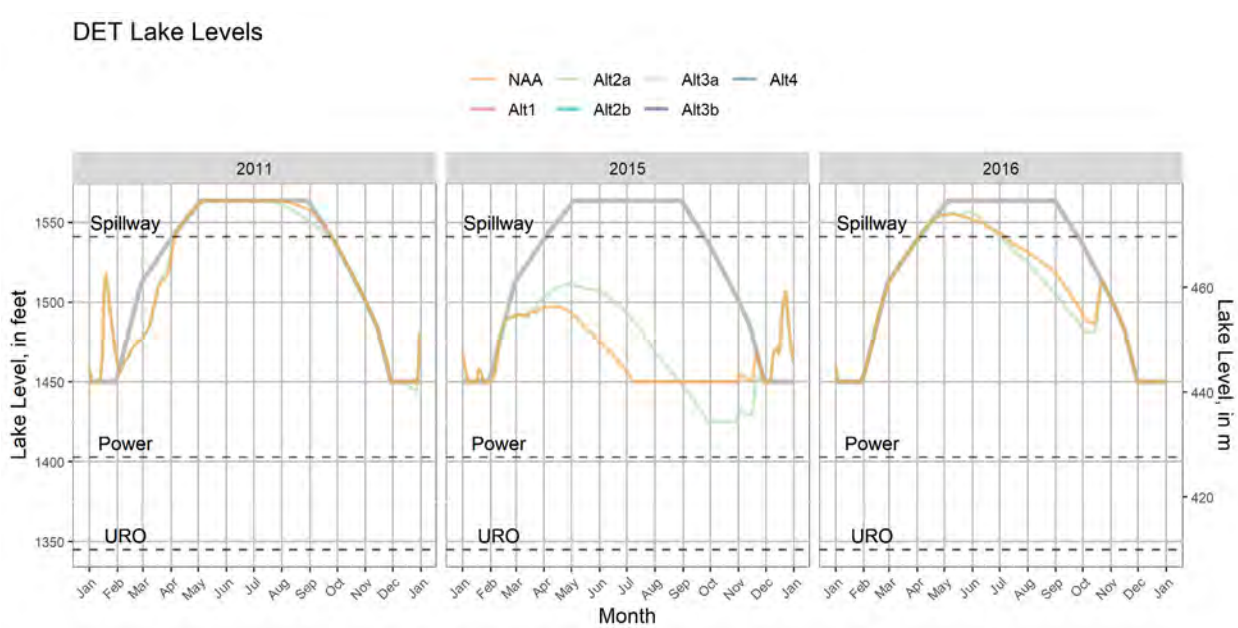

Figure 1-98. WV EIS RES-SIM Detroit Lake Levels in 2011, 2015, and 2016 Under Alternative 2a and NAA.

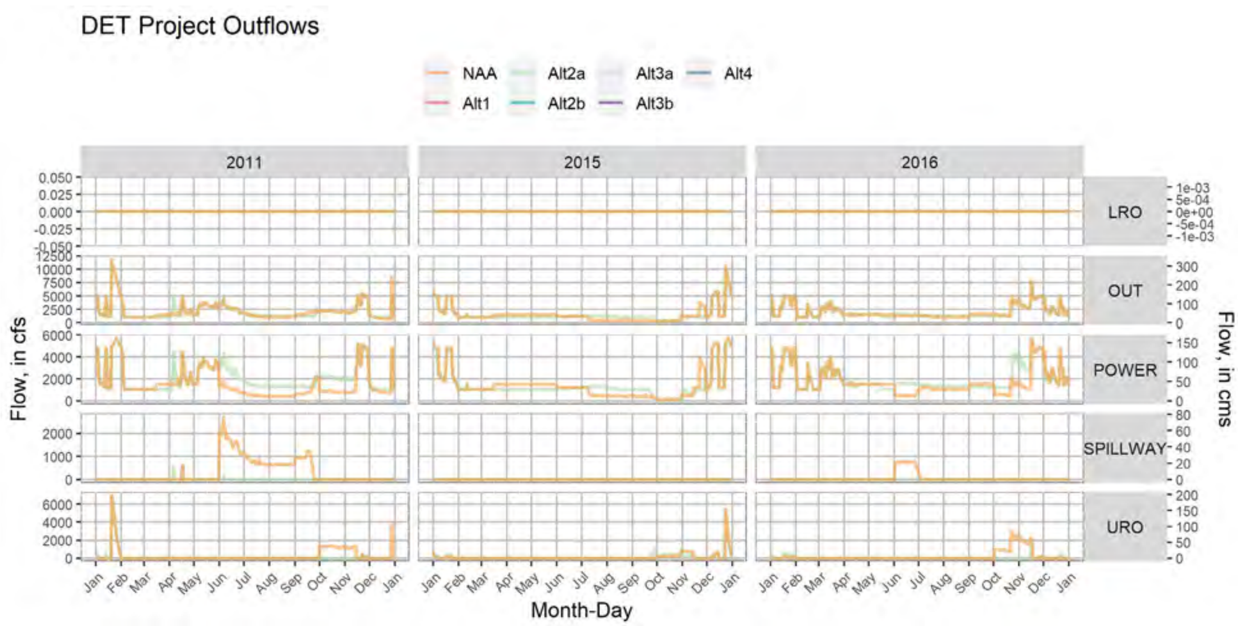

Figure 1-99. WV EIS RES-SIM gate-specific outflows in 2011, 2015, and 2016 Under Alternative 2a and NAA.

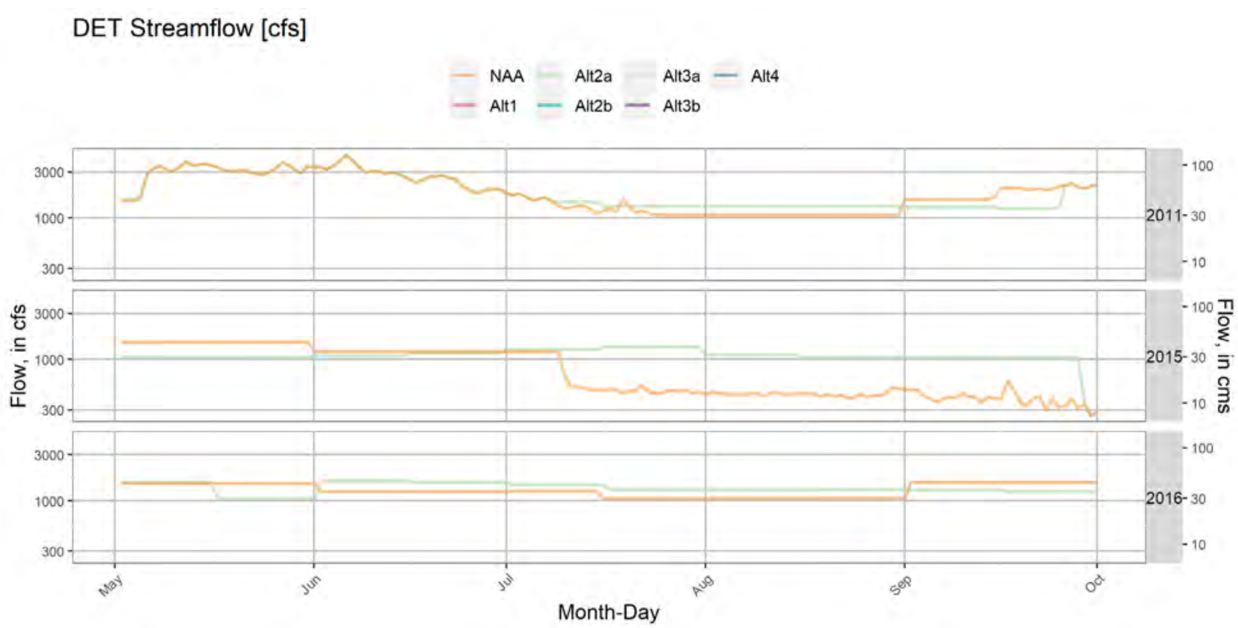

Figure 1-100. WV EIS RES-SIM Detroit Total Outflow in 2011, 2015, and 2016 Under Alternative 2a and NAA.

Lake Levels and Temperatures from CE-QUAL-W2

Depth-varying temperature, gate-specific outflows, and outflow temperatures through each calendar year scenario at Detroit Lake are shown in Figure 1-101, Figure 1-102, and Figure 1-103. Temperature tower outflows blended between a floating outlet (25 feet below lake surface) and a deeper outlet at the elevation of the Upper RO. Tailwater release temperatures generally matched the temperature target when sufficient warm or cool water was available. Generally, the proposed SWS-FSS structures allowed temperatures to be warmer than NAA in spring/summer and cooler than NAA in autumn (Figure 1-104, Figure 1-105).

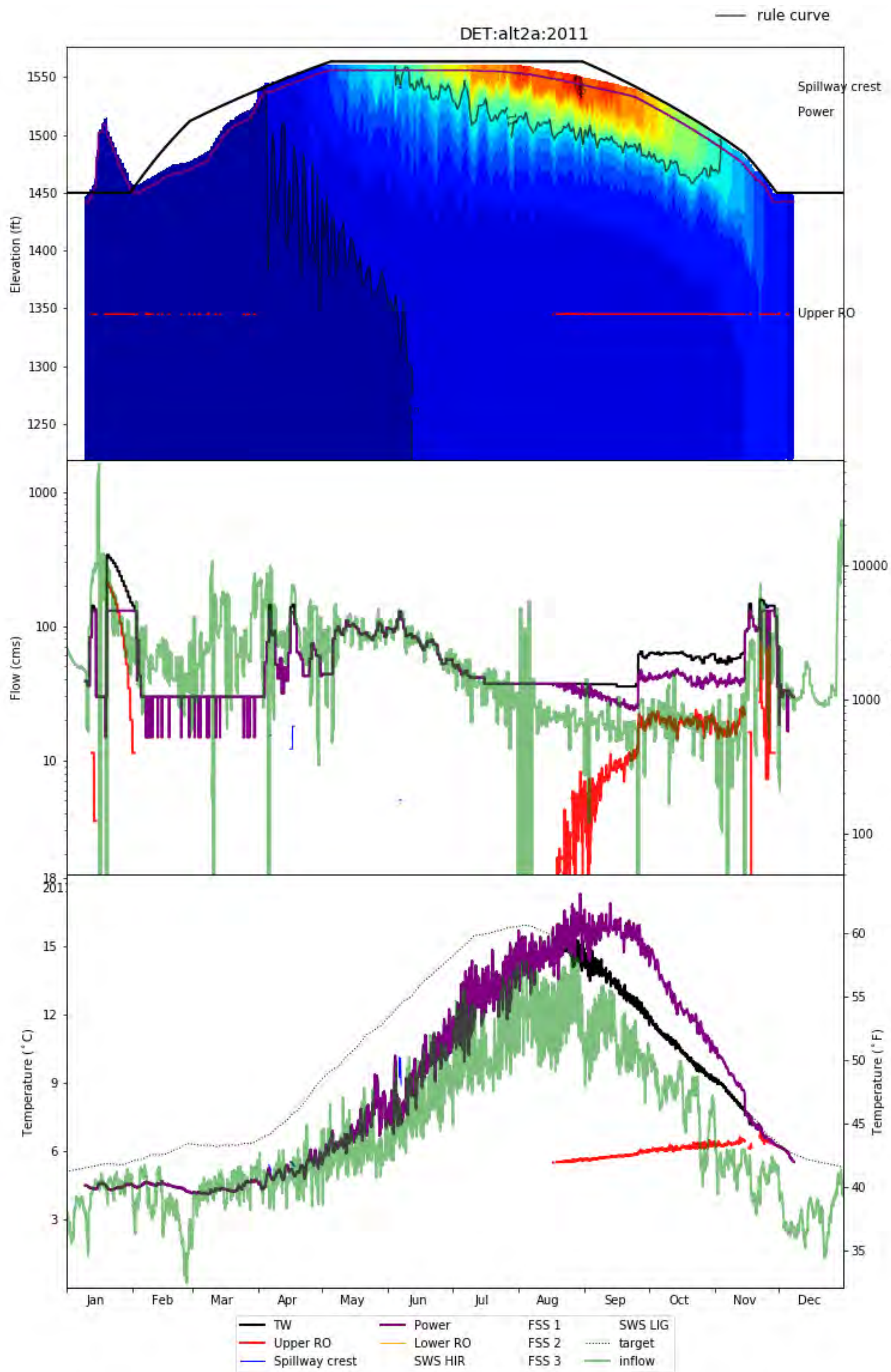

Figure 1-101. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at Detroit under Alternative 2a in 2011.

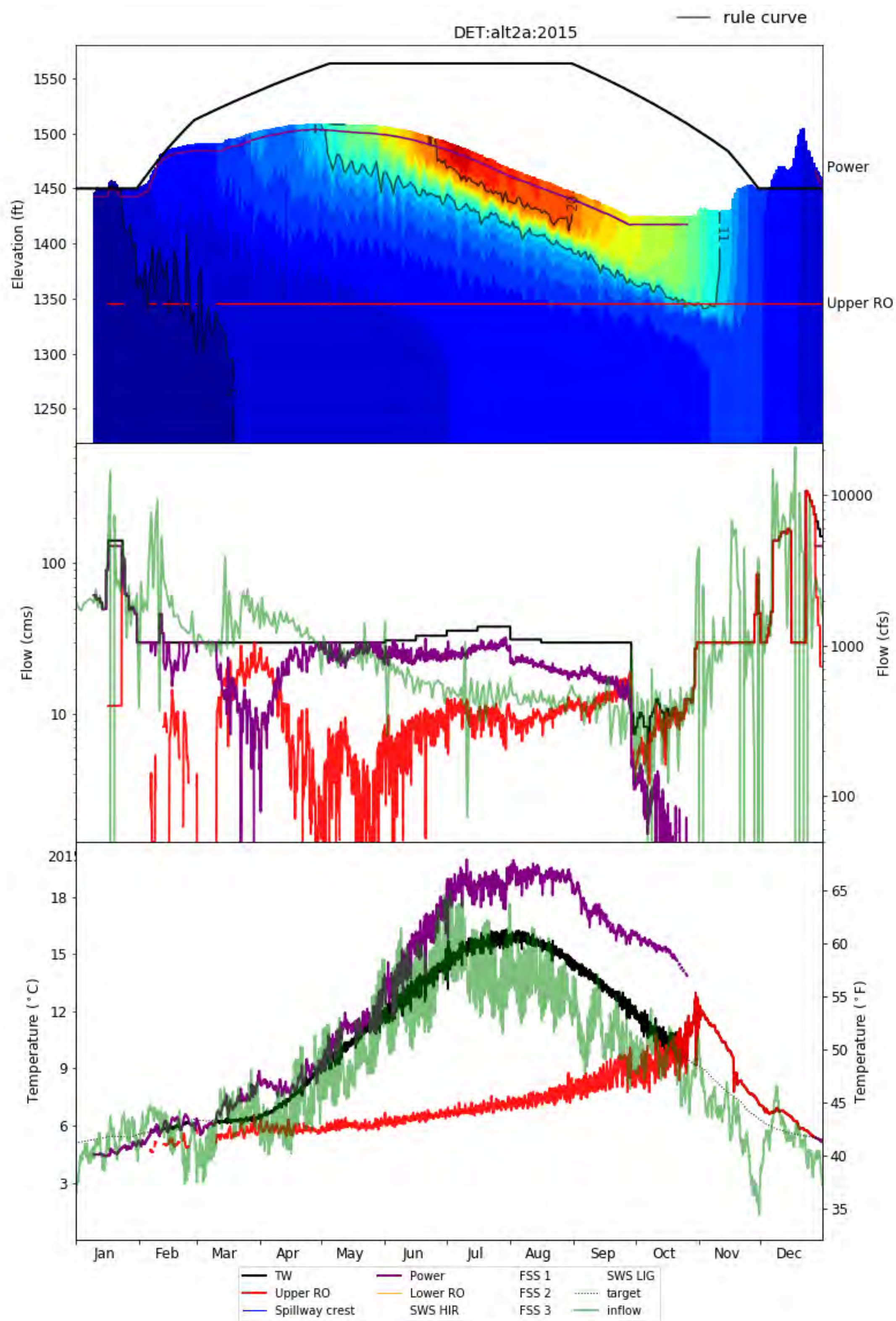

Figure 1-102. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at Detroit under Alternative 2a in 2015.

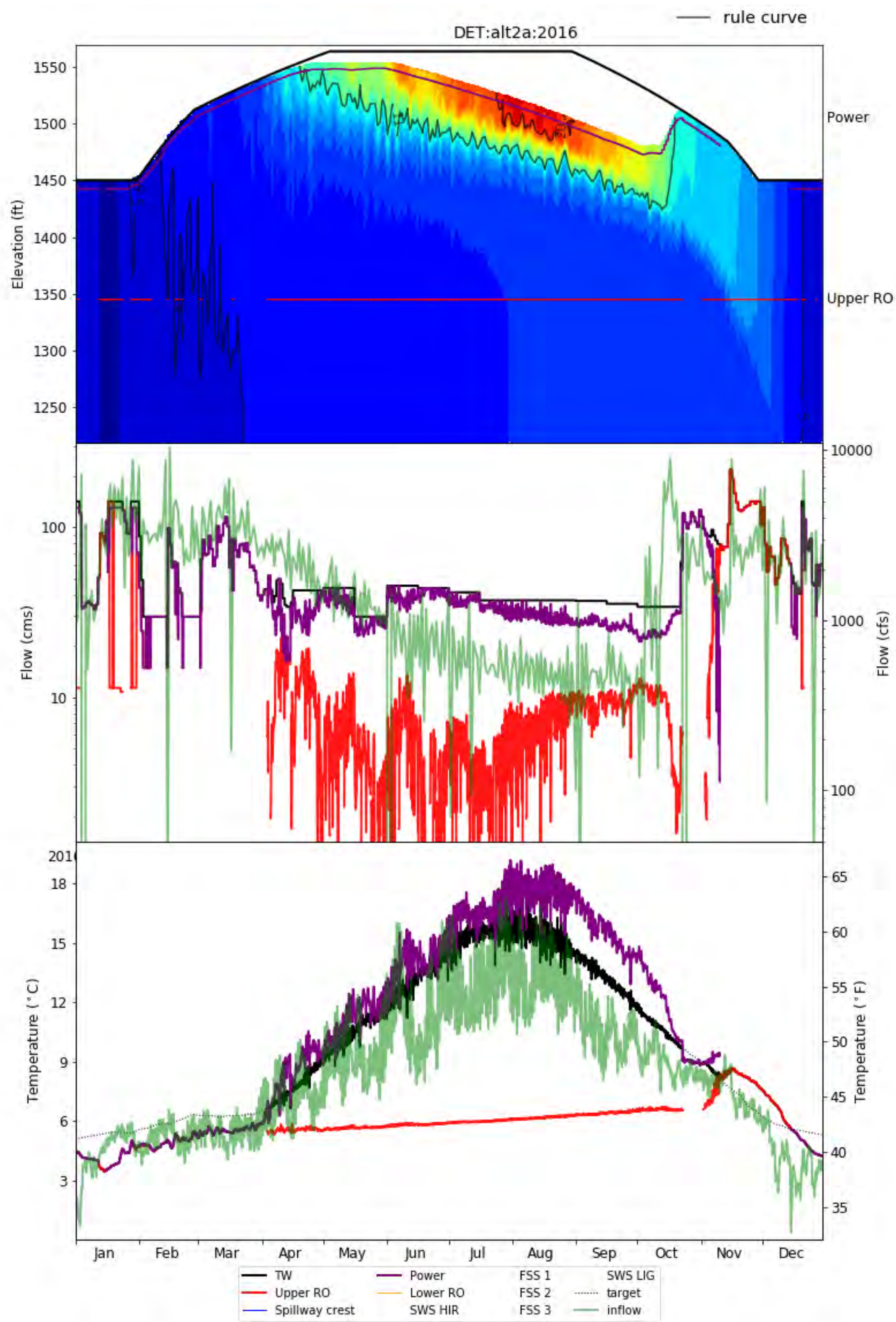

Figure 1-103. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at Detroit under Alternative 2a in 2016.

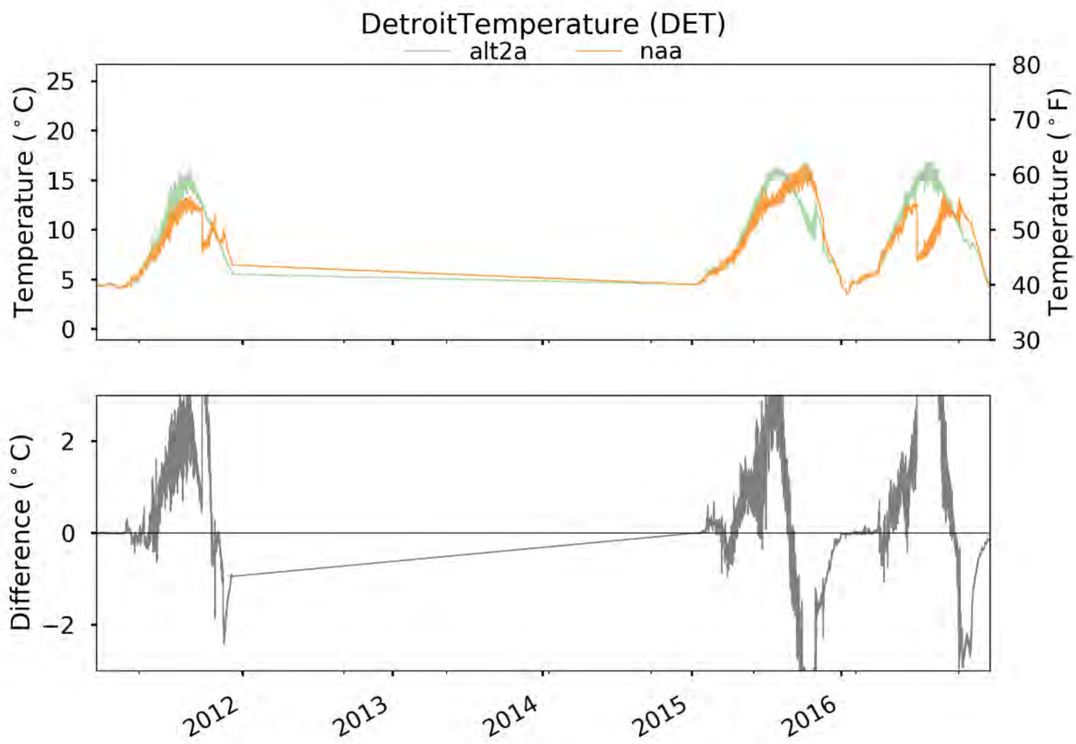

Figure 1-104. Comparison of DET Outflow Temperatures in NAA and Alternative 2a.

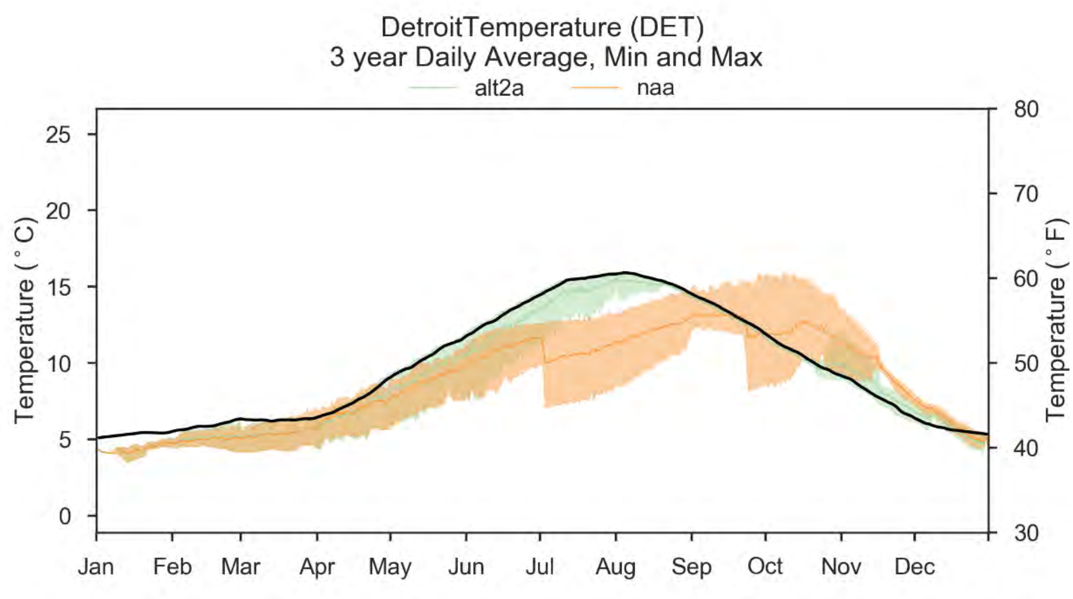

Figure 1-105. Comparison of DET 3-year Daily Average, Min, Max Outflow Temperatures in NAA and Alternative 2a. Black Line Indicates Temperature Target.

1.5.3.2 SOUTH SANTIAM DAMS

1.5.3.2.1 Green Peter

RES-SIM Lake Levels and Outflows

Lake level and storage at Green Peter were generally similar in Alternative 2a and NAA in 2011, 2015, and 2016 aside from October-December when a drawdown for fish passage RO operation occurred (Figure 1-106, Figure 1-107, Figure 1-108). Some increased storage in 2015 coincided with reduced outflows during spring and increased outflows in July-October. The proposed operational temperature management through the spillway (during spring/summer) and RO (during autumn) in Alternative 2a resulted in decreased power outflow compared to NAA (Figure 1-107).

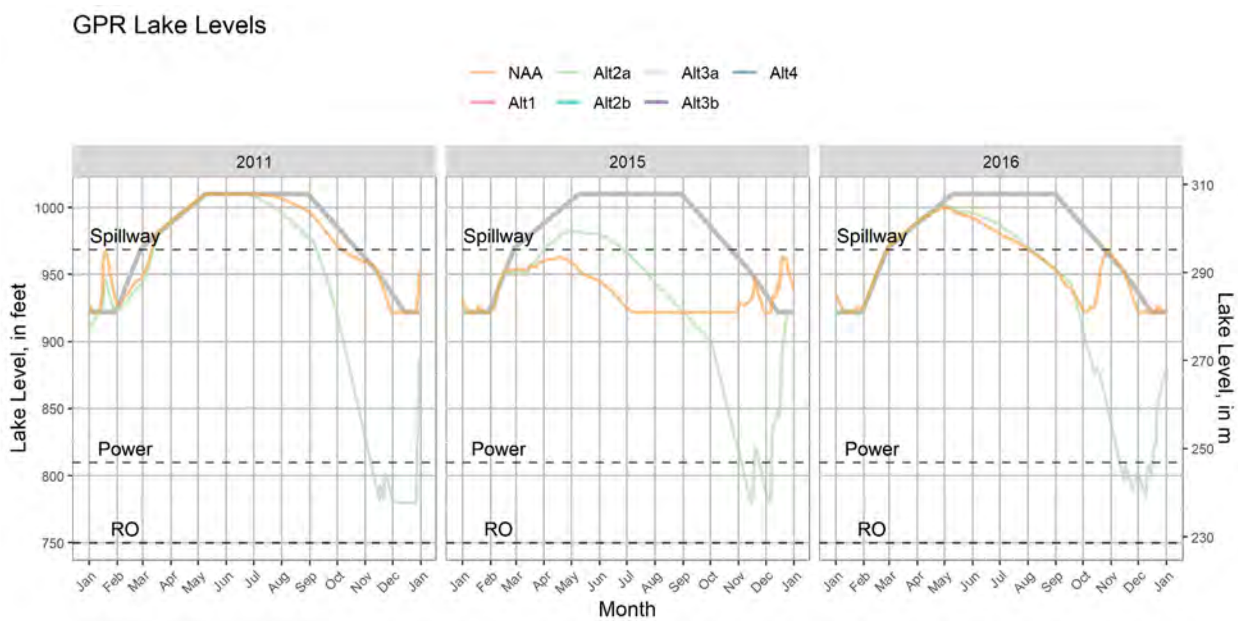

Figure 1-106. WV EIS RES-SIM Green Peter Lake Levels in 2011, 2015, and 2016 Under Alternative 2a and NAA.

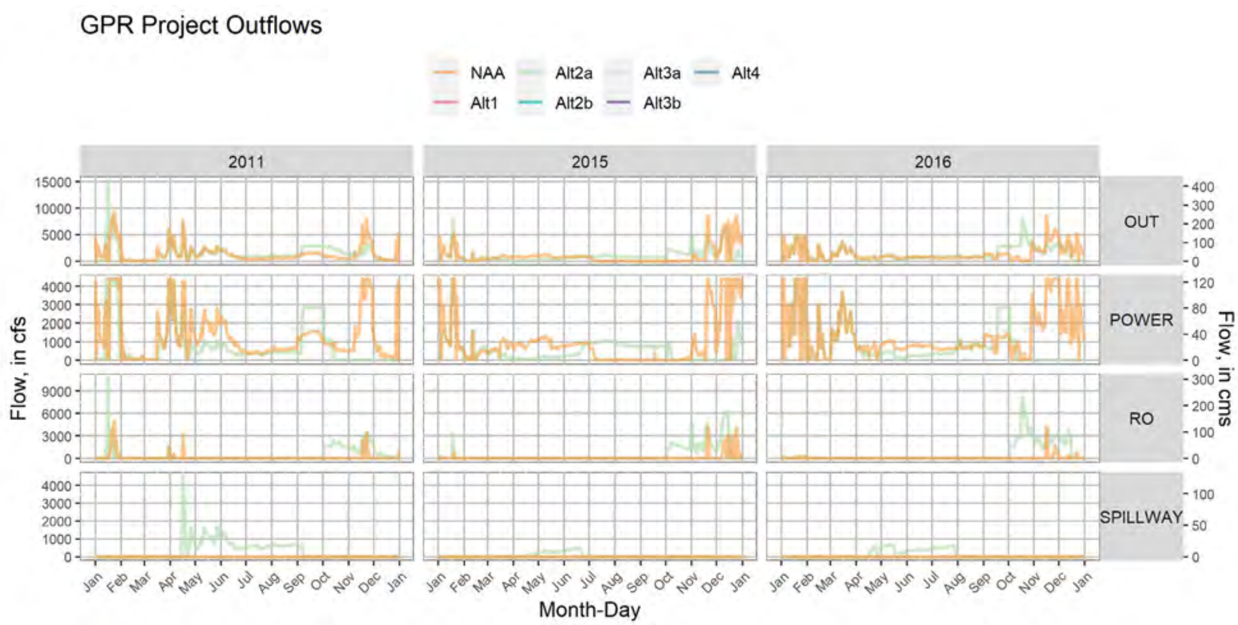

Figure 1-107. WV EIS RES-SIM Green Peter Dam Gate-Specific Outflows in 2011, 2015, and 2016 Under Alternative 2a and NAA.

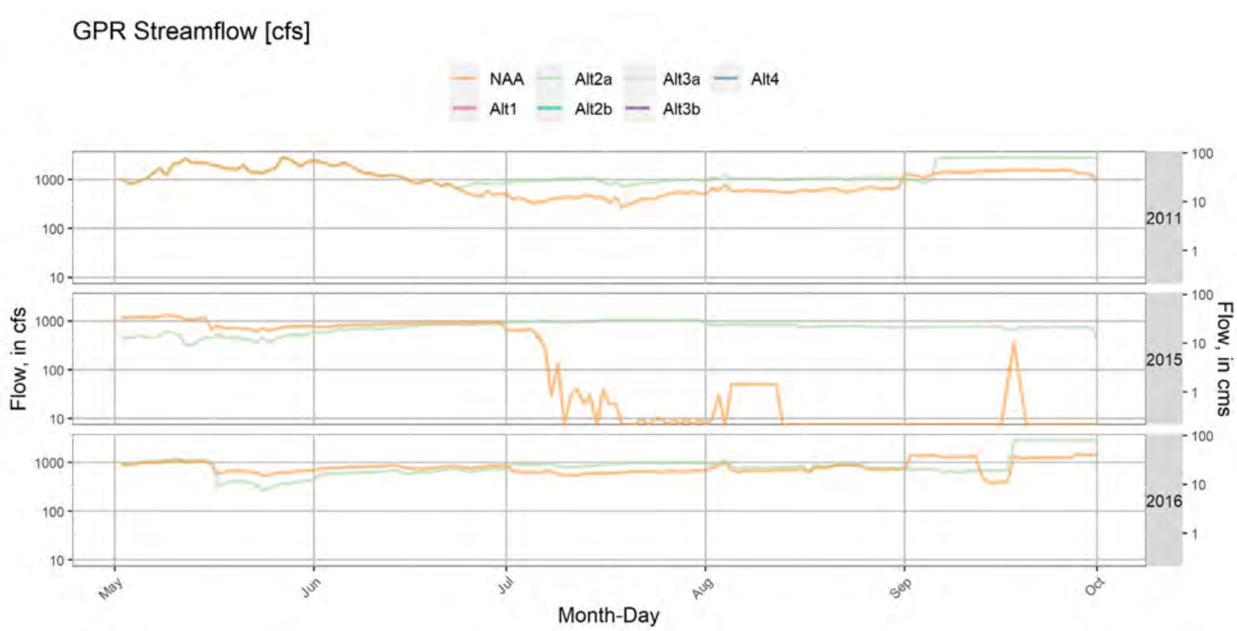

Figure 1-108. WV EIS RES-SIM Green Peter Dam Total Outflow in 2011, 2015, and 2016 Under Alternative 2a and NAA.

Lake Levels and Temperatures from CE-QUAL-W2

Depth-varying temperature, gate-specific outflows, and outflow temperatures through each calendar year scenario at Green Peter Lake are shown in Figure 1-109, Figure 1-110, and Figure 1-111. Alternative 2a included releases through the spillway during spring-summer (when the lake was above the spillway crest) as well as releases through the Regulating Outlets during autumn to mix non-power releases with relatively deep power penstock releases to meet the downstream temperature target. Tailwater release temperatures generally matched the temperature target when sufficient warm or cool water was available and those outlets were submerged (available for use). Spillway access was limited in some years (2015 especially), which led to an abrupt drop in tailwater temperature when spillway access ended in mid-summer of those years. This was followed by a large peak in tailwater temperature in the 2015 scenario during September-October as the lake was drafted at a relatively high outflow rate, effectively mixing the thermal layers near the dam (Figure 1-112, Figure 1-113). Generally, the autumn fish passage operation (drawdown to the RO) resulted in cooler autumn temperatures (November-December) compared to NAA (Figure 1-113).

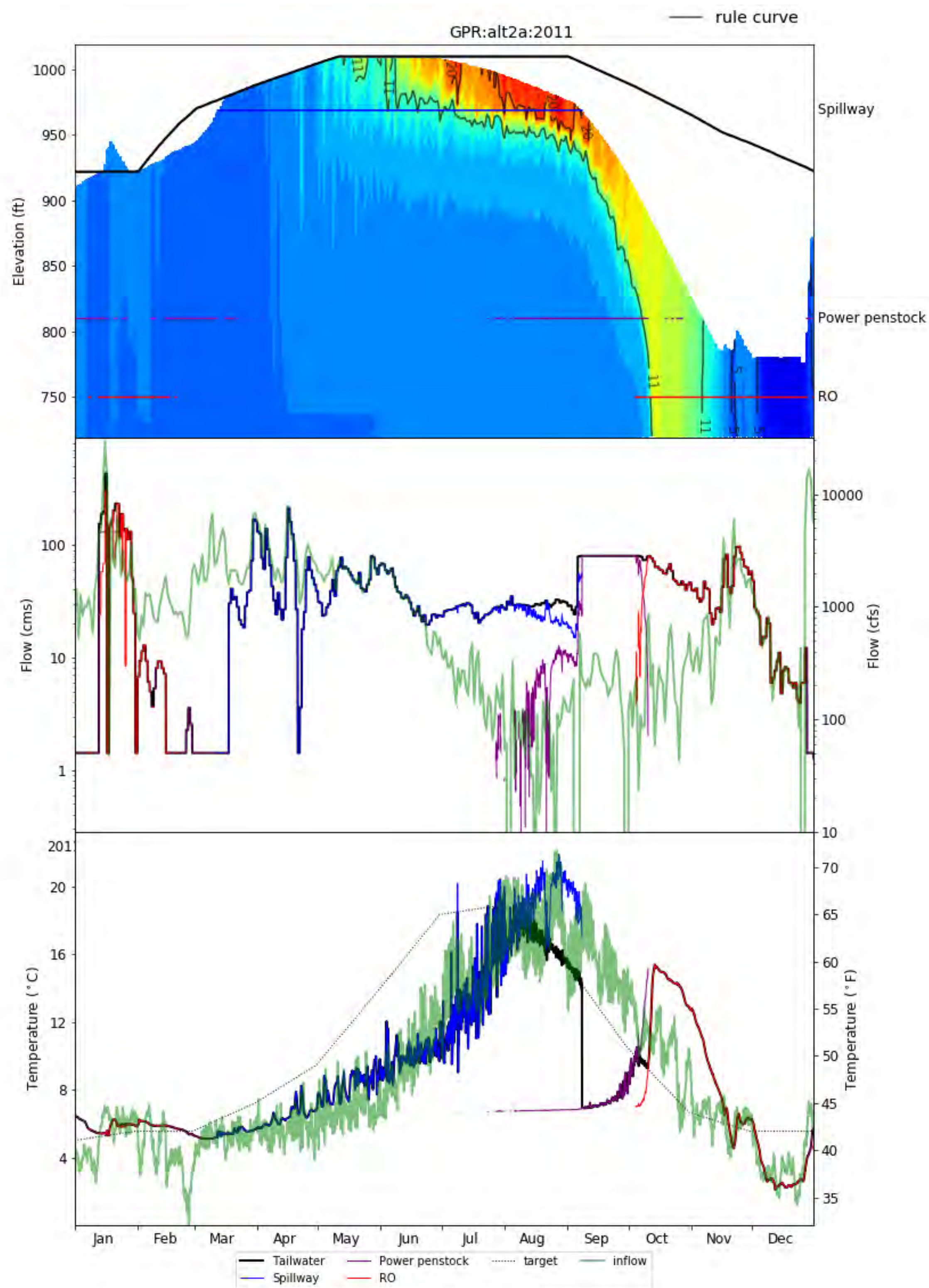

Figure 1-109. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at GPR under Alternative 2a in 2011.

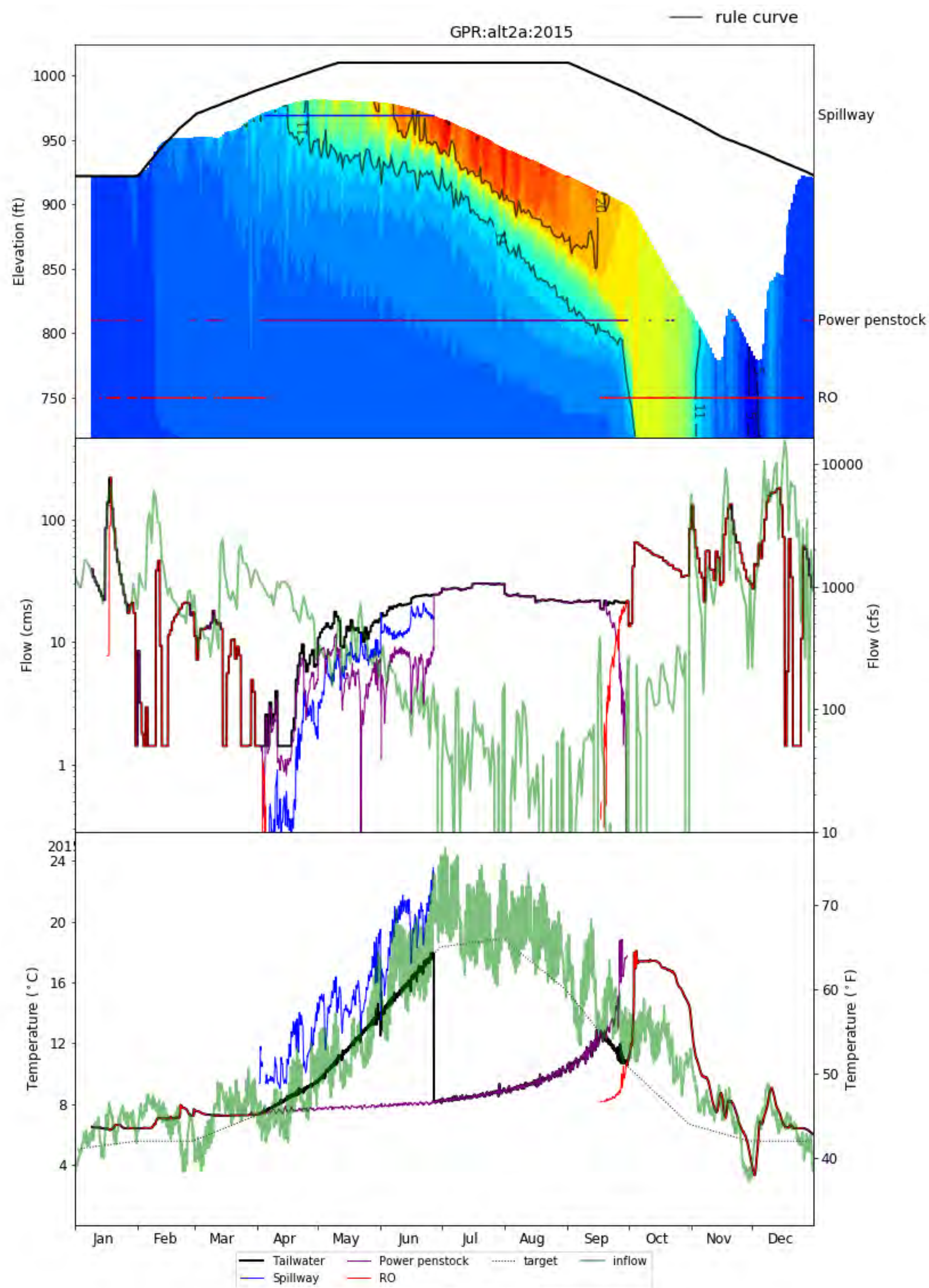

Figure 1-110. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at GPR under Alternative 2a in 2015.

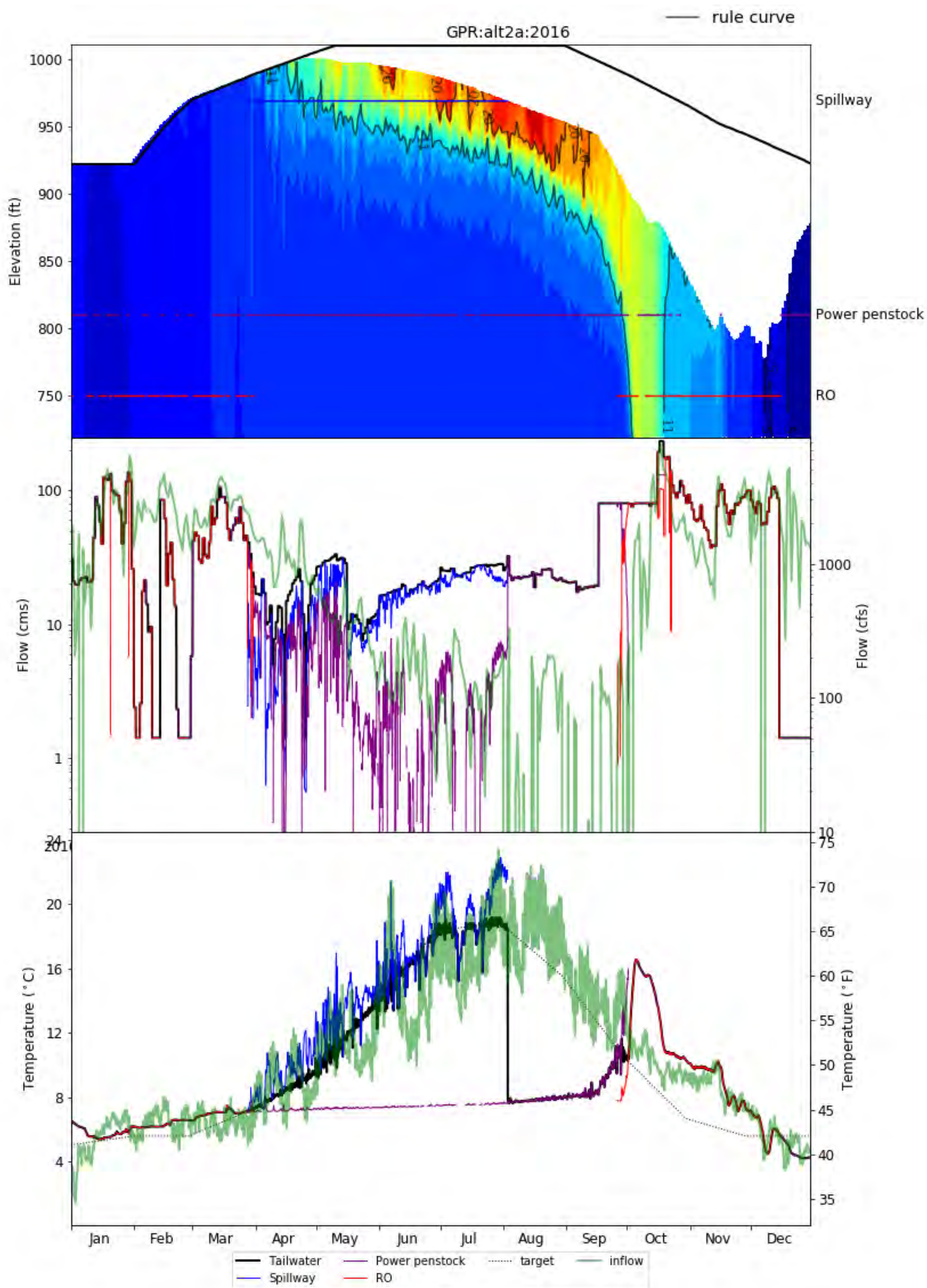

Figure 1-111. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at GPR under Alternative 2a in 2016.

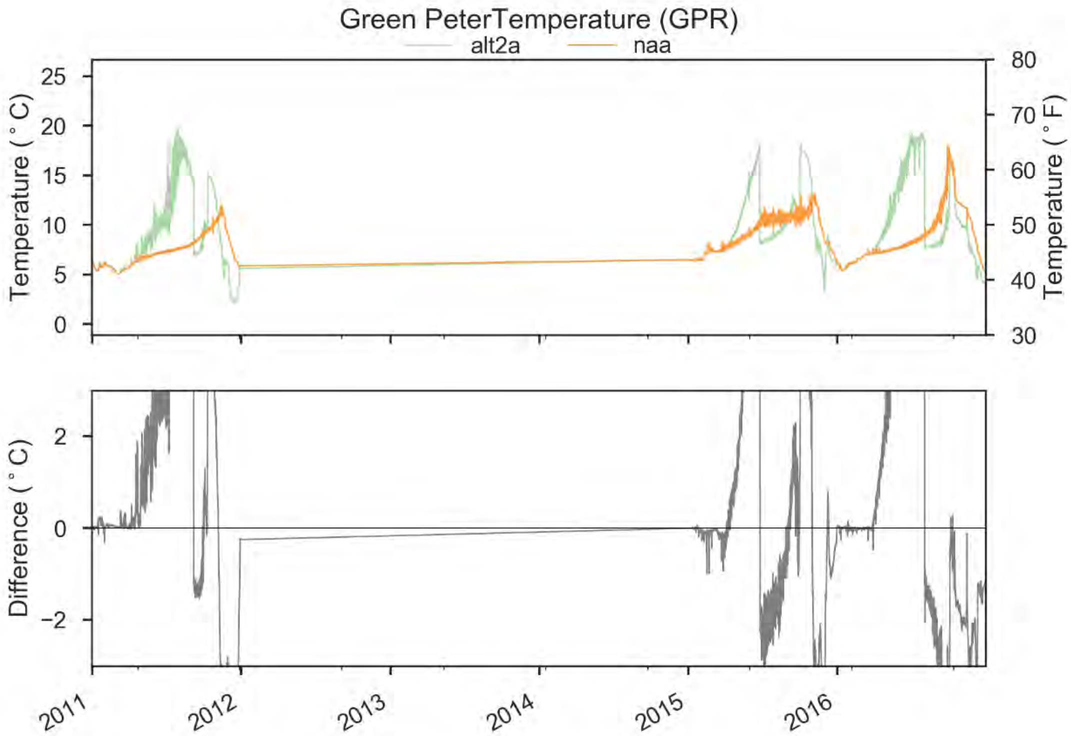

Figure 1-112. Comparison of GPR outflow temperatures in NAA and Alternative 2a.

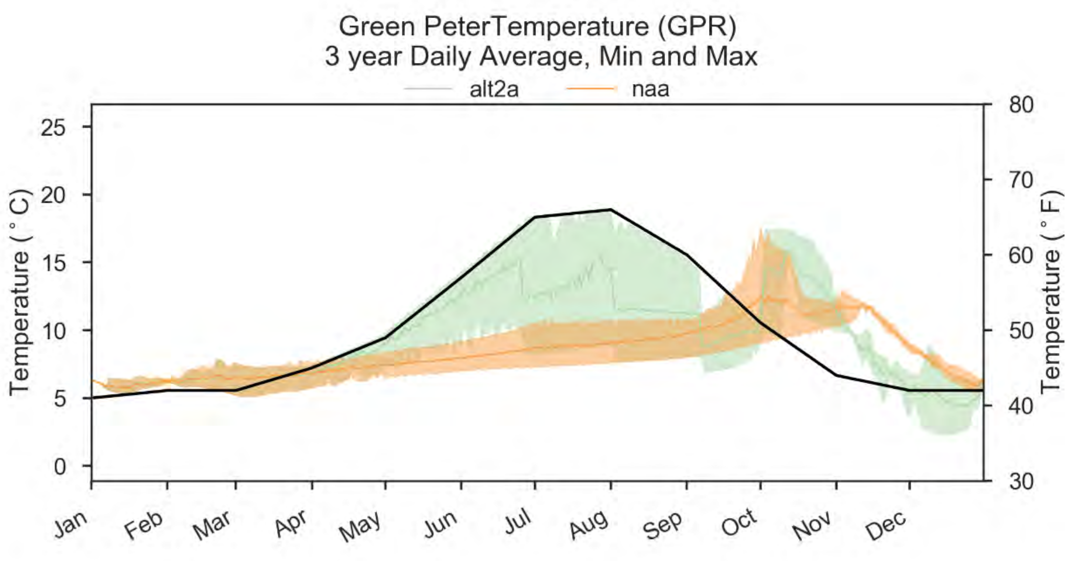

Figure 1-113. Comparison of GPR 3-year Daily Average, Min, Max Outflow Temperatures in NAA and Alternative 2a. Black Line Indicates Temperature Target.

1.5.3.2.2 Foster

RES-SIM Lake Levels and Outflows

Lake level and storage at Foster were generally similar under Alternative 2a compared to NAA in 2011 and 2016 but increased in 2015 in Alternative 2a compared to NAA (Figure 1-114, Figure 1-116). Total outflow from Foster Dam was affected by upstream operations at Green Peter Dam. The proposed modifications to the fish weir and FWWS in Alternative 2a resulted in lower outflow routed through the Power outlets for temperature management, especially during spring and summer compared to NAA (Figure 1-115).

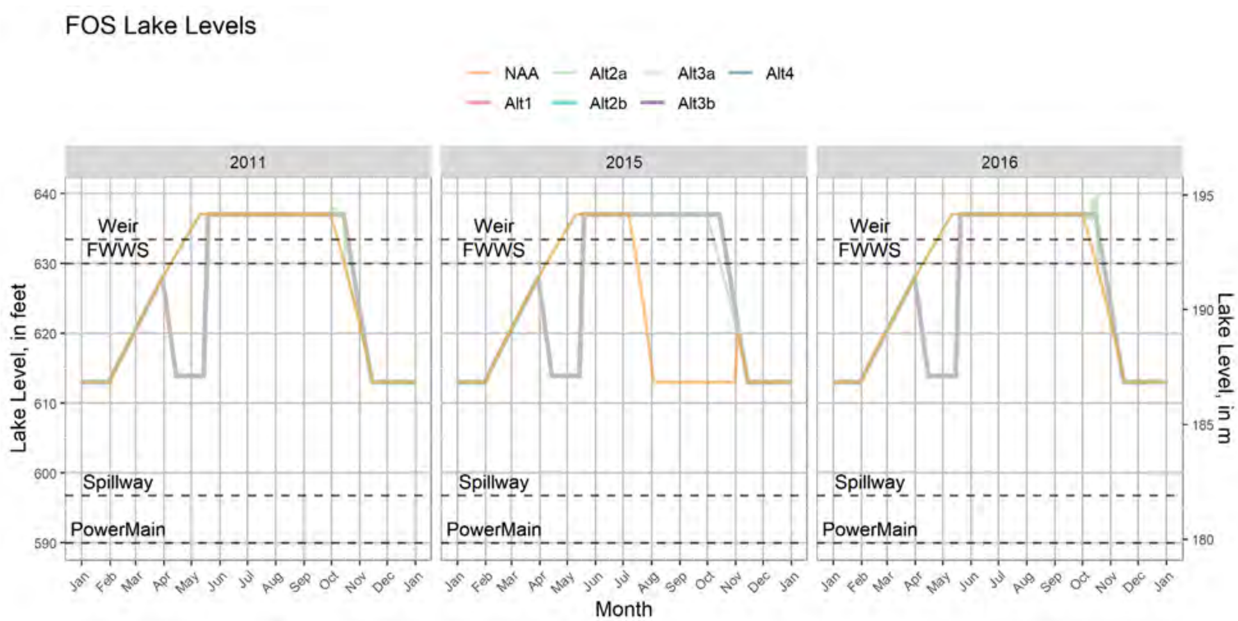

Figure 1-114. WV EIS RES-SIM Foster Lake Levels in 2011, 2015, and 2016 Under Alternative 2a and NAA.

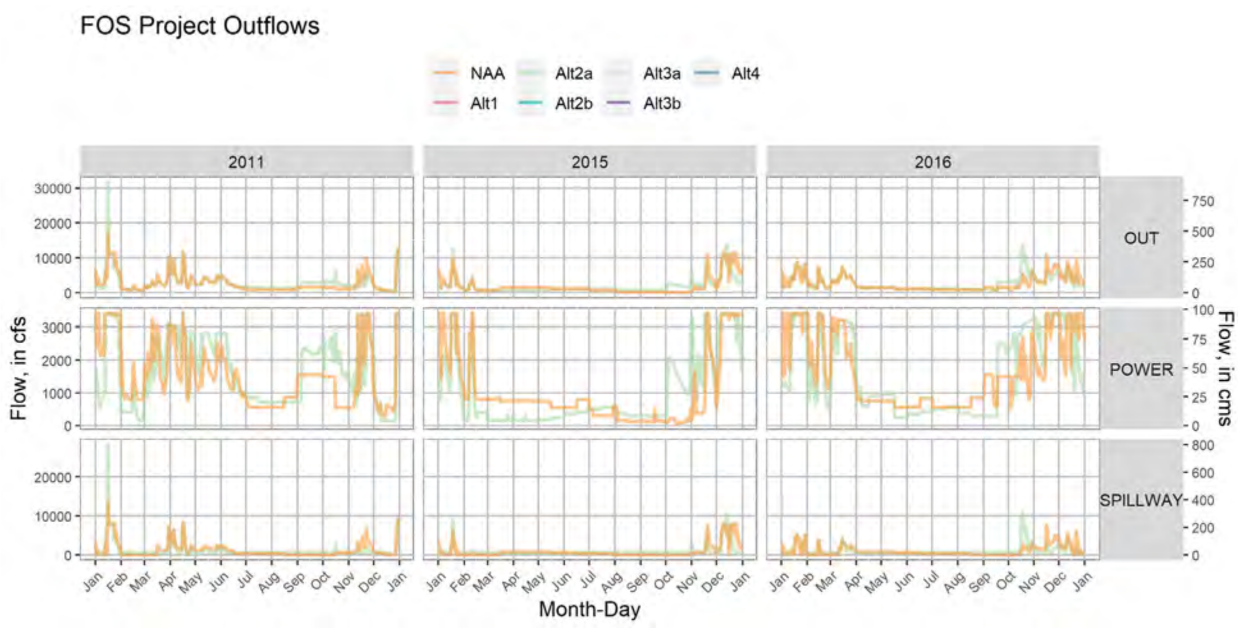

Figure 1-115. WV EIS RES-SIM Foster Dam Gate-Specific Outflows in 2011, 2015, and 2016 Under Alternative 2a and NAA.

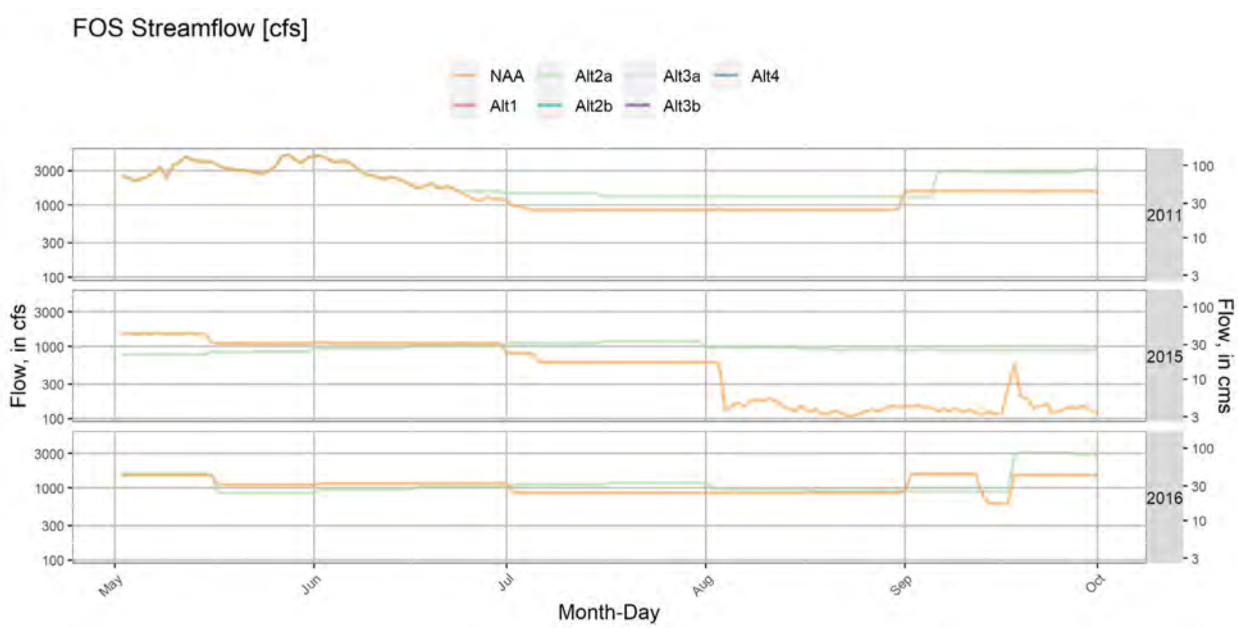

Figure 1-116. WV EIS RES-SIM Foster Dam Total Outflow in 2011, 2015, and 2016 Under Alternative 2a and NAA.

Lake Levels and Temperatures from CE-QUAL-W2

Depth-varying temperature, gate-specific outflows, and outflow temperatures through each calendar year scenario at Foster Lake are shown in Figure 1-117, Figure 1-118, and Figure 1-119. Foster Lake temperature was affected by Green Peter Dam operations release temperatures, generally resulting in travel times through Foster of 10-20 days during summer and a time lag in the temperature pattern (Sullivan and Rounds, 2021). Outflows from the proposed fish weir and FWWS combined with warmer spillway releases from Green Peter upstream resulted in warmer tailwater temperature in spring and summer compared to NAA (Figure 1-120, Figure 1-121). Generally, the autumn fish passage operation (drawdown to the RO at Green Peter) resulted in cooler autumn temperatures (November-December) compared to NAA downstream of Foster Dam.

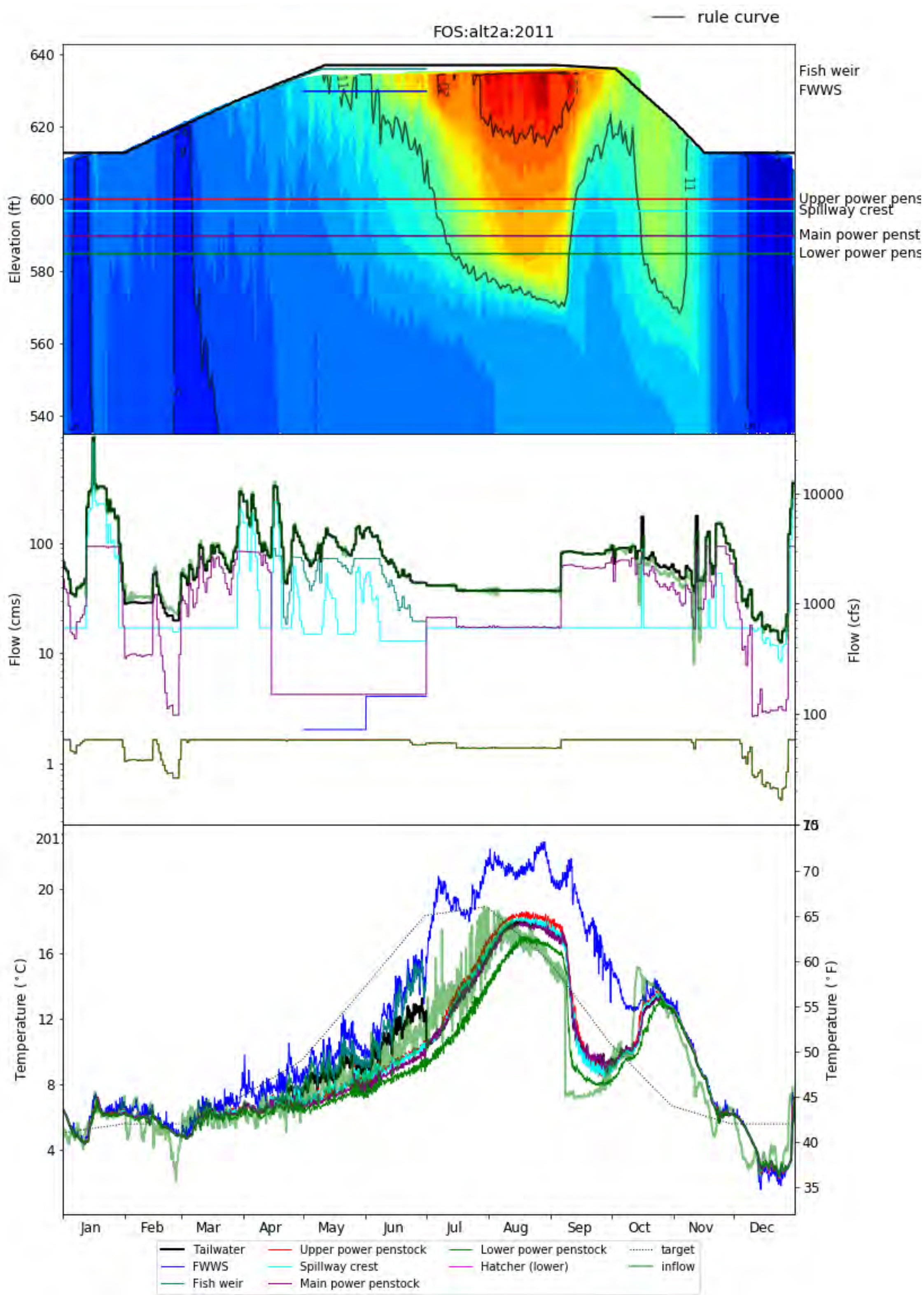

Figure 1-117. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at FOS under Alternative 2a in 2011.

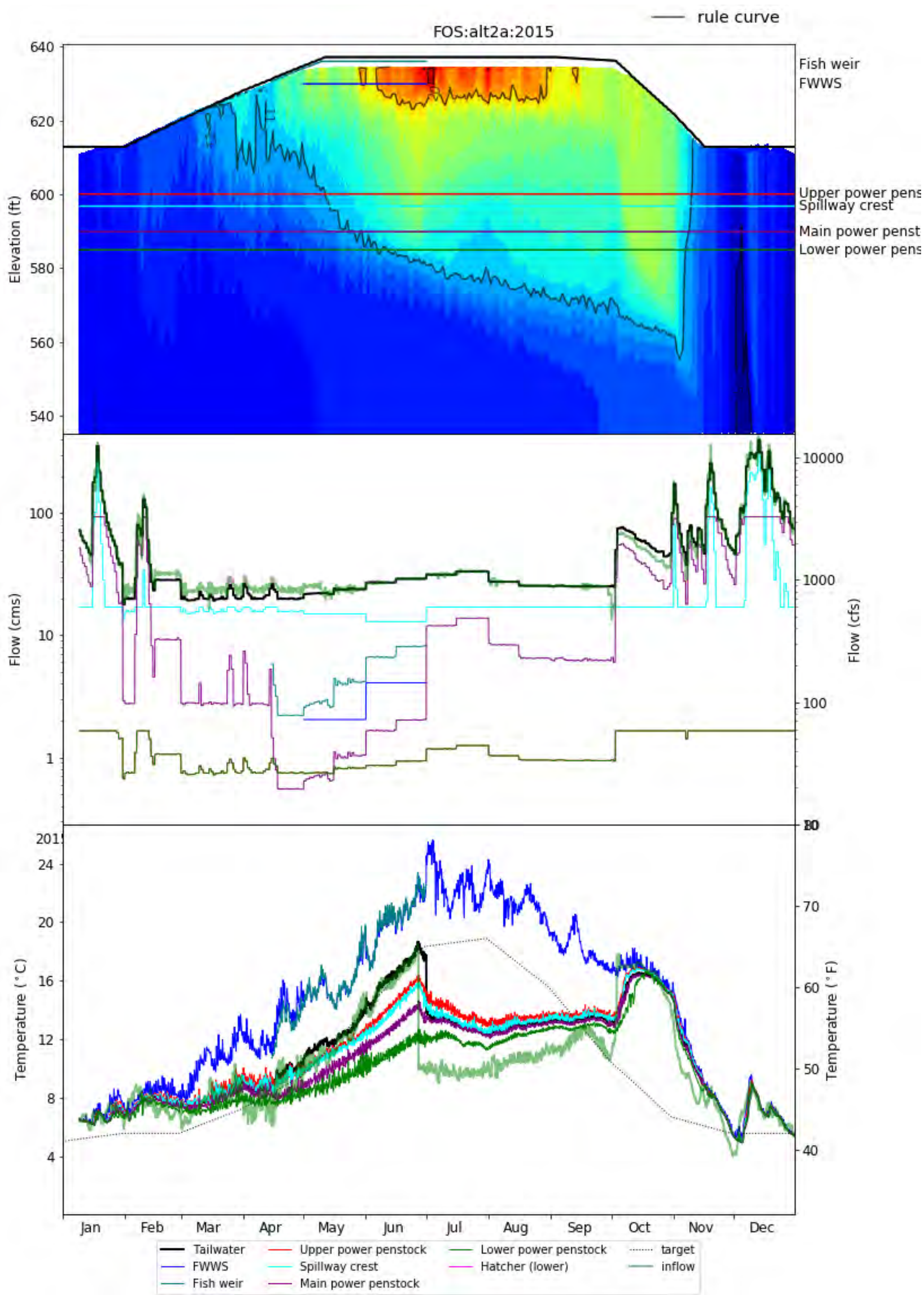

Figure 1-118. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at FOS under Alternative 2a in 2015.

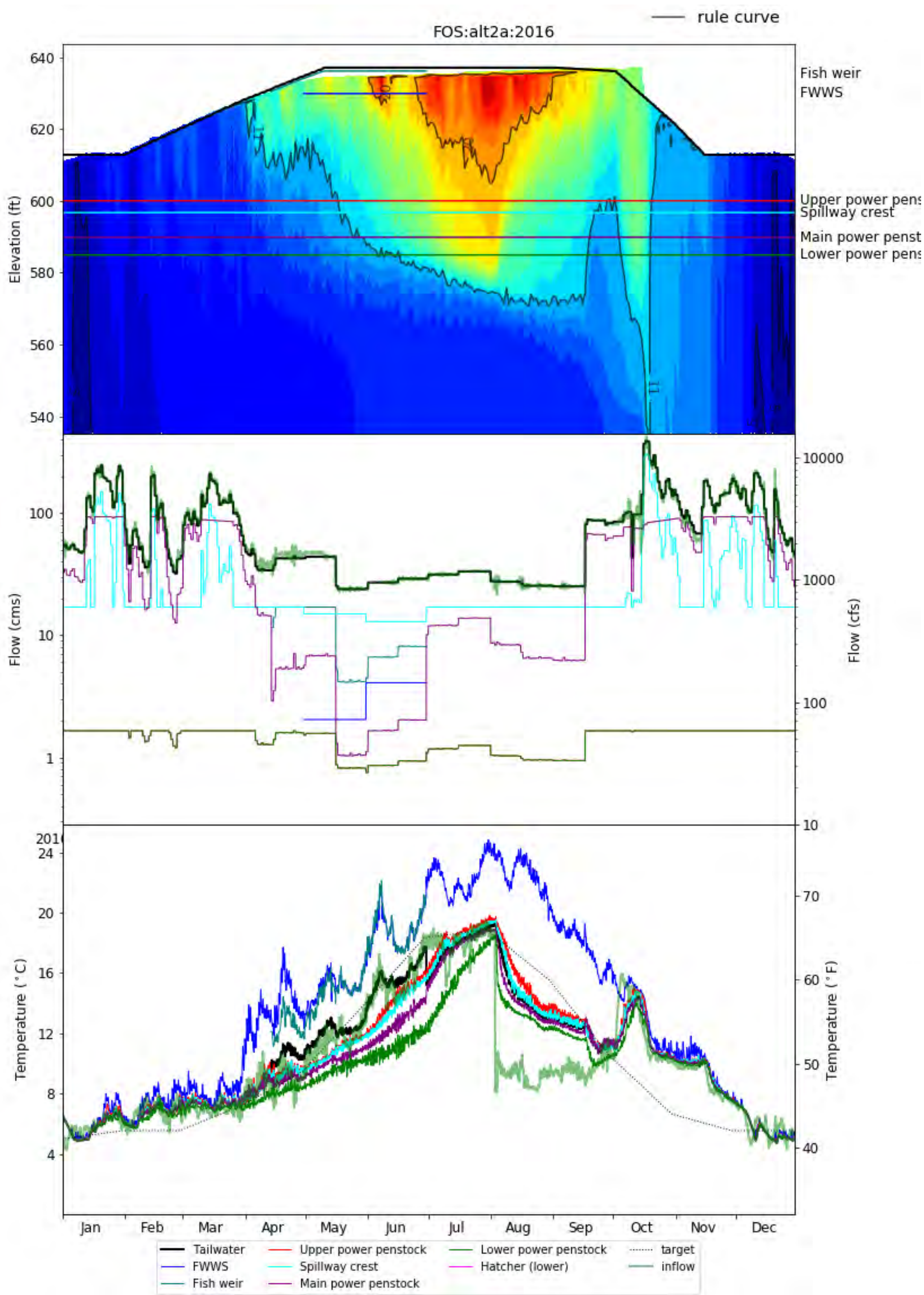

Figure 1-119. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at FOS under Alternative 2a in 2016.

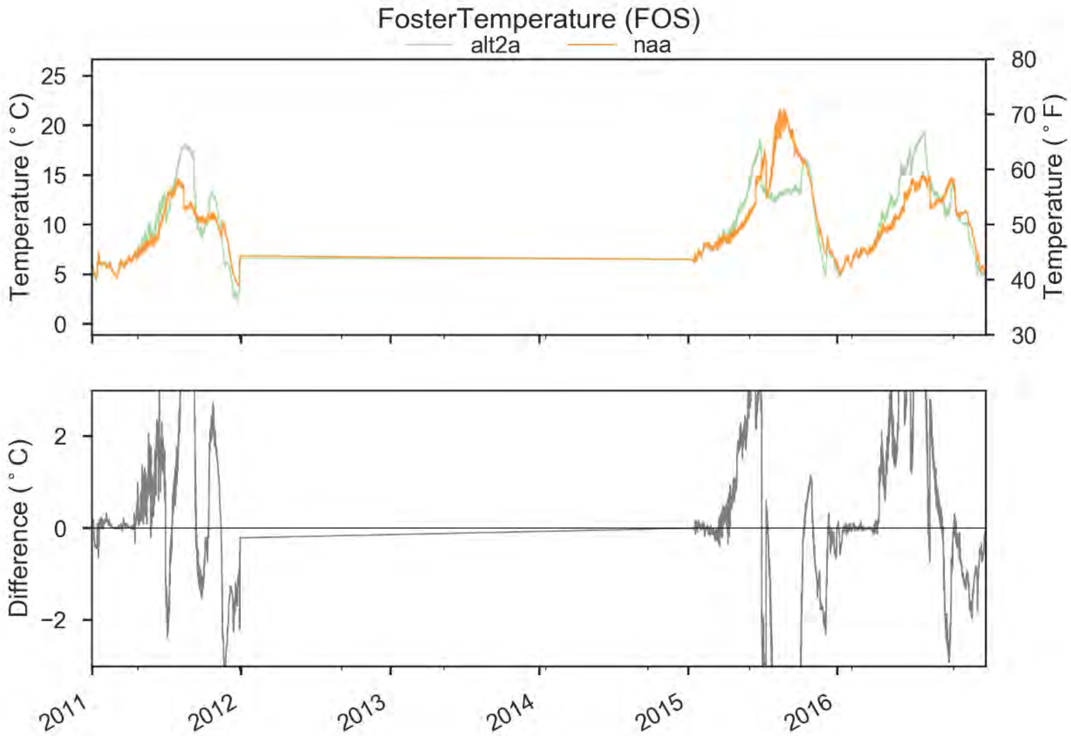

Figure 1-120. Comparison of FOS Outflow Temperatures in NAA and Alternative 2a.

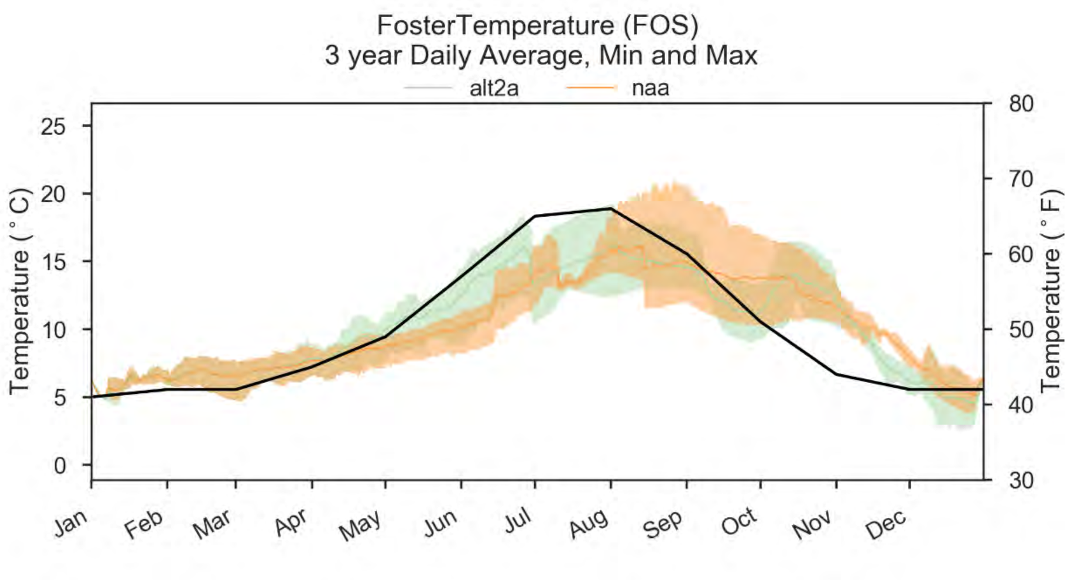

Figure 1-121. Comparison of FOS 3-year Daily Average, Min, Max Outflow Temperatures in NAA and Alternative 2a. Black Line Indicates Temperature Target.

1.5.3.3 MCKENZIE DAMS

1.5.3.3.1 Cougar

RES-SIM Lake Levels and Outflows

Lake level and storage at Cougar Lake generally increased under Alternative 2a compared to NAA in 2015 and 2016 aside from September-November in 2015 where the power pool was utilized for downstream flow augmentation when available (Figure 1-122, Figure 1-123, Figure 1-124). The increased storage coincided with reduced outflows during spring and increased outflows in summer (while the lake was above minimum lake elevation rules set in RES-SIM) during 2015 and 2016 comparing Alternative 2a to NAA (Figure 1-123). 2011 operations were generally similar in Alternative 2a and NAA at Cougar Lake.

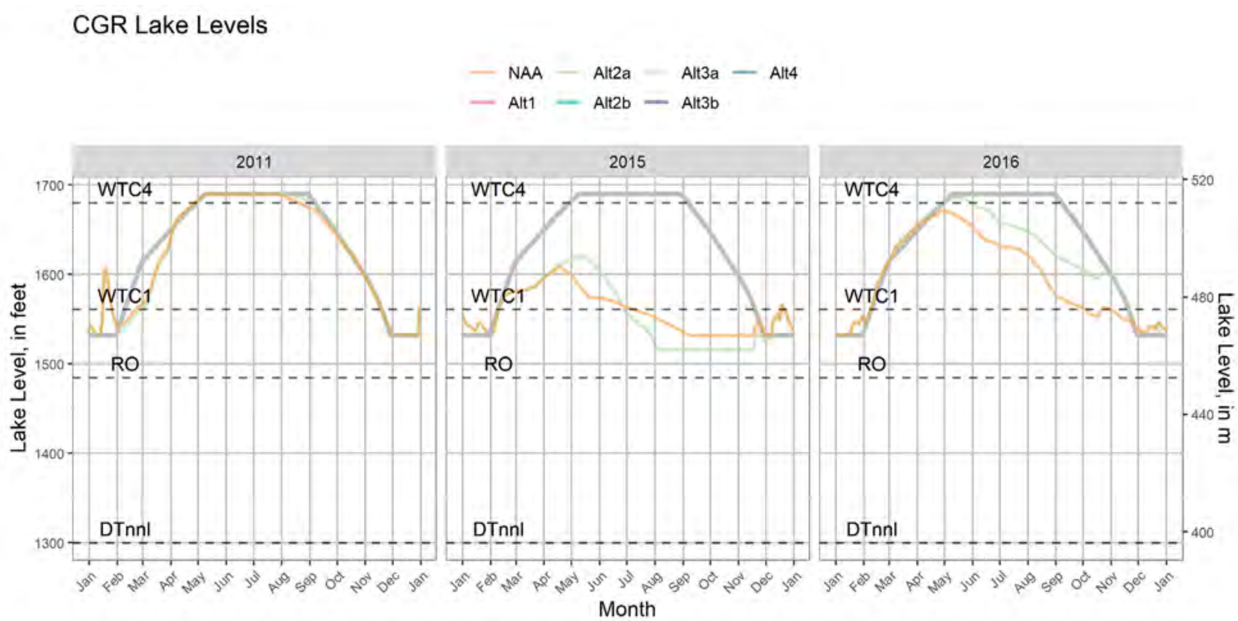

Figure 1-122. WV EIS RES-SIM Cougar Lake Levels in 2011, 2015, and 2016 under Alternative 2a and NAA.

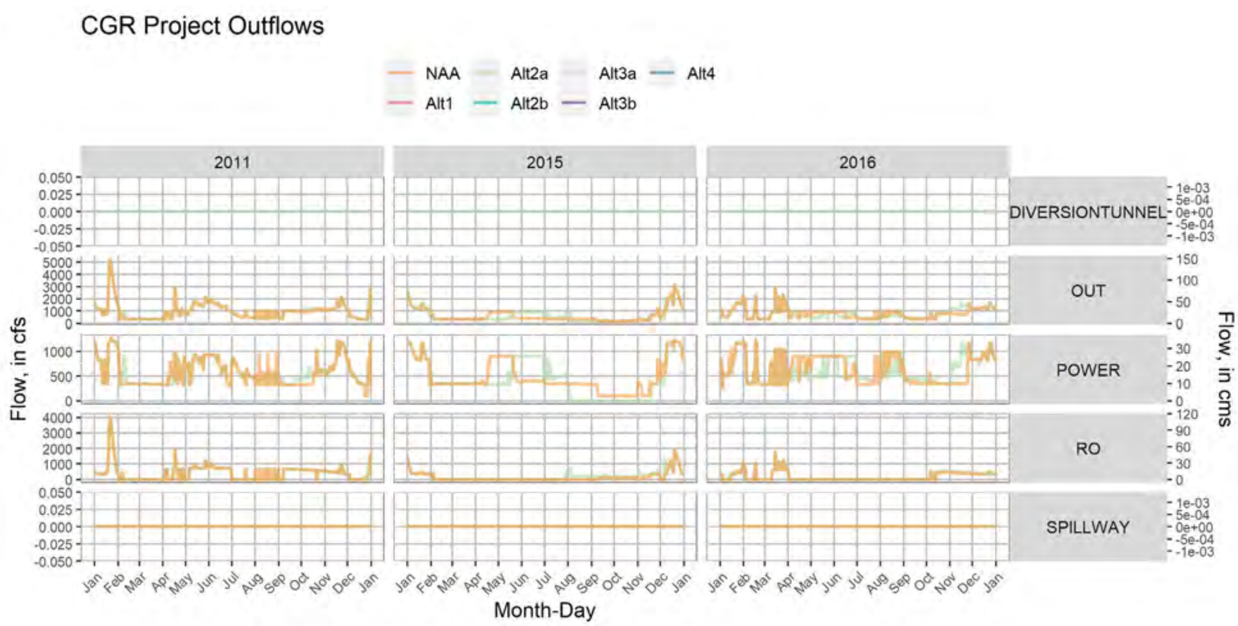

Figure 1-123. WV EIS RES-SIM Cougar Dam Gate-Specific Outflows in 2011, 2015, and 2016 Under Alternative 2a and NAA.

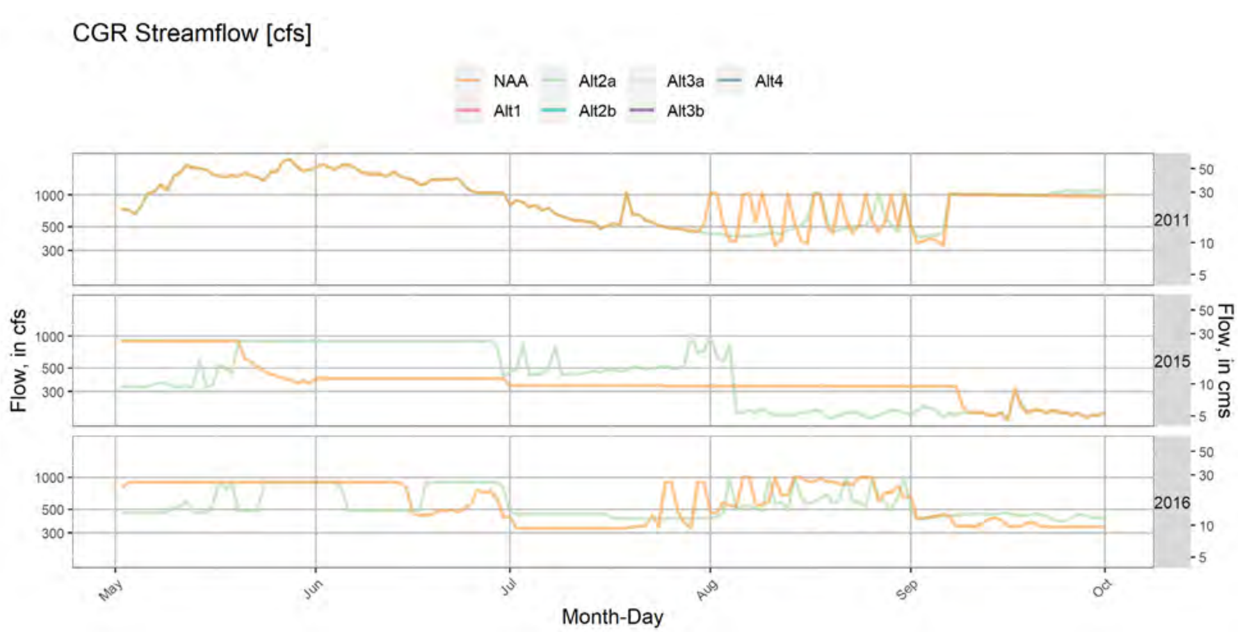

Figure 1-124. WV EIS RES-SIM Cougar Dam Total Outflow in 2011, 2015, and 2016 Under Alternative 2a and NAA.

Lake Levels and Temperatures from CE-QUAL-W2

Depth-varying temperature, gate-specific outflows, and outflow temperatures through each calendar year scenario at Cougar Lake are shown in Figure 1-125, Figure 1-126, and Figure 1-127. Outflows from the existing temperature tower and proposed FSS resulted in similar tailwater temperature in Alternative 2a compared to NAA (Figure 1-128 and Figure 1-129) aside from minor differences in each calendar year scenario that were likely linked to differences in lake levels and the shift in timing of when the lake was drafted below the bottom usable elevation of the WTCT. The addition of a FSS structure in Alternative 2a is not expected to have a large effect on the ability of the existing WTCT functionality with respect to temperature management (USACE, 2019a).

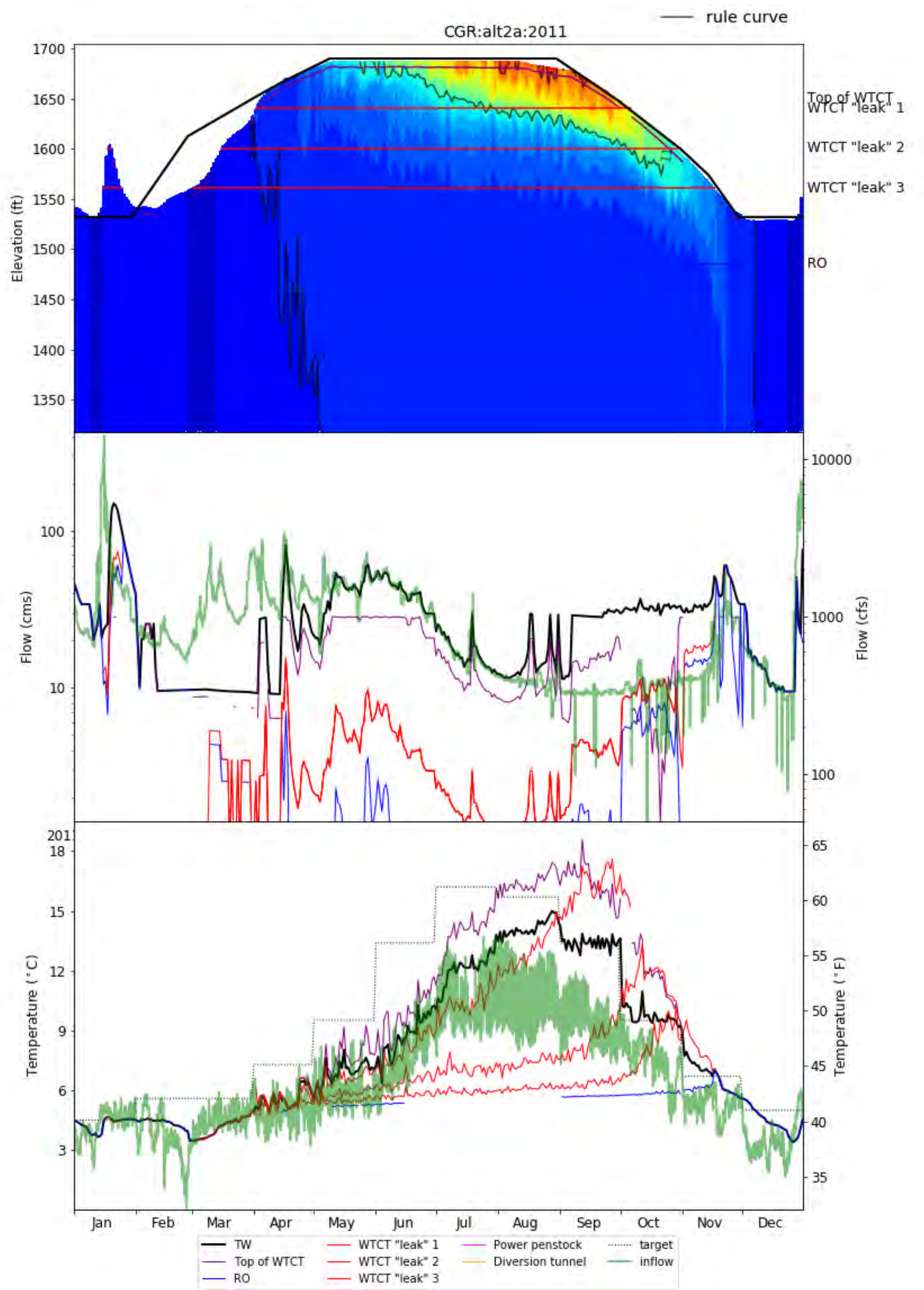

Figure 1-125. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at CGR under Alternative 2a in 2011.

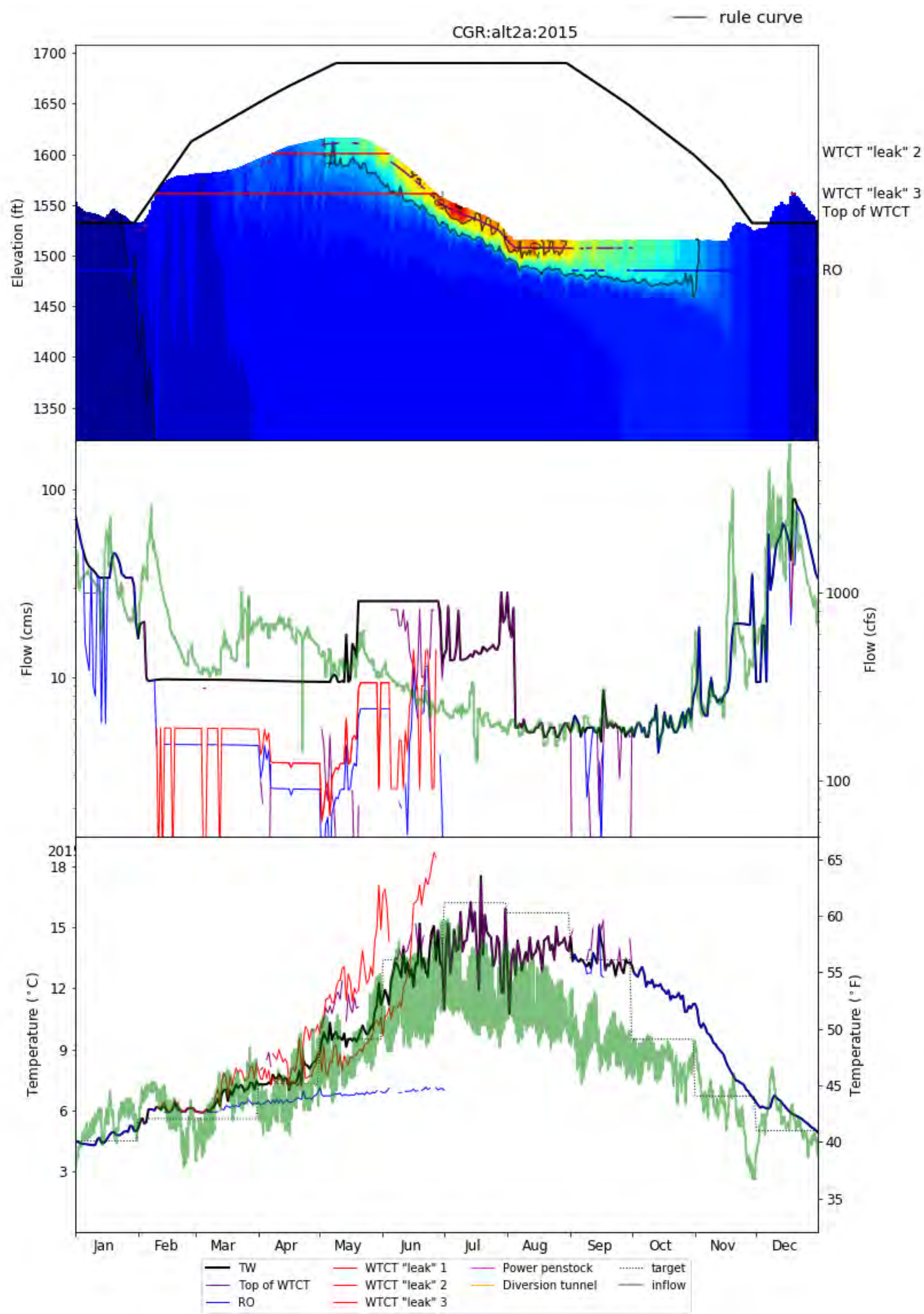

Figure 1-126. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at CGR under Alternative 2a in 2015.

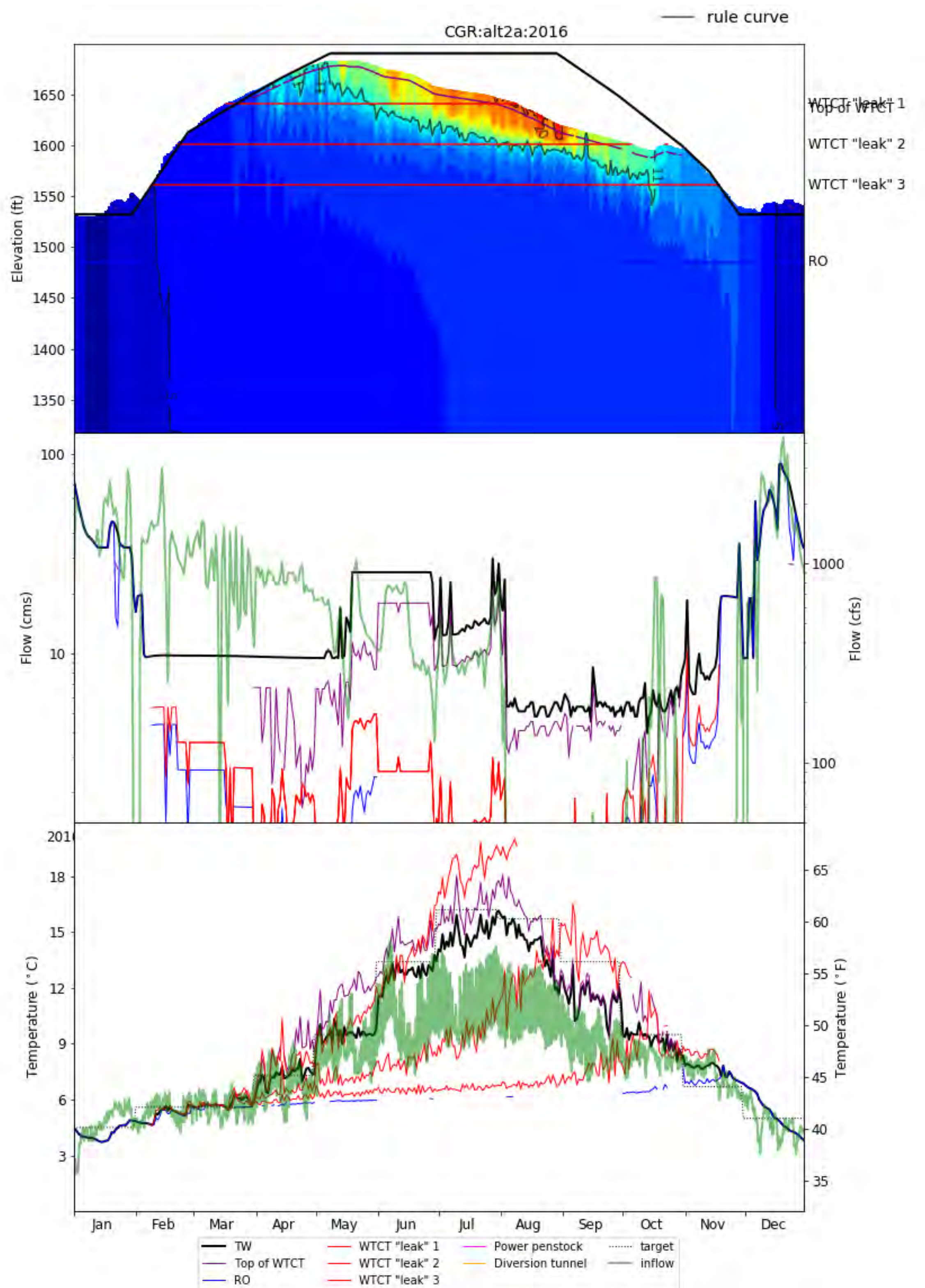

Figure 1-127. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at CGR under Alternative 2a in 2016.

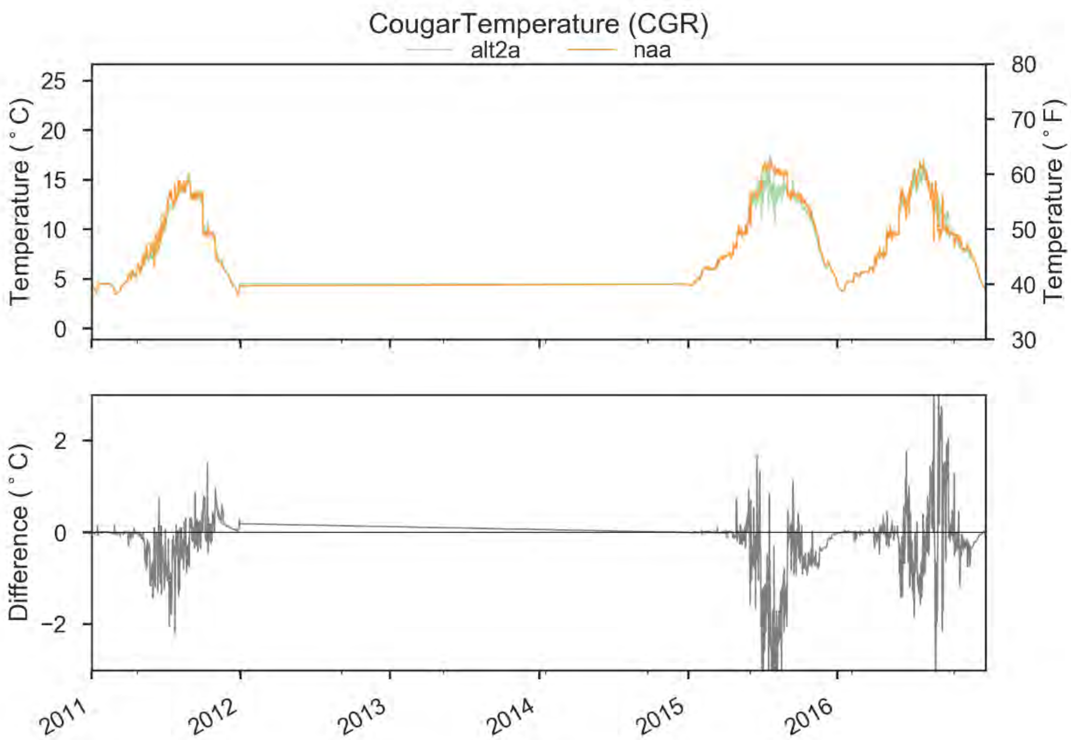

Figure 1-128. Comparison of CGR outflow temperatures in NAA and Alternative 2a.

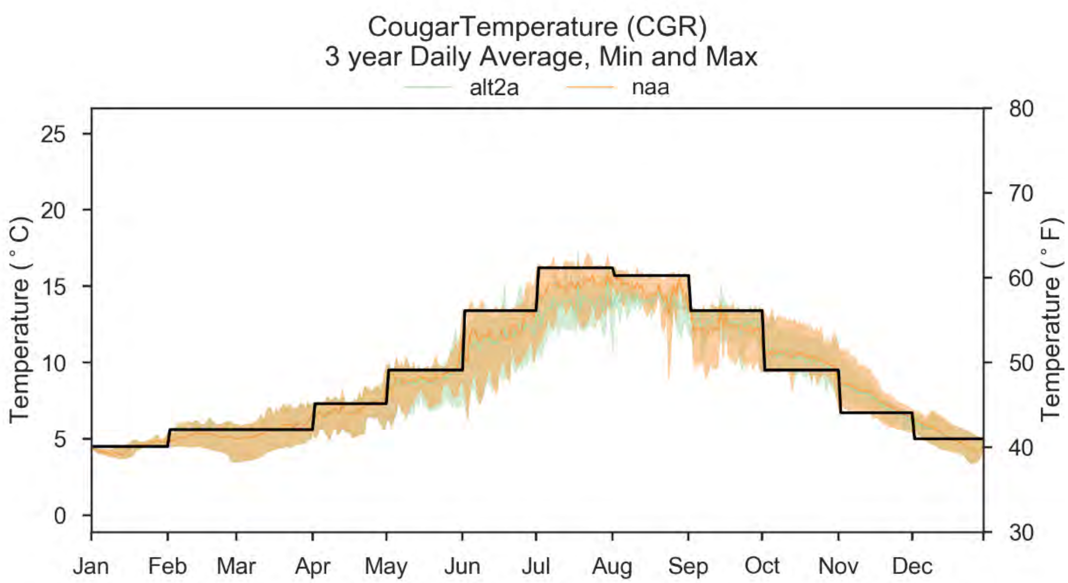

Figure 1-129. Comparison of CGR 3-year Daily Average, Min, Max Outflow Temperatures in NAA and Alternative 2a. Black Line Indicates Temperature Target.

1.5.3.4 MIDDLE FORK WILLAMETTE DAMS

1.5.3.4.1 Hills Creek

RES-SIM Lake Levels and Outflows

Lake level and storage at Hills Creek Lake generally increased under Alternative 2a compared to NAA in 2015 and 2016 aside from August-November in 2015 where the power pool was utilized for downstream flow augmentation (Figure 1-130, Figure 1-131, and Figure 1-132). The increased storage coincided with reduced outflows during spring and increased outflows in June-August during 2015 and August-October in 2016 comparing Alternative 2a to NAA (Figure 1-131). 2011 operations were generally similar in Alternative 2a and NAA at Hills Creek Lake.

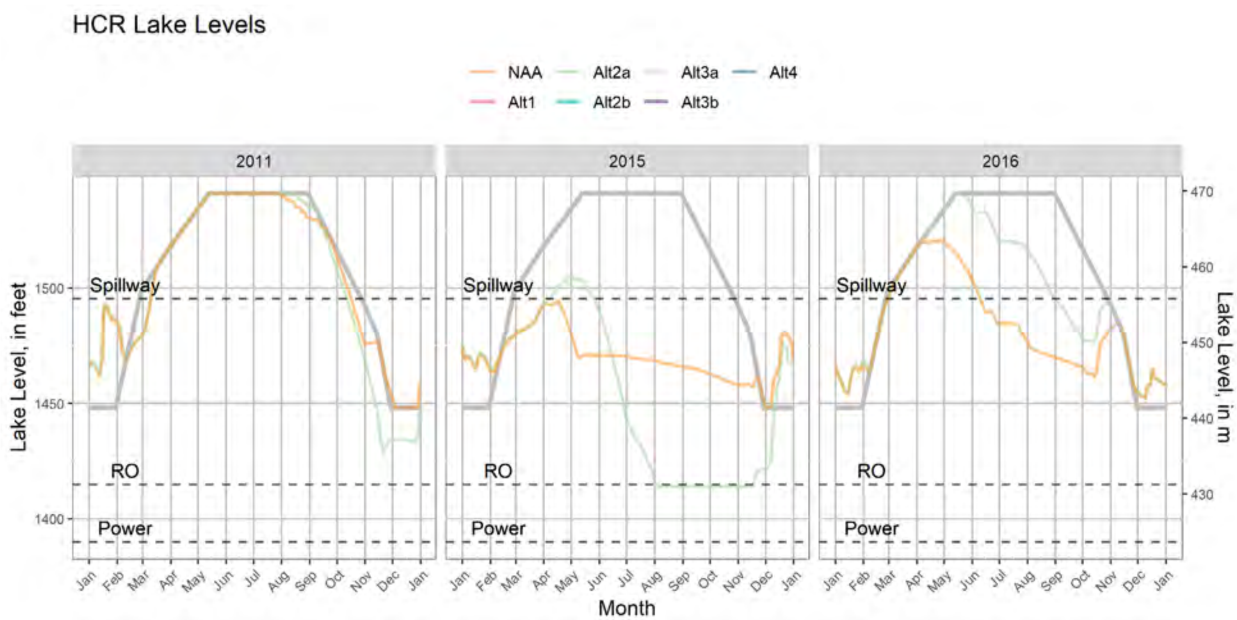

Figure 1-130. WV EIS RES-SIM Hills Creek Lake Levels in 2011, 2015, and 2016 Under Alternative 2a and NAA.

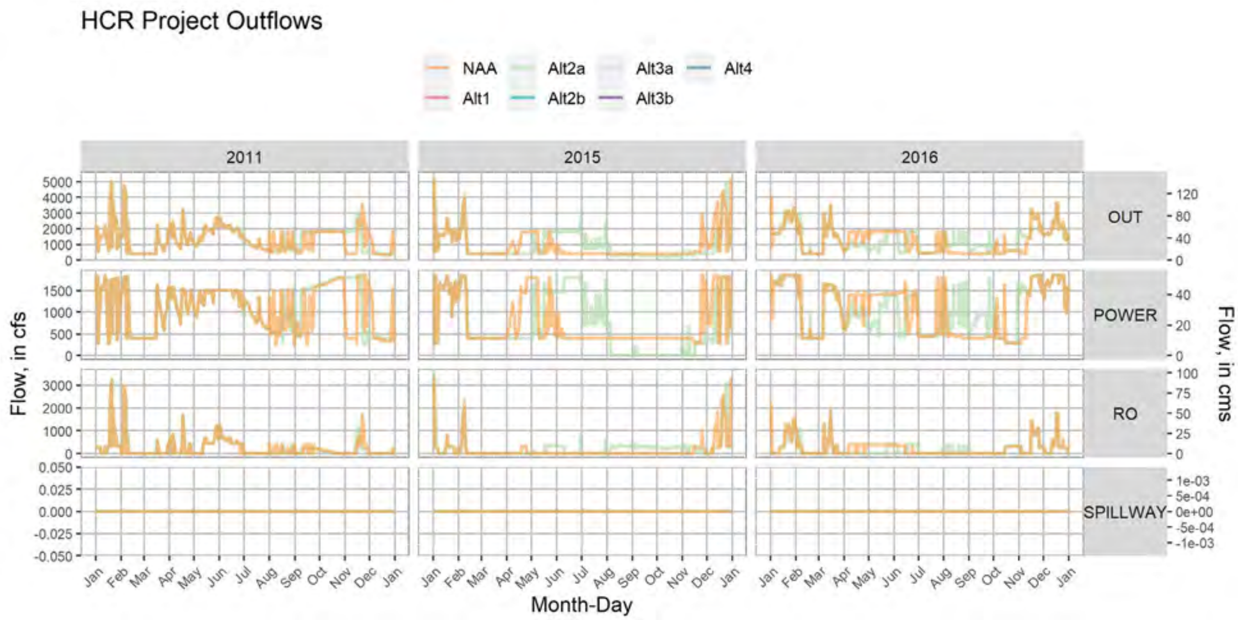

Figure 1-131. WV EIS RES-SIM Hills Creek Dam Gate-Specific Outflows in 2011, 2015, and 2016 under Alternative 2a and NAA.

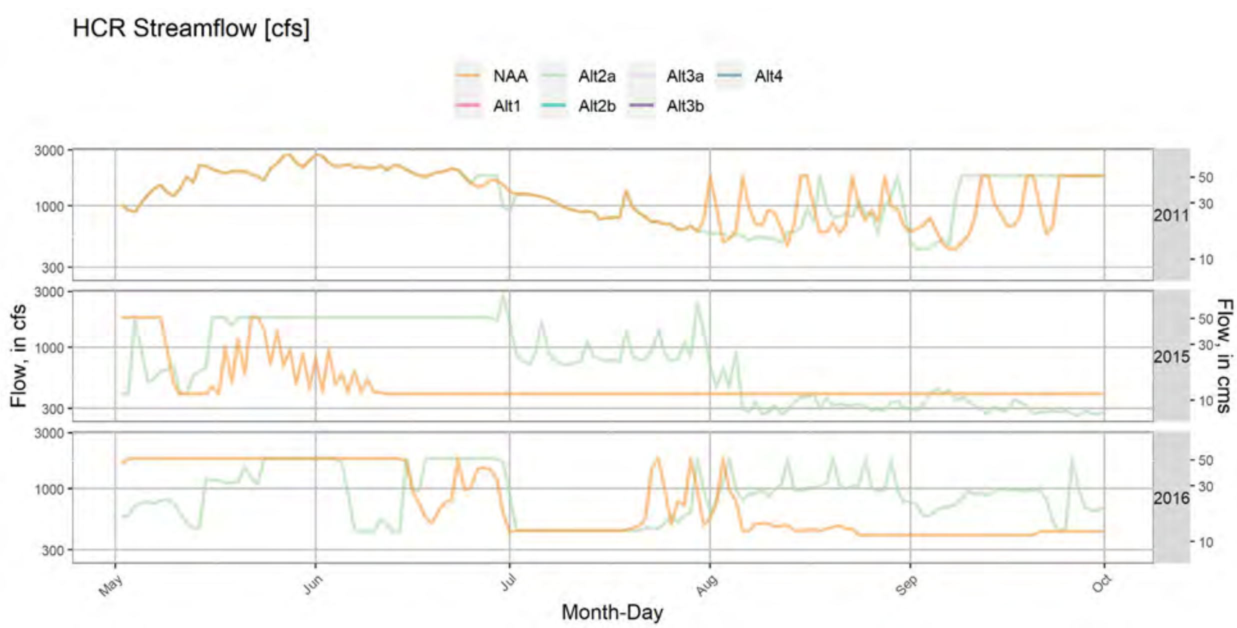

Figure 1-132. WV EIS RES-SIM Hills Creek Dam Total Outflow in 2011, 2015, and 2016 under Alternative 2a and NAA.

Lake Levels and Temperatures from CE-QUAL-W2

Depth-varying temperature, gate-specific outflows, and outflow temperatures through each calendar year scenario in Alternative 2a at Hills Creek Lake are shown in Figure 1-133, Figure 1-134, and Figure 1-135. The timing of the seasonal peak in outflow tailwater temperature in Alternative 2a was higher in magnitude and occurred about one month earlier in 2015, which resulted in cooler tailwater temperature during autumn of that year compared to NAA (Figure 1-136, Figure 1-137). 2016 outflow tailwater temperature in Alternative 2a was generally cooler than NAA in spring and summer but similar during autumn.

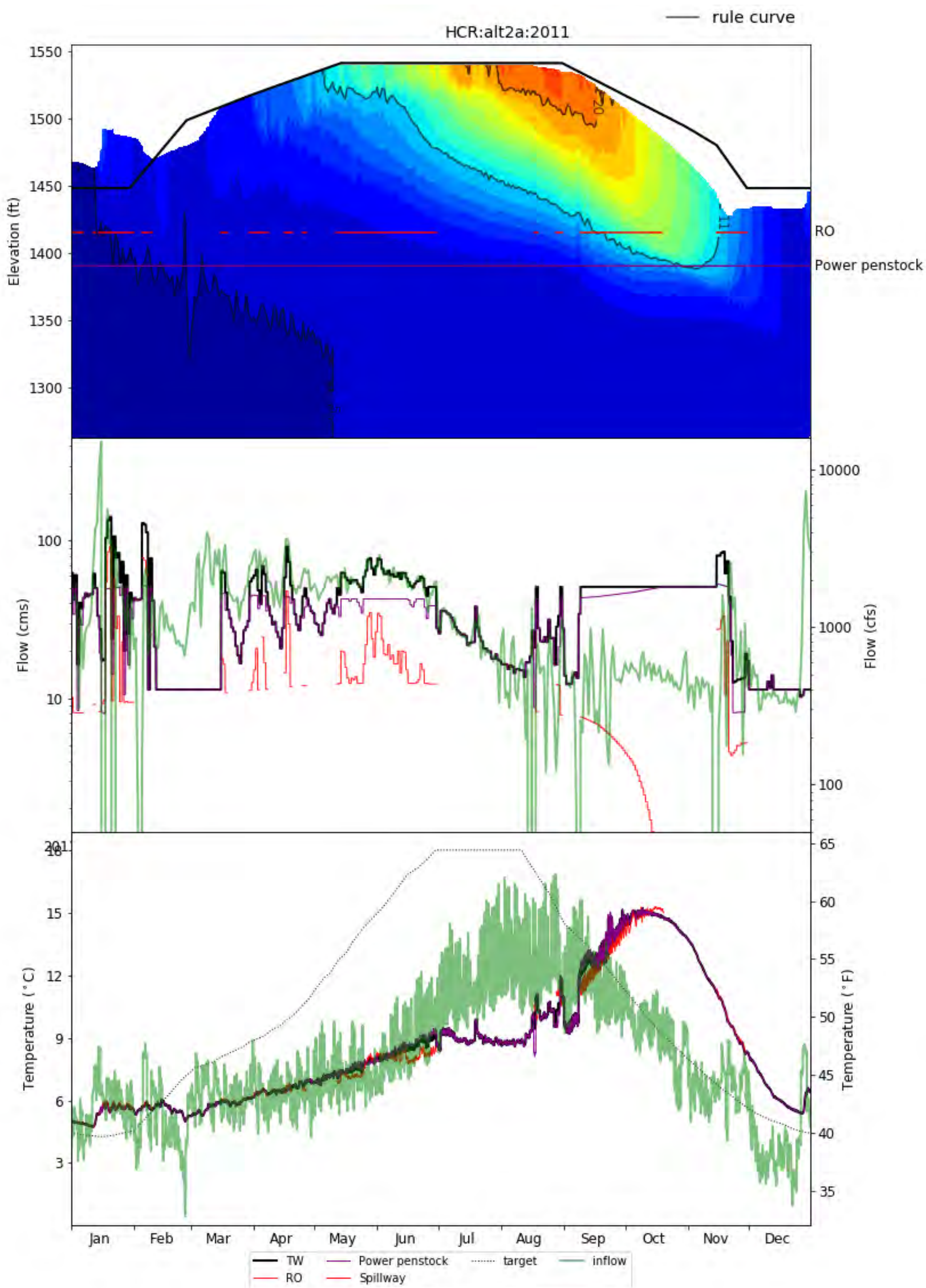

Figure 1-133. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at HCR under Alternative 2a in 2011.

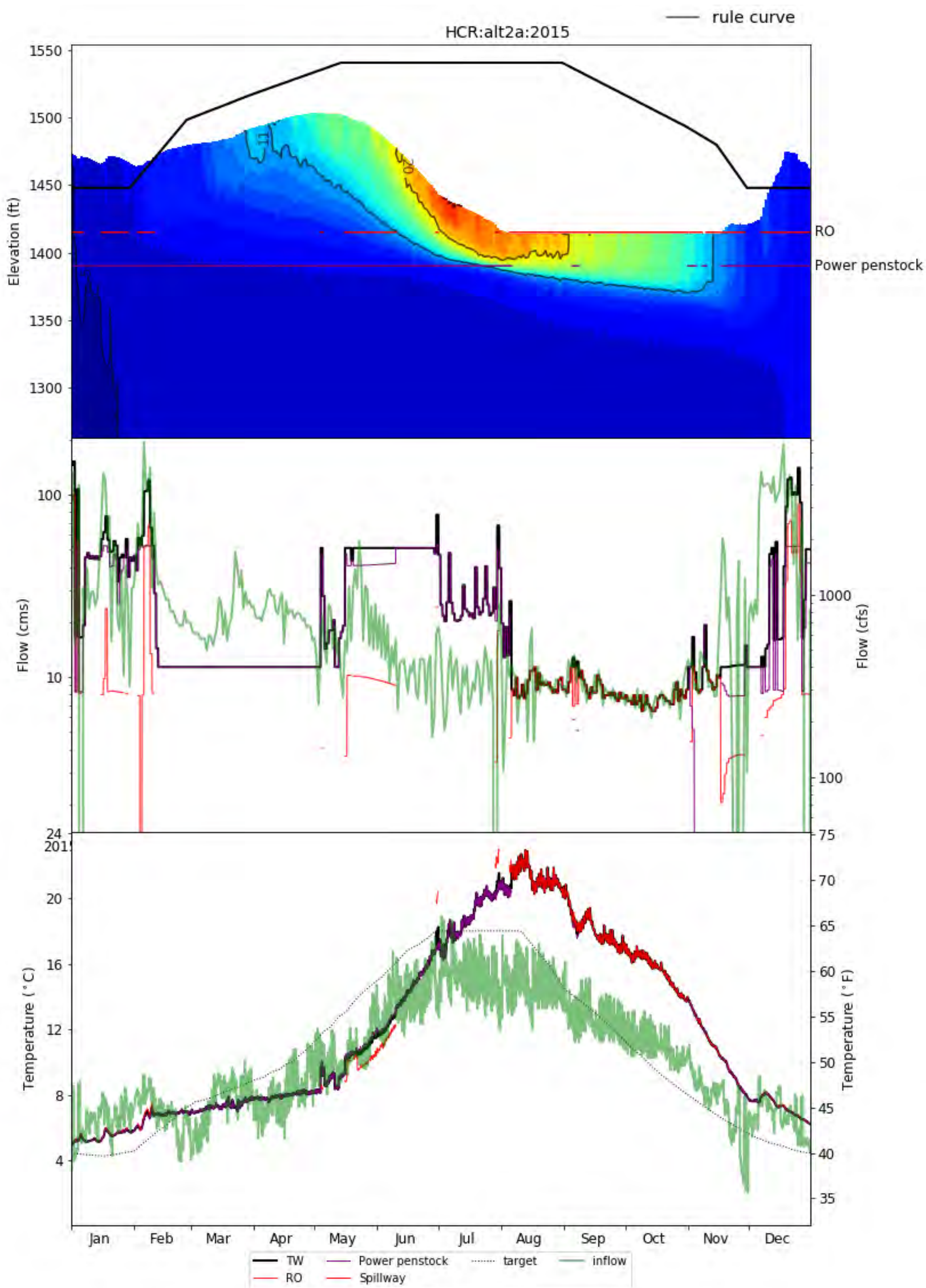

Figure 1-134. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at HCR under Alternative 2a in 2015.

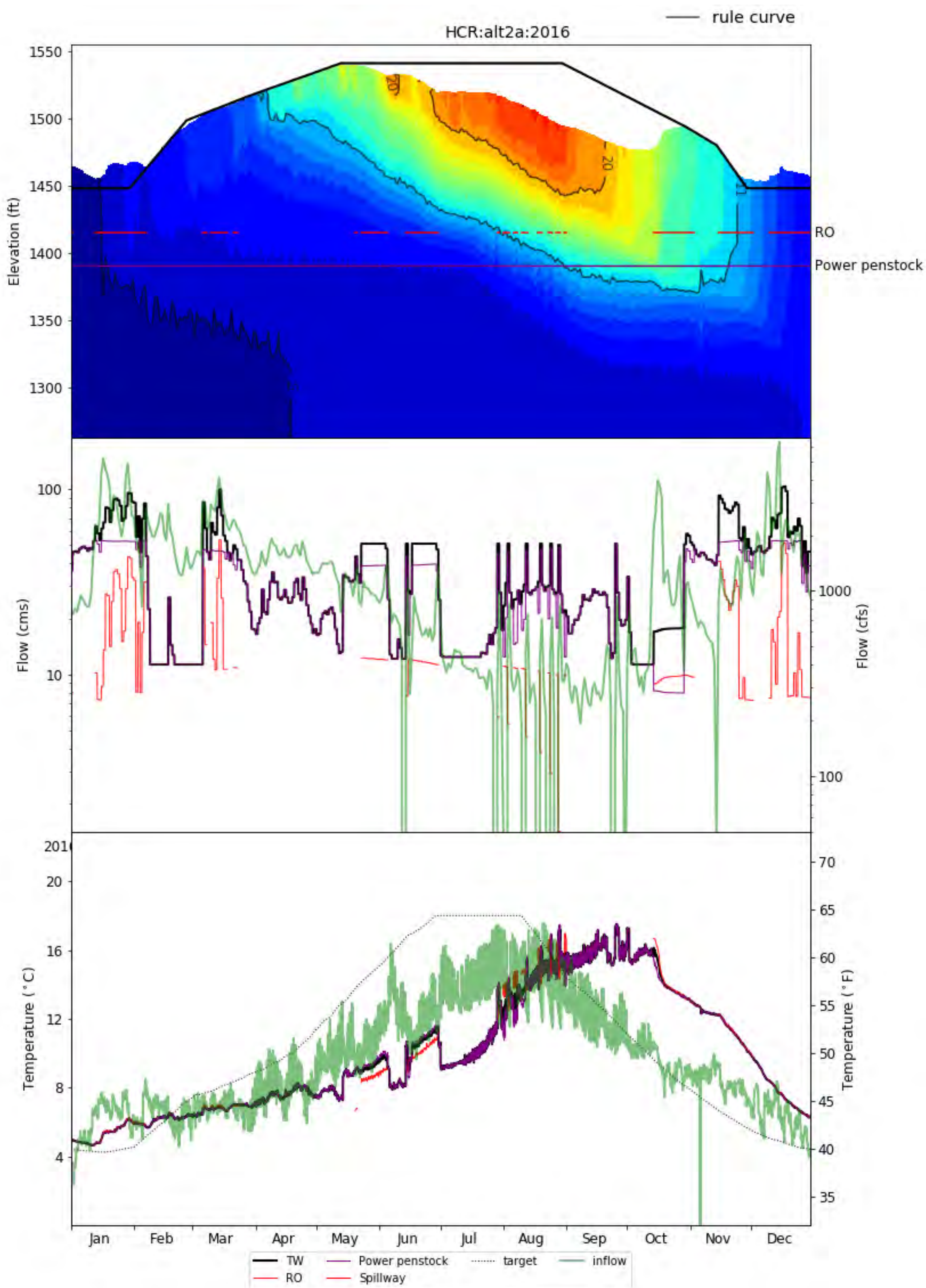

Figure 1-135. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at HCR under Alternative 2a in 2016.

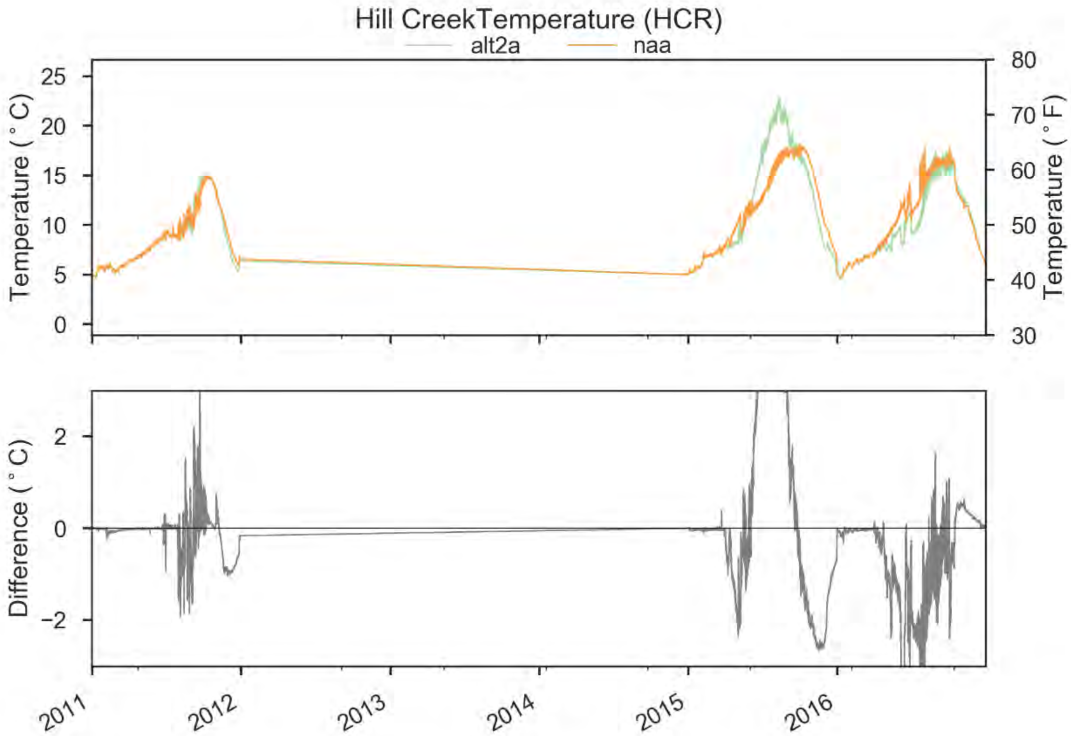

Figure 1-136. Comparison of HCR Outflow Temperatures in NAA and Alternative 2a.

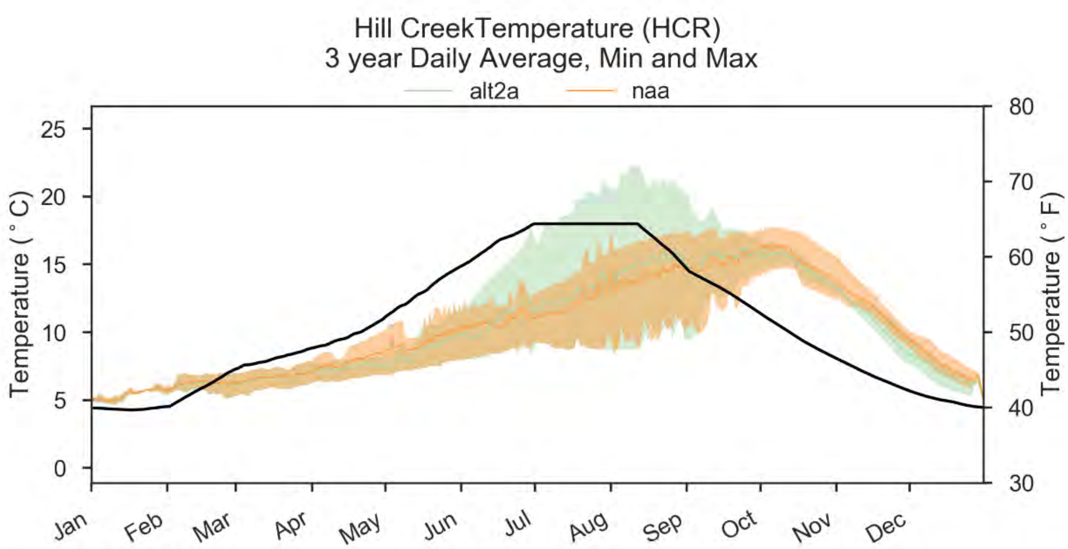

Figure 1-137. Comparison of HCR 3-year Daily Average, Min, Max Outflow Temperatures in NAA and Alternative 2a. Black Line Indicates Temperature Target.

1.5.3.4.2 Lookout Point

RES-SIM Lake Levels and Outflows

Lake level and storage at Lookout Point Lake was generally similar to NAA in 2011, 2015, and 2016 (Figure 1-138, Figure 1-139, Figure 1-140) aside from minor differences in timing of refill and release rates that were associated.

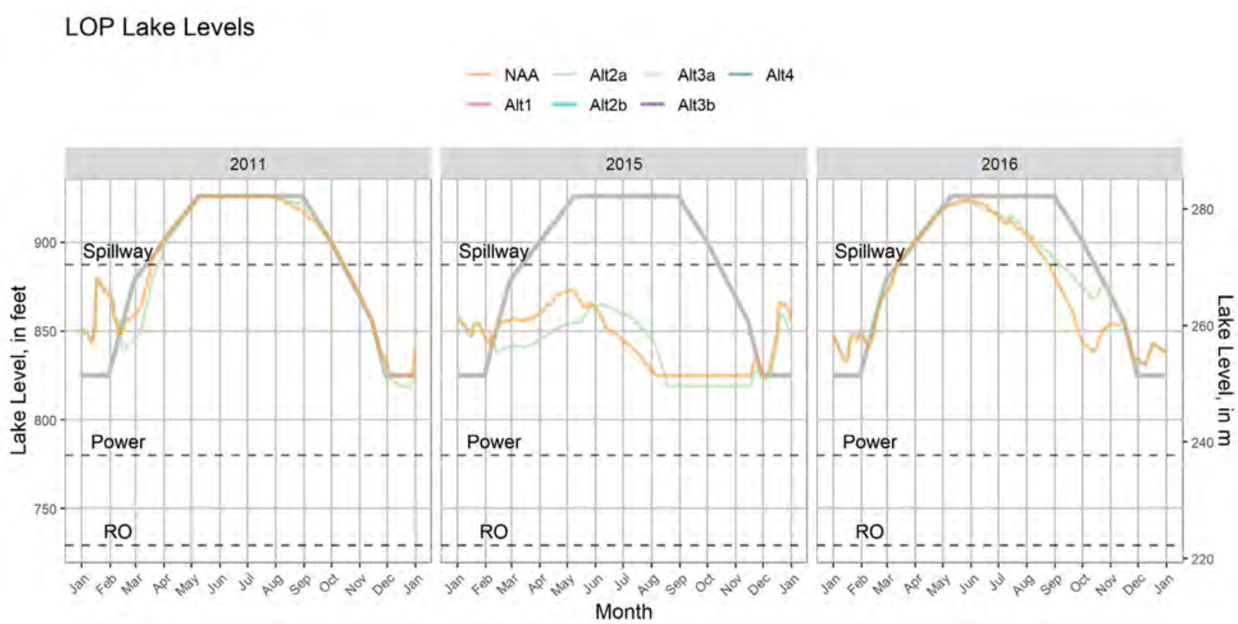

Figure 1-138. WV EIS RES-SIM Lookout Point Lake Levels in 2011, 2015, and 2016 Under Alternative 2a and NAA.

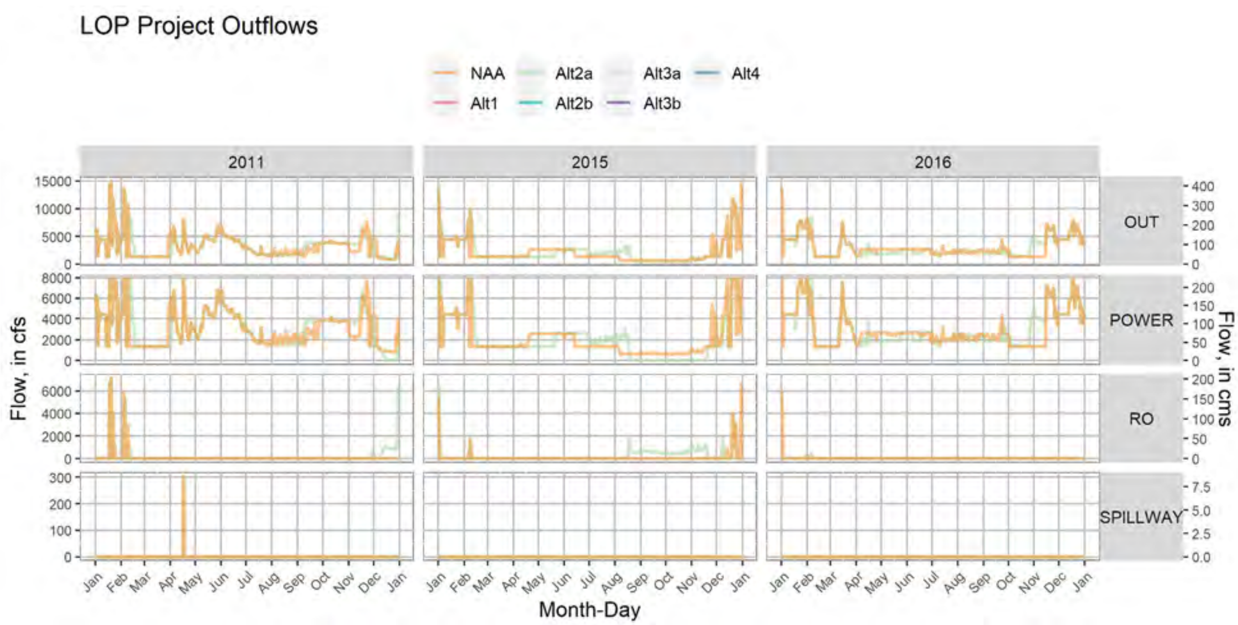

Figure 1-139. WV EIS RES-SIM Lookout Point Dam Gate-Specific Outflows in 2011, 2015, and 2016 Under Alternative 2a and NAA.

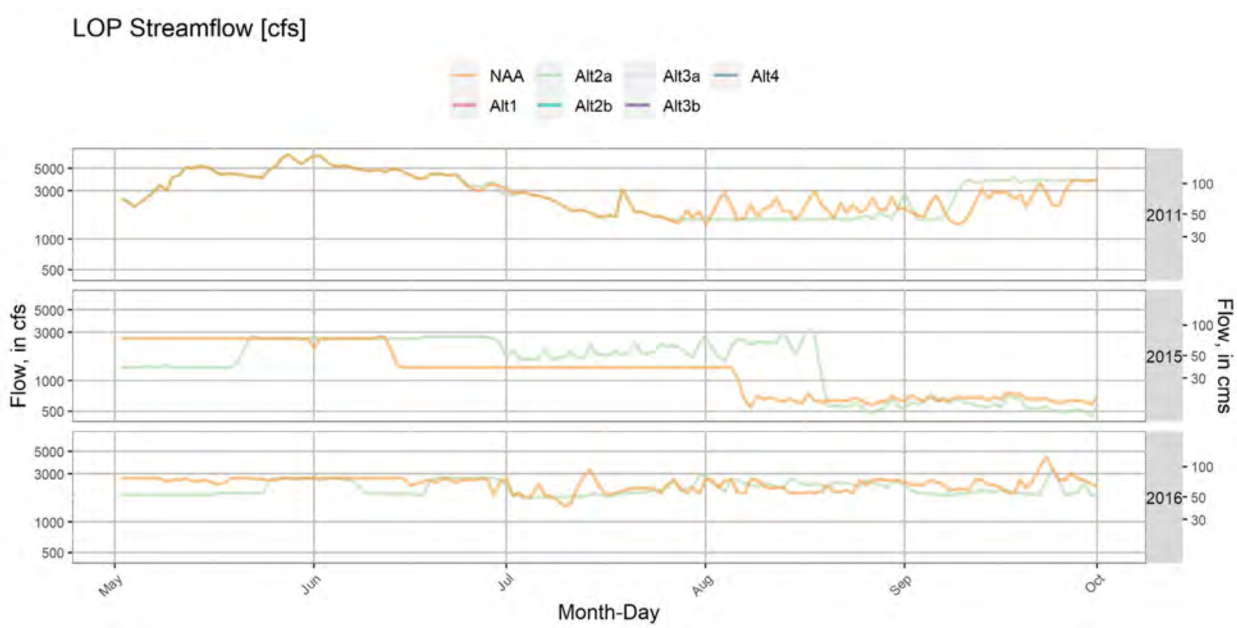

Figure 1-140. WV EIS RES-SIM Lookout Point Dam Total Outflow in 2011, 2015, and 2016 Under Alternative 2a and NAA.

Lake Levels and Temperatures from CE-QUAL-W2

Depth-varying temperature, gate-specific outflows, and outflow temperatures through each calendar year scenario at Lookout Point Lake are shown in Figure 1-141, Figure 1-142, and Figure 1-143. The effect of the proposed FSC (and attraction pumps intended for fish collection) in Lookout Point Lake is currently assumed to have minimal effect on release temperature from the relatively deep Lookout Point Penstocks, but has potential to result in mixing thermal layering and de-stratification in the forebay of Lookout Point Lake. Simulating this effect on water temperature was beyond the scope of the WV EIS. Generally, temperatures downstream of LOP-DEX were similar to NAA, aside from short-term differences in late summer of 2015 likely related to upstream Hills Creek operations (Figure 1-144, Figure 1-145).

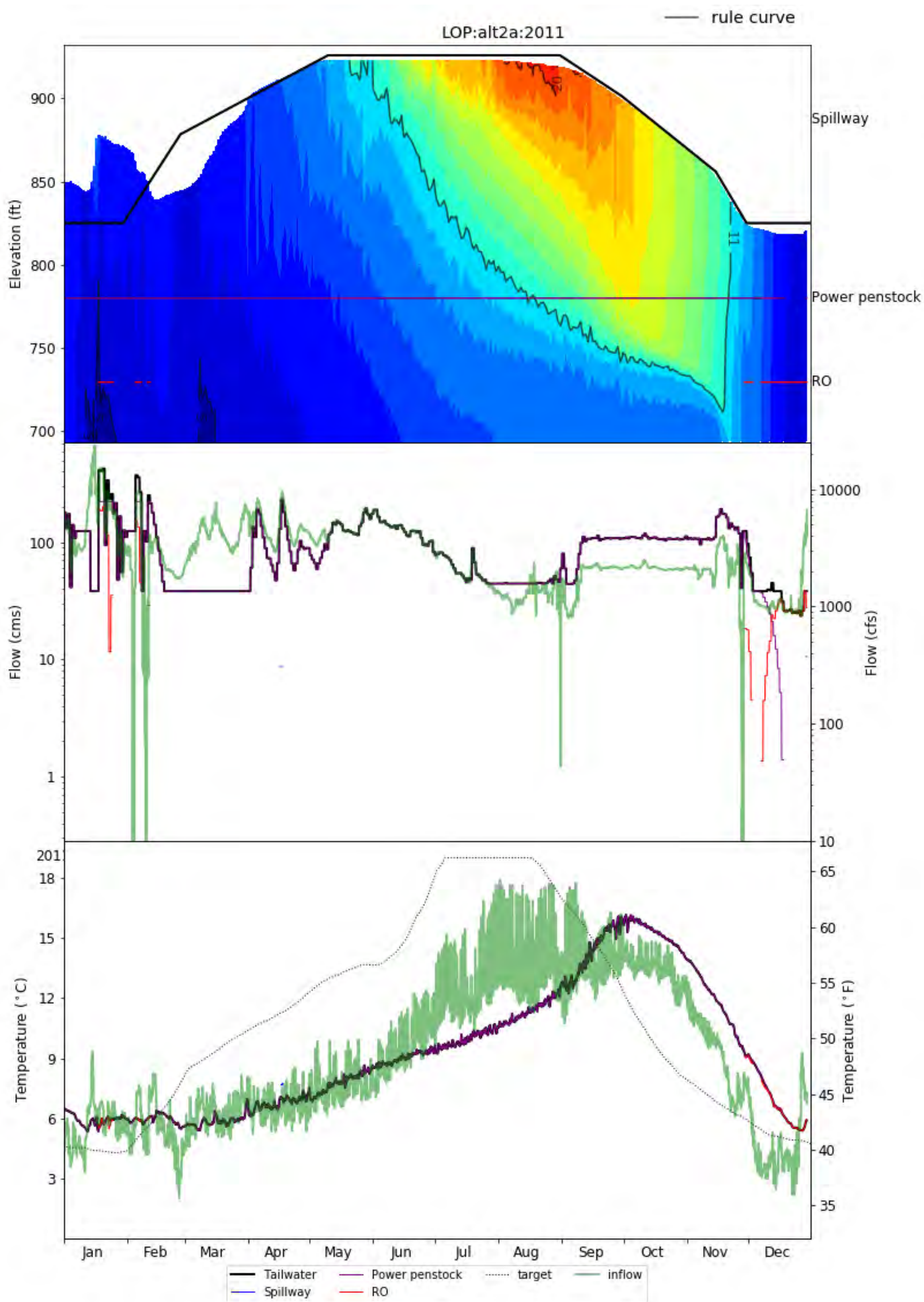

Figure 1-141. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at LOP under Alternative 2a in 2011.

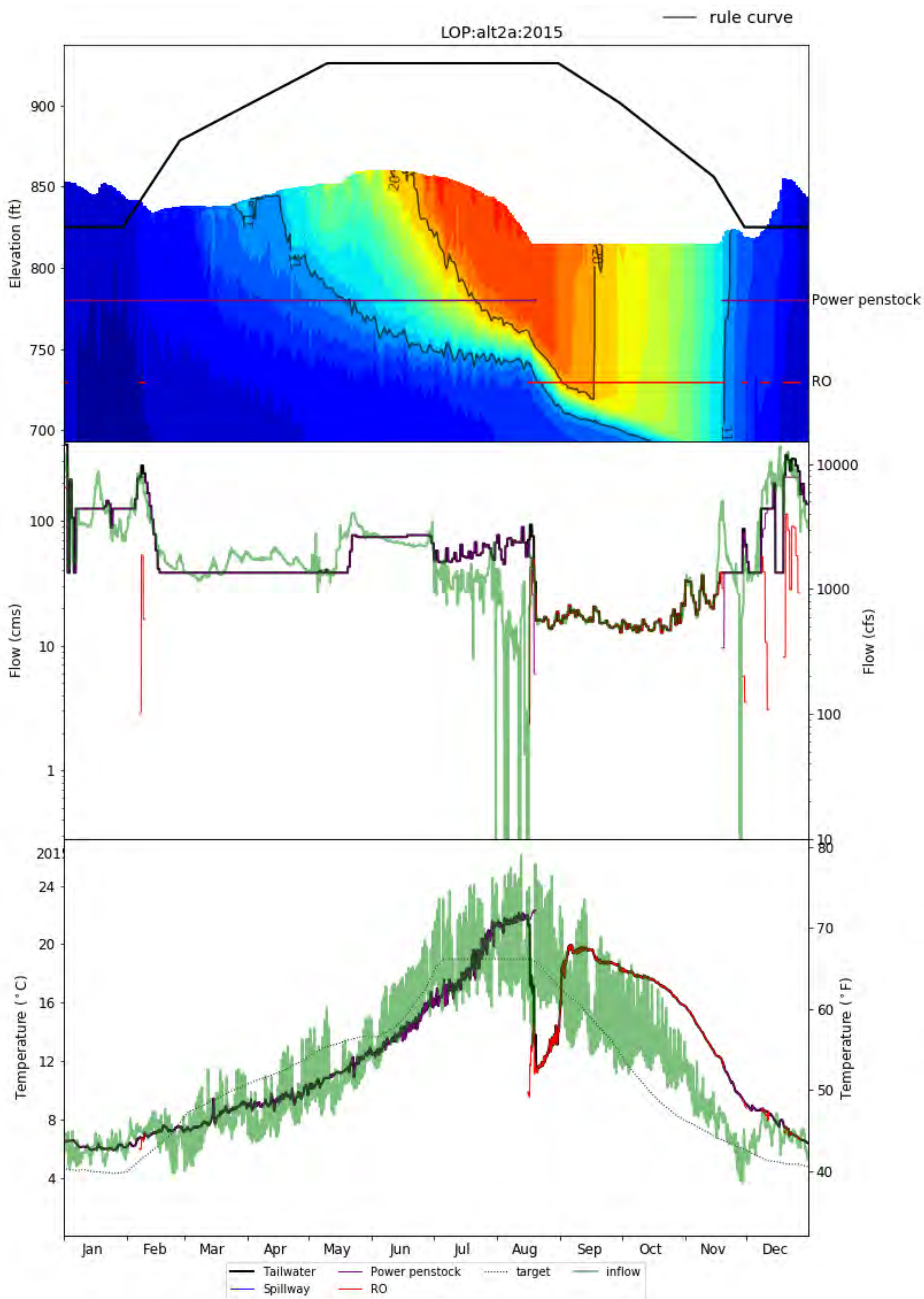

Figure 1-142. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at LOP under Alternative 2a in 2015.

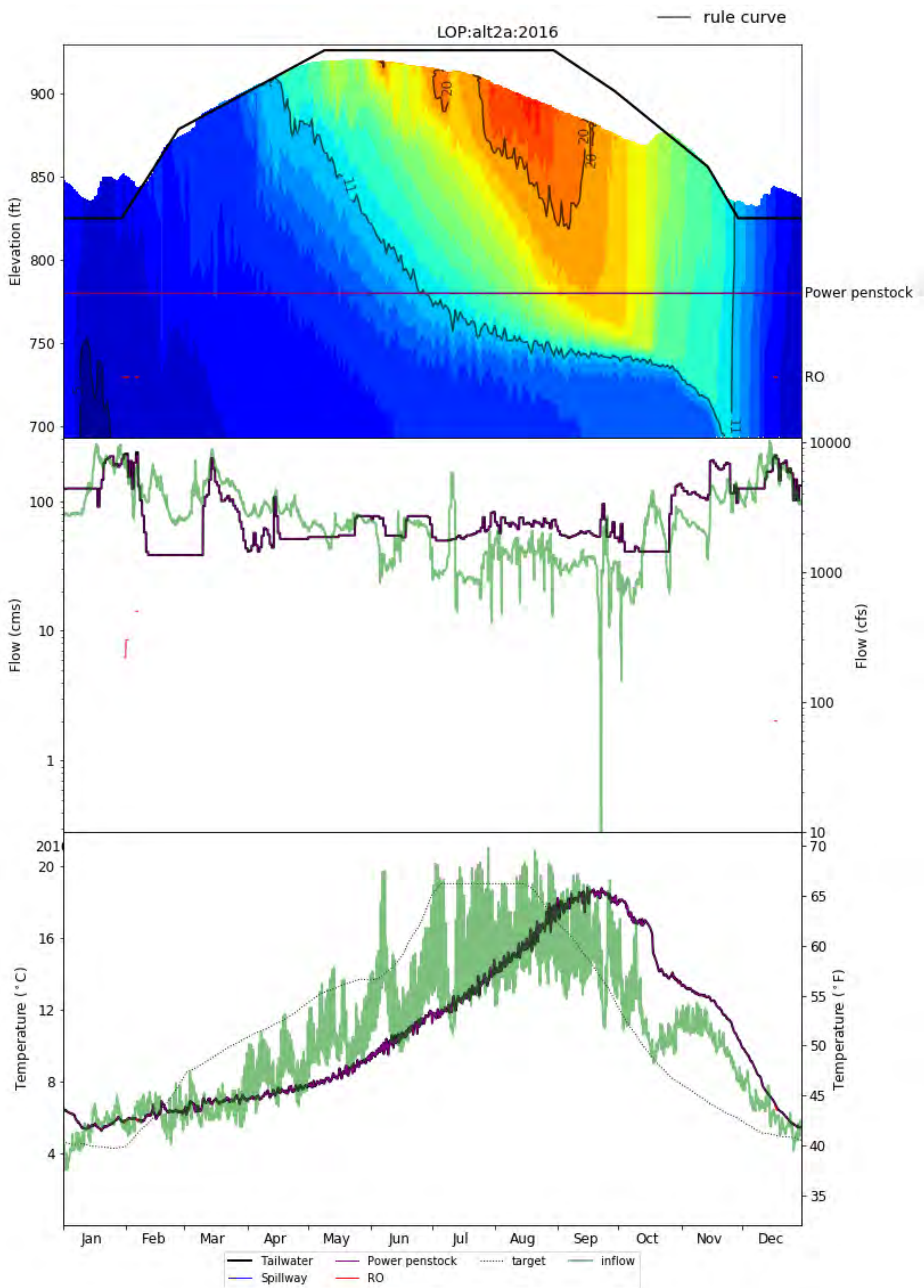

Figure 1-143. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at LOP under Alternative 2a in 2016.

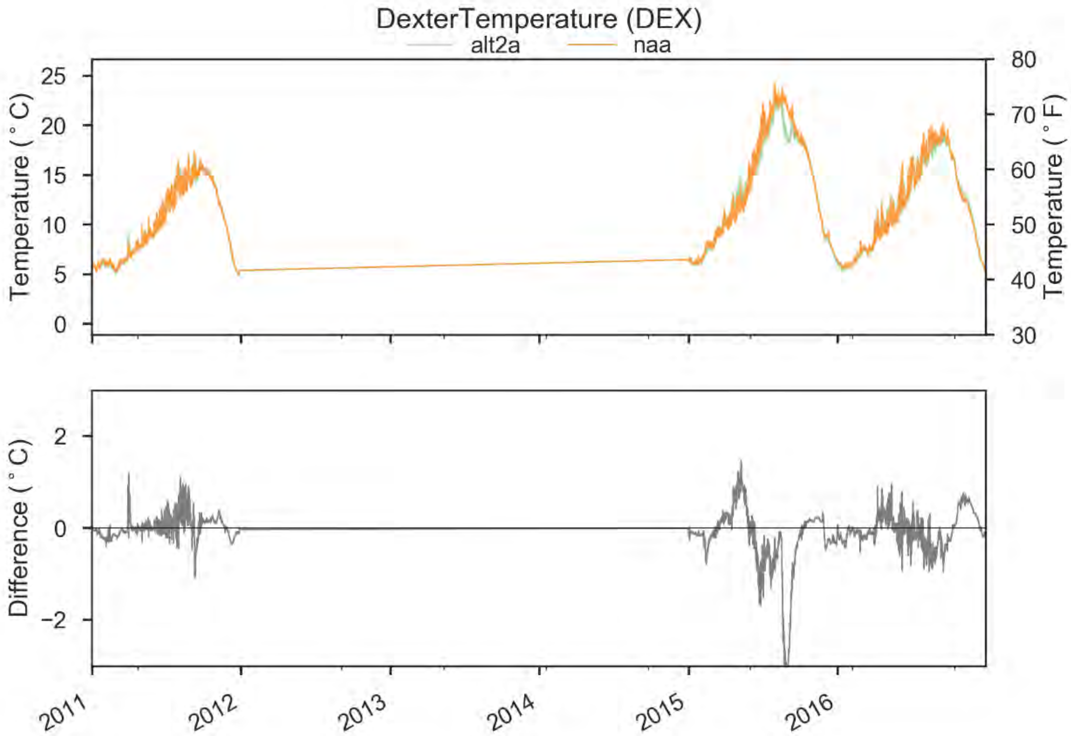

Figure 1-144. Comparison of DEX Outflow Temperatures in NAA and Alternative 2a.

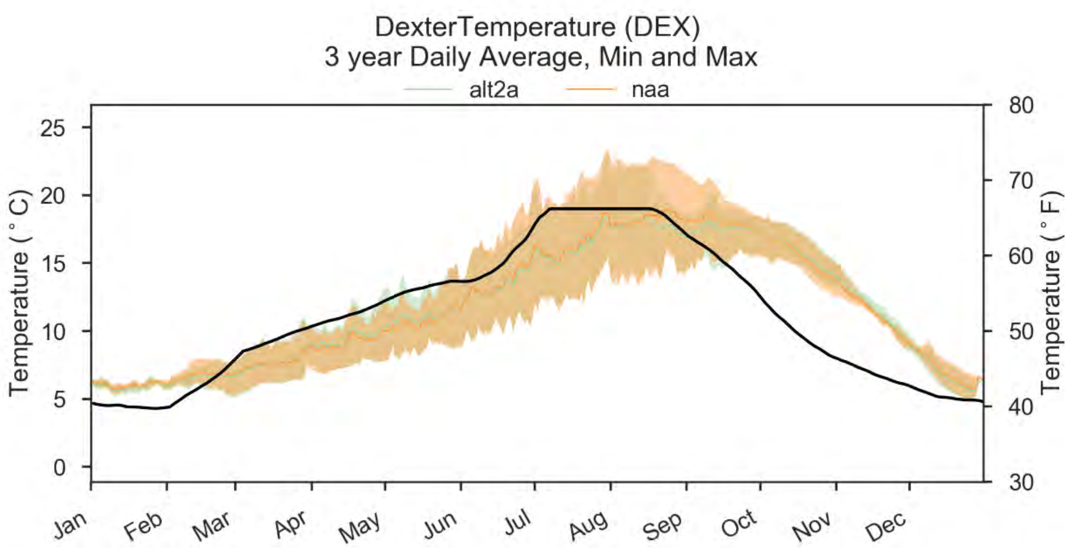

Figure 1-145. Comparison of DEX 3-year Daily Average, Min, Max Outflow Temperatures in NAA and Alternative 2a. Black Line Indicates Temperature Target.

1.5.3.5 Mainstem Willamette River

Streamflow on the mainstem Willamette River under Alternative 2a was generally lower from April to mid-June and higher from mid-June to mid-September compared with NAA (Figure 1-146). However, these flow differences were primarily in 2015 and responsive to the flow Measure 30 rules that increase dam outflows in advance of heat wave events (Figure 1-147). These flow changes resulted in warmer water temperatures April to mid-June and cooler water temperatures from mid-June to mid-September compared with NAA in 2015 (

Figure 1-148. Comparison of Willamette River at SLMO Water Temperatures in NAA and Alternative 2a.

and Figure 1-149). Water temperatures at Salem were also affected by upstream dam operations and the proposed SWS-FSS structure at Detroit Dam, which likely contributed to warmer temperatures seen in 2011 and 2015 under Alternative 2a. Overall water temperature differences between Alternative 2a and NAA were less than 2 degrees Celsius.

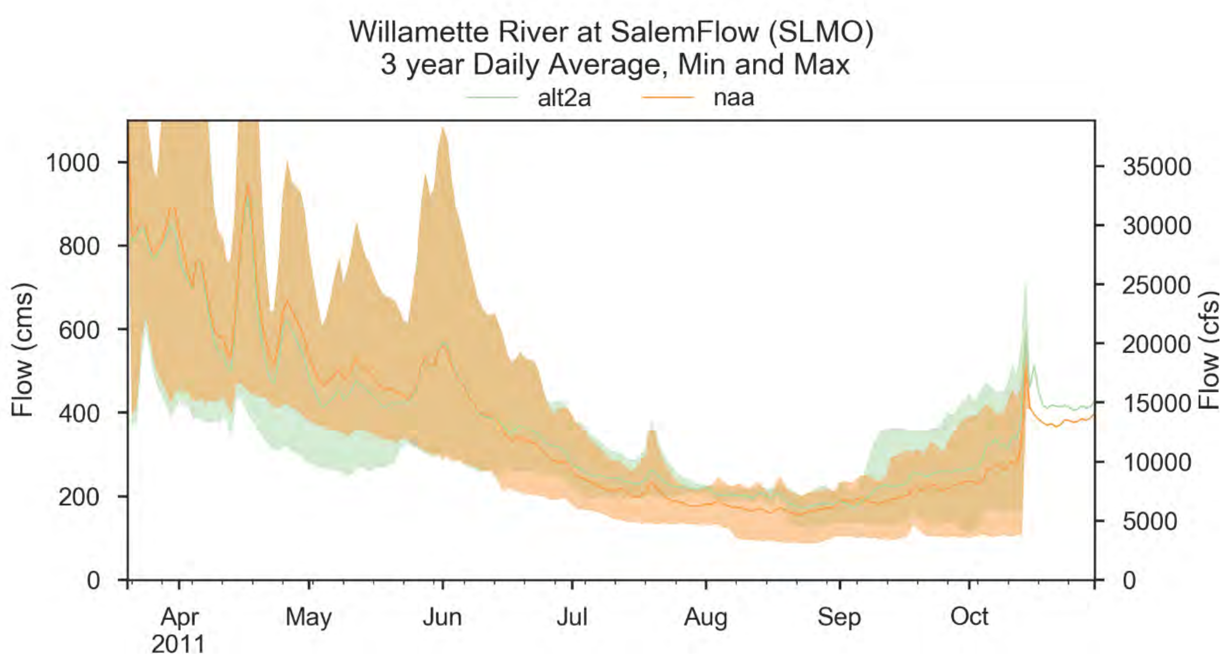

Figure 1-146. Streamflow Comparison of Average, Min, and Max Willamette River at SLMO under NAA and Alternative 2a Conditions.

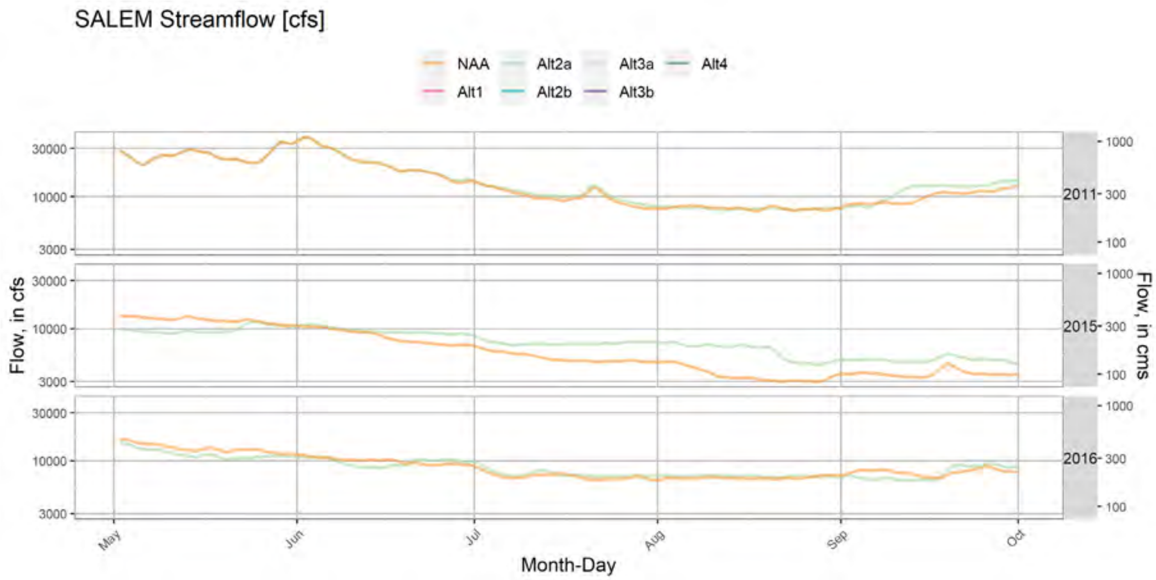

Figure 1-147. Streamflow Comparison Between Alternative 2a and NAA at Willamette River at SLMO.

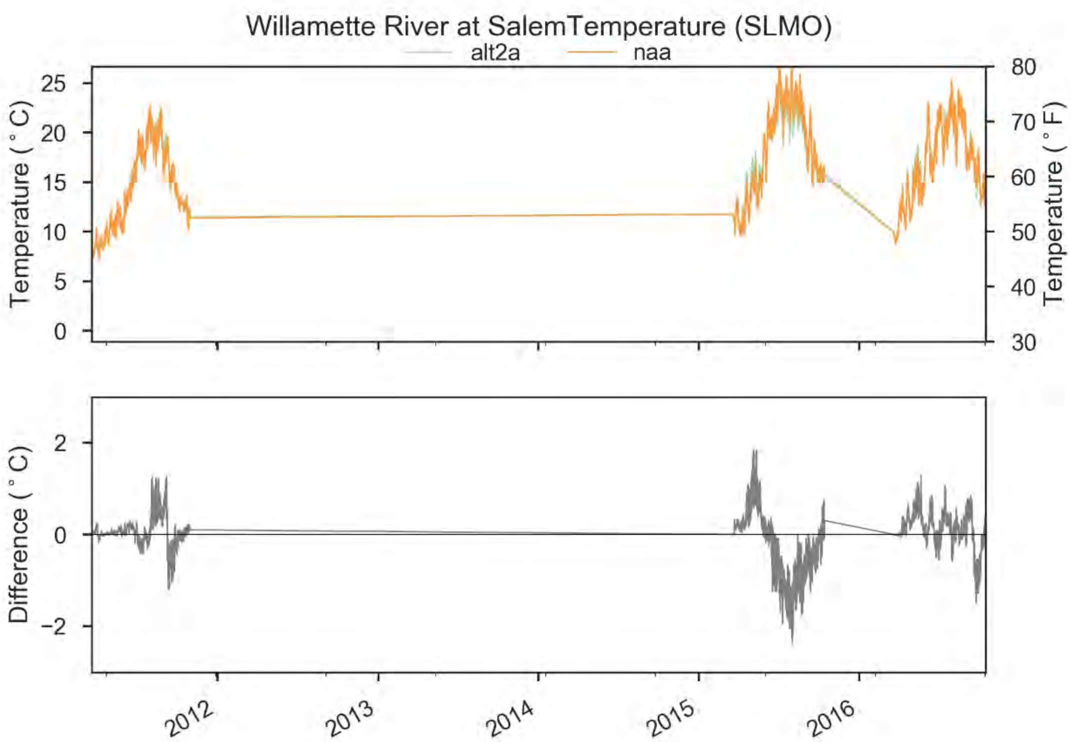

Figure 1-148. Comparison of Willamette River at SLMO Water Temperatures in NAA and Alternative 2a.

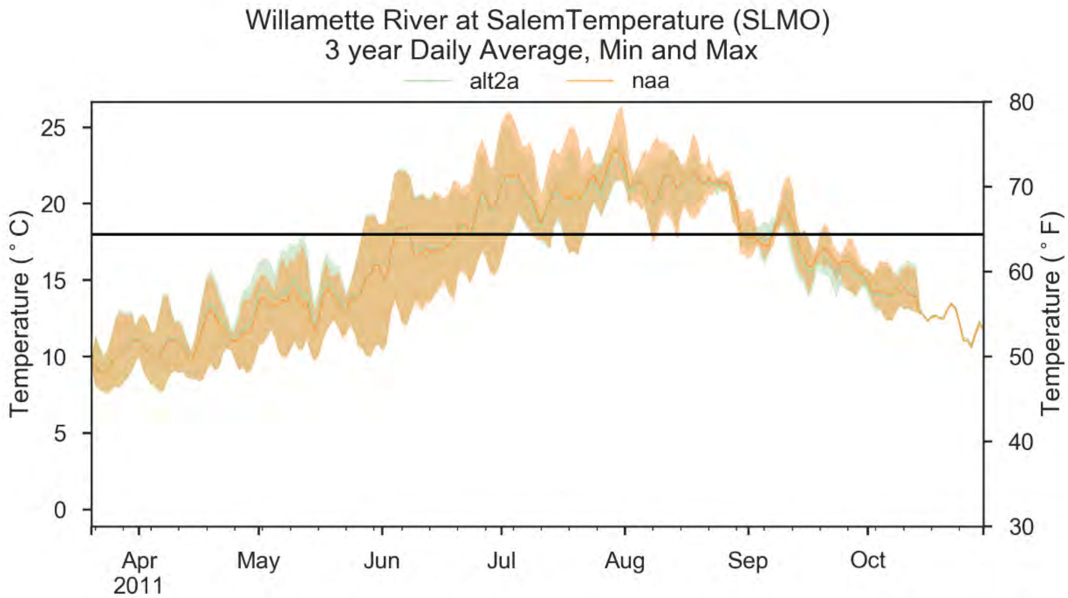

Figure 1-149. Comparison of Willamette River at SLMO 3-year Average, Min, Max Outflow Temperatures in NAA and Alternative 2a.

1.5.4 Alternative 2b-- Hybrid Alternative

Alternative 2b measures that affected operations, lake storage, and water temperature included:

- Changes to tributary targets below Foster, Detroit, Lookout Point, and Cougar that are higher than the NAA BiOp targets when those reservoirs are more than 90% full and less than the NAA BiOp when those reservoirs are less than 90% full.
- Changes to baseline mainstem targets at Salem and Albany while adding a Salem flow target tied to forecasted air temperature.
- Construct temperature control structure at Detroit.
- Deep fall drawdown to 35' over the regulating outlet at Green Peter, use of RO in fall, use spillway for surface spill in spring and summer
- Deep spring and fall drawdown to 30 feet over the diversion tunnel at Cougar, with a limited refill window between June 15th and November 15th (essentially a delayed refill).
- Modifications to existing outlets at Foster Dam that would allow releases at varying depths for temperature control by modifying the Facility Warm Water Supply (FWWS) pipe and fish weirs.

1.5.4.1 NORTH SANTIAM DAMS

1.5.4.1.1 Detroit

RES-SIM Lake Levels and Outflows

Lake level and storage at Detroit Lake generally increased under Alternative 2b compared to NAA in 2015 and 2016 aside from September-November in 2015 where the power pool was utilized for downstream flow augmentation (Figure 1-150, Figure 1-151, and Figure 1-152). The increased storage coincided with reduced outflows during spring (e.g., April-May of 2015) and increased outflows in summer (July-September in 2015, June-Aug in 2016) under Alternative 2b. Total outflow in 2011 was generally similar in Alternative 2b and NAA at Detroit Lake. The proposed SWS and FSS in Alternative 2a allowed all outflow within powerhouse capacity (assumed at 4600 cfs) to be routed from a floating outlet through the Power outlets for temperature management, rather than the Spillway or URO flow for temperature management that was used in NAA (Figure 1-151).

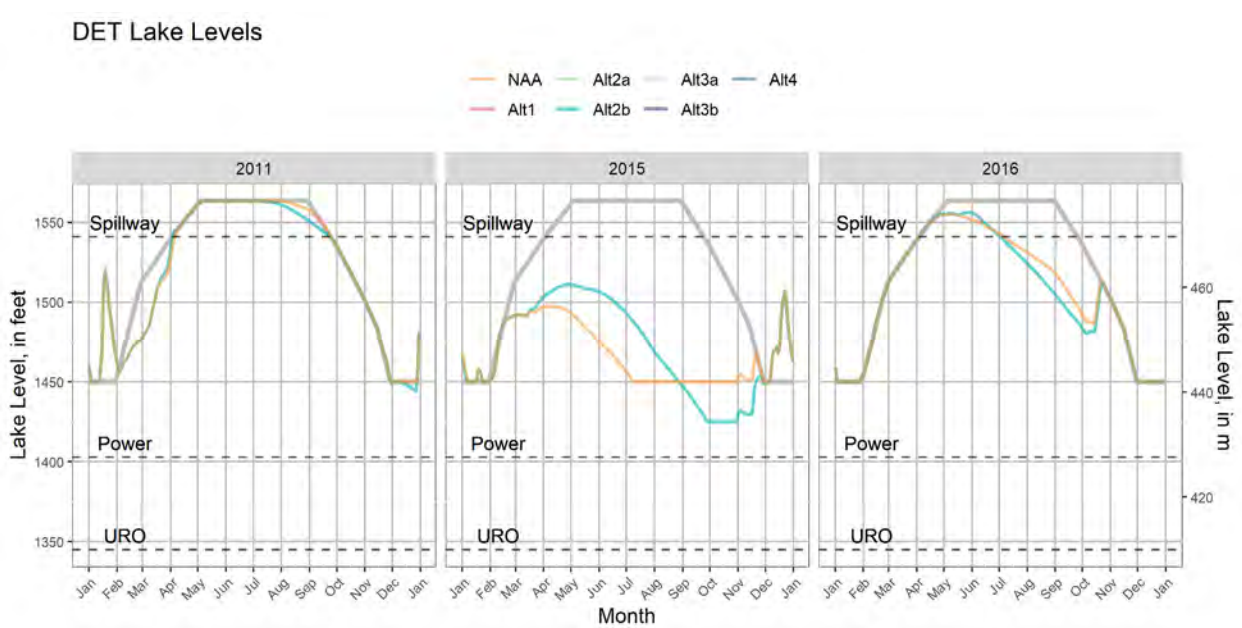

Figure 1-150. WV EIS RES-SIM Detroit Lake Levels in 2011, 2015, and 2016 Under Alternative 2b and NAA.

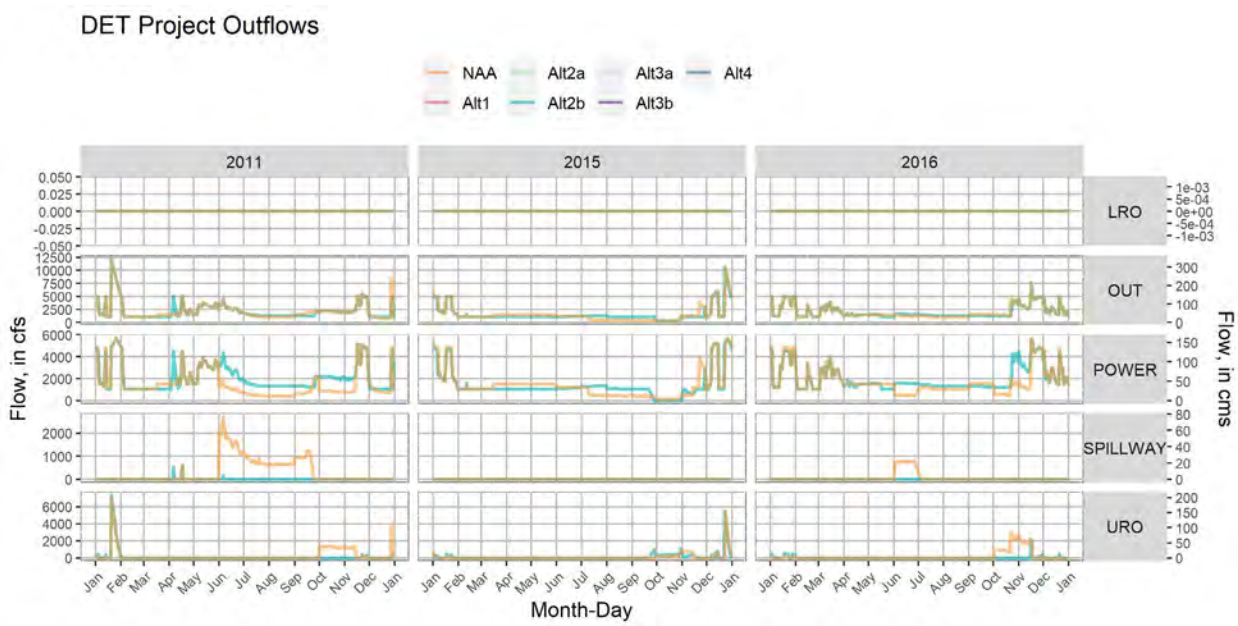

Figure 1-151. WV EIS RES-SIM Gate-Specific Outflows in 2011, 2015, and 2016 Under Alternative 2b and NAA.

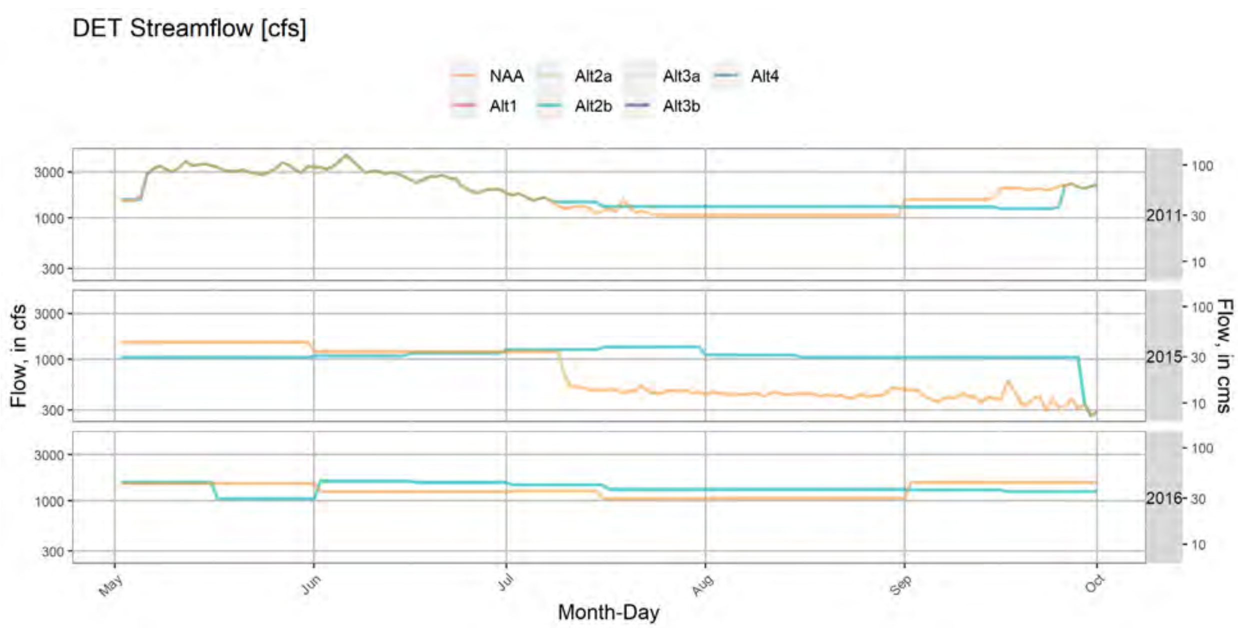

Figure 1-152. WV EIS RES-SIM Detroit Total Outflow in 2011, 2015, and 2016 Under Alternative 2b and NAA.

Lake Levels and Temperatures from CE-QUAL-W2

Depth-varying temperature, gate-specific outflows, and outflow temperatures through each calendar year scenario at Detroit Lake are shown in Figure 1-153, Figure 1-154, and Figure 1-155. Temperature tower outflows blended between a floating outlet (25 feet below lake surface) and a deeper outlet at the elevation of the Upper RO. Tailwater release temperatures generally matched the temperature target when sufficient warm or cool water was available. Generally, the proposed SWS-FSS structures allowed temperatures to be warmer than NAA in spring/summer and cooler than NAA in autumn (Figure 1-156, Figure 1-157).

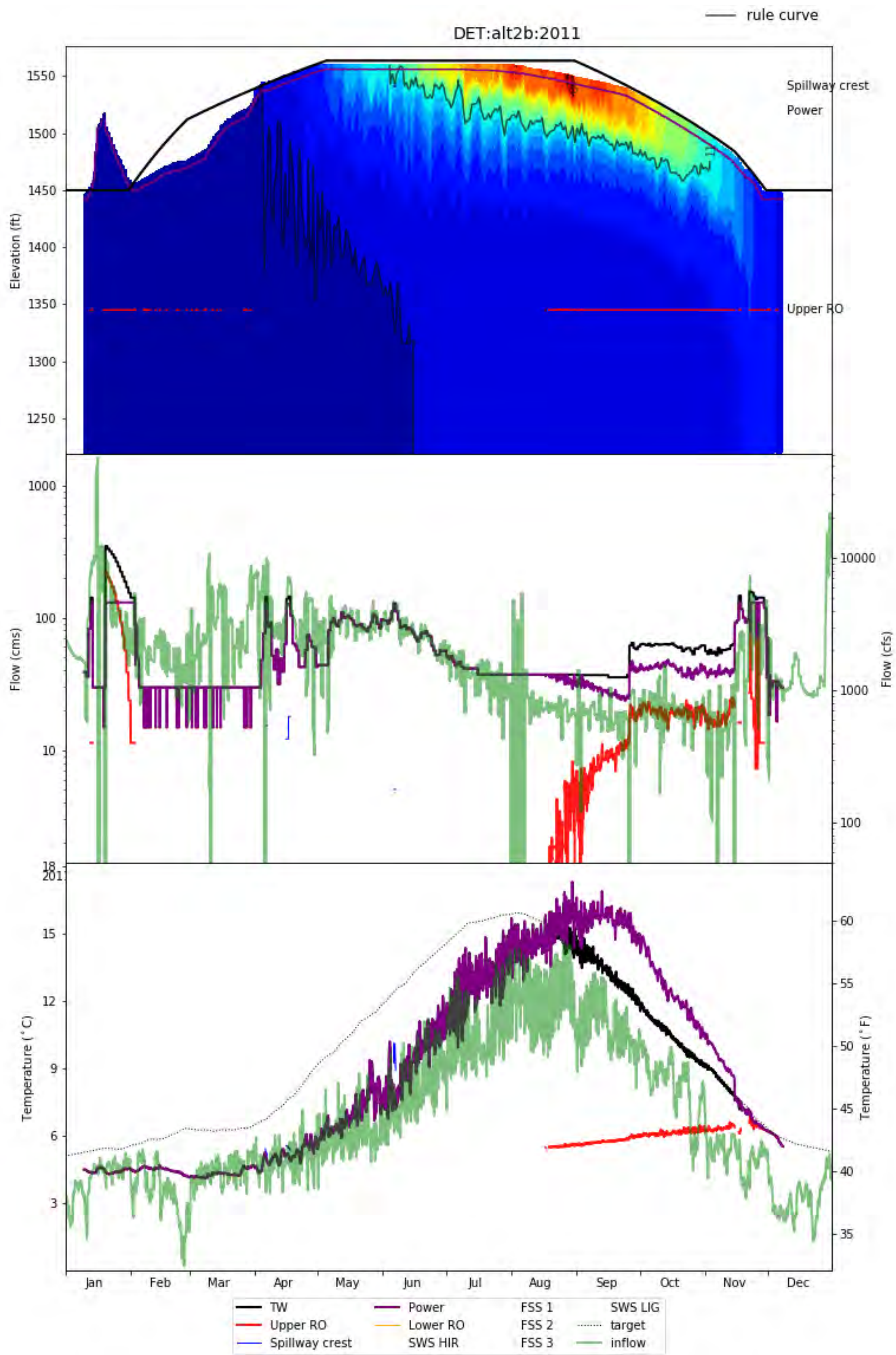

Figure 1-153. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at Detroit under Alternative 2b in 2011.

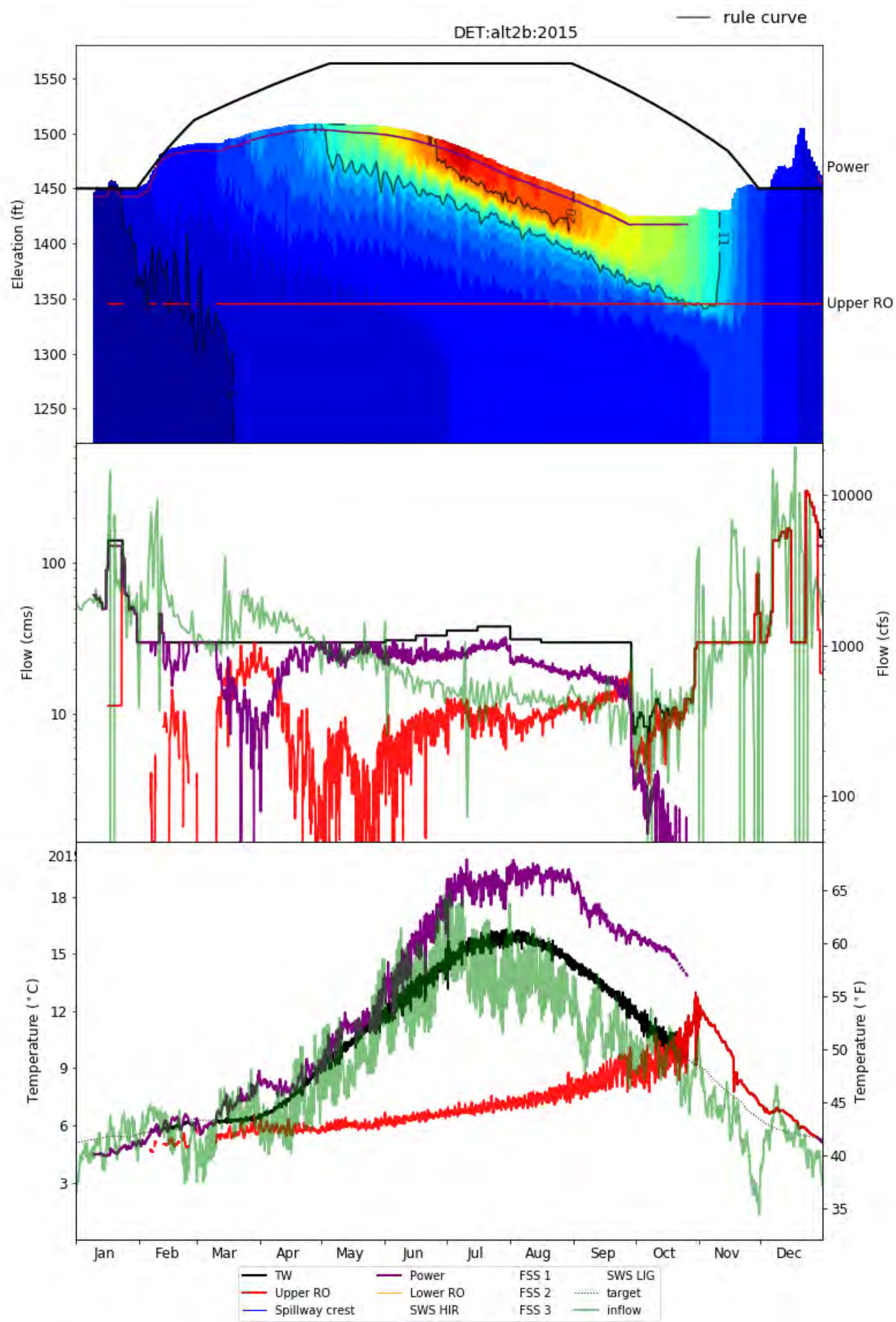

Figure 1-154. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at Detroit under Alternative 2b in 2015.

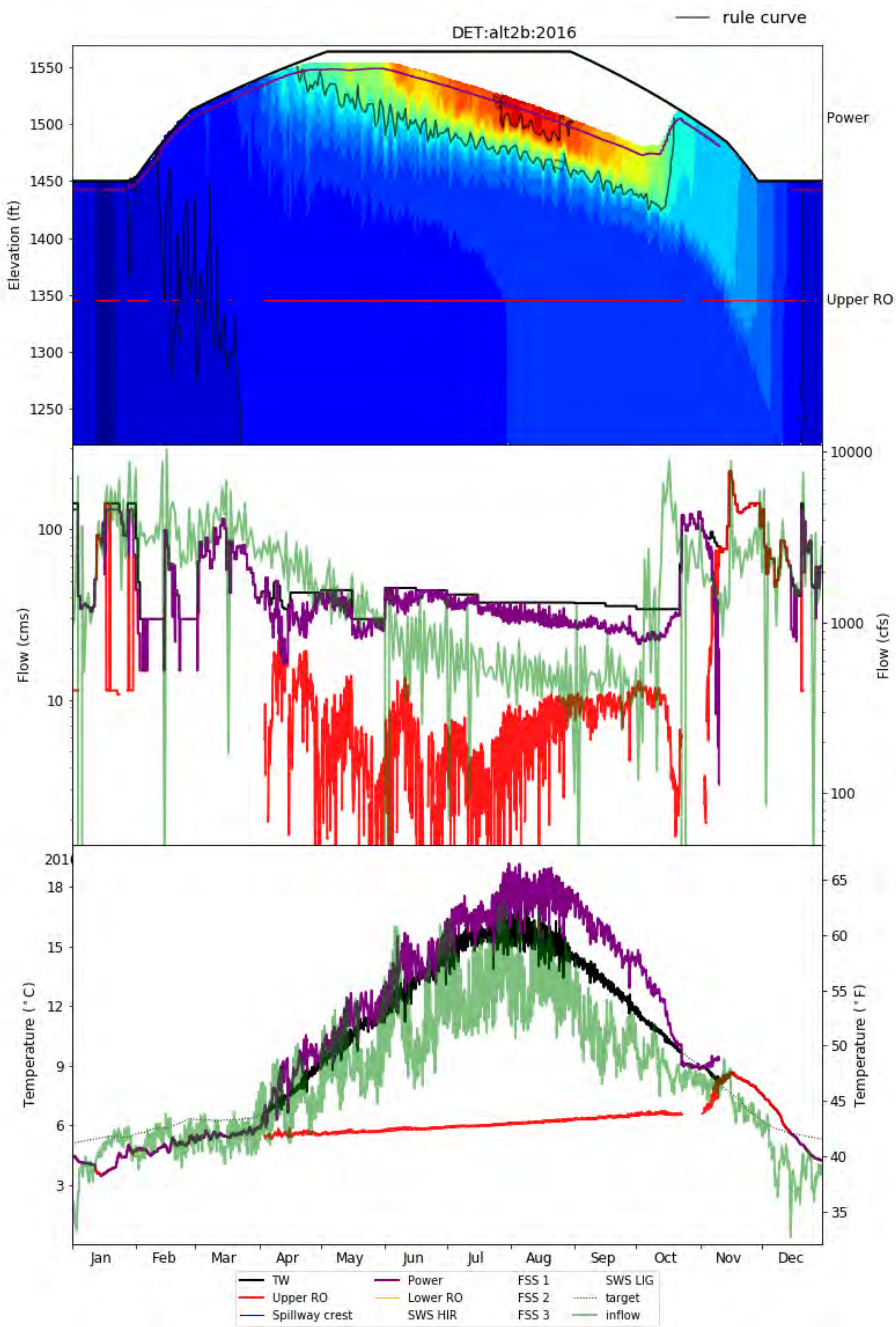

Figure 1-155. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at Detroit under Alternative 2b in 2016.

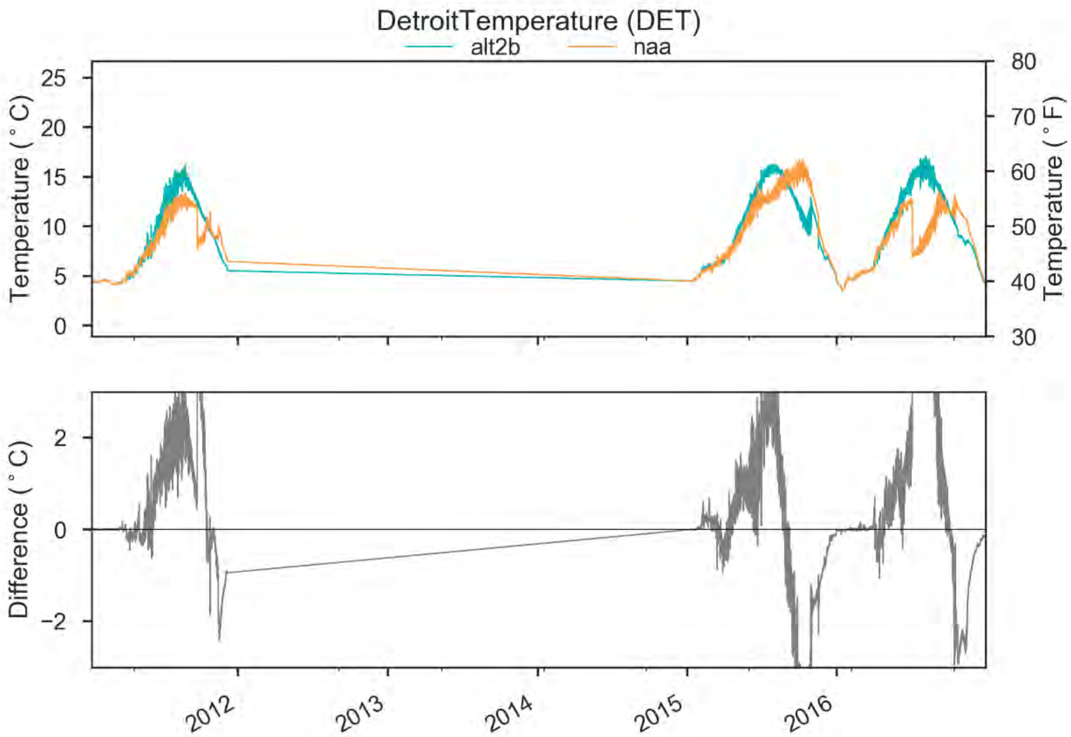

Figure 1-156. Comparison of DET outflow temperatures in NAA and Alternative 2b.

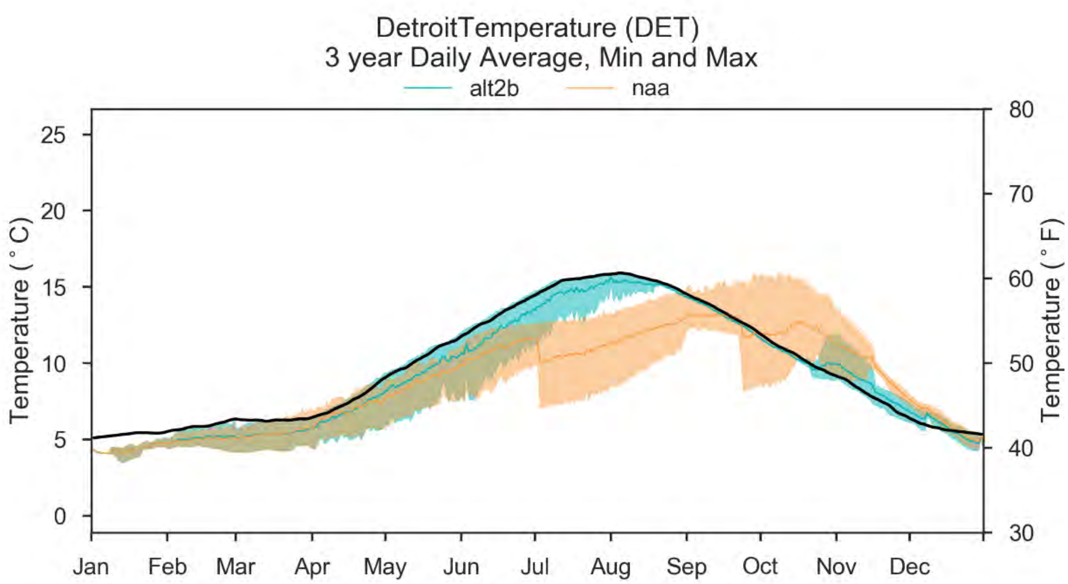

Figure 1-157. Comparison of DET 3-year Daily Average, Min, Max Outflow Temperatures in NAA and Alternative 2b. Black Line Indicates Temperature Target.

1.5.4.2 SOUTH SANTIAM DAMS

1.5.4.2.1 Green Peter

RES-SIM Lake Levels and Outflows

Lake level and storage at Green Peter were generally similar under Alternative 2b and NAA in 2011, 2015, and 2016 aside from October-November during RO drawdown for fish passage (Figure 1-158, Figure 1-159, and Figure 1-160). Some increased storage in 2015 coincided with reduced outflows during spring and increased outflows in July-October comparing Alternative 2b to NAA. 2011 and 2016 operations were generally similar in Alternative 2b and NAA at Green Peter Lake January-June but followed increased outflows in July-October to draft the lake for fish passage operations through the ROs in autumn. The proposed operational temperature management through the spillway (during spring/summer) and RO (during autumn) in Alternative 2b led to increased outflow from these outlets and decreased power outflow compared to NAA (Figure 1-159).

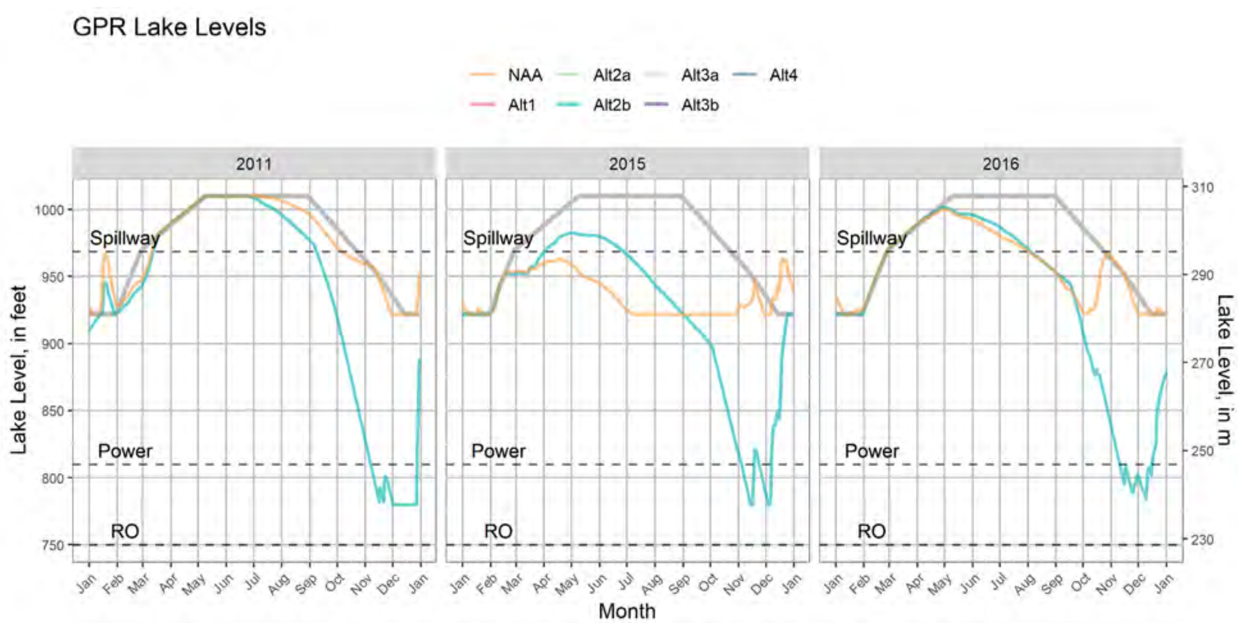

Figure 1-158. WV EIS RES-SIM Green Peter Lake Levels in 2011, 2015, and 2016 Under Alternative 2b and NAA.

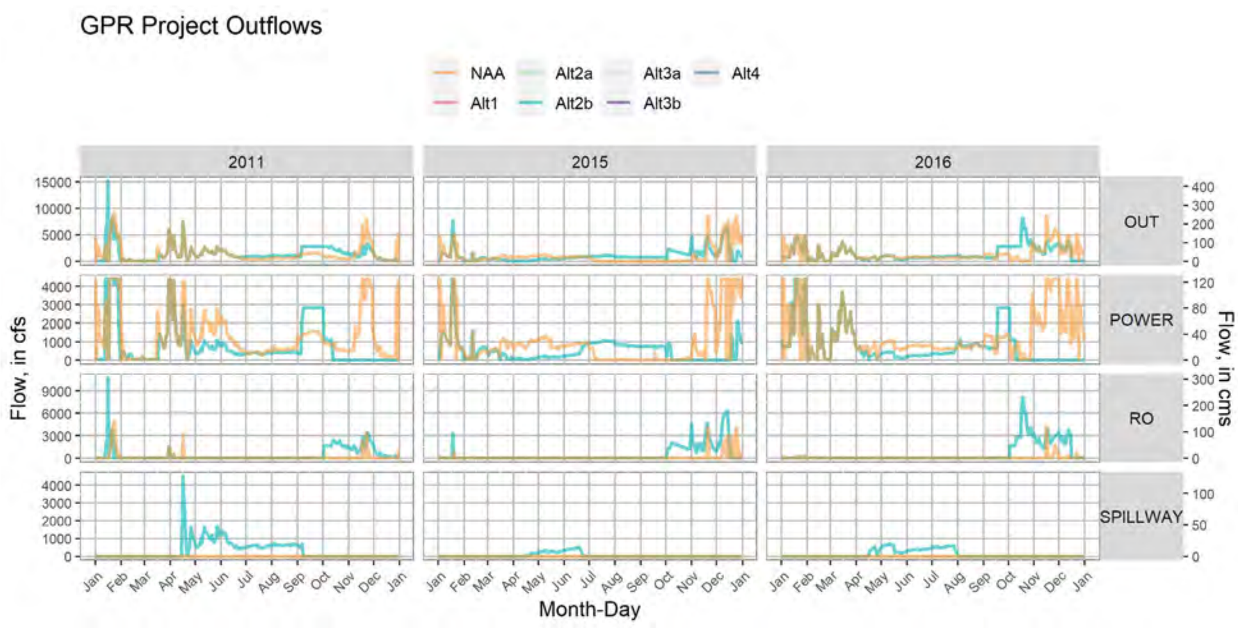

Figure 1-159. WV EIS RES-SIM Green Peter Dam gate-specific outflows in 2011, 2015, and 2016 under Alternative 2b and NAA.

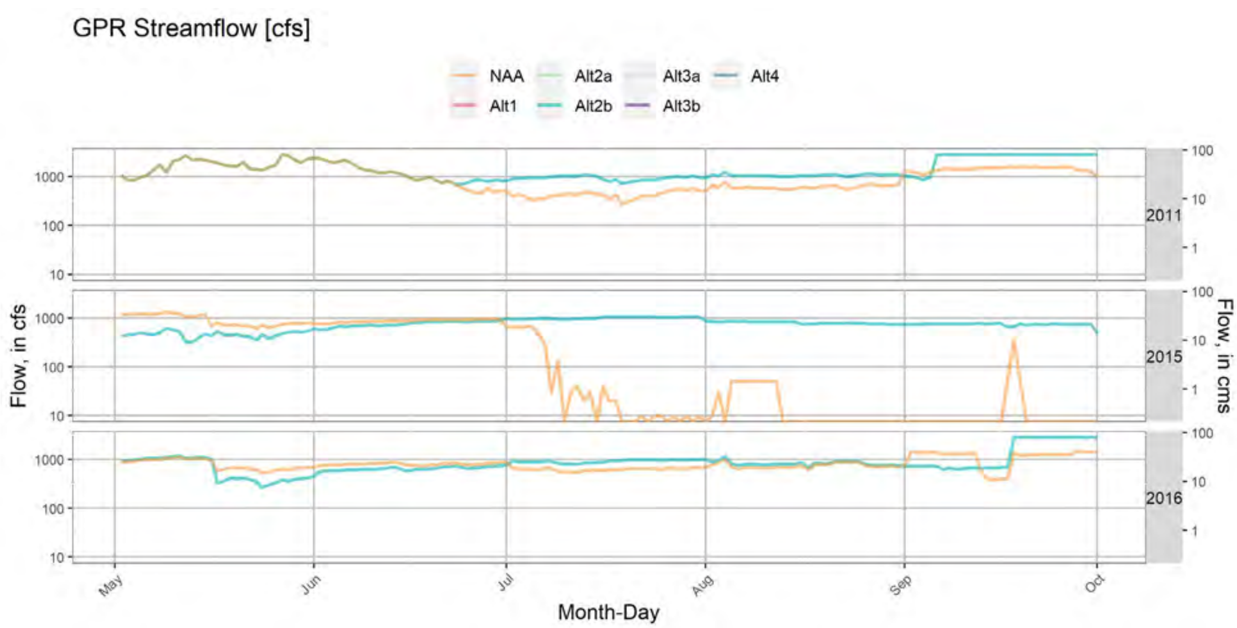

Figure 1-160. WV EIS RES-SIM Green Peter Dam Total Outflow in 2011, 2015, and 2016 Under Alternative 2b and NAA.

Lake Levels and Temperatures from CE-QUAL-W2

Depth-varying temperature, gate-specific outflows, and outflow temperatures through each calendar year scenario at Green Peter Lake are shown in Figure 1-161, Figure 1-162, and Figure 1-163 . Alternative 2b included releases through the spillway during spring-summer (when the lake was above the spillway crest) as well as releases through the Regulating Outlets during autumn to mix releases from these non-power releases with relatively deep power penstock releases in an attempt to meet the downstream temperature target. Tailwater release temperatures generally matched the temperature target when sufficient warm or cool water was available and those outlets were submerged. Spillway access was limited in some years (2015 especially), which led to an abrupt drop in tailwater temperature when spillway access ended in mid-summer of those years. This was followed by a large peak in tailwater temperature in the 2015 scenario during September-October as the lake was drafted at a relatively high outflow rate, effectively mixing the thermal layers near the dam (Figure 1-164, Figure 1-165). Generally, the autumn fish passage operation (drawdown to the RO) resulted in cooler autumn temperatures (November-December) compared to NAA (Figure 1-165).

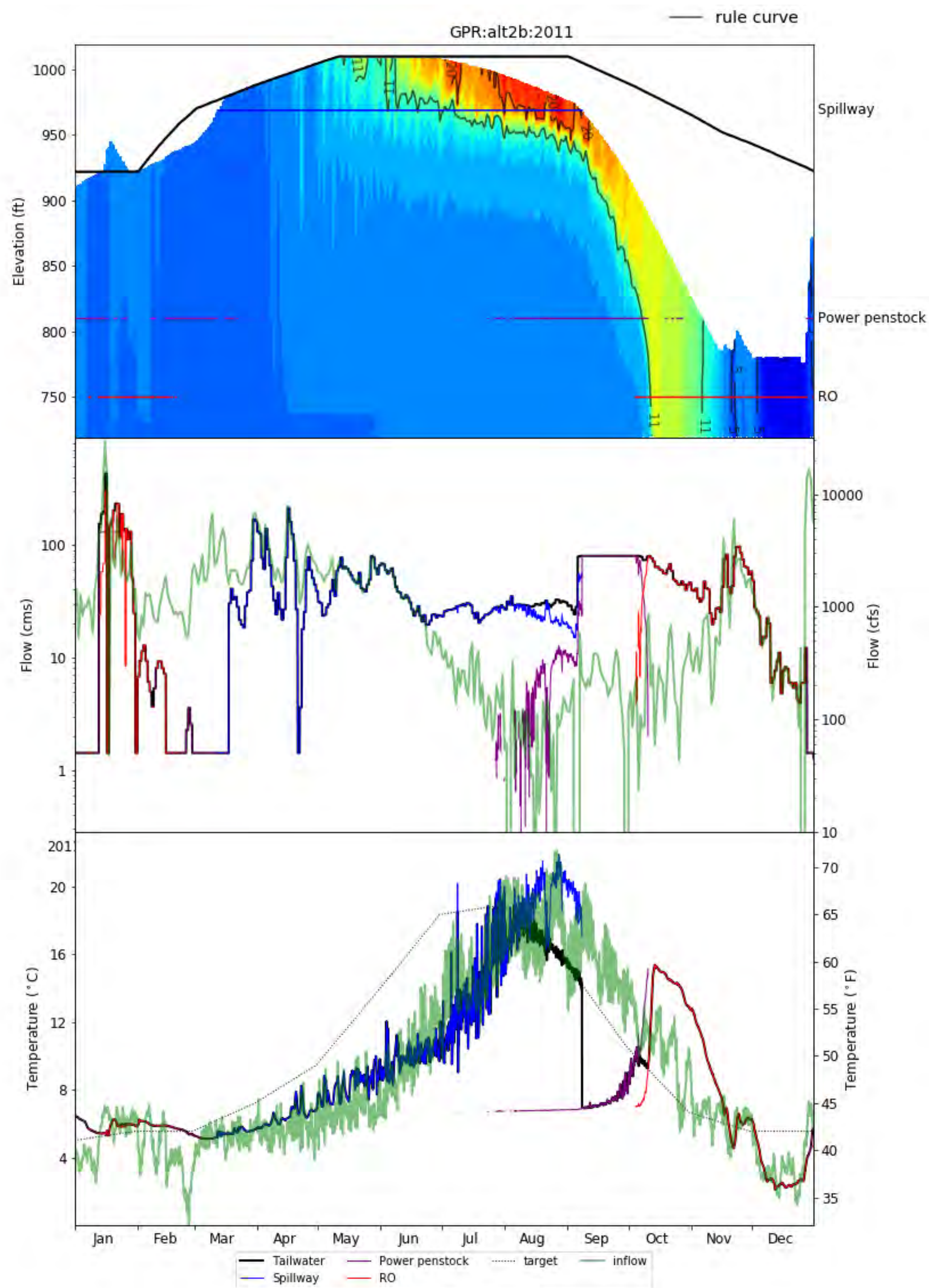

Figure 1-161. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at GPR under Alternative 2b in 2011.

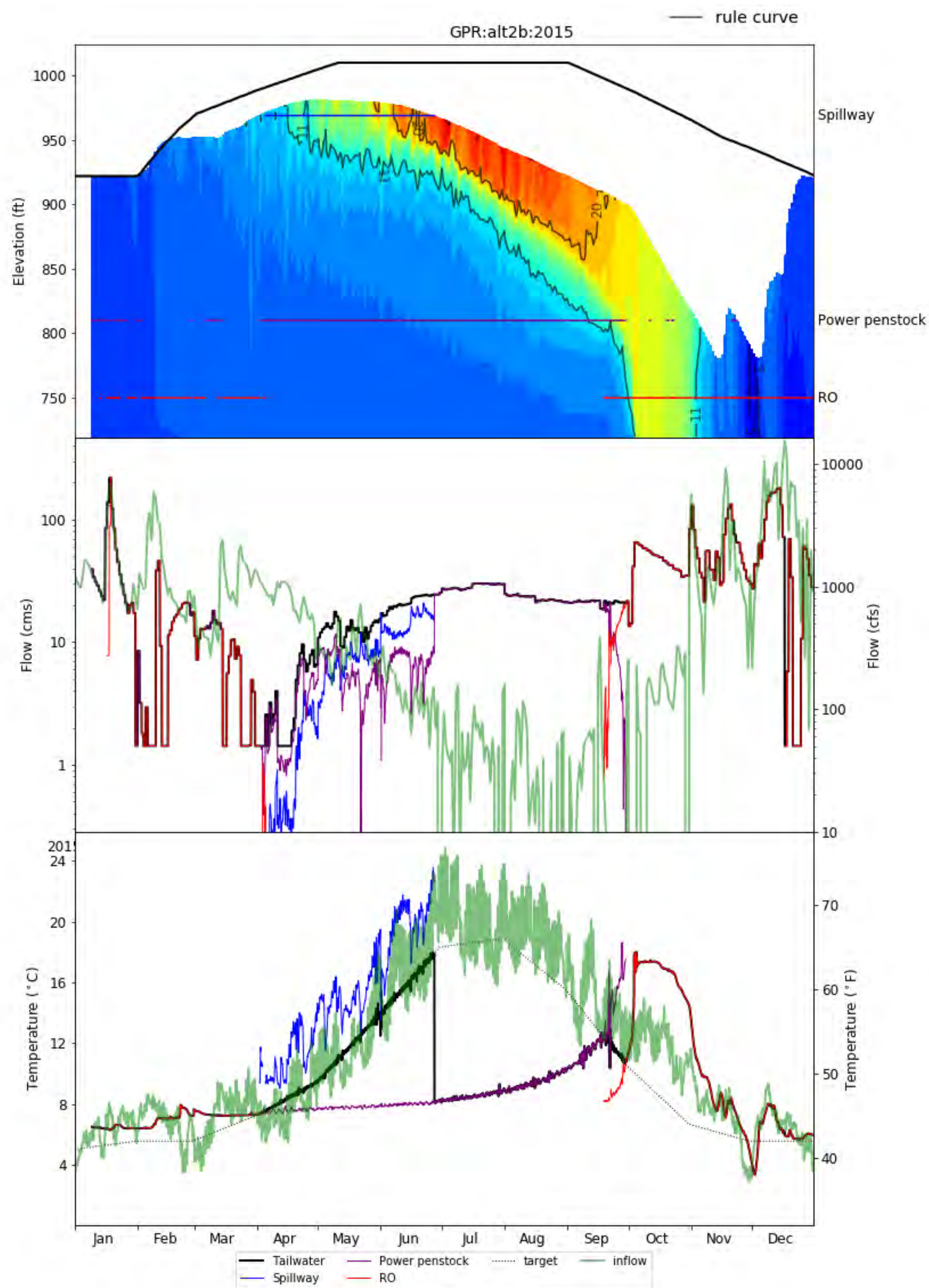

Figure 1-162. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at GPR under Alternative 2b in 2015.

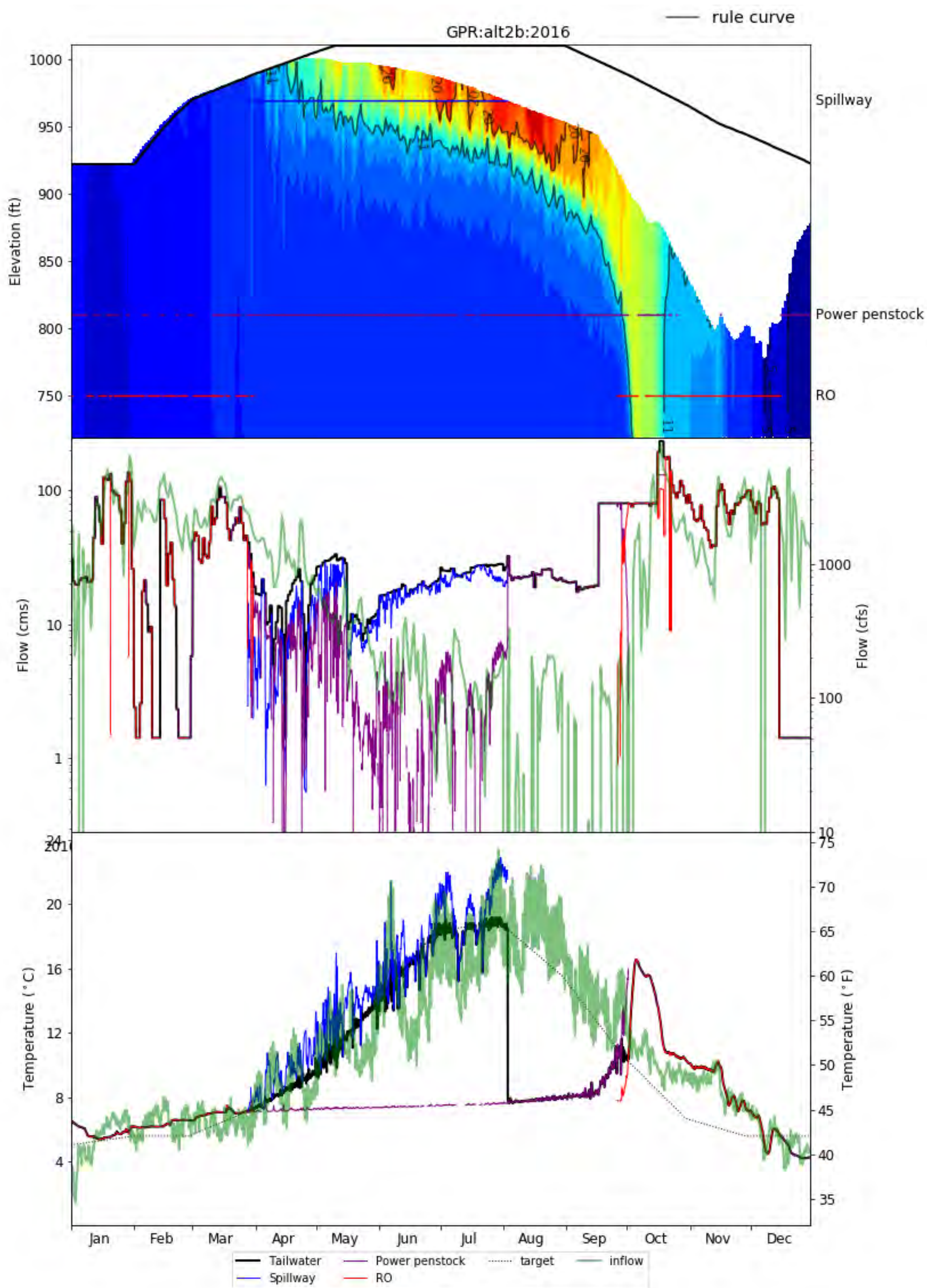

Figure 1-163. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at GPR under Alternative 2b in 2016.

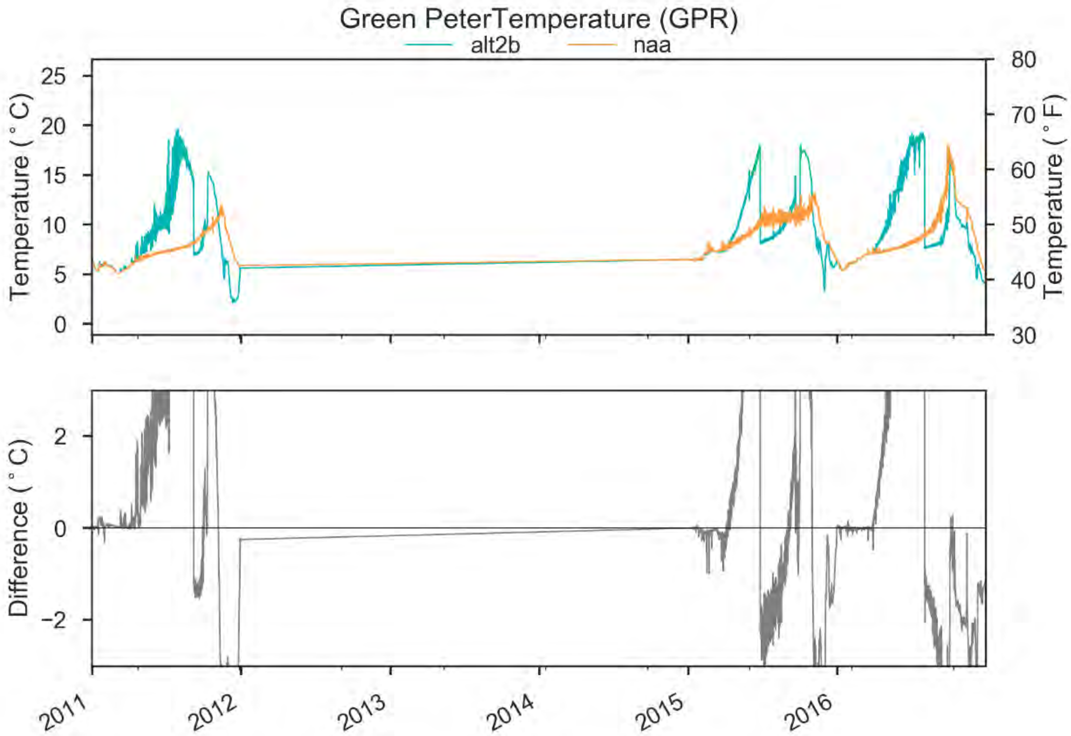

Figure 1-164. Comparison of GPR Outflow Temperatures in NAA and Alternative 2b.

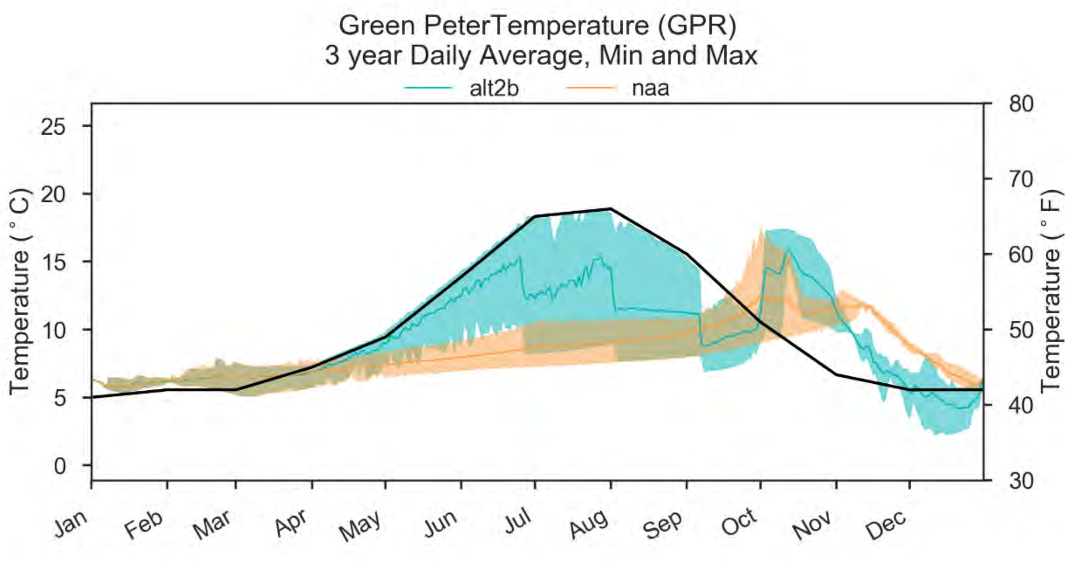

Figure 1-165. Comparison of GPR 3-year Daily Average, Min, Max Outflow Temperatures in NAA and Alternative 2b. Black Line Indicates Temperature Target.

1.5.4.2.2 Foster

RES-SIM Lake Levels and Outflows

Lake level and storage at Foster was generally similar in Alternative 2b compared to NAA in 2011 and 2016 but increased in 2015 in Alternative 2b compared to NAA (Figure 1-166, Figure 1-167, and Figure 1-168). Total outflow from Foster Dam was affected by upstream operations at Green Peter Dam. The proposed modifications to the fish weir and FWWS in Alternative 2b resulted in lower outflow routed through the Power outlets for temperature management, especially during spring and summer compared to NAA (Figure 1-167).

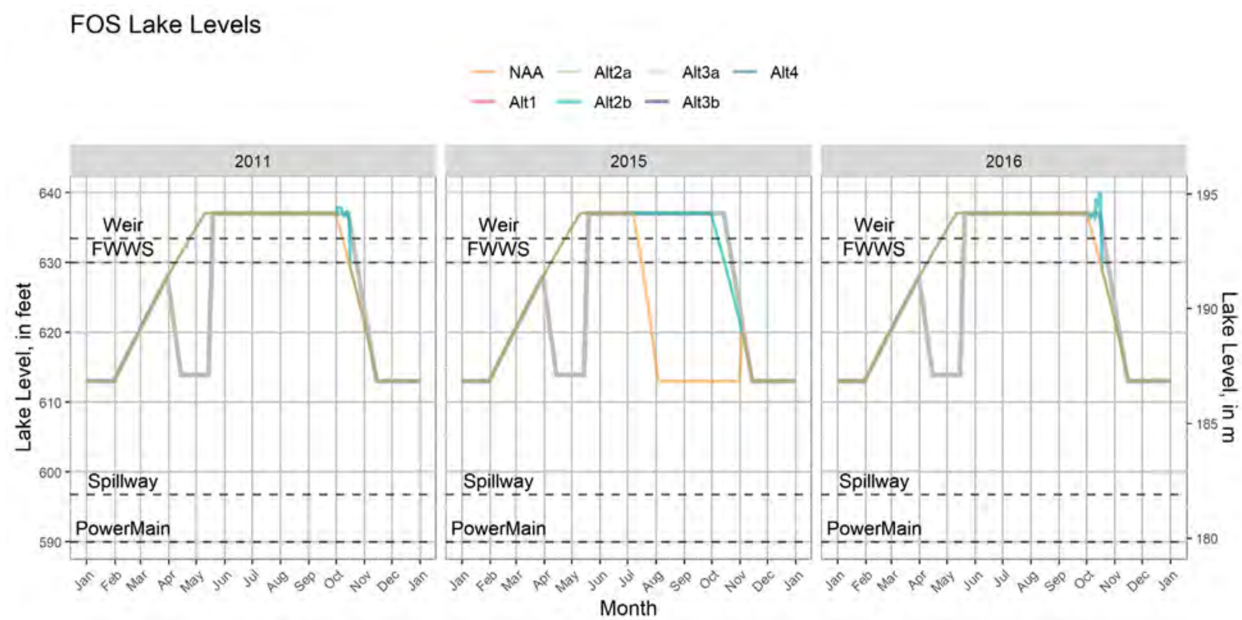

Figure 1-166. WV EIS RES-SIM Foster Lake Levels in 2011, 2015, and 2016 under Alternative 2b and NAA.

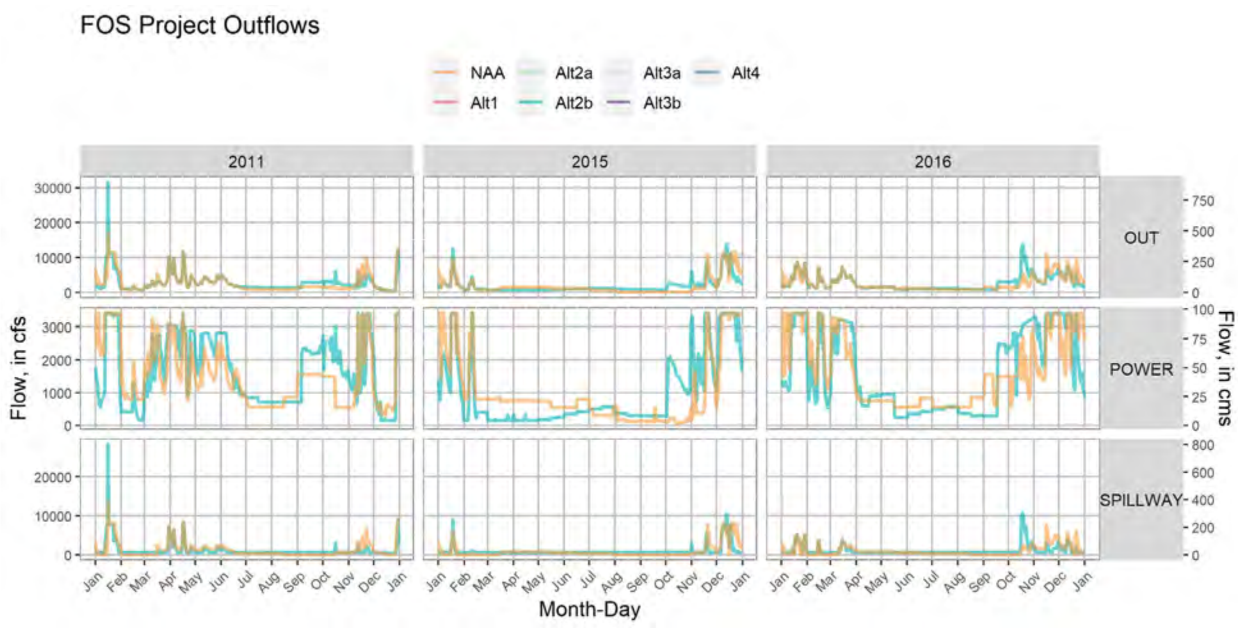

Figure 1-167. WV EIS RES-SIM Foster Dam Gate-Specific Outflows in 2011, 2015, and 2016 Under Alternative 2b and NAA.

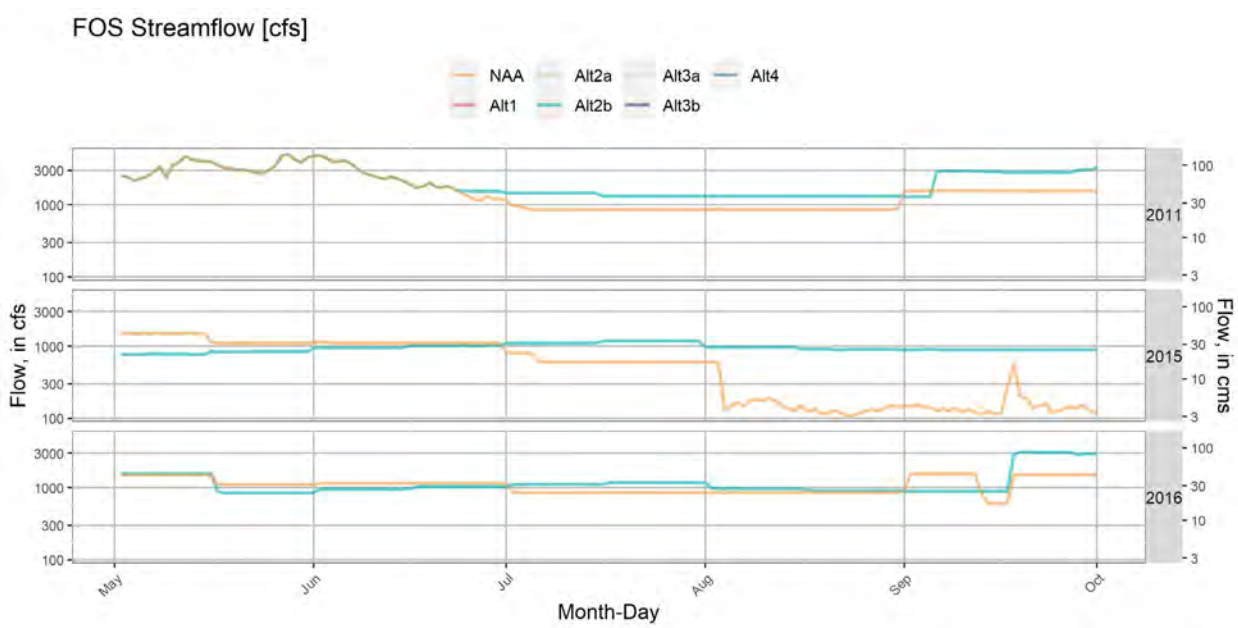

Figure 1-168. WV EIS RES-SIM Foster Dam Total Outflow in 2011, 2015, and 2016 Under Alternative 2b and NAA.

Lake Levels and Temperatures from CE-QUAL-W2

Depth-varying temperature, gate-specific outflows, and outflow temperatures through each calendar year scenario at Foster Lake are shown in Figure 1-169, Figure 1-170, and Figure 1-171. Foster Lake temperature was affected by Green Peter Dam operations release temperatures, generally resulting in travel times through Foster of 10-20 days during summer and a time lag in the temperature pattern (Sullivan and Rounds, 2021). Outflows from the proposed fish weir and FWWS combined with warmer spillway releases from Green Peter upstream resulted in warmer tailwater temperature in spring and summer compared to NAA (Figure 1-172, Figure 1-173). Generally, the autumn fish passage operation (drawdown to the RO at Green Peter) resulted in cooler autumn temperatures (November-December) compared to NAA downstream of Foster Dam.

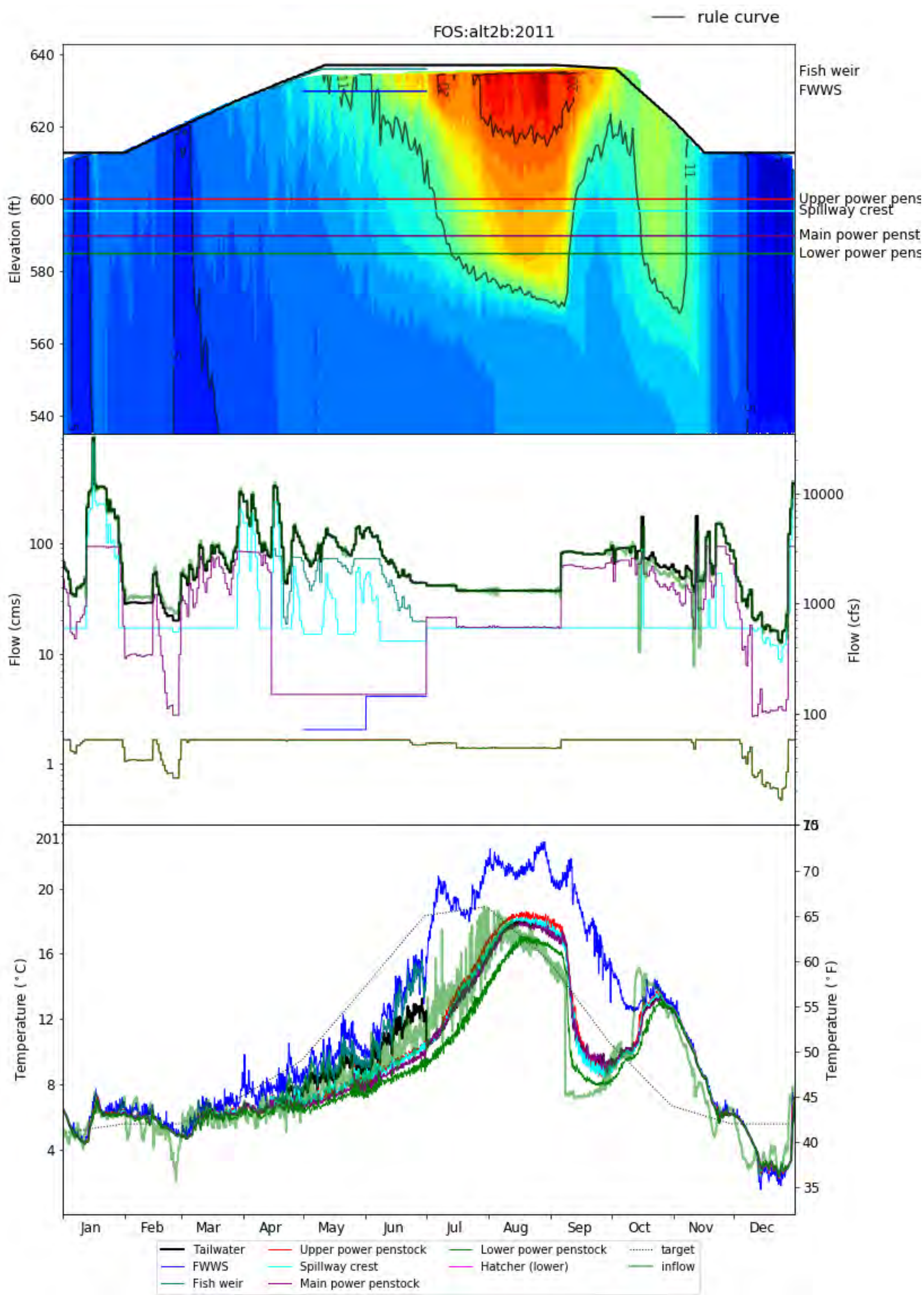

Figure 1-169. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at FOS under Alternative 2b in 2011.

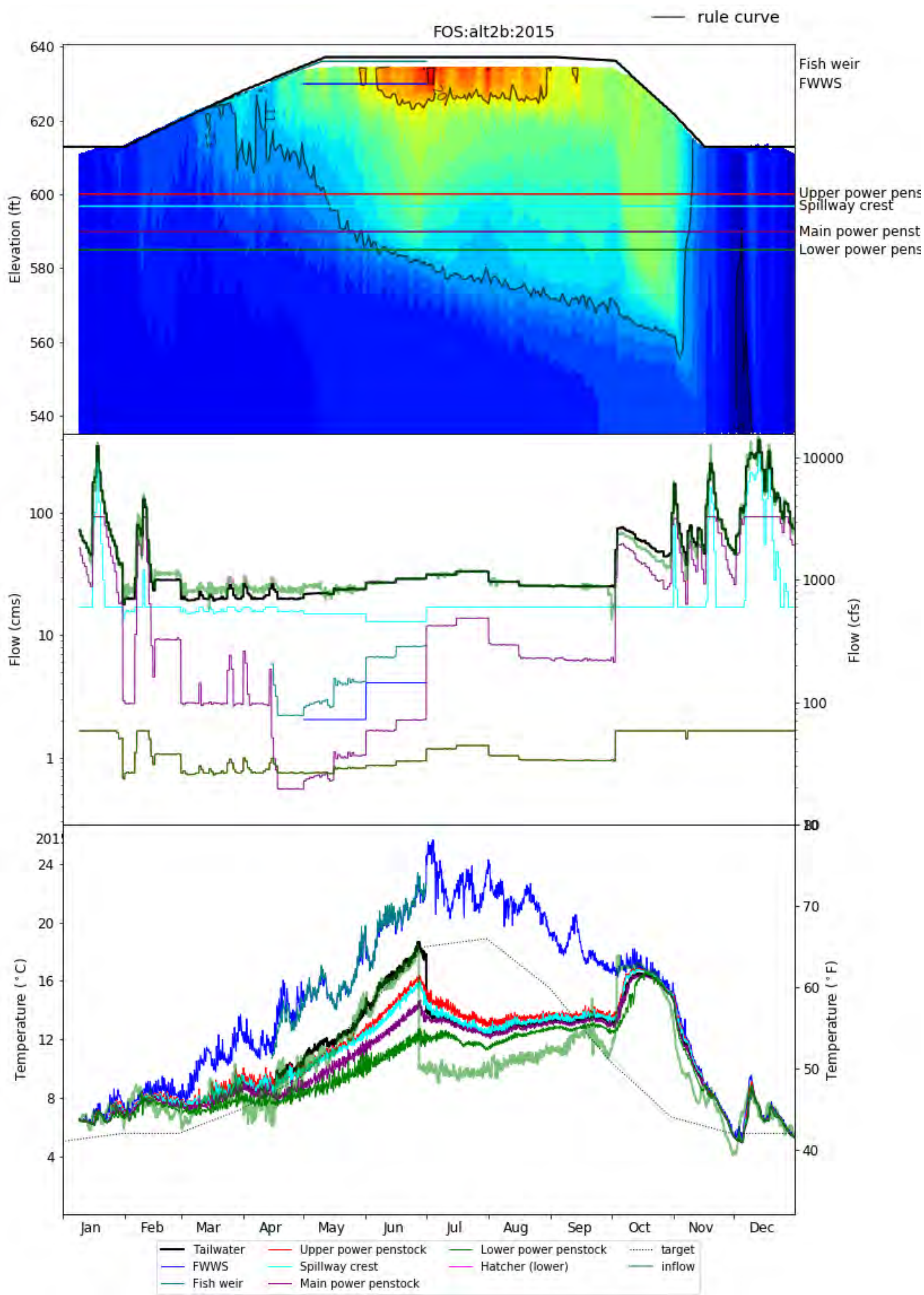

Figure 1-170. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at FOS under Alternative 2b in 2015.

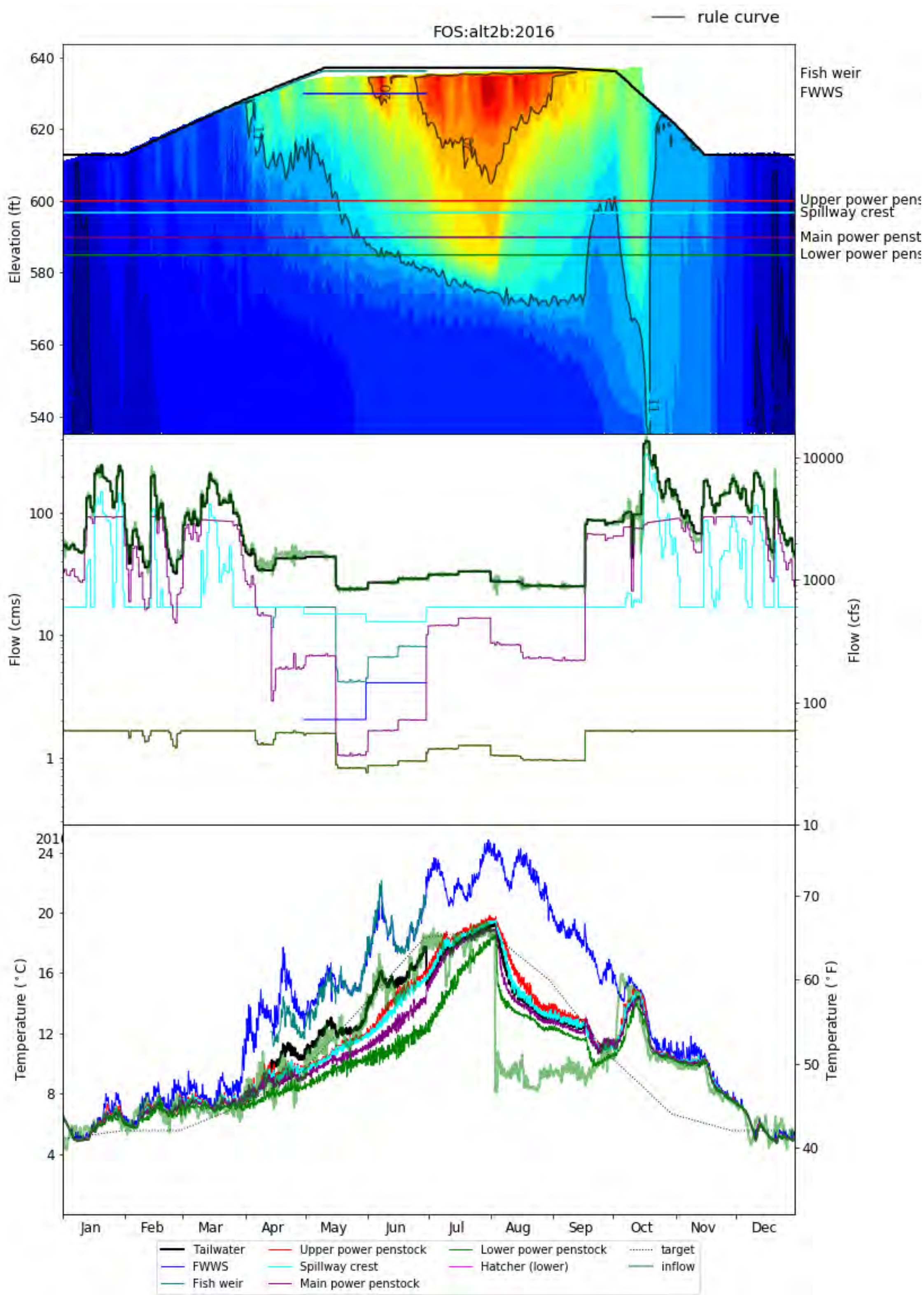

Figure 1-171. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at FOS under Alternative 2b in 2016.

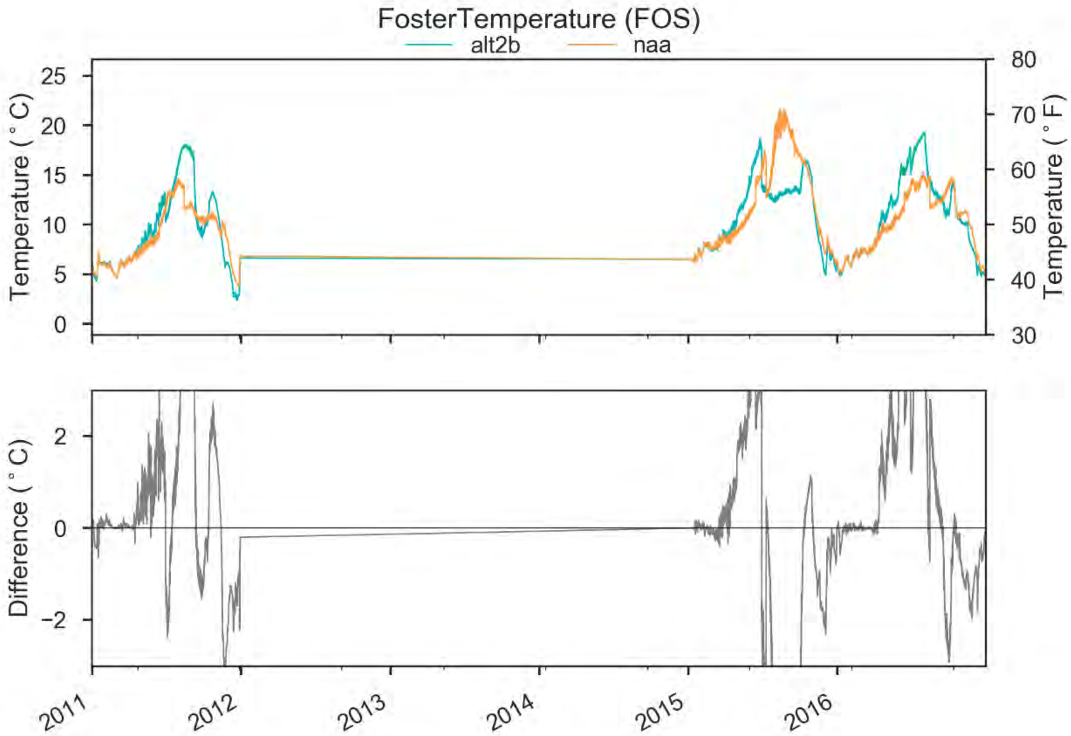

Figure 1-172. Comparison of FOS outflow temperatures in NAA and Alternative 2b.

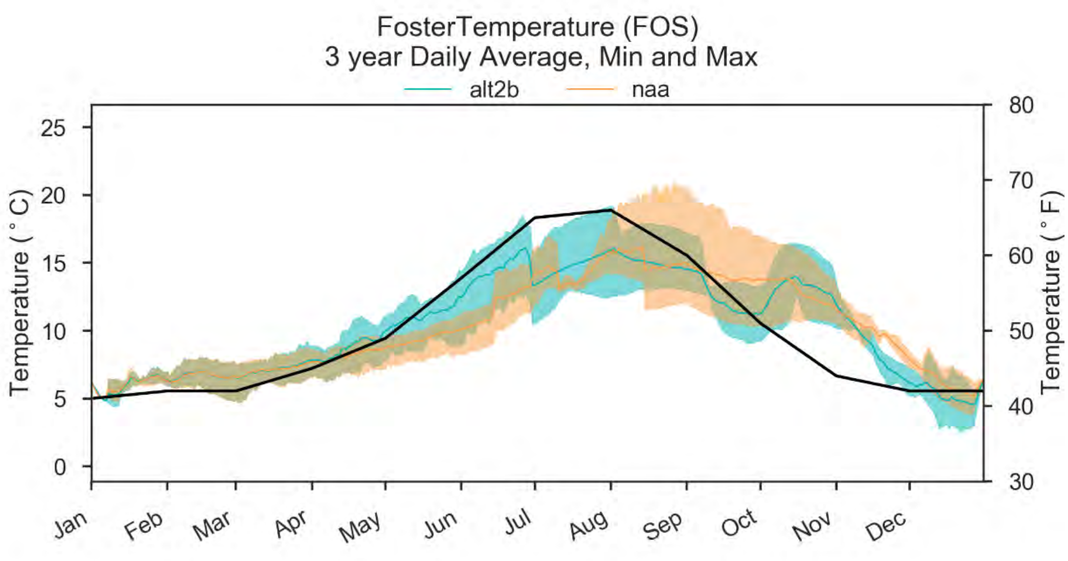

Figure 1-173. Comparison of FOS 3-year Daily Average, Min, Max Outflow Temperatures in NAA and Alternative 2b. Black line indicates temperature target.

1.5.4.3 MCKENZIE DAMS

1.5.4.3.1 Cougar

RES-SIM Lake Levels and Outflows

Lake level and storage at Cougar Lake decreased under in Alternative 2b compared to NAA in 2011, 2015, and 2016 to allow for proposed fish passage operations through the diversion tunnel (Figure 1-174, Figure 1-175, Figure 1-176). The decreased storage coincided with reduced outflows during spring and summer (Figure 1-176). Outflows were primarily routed through the diversion tunnel in Alternative 2b, except when the lake refilled to about 30 feet above the RO intake (e.g., 2011).

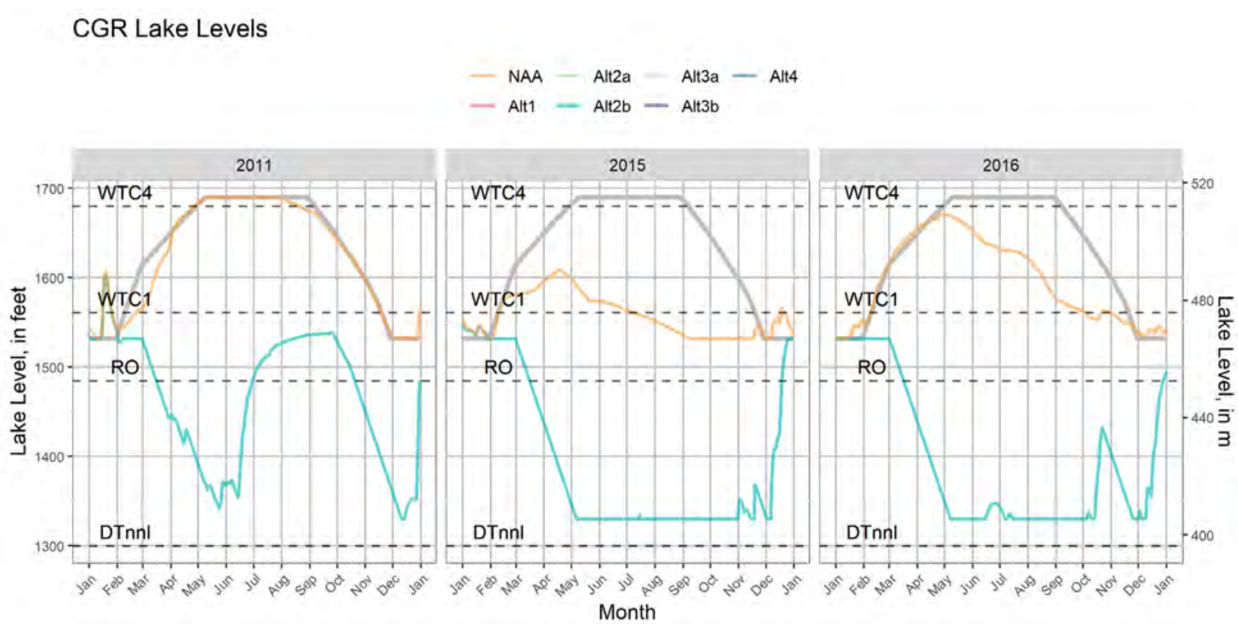

Figure 1-174. WV EIS RES-SIM Cougar Lake Levels in 2011, 2015, and 2016 Under Alternative 2b and NAA.

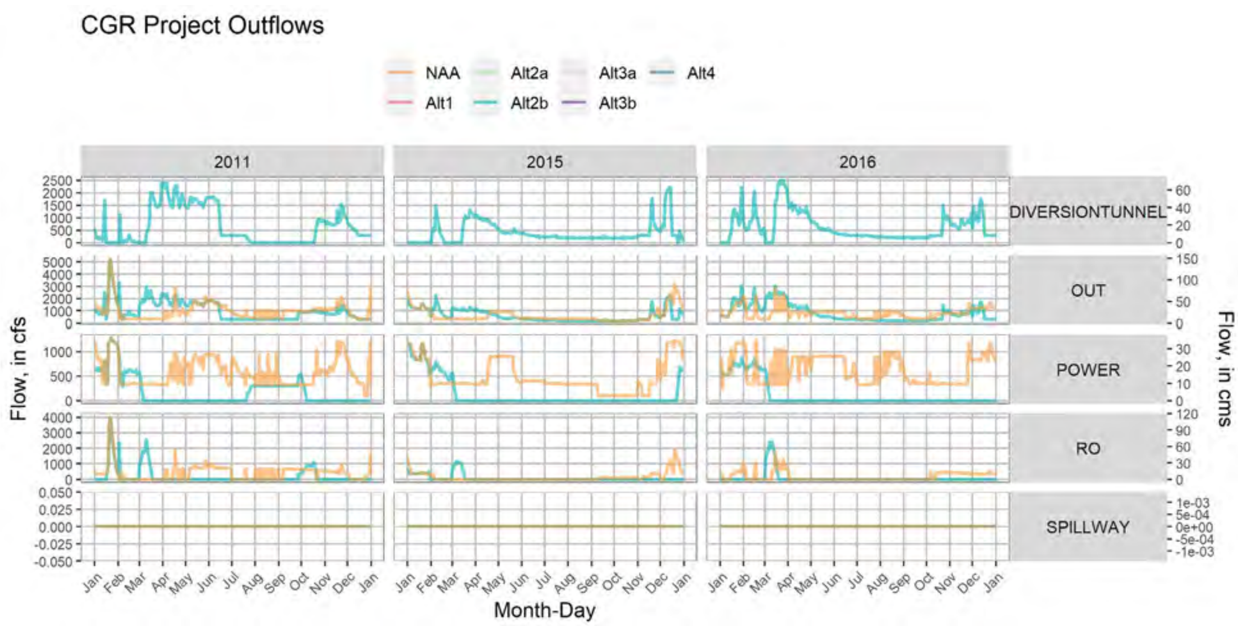

Figure 1-175. WV EIS RES-SIM Cougar Dam Gate-Specific Outflows in 2011, 2015, and 2016 Under Alternative 2b and NAA.

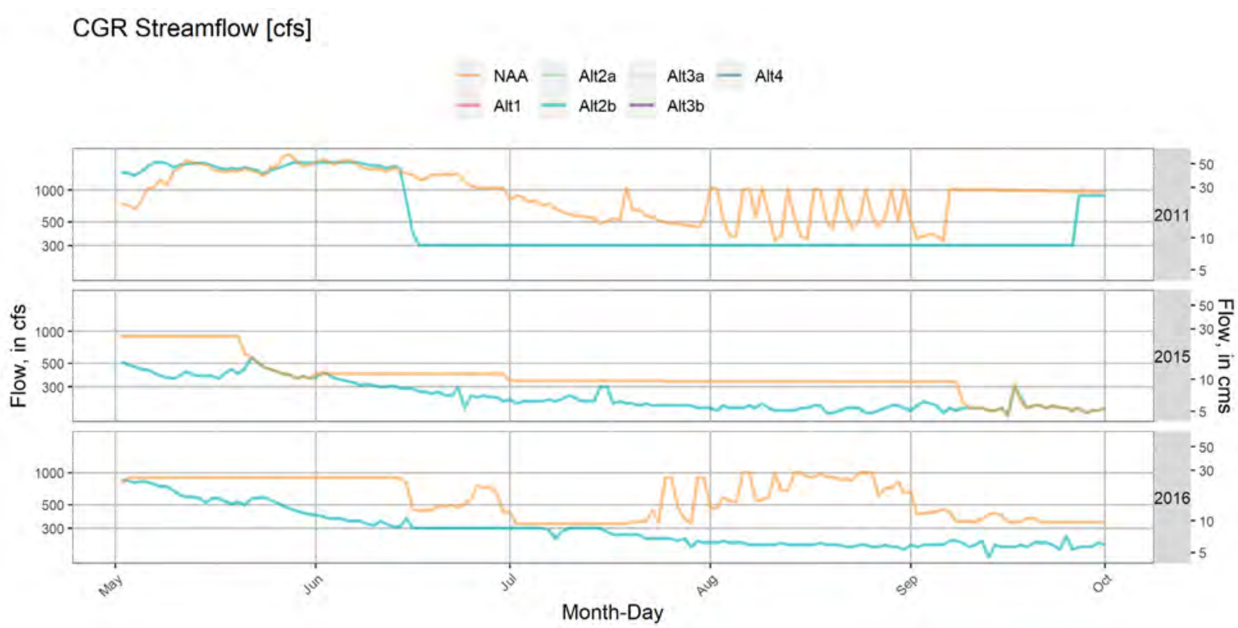

Figure 1-176. WV EIS RES-SIM Cougar Dam Total Outflow in 2011, 2015, and 2016 Under Alternative 2b and NAA.

Lake Levels and Temperatures from CE-QUAL-W2

Depth-varying temperature, gate-specific outflows, and outflow temperatures through each calendar year scenario at Cougar Lake are shown in Figure 1-177, Figure 1-178, and Figure 1-179. Outflow temperatures from Cougar Dam in Alternative 2b were cooler than NAA year-round in 2011, 2015, and 2016 as the lake surface area, volume, and residence time was reduced (Figure 1-180 and Figure 1-181).

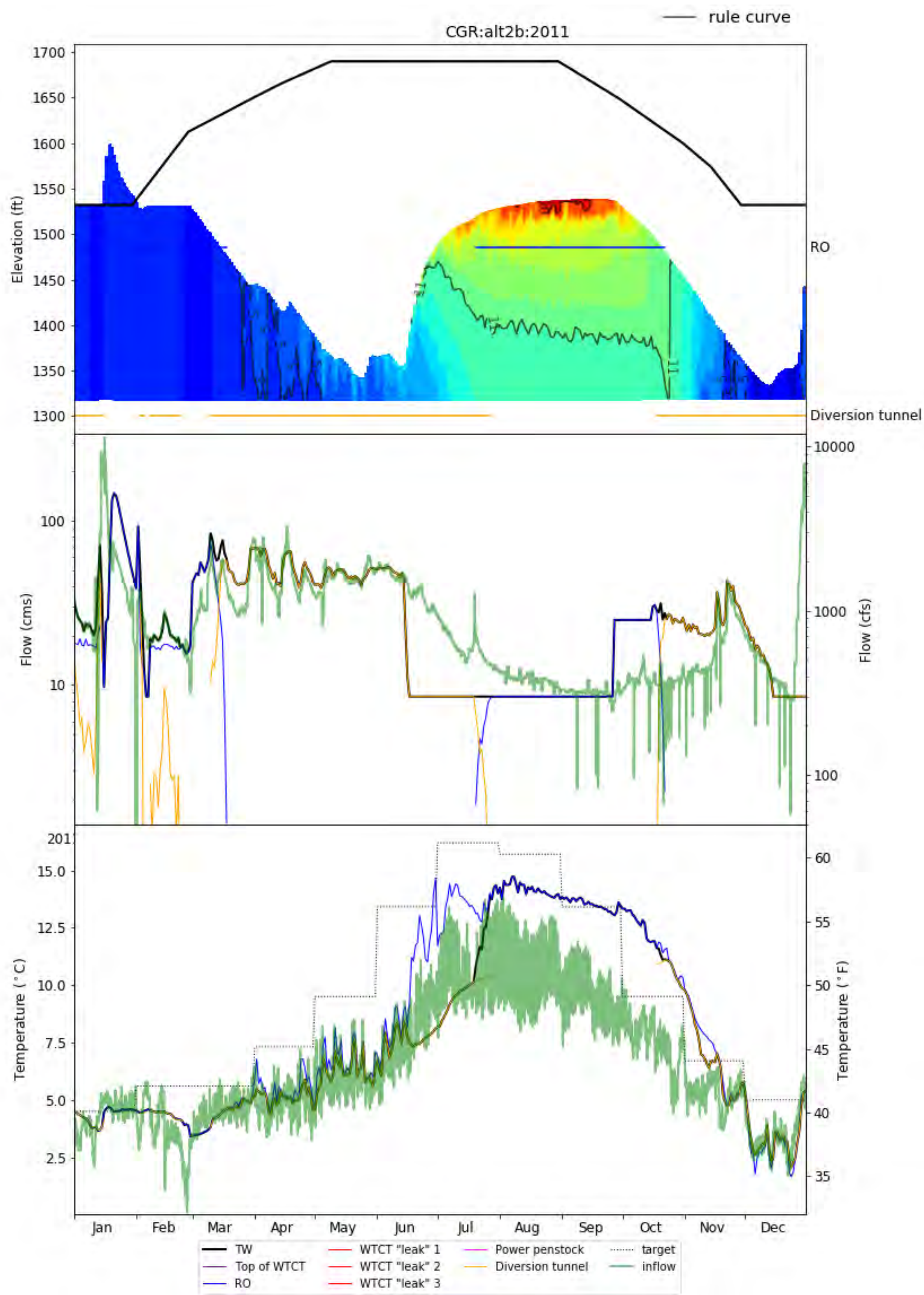

Figure 1-177. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at CGR under Alternative 2b in 2011.

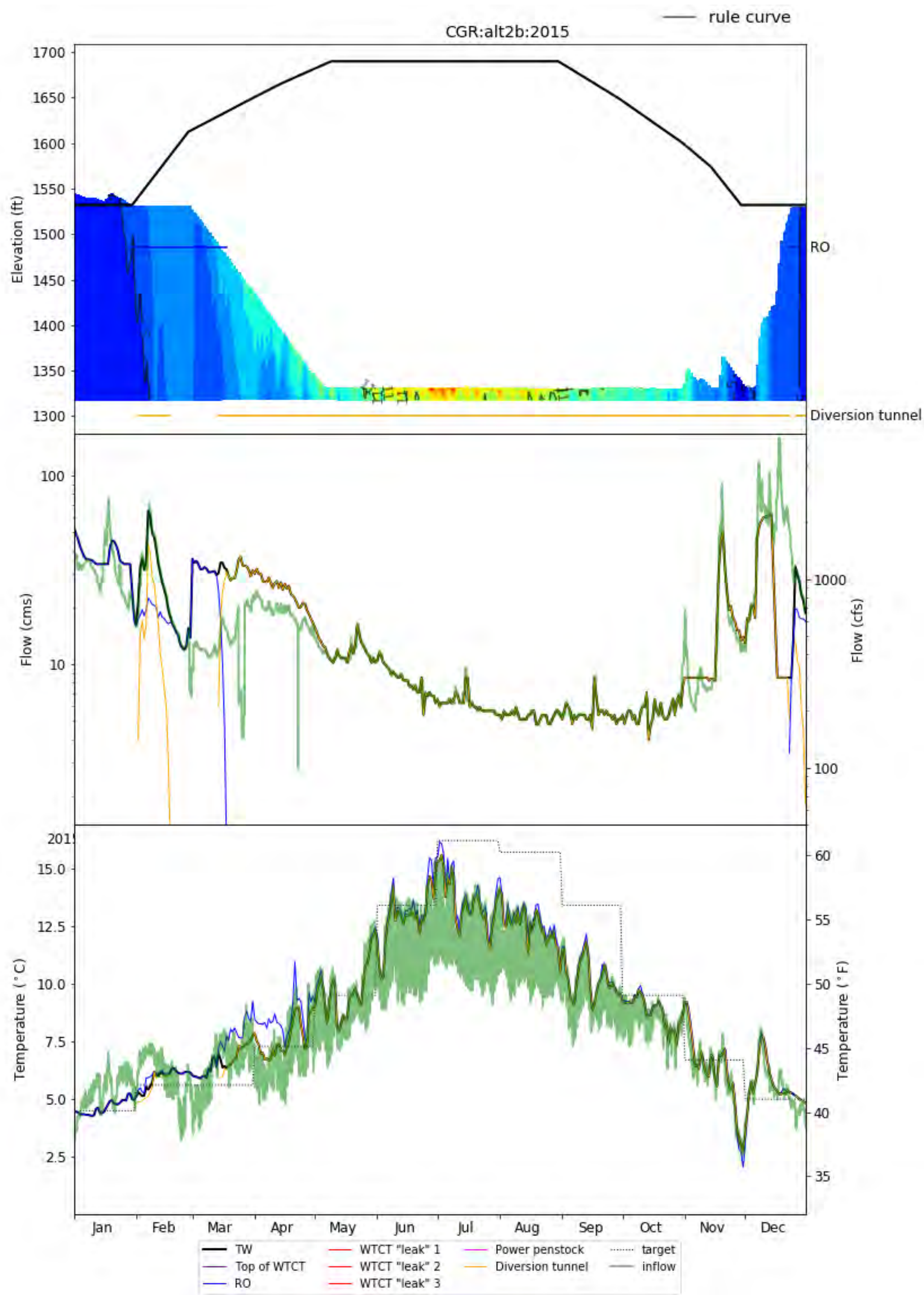

Figure 1-178. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at CGR under Alternative 2b in 2015.

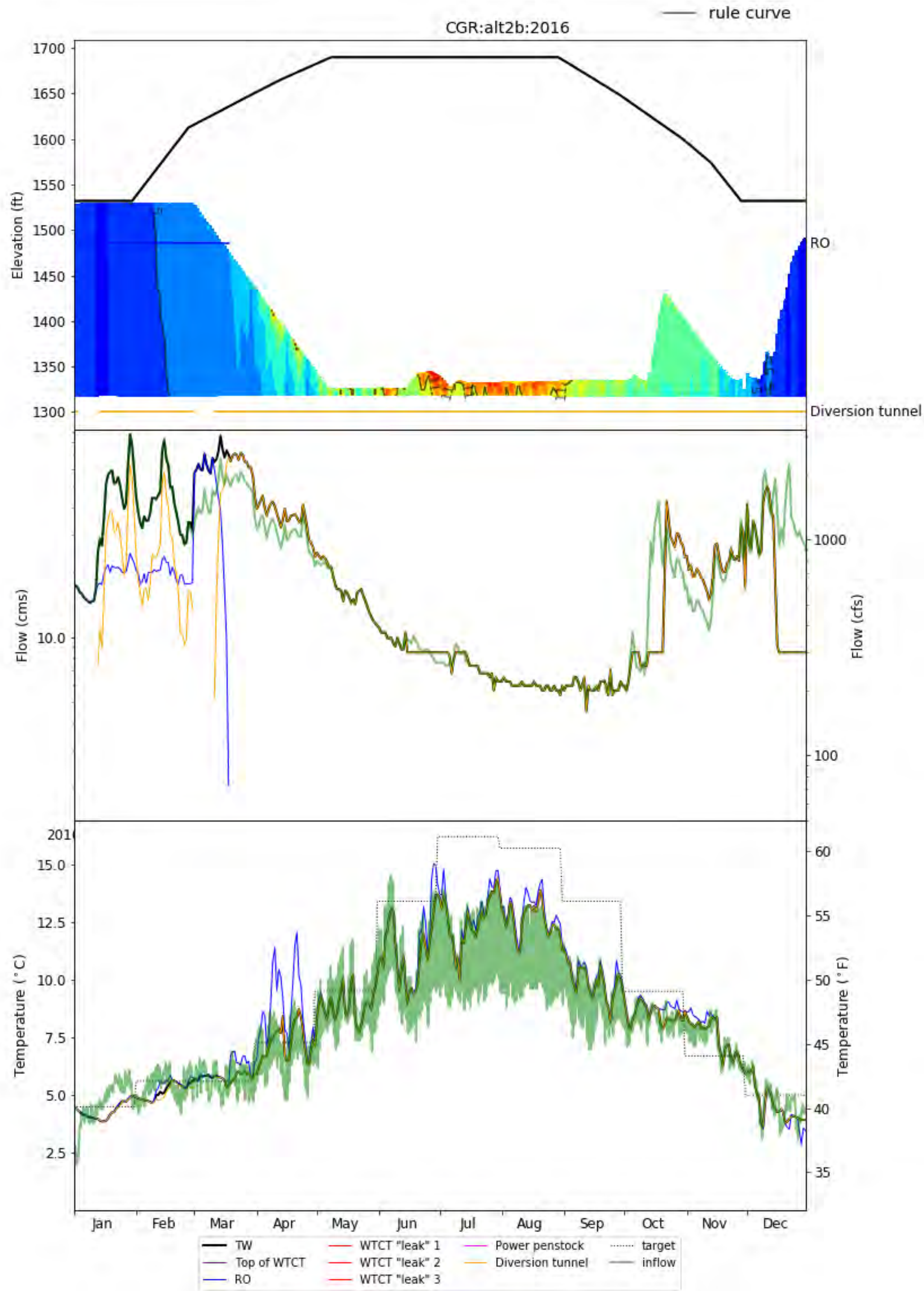

Figure 1-179. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at CGR under Alternative 2b in 2016.

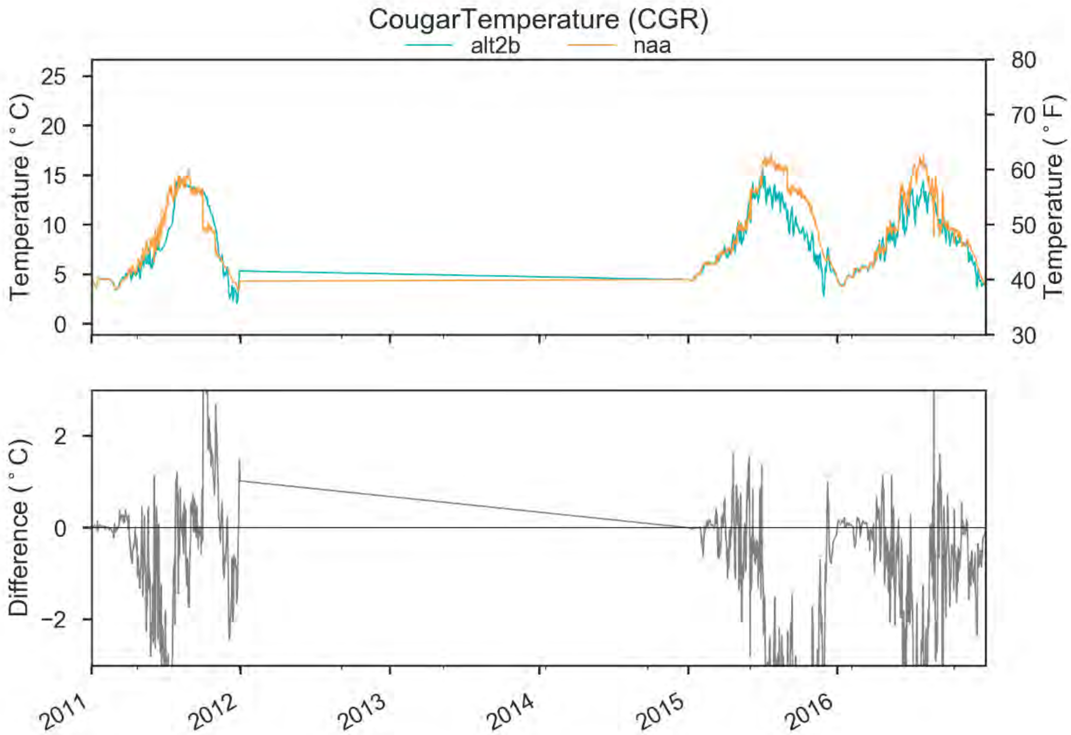

Figure 1-180. Comparison of CGR Outflow Temperatures in NAA and Alternative 2b.

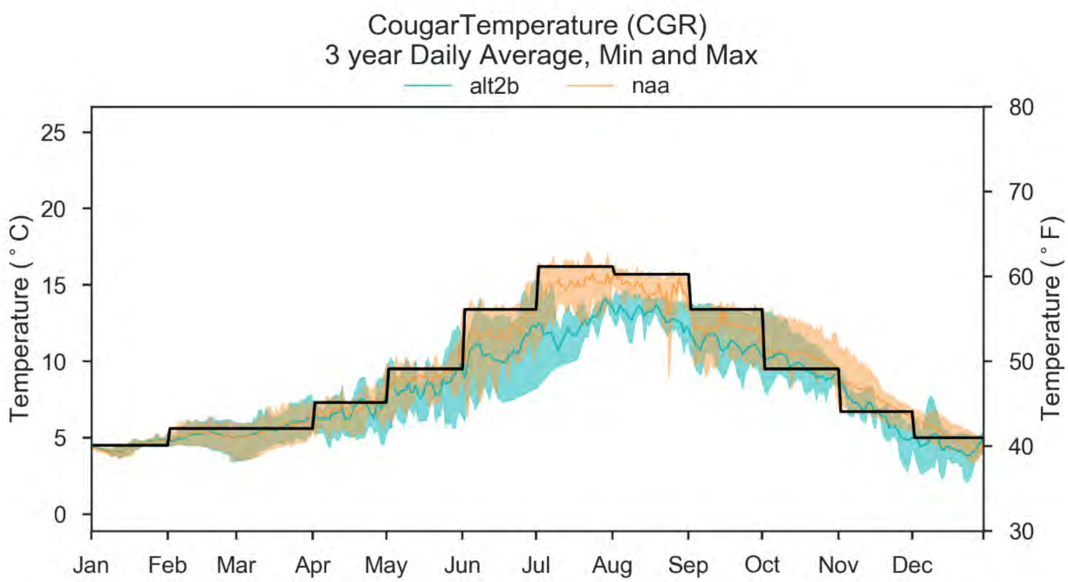

Figure 1-181. Comparison of CGR 3-year Daily Average, Min, Max Outflow Temperatures in NAA and Alternative 2b. Black Line Indicates Temperature Target.

1.5.4.4 MIDDLE FORK WILLAMETTE DAMS

1.5.4.4.1 Hills Creek

<u>RES-SIM Lake Levels and Outflows</u>

Lake level and storage at Hills Creek Lake generally increased under Alternative 2b compared to NAA in 2015 and 2016 except for August-November, 2015, when the power pool was utilized for downstream flow augmentation (Figure 1-182, Figure 1-183, and Figure 1-184). The increased storage coincided with reduced outflows during spring and increased outflows in May-July during 2015 and August-October in 2016 (Figure 1-183). 2011 operations were generally similar in Alternative 2b and NAA at Hills Creek Lake.

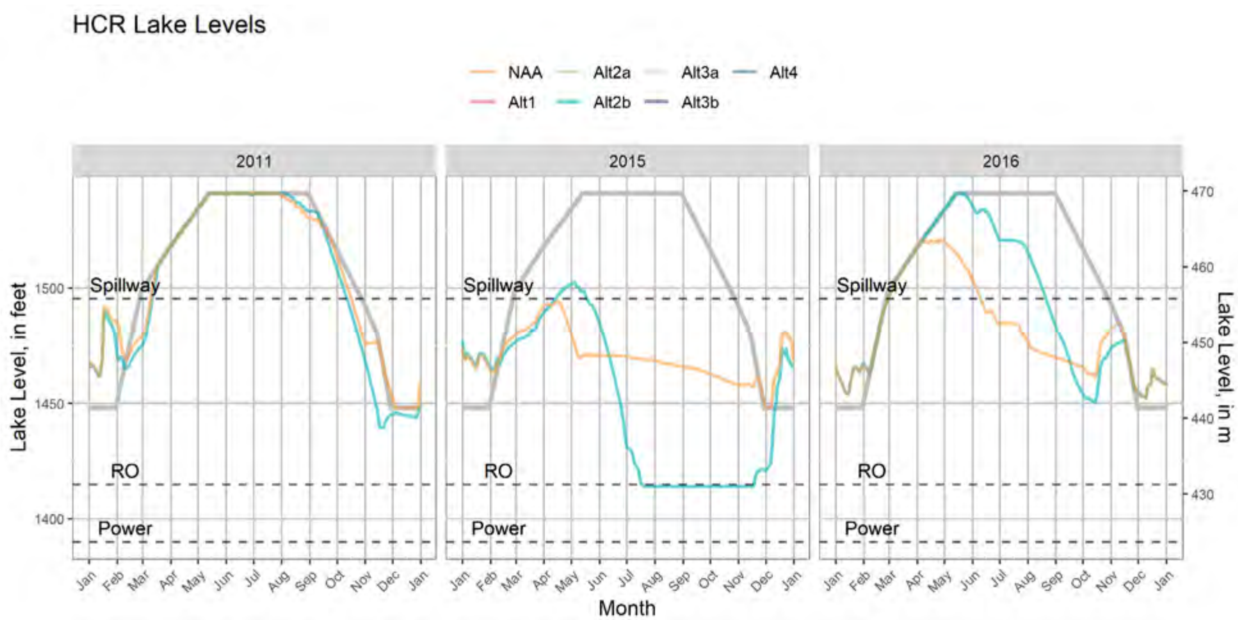

Figure 1-182. WV EIS RES-SIM Hills Creek Lake Levels in 2011, 2015, and 2016 under Alternative 2b and NAA.

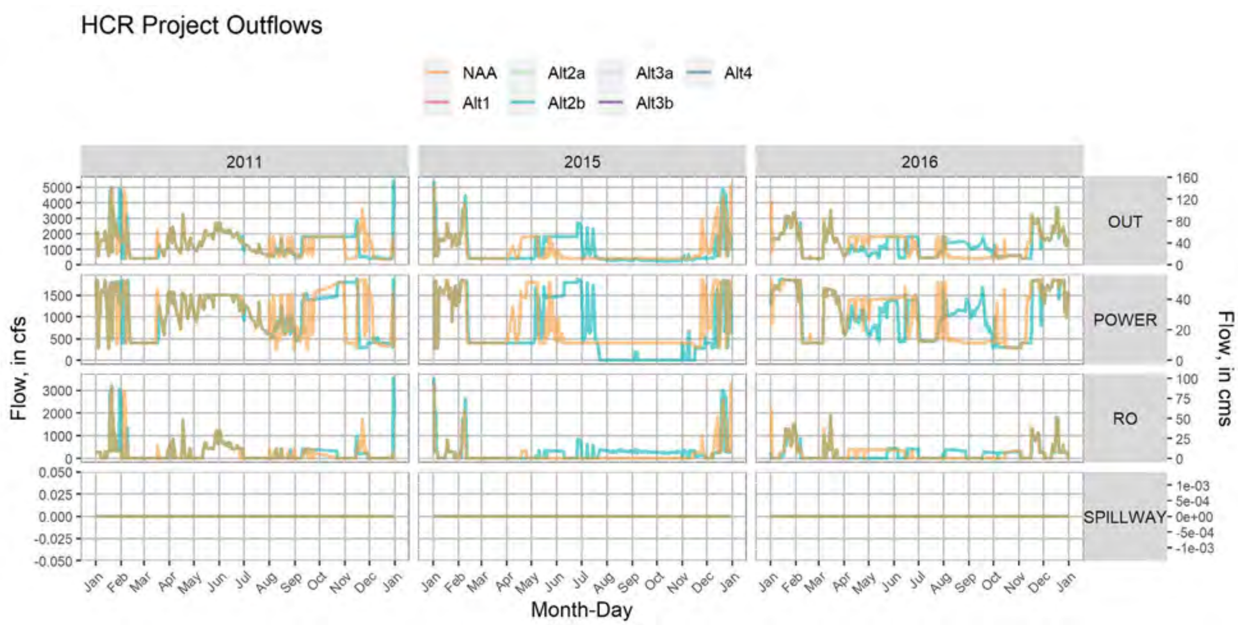

Figure 1-183. WV EIS RES-SIM Hills Creek Dam Gate-Specific Outflows in 2011, 2015, and 2016 under Alternative 2b and NAA.

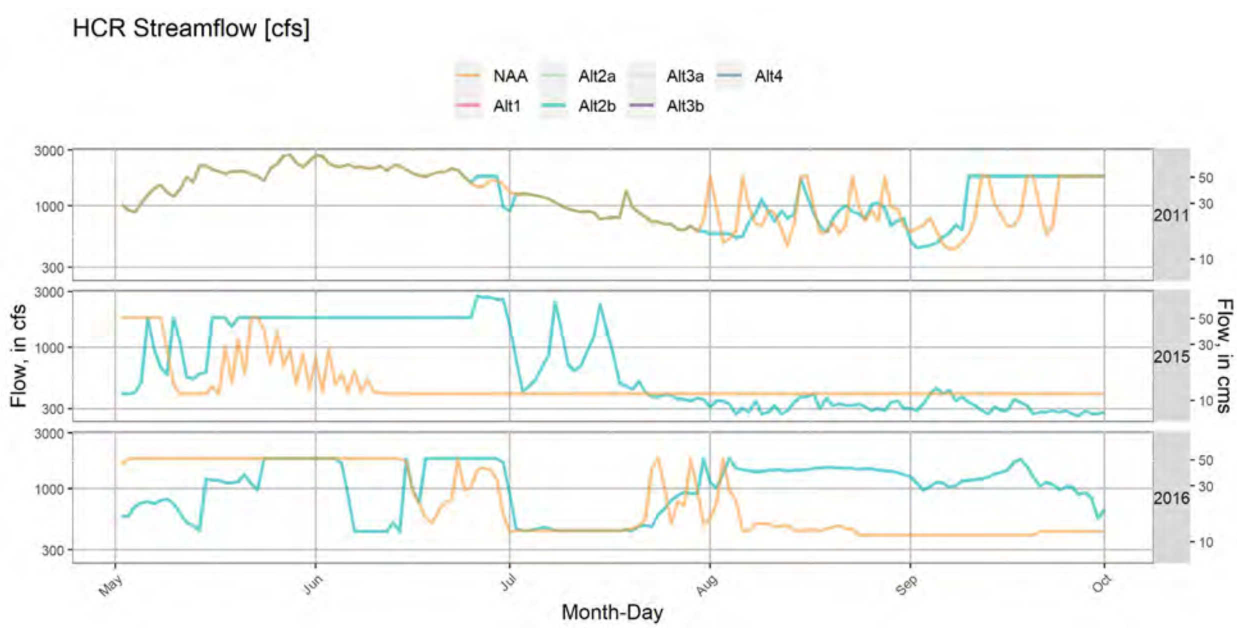

Figure 1-184. WV EIS RES-SIM Hills Creek Dam Total Outflow in 2011, 2015, and 2016 under Alternative 2b and NAA.

Lake Levels and Temperatures from CE-QUAL-W2

Depth-varying temperature, gate-specific outflows, and outflow temperatures through each calendar year scenario in Alternative 2b at Hills Creek Lake are shown in Figure 1-185, Figure 1-186, and Figure 1-187. The seasonal peak tailwater temperature under Alternative 2b was higher and occurred about one month earlier in 2015, which resulted in cooler tailwater temperature during autumn of that year compared to NAA (Figure 1-188, Figure 1-189). 2016 outflow tailwater temperature in Alternative 2b was generally cooler than NAA in spring and summer but similar during autumn. Hills Creek tailwater temperatures in 2011 were generally similar in Alternative 2b and NAA.

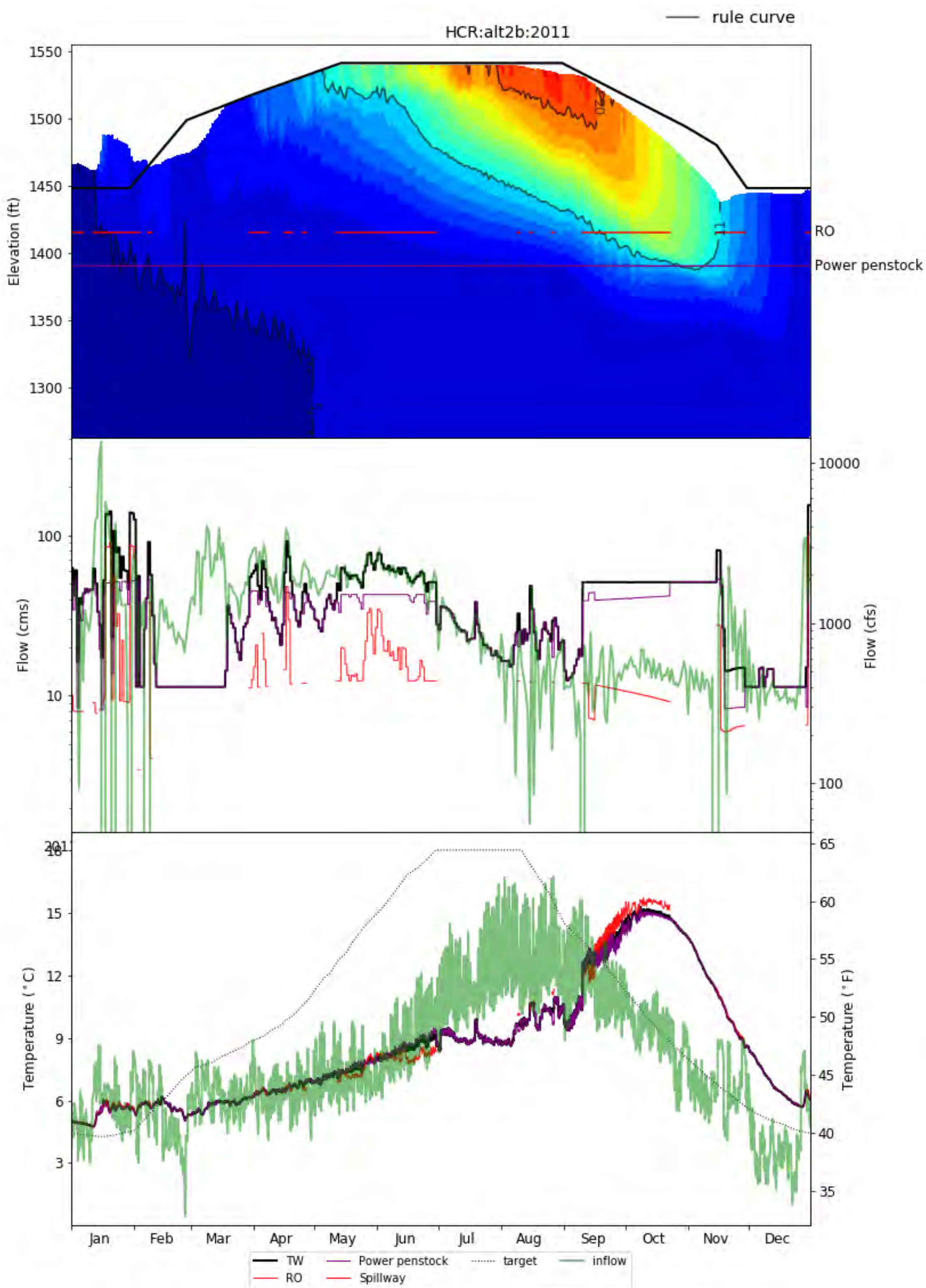

Figure 1-185. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at HCR under Alternative 2b in 2011.

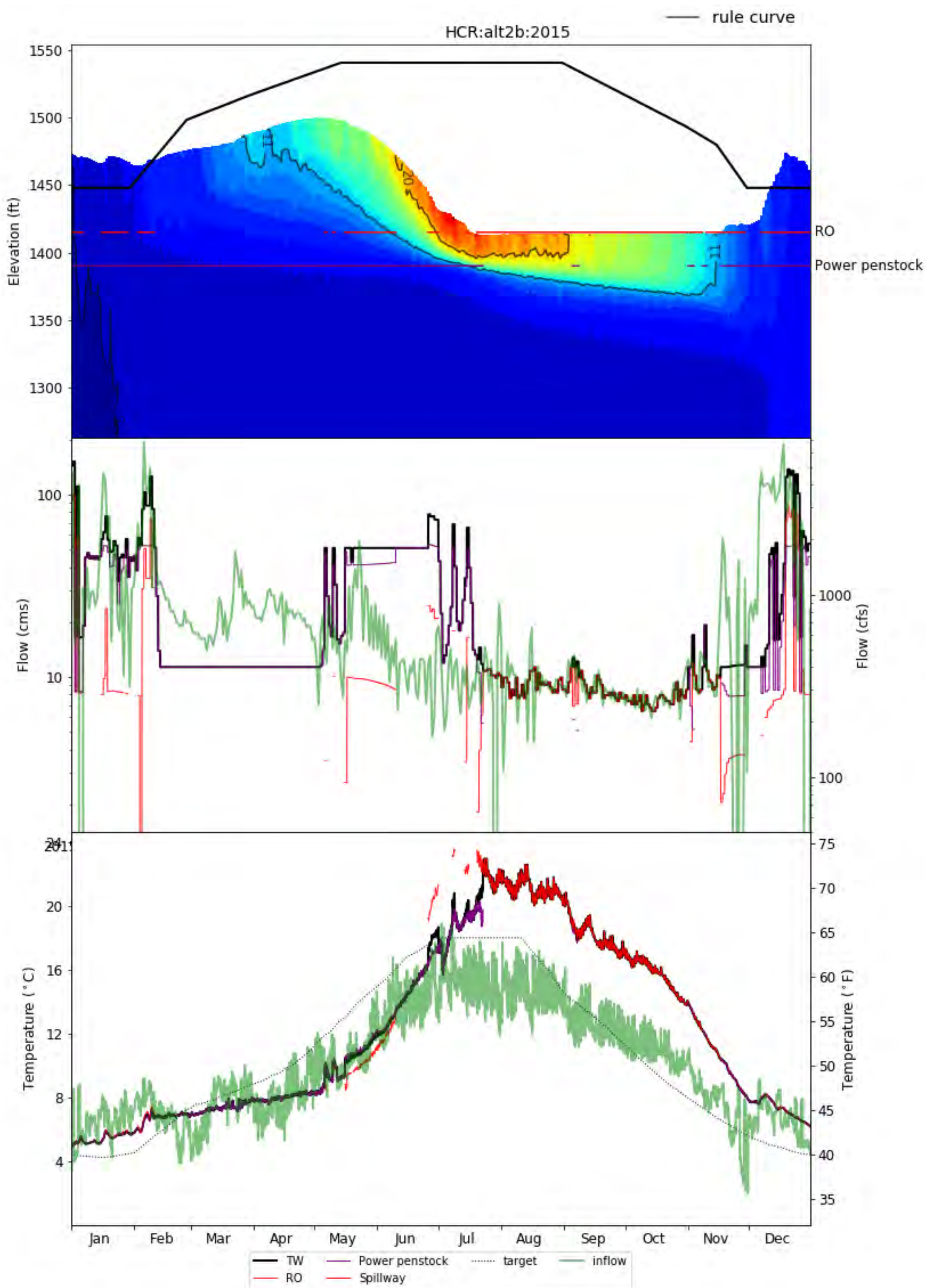

Figure 1-186. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at HCR under Alternative 2b in 2015.

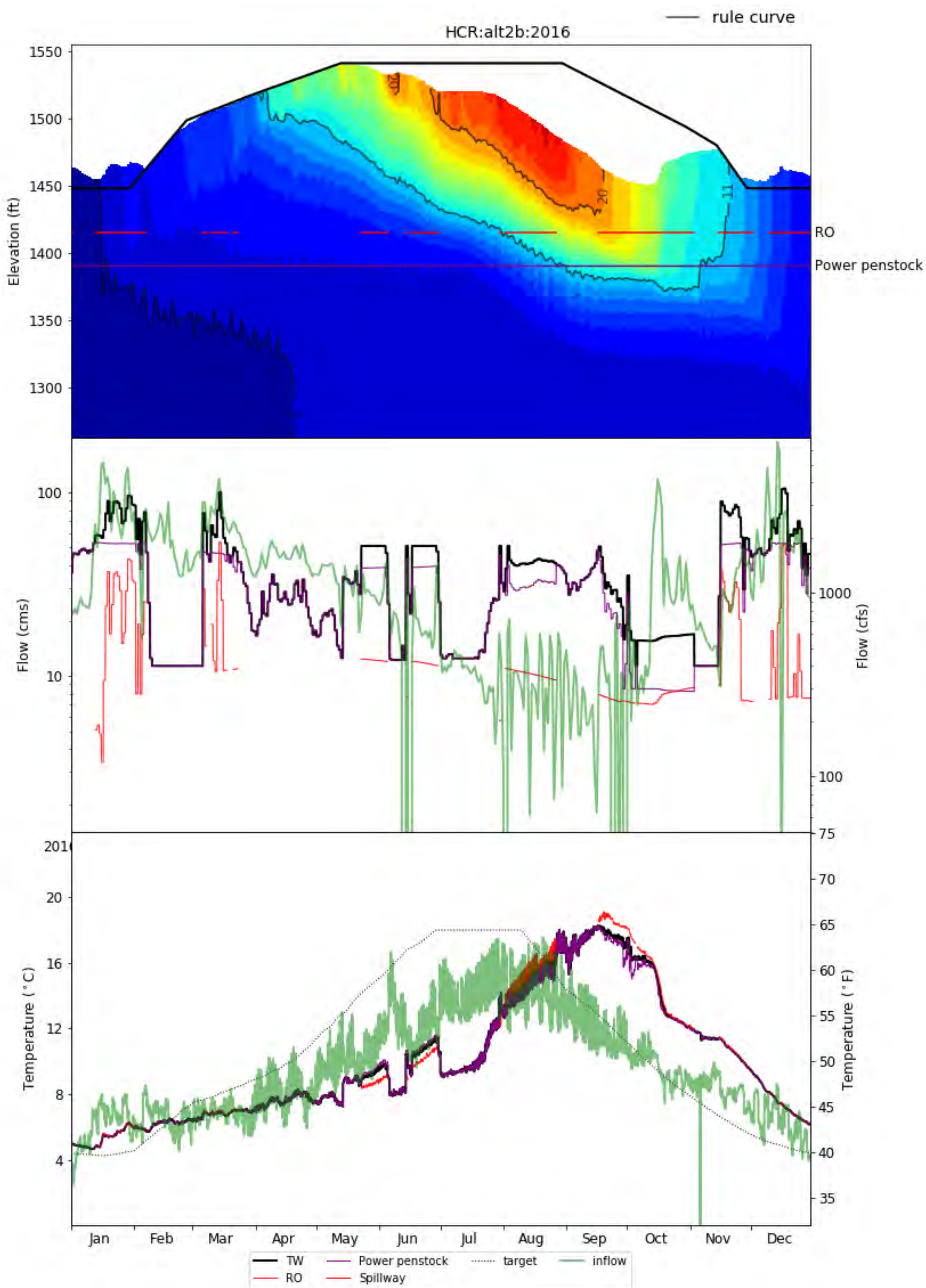

Figure 1-187. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at HCR under Alternative 2b in 2016.

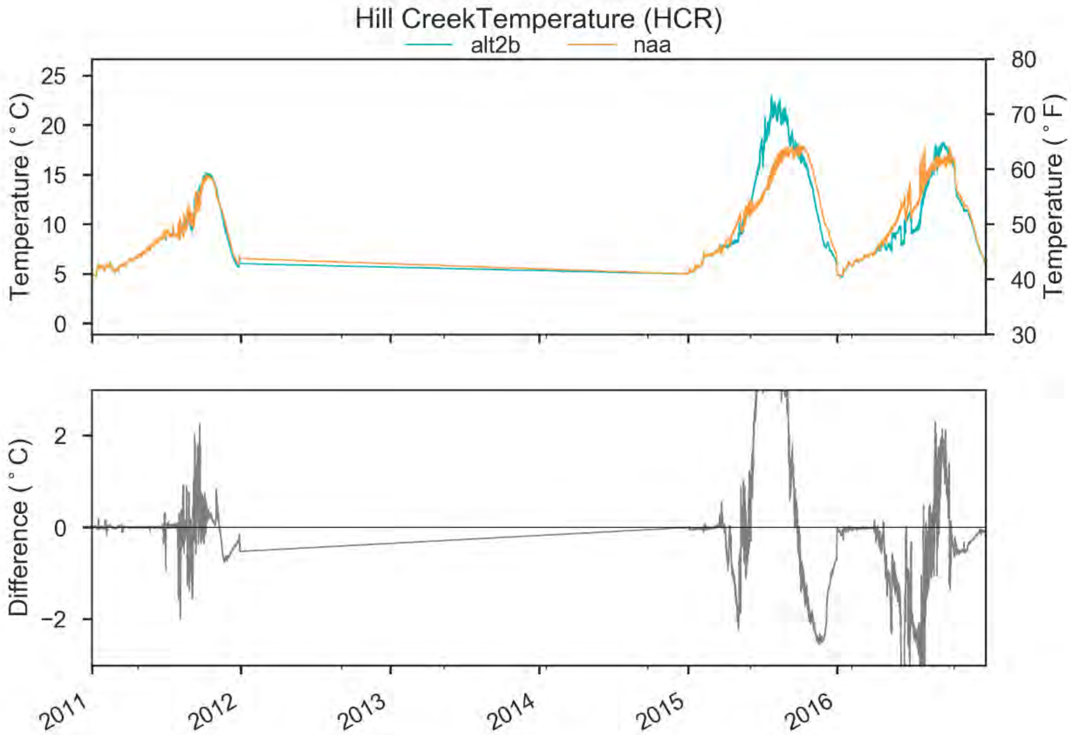

Figure 1-188. Comparison of HCR outflow temperatures in NAA and Alternative 2b.

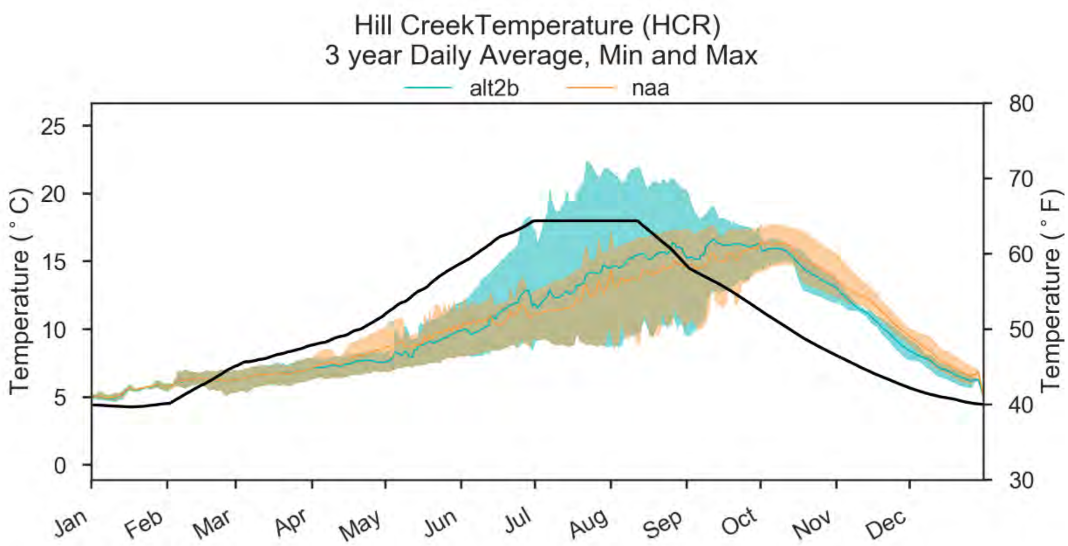

Figure 1-189. Comparison of HCR 3-year Daily Average, Min, Max Outflow Temperatures in NAA and Alternative 2b. Black Line Indicates Temperature Target.

1.5.4.4.2 Lookout Point

RES-SIM Lake Levels and Outflows

Lake level and storage at Lookout Point Lake was generally similar to NAA in 2011, 2015, and 2016 (Figure 1-190, Figure 1-191, and Figure 1-192) aside from minor differences in timing of refill and release rates that were associated with upstream Hills Creek Dam operations.

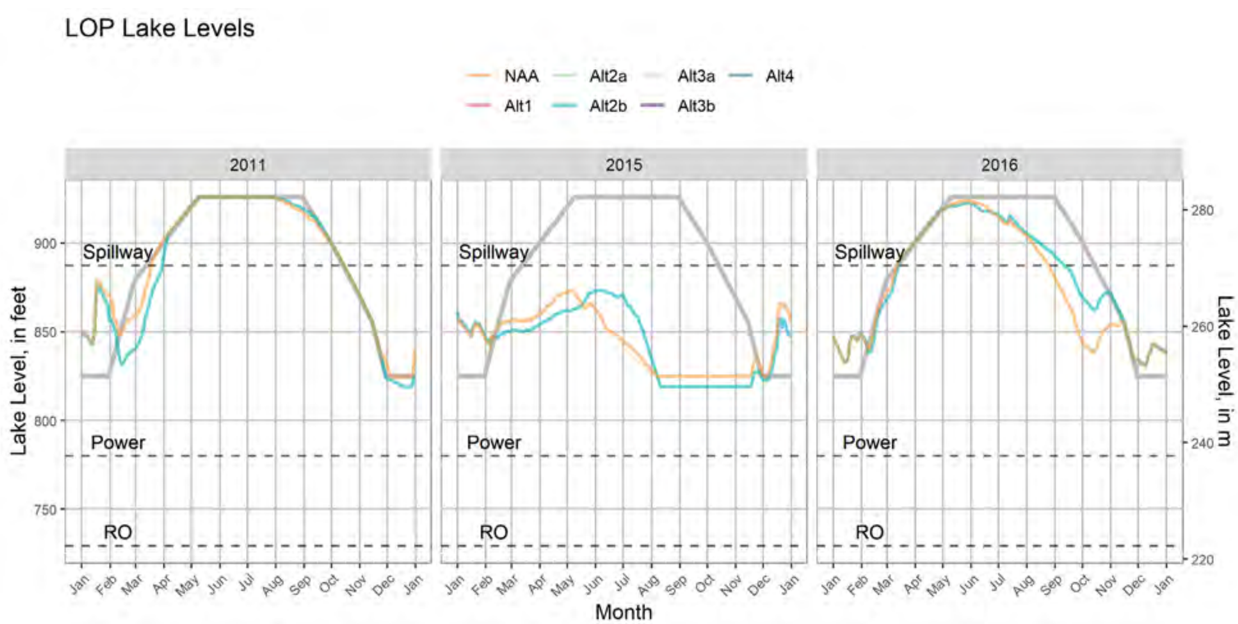

Figure 1-190. WV EIS RES-SIM Lookout Point Lake Levels in 2011, 2015, and 2016 Under Alternative 2b and NAA.

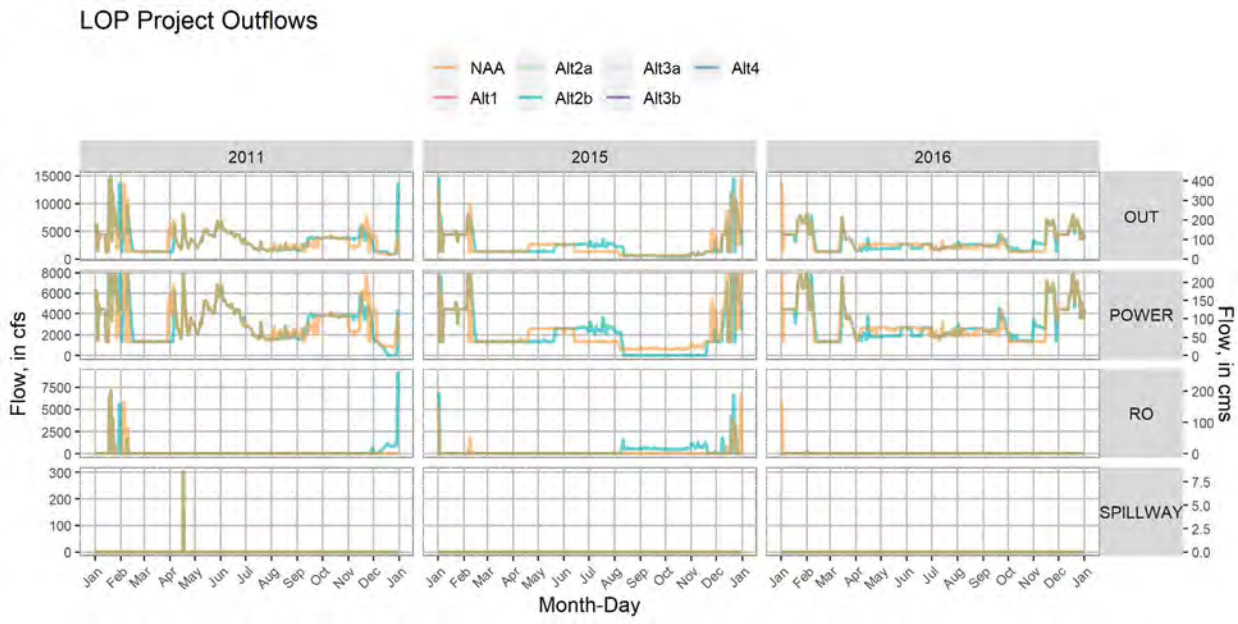

Figure 1-191. WV EIS RES-SIM Lookout Point Dam Gate-Specific Outflows in 2011, 2015, and 2016 under Alternative 2b and NAA.

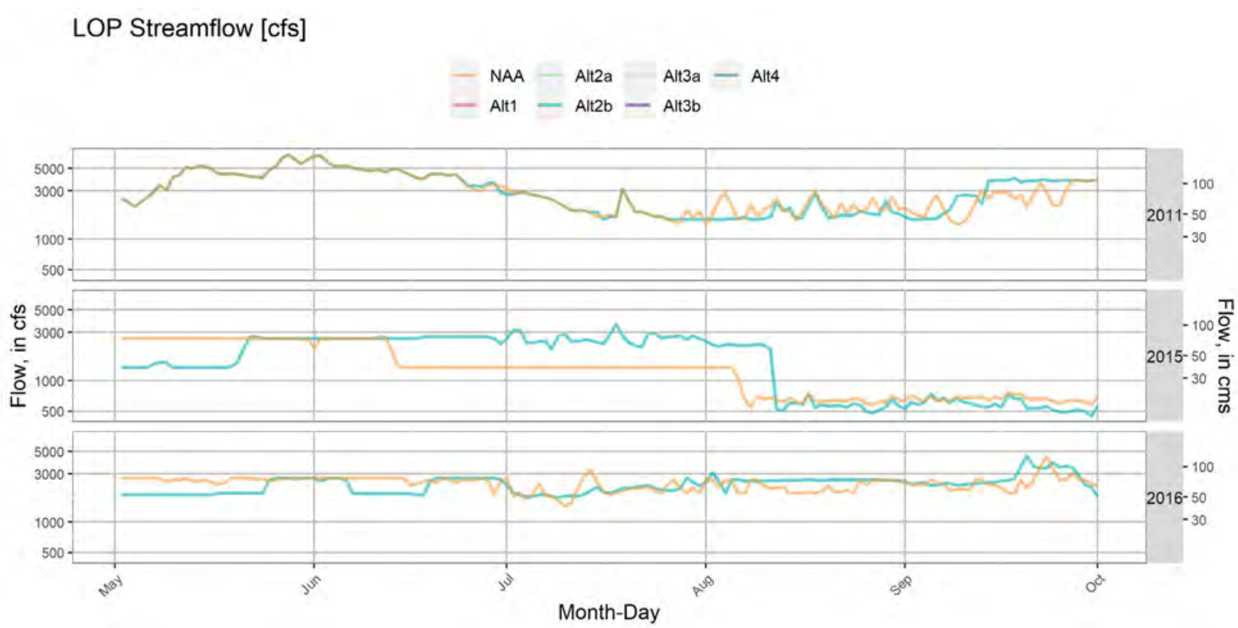

Figure 1-192. WV EIS RES-SIM Lookout Point Dam Total Outflow in 2011, 2015, and 2016 under Alternative 2b and NAA.

Lake Levels and Temperatures from CE-QUAL-W2

Depth-varying temperature, gate-specific outflows, and outflow temperatures through each calendar year scenario at Lookout Point Lake are shown in Figure 1-193, Figure 1-194, and Figure 1-195. The proposed FSC (and attraction pumps intended for fish collection) in Lookout Point Lake is currently assumed to have minimal effect on release temperature from the relatively deep Lookout Point Penstocks, but has potential to result in mixing thermal layering and de-stratification in the forebay of Lookout Point Lake. Simulating this effect on water temperature was beyond the scope of the WV EIS. Generally, temperatures downstream of LOP-DEX were similar to NAA, aside from short-term differences in late summer of 2015 likely related to upstream Hills Creek operations (Figure 1-196, Figure 1-197).

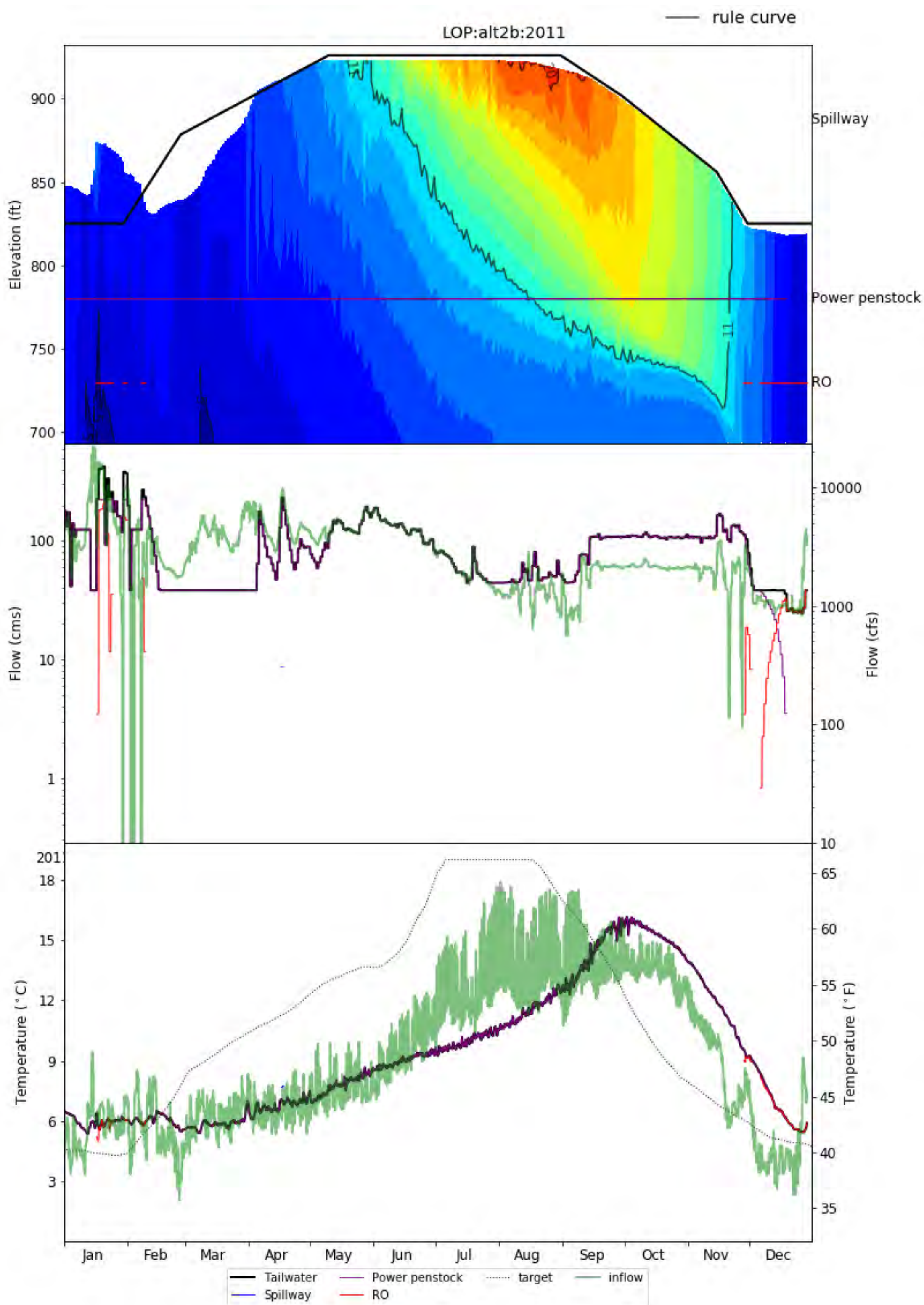

Figure 1-193. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at LOP under Alternative 2b in 2011.

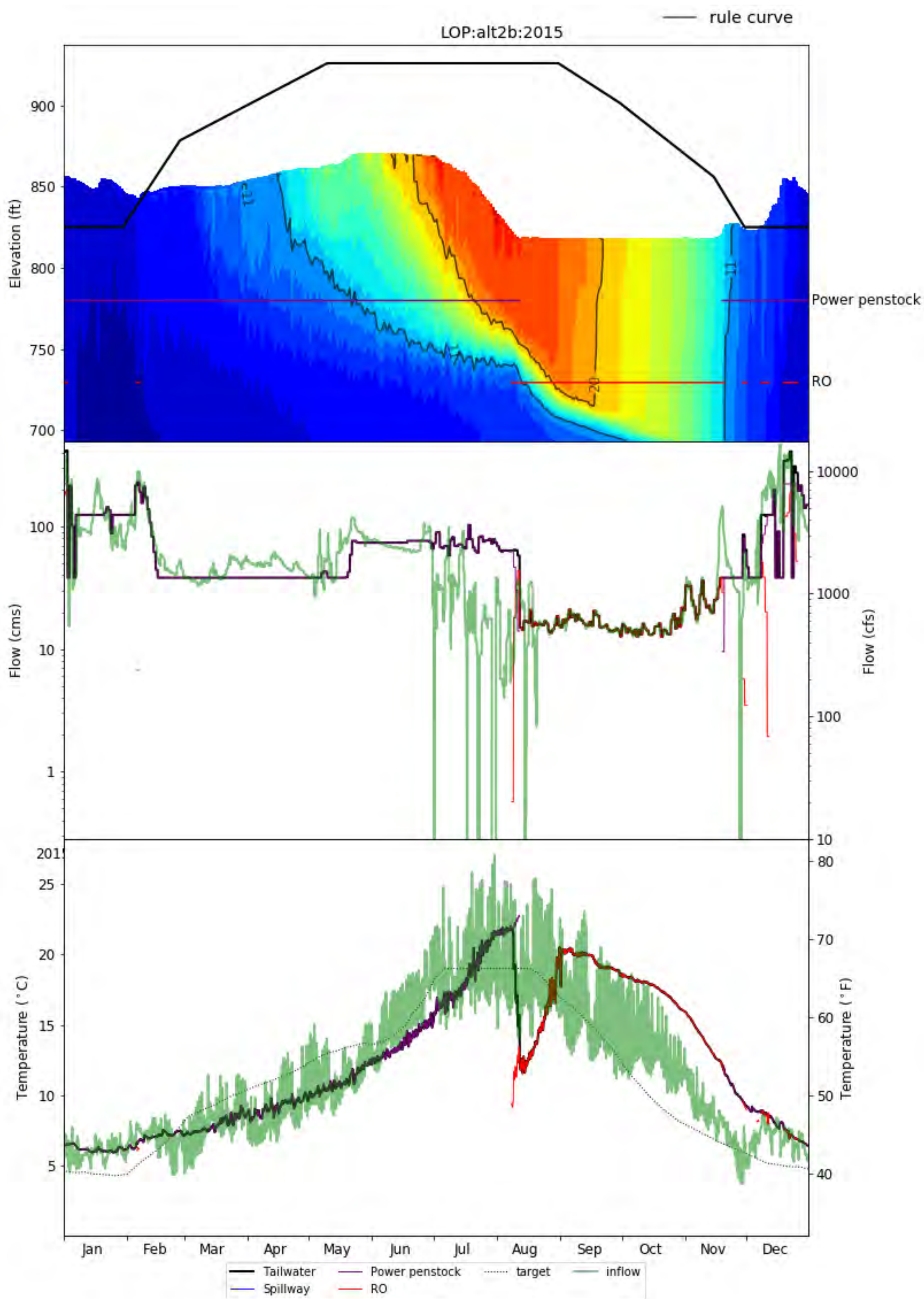

Figure 1-194. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at LOP under Alternative 2b in 2015.

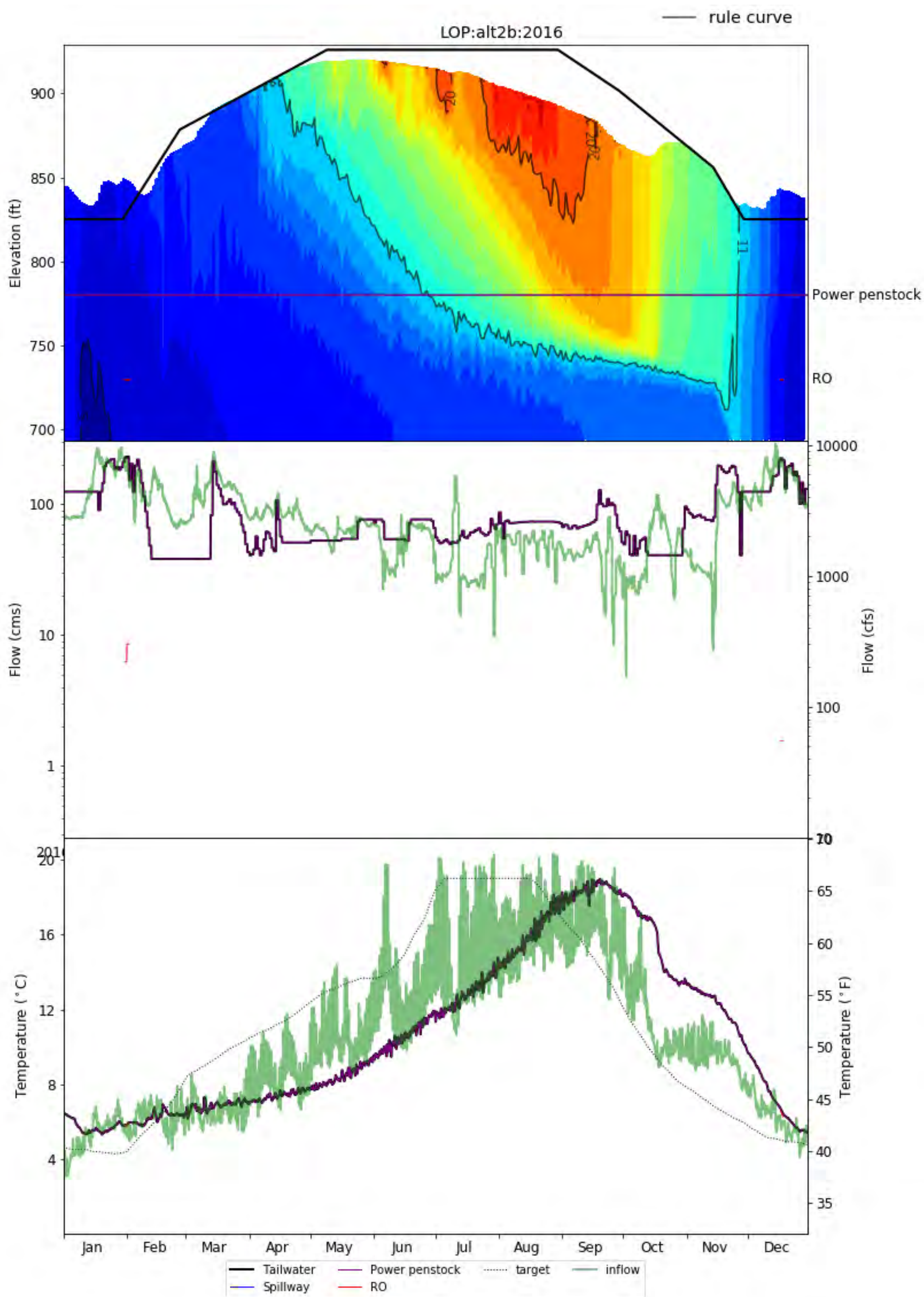

Figure 1-195. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at LOP under Alternative 2b in 2016.

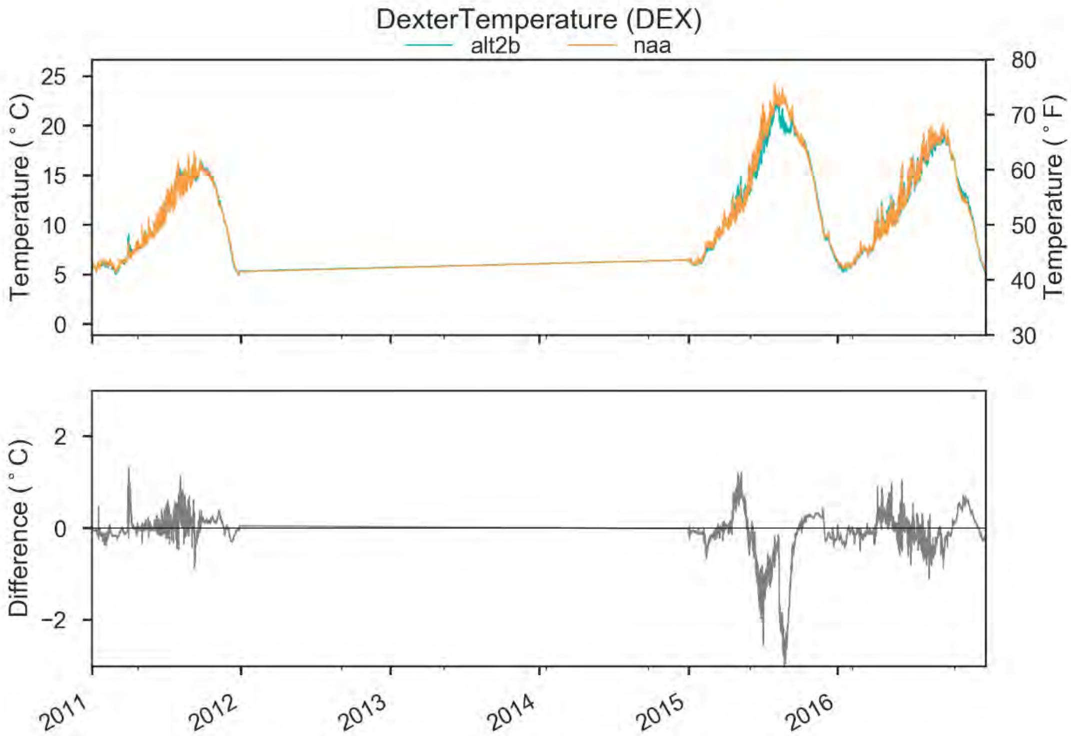

Figure 1-196. Comparison of DEX Outflow Temperatures in NAA and Alternative 2b.

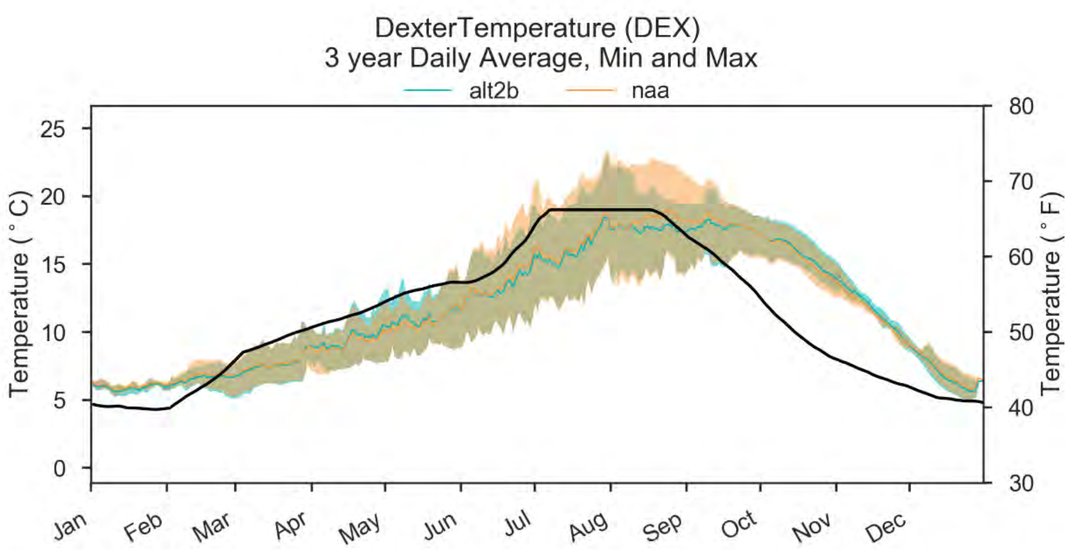

Figure 1-197. Comparison of DEX 3-year Daily Average, Min, Max Outflow Temperatures in NAA and Alternative 2b. Black Line Indicates Temperature Target.

1.5.4.5 Mainstem Willamette River

Streamflow under Alternative 2b was generally lower from April to mid-June and higher from mid-June to mid-September compared with NAA (Figure 1-198).

As explained in the Hydrologic and Hydraulic Processes section, under Measure 30b Res-Sim determines whether to use the max or minimum flow target in half-month increments based on whether a reservoir is above or below 90% of rule curve (Table 1-4) throughout the refill period. On June 1 of each year, Res-Sim determines whether to use the max or minimum flow target for the rest of the conservation season in each tributary under Measure 30b (Alternative 2b, 5). For the three years, 2011, 2015, and 2016, only 2015 was below 90% rule curve on June 1, which triggered the lower minimum flow target (Table 1-4). When comparing observed water surface elevations and Res-Sim, it is important to be aware that Res-Sim does not reduce flows as real-time operations staff and WATER team stakeholders are able to do (as seen in the observed data records).

Table 1-4. Percent Of Rule Curve Fill Level in Alternative 2b

Major Storage Reservoir	2011	2015	2016
Detroit	> 90% except Feb 16 - April 15	< 90% except Feb 16 - Feb 29	> 90% except May 16 - May 30
Green Peter	> 90% except Feb 16 - April 1	< 90% except Feb 16 - Feb 29	> 90% except May 16 - May 30
Cougar	< 90% all year	< 90% all year	< 90% all year
Lookout Point	> 90% except Feb 16 - April 1	< 90% except Feb 16 - Feb 29	> 90% except Feb 16 - Mar 16

However, these flow differences were primarily in 2015 and responsive to the Measure 30b dam outflow increases in advance of heat wave events (Figure 1-199). These flow changes resulted in warmer water temperatures April to mid-June and cooler water temperatures from mid-June to mid-September compared with NAA in 2015 (Figure 1-200, Figure 1-201).

Water temperatures at Salem were also affected by upstream dam operations and the proposed SWS-FSS structure at Detroit Dam, which likely contributed to warmer temperatures seen in 2011 and 2015 comparing Alternative 2b to NAA. Overall water temperature differences between Alternative 2b and NAA were less than 2 degrees Celsius.

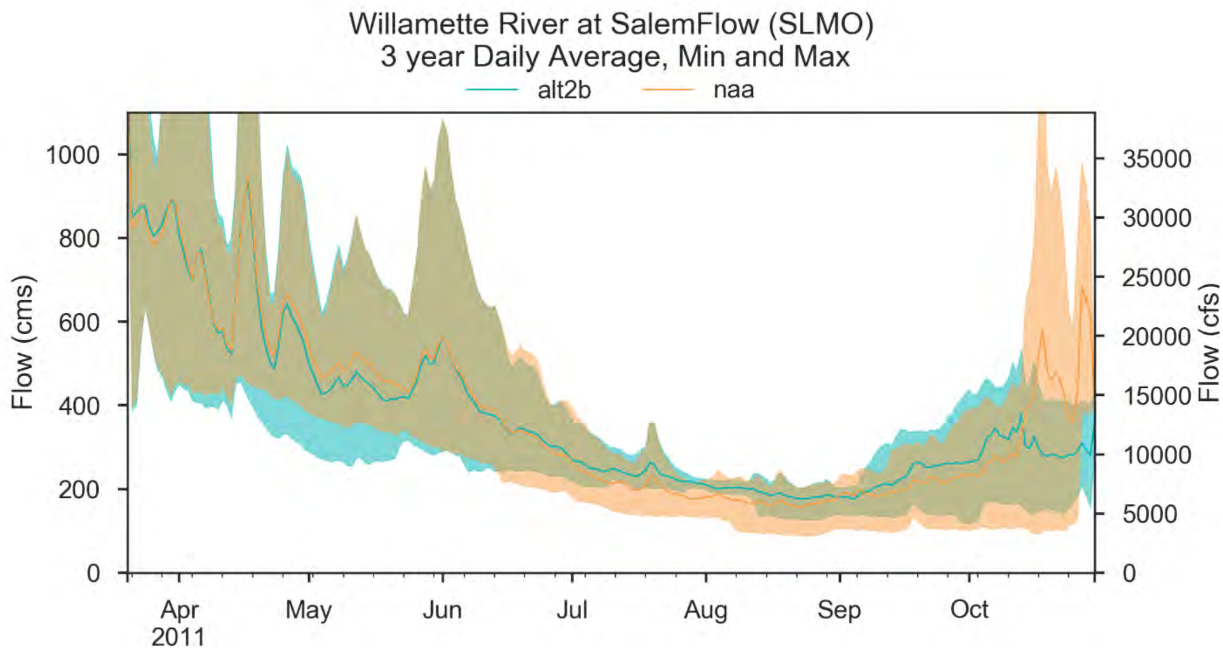

Figure 1-198. Streamflow Comparison of Daily Average, Min, and Max Willamette River at SLMO under NAA and Alternative 2b Conditions.

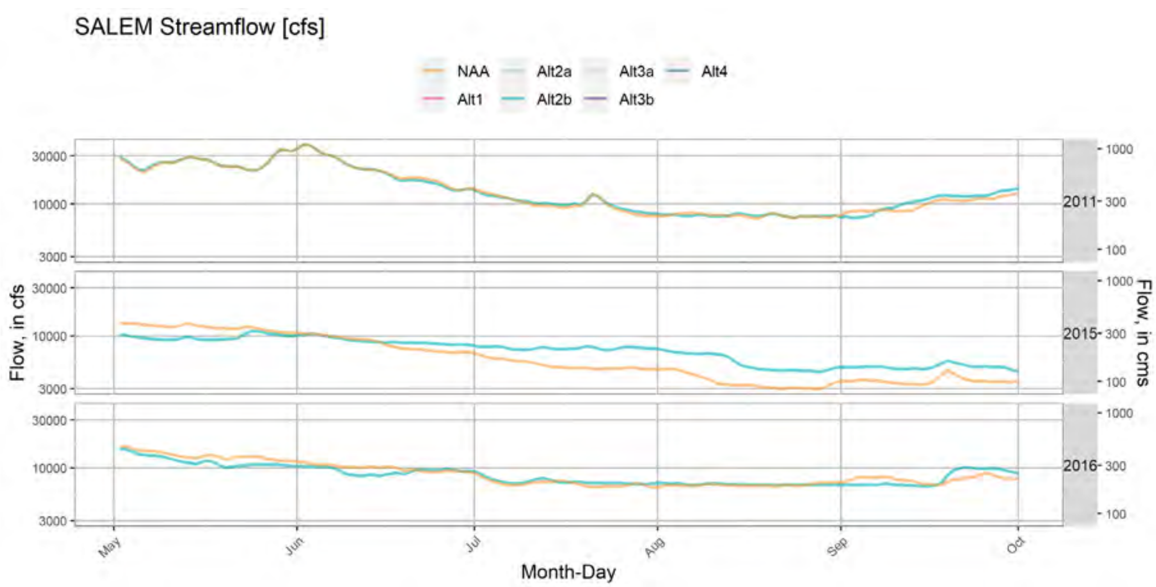

Figure 1-199. Streamflow Comparison Between Alternative 2b and NAA at Willamette River at SLMO.

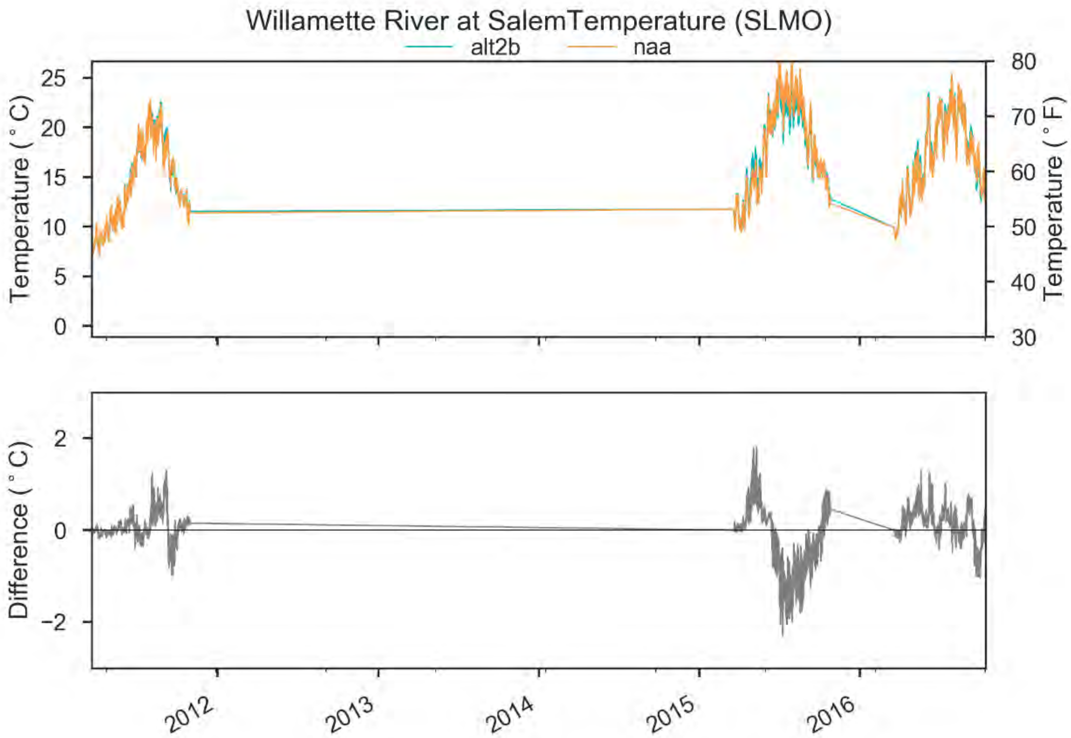

Figure 1-200. Comparison of Willamette River at SLMO Water Temperatures in NAA and Alternative 2b.

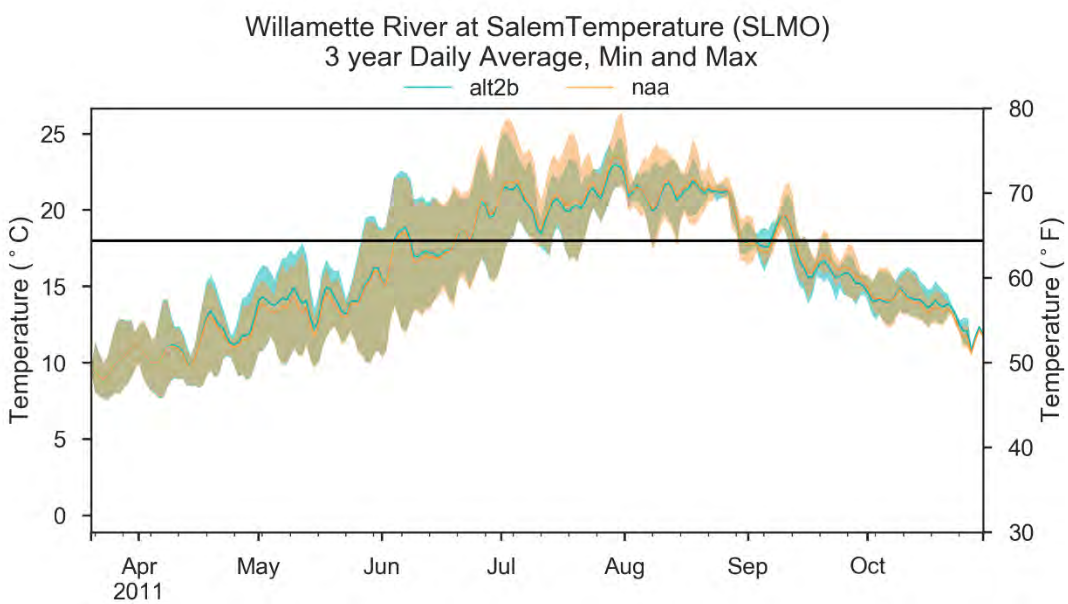

Figure 1-201. Comparison of Willamette River at SLMO 3-year Daily Average, Min, Max Outflow Temperatures in NAA and Alternative 2b.

1.5.5 Alternative 3a– Operations-Focused Fish Passage

Alternative 3a measures that affected operations, lake storage, and water temperature included:

- Changes to tributary targets below Foster, Detroit, Lookout Point, and Cougar that are higher than the NAA BiOp targets when those reservoirs are more than 90% full and less than the NAA BiOp when those reservoirs are less than 90% full.
- Changes to baseline mainstem targets at Salem and Albany while adding a Salem flow target tied to forecasted air temperature.
- Spring drawdown operations at Detroit, Lookout Point and Cougar (to the regulating outlet)
- Fall drawdown operations to lowest level possible given operational constraints at Blue River, Hills Creek, Green Peter, Detroit, Lookout Point and Cougar.

1.5.5.1 NORTH SANTIAM DAMS

1.5.5.1.1 Detroit

<u>RES-SIM Lake Levels and Outflows</u>

Lake level and storage at Detroit Lake decreased under Alternative 3a compared to NAA in 2011, 2015 and 2016 as the lake was drafted for the proposed fish passage operation through the UROs (Figure 1-202, Figure 1-203). The decreased storage coincided with reduced outflows during May-October (Figure 1-204).

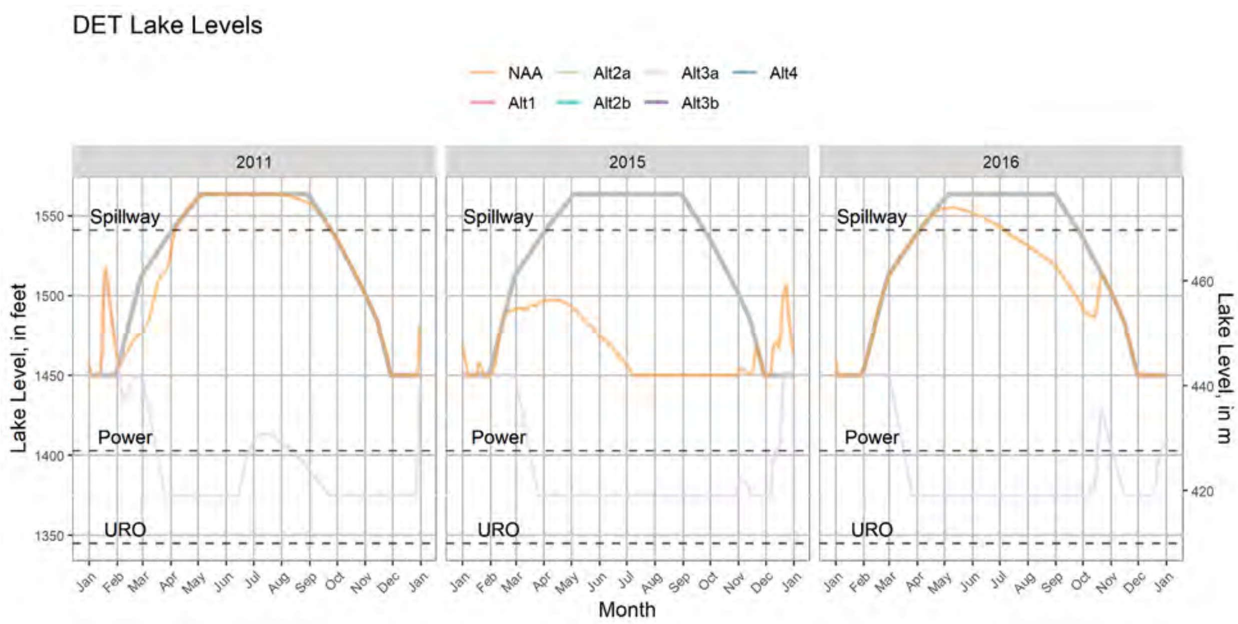

Figure 1-202. WV EIS RES-SIM Detroit Lake Levels in 2011, 2015, and 2016 Under Alternative 3a and NAA.

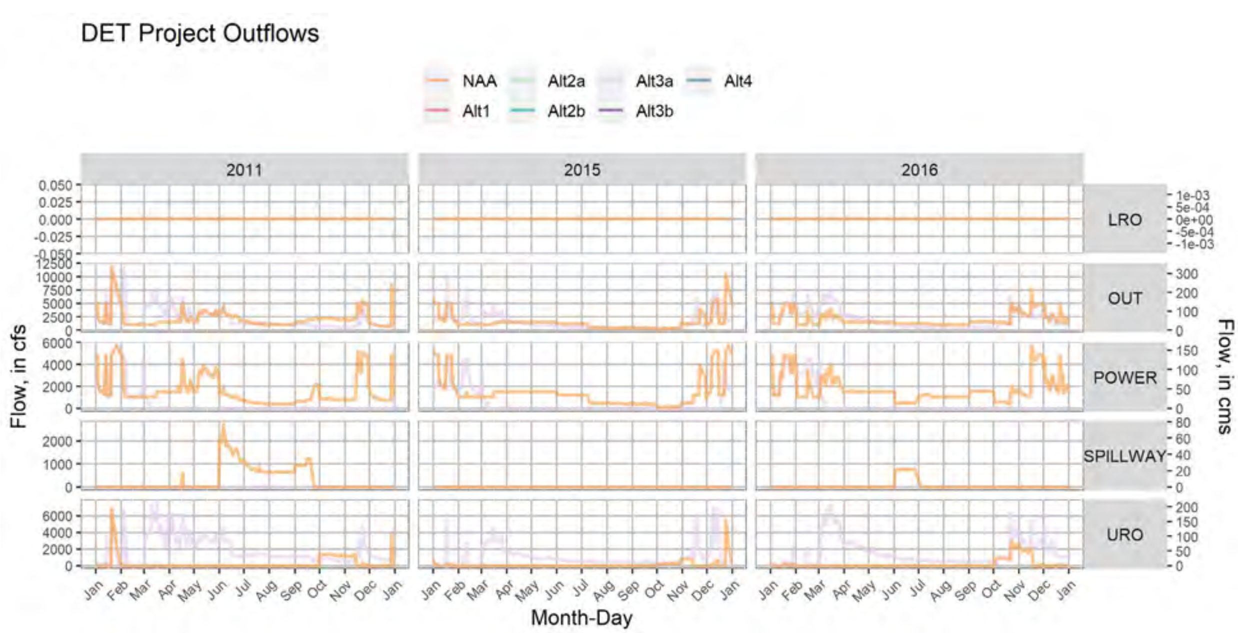

Figure 1-203. WV EIS RES-SIM Gate-Specific Outflows in 2011, 2015, and 2016 Under Alternative 3a and NAA.

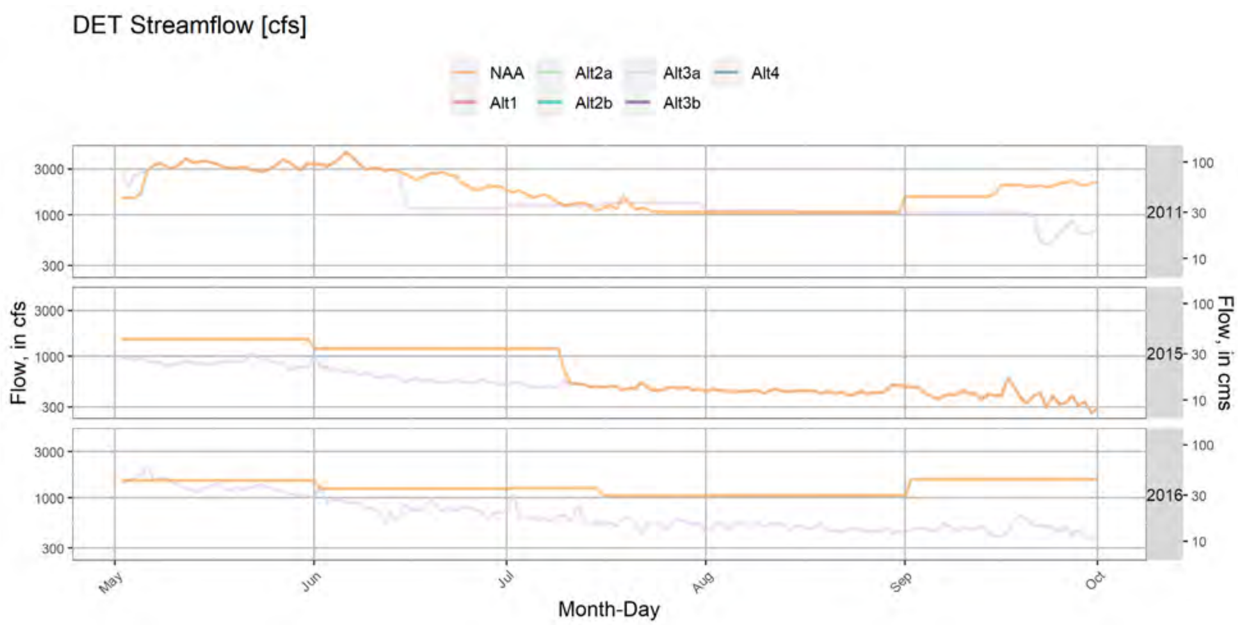

Figure 1-204. WV EIS RES-SIM Detroit Total Outflow in 2011, 2015, and 2016 under Alternative 3a and NAA.

Lake Levels and Temperatures from CE-QUAL-W2

Depth-varying temperature, gate-specific outflows, and outflow temperatures through each calendar year scenario at Detroit Lake are shown in Figure 1-205, Figure 1-206, and Figure 1-207. Outflow temperatures from Detroit Dam in Alternative 3a were generally warmer than NAA May-September and cooler than NAA October-December as the lake surface area, volume, and residence time were decreased and releases were generally made through the UROs for fish passage operations (Figure 1-208, Figure 1-209).

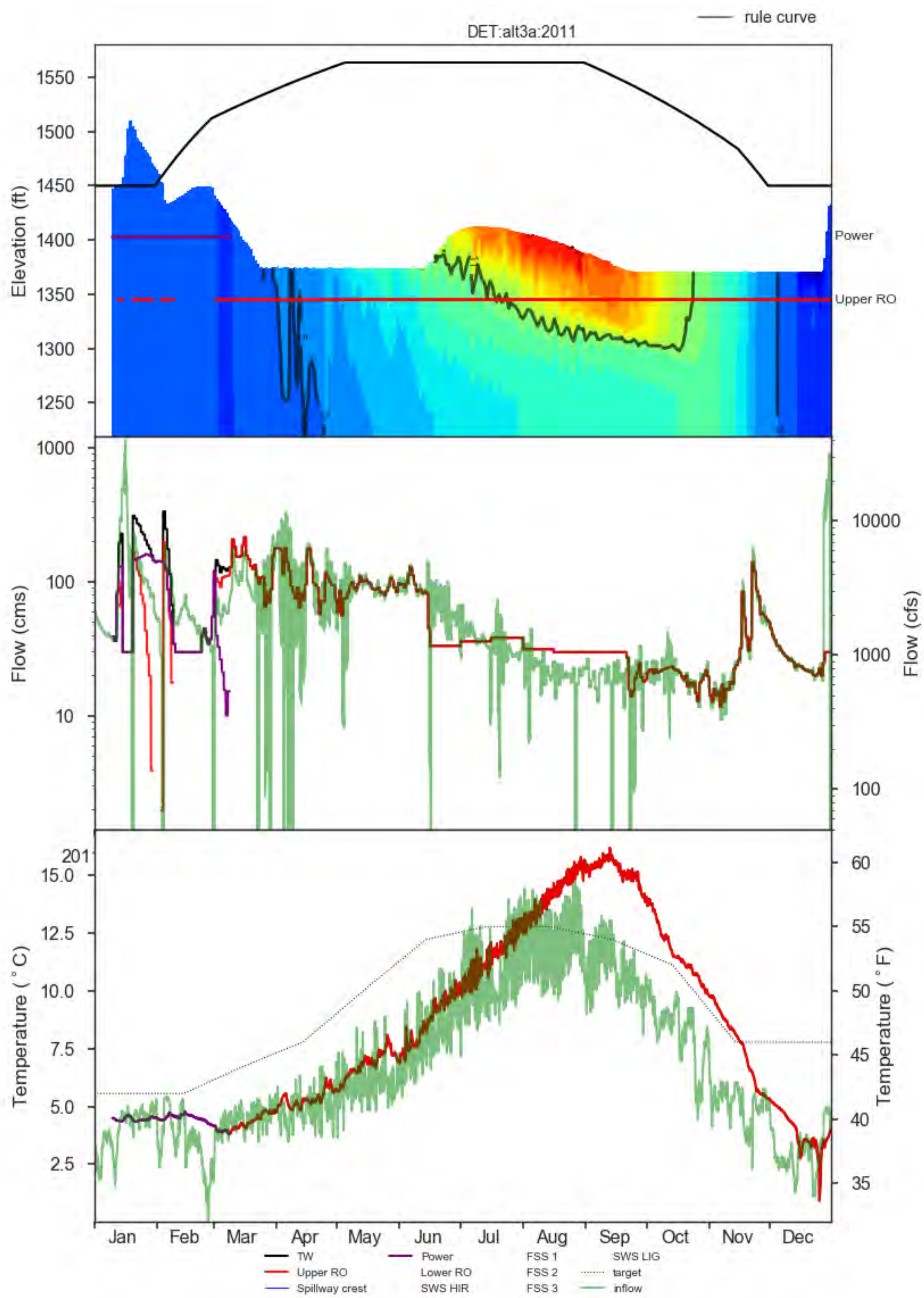

Figure 1-205. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at Detroit under Alternative 3a in 2011.

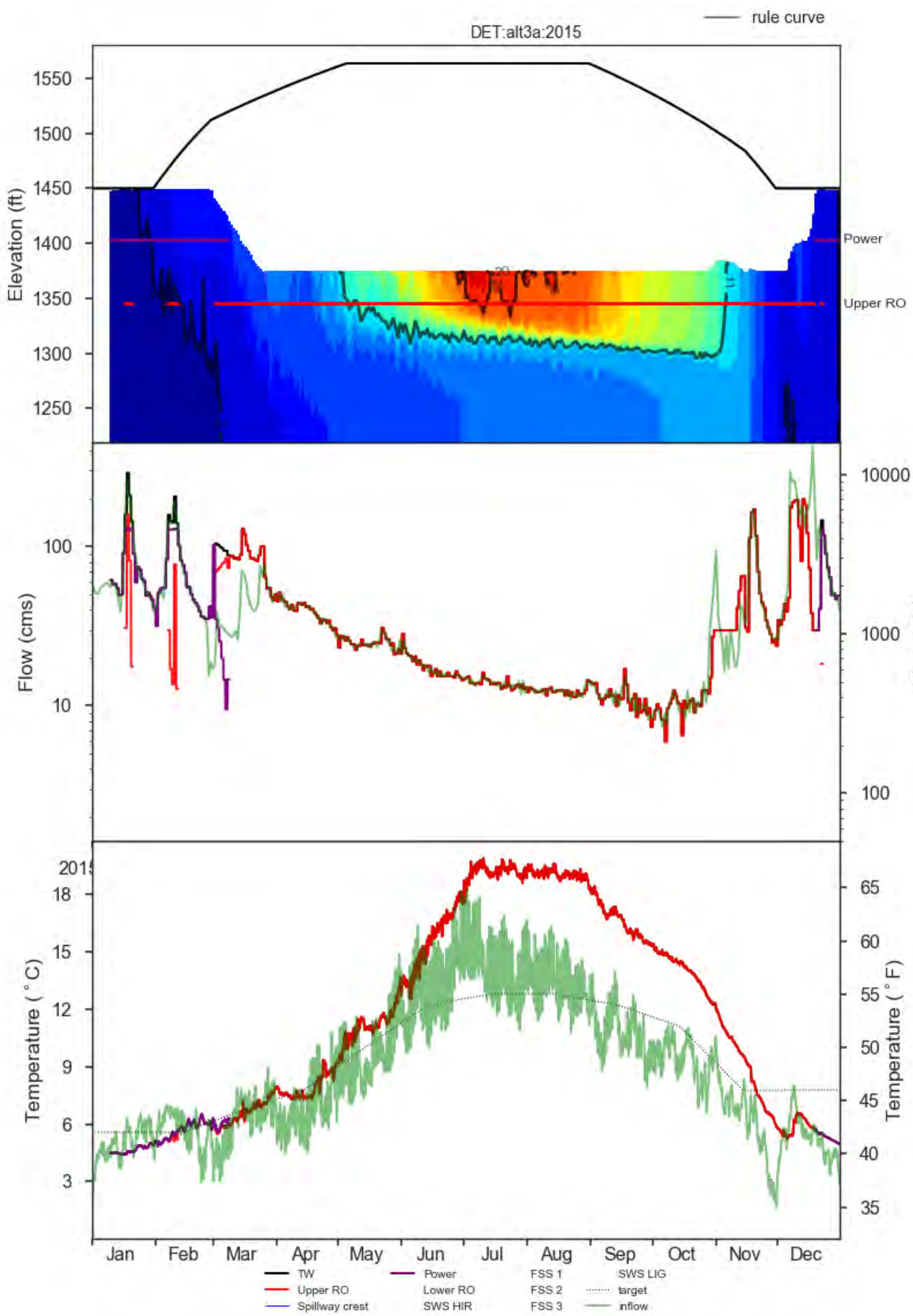

Figure 1-206. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at Detroit under Alternative 3a in 2015.

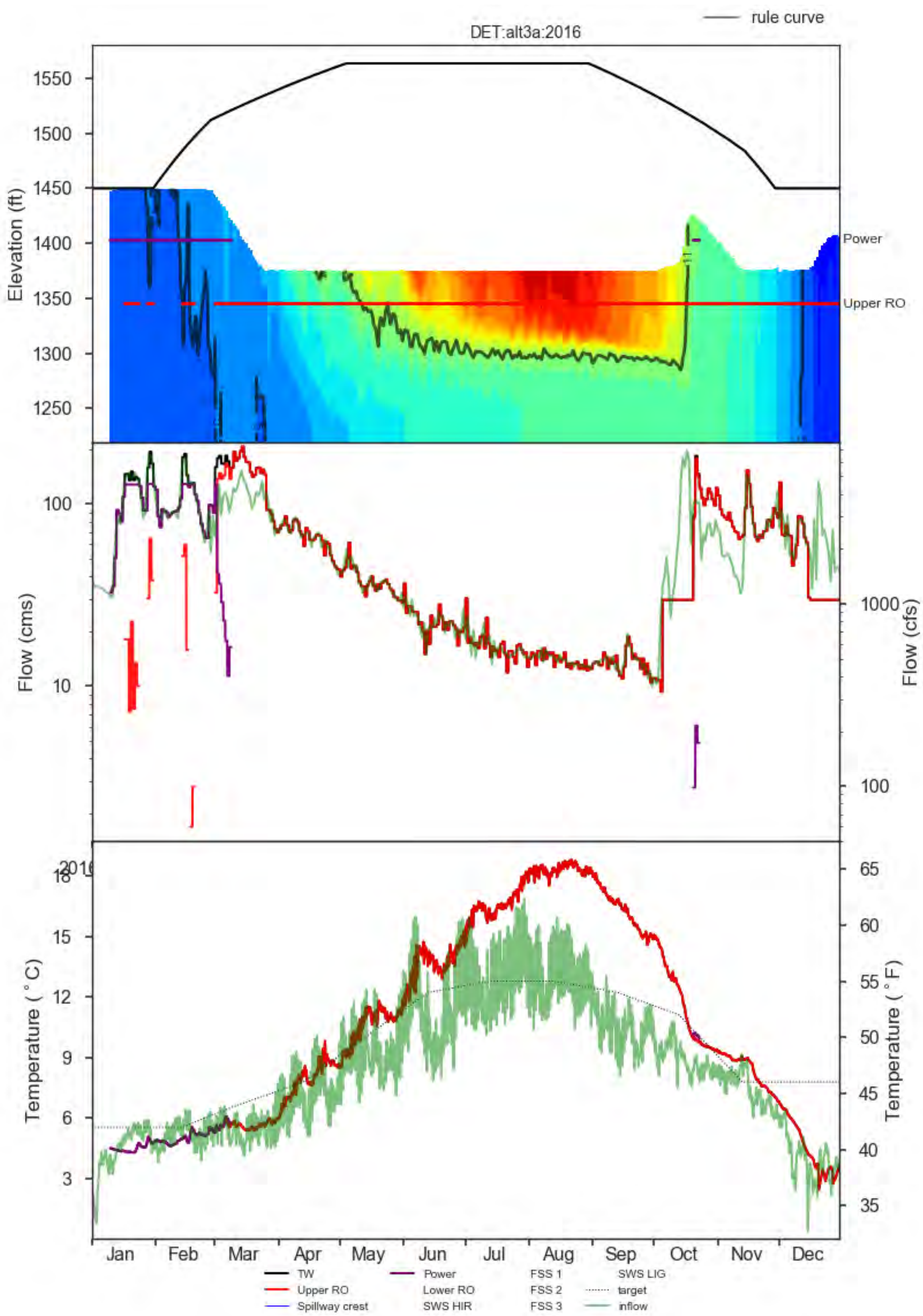

Figure 1-207. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at Detroit under Alternative 3a in 2016.

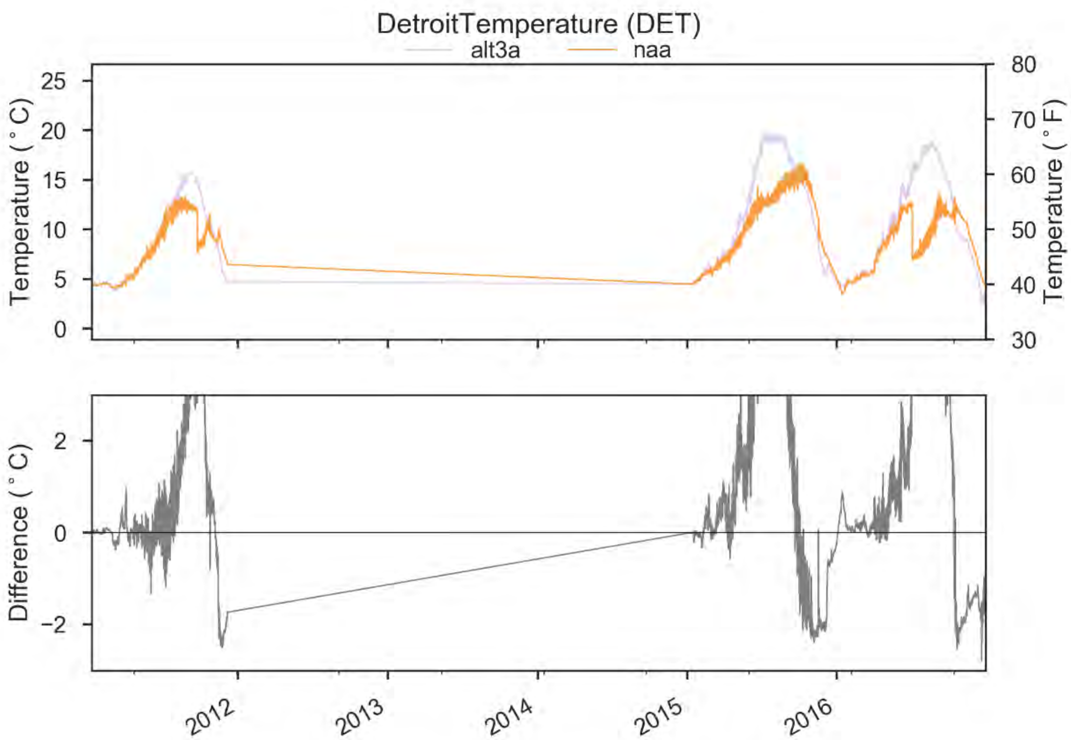

Figure 1-208. Comparison of DET Outflow Temperatures in NAA and Alternative 3a.

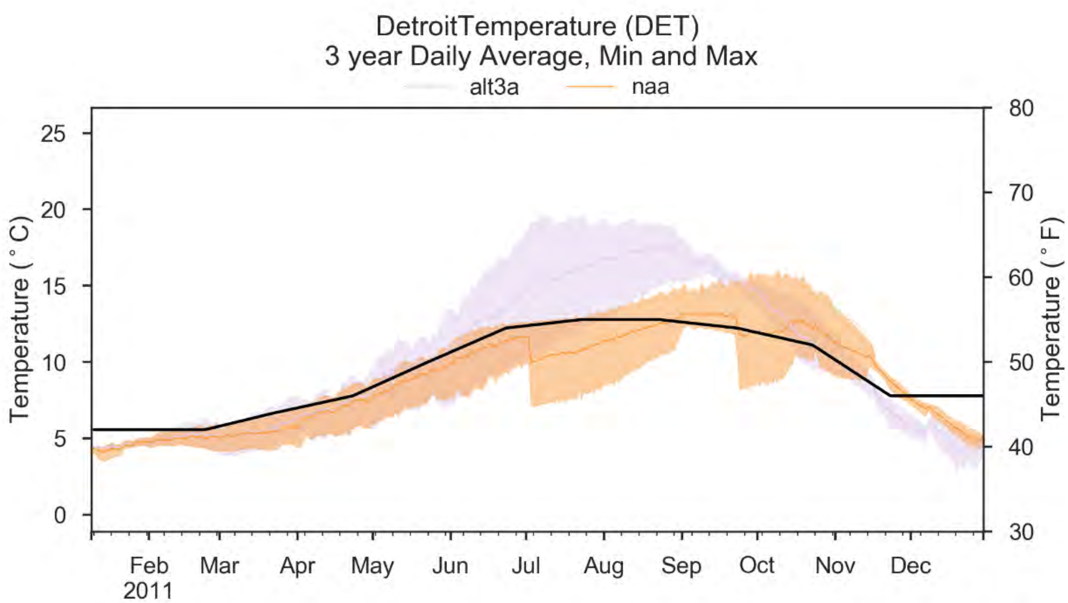

Figure 1-209. Comparison of DET 3-year Daily Average, Min, Max Outflow Temperatures in NAA and Alternative 3a. Black Line Indicates Temperature Target.

1.5.5.2 SOUTH SANTIAM DAMS

1.5.5.2.1 Green Peter

RES-SIM Lake Levels and Outflows

Lake level and storage at Green Peter were generally similar in Alternative 3a and NAA in 2011, 2015, and 2016 except for drawdown through the RO for fish passage during October-November (Figure 1-210, Figure 1-211, and Figure 1-212). Increased storage in July-October 2015 coincided with reduced outflows during spring and increased outflows. 2011 and 2016 operations were generally similar in Alternative 3a and NAA at Green Peter Lake January-June until increased outflows in July-October drafted the lake for fish passage operations through the ROs. The proposed operational temperature management through the spillway (during spring/summer) and RO (during autumn) in Alternative 2a led to increased outflow from these outlets and decreased power outflow compared to NAA (Figure 1-107).

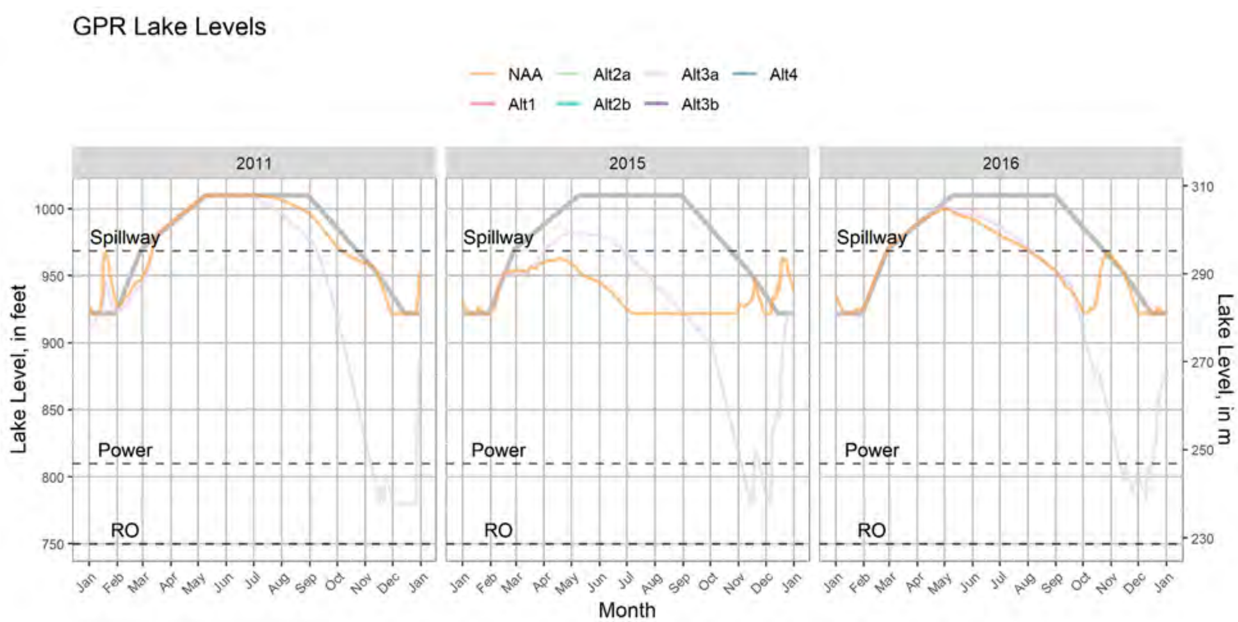

Figure 1-210. WV EIS RES-SIM Green Peter Lake Levels in 2011, 2015, and 2016 Under Alternative 3a and NAA.

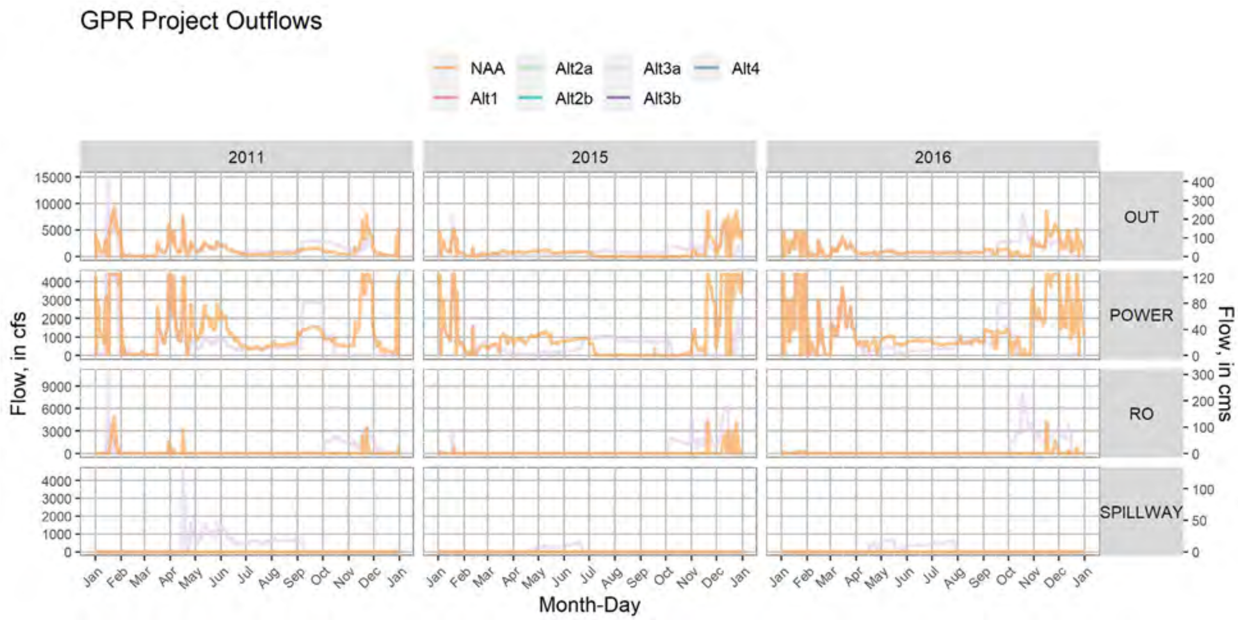

Figure 1-211. WV EIS RES-SIM Green Peter Dam Gate-Specific Outflows in 2011, 2015, and 2016 Under Alternative 3a and NAA.

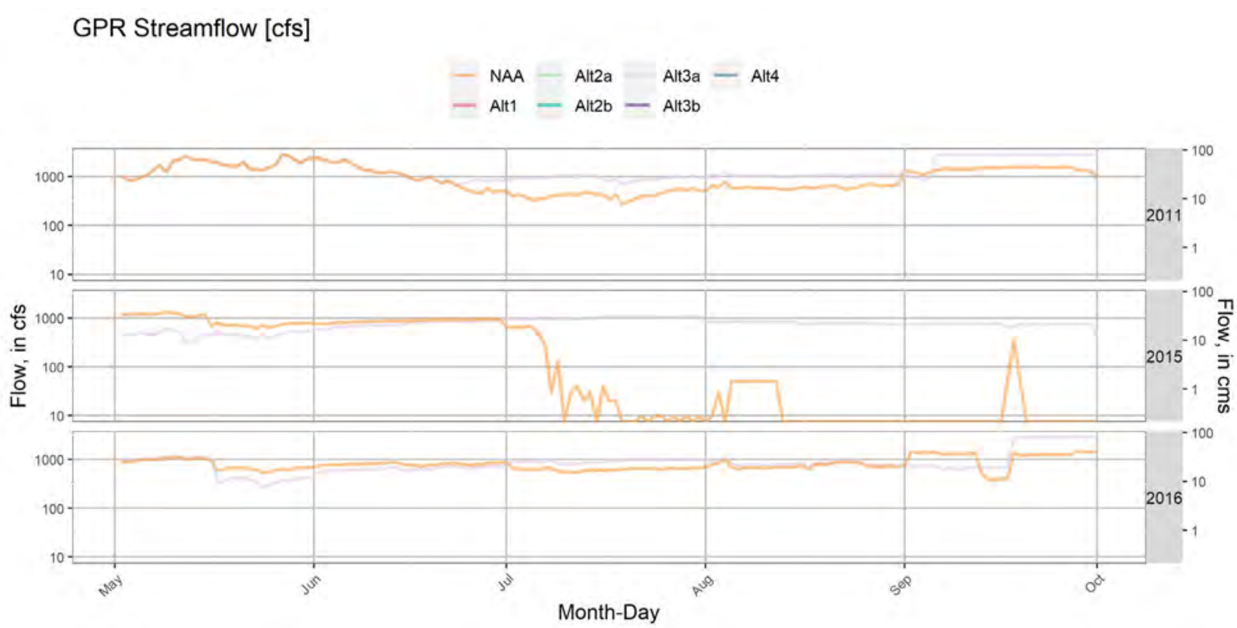

Figure 1-212. WV EIS RES-SIM Green Peter Dam Total Outflow in 2011, 2015, and 2016 Under Alternative 3a and NAA.

Lake Levels and Temperatures from CE-QUAL-W2

Depth-varying temperature, gate-specific outflows, and outflow temperatures through each calendar year scenario at Green Peter Lake are shown in Figure 1-213, Figure 1-214, and Figure 1-215. Alternative 3a includes releases through the spillway during spring-summer (when the lake was above the spillway crest) as well as releases through the Regulating Outlets during autumn to mixed with relatively deep power penstock releases to meet the downstream temperature target. Tailwater release temperatures generally matched the temperature target when sufficient warm or cool water was available and outlets were submerged. Spillway access was limited in some years (2015 especially), which led to an abrupt drop in tailwater temperature when spillway access ended in mid-summer of those years. This was followed by a large peak in tailwater temperature in the 2015 scenario during September-October as the lake was drafted at a relatively high outflow rate, effectively mixing the thermal layers near the dam (Figure 1-216, Figure 1-217). Generally, the autumn fish passage operation (drawdown to the RO) resulted in cooler autumn temperatures (November-December) compared to NAA (Figure 1-217).

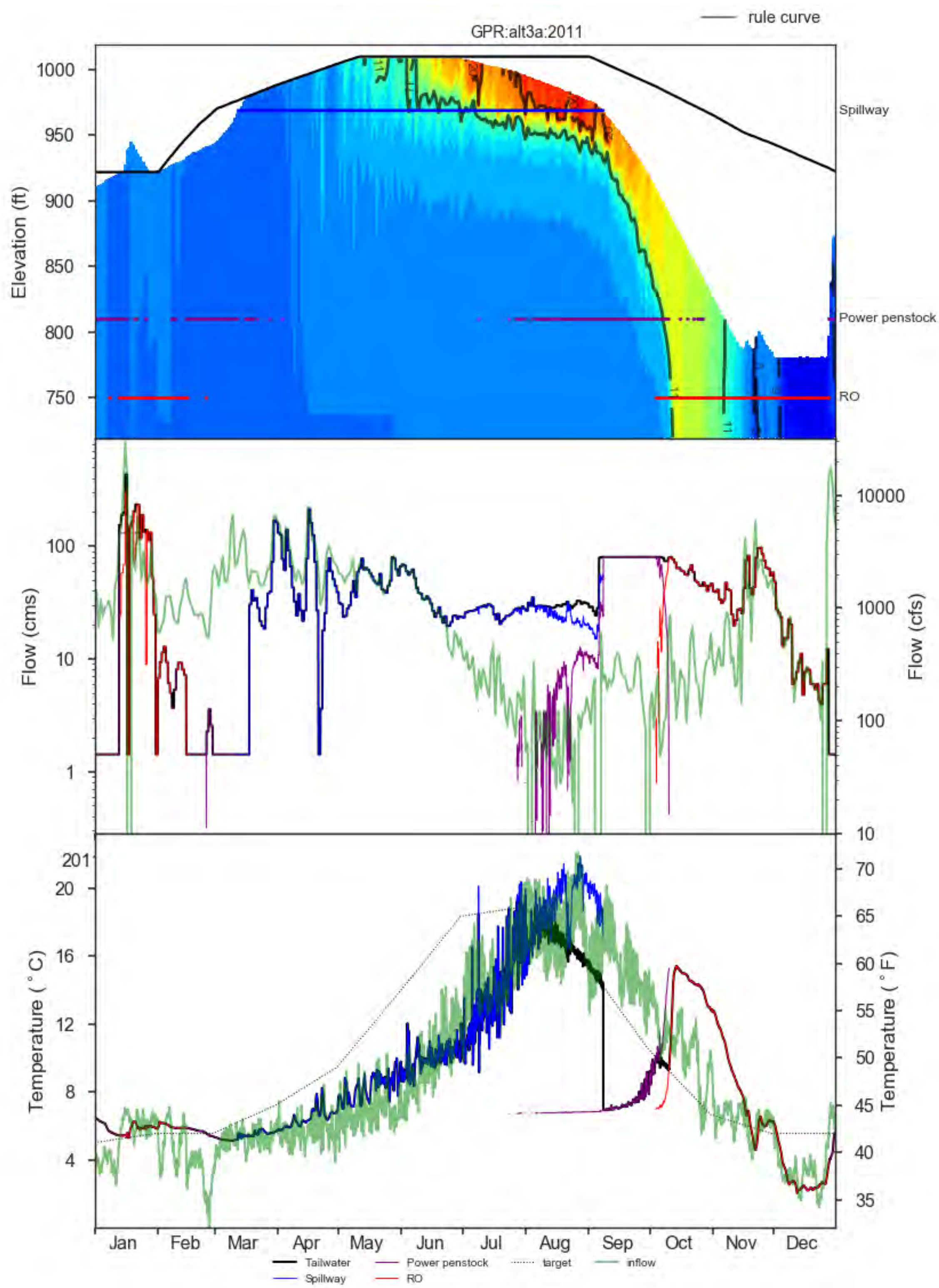

Figure 1-213. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at GPR under Alternative 3a in 2011.

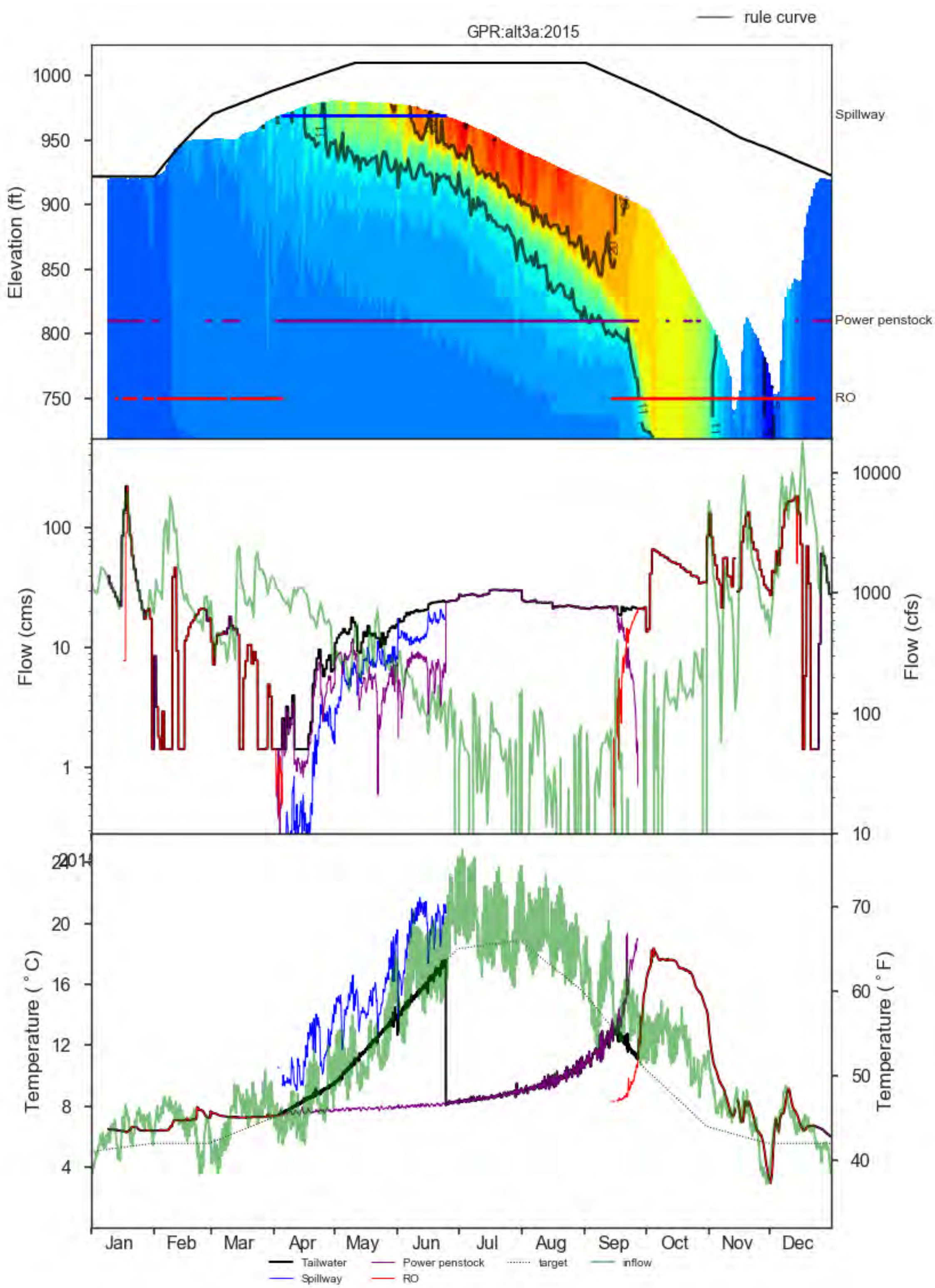

Figure 1-214. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at GPR under Alternative 3a in 2015.

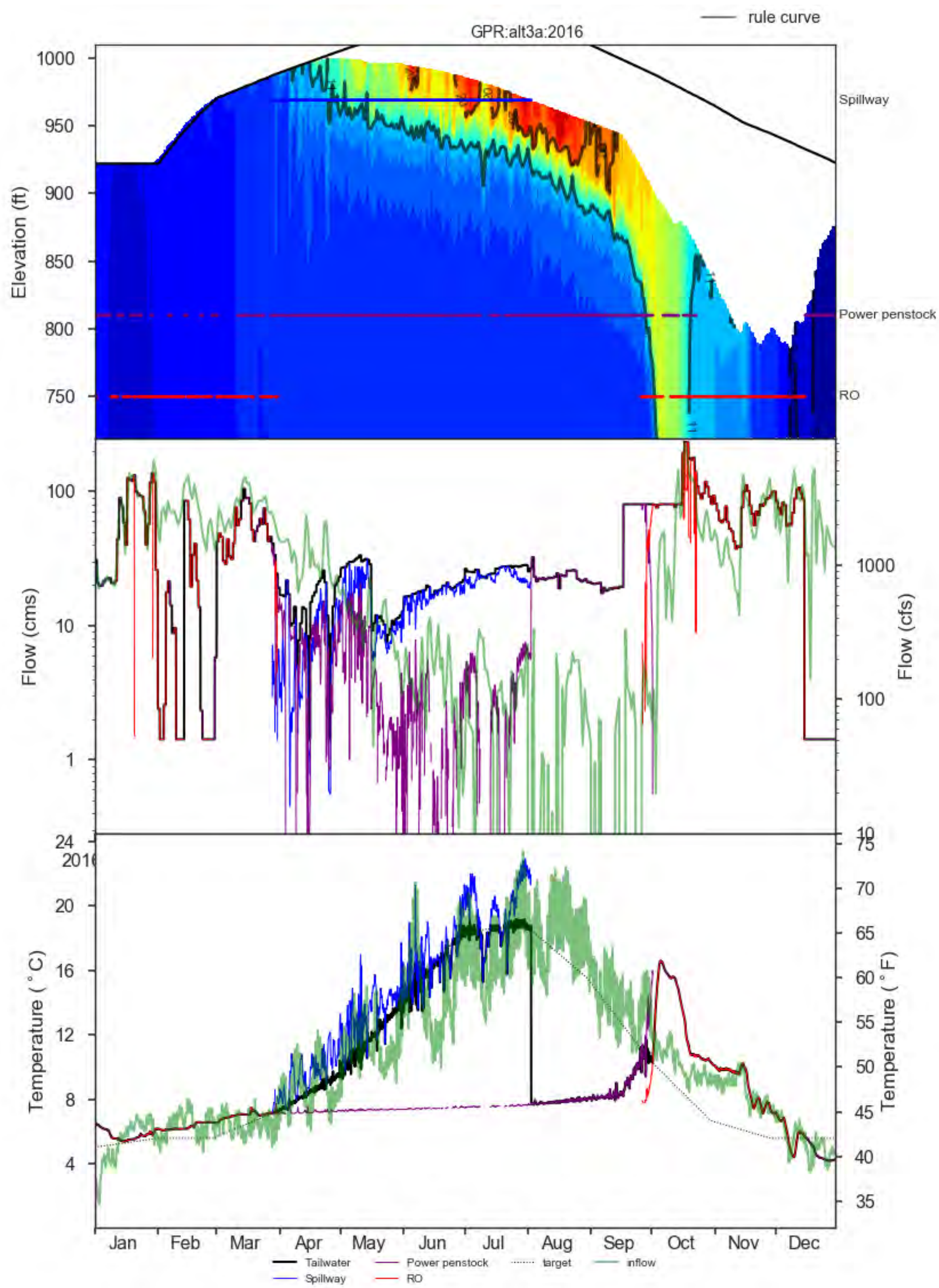

Figure 1-215. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at GPR under Alternative 3a in 2016.

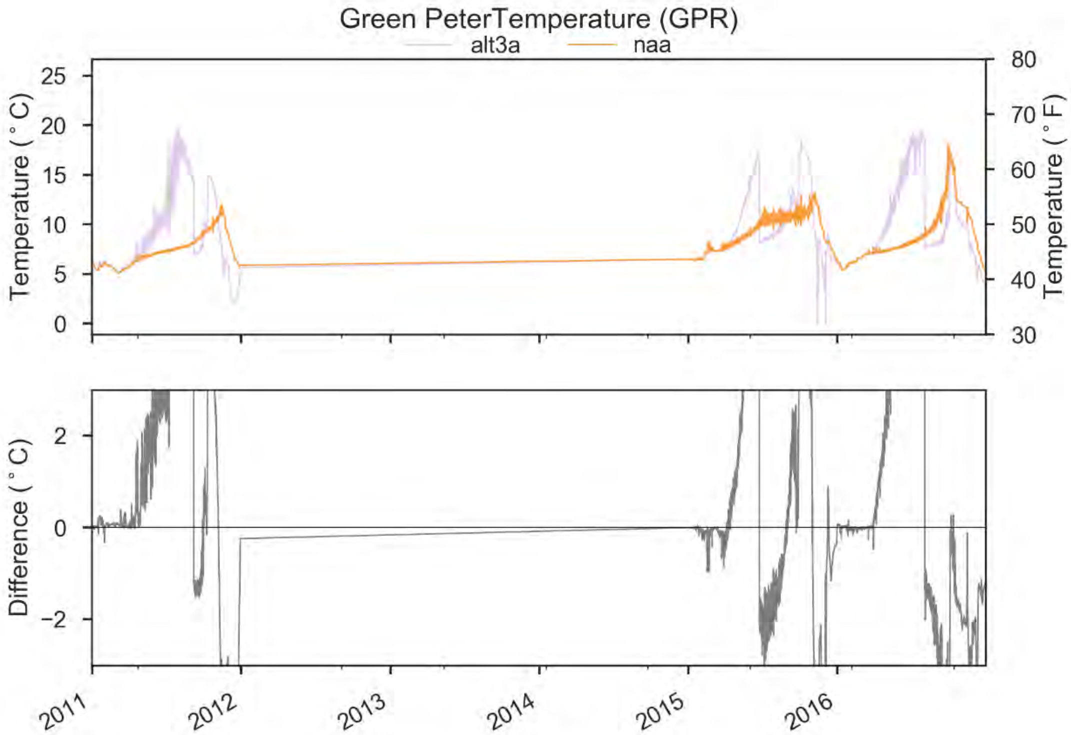

Figure 1-216. Comparison of GPR Outflow Temperatures in NAA and Alternative 3a.

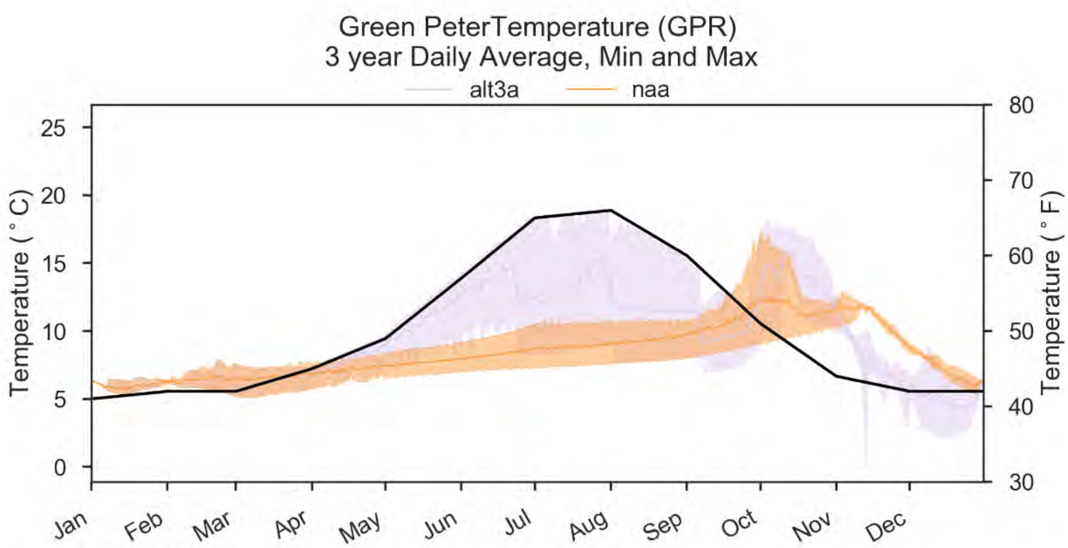

Figure 1-217. Comparison of GPR 3-year Daily Average, Min, Max Outflow Temperatures in NAA and Alternative 3a. Black Line Indicates Temperature Target.

1.5.5.2.2 Foster

RES-SIM Lake Levels and Outflows

Lake level and storage at Foster were generally similar in Alternative 3a compared to NAA in 2011 and 2016 but increased in 2015 in Alternative 3a compared to NAA (Figure 1-218, Figure 1-219, and Figure 1-220). Total outflow from Foster Dam increased July-September in 2015 due to upstream GPR operations, coinciding with greater storage at FOS in Alternative 3a compared to NAA during that time.

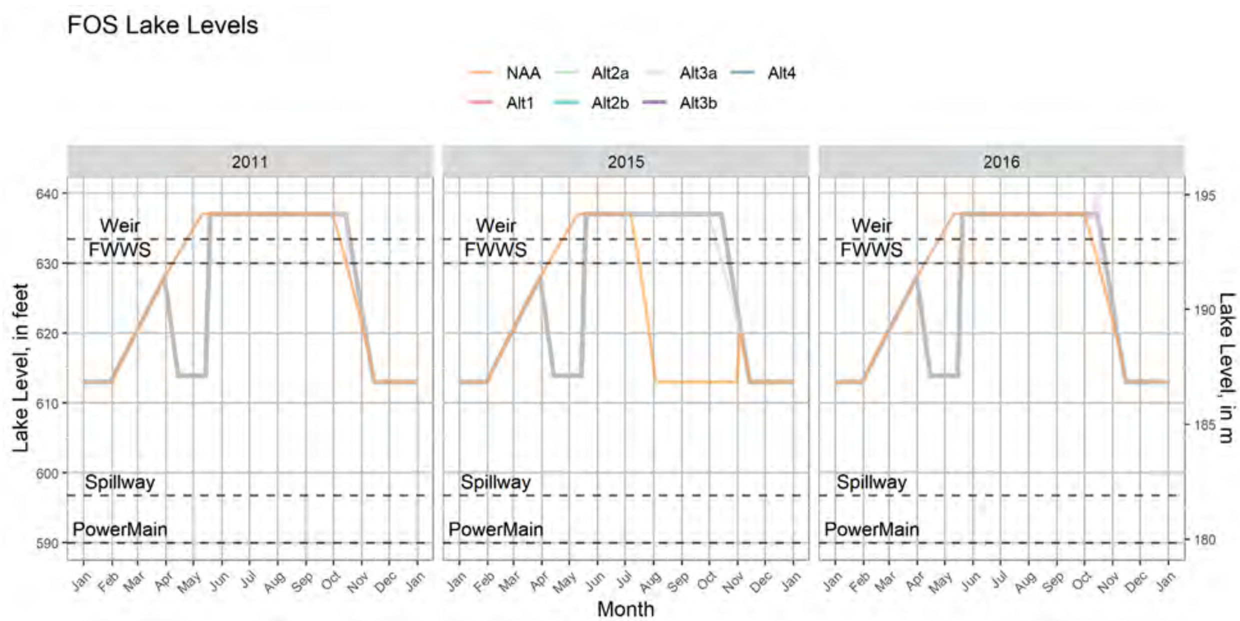

Figure 1-218. WV EIS RES-SIM Foster Lake Levels in 2011, 2015, and 2016 Under Alternative 3a and NAA.

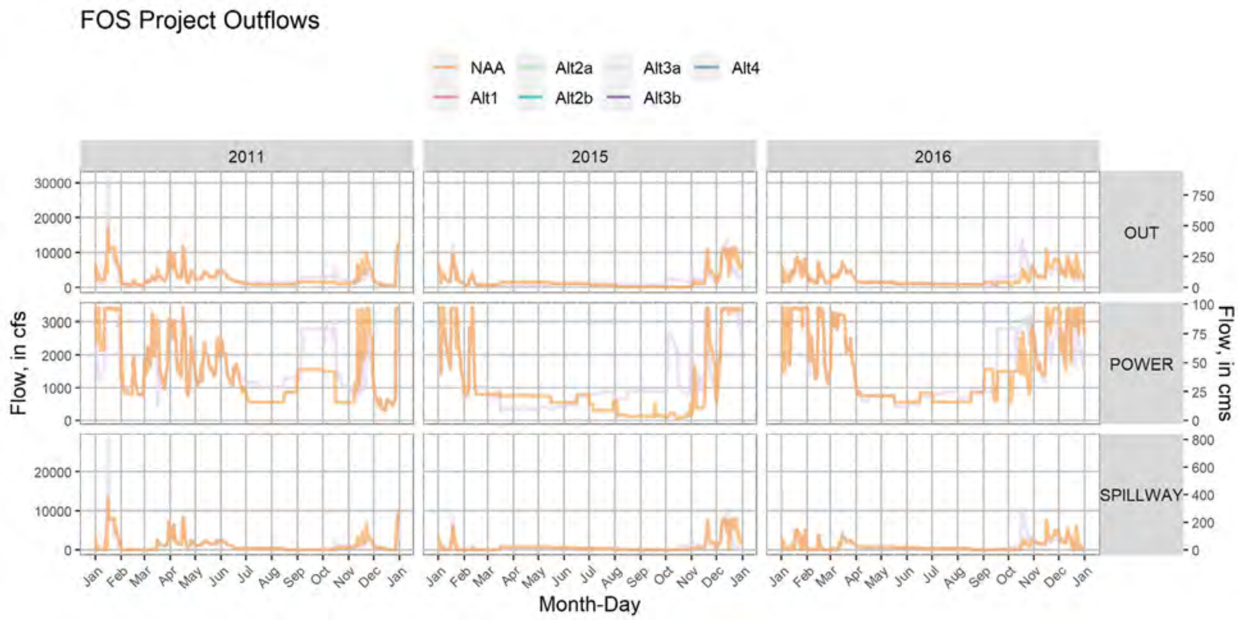

Figure 1-219. WV EIS RES-SIM Foster Dam Gate-Specific Outflows in 2011, 2015, and 2016 under Alternative 3a and NAA.

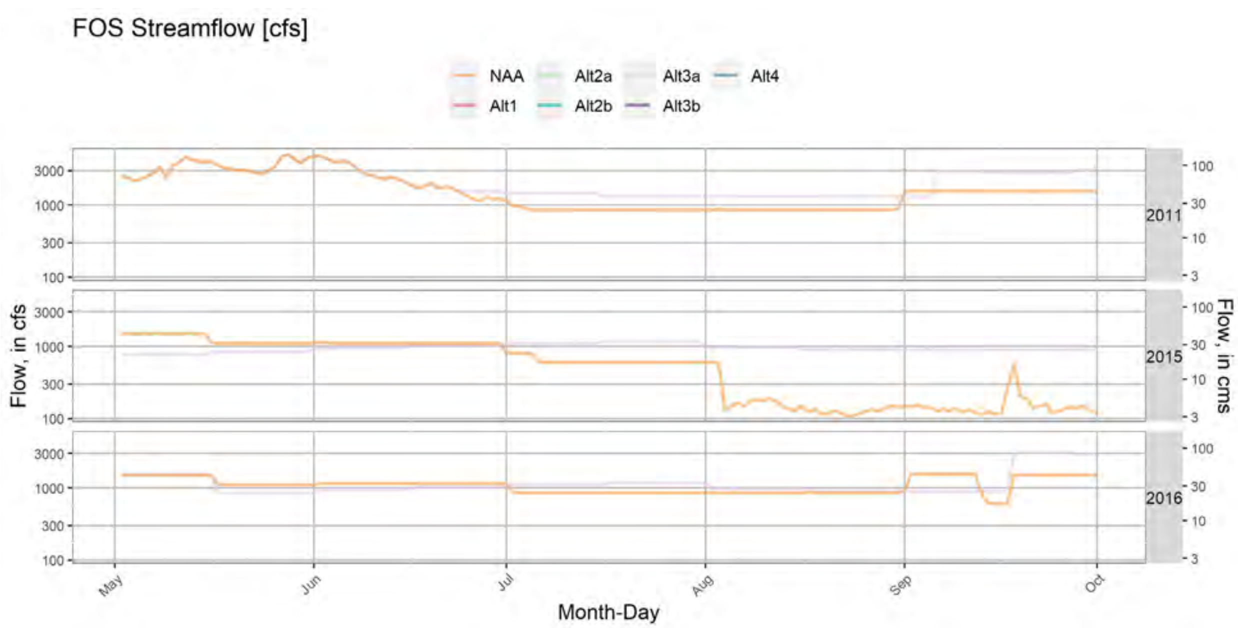

Figure 1-220. WV EIS RES-SIM Foster Dam Total Outflow in 2011, 2015, and 2016 under Alternative 3a and NAA.

Lake Levels and Temperatures from CE-QUAL-W2

Depth-varying temperature, gate-specific outflows, and outflow temperatures through each calendar year scenario at Foster Lake are shown in Figure 1-221, Figure 1-222, and Figure 1-223. Foster Lake temperature was affected by Green Peter Dam release temperatures, generally resulting in travel times through Foster of 10-20 days during summer and a time lag in the temperature pattern (Sullivan and Rounds, 2021). Relatively warmer spillway releases from Green Peter upstream resulted in warmer tailwater temperature in spring and summer compared to NAA (Figure 1-224, Figure 1-225). Generally, the autumn fish passage operation (drawdown to the RO at Green Peter) resulted in cooler autumn temperatures (November-December) compared to NAA downstream of Foster Dam.

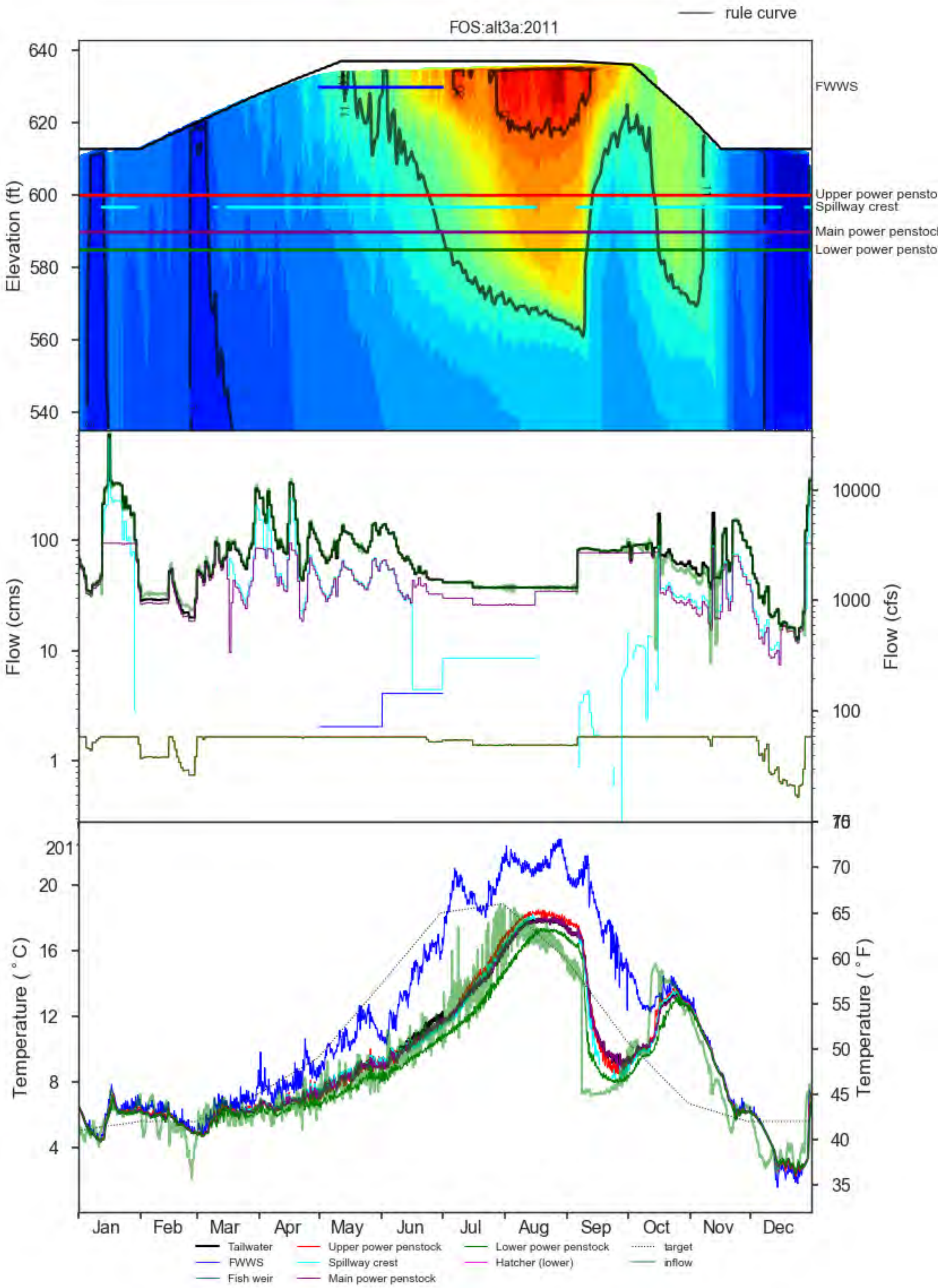

Figure 1-221. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at FOS under Alternative 3a in 2011.

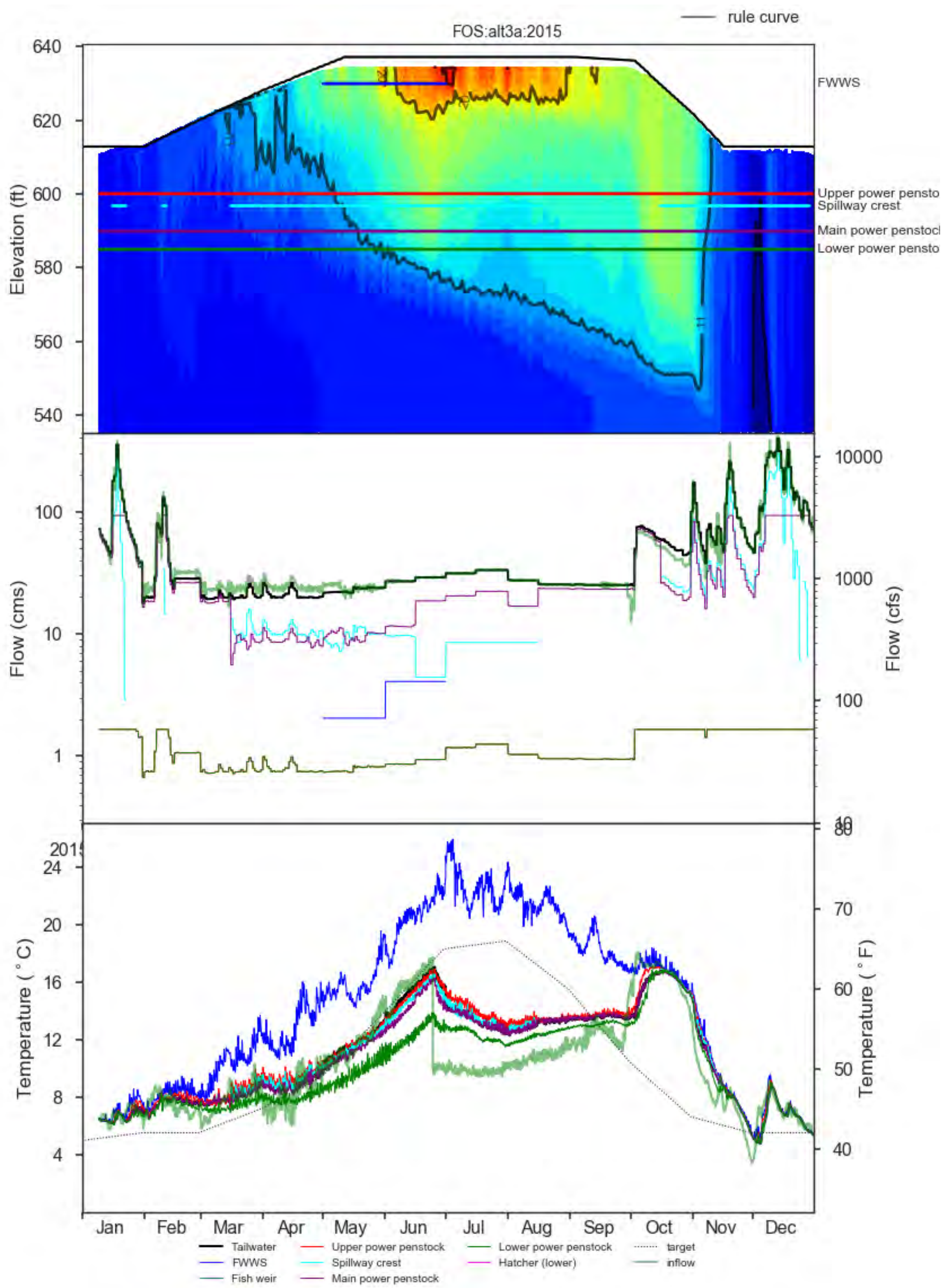

Figure 1-222. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at FOS under Alternative 3a in 2015.

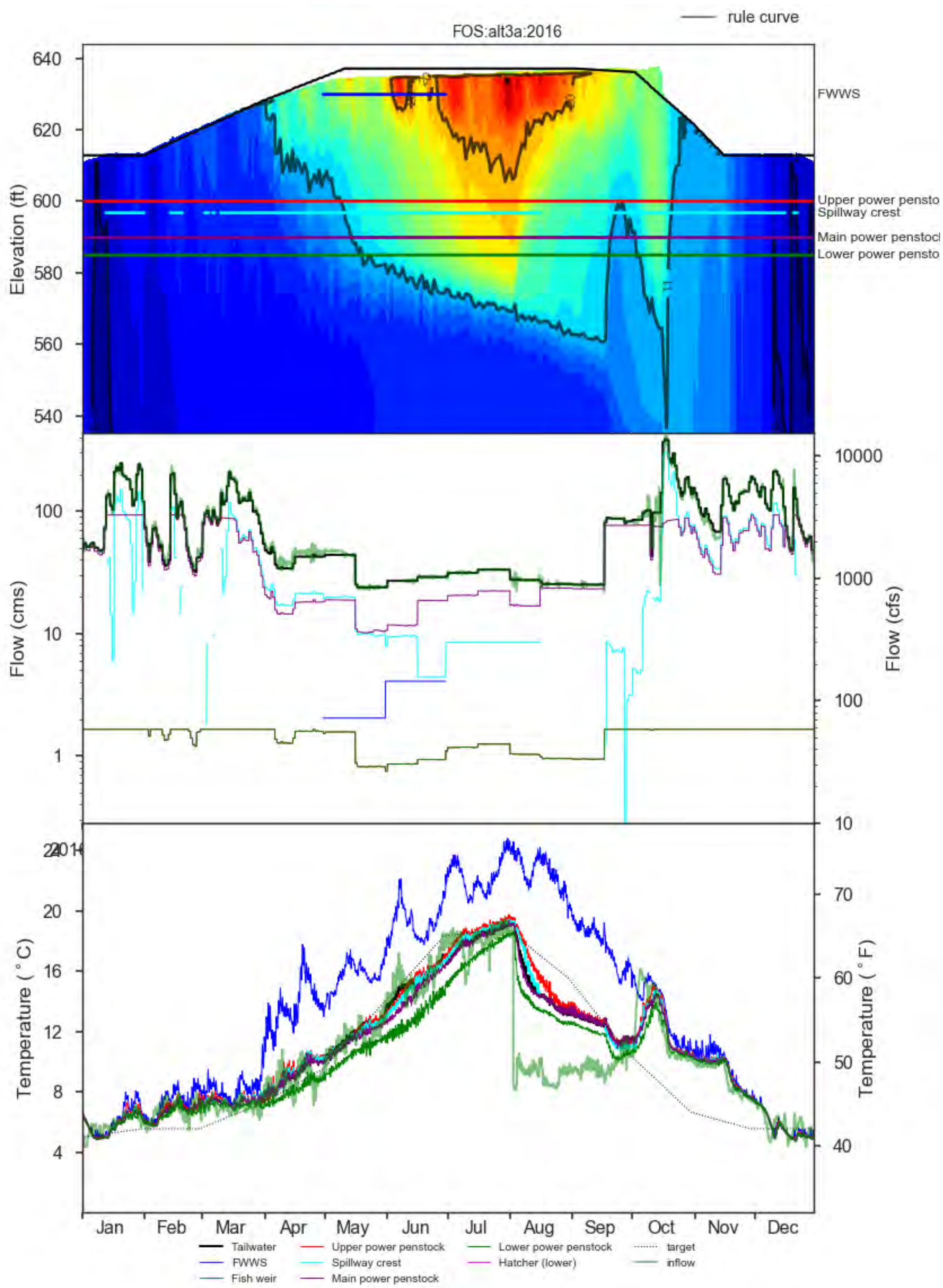

Figure 1-223. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at FOS under Alternative 3a in 2016.

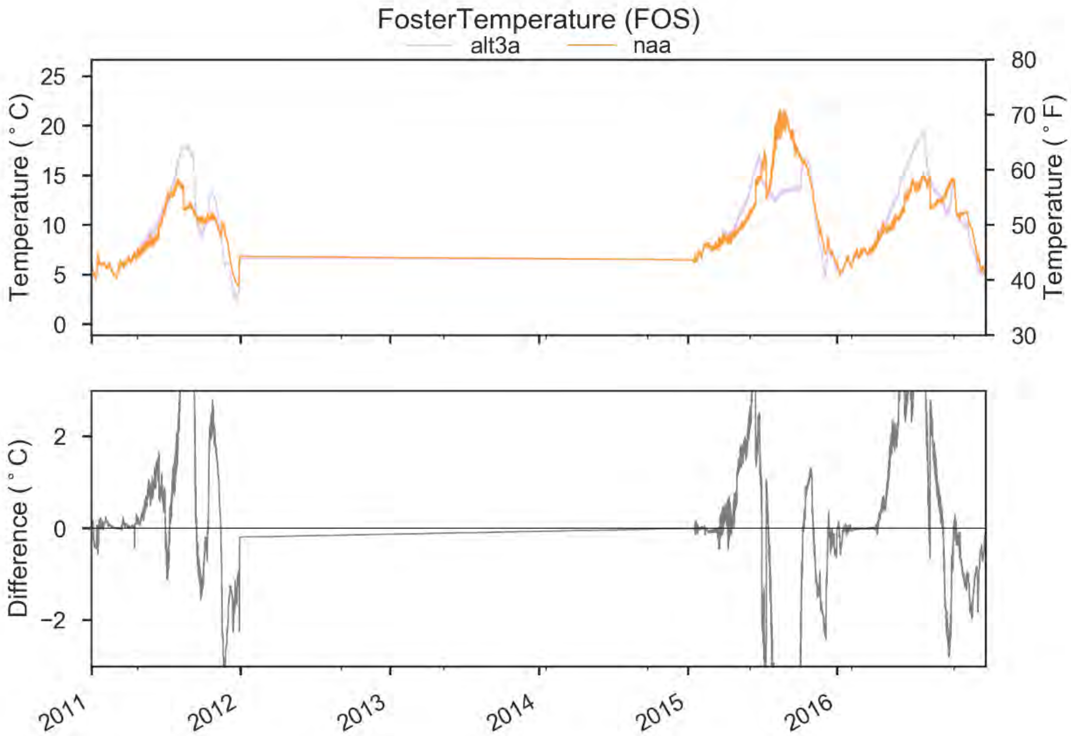

Figure 1-224. Comparison of FOS outflow temperatures in NAA and Alternative 3a.

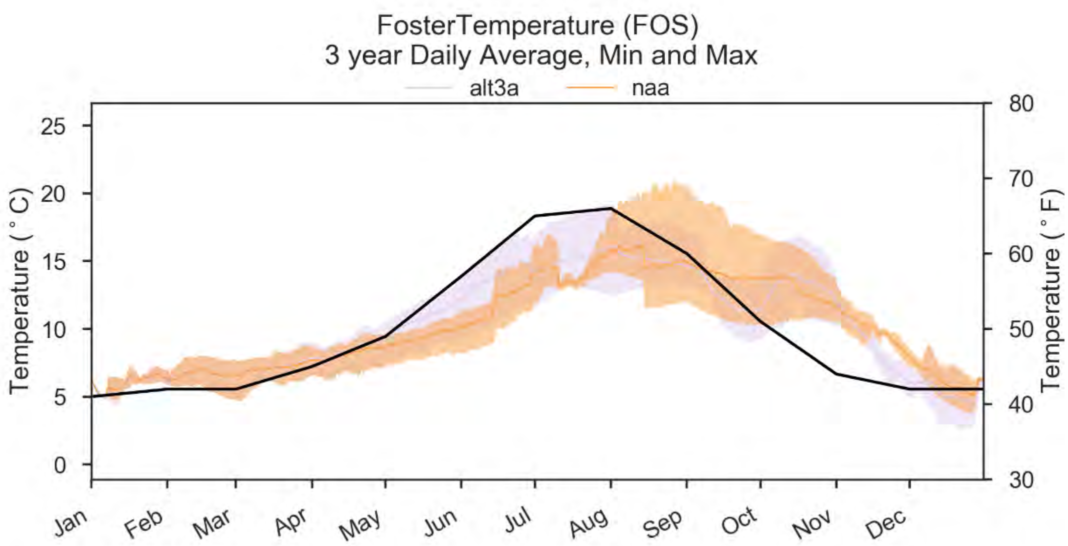

Figure 1-225. Comparison of FOS 3-year Daily Average, Min, Max Outflow Temperatures in NAA and Alternative 3a. Black Line Indicates Temperature Target.

1.5.5.3 MCKENZIE DAMS

1.5.5.3.1 Cougar

RES-SIM Lake Levels and Outflows

Lake level and storage at Cougar Lake decreased in Alternative 3a compared to NAA in 2011, 2015, and 2016 to allow for proposed fish passage operations through the diversion tunnel (Figure 1-226, Figure 1-227, and Figure 1-228). Decreased storage coincided with reduced outflows during spring and summer (Figure 1-227). Outflows were primarily routed through the RO in Alternative 3a.

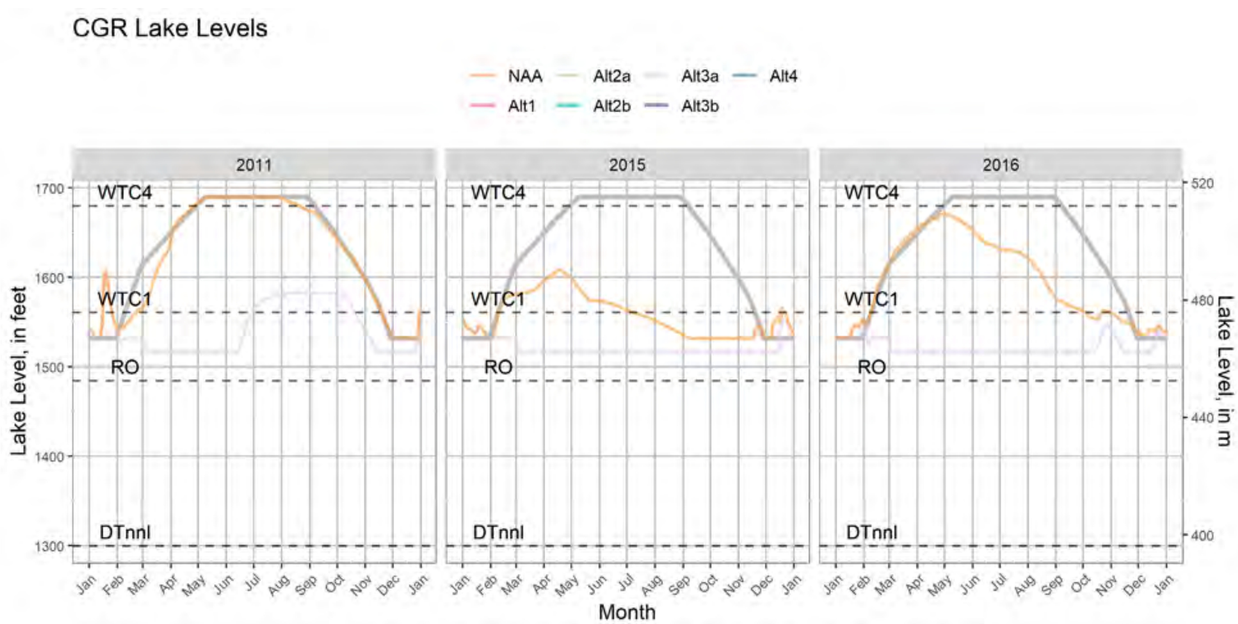

Figure 1-226. WV EIS RES-SIM Cougar Lake Levels in 2011, 2015, and 2016 Under Alternative 3a and NAA.

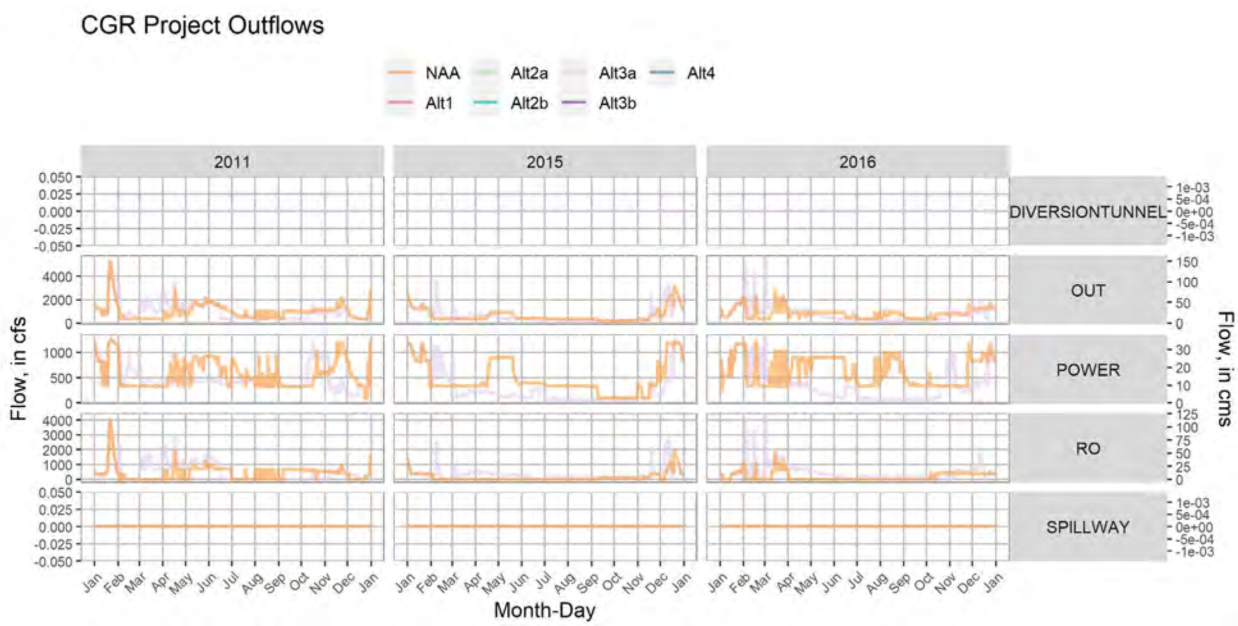

Figure 1-227. WV EIS RES-SIM Cougar Dam Gate-Specific Outflows in 2011, 2015, and 2016 under Alternative 3a and NAA.

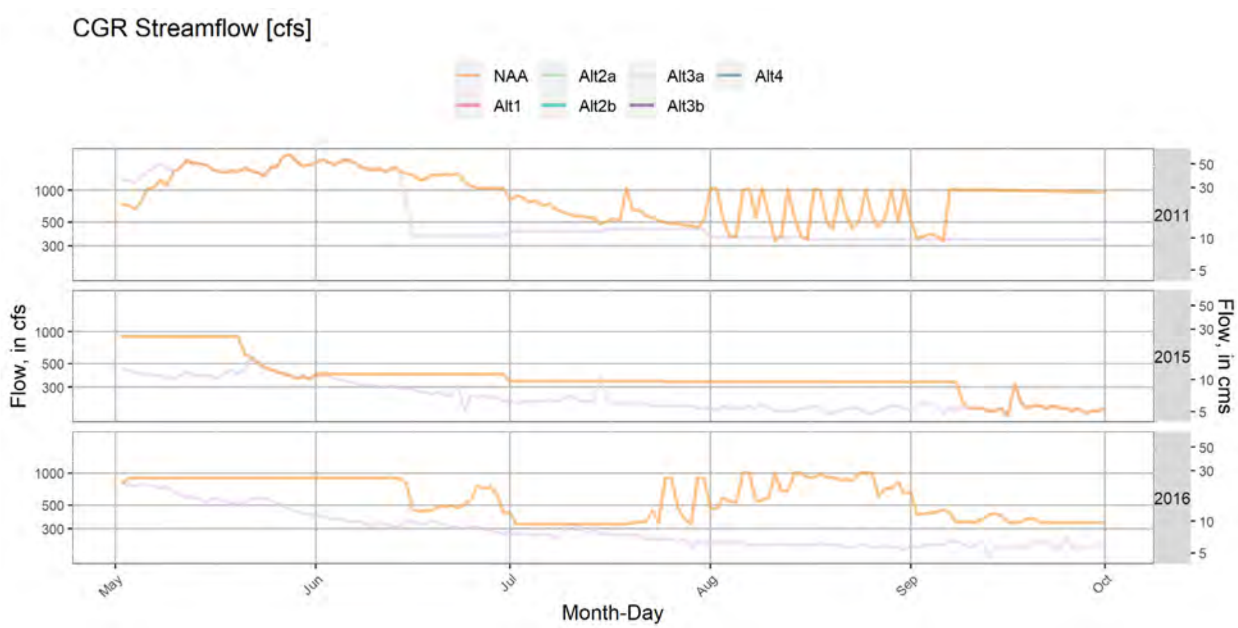

Figure 1-228. WV EIS RES-SIM Cougar Dam Total Outflow in 2011, 2015, and 2016 Under Alternative 3a and NAA.

Lake Levels and Temperatures from CE-QUAL-W2

Depth-varying temperature, gate-specific outflows, and outflow temperatures through each calendar year scenario at Cougar Lake are shown in Figure 1-229, Figure 1-230, and Figure 1-231. Outflow temperatures from Cougar Dam in Alternative 3a were cooler than NAA June-August and warmer than NAA September-November. Downstream release temperatures were sensitive to the depth of the thermocline throughout the year in Alternative 3a as the proposed fish operation routed all releases through the RO (Figure 1-232, Figure 1-233).

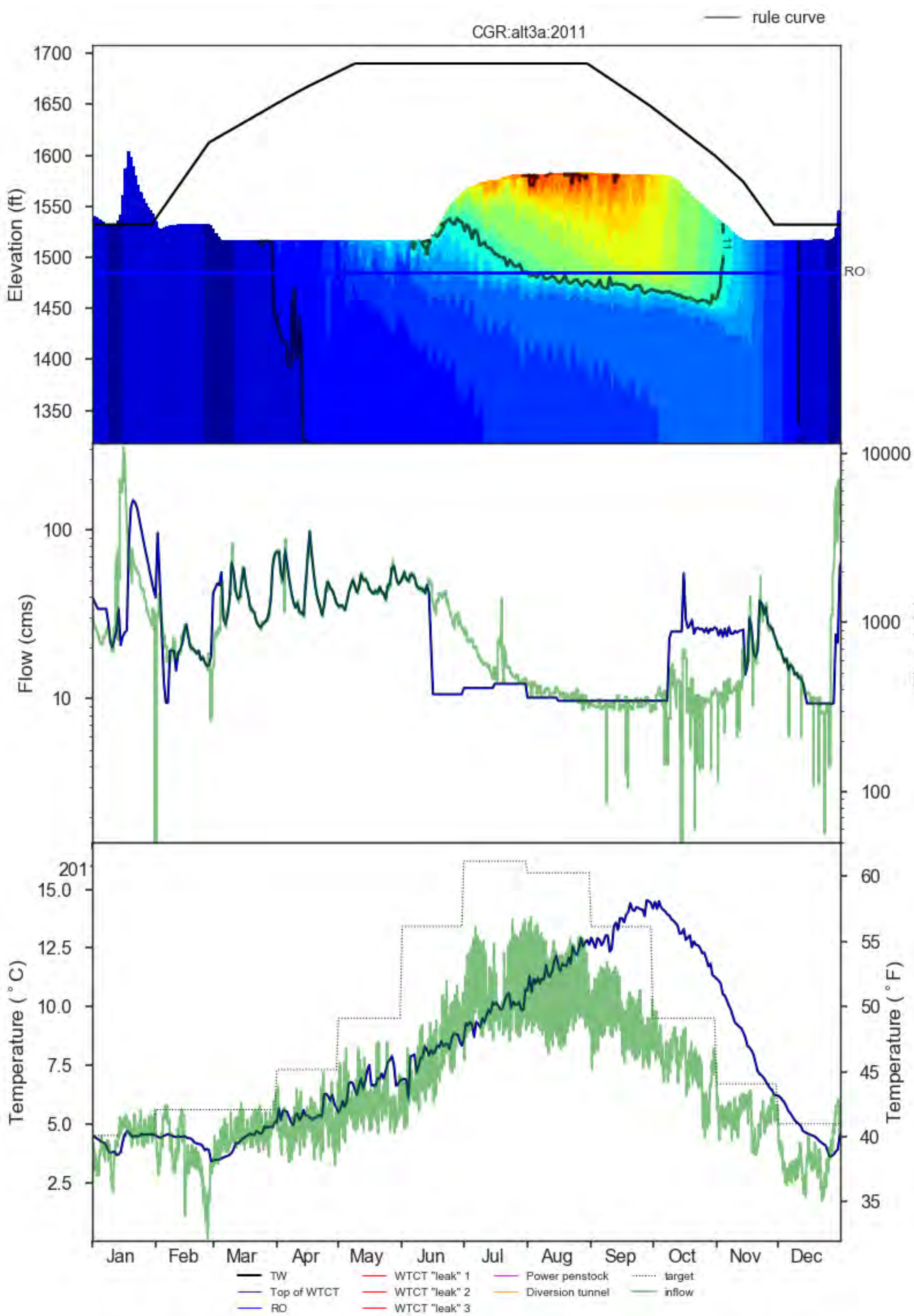

Figure 1-229. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at CGR under Alternative 3a in 2011.

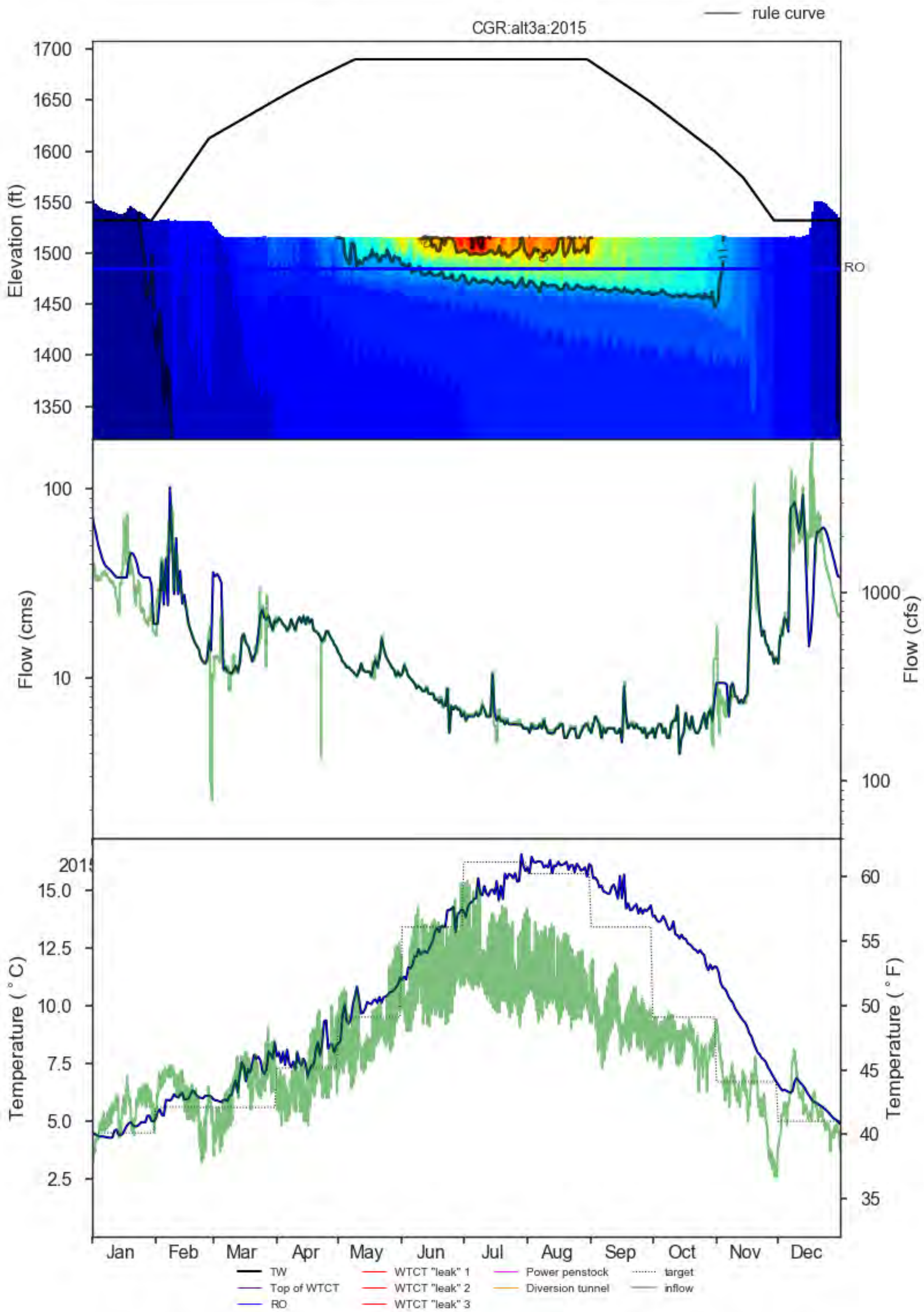

Figure 1-230. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at CGR under Alternative 3a in 2015.

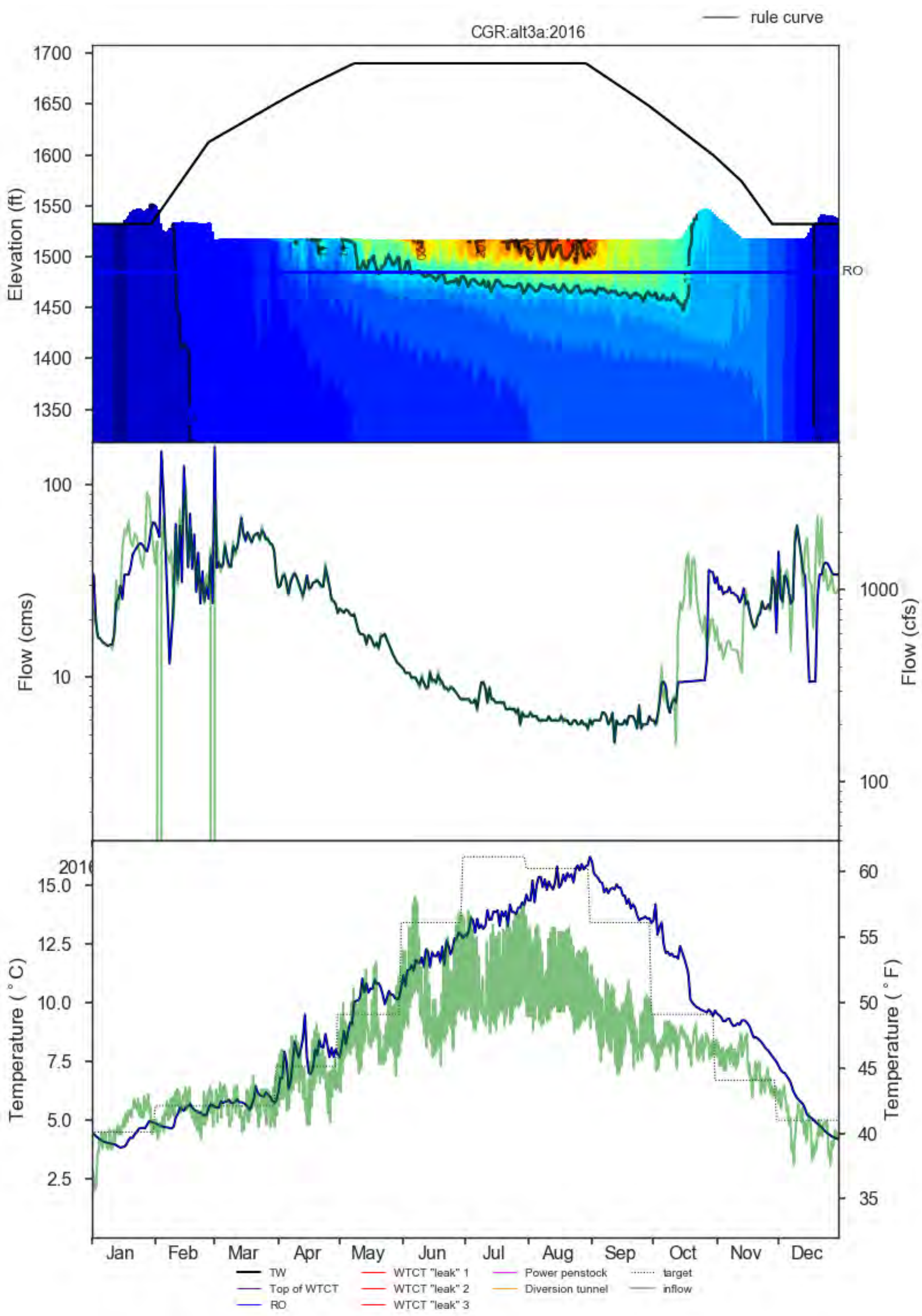

Figure 1-231. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at CGR under Alternative 3a in 2016.

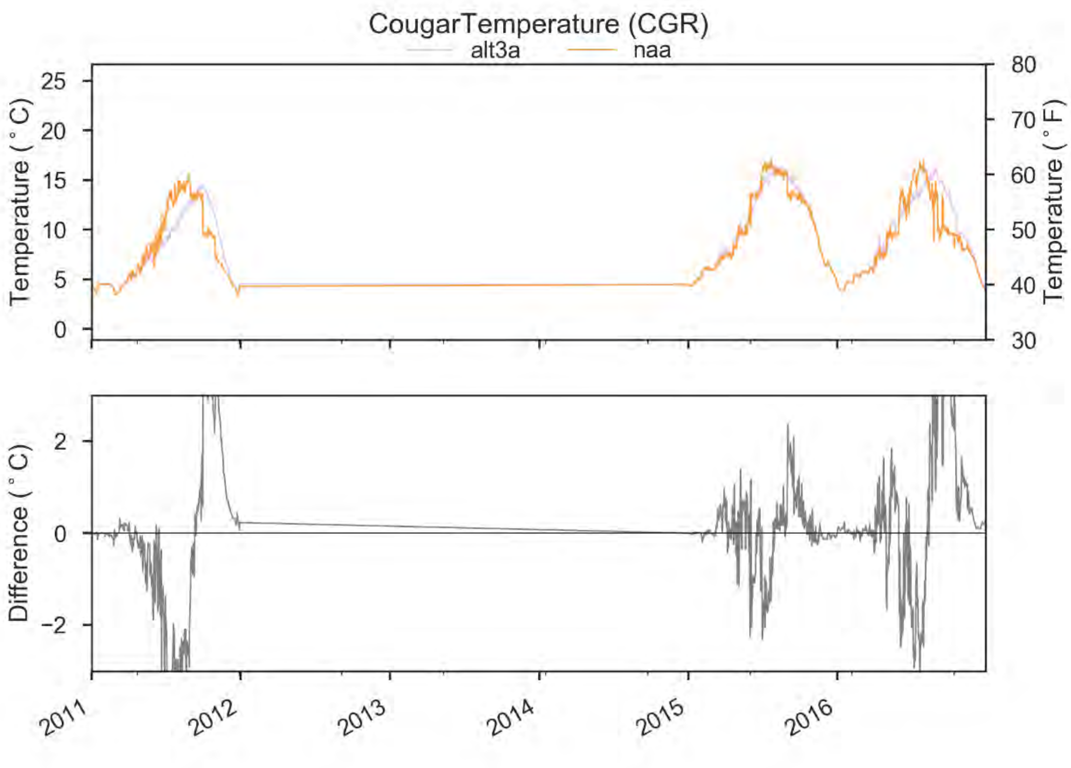

Figure 1-232. Comparison of CGR Outflow Temperatures in NAA and Alternative 3a.

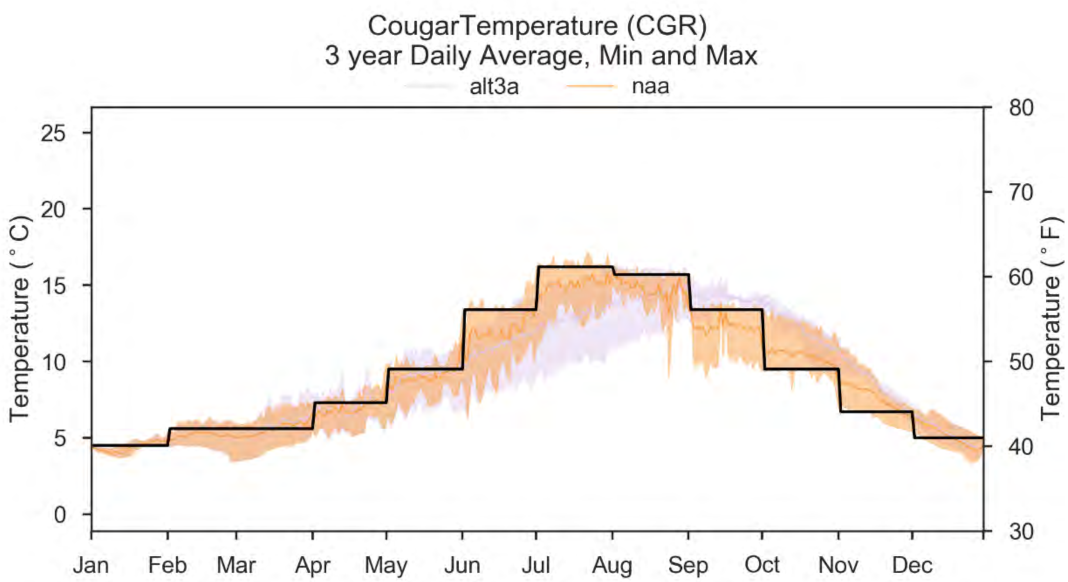

Figure 1-233. Comparison of CGR 3-year Daily Average, Min, Max Outflow Temperatures in NAA and Alternative 3a. Black Line Indicates Temperature Target.

1.5.5.4 MIDDLE FORK WILLAMETTE DAMS

1.5.5.4.1 Hills Creek

RES-SIM Lake Levels and Outflows

Lake level and storage at Hills Creek Lake generally increased under Alternative 3a compared to NAA from the spring to early summer and decreased from the late summer to winter. (Figure 1-234, Figure 1-235, and Figure 1-236). Outflow was routed through the power penstocks and emergency spillway (assumed to be structurally modified to allow for small non-emergency flow without causing dam safety issues) at Hills Creek in Alternative 3a (Figure 1-235).

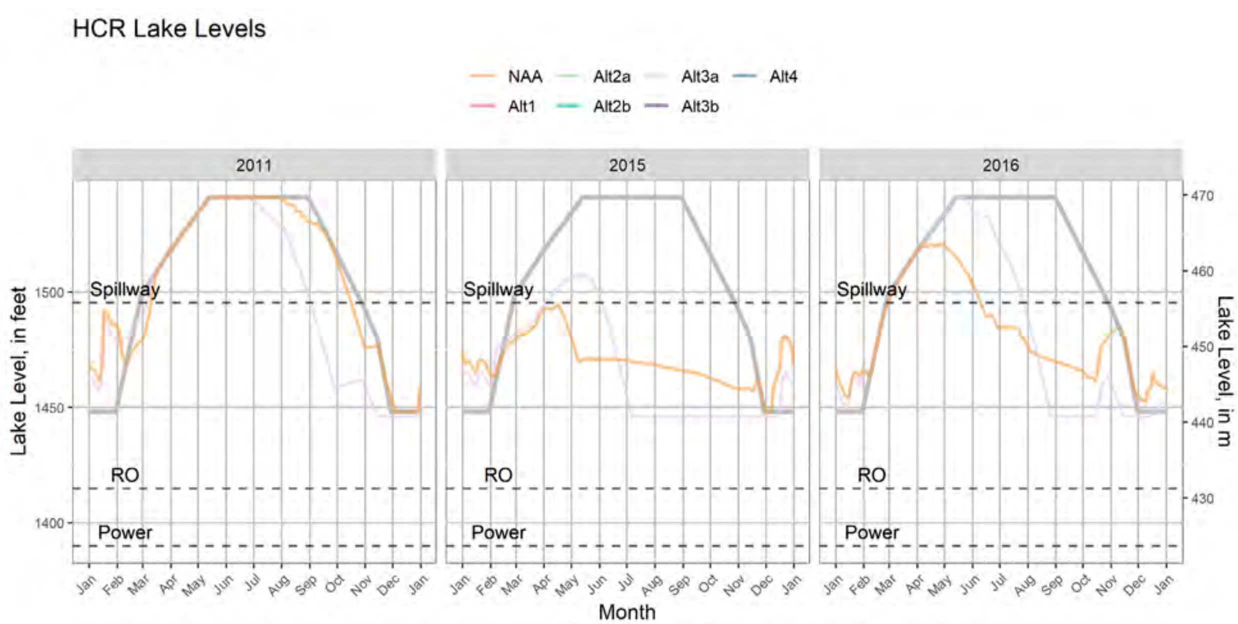

Figure 1-234. WV EIS RES-SIM Hills Creek Lake Levels in 2011, 2015, and 2016 Under Alternative 3a and NAA.

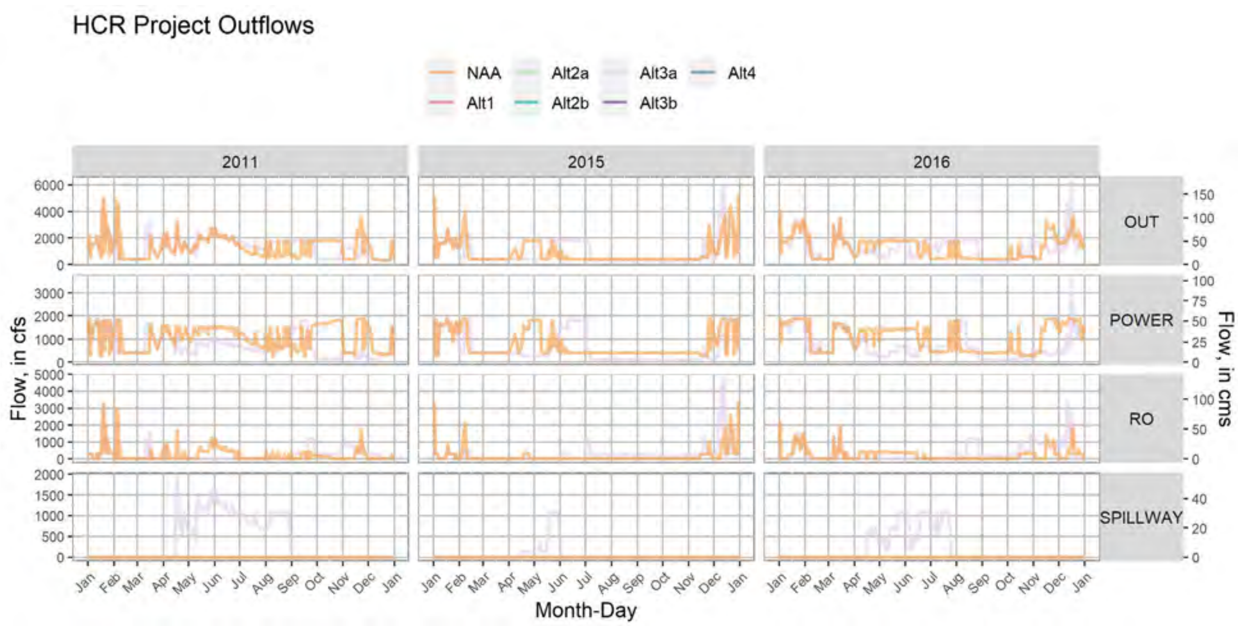

Figure 1-235. WV EIS RES-SIM Hills Creek Dam Gate-Specific Outflows in 2011, 2015, and 2016 under Alternative 3a and NAA.

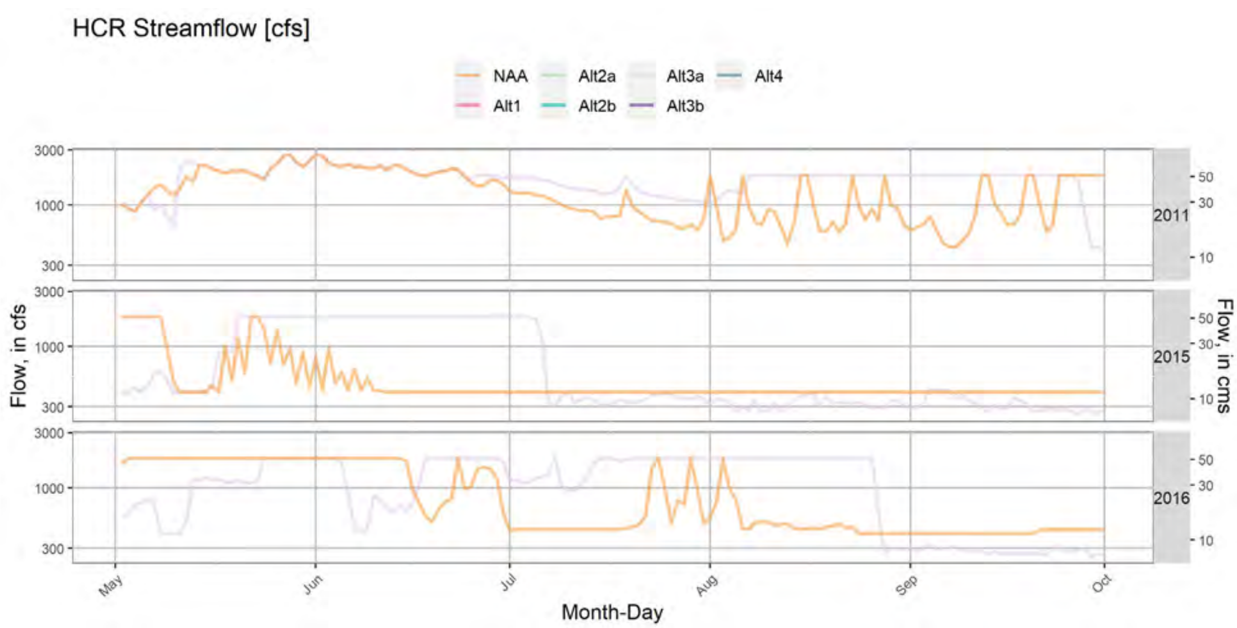

Figure 1-236. WV EIS RES-SIM Hills Creek Dam Total Outflow in 2011, 2015, and 2016 Under Alternative 3a and NAA.

Lake Levels and Temperatures from CE-QUAL-W2

Depth-varying temperature, gate-specific outflows, and outflow temperatures through each calendar year scenario in Alternative 3a at Hills Creek Lake are shown in Figure 1-237, Figure 1-238, and Figure 1-239. Hills Creek tailwater temperatures were generally warmer in Alternative 3a compared to NAA in May-July and cooler than NAA September - December (Figure 1-240, Figure 1-241) because of the proposed spillway operations (and spillway modifications).

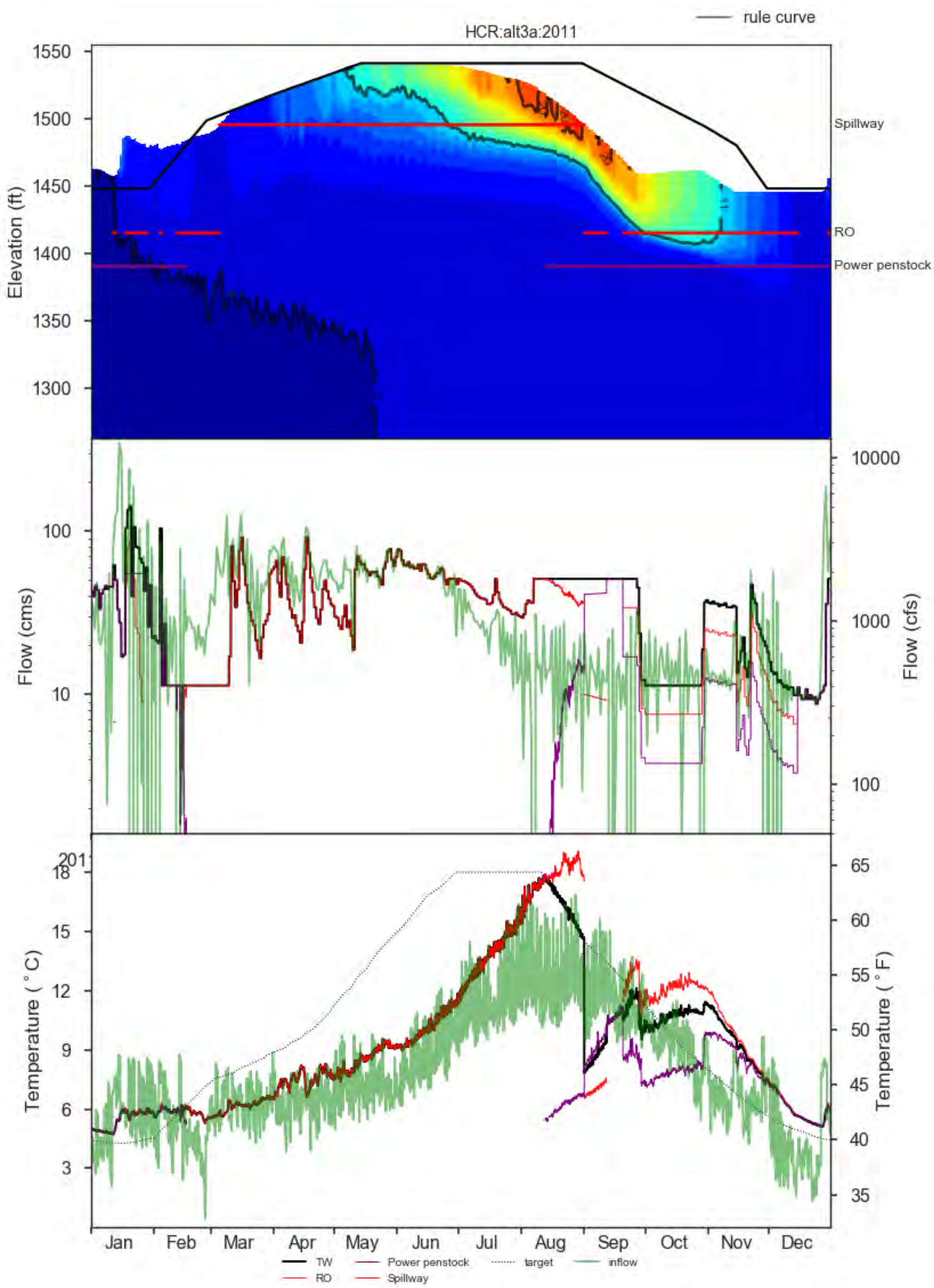

Figure 1-237. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at HCR under Alternative 3a in 2011.

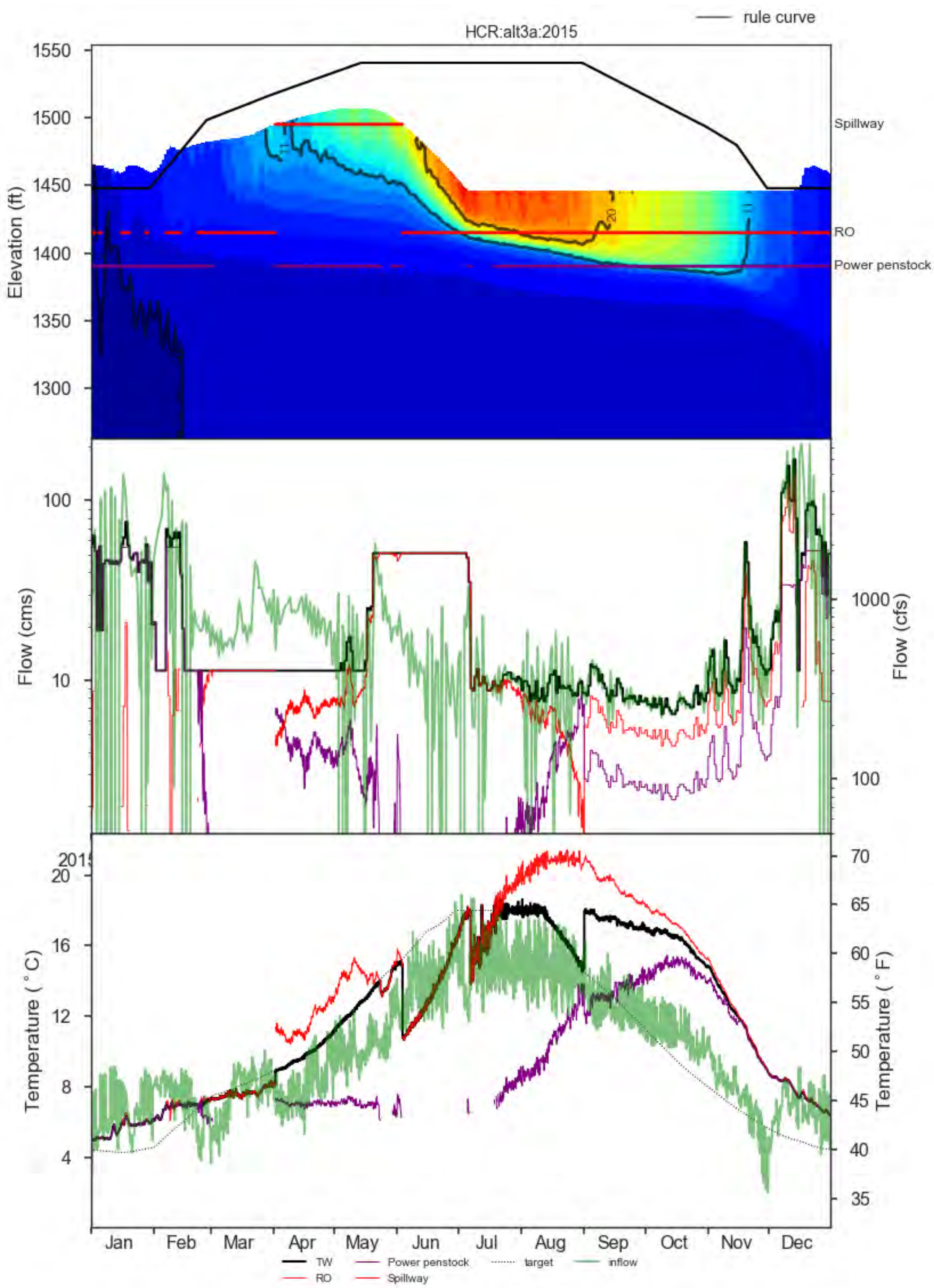

Figure 1-238. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at HCR under Alternative 3a in 2015.

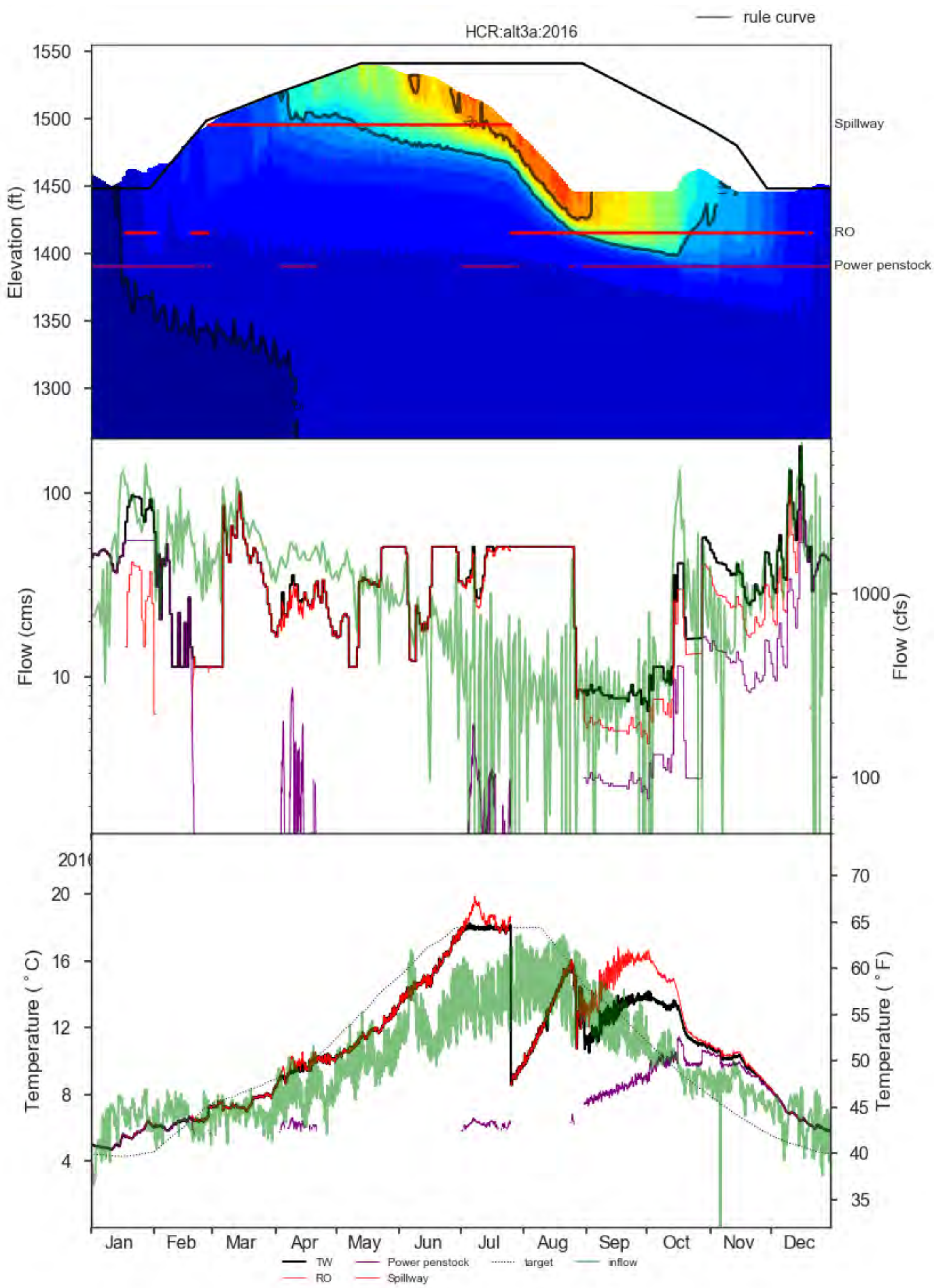

Figure 1-239. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at HCR under Alternative 3a in 2016.

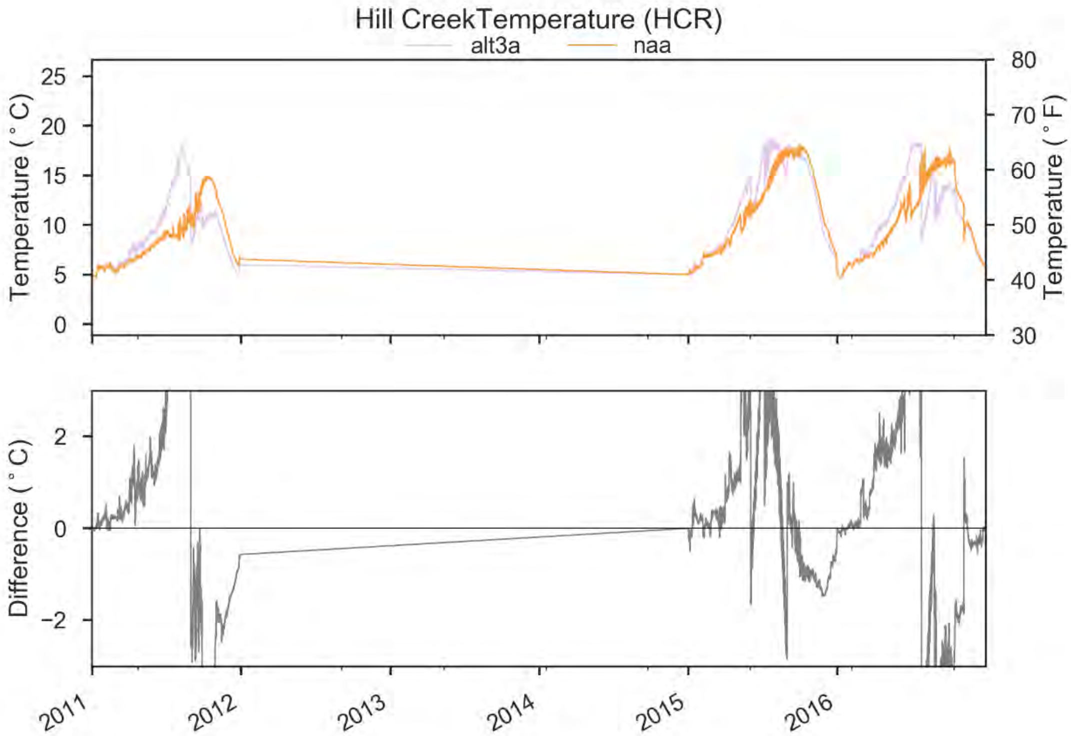

Figure 1-240. Comparison of HCR Outflow Temperatures in NAA and Alternative 3a.

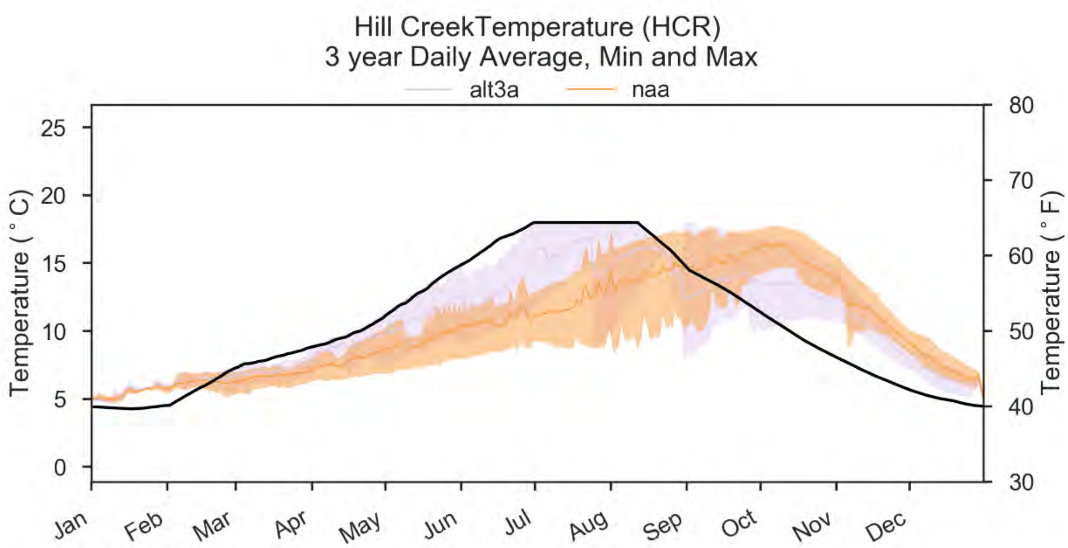

Figure 1-241. Comparison of HCR 3-year Average, Min, Max Outflow Temperatures in NAA and Alternative 3a. Black Line Indicates Temperature Target.

1.5.5.4.2 Lookout Point

RES-SIM Lake Levels and Outflows

Lake level and storage at Lookout Point decreased in Alternative 3a compared to NAA in 2011, 2015 and 2016 as the lake was drafted for the proposed fish passage operation through the ROs (Figure 1-242, Figure 1-243, and Figure 1-244). The decreased storage generally coincided with reduced outflows during May-October comparing Alternative 3a to NAA (Figure 1-244).

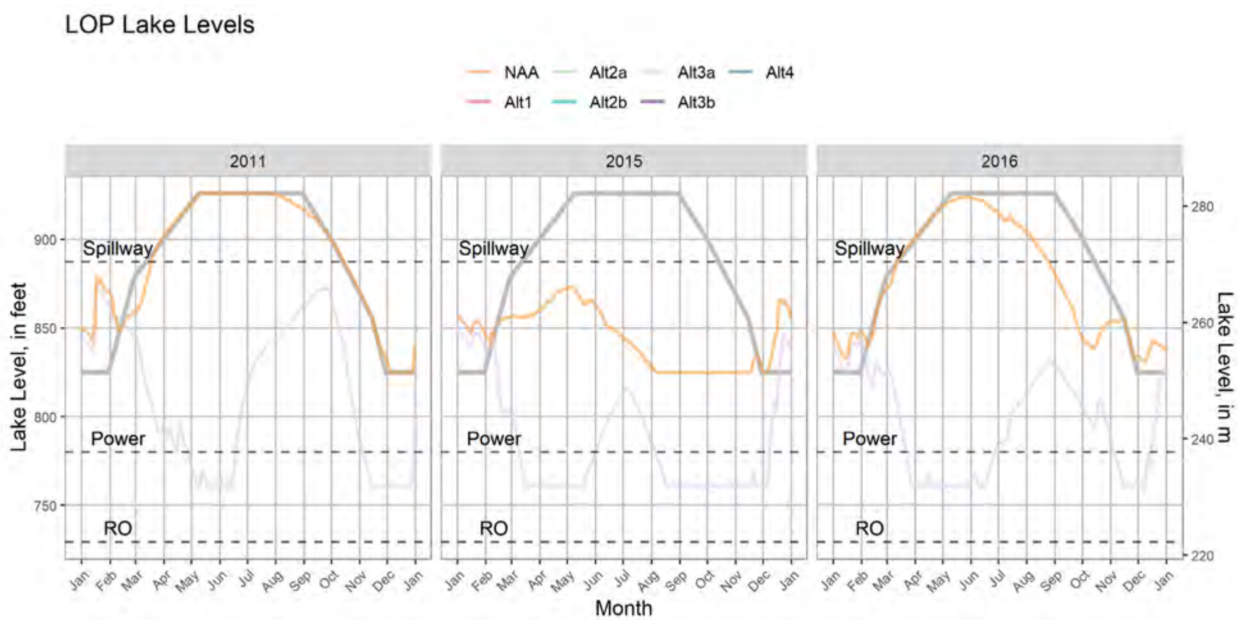

Figure 1-242. WV EIS RES-SIM Lookout Point Lake Levels in 2011, 2015, and 2016 Under Alternative 3a and NAA.

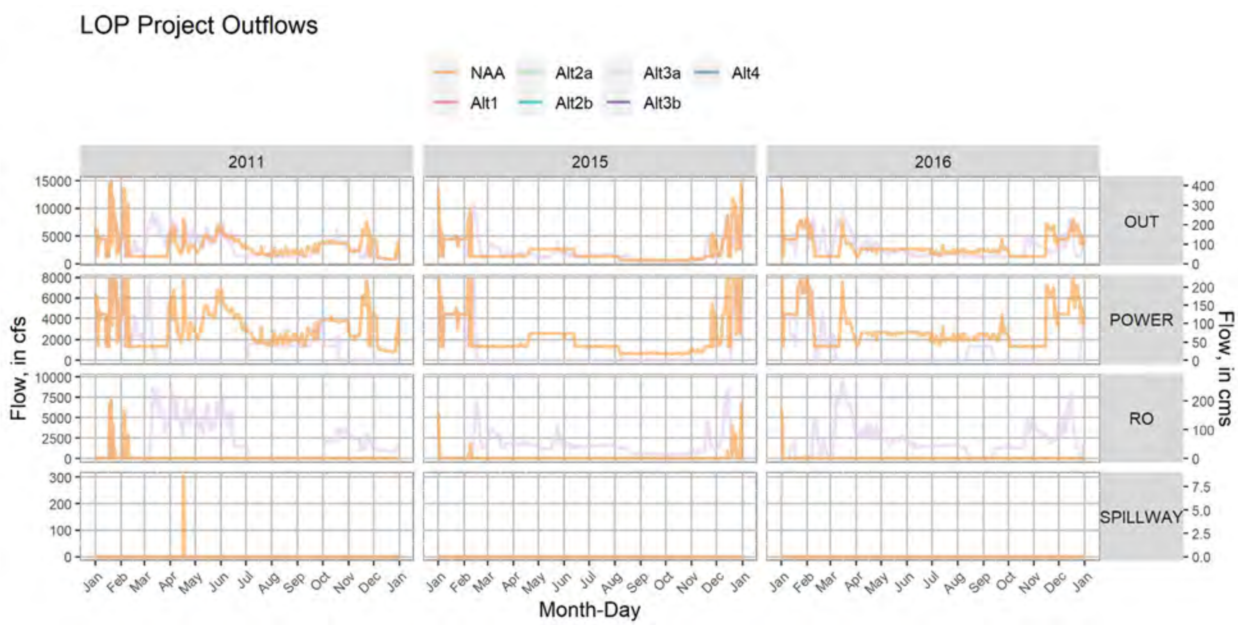

Figure 1-243. WV EIS RES-SIM Lookout Point Dam Gate-Specific Outflows in 2011, 2015, and 2016 under Alternative 3a and NAA.

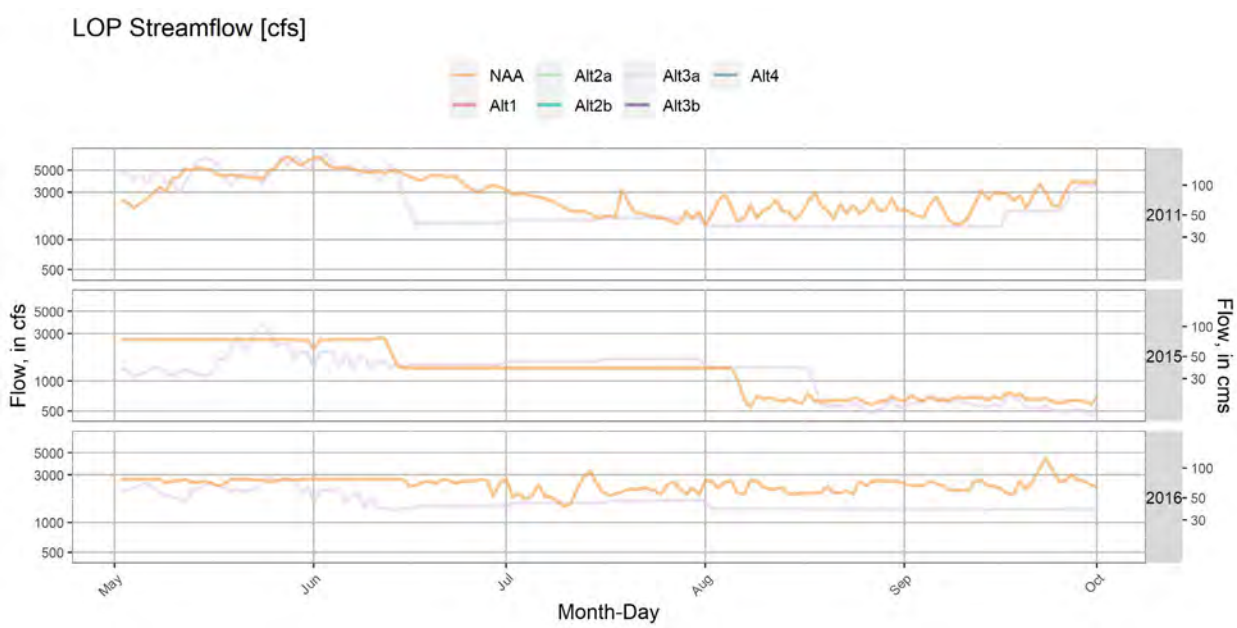

Figure 1-244. WV EIS RES-SIM Lookout Point Dam Total Outflow in 2011, 2015, and 2016 Under Alternative 3a and NAA.

Lake Levels and Temperatures from CE-QUAL-W2

Depth-varying temperature, gate-specific outflows, and outflow temperatures through each calendar year scenario at Lookout Point Lake are shown in Figure 1-245, Figure 1-246, and Figure 1-247. Outflow temperatures from Lookout Point Dam in Alternative 3a were generally warmer than NAA May-September and cooler than NAA October-December in 2011, 2015, and 2016 as the lake surface area, volume, and residence time was decreased and releases were primarily made through the ROs for fish passage operations (Figure 1-248, Figure 1-249).

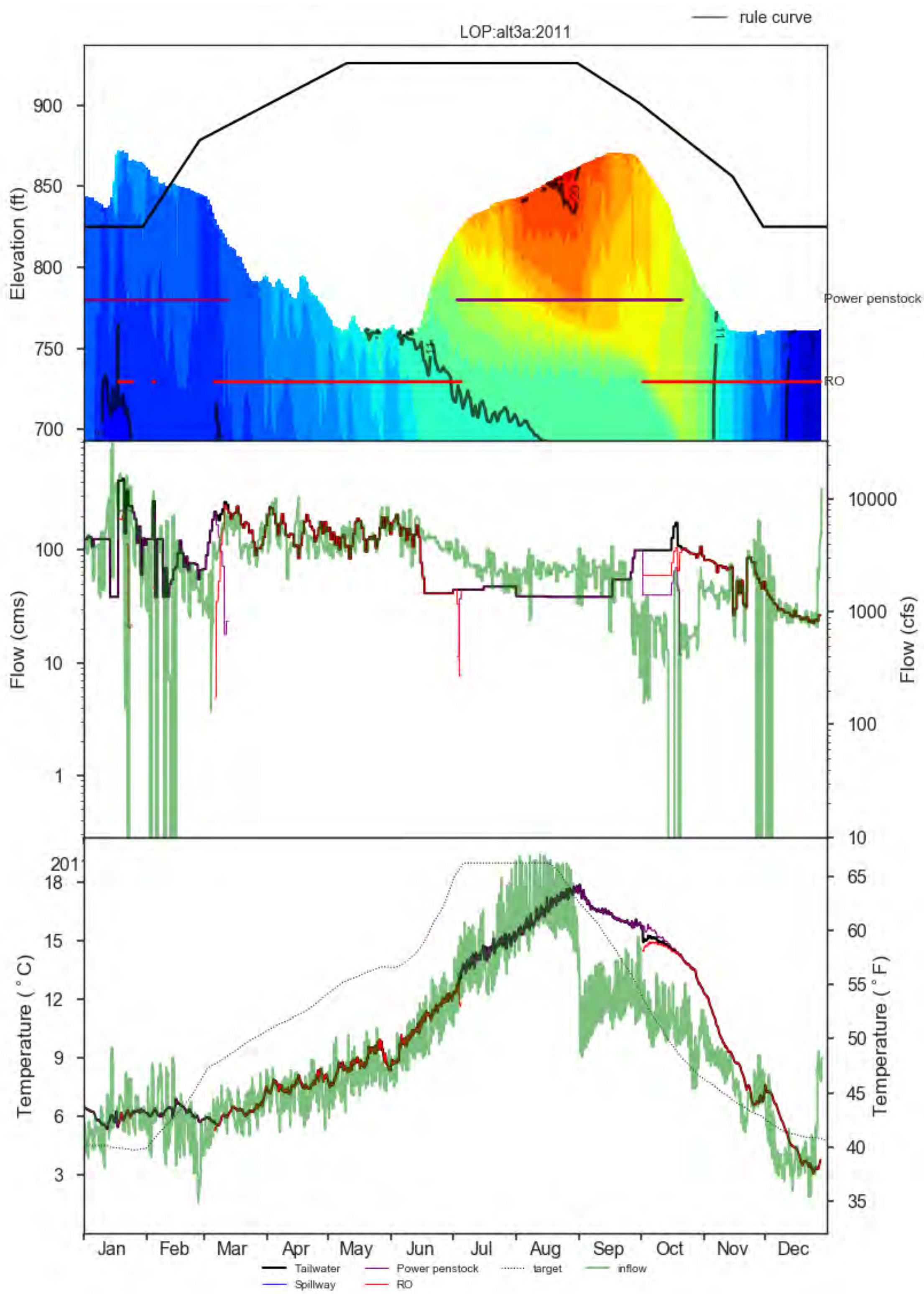

Figure 1-245. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at LOP under Alternative 3a in 2011.

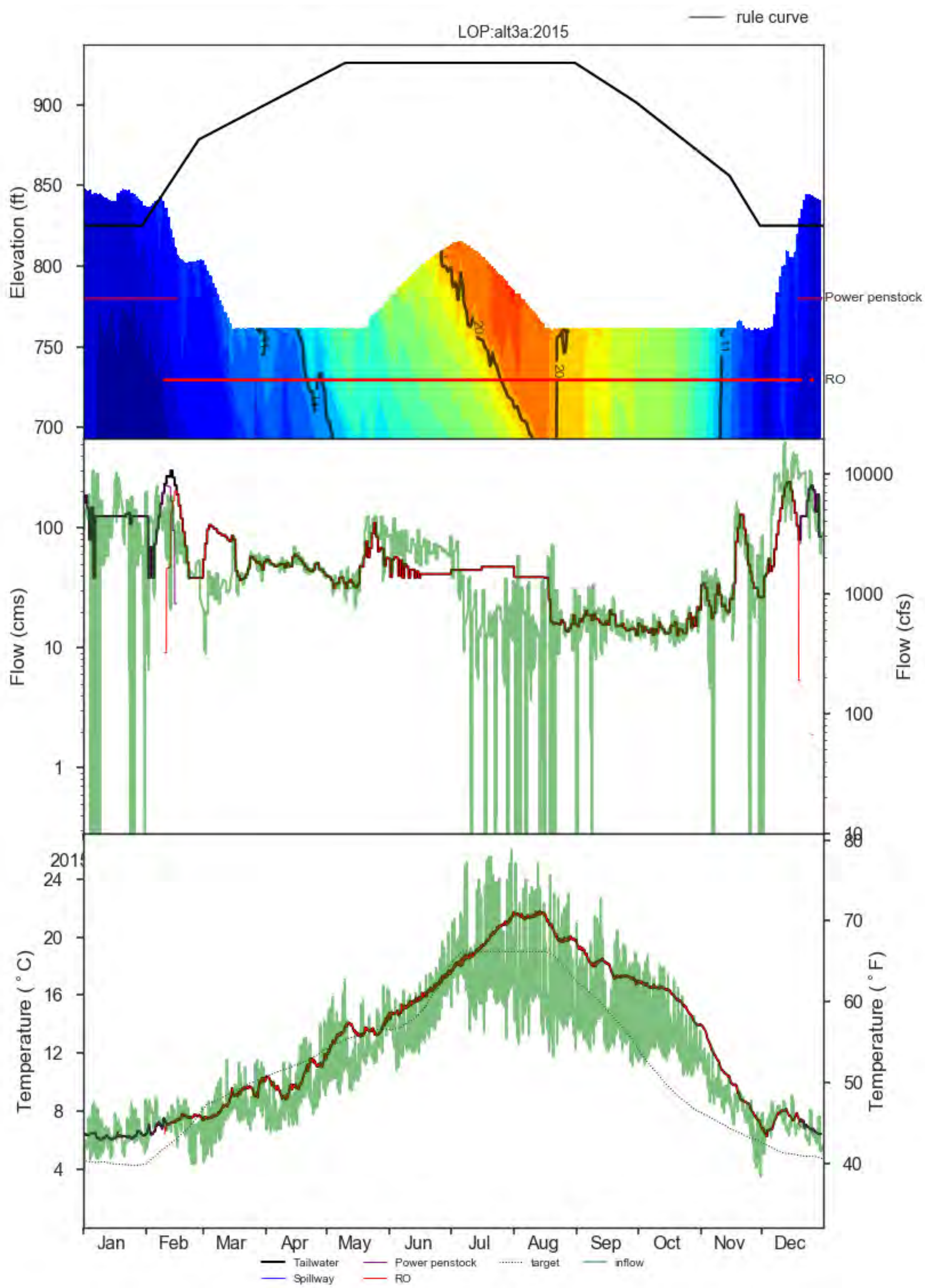

Figure 1-246. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at LOP under Alternative 3a in 2015.

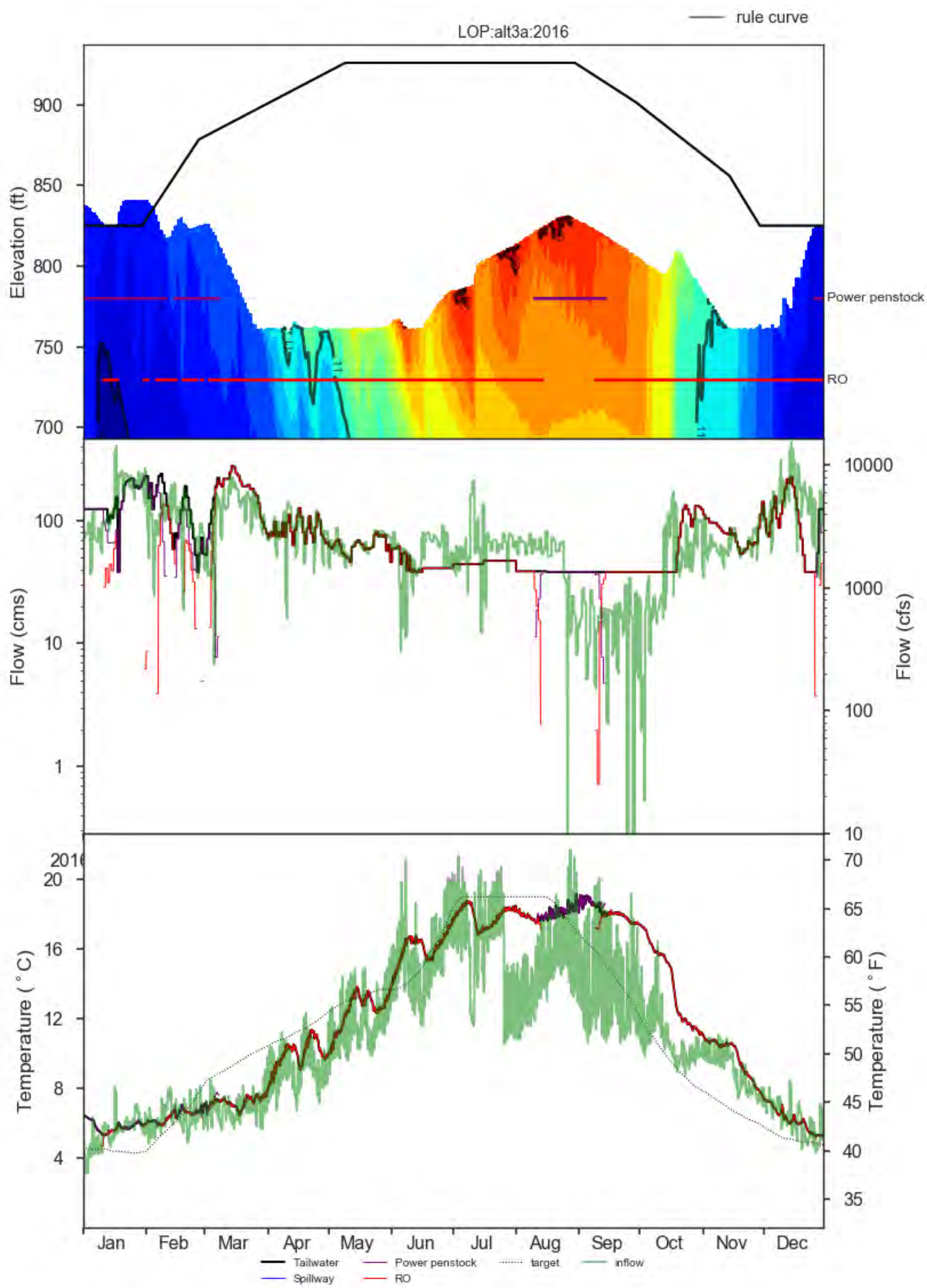

Figure 1-247. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at LOP under Alternative 3a in 2016.

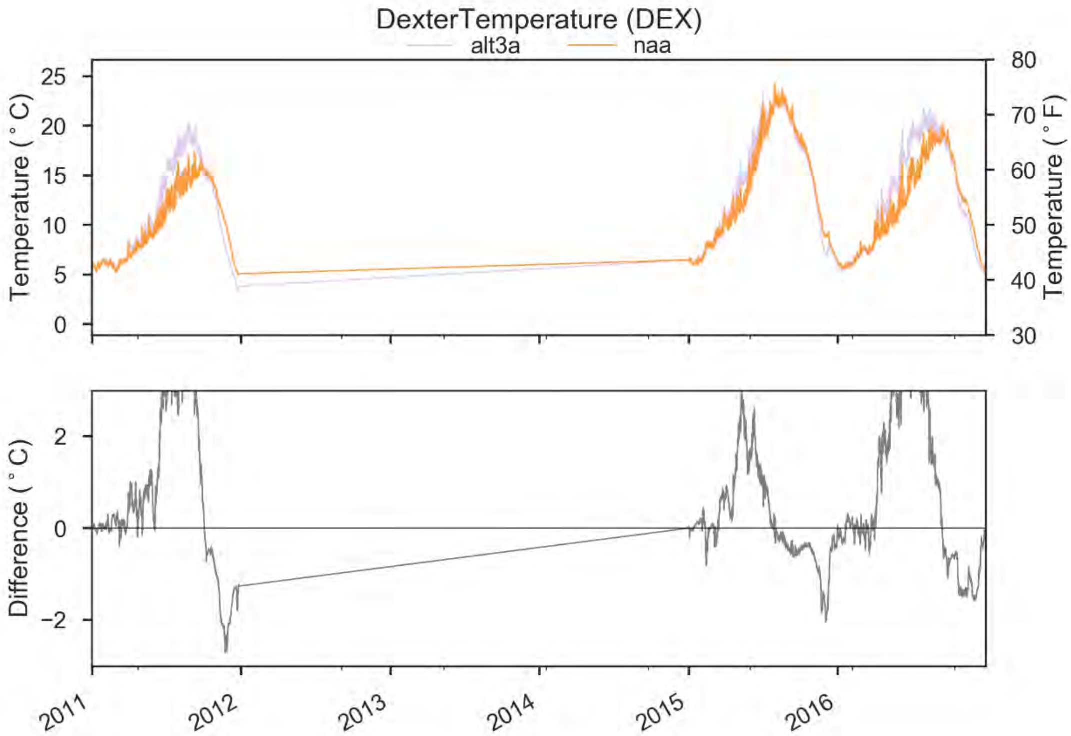

Figure 1-248. Comparison of DEX Outflow Temperatures in NAA and Alternative 3a.

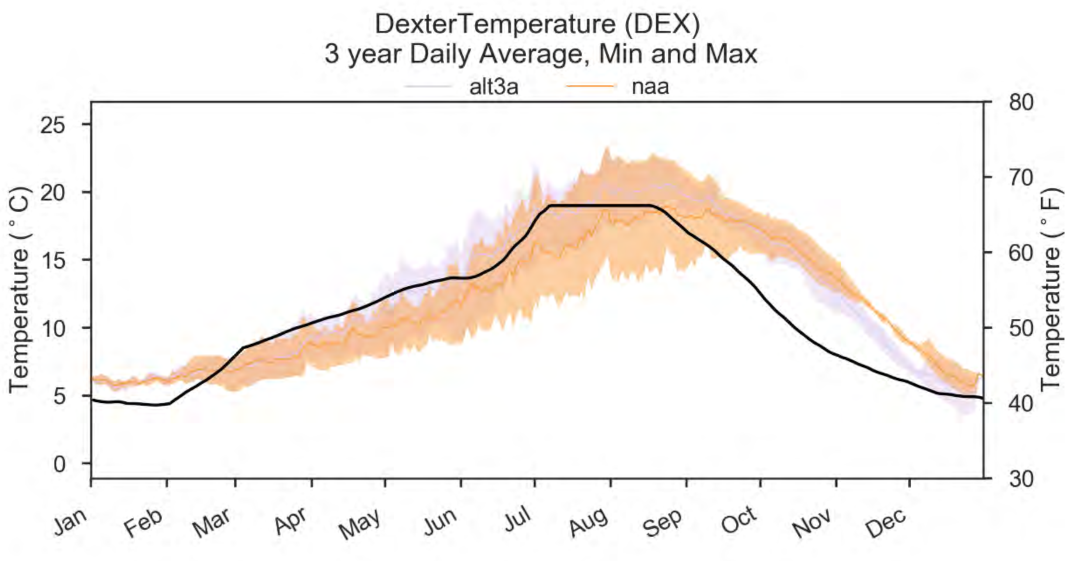

Figure 1-249. Comparison of DEX 3-year Average, Min, Max Outflow Temperatures in NAA and Alternative 3a. Black Line Indicates Temperature Target.

1.5.5.5 Mainstem Willamette River

Streamflow under Alternative 3a was generally lower than NAA (Figure 1-250). The exception to this result was in 2015, where flow differences were generally lower April to mid-June and higher from mid-June to mid-September compared to NAA, likely due to Measure 30 rules that increase dam outflows in advance of heat wave events (Figure 1-251). These flow changes resulted in warmer water temperatures from April until mid-June and cooler water temperatures from mid-June to mid-September compared with NAA in 2015 (Figure 1-252, Figure 1-253). Water temperatures at Salem were also affected by upstream dam operations, which likely contributed to warmer temperatures when comparing Alternative 3a to NAA. Overall water temperature differences between Alternative 3a and NAA were less than 2 degrees Celsius.

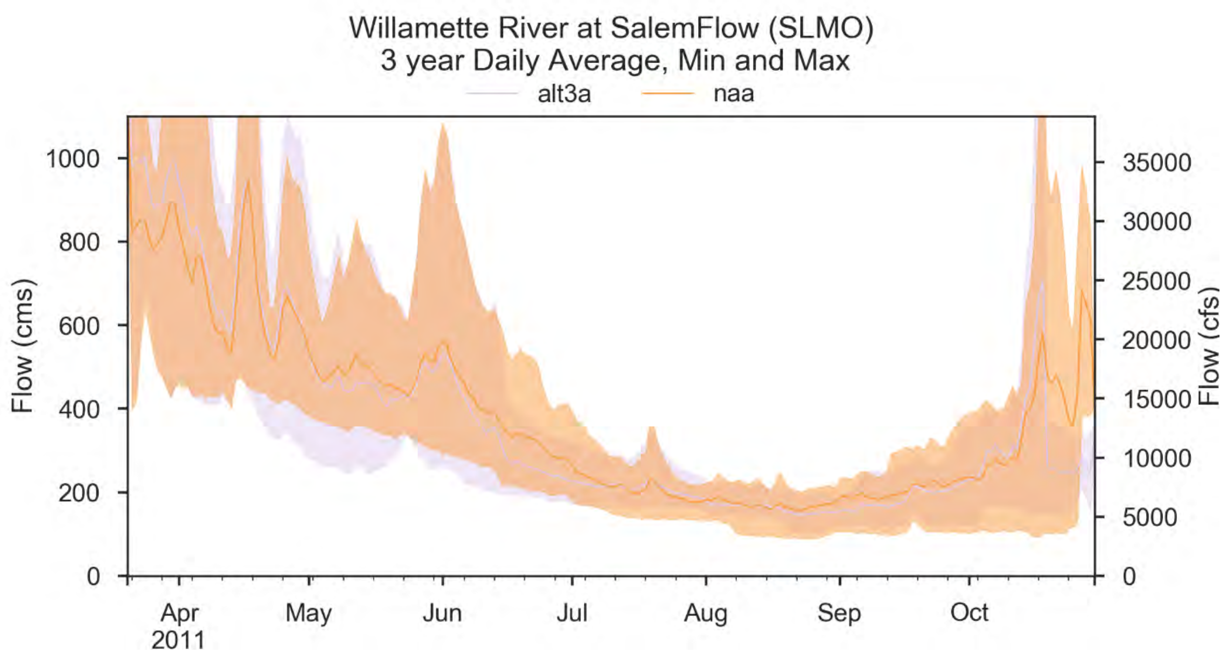

Figure 1-250. Streamflow Comparison of Average, Min, Max Willamette River at SLMO under NAA and Alternative 3a Conditions.

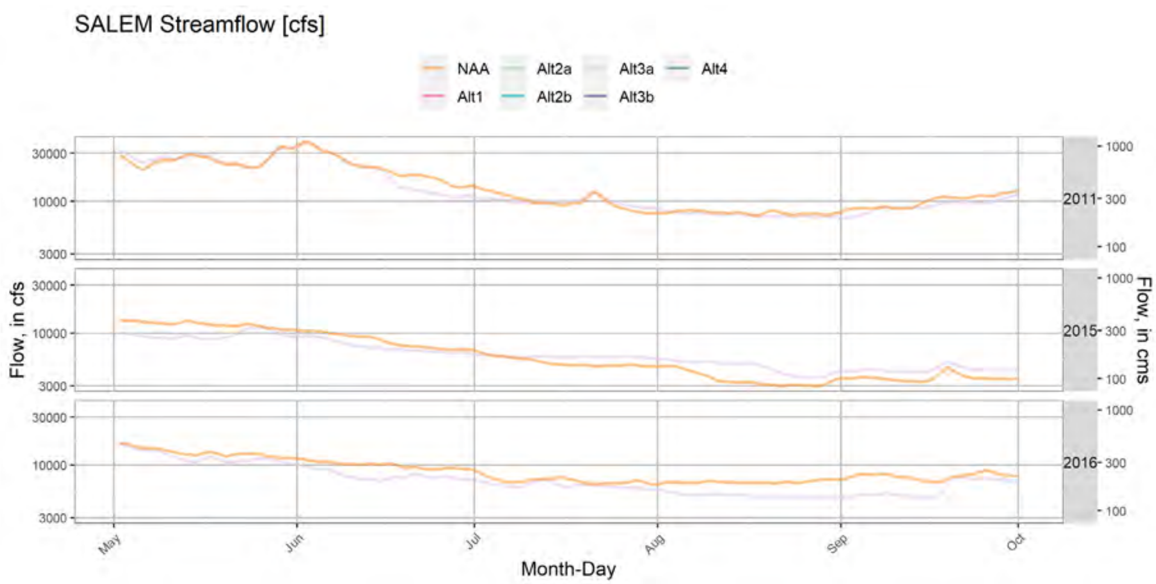

Figure 1-251. Streamflow Comparison Between Alternative 3a and NAA at Willamette River at SLMO.

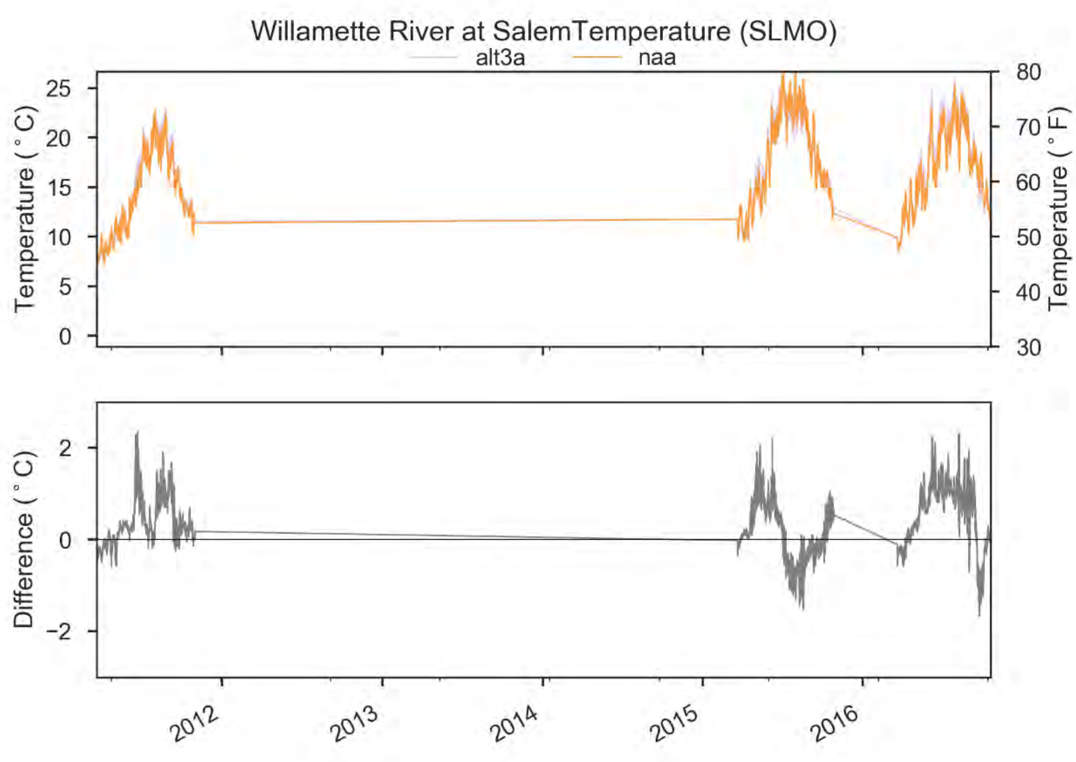

Figure 1-252. Comparison of Willamette River at SLMO Water Temperatures in NAA and Alternative 3a.

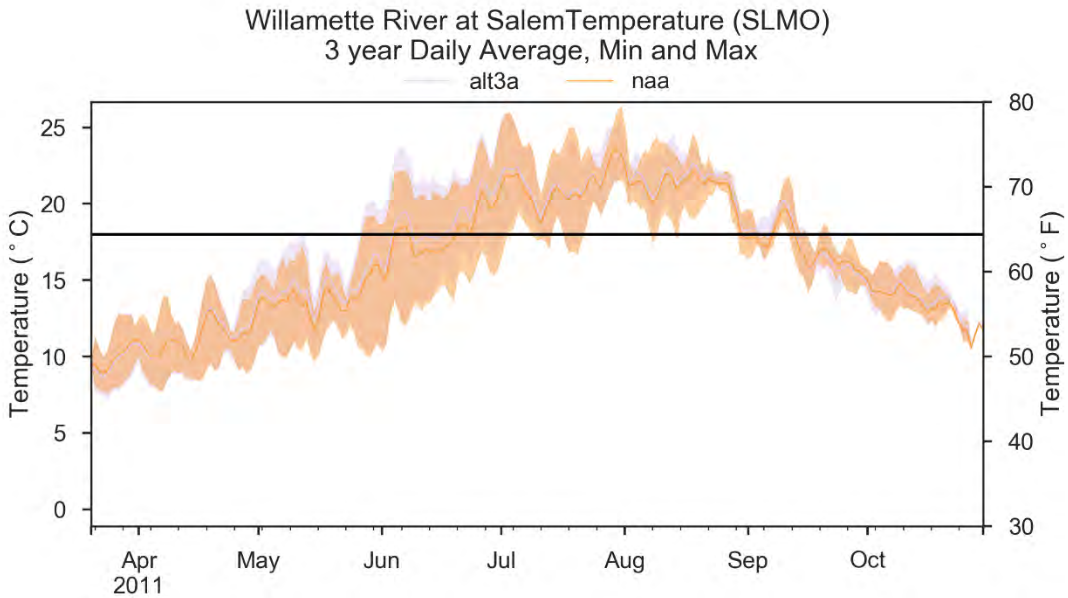

Figure 1-253. Comparison of Willamette River at SLMO 3-year Daily Average, Min, Max Outflow Temperatures in NAA and Alternative 3a.

1.5.6 Alternative 3b– Operations-Focused Fish Passage Alternative (using diversion tunnel at COU)

Alternative 3b measures that affected operations, lake storage, and water temperature included:

- Changes to tributary targets below Foster, Detroit, Lookout Point, and Cougar that are higher than the NAA BiOp targets when those reservoirs are more than 90% full and less than the NAA BiOp when those reservoirs are less than 90% full.
- Changes to baseline mainstem targets at Salem and Albany while adding a Salem flow target tied to forecasted air temperature.
- Spring drawdown operations at Hills Creek, Green Peter and Cougar (to the diversion tunnel)
- Fall drawdown operations to lowest level possible given operational constraints at Blue River, Hills Creek, Green Peter, Detroit, Lookout Point and Cougar.

1.5.6.1 NORTH SANTIAM DAMS

1.5.6.1.1 Detroit

RES-SIM Lake Levels and Outflows

Lake level and storage at Detroit were generally similar in Alternative 3b and NAA in 2011, 2015, and 2016 aside from October-November during drawdown to the UROs for fish passage

(Figure 1-254, Figure 1-255, and Figure 1-256). Some increased storage in 2015 coincided with reduced outflows during spring and increased outflows in July-October.. 2011 and 2016 operations were generally similar in Alternative 3b and NAA at Detroit Lake January-June but followed increased outflows in July-October to draft the lake for fish passage operations through the UROs in autumn. The proposed temperature management and fish passage operation through the spillway (during spring/summer) and URO (during autumn) in Alternative 3b led to increased outflow from these outlets and decreased power outflow compared to NAA (Figure 1-255).

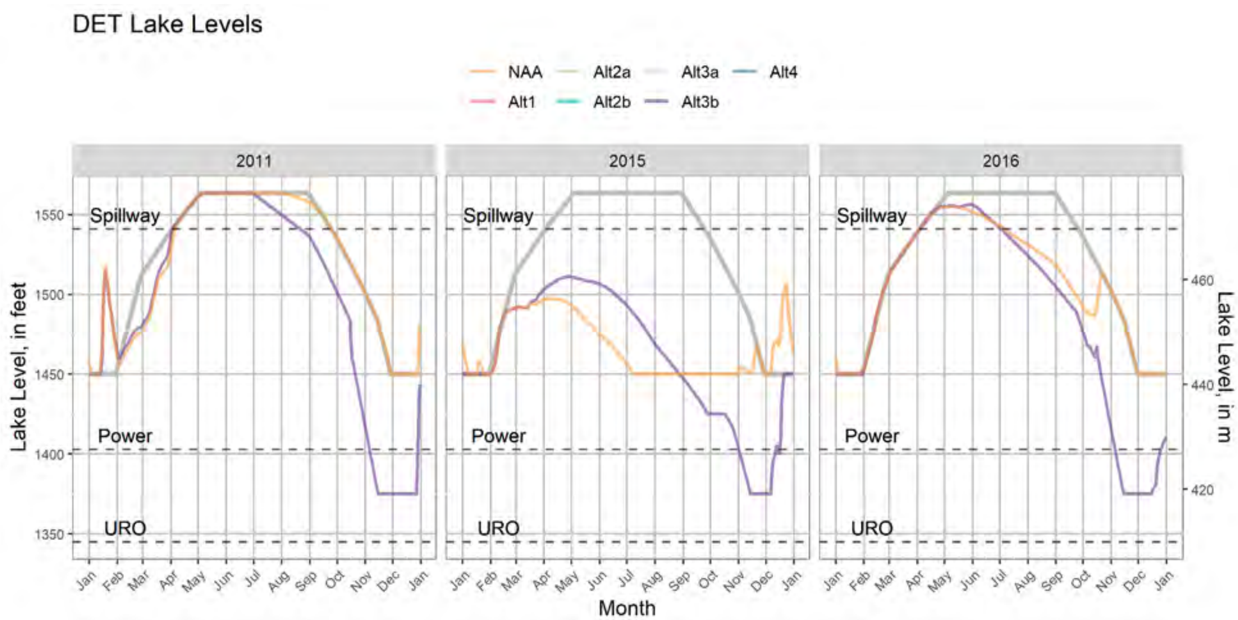

Figure 1-254. WV EIS RES-SIM Detroit Lake Levels in 2011, 2015, and 2016 Under Alternative 3b and NAA.

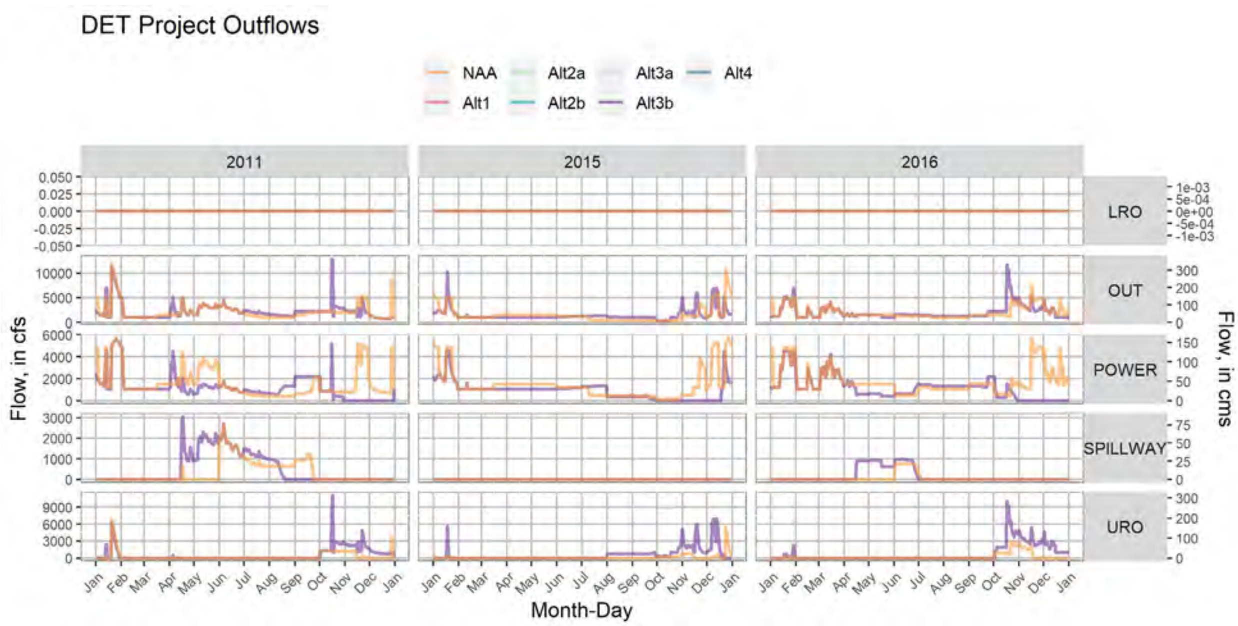

Figure 1-255. WV EIS RES-SIM Gate-Specific Outflows in 2011, 2015, and 2016 Under Alternative 3b and NAA.

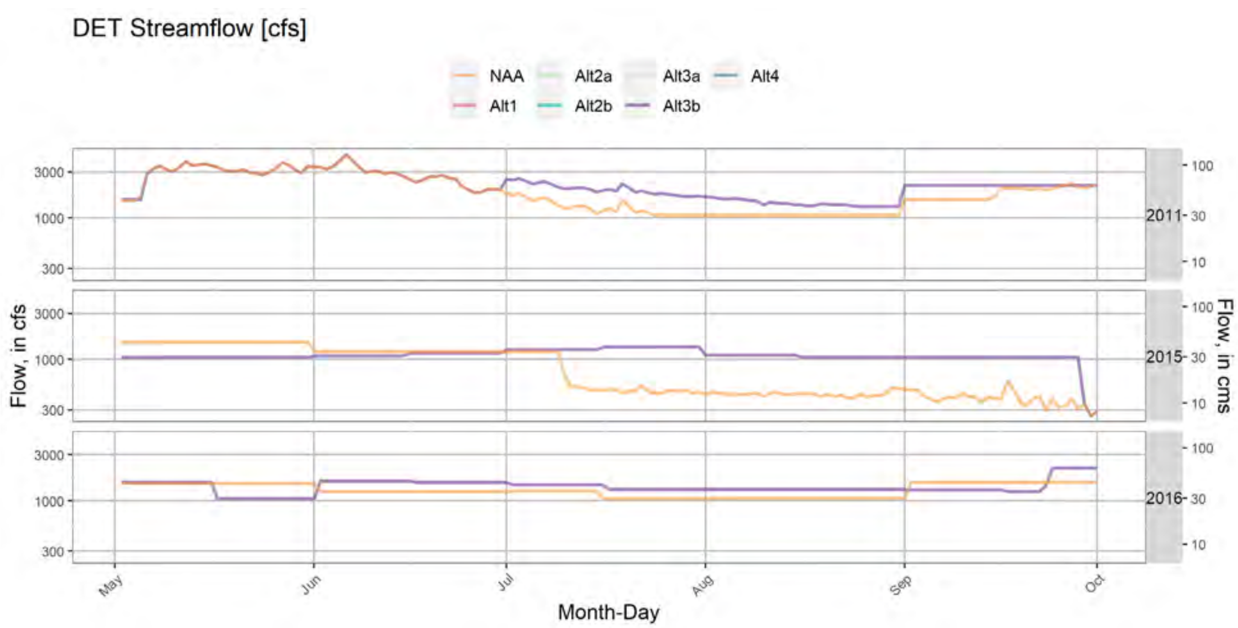

Figure 1-256. WV EIS RES-SIM Detroit Total Outflow in 2011, 2015, and 2016 Under Alternative 3b and NAA.

Lake Levels and Temperatures from CE-QUAL-W2

Depth-varying temperature, gate-specific outflows, and outflow temperatures through each calendar year scenario at Detroit Lake are shown in Figure 1-257, Figure 1-258, and Figure 1-259. Alternative 3b included releases through the spillway during spring-summer (when the lake was above the spillway crest) as well as releases through the Regulating Outlets during autumn to mix non-power releases with relatively deep power penstock releases to meet the downstream temperature target. Tailwater release temperatures generally matched the temperature target when sufficient warm or cool water was available and outlets were submerged. Spillway access was not available in 2015 and was limited in 2016 and 2011, which led to an abrupt drop in tailwater temperature when spillway access ended in mid-summer. This was followed by a large peak in tailwater temperature in the 2015 scenario during September-October as the lake was drafted at a relatively high outflow rate, effectively mixing the thermal layers near the dam (Figure 1-260, Figure 1-261). Lower RO (LRO) outlets were used in Alternative 3b as the CE-QUAL-W2 attempted to blend deeper, cooler water to meet the relatively cool temperature target; typically during late-September through mid-October. Generally, the autumn fish passage operation (drawdown to about the URO level) resulted in cooler autumn temperatures (November-December) compared to NAA (Figure 1-261).

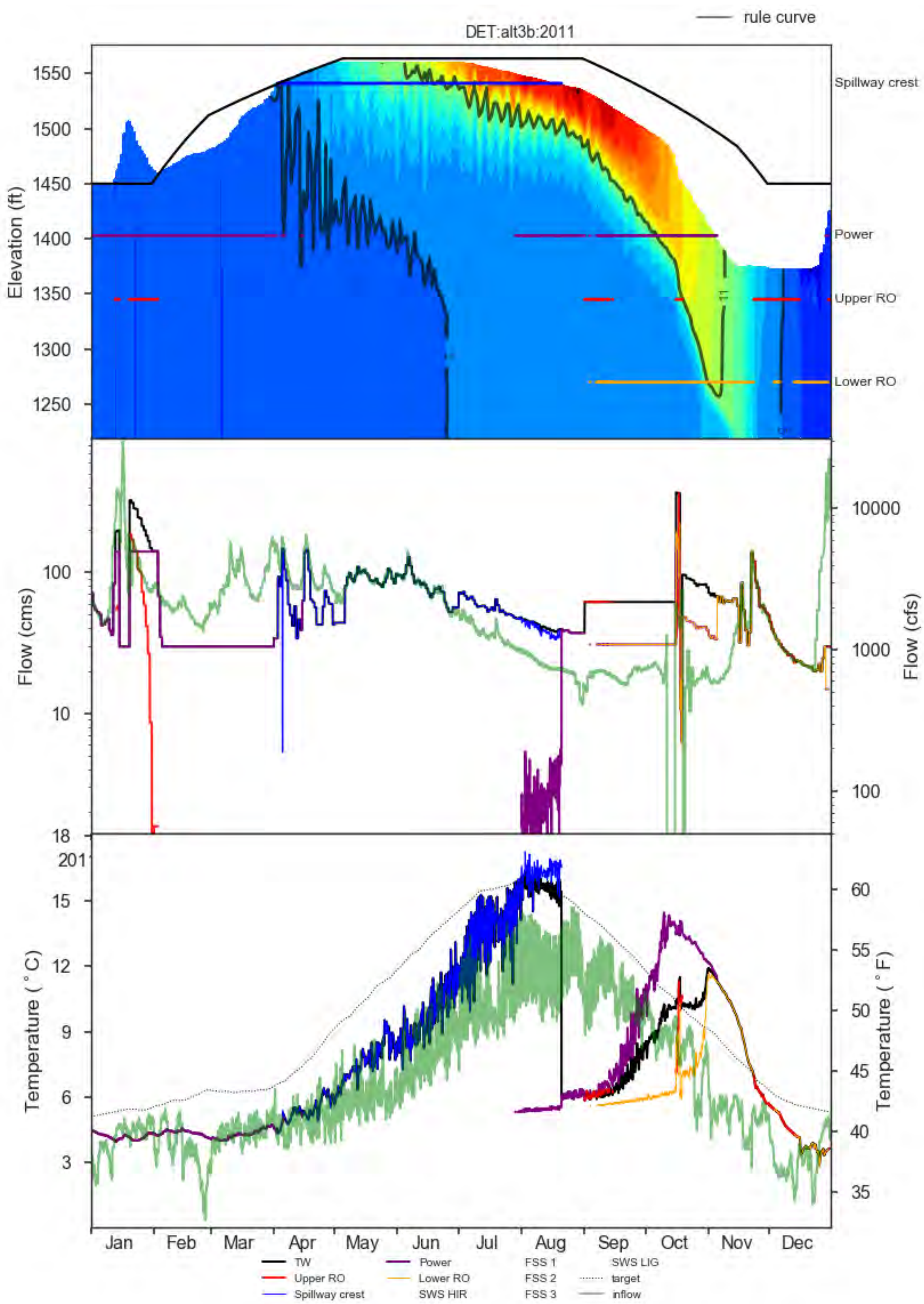

Figure 1-257. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at Detroit under Alternative 3b in 2011.

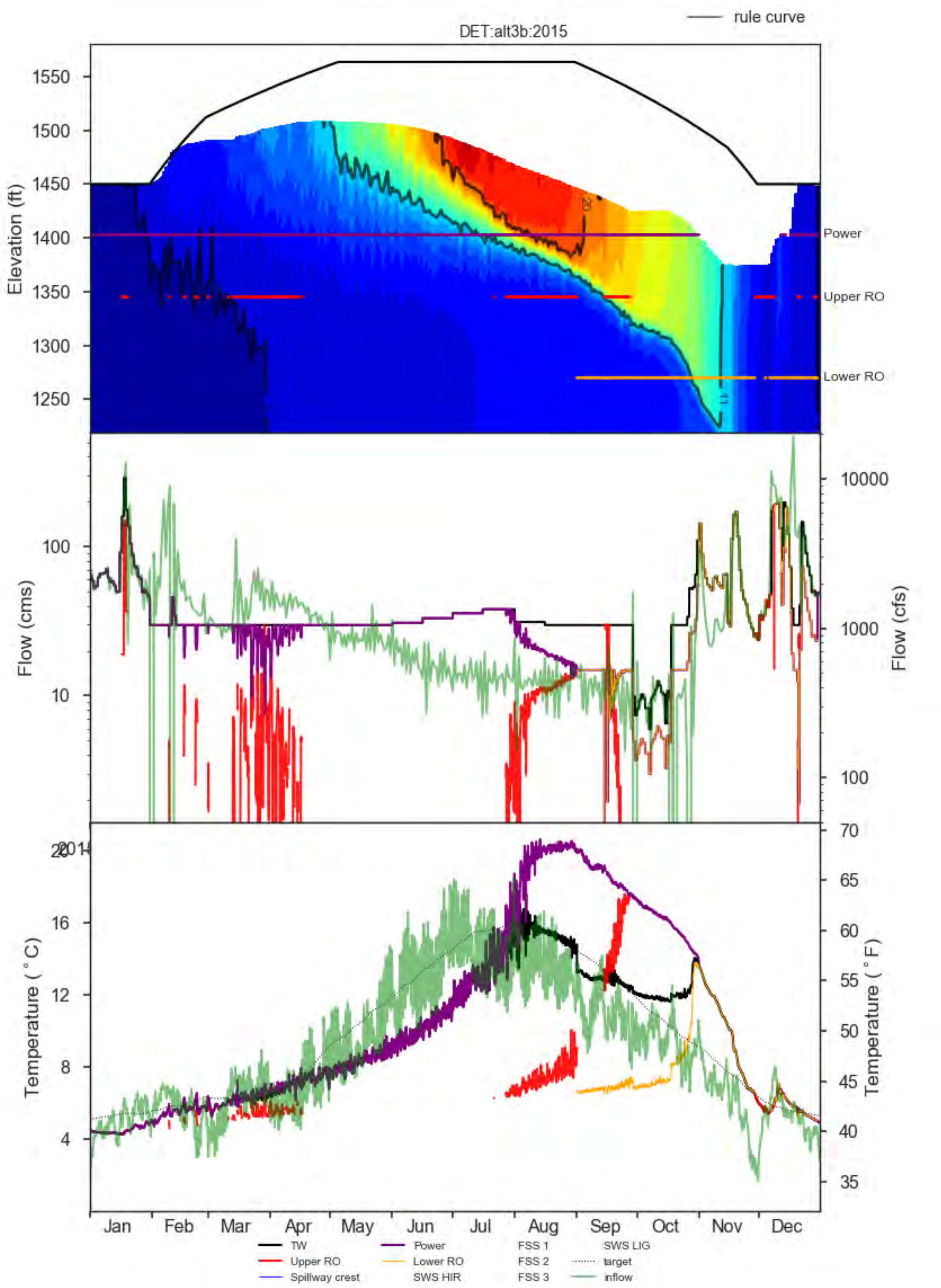

Figure 1-258. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at Detroit under Alternative 3b in 2015.

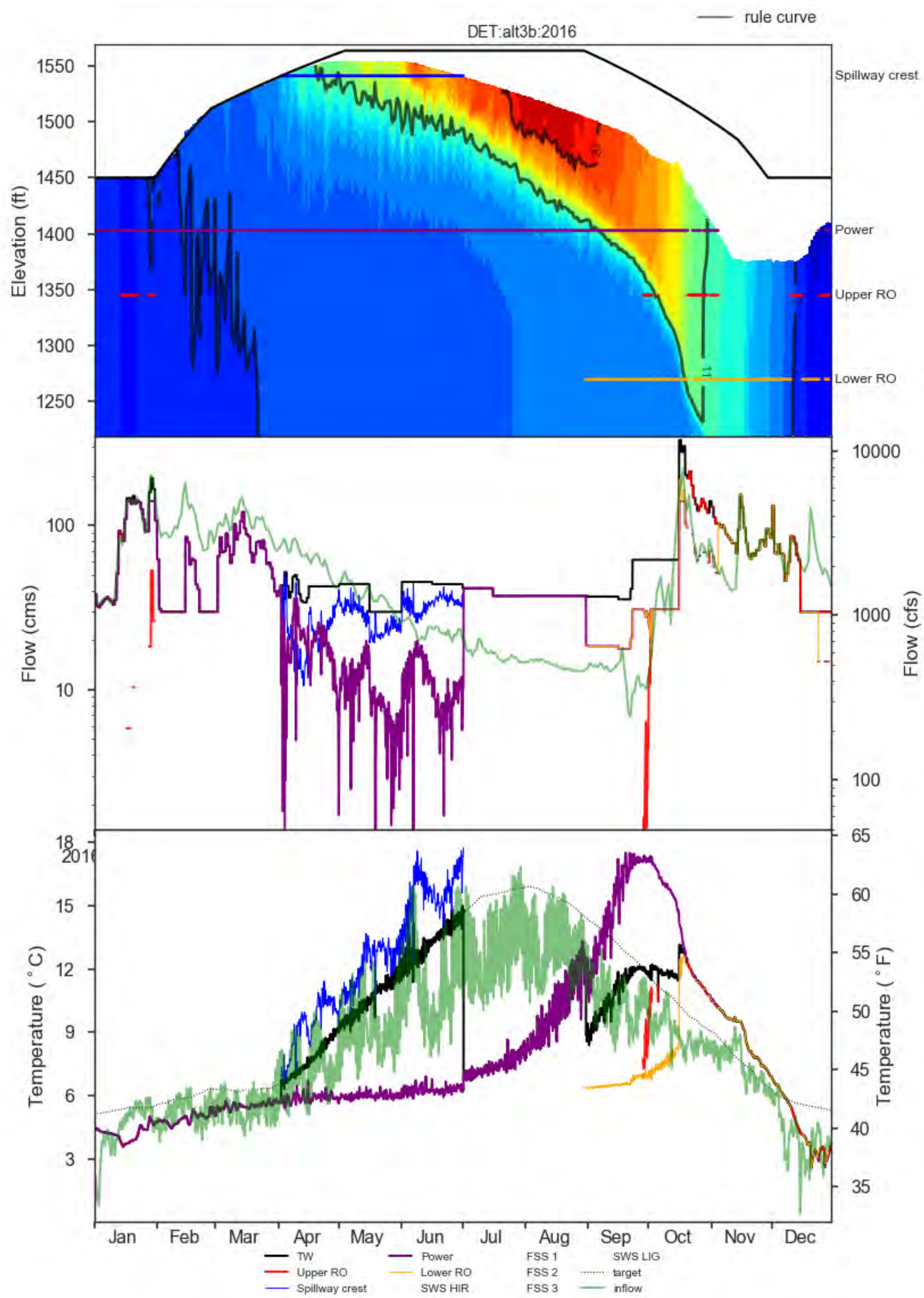

Figure 1-259. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at Detroit under Alternative 3b in 2016.

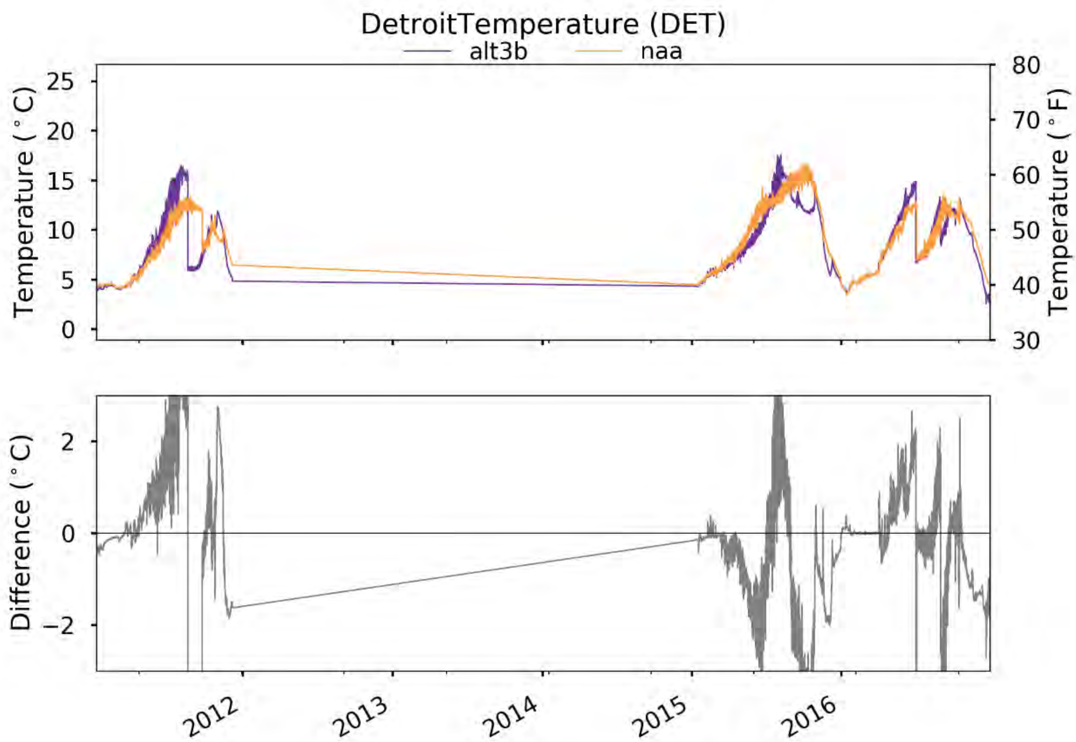

Figure 1-260. Comparison of DET outflow temperatures in NAA and Alternative 3b.

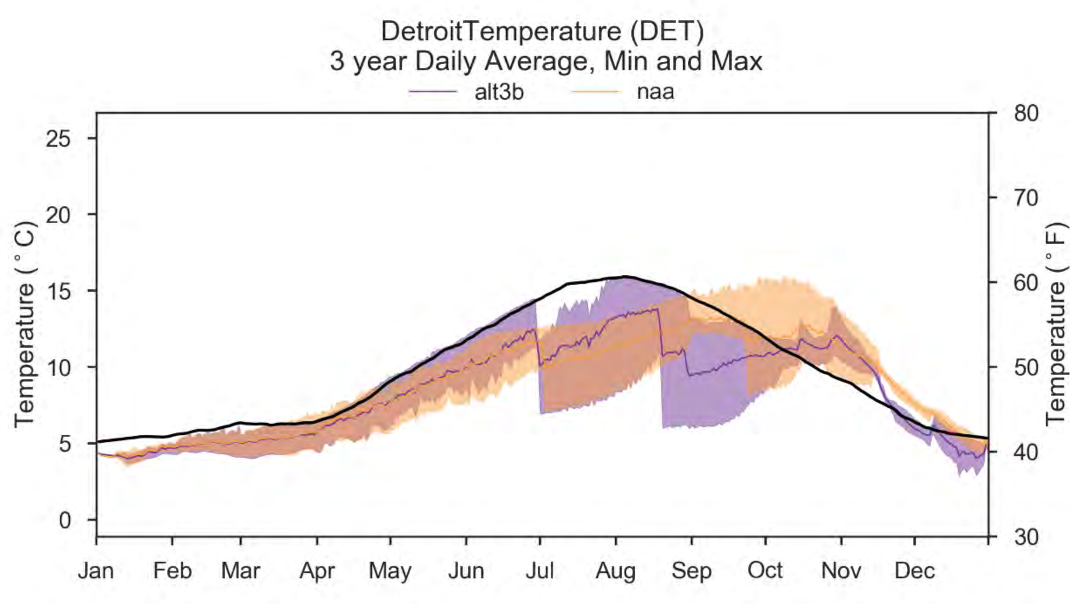

Figure 1-261. Comparison of DET 3-year Daily Average, Min, Max Outflow Temperatures in NAA and Alternative 3b. Black Line Indicates Temperature Target.

1.5.6.2 SOUTH SANTIAM DAMS

1.5.6.2.1 Green Peter

RES-SIM Lake Levels and Outflows

Lake level and storage at Green Peter Lake decreased in Alternative 3b compared to NAA in 2011, 2015 and 2016 as the lake was drafted for the proposed fish passage operation through the ROs (Figure 1-262, Figure 1-263, Figure 1-264). The decreased storage coincided with reduced outflows during May-October comparing Alternative 3b to NAA (Figure 1-264).

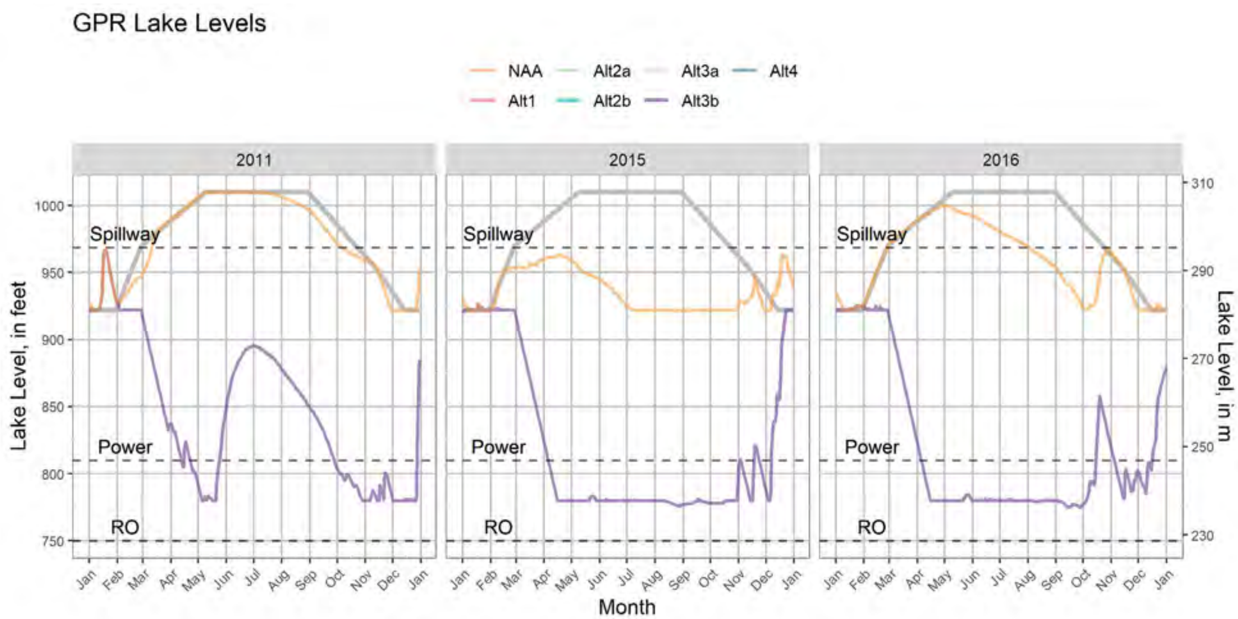

Figure 1-262. WV EIS RES-SIM Green Peter Lake Levels in 2011, 2015, and 2016 Under Alternative 3b and NAA.

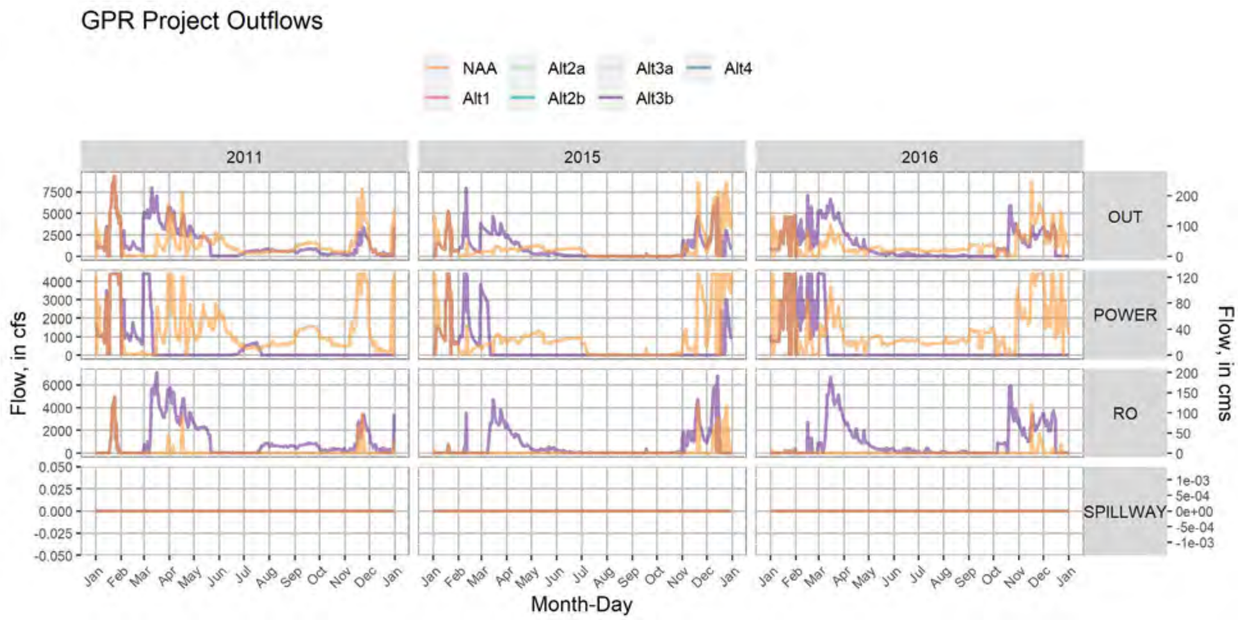

Figure 1-263. WV EIS RES-SIM Green Peter Dam Gate-Specific Outflows in 2011, 2015, and 2016 under Alternative 3b and NAA.

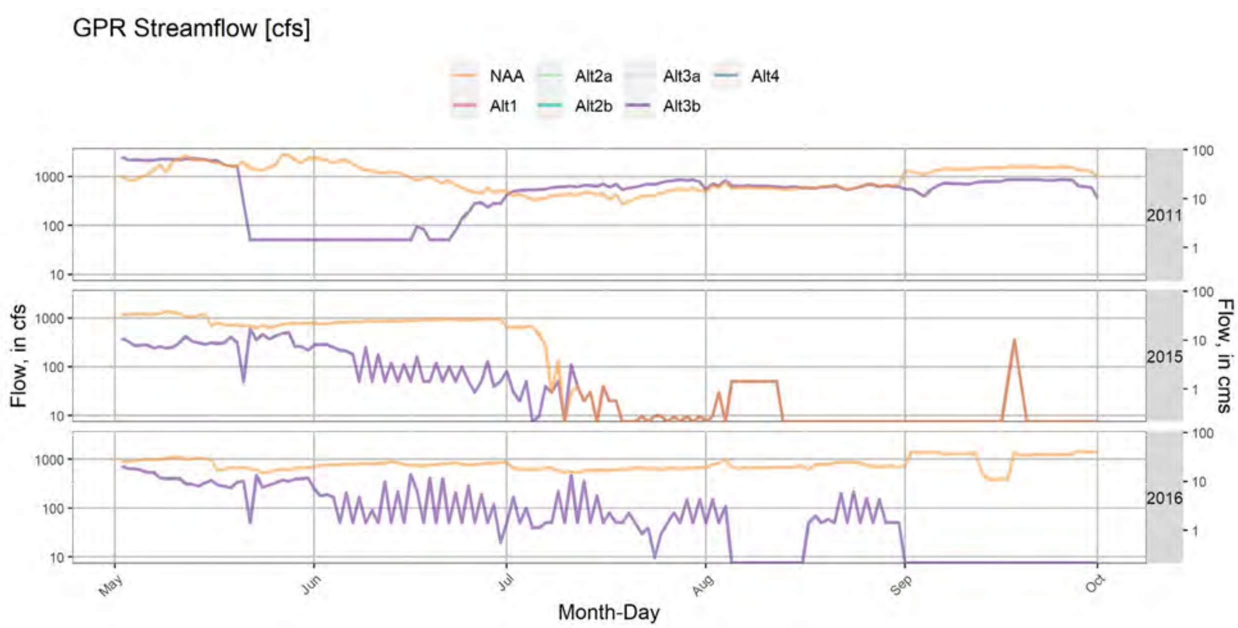

Figure 1-264. WV EIS RES-SIM Green Peter Dam Total Outflow in 2011, 2015, and 2016 under Alternative 3b and NAA.

Lake Levels and Temperatures from CE-QUAL-W2

Depth-varying temperature, gate-specific outflows, and outflow temperatures through each calendar year scenario at Detroit Lake are shown in Figure 1-265, Figure 1-266, and Figure 1-267. Outflow temperatures from Green Peter Dam in Alternative 3b were generally warmer than NAA May-September and cooler than NAA October-December in 2011, 2015, and 2016 as the lake surface area, volume, and residence time decreased and releases were generally through the ROs for fish passage operations (Figure 1-268, Figure 1-269).

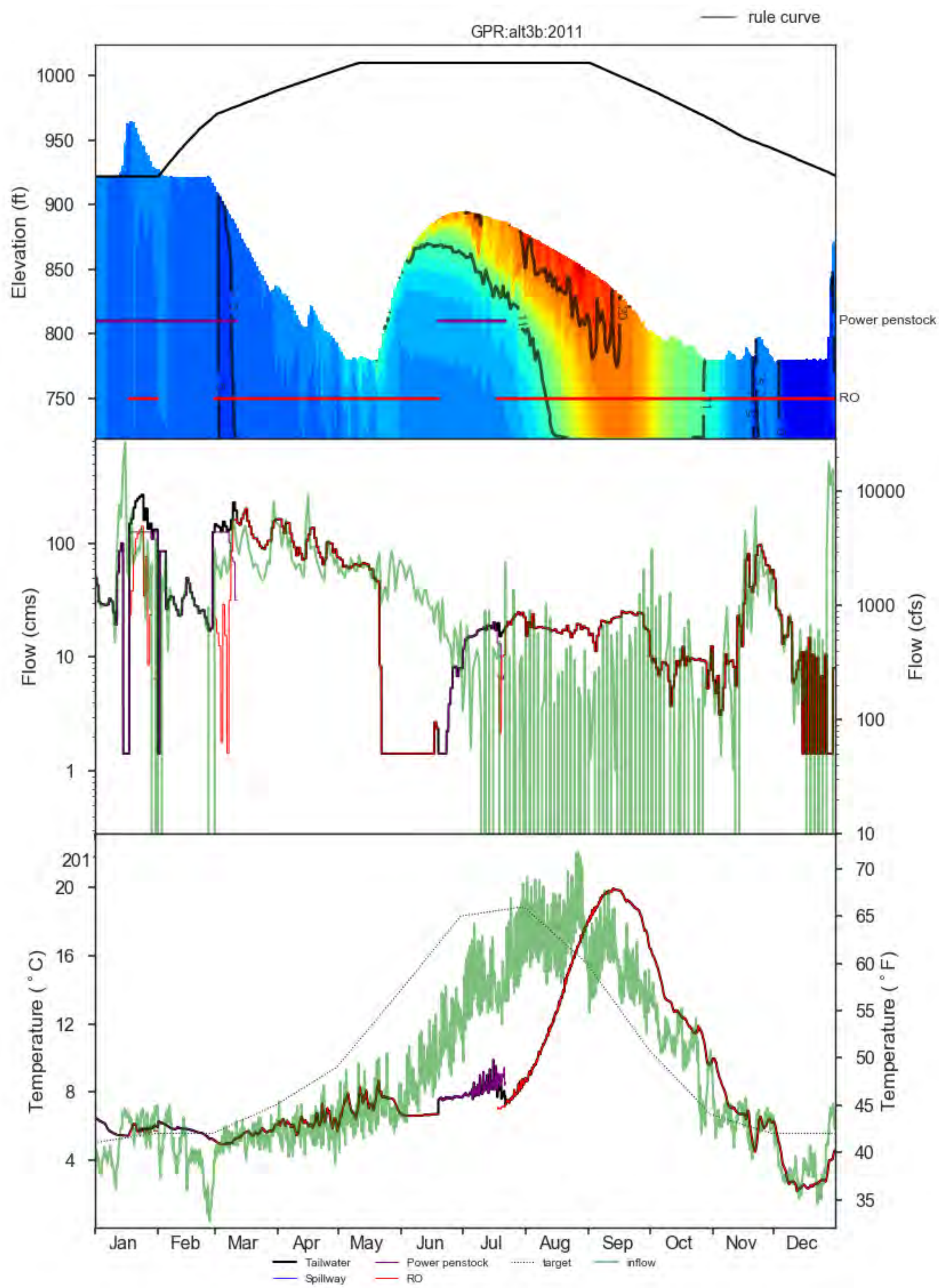

Figure 1-265. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at GPR under Alternative 3b in 2011.

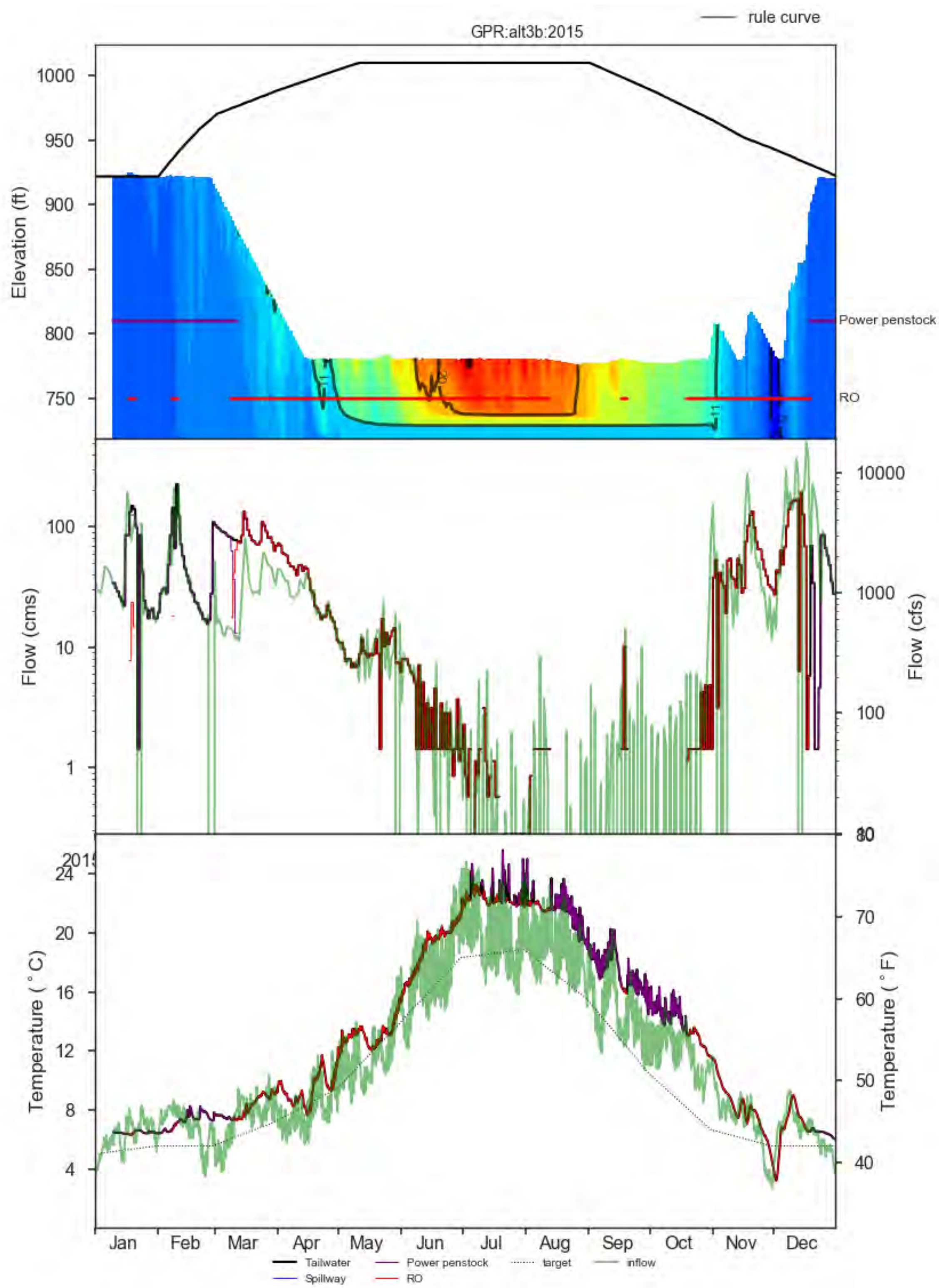

Figure 1-266. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at GPR under Alternative 3b in 2015.

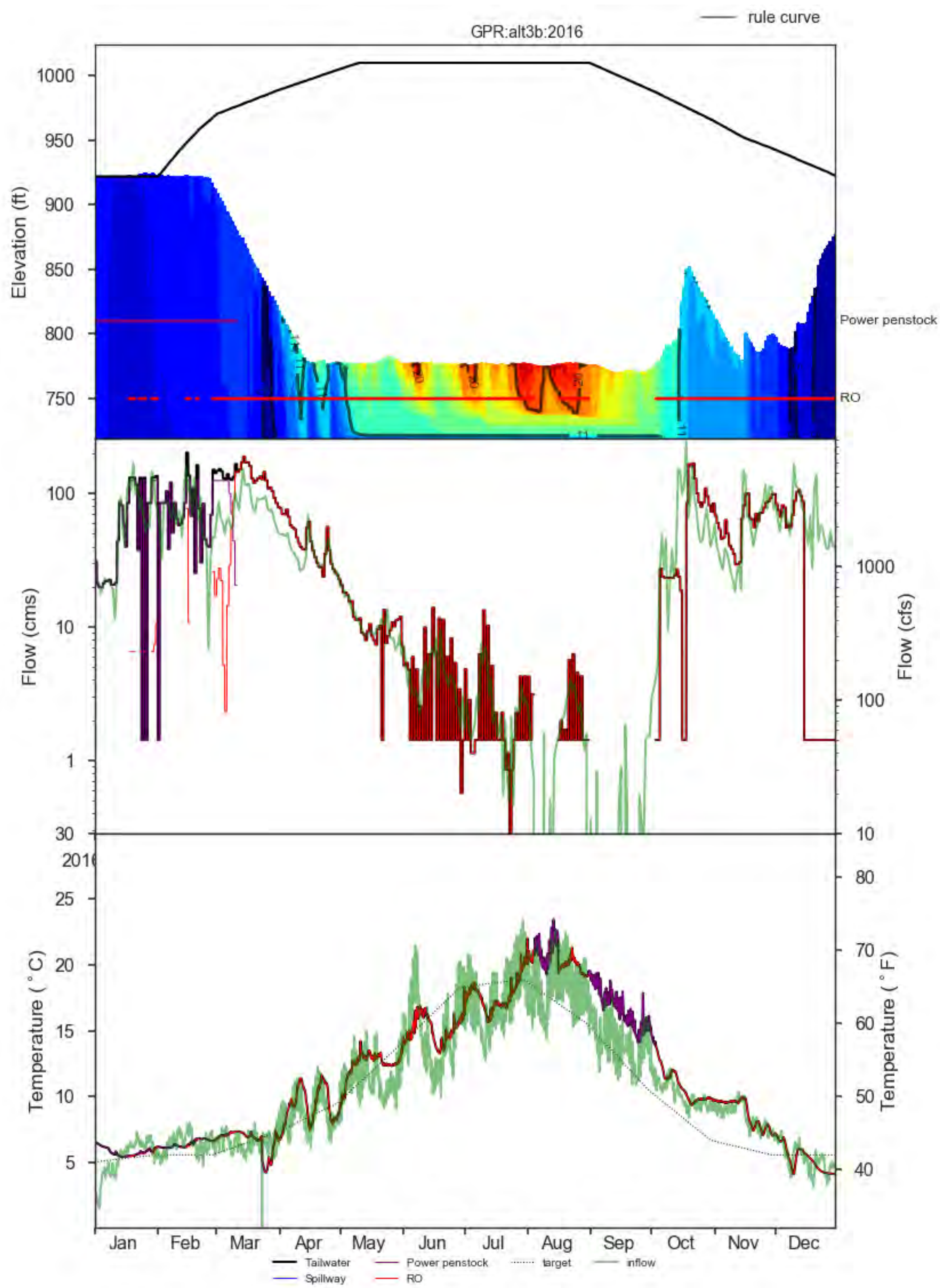

Figure 1-267. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at GPR under Alternative 3b in 2016.

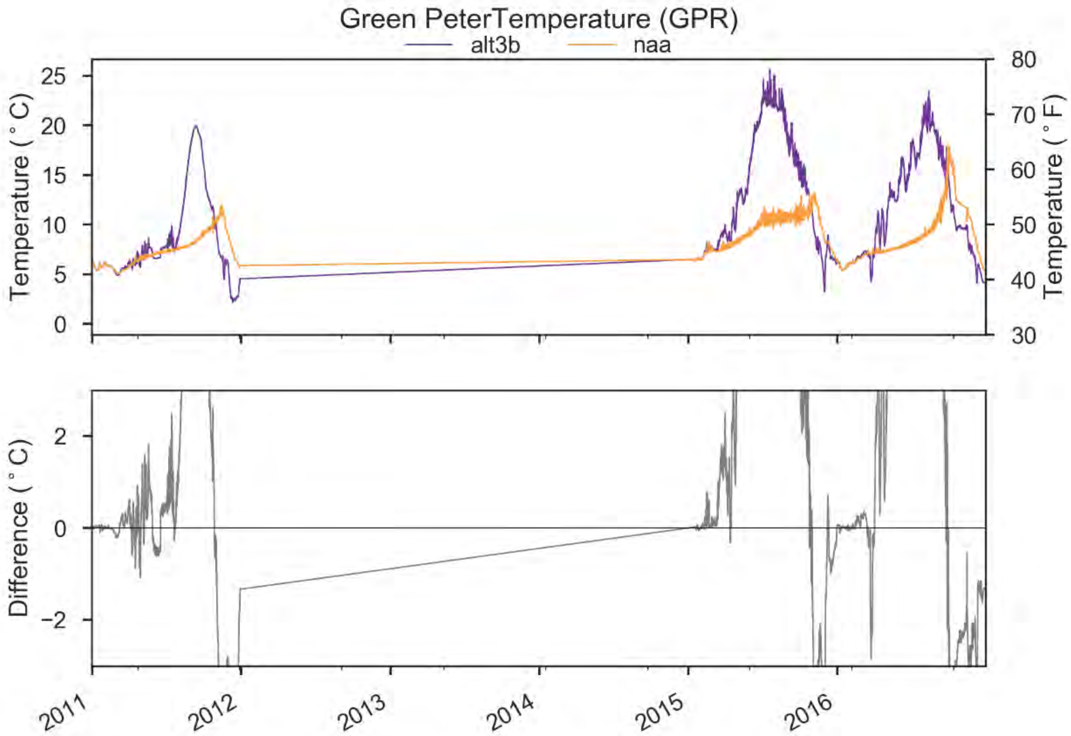

Figure 1-268. Comparison of GPR Outflow Temperatures in NAA and Alternative 3b.

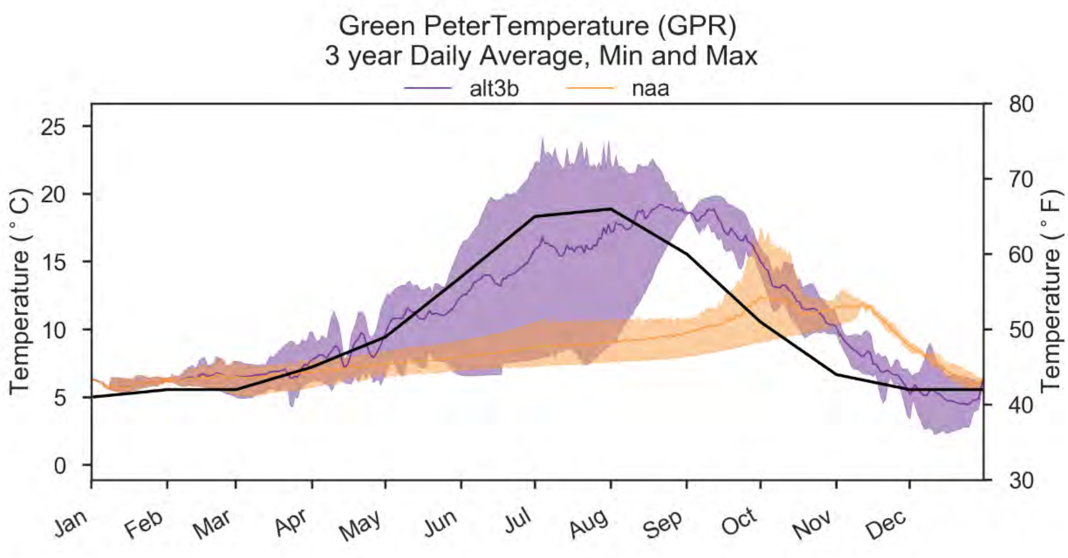

Figure 1-269. Comparison of GPR 3-year Daily Average, Min, Max Outflow Temperatures in NAA and Alternative 3b. Black Line Indicates Temperature Target.

1.5.6.2.2 Foster

RES-SIM Lake Levels and Outflows

Lake level and storage at Foster were generally lower in Alternative 3b compared to NAA in 2015 and 2016 but similar to NAA in 2011 (Figure 1-218, Figure 1-219, and Figure 1-220). Upstream flows from Green Peter were reduced in Alternative 3b, which resulted in early drafting of Foster Lake as RES-SIM rules attempted to meet downstream flow targets. Total outflow from Foster Dam was generally decreased May-October in Alternative 3b compared to NAA.

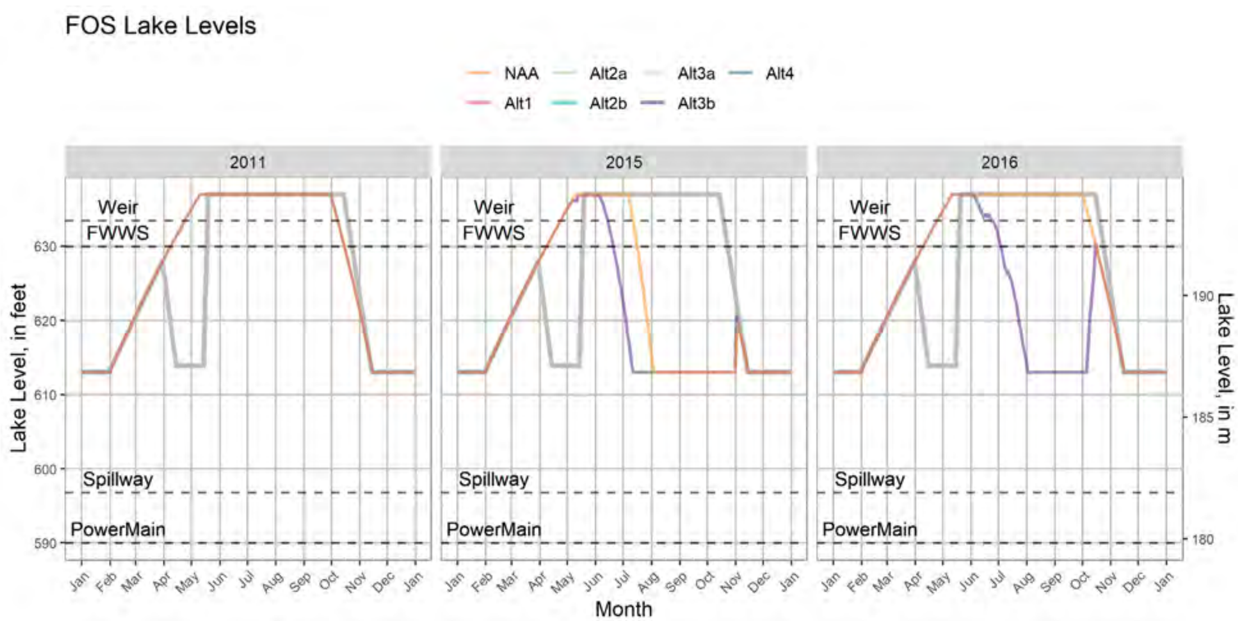

Figure 1-270. WV EIS RES-SIM Foster Lake Levels in 2011, 2015, and 2016 Under Alternative 3b and NAA.

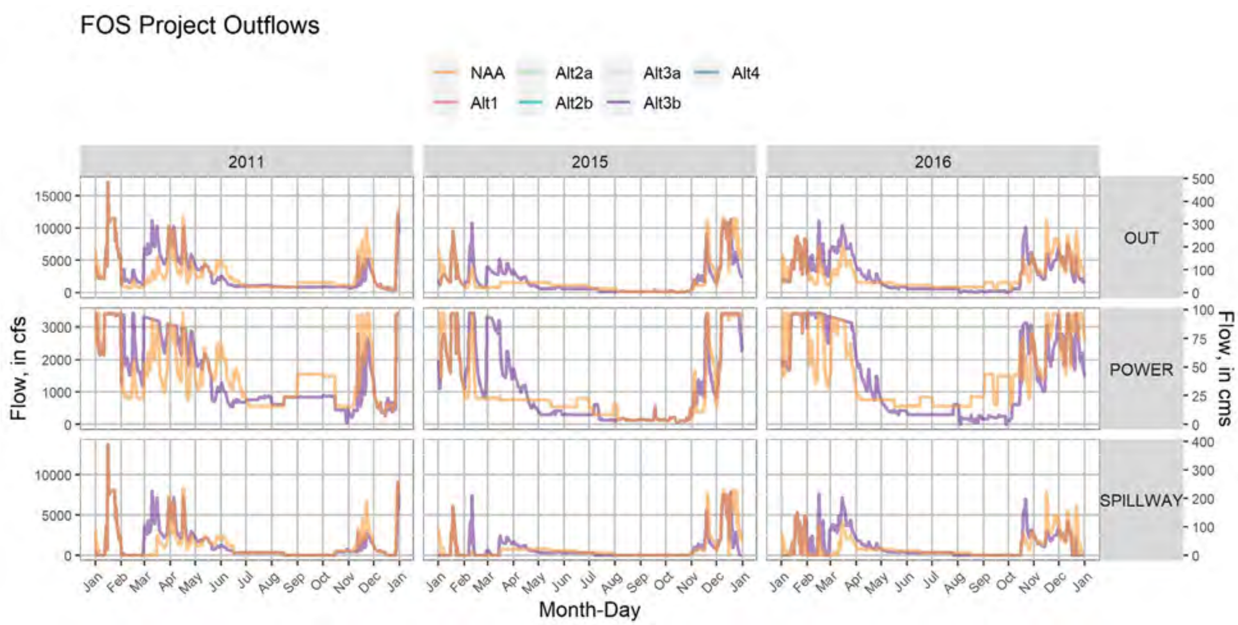

Figure 1-271. WV EIS RES-SIM Foster Dam Gate-Specific Outflows in 2011, 2015, and 2016 under Alternative 3b and NAA.

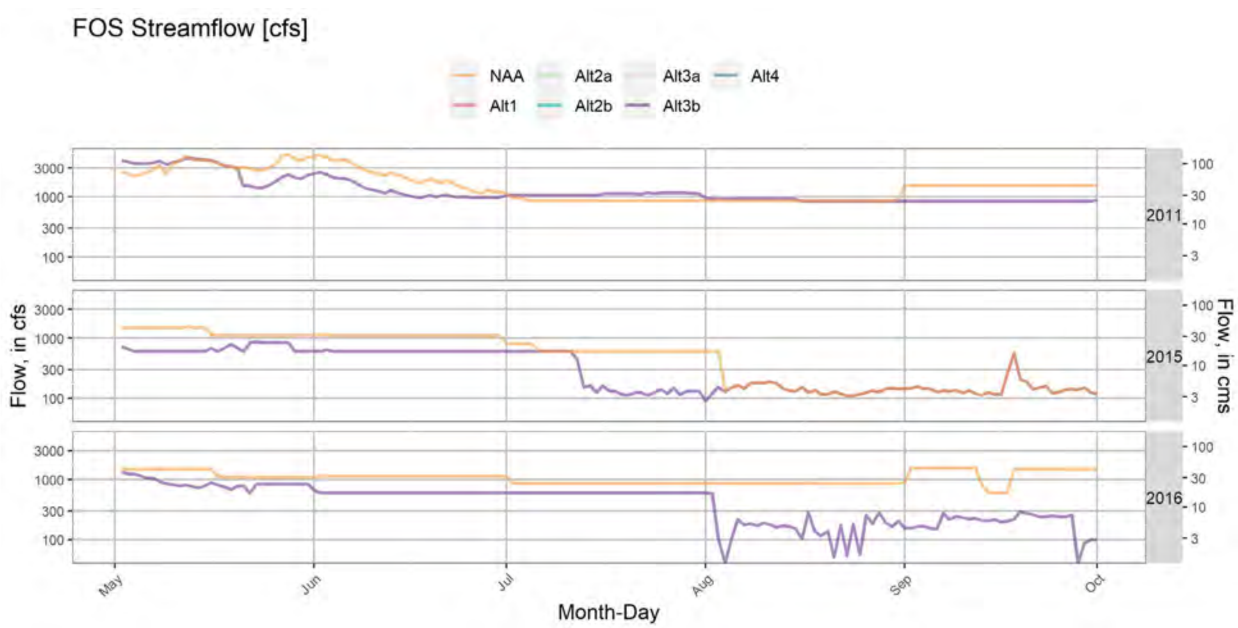

Figure 1-272. WV EIS RES-SIM Foster Dam Total Outflow in 2011, 2015, and 2016 Under Alternative 3b and NAA.

Lake Levels and Temperatures from CE-QUAL-W2

Depth-varying temperature, gate-specific outflows, and outflow temperatures through each calendar year scenario at Foster Lake are shown in Figure 1-270, Figure 1-271, and Figure 1-272. Foster Lake temperature was affected by Green Peter Dam operations release temperatures, generally resulting in travel times through Foster of 10-20 days during summer and a time lag in the temperature pattern (Sullivan and Rounds, 2021). Relatively warmer spillway releases from Green Peter upstream resulted in warmer tailwater temperature in May-October comparing Alternative 3b to NAA (Figure 1-273, Figure 1-274). Generally, the extended drawdown to the RO at Green Peter upstream resulted in warmer tailwater temperature in May-October and cooler autumn temperatures (November-December) compared to NAA downstream of Foster Dam.

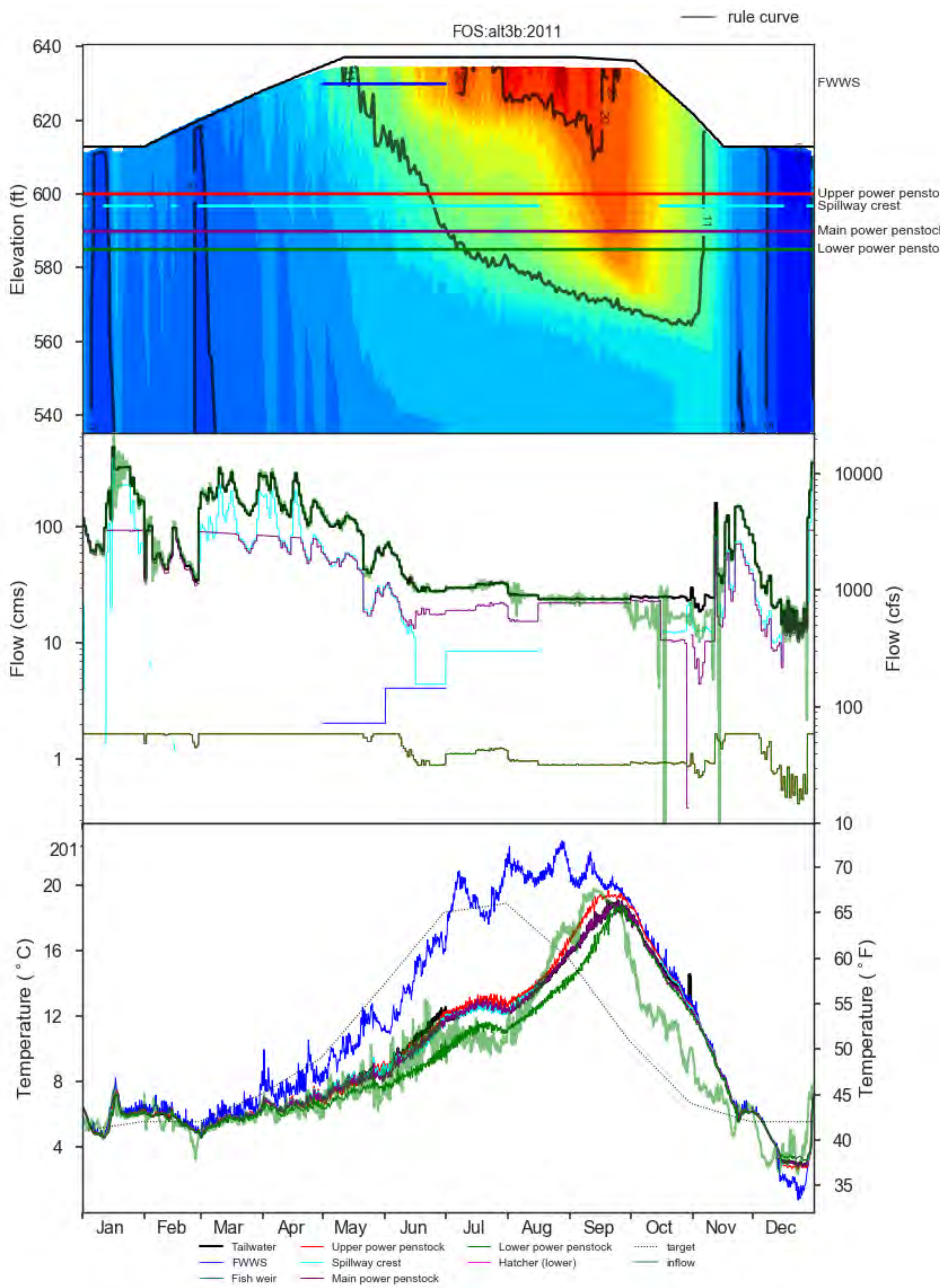

Figure 1-273. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at FOS under Alternative 3b in 2011.

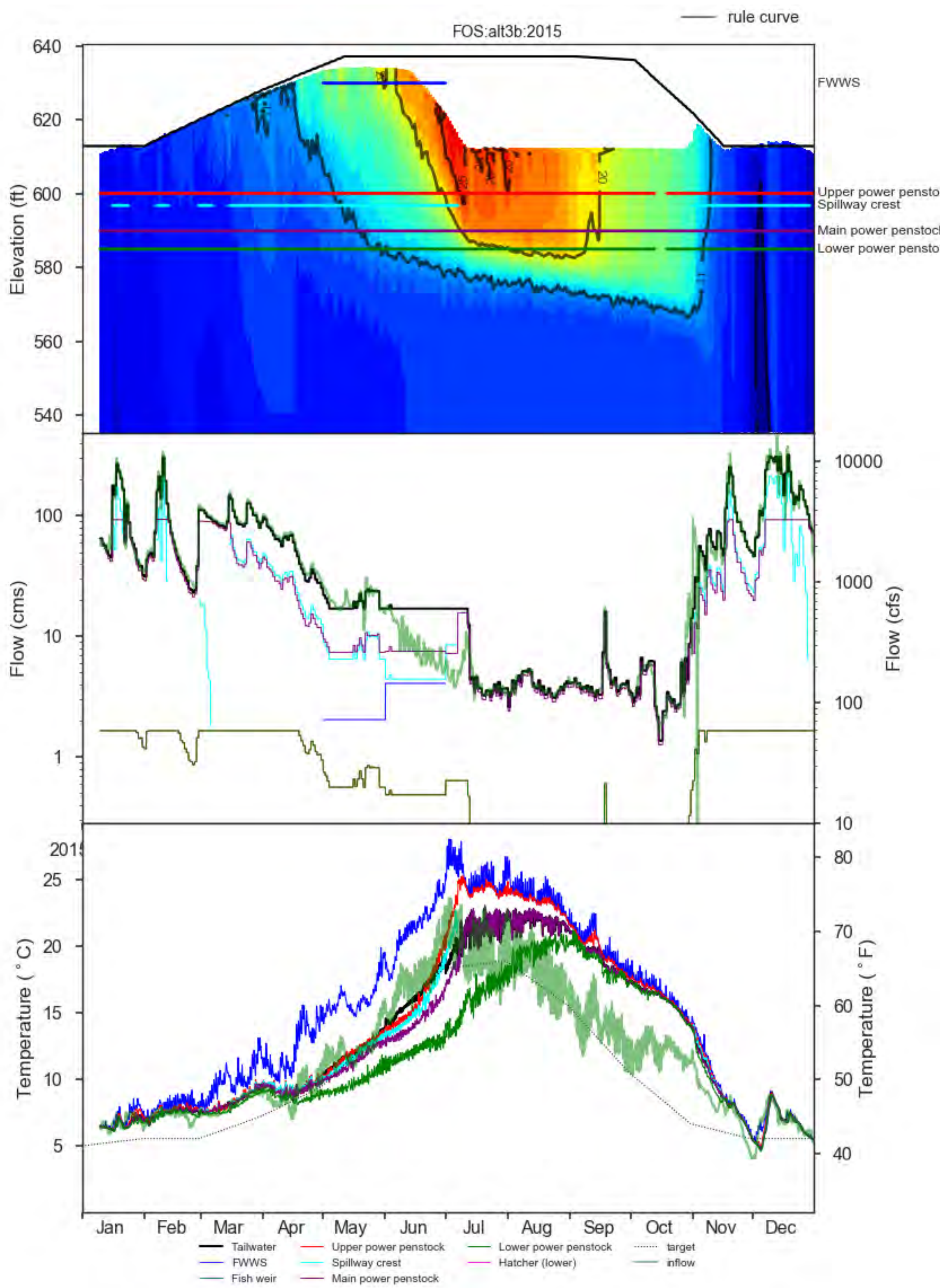

Figure 1-274. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at FOS under Alternative 3b in 2015.

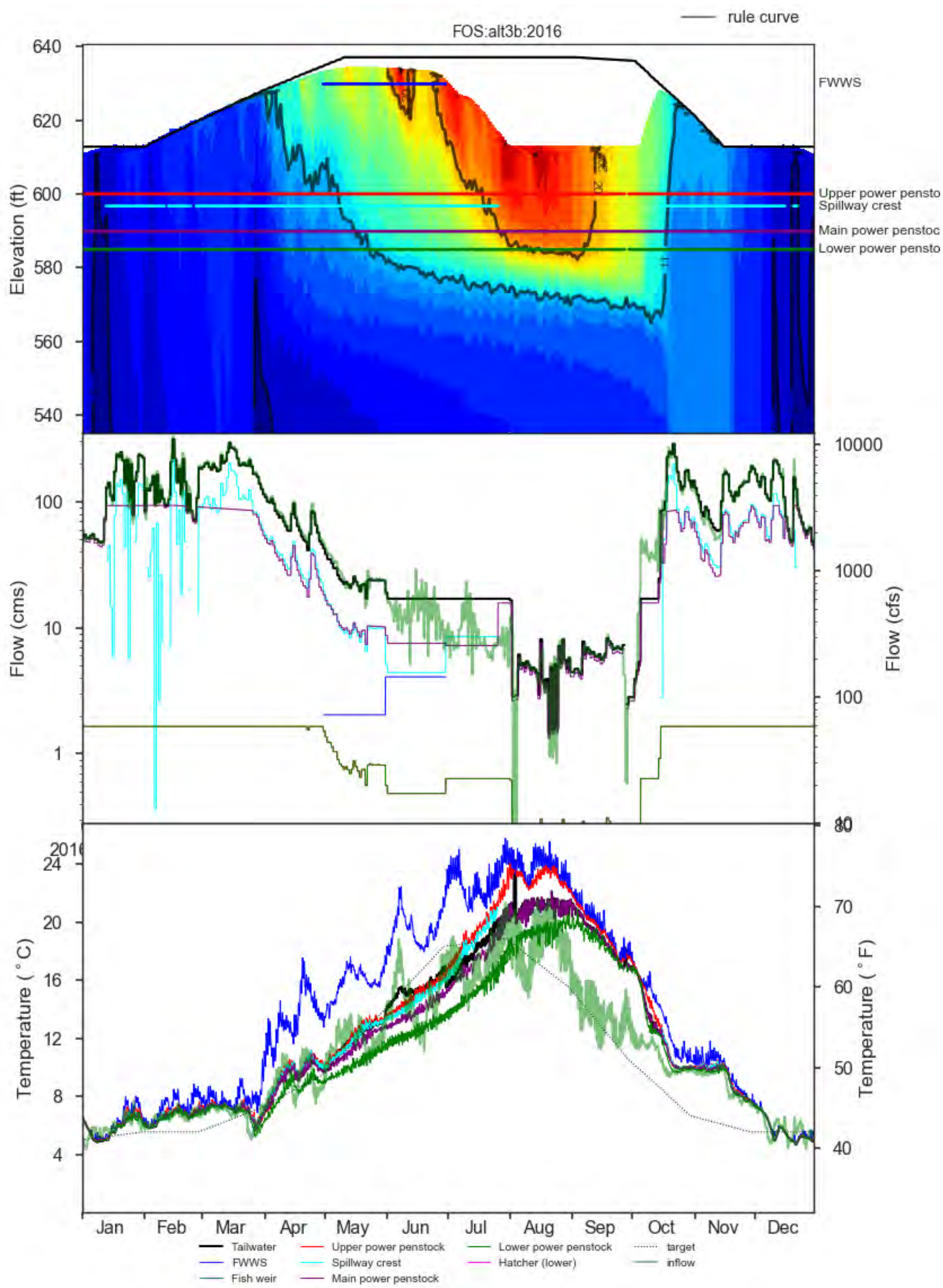

Figure 1-275. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at FOS under Alternative 3b in 2016.

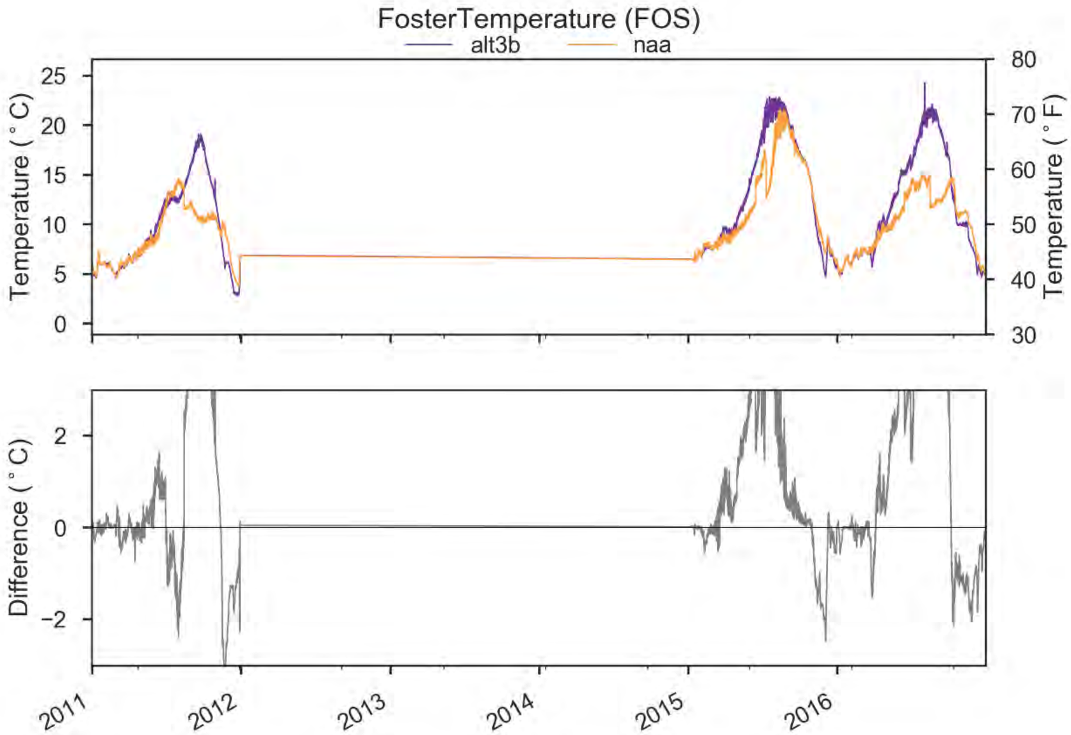

Figure 1-276. Comparison of FOS outflow temperatures in NAA and Alternative 3b.

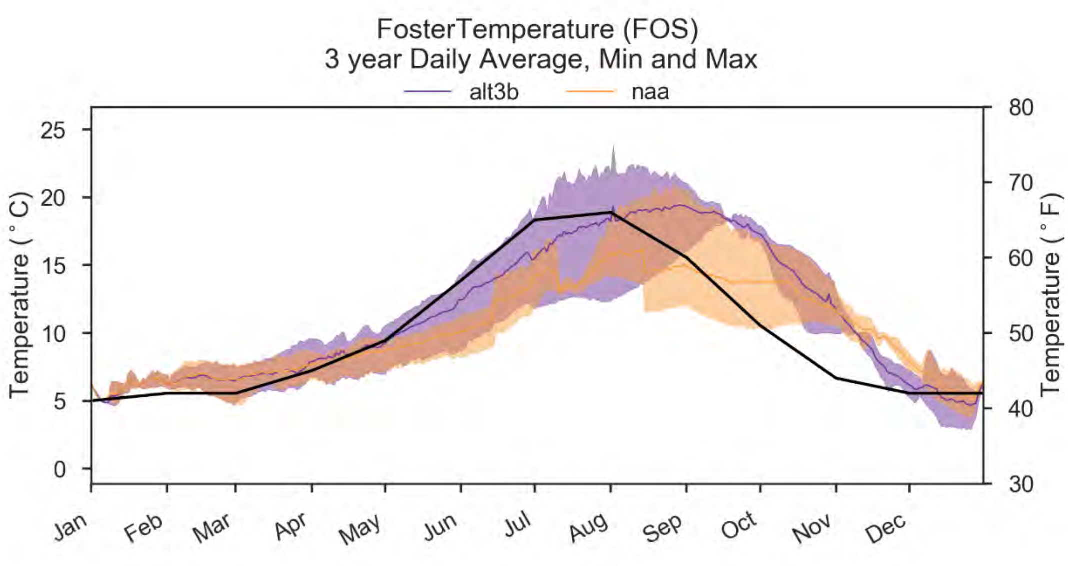

Figure 1-277. Comparison of FOS 3-year Daily Average, Min, Max Outflow Temperatures in NAA and Alternative 3b. Black Line Indicates Temperature Target.

1.5.6.3 MCKENZIE DAMS

1.5.6.3.1 Cougar

RES-SIM Lake Levels and Outflows

Lake level and storage at Cougar Lake decreased significantly under Alternative 3b compared to NAA in 2011, 2015, and 2016 to allow for proposed fish passage operations through the diversion tunnel (Figure 1-278, Figure 1-279, Figure 1-280). The decreased storage coincided with reduced outflows during spring and summer (Figure 1-279). Outflows were primarily routed through the diversion tunnel in Alternative 2b, except when the lake refilled to about 30 feet above the RO intake (e.g., 2011).

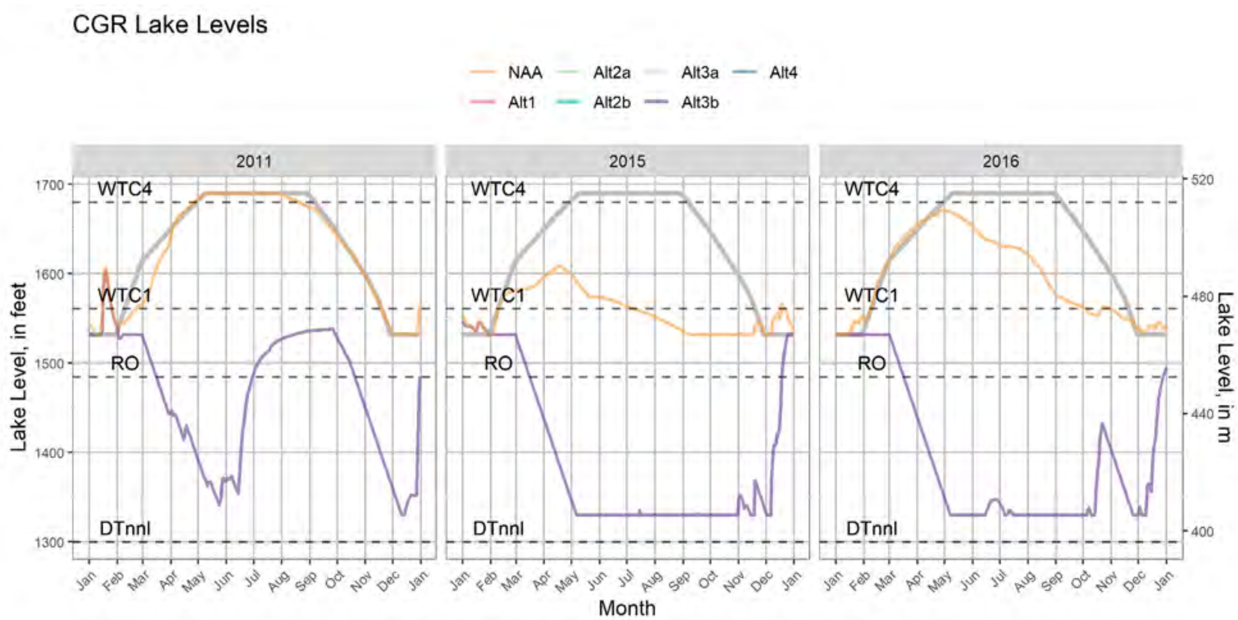

Figure 1-278. WV EIS RES-SIM Cougar Lake Levels in 2011, 2015, and 2016 Under Alternative 3b and NAA.

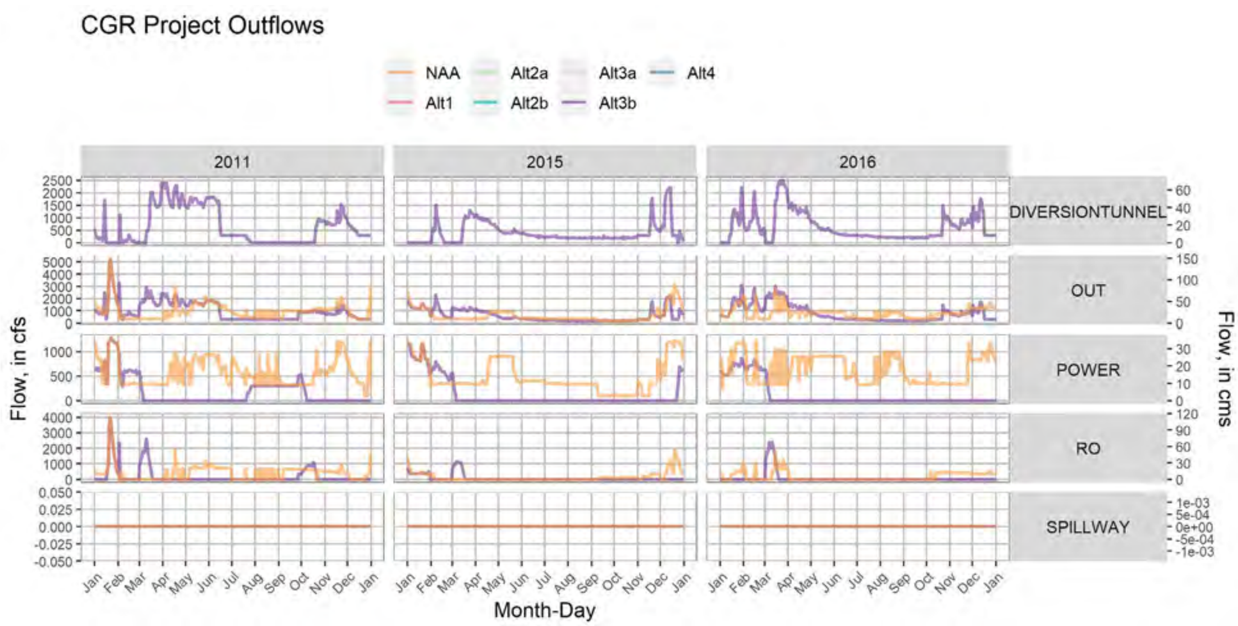

Figure 1-279. WV EIS RES-SIM Cougar Dam Gate-Specific Outflows in 2011, 2015, and 2016 under Alternative 3b and NAA.

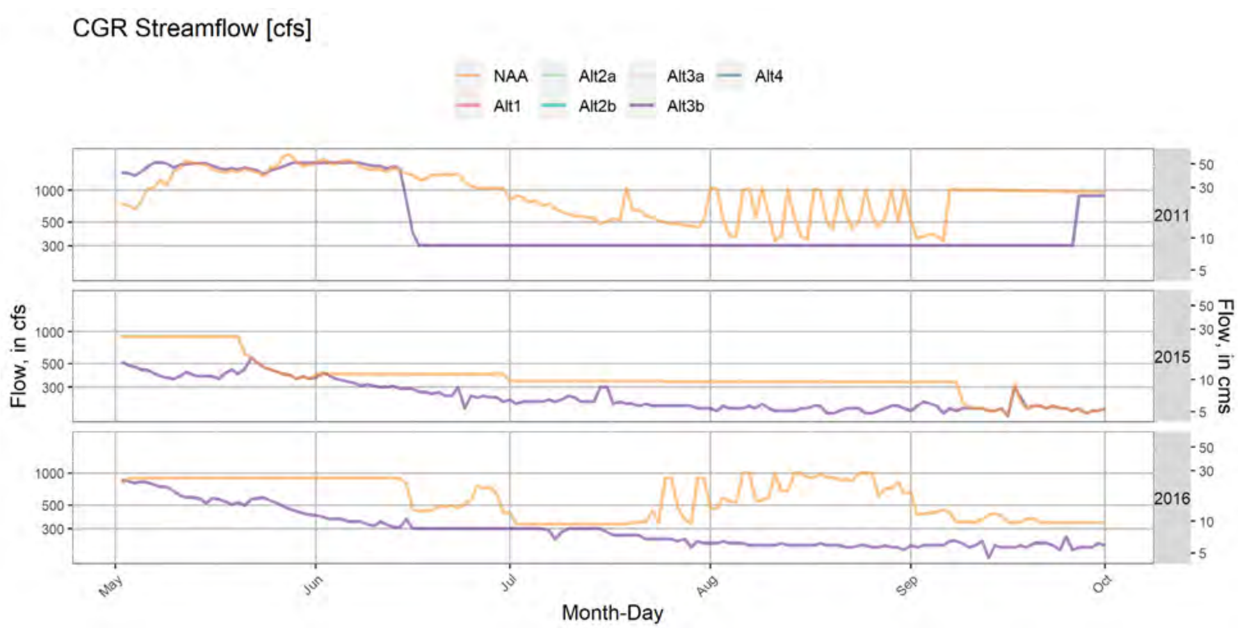

Figure 1-280. WV EIS RES-SIM Cougar Dam Total Outflow in 2011, 2015, and 2016 under Alternative 3b and NAA.

Lake Levels and Temperatures from CE-QUAL-W2

Depth-varying temperature, gate-specific outflows, and outflow temperatures through each calendar year scenario in Alternative 3b at Cougar Lake are shown in Figure 1-281, Figure 1-282, and Figure 1-283. Outflow temperatures from Cougar Dam in Alternative 3b were cooler than NAA year-round in 2011, 2015, and 2016 as the lake surface area, volume, and residence time decreased (Figure 1-284, Figure 1-285).

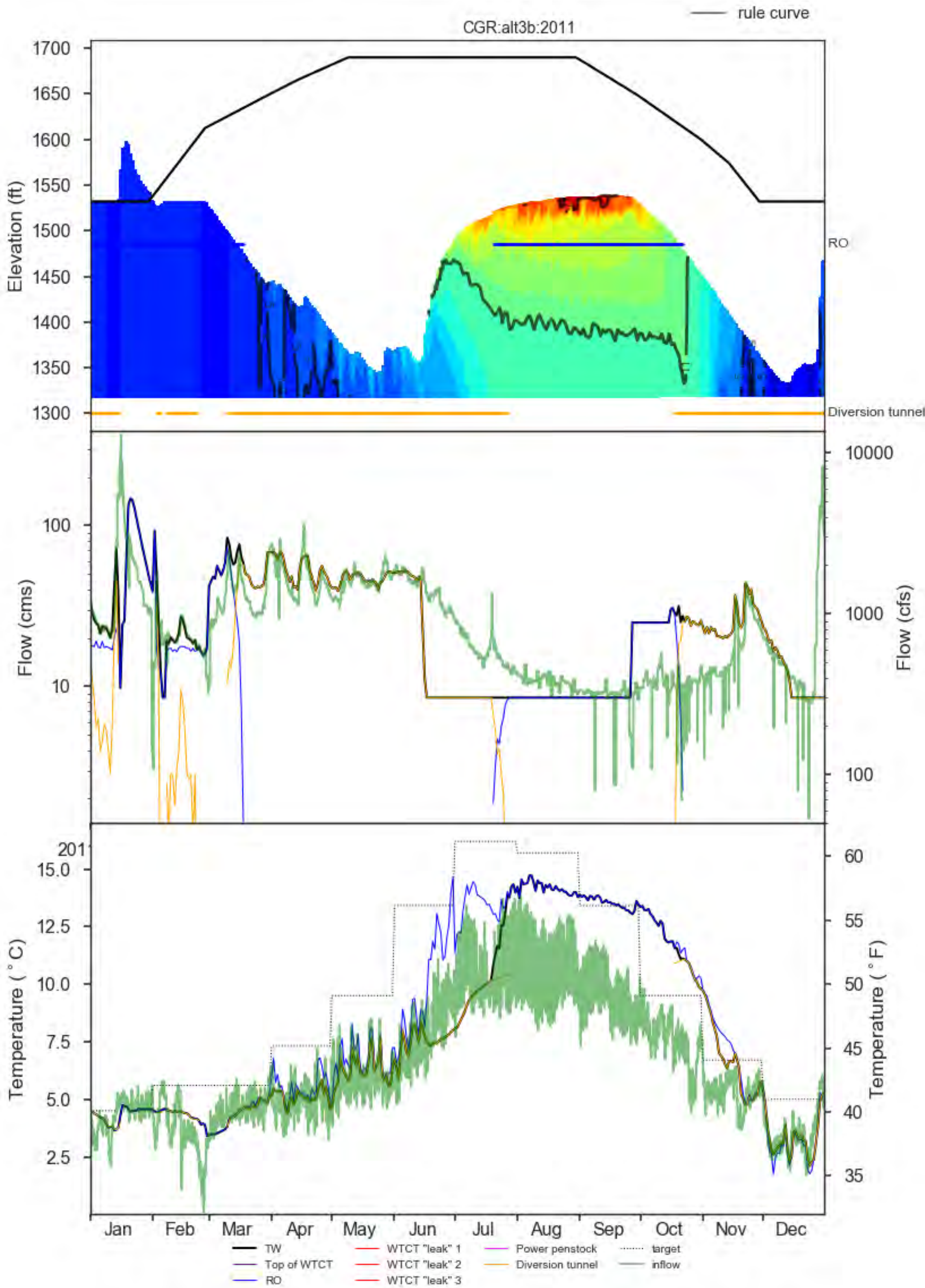

Figure 1-281. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at CGR under Alternative 3b in 2011.

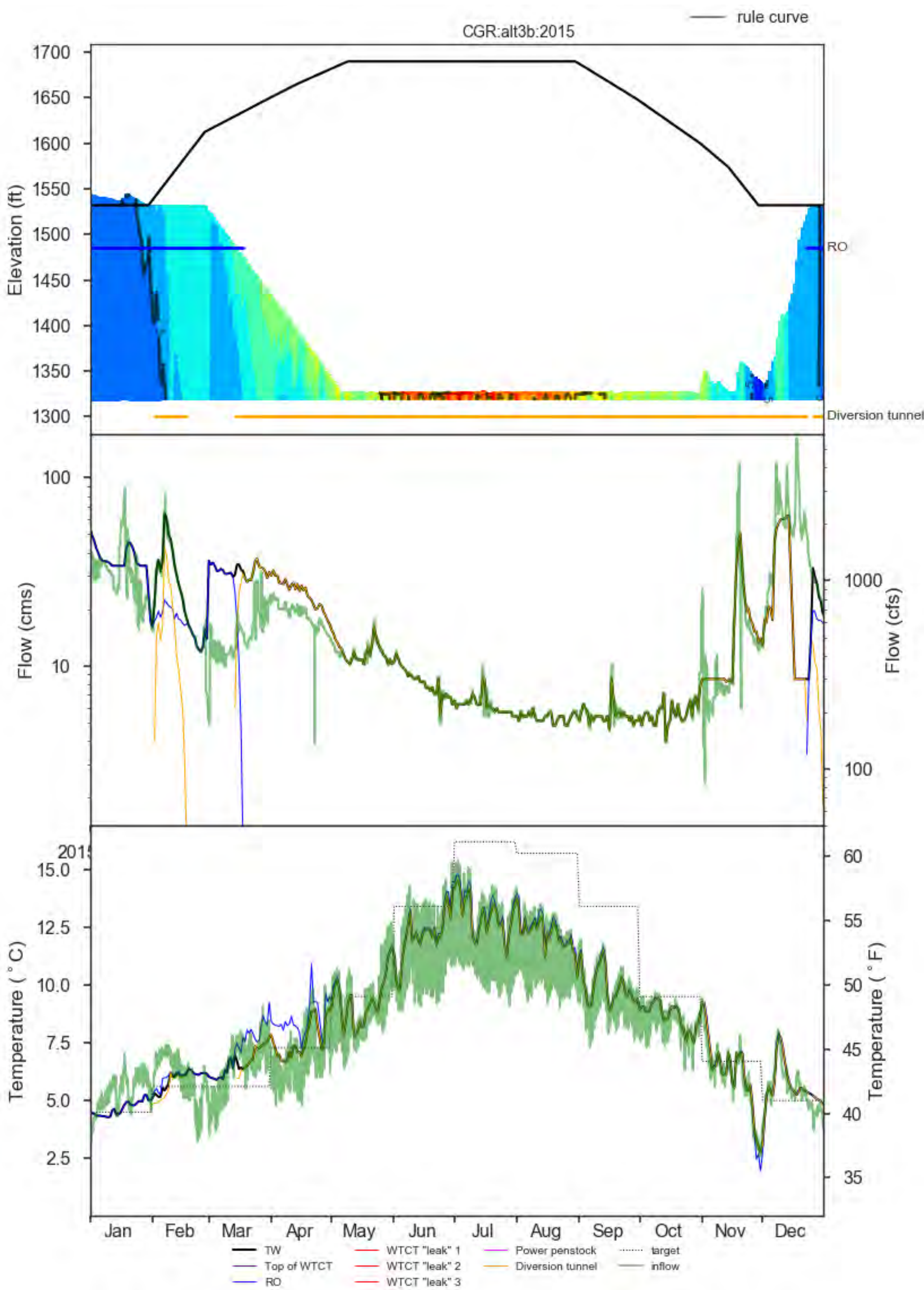

Figure 1-282. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at CGR under Alternative 3b in 2015.

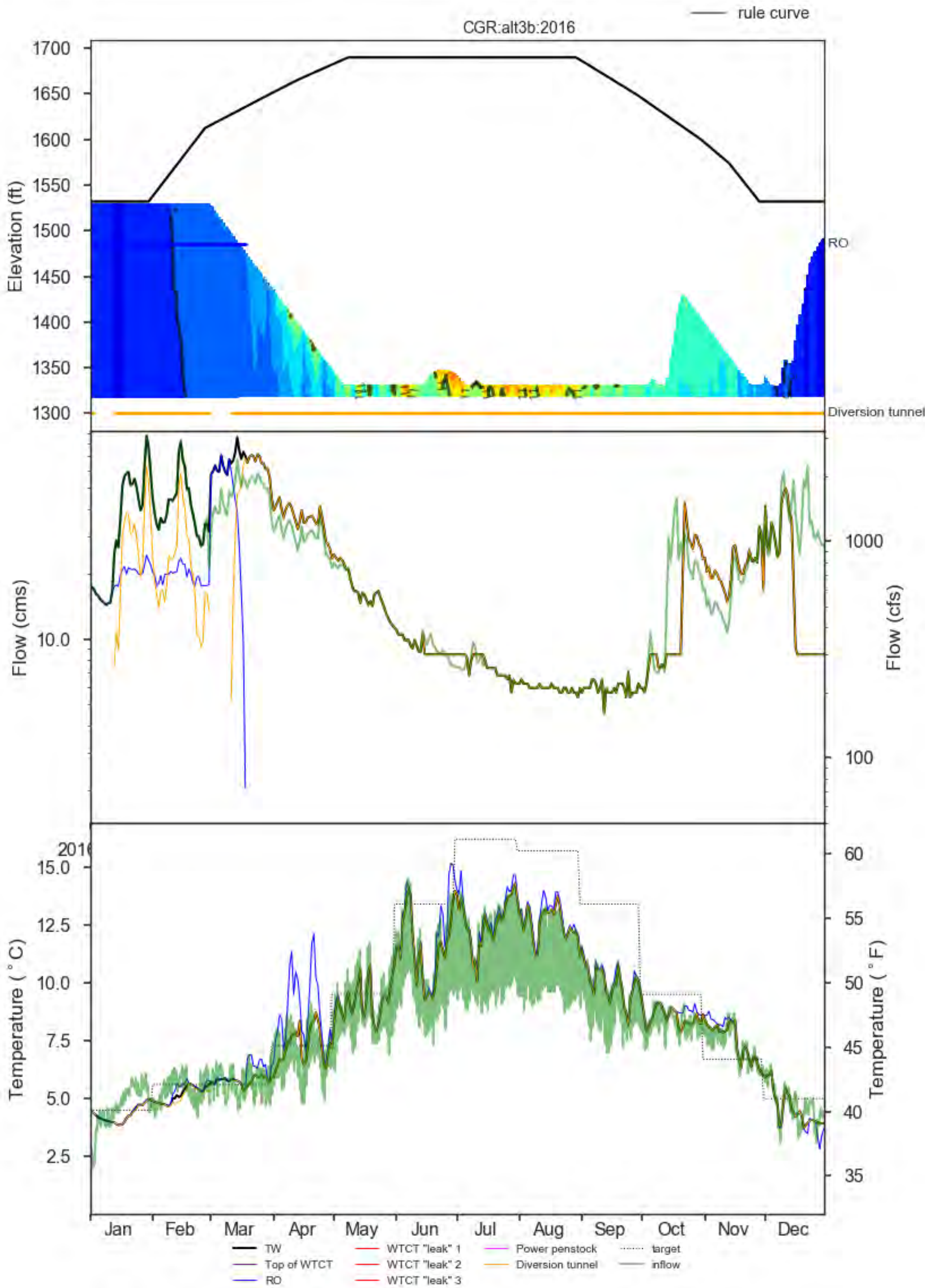

Figure 1-283. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at CGR under Alternative 3b in 2016.

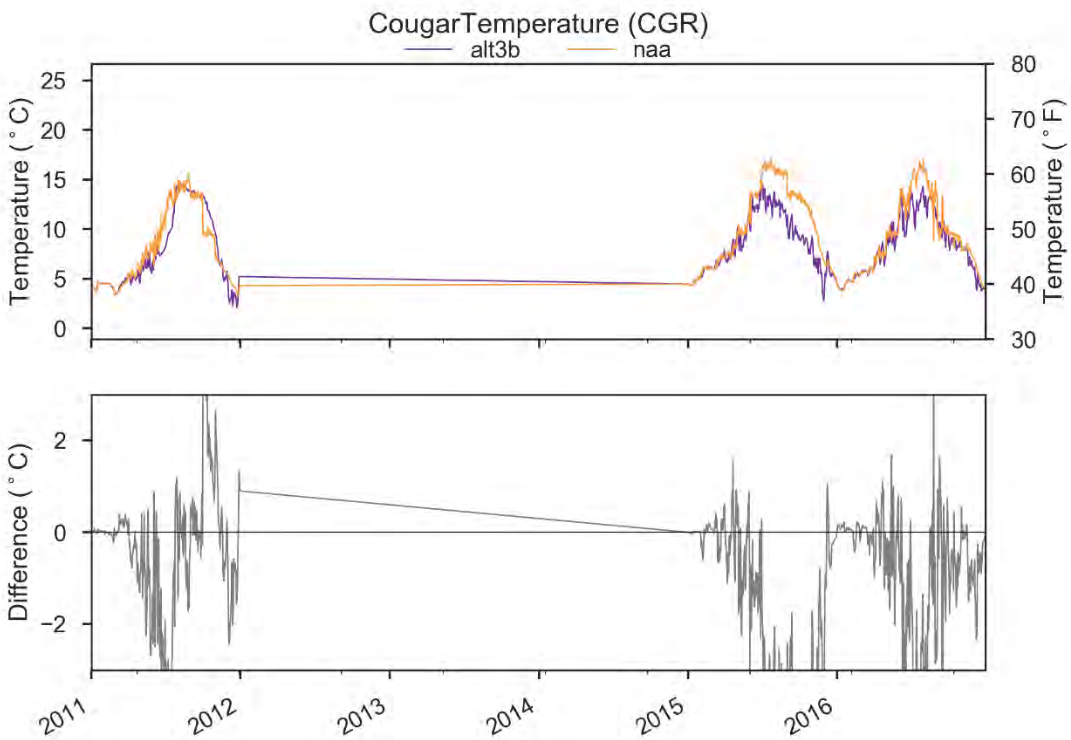

Figure 1-284. Comparison of CGR Outflow Temperatures in NAA and Alternative 1.

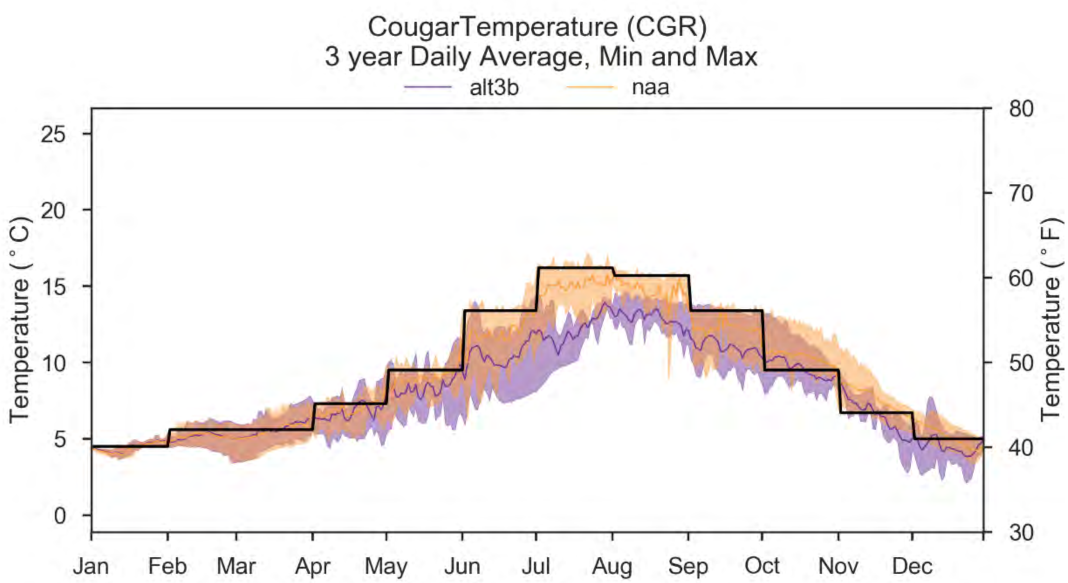

Figure 1-285. Comparison of CGR 3-year Daily Average, Min, Max Outflow Temperatures in NAA and Alternative 3b. Black Line Indicates Temperature Target.

1.5.6.4 MIDDLE FORK WILLAMETTE DAMS

1.5.6.4.1 Hills Creek

RES-SIM Lake Levels and Outflows

Lake level and storage at Hills Creek Lake generally decreased under Alternative 3b compared to NAA in 2015 and 2016 aside from August-November in 2015 when multiple measures were utilized related to fish passage and downstream flow targets (Figure 1-286, Figure 1-287, and Figure 1-288). The decreased storage generally coincided with reduced outflows comparing Alternative 3b to NAA (Figure 1-288).

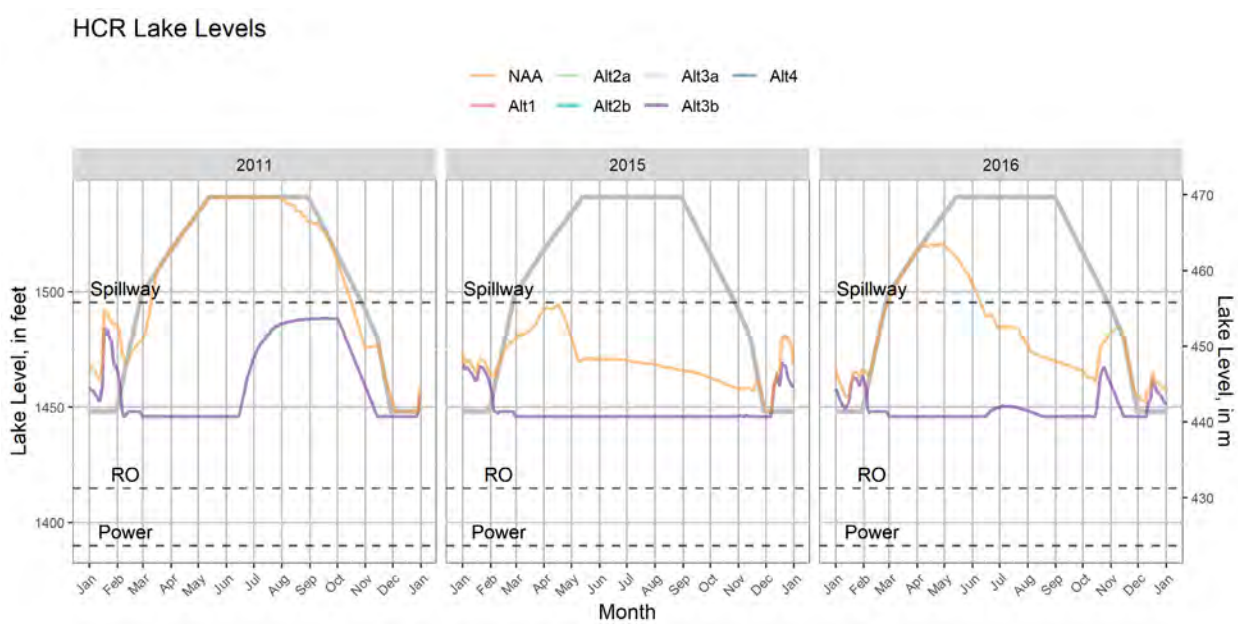

Figure 1-286. WV EIS RES-SIM Hills Creek Lake Levels in 2011, 2015, and 2016 Under Alternative 3b and NAA.

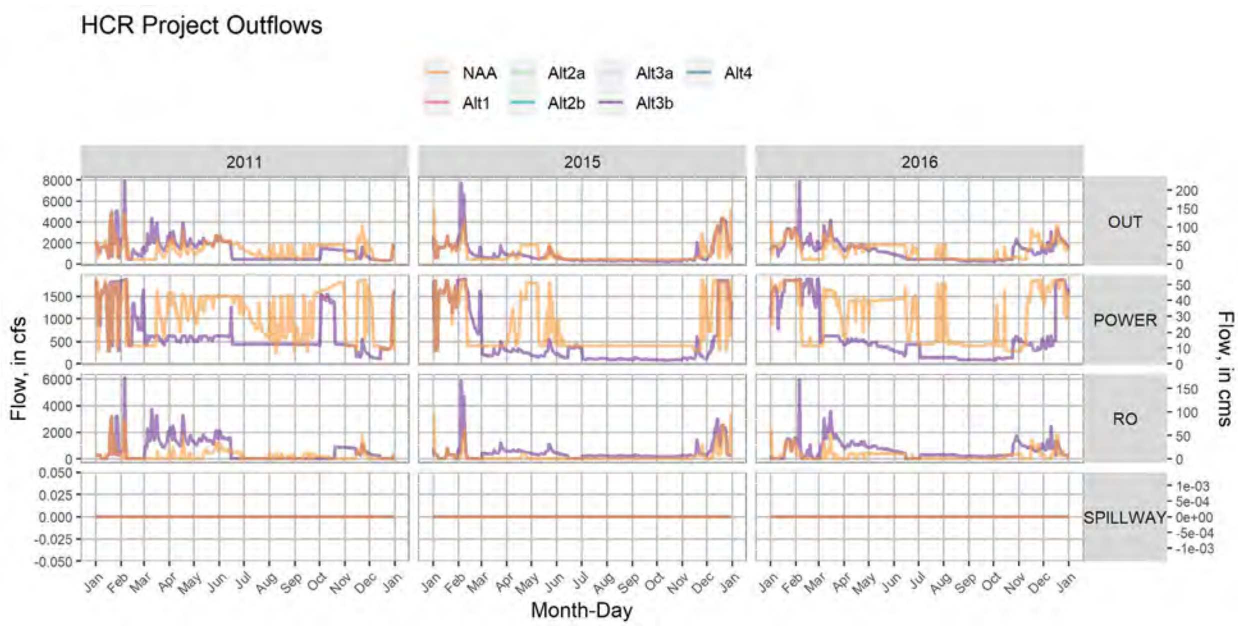

Figure 1-287. WV EIS RES-SIM Hills Creek Dam Gate-Specific Outflows in 2011, 2015, and 2016 under Alternative 3b and NAA.

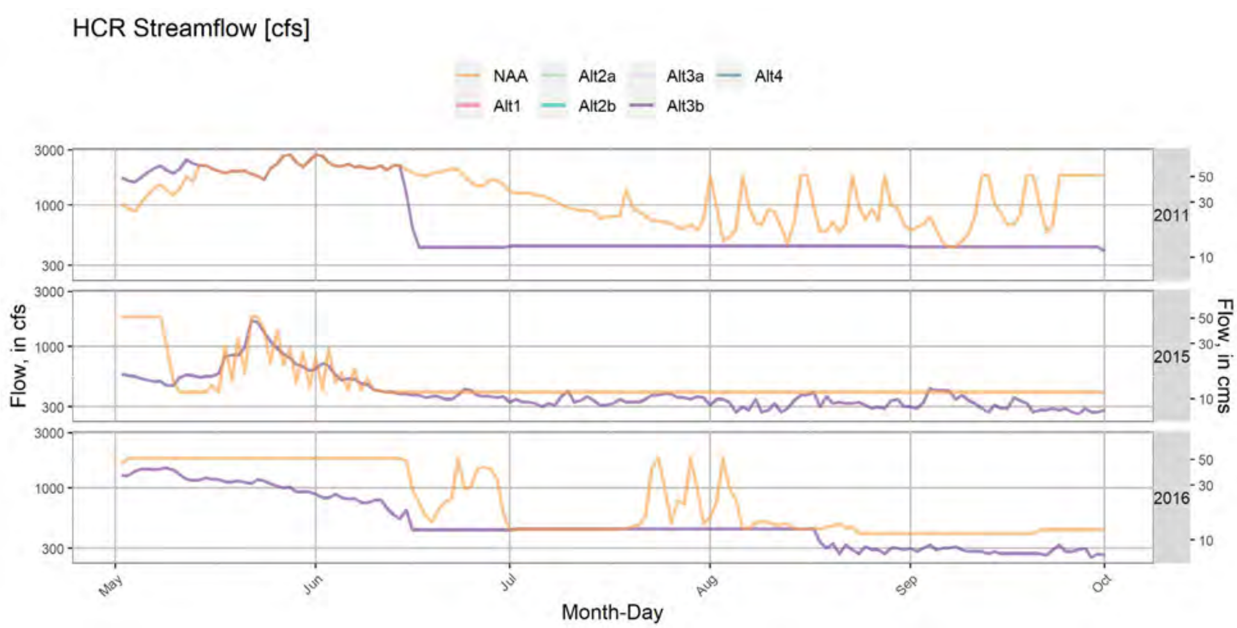

Figure 1-288. WV EIS RES-SIM Hills Creek Dam Total Outflow in 2011, 2015, and 2016 under Alternative 3b and NAA.

Lake Levels and Temperatures from CE-QUAL-W2

Depth-varying temperature, gate-specific outflows, and outflow temperatures through each calendar year scenario in Alternative 3b at Hills Creek Lake are shown in Figure 1-289, Figure 1-290, and Figure 1-291. Hills Creek tailwater temperatures were generally warmer in Alternative 3a compared to NAA in April-October and similar to NAA November-December (Figure 1-292, Figure 1-293) as a result of the proposed drawdown operations.

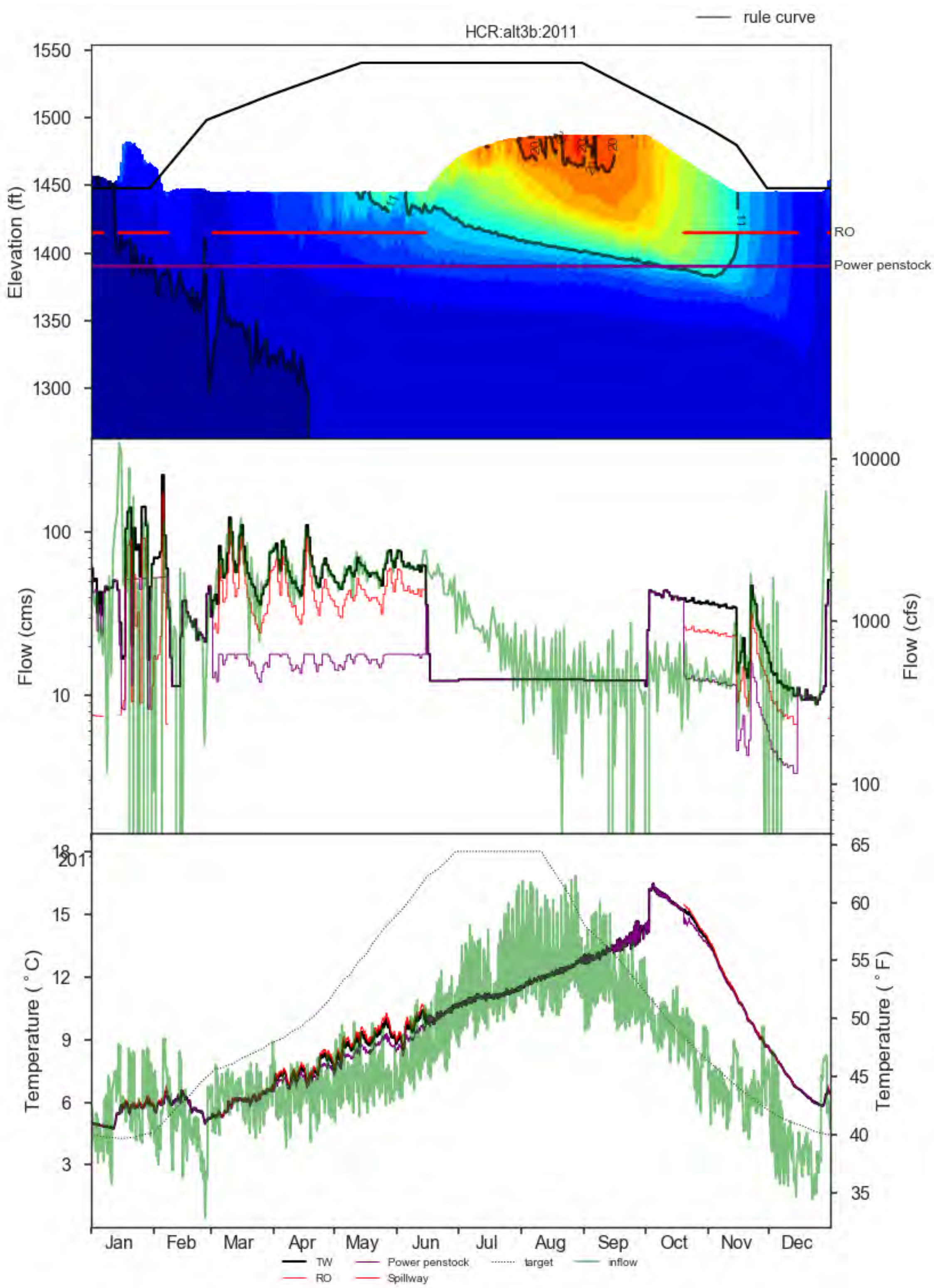

Figure 1-289. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at HCR under Alternative 3b in 2011.

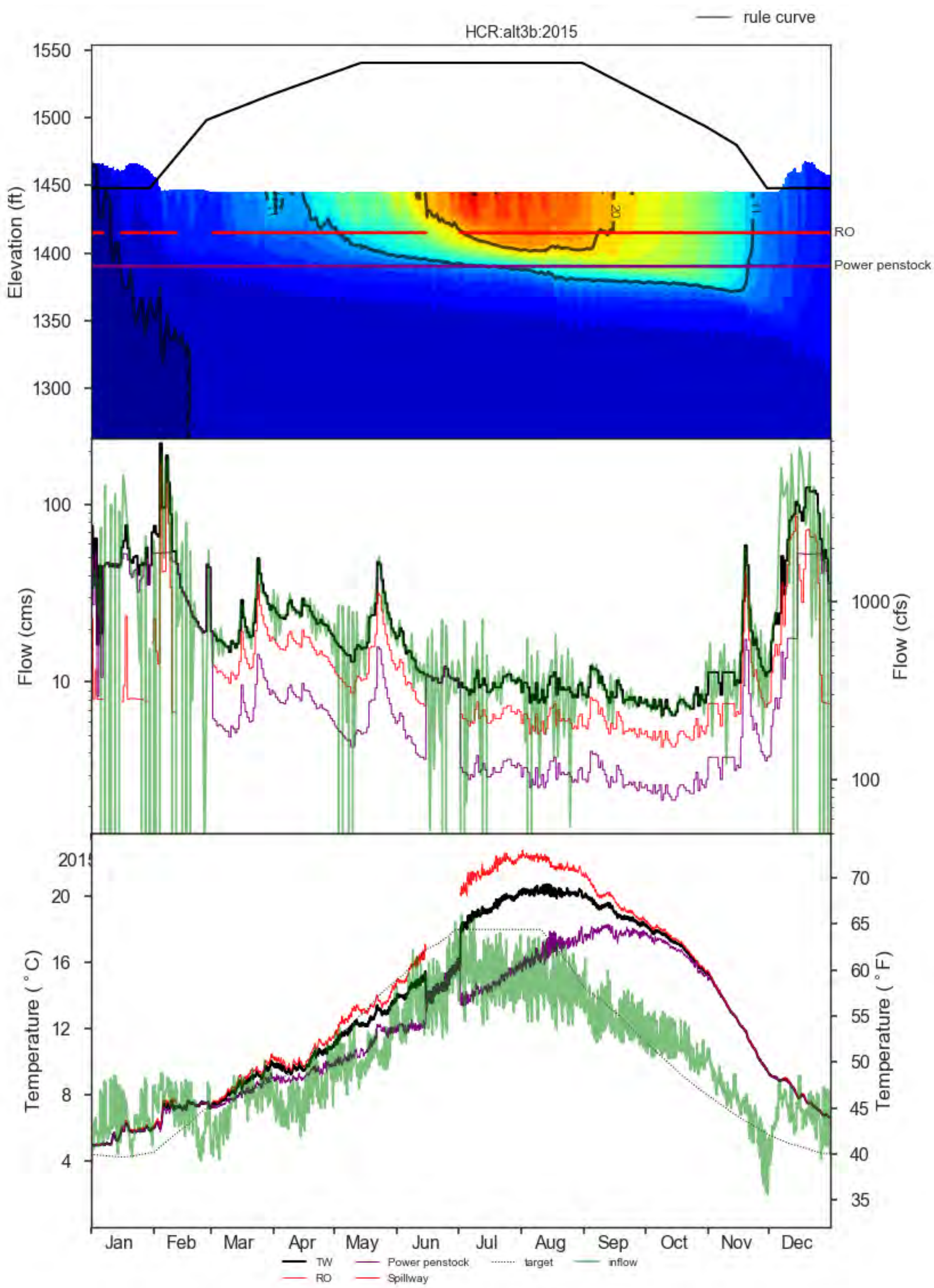

Figure 1-290. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at HCR under Alternative 3b in 2015.

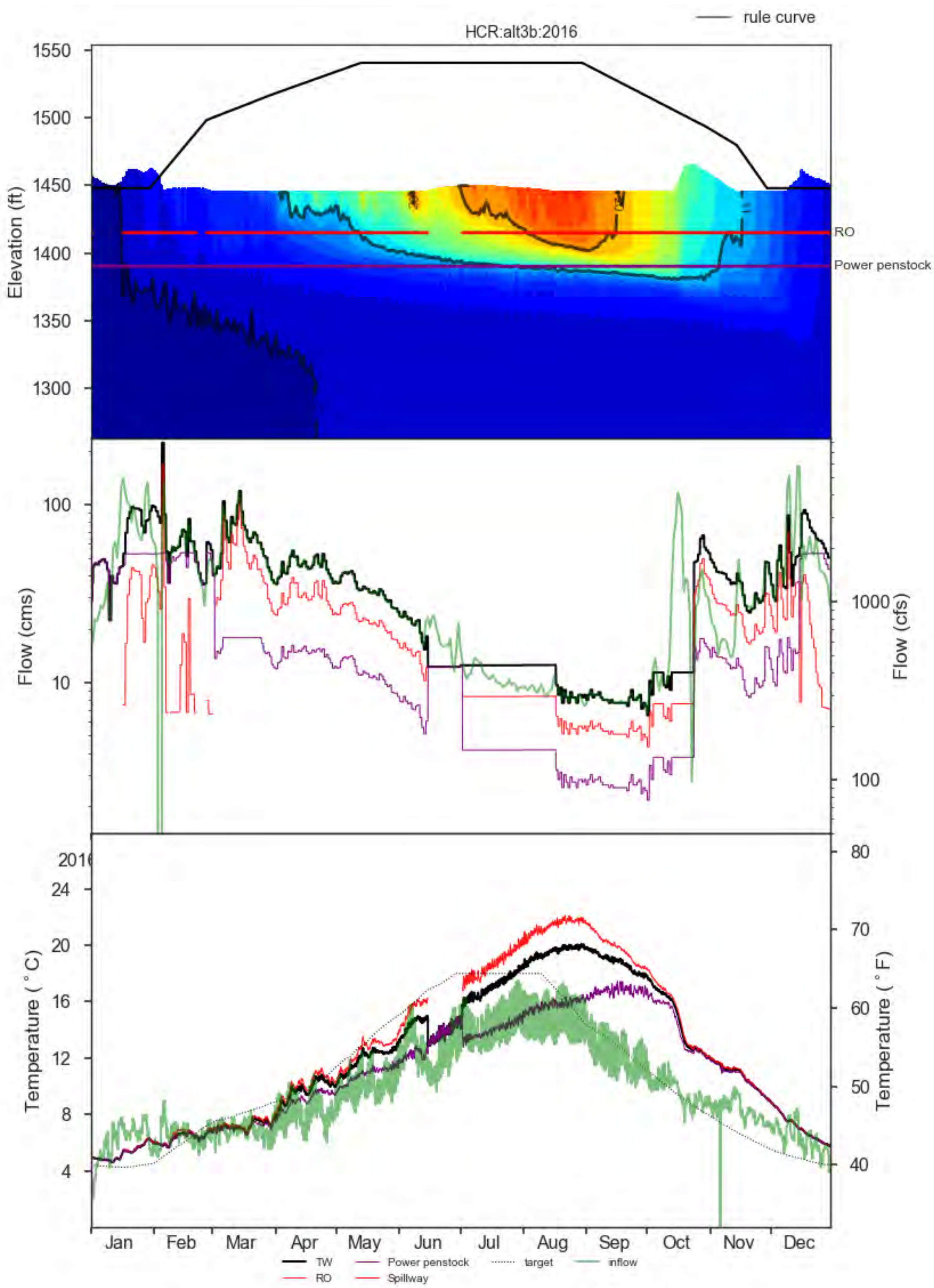

Figure 1-291. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at HCR under Alternative 3b in 2016.

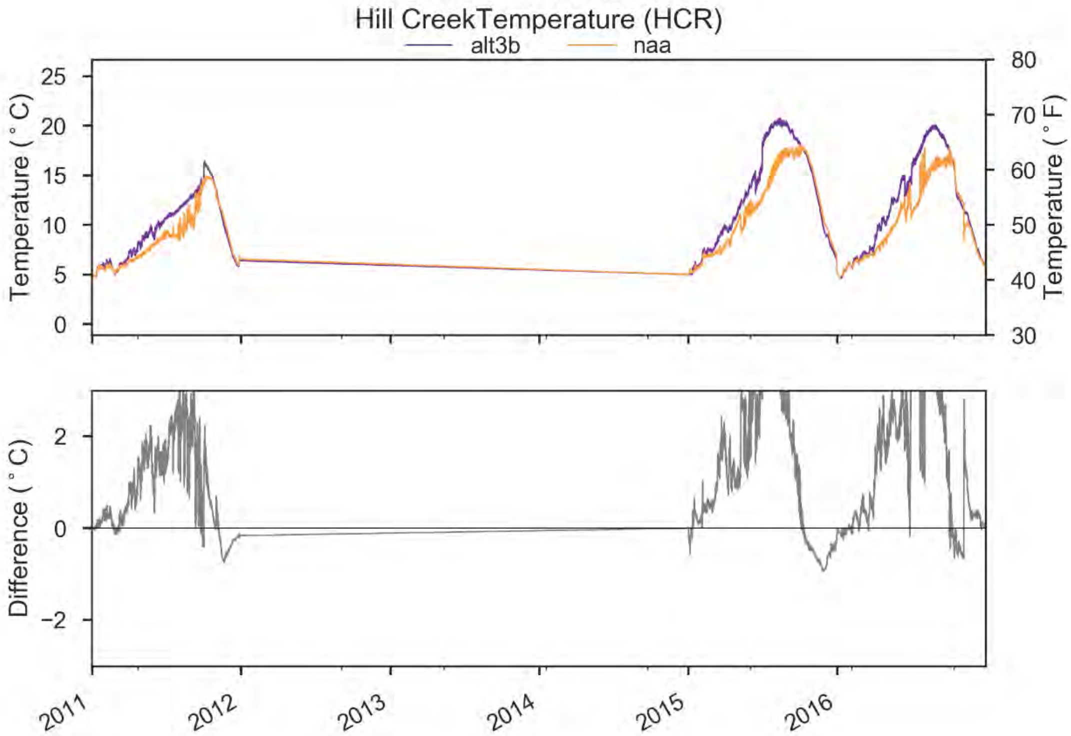

Figure 1-292. Comparison of HCR Outflow Temperatures in NAA and Alternative 3b.

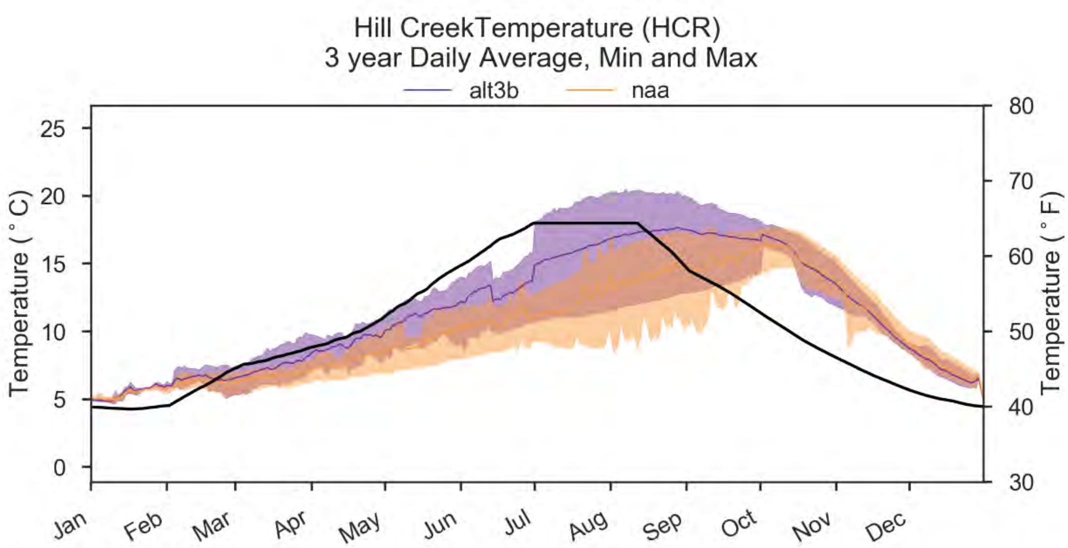

Figure 1-293. Comparison of HCR 3-year Daily Average, Min, Max Outflow Temperatures in NAA and Alternative 3b. Black Line Indicates Temperature Target.

1.5.6.4.2 Lookout Point

RES-SIM Lake Levels and Outflows

Lake level and storage at Lookout Point were generally similar in Alternative 3b and NAA in 2011, 2015, and 2016 aside from October-November, during drawdown to the ROs for fish passage (Figure 1-294, Figure 1-295, Figure 1-296). Some increased storage in 2015 coincided with reduced outflows during spring... 2011 and 2016 operations were generally similar in Alternative 3b and NAA at Lookout Point Lake in January-June followed by increased outflows in July-October to draft the lake for fish passage operations through the ROs in autumn. The proposed temperature management and fish passage operation through the spillway (during spring/summer) and RO (during autumn) in Alternative 3b led to increased outflow from these outlets and decreased power outflow compared to NAA (Figure 1-295).

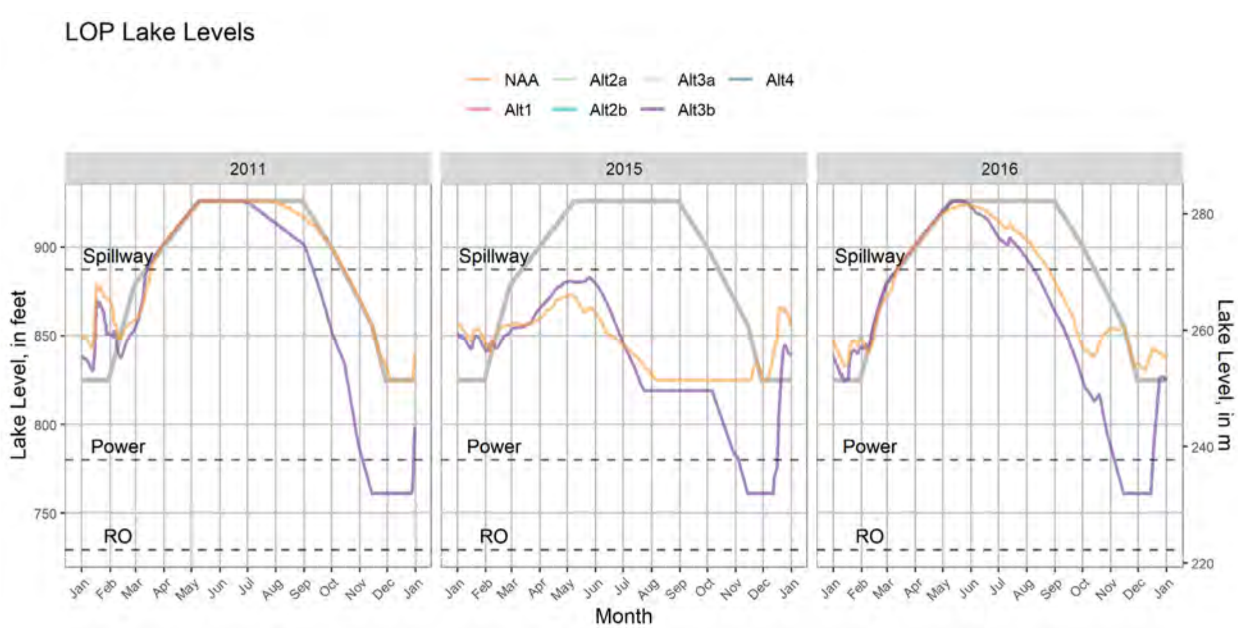

Figure 1-294. WV EIS RES-SIM Lookout Point Lake Levels in 2011, 2015, and 2016 Under Alternative 3b and NAA.

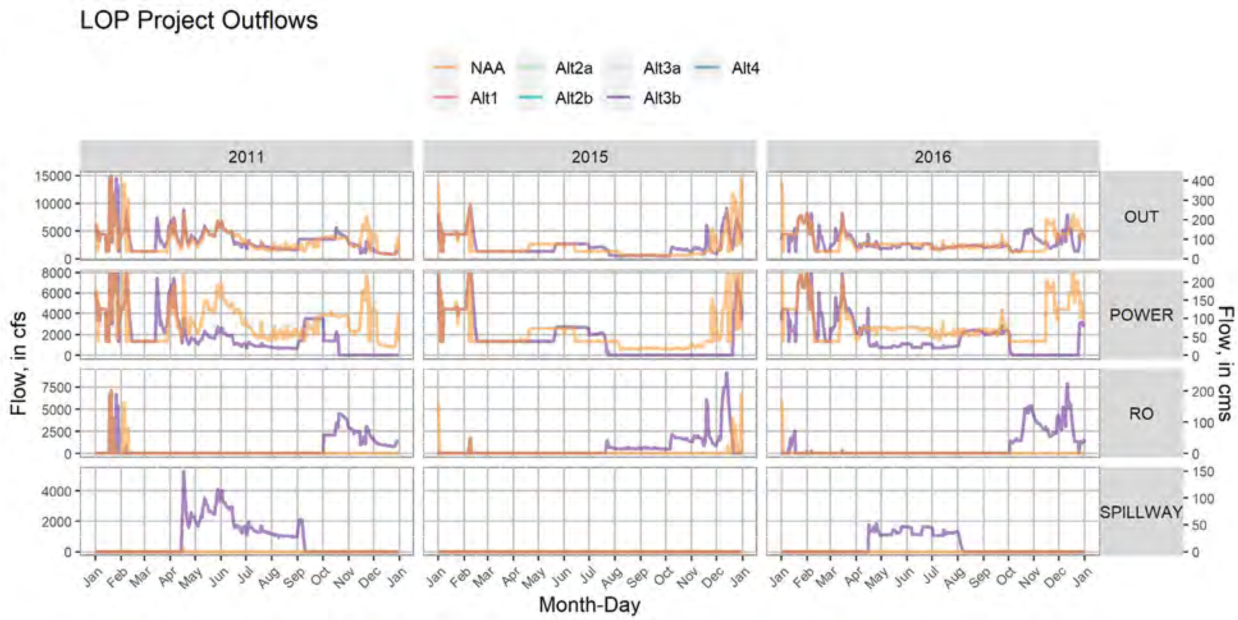

Figure 1-295. WV EIS RES-SIM Lookout Point Dam Gate-Specific Outflows in 2011, 2015, and 2016 under Alternative 3b and NAA.

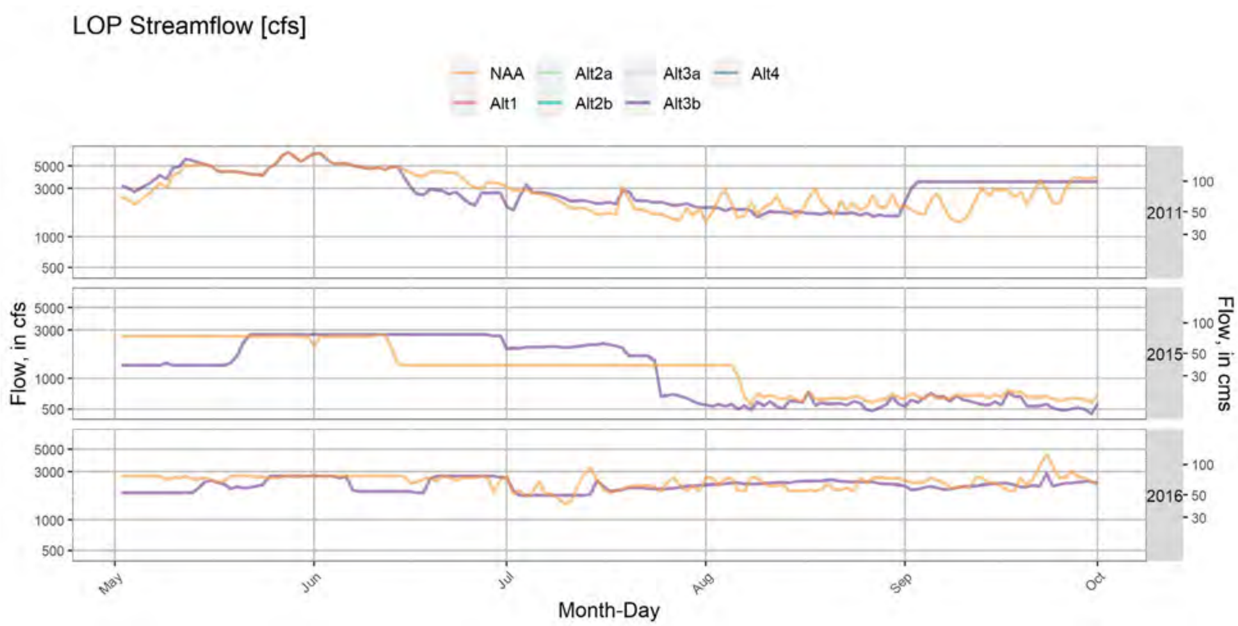

Figure 1-296. WV EIS RES-SIM Lookout Point Dam Total Outflow in 2011, 2015, and 2016 Under Alternative 3b and NAA.

Lake Levels and Temperatures from CE-QUAL-W2

Depth-varying temperature, gate-specific outflows, and outflow temperatures through each calendar year scenario at Lookout Point Lake are shown in Figure 1-297, Figure 1-298, and Figure 1-299. Alternative 3b included releases through the spillway during spring-summer (when the lake was above the spillway crest) as well as releases through the Regulating Outlets during autumn to mix releases from these non-power releases with relatively deep power penstock releases to meet the downstream temperature target.

Alternative 3b tailwater release temperatures from LOP-DEX generally matched the temperature target (warmer than NAA during summer) when sufficient warm or cool water was available and outlets were submerged. LOP spillway access was not available in 2015 and was limited in 2016 which led to an abrupt drop in tailwater temperature when spillway access ended in mid-summer (Figure 1-300, Figure 1-301). Generally, the autumn fish passage operation at LOP (drawdown to about the RO level) resulted in cooler temperatures September-December compared to NAA (Figure 1-301), but tailwater temperature was highly variable across the three years simulated.

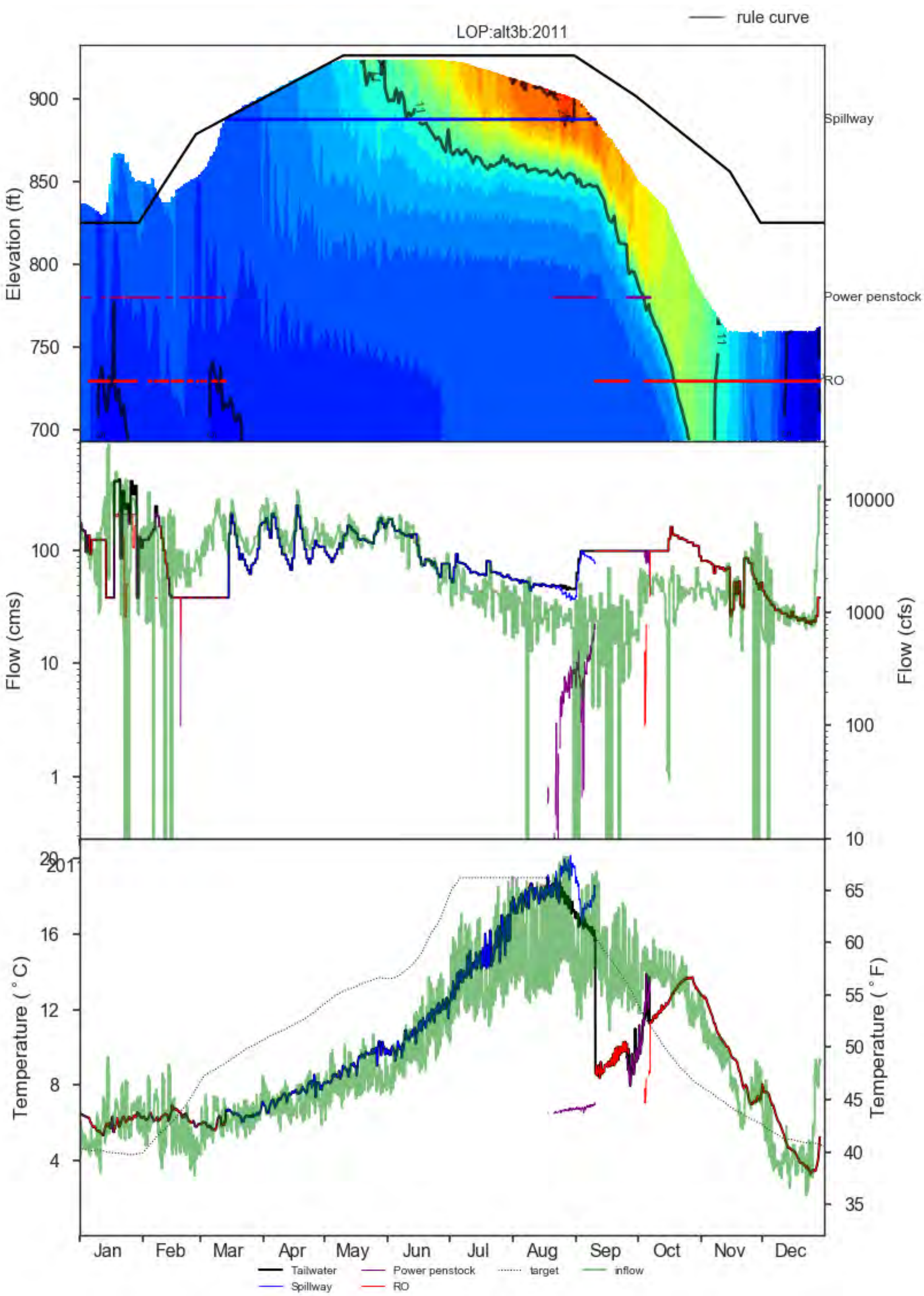

Figure 1-297. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at LOP under Alternative 3b in 2011.

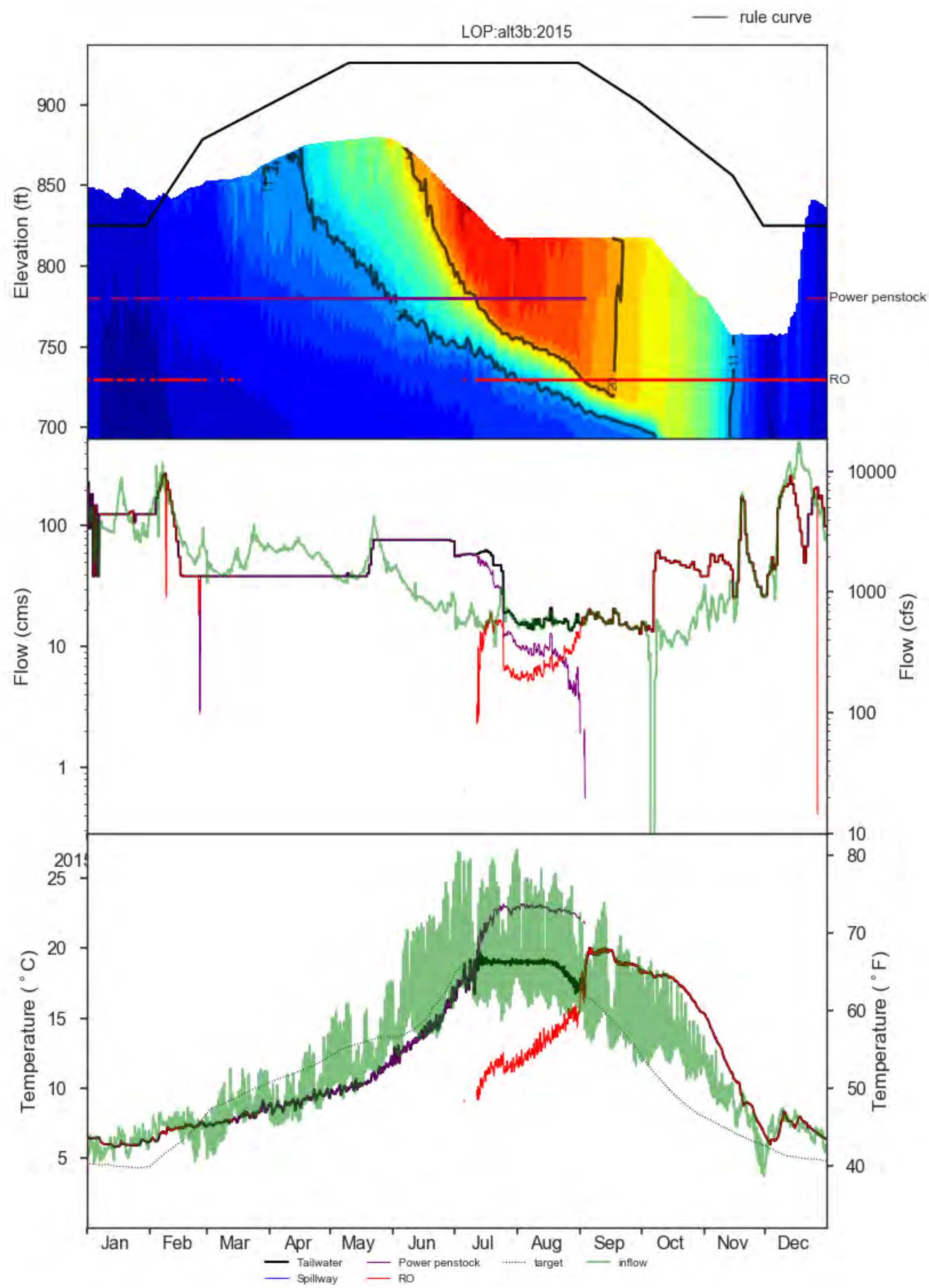

Figure 1-298. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at LOP under Alternative 3b in 2015.

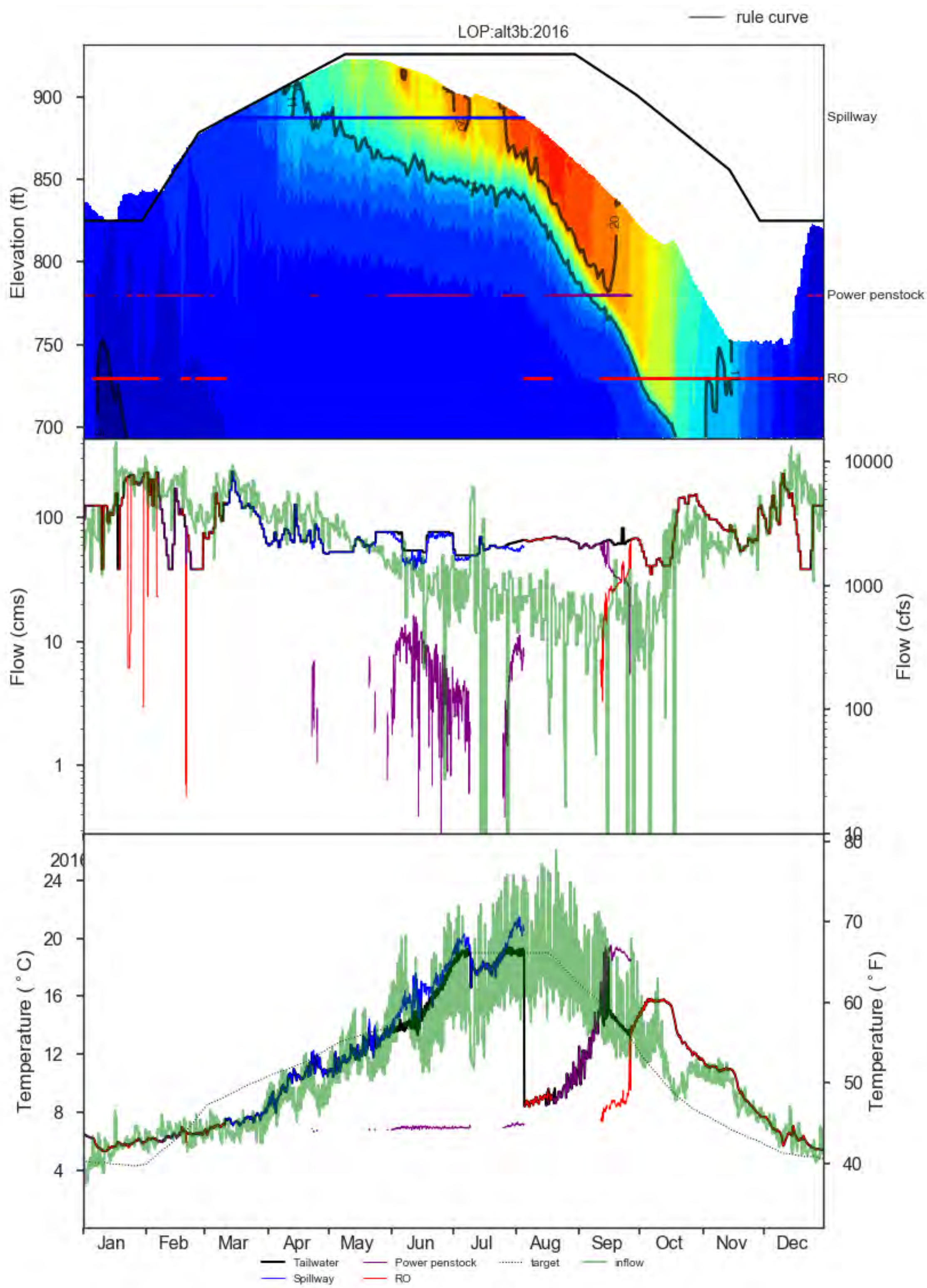

Figure 1-299. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at LOP under Alternative 3b in 2016.

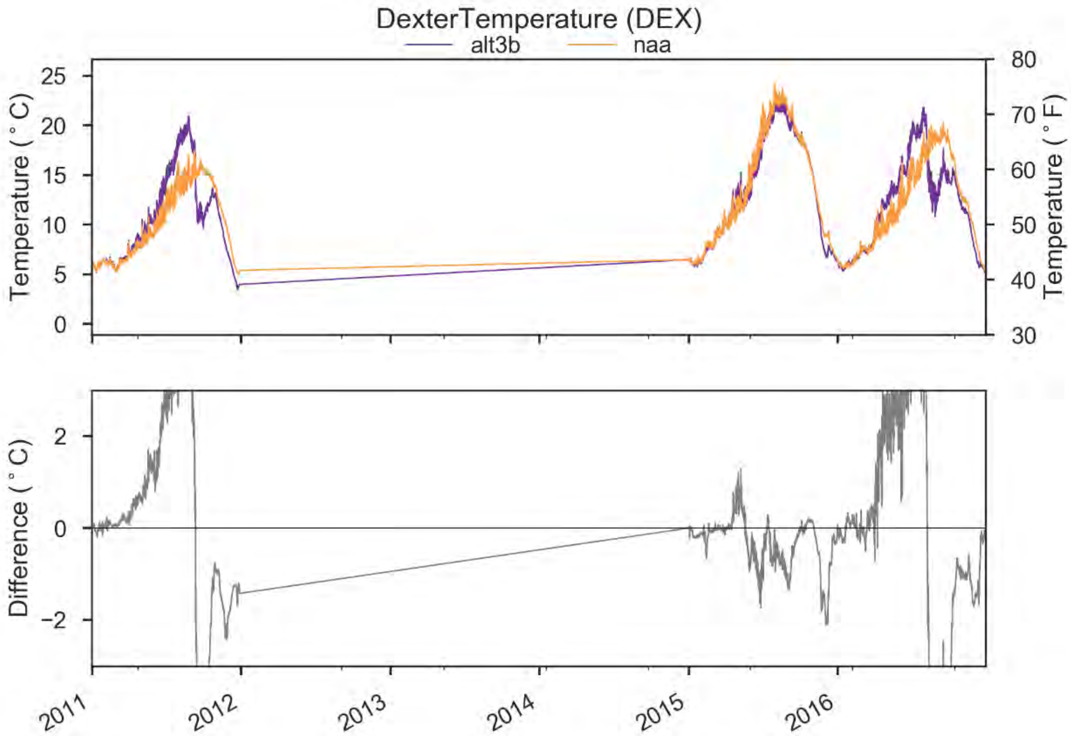

Figure 1-300. Comparison of DEX Outflow Temperatures in NAA and Alternative 3b.

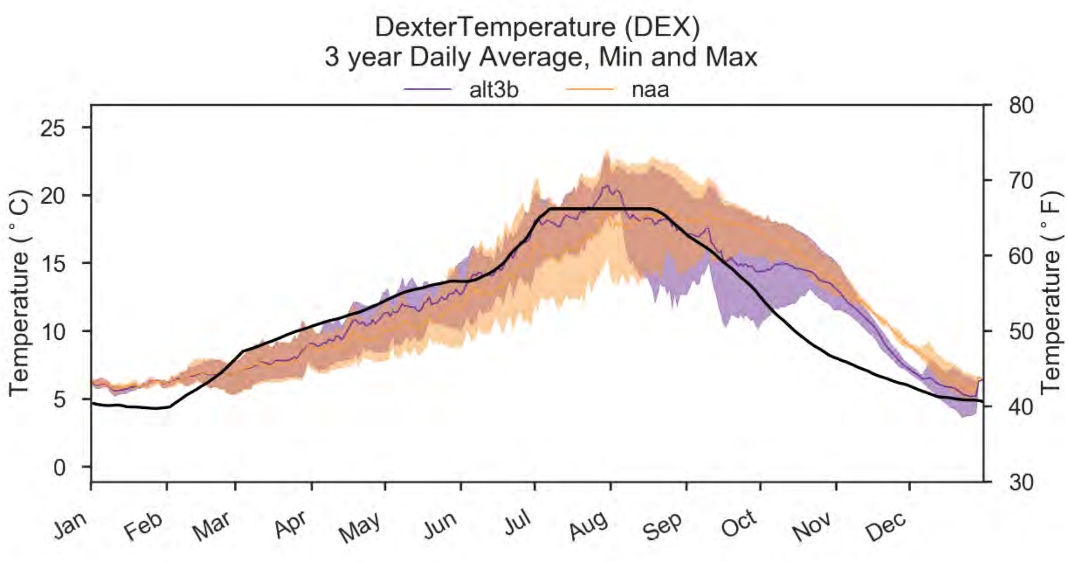

Figure 1-301. Comparison of DEX 3-year Daily Average, Min, Max Outflow Temperatures in NAA and Alternative 3b. Black Line Indicates Temperature Target.

1.5.6.5 Mainstem Willamette River

Streamflow under Alternative 3b was generally lower than NAA (Figure 1-302) except in 2015, when flows were higher from mid-June to October, due to Measure 30 rules that increase dam outflows in advance of heat wave events (Figure 1-303). These flow changes resulted in warmer water temperatures April to mid-June and cooler water temperatures from mid-June to October compared with NAA in 2015 (Figure 1-304, Figure 1-305). Water temperatures at Salem were also affected by upstream dam operations, which likely contributed to warmer temperatures when comparing Alternative 3b to NAA. Overall water temperature differences between Alternative 3b and NAA were less than 2 degrees Celsius.

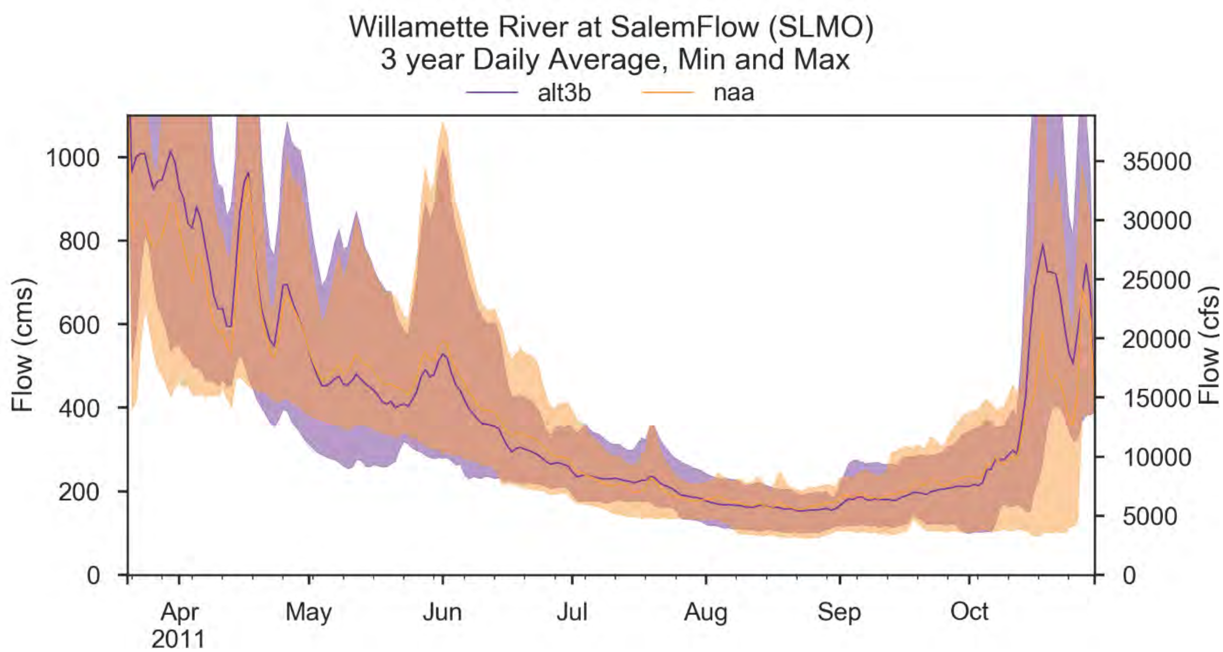

Figure 1-302. Streamflow Comparison of Average, Min, and Max Willamette River at SLMO under NAA and Alternative 3b Conditions.

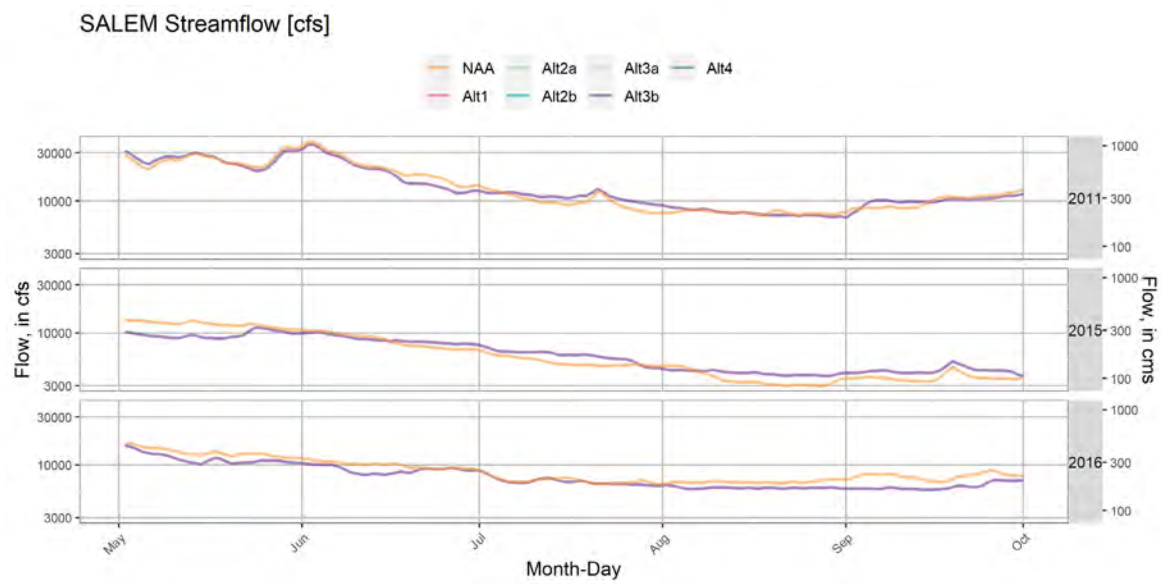

Figure 1-303. Streamflow Comparison Between Alternative 3b and NAA at Willamette River at SLMO.

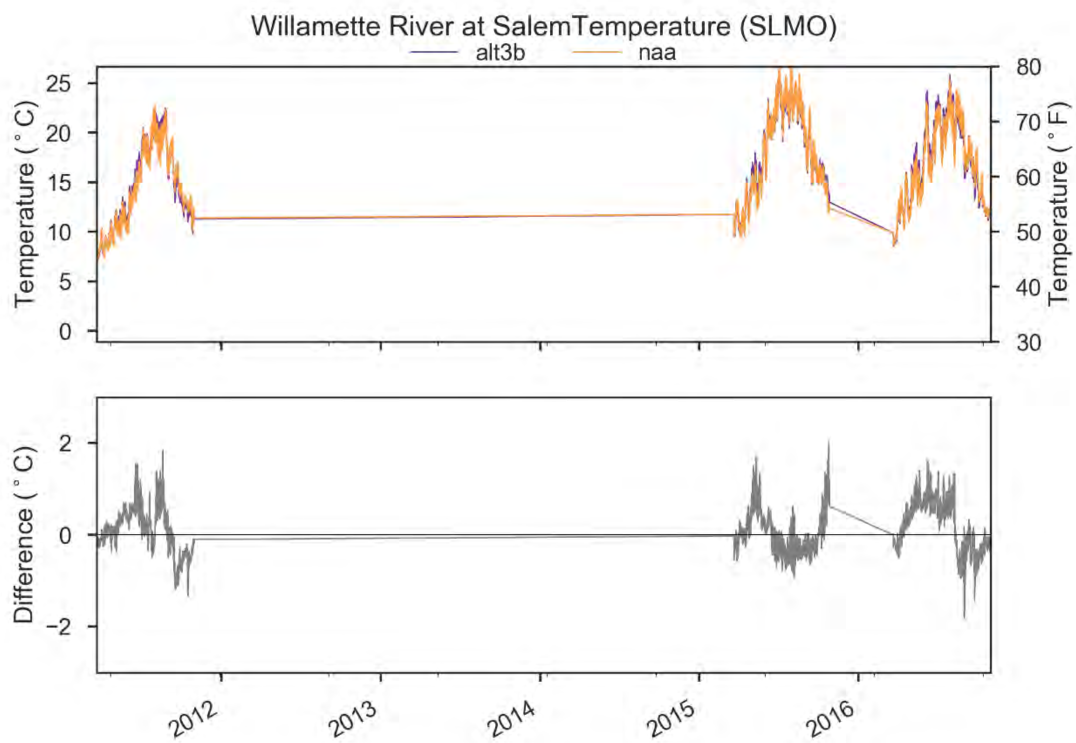

Figure 1-304. Comparison of Willamette River at SLMO Water Temperatures in NAA and Alternative 3b.

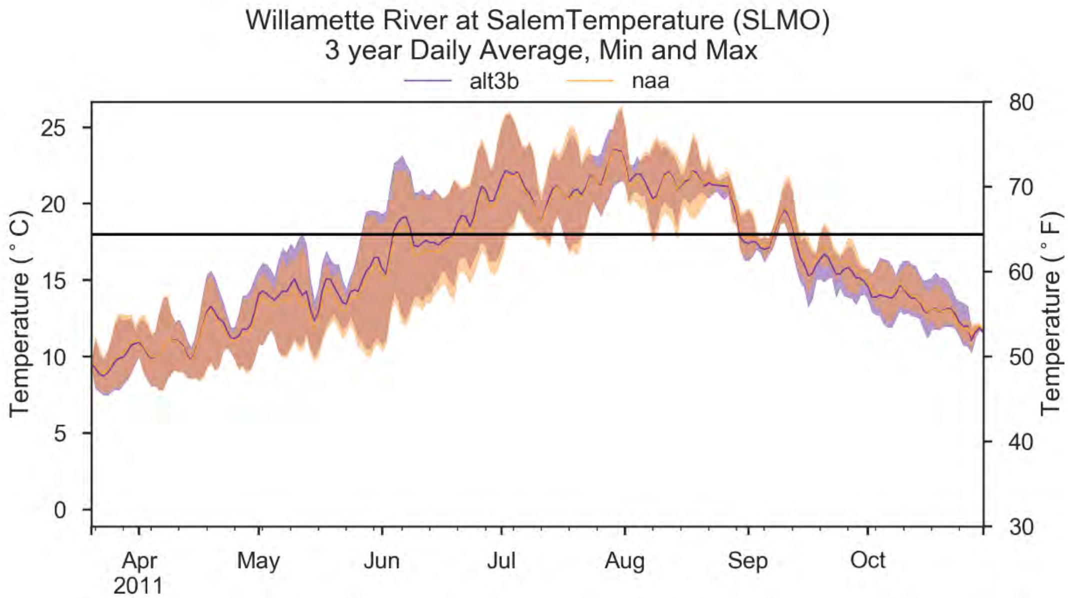

Figure 1-305. Comparison of Willamette River at SLMO 3-year Daily Average, Min, Max Outflow Temperatures in NAA and Alternative 3b.

1.5.7 Alternative 4– Structures-Based Fish Passage Alternative

Alternative 4 measures that affected operations, lake storage, and water temperature included:

- Structural improvements for water temperature (water temperature control towers or selective water withdrawal structures) at Detroit, Hills Creek, and Lookout Point dams.
- Modifications to existing outlets at Foster Dam that would allow releases at varying depths for temperature control by modifying the Facility Warm Water Supply (FWWS) pipe and fish weirs.
- Use of spillway for surface spill in spring and summer and RO during fall at Green Peter.
- Changes to tributary targets below Foster, Detroit, Lookout Point, and Cougar that are higher than the NAA BiOp targets when those reservoirs are more than 90% full and less than the NAA BiOp when those reservoirs are less than 90% full.
- Changes to baseline mainstem targets at Salem and Albany while adding a Salem flow target tied to forecasted air temperature.

1.5.7.1 NORTH SANTIAM DAMS

1.5.7.1.1 Detroit

RES-SIM Lake Levels and Outflows

Lake level and storage at Detroit Lake generally increased under Alternative 4 compared to NAA in 2015 and 2016 aside from September-November in 2015 when the power pool was utilized for downstream flow augmentation (Figure 1-306, Figure 1-308). The increased storage coincided with reduced outflows during spring and increased outflows in summer during 2015 and 2016.Total outflow in 2011 was generally similar in Alternative 4 and NAA at Detroit Lake. The proposed SWS and FSS in Alternative 4 allowed all outflow within powerhouse capacity (assumed at 4600 cfs) to be routed from a floating outlet through the Power outlets for temperature management, rather than the Spillway or URO flow used in NAA for temperature management (Figure 1-307).

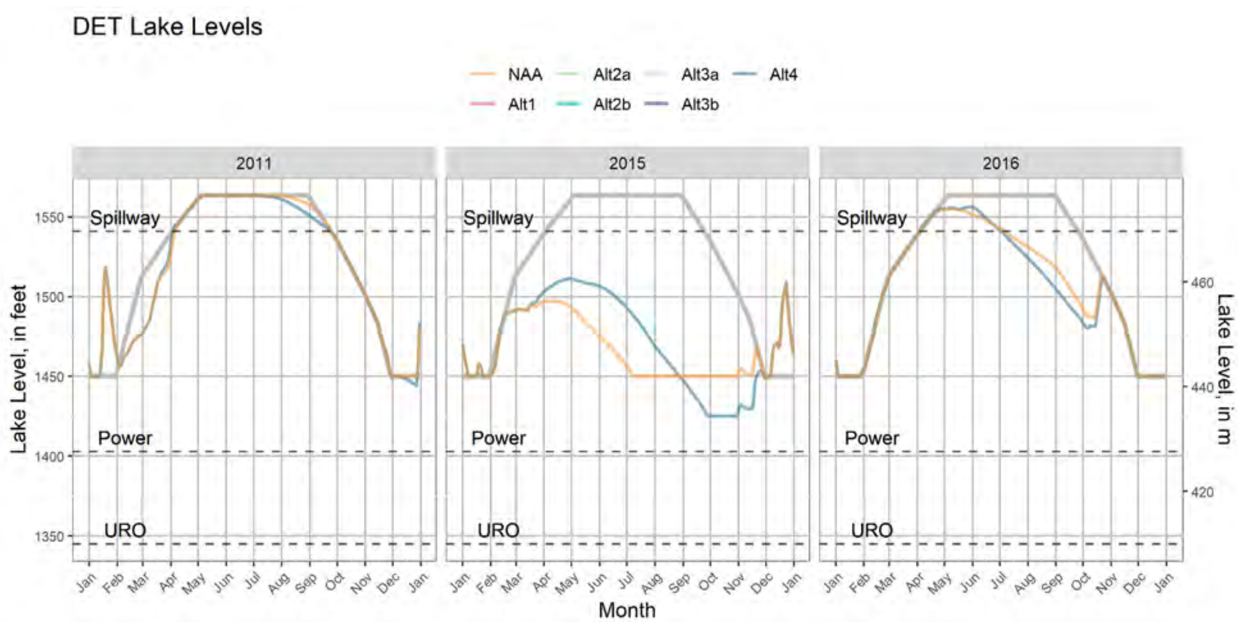

Figure 1-306. WV EIS RES-SIM Detroit Lake Levels in 2011, 2015, and 2016 under Alternative 4 and NAA.

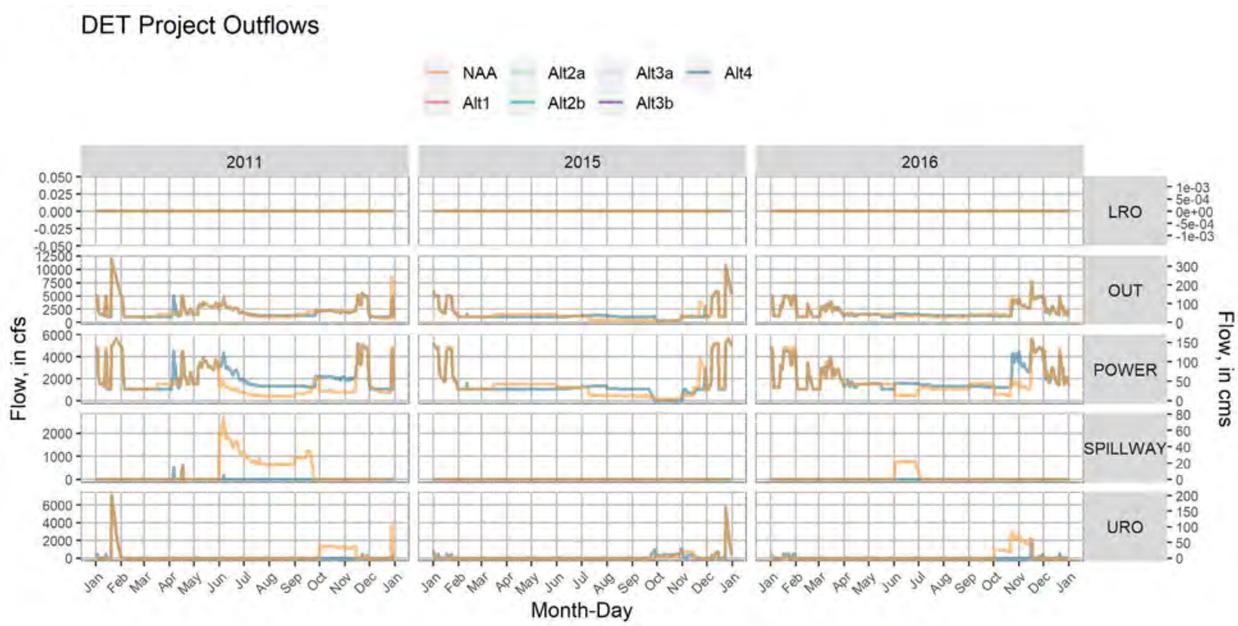

Figure 1-307. WV EIS RES-SIM Gate-Specific Outflows in 2011, 2015, and 2016 under Alternative 4 and NAA.

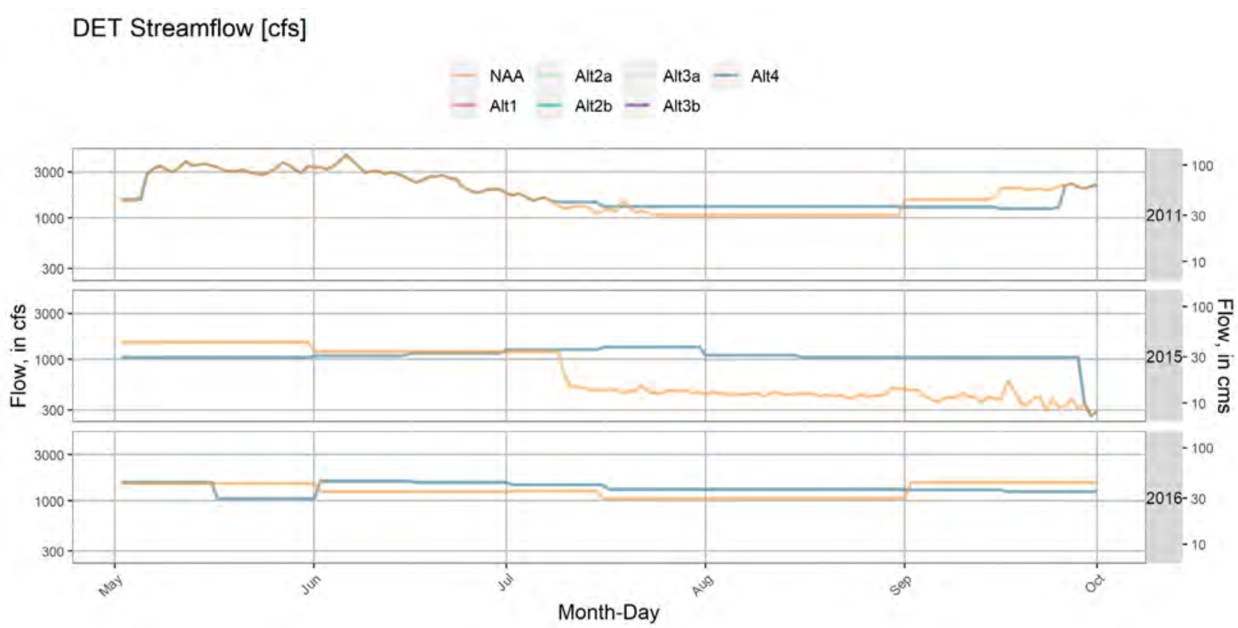

Figure 1-308. WV EIS RES-SIM Detroit Total Outflow in 2011, 2015, and 2016 under Alternative 4 and NAA.

Lake Levels and Temperatures from CE-QUAL-W2

Depth-varying temperature, gate-specific outflows, and outflow temperatures through each calendar year scenario at Detroit Lake are shown in Figure 1-309, Figure 1-310, and Figure 1-311 . Temperature tower outflows blended between a floating outlet (25 feet below lake surface) and a deeper outlet at the elevation of the Upper RO. Tailwater release temperatures generally matched the temperature target when sufficient warm or cool water was available. Generally, the proposed SWS-FSS structures allowed temperatures to be warmer than NAA in spring/summer and cooler than NAA in autumn (Figure 1-312, Figure 1-313).

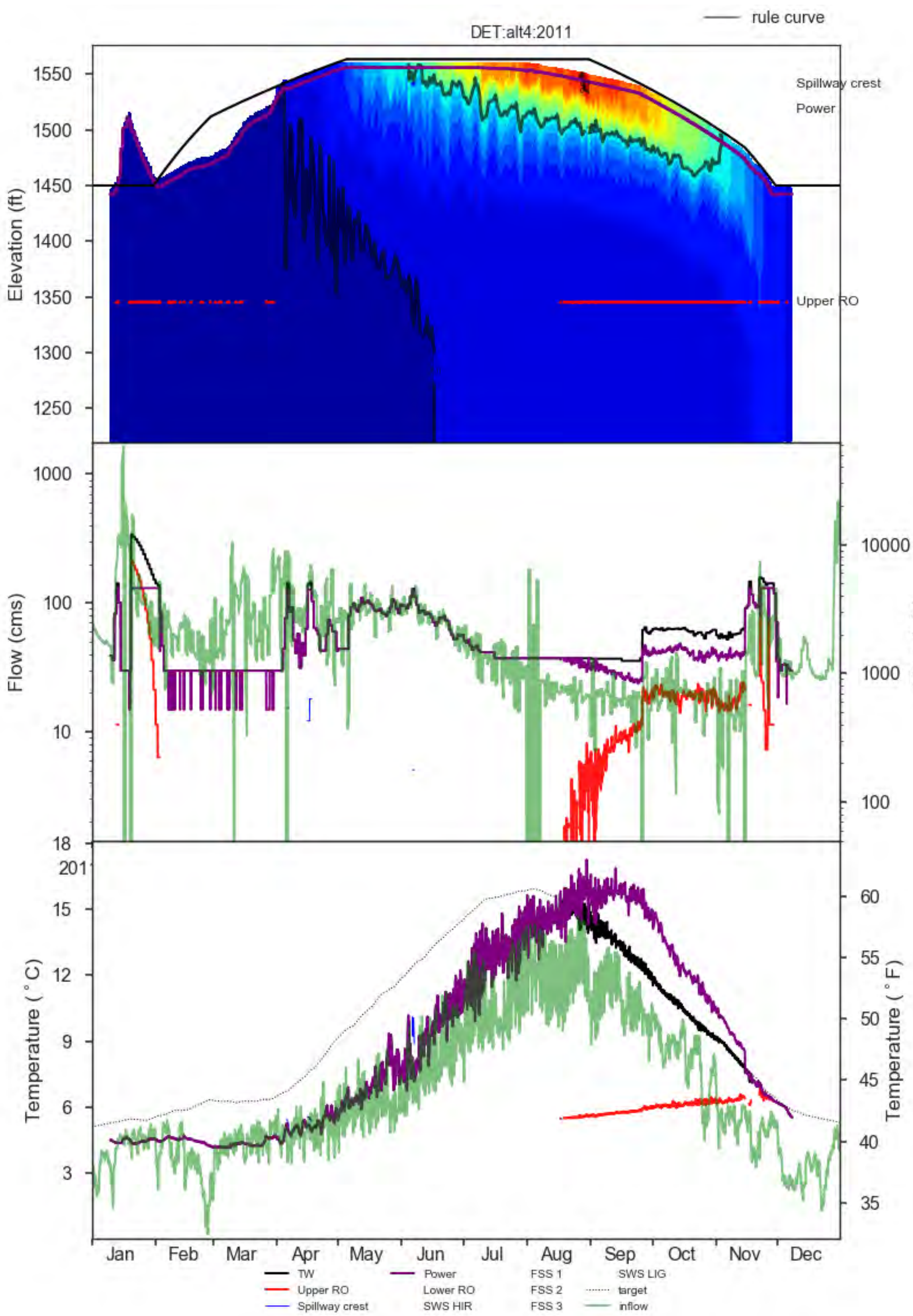

Figure 1-309. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at Detroit under Alternative 4 in 2011.

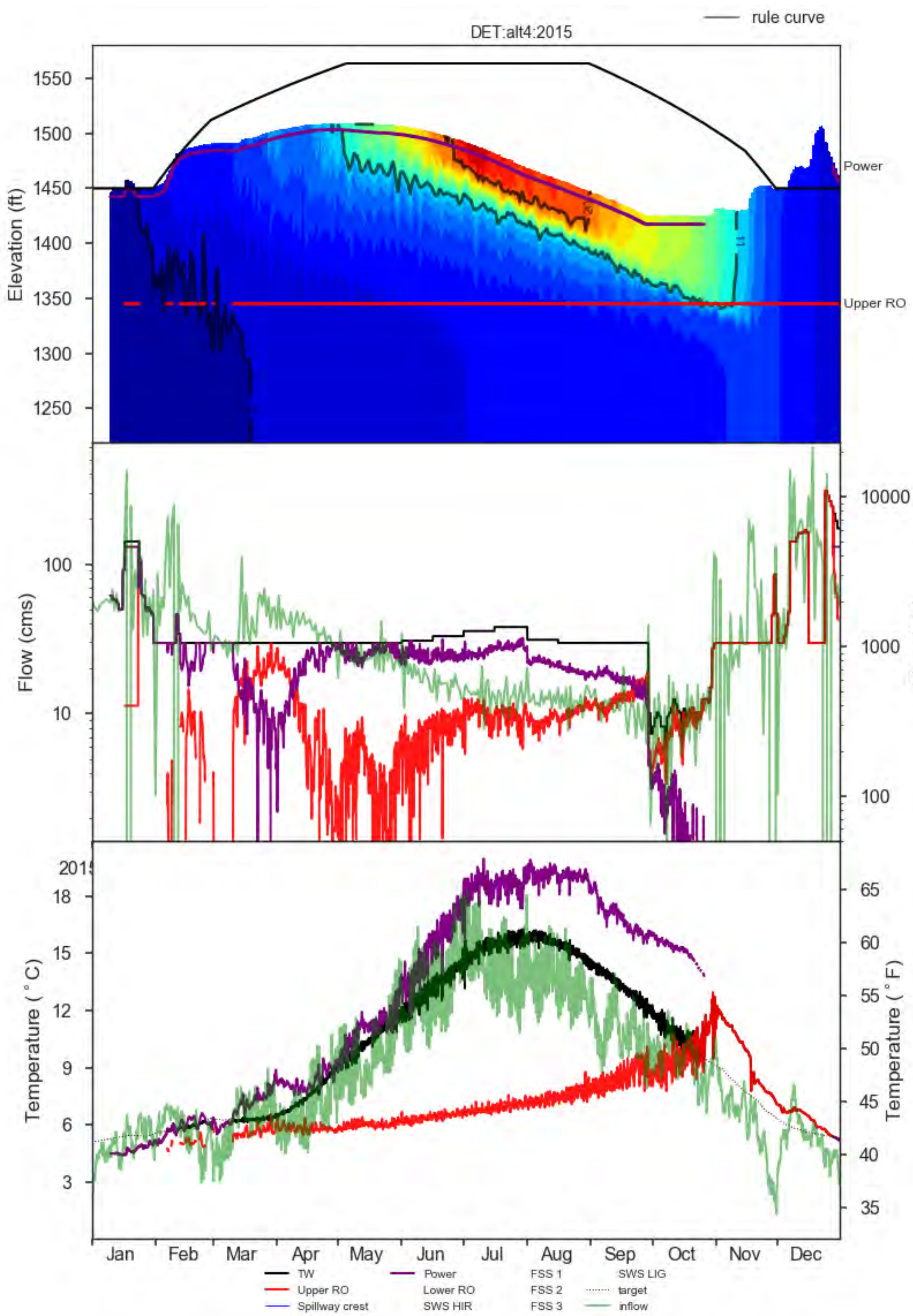

Figure 1-310. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at Detroit under Alternative 4 in 2015.

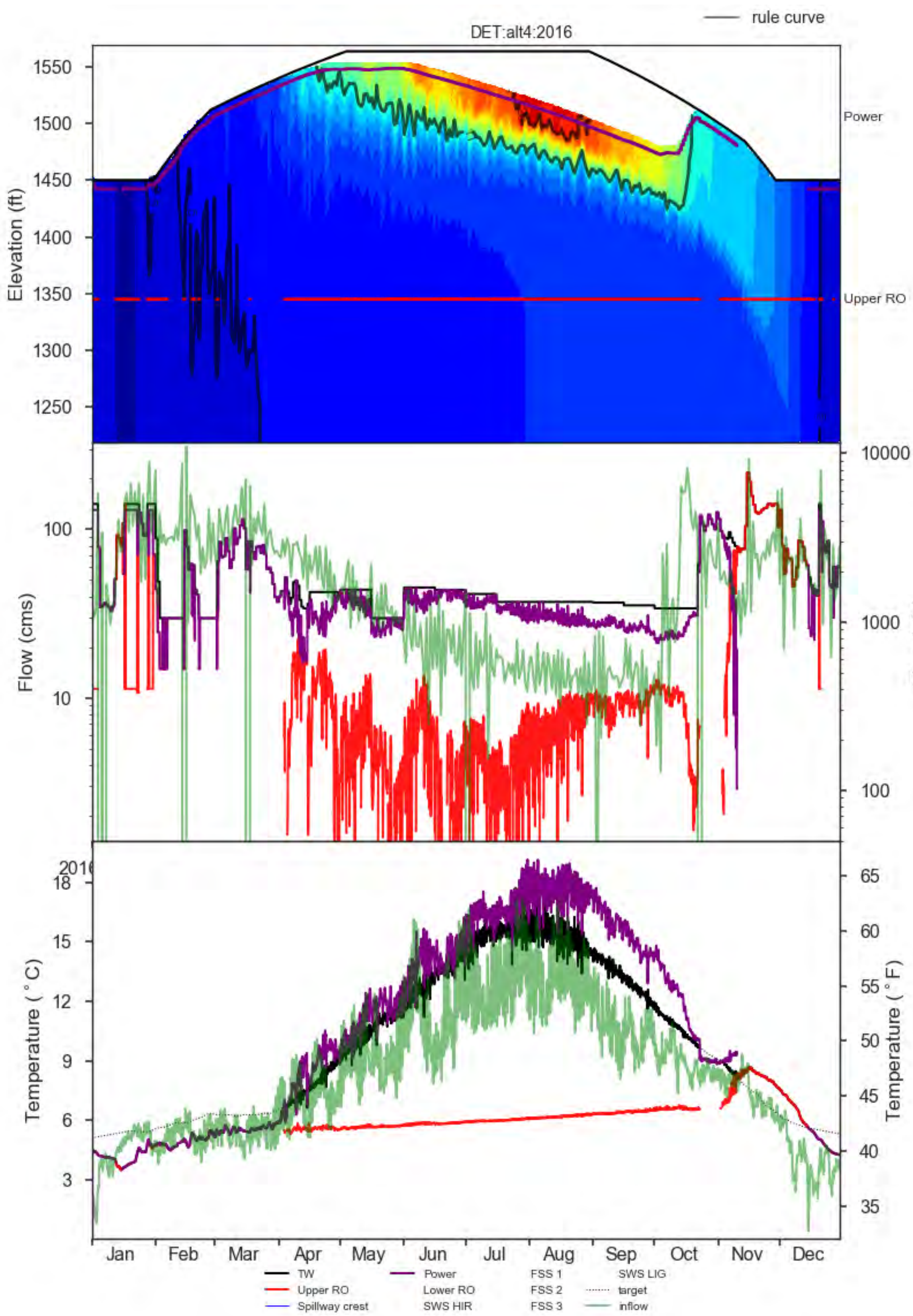

Figure 1-311. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at Detroit under Alternative 4 in 2016.

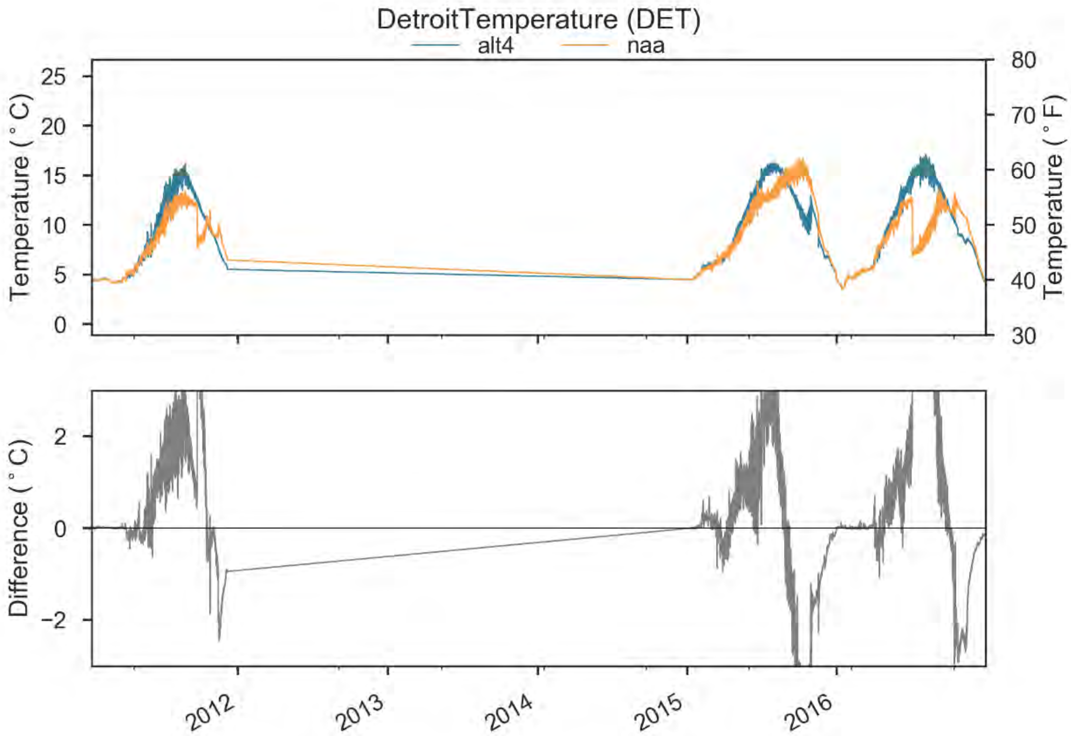

Figure 1-312. Comparison of DET outflow temperatures in NAA and Alternative 4.

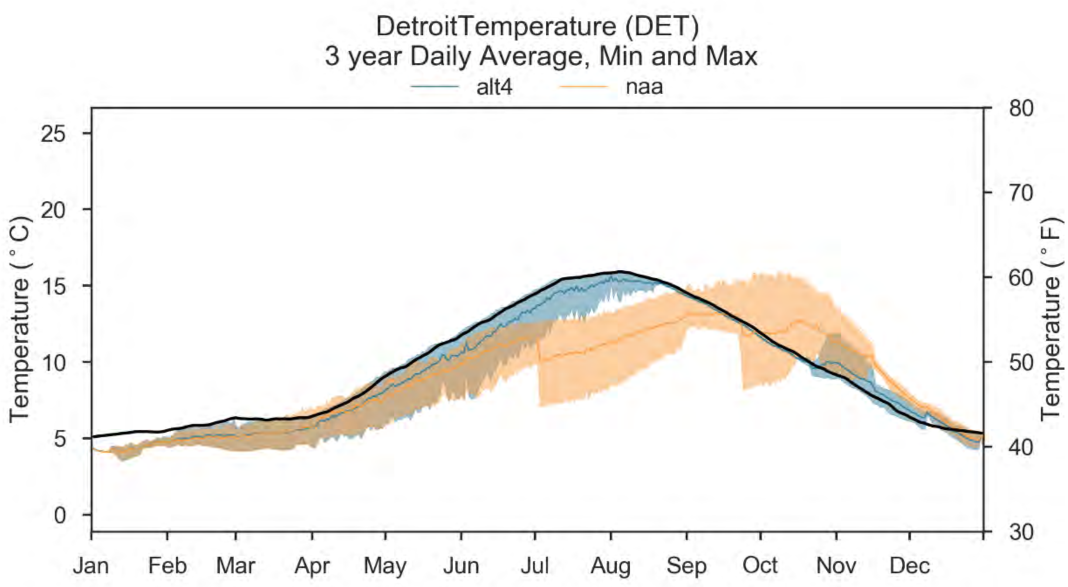

Figure 1-313. Comparison of DET 3-year Daily Average, Min, Max Outflow Temperatures in NAA and Alternative 4. Black Line Indicates Temperature Target.

1.5.7.2 SOUTH SANTIAM DAMS

1.5.7.2.1 Green Peter

RES-SIM Lake Levels and Outflows

Lake level and storage at Green Peter generally similar under Alternative 4 compared to NAA in 2016, decreased in 2011, and increased in 2015 aside from October-November in 2015 where the power pool was utilized for downstream flow augmentation (Figure 1-314, Figure 1-316). The increased storage coincided with reduced outflows during spring and increased outflows in July-October during 2015. 2011 and 2016 operations were generally similar in Alternative 4 and NAA at Green Peter Lake. The proposed temperature management operation through the spillway (during spring/summer) and RO (during autumn) in Alternative 4 led to increased outflow from these outlets compared to NAA (Figure 1-315).

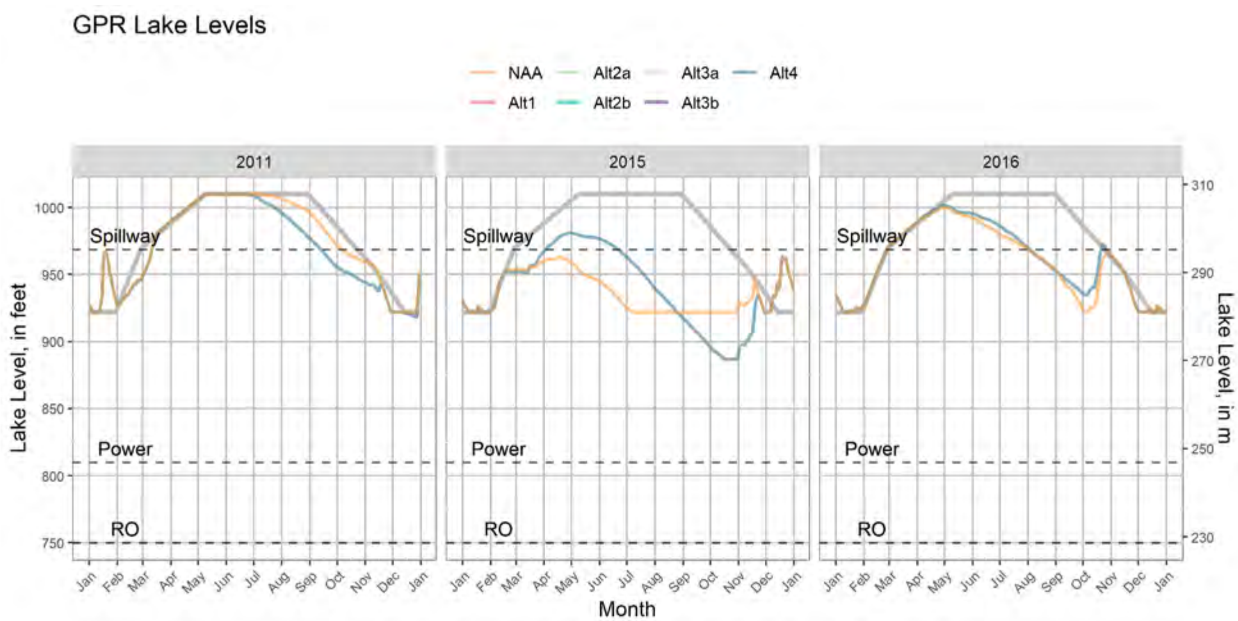

Figure 1-314. WV EIS RES-SIM Green Peter Lake Levels in 2011, 2015, and 2016 under Alternative 4 and NAA.

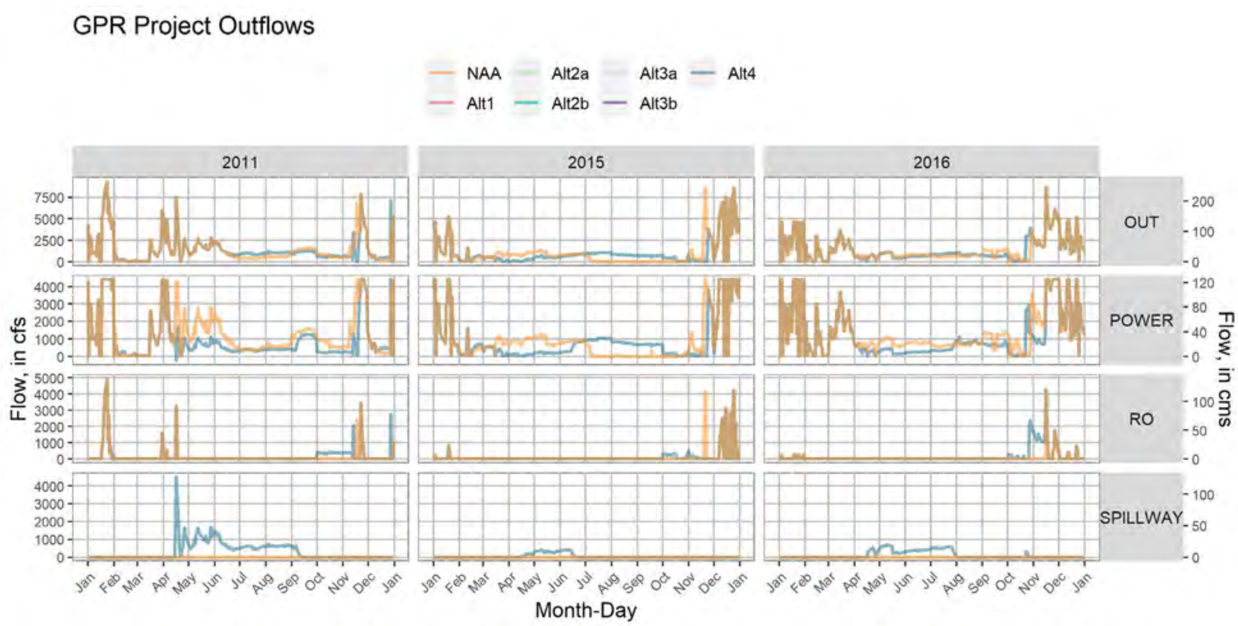

Figure 1-315. WV EIS RES-SIM Green Peter Dam Gate-Specific Outflows in 2011, 2015, and 2016 under Alternative 4 and NAA.

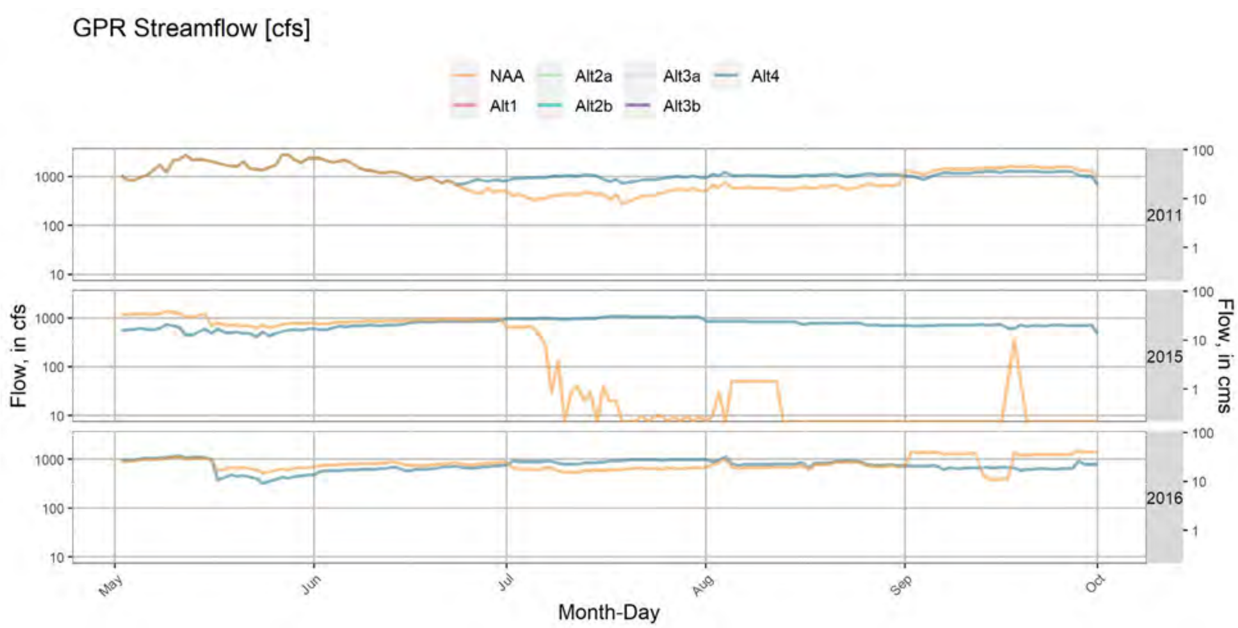

Figure 1-316. WV EIS RES-SIM Green Peter Dam Total Outflow in 2011, 2015, and 2016 under Alternative 4 and NAA.

Lake Levels and Temperatures from CE-QUAL-W2

Depth-varying temperature, gate-specific outflows, and outflow temperatures through each calendar year scenario at Green Peter Lake are shown in Figure 1-317, Figure 1-318, and Figure 1-319. Alternative 4 included releases through the spillway during spring-summer (when the lake was above the spillway crest) as well as releases through the Regulating Outlets during autumn to mix with relatively deep power penstock releases in to meet the downstream temperature target. Tailwater release temperatures generally matched the temperature target when sufficient warm or cool water was available and those outlets were submerged. However, spillway access was limited in all 3 years, leading to an abrupt drop in tailwater temperature when spillway access ended in mid-summer. This was followed by a large peak in tailwater temperature in the 2015 scenario during September-October as the lake was drafted at a relatively high outflow rate, effectively mixing the thermal layers near the dam (Figure 1-320, Figure 1-321).

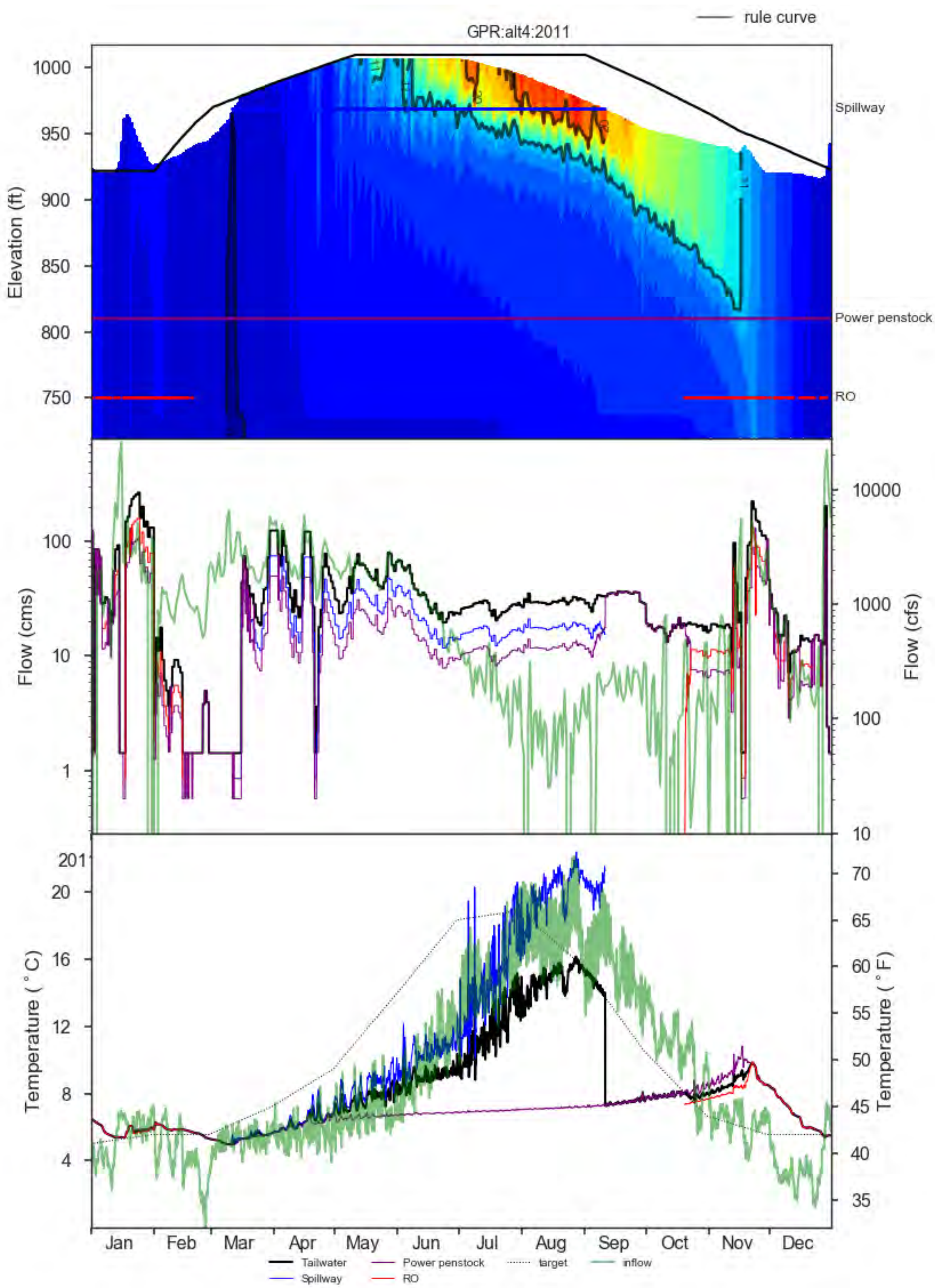

Figure 1-317. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at GPR under Alternative 4 in 2011.

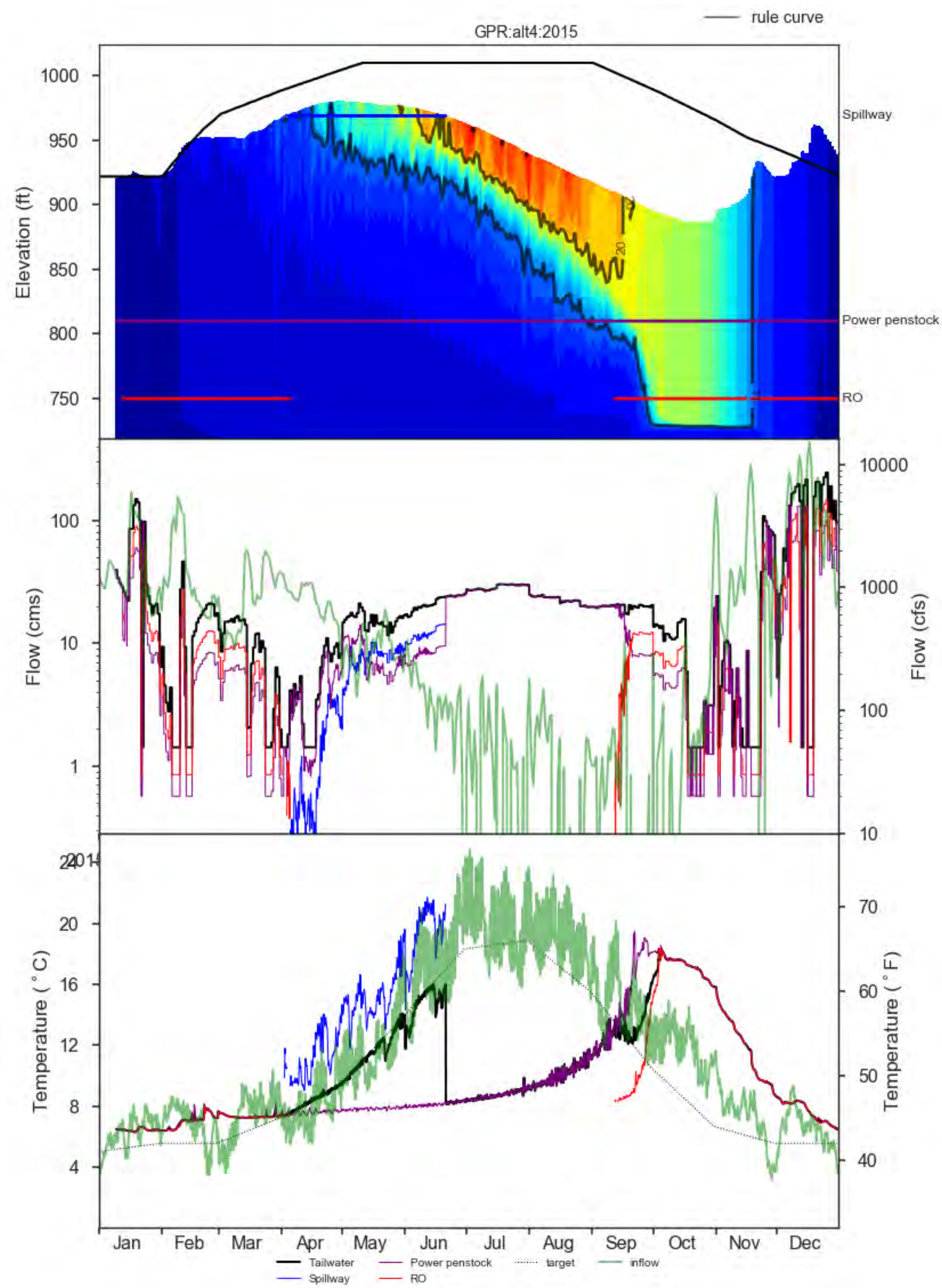

Figure 1-318. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at GPR under Alternative 4 in 2015.

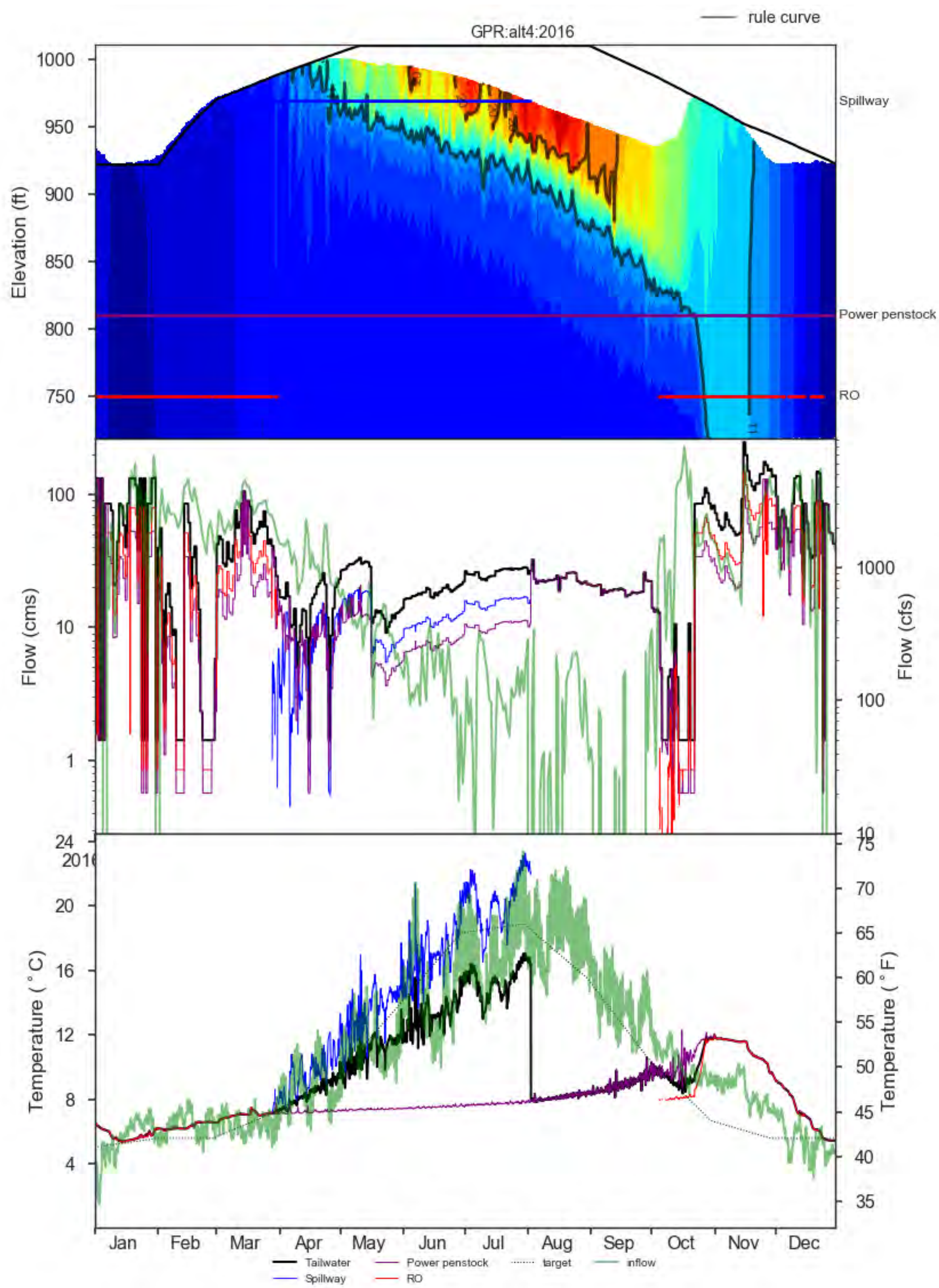

Figure 1-319. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at GPR under Alternative 4 in 2016.

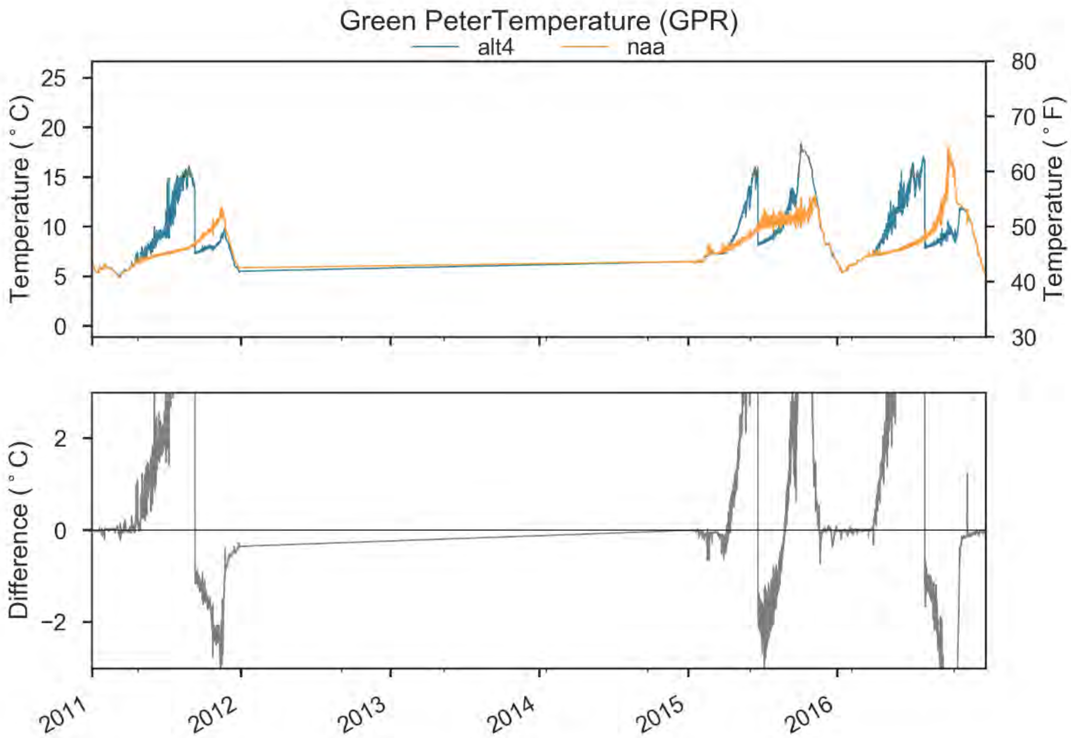

Figure 1-320. Comparison of GPR Outflow Temperatures in NAA and Alternative 4.

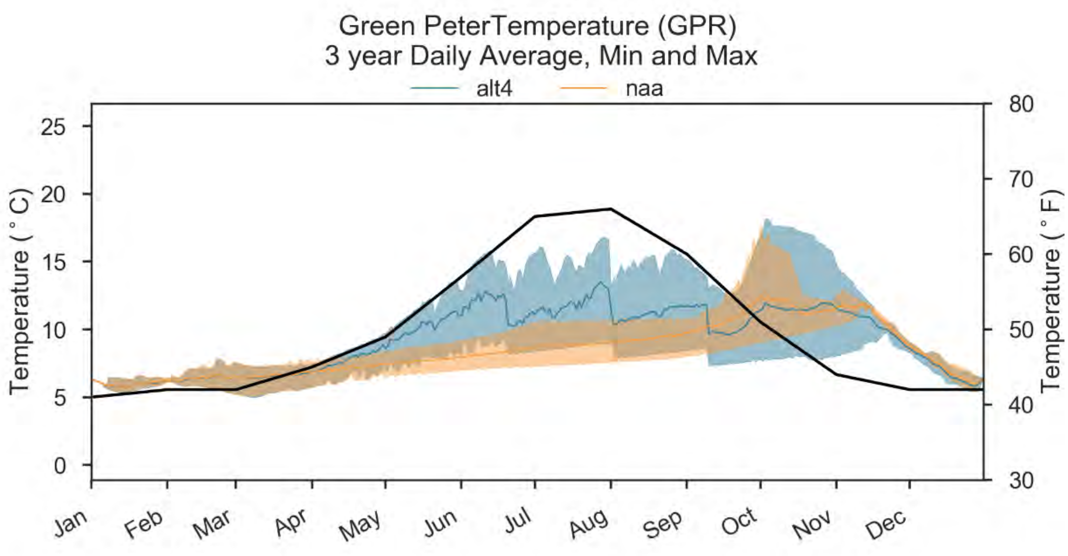

Figure 1-321. Comparison of GPR 3-year Daily Average, Min, Max Outflow Temperatures in NAA and Alternative 4. Black Line Indicates Temperature Target.

1.5.7.2.2 Foster

RES-SIM Lake Levels and Outflows

Lake level and storage at Foster were generally similar in 2011 and 2016 but increased in 2015 under Alternative 4 compared to NAA (Figure 1-322, Figure 1-324). Total outflow from Foster Dam was affected by upstream operations at Green Peter Dam. The proposed modifications to the fish weir and FWWS in Alternative 4 resulted in lower outflow routed through the Power outlets for temperature management, especially during spring and summer, compared to NAA (Figure 1-323).

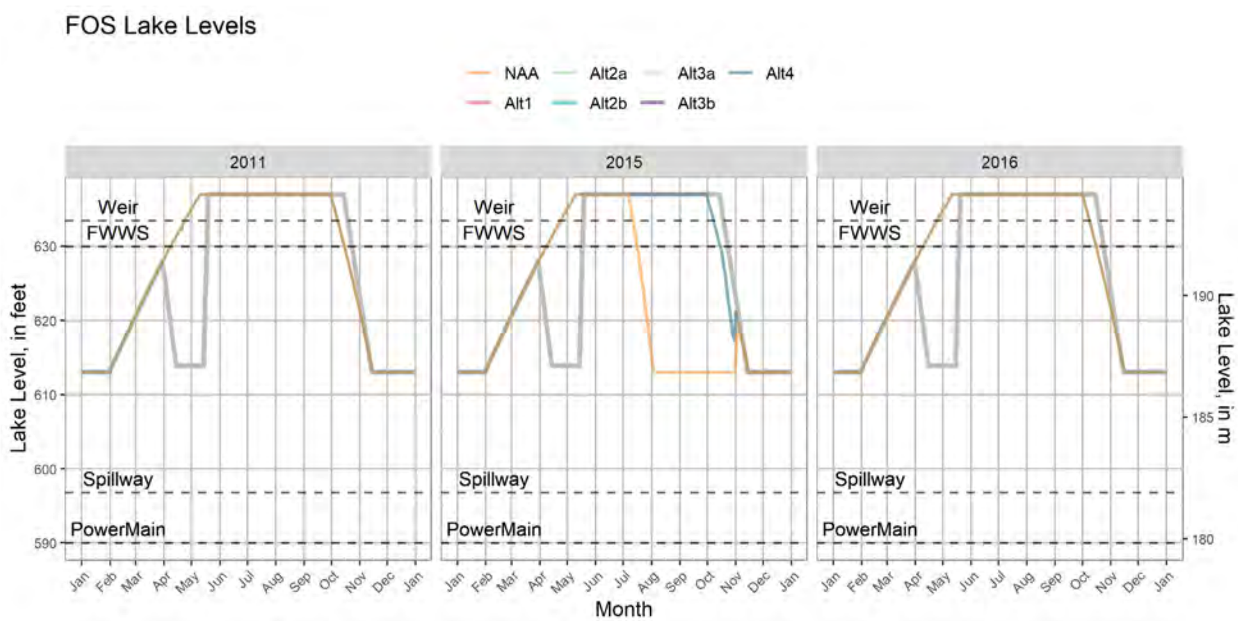

Figure 1-322. WV EIS RES-SIM Foster Lake Levels in 2011, 2015, and 2016 Under Alternative 4 and NAA.

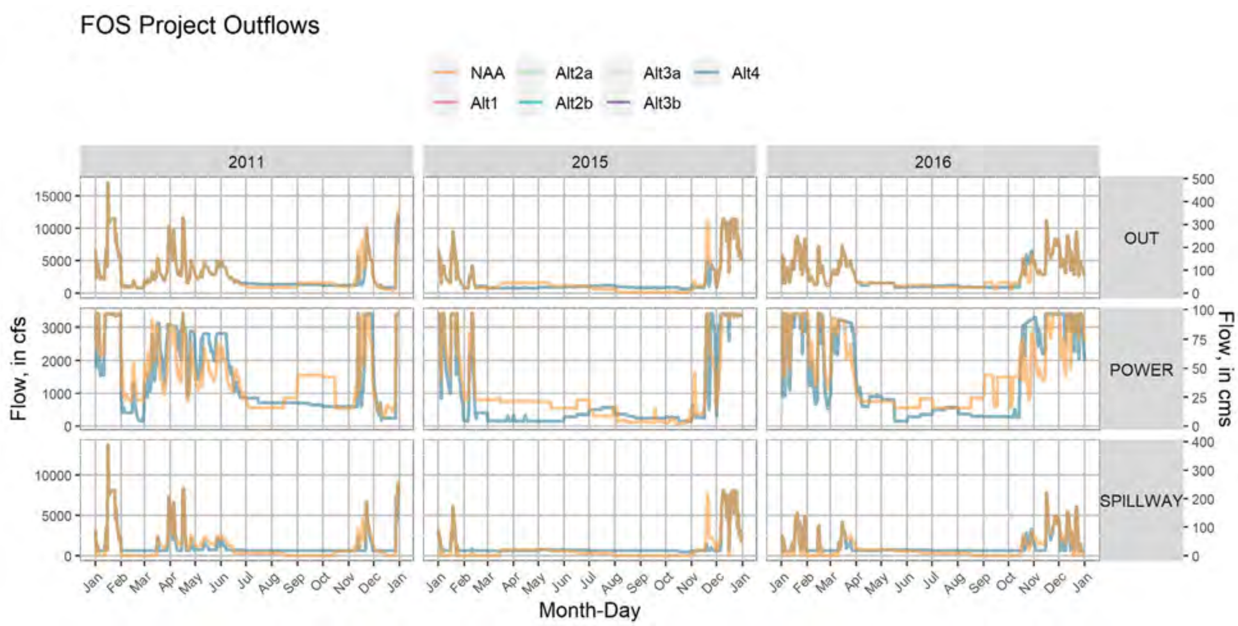

Figure 1-323. WV EIS RES-SIM Foster Dam Gate-Specific Outflows in 2011, 2015, and 2016 under Alternative 4 and NAA.

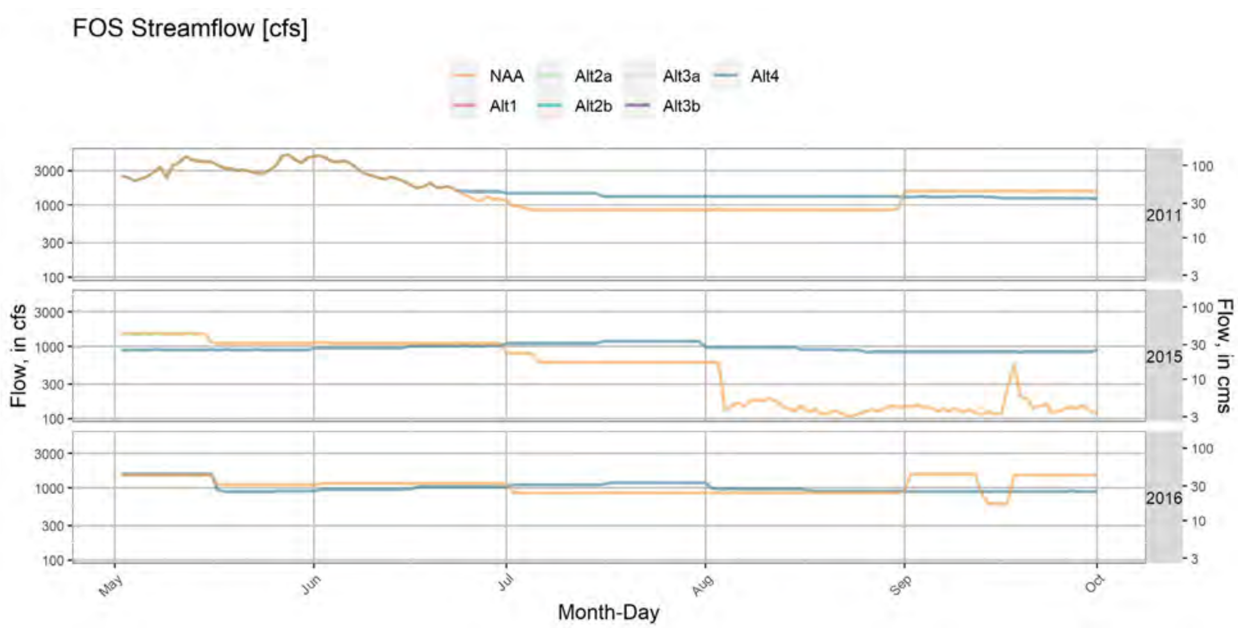

Figure 1-324. WV EIS RES-SIM Foster Dam Total Outflow in 2011, 2015, and 2016 under Alternative 4 and NAA.

Lake Levels and Temperatures from CE-QUAL-W2

Depth-varying temperature, gate-specific outflows, and outflow temperatures through each calendar year scenario at Foster Lake are shown in Figure 1-325, Figure 1-326, and Figure 1-327. Foster Lake temperature was affected by Green Peter Dam operations release temperatures, generally resulting in travel times through Foster of 10-20 days during summer and a time lag in the temperature pattern (Sullivan and Rounds, 2021). Outflows from the proposed fish weir and FWWS resulted in warmer tailwater temperature in spring and summer compared to NAA and similar temperatures to NAA in autumn (Figure 1-328, Figure 1-329).

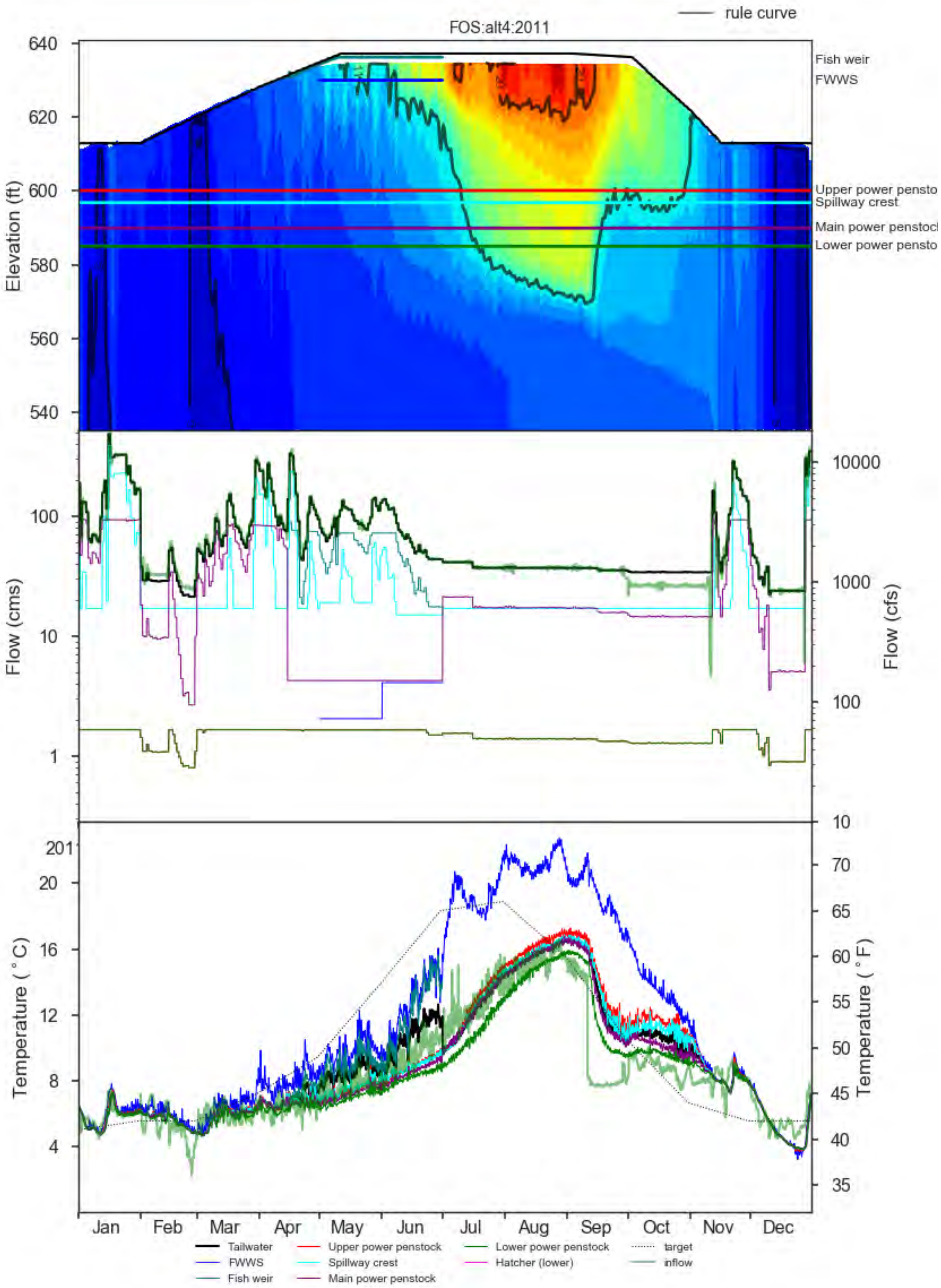

Figure 1-325. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at FOS under Alternative 4 in 2011.

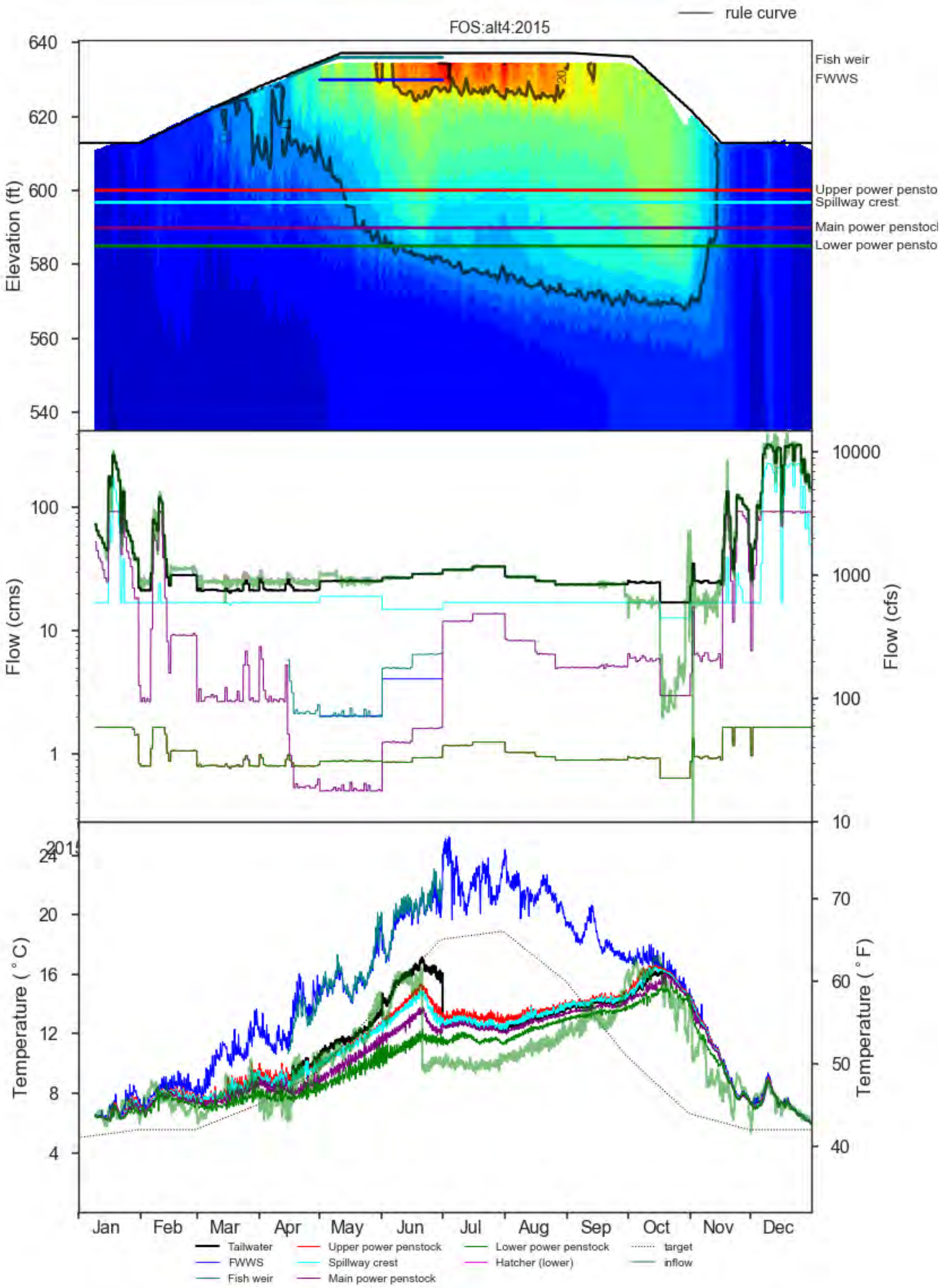

Figure 1-326. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at FOS under Alternative 4 in 2015.

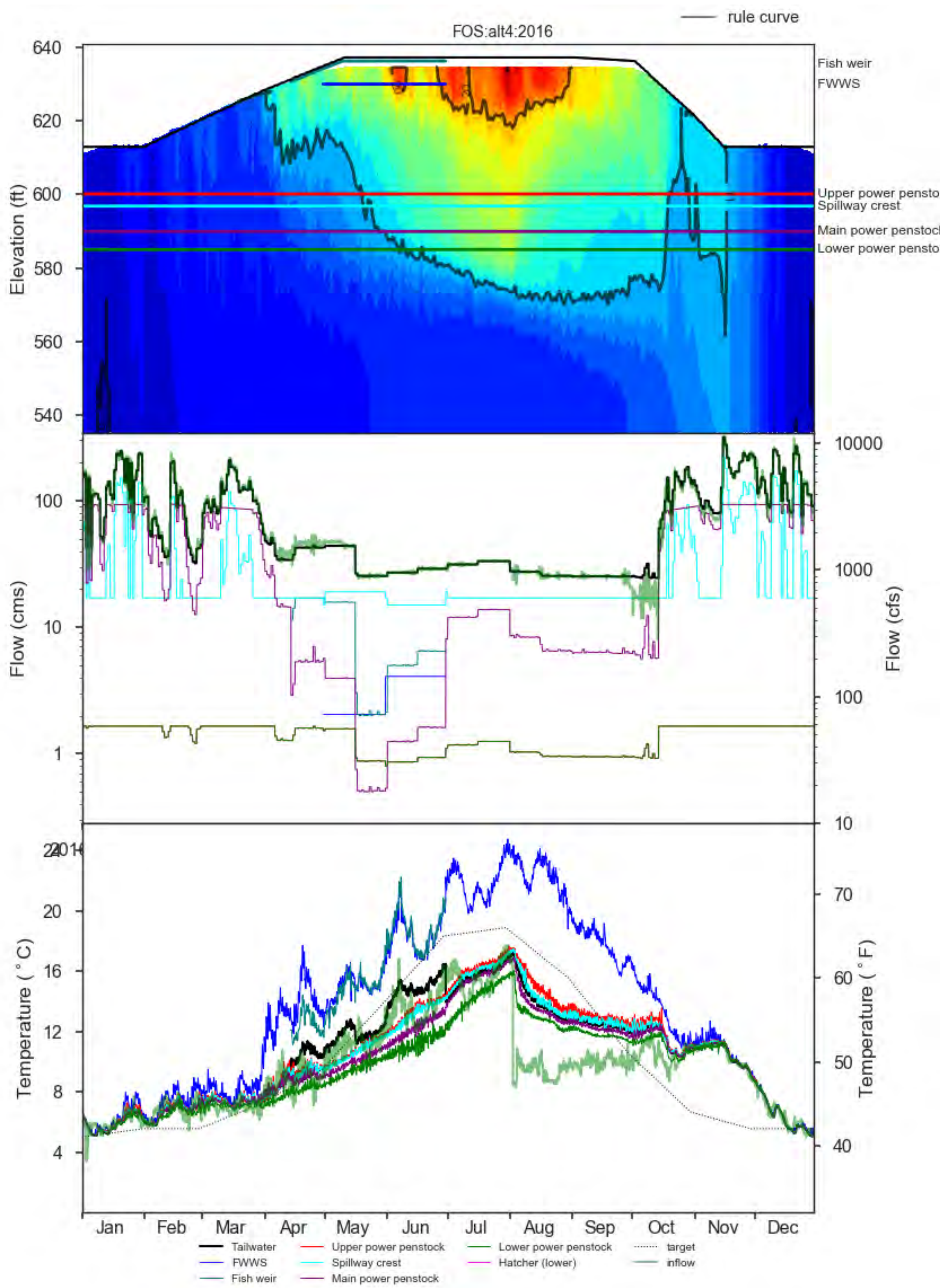

Figure 1-327. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at FOS under Alternative 4 in 2016.

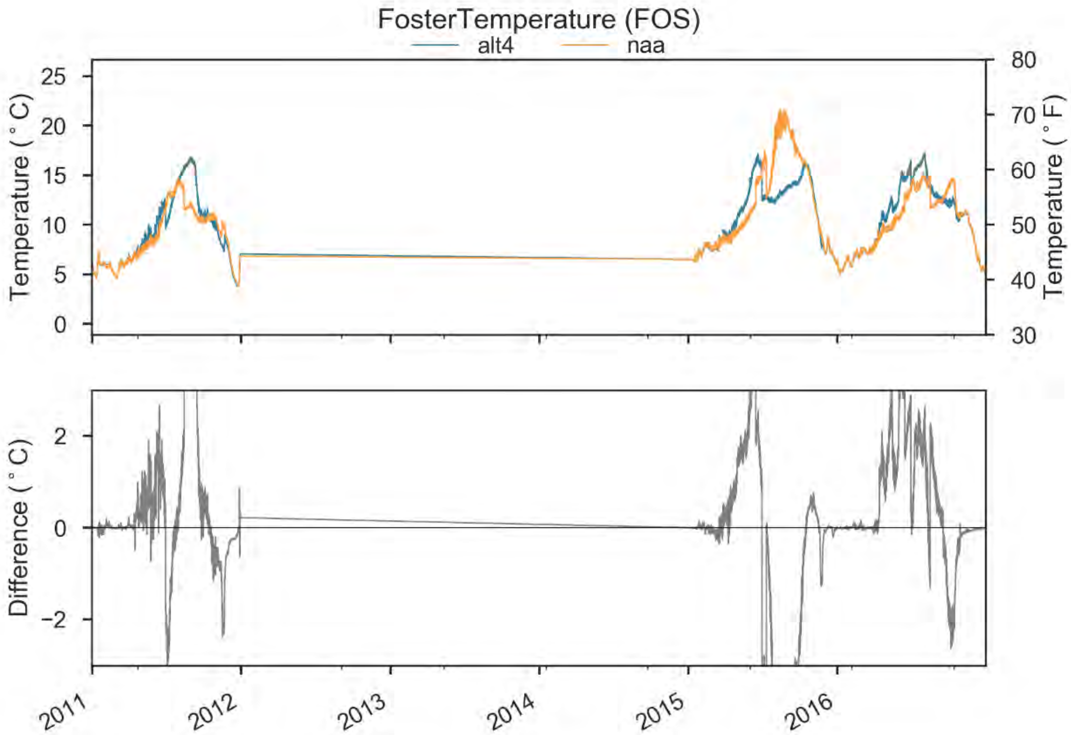

Figure 1-328. Comparison of FOS outflow temperatures in NAA and Alternative 4.

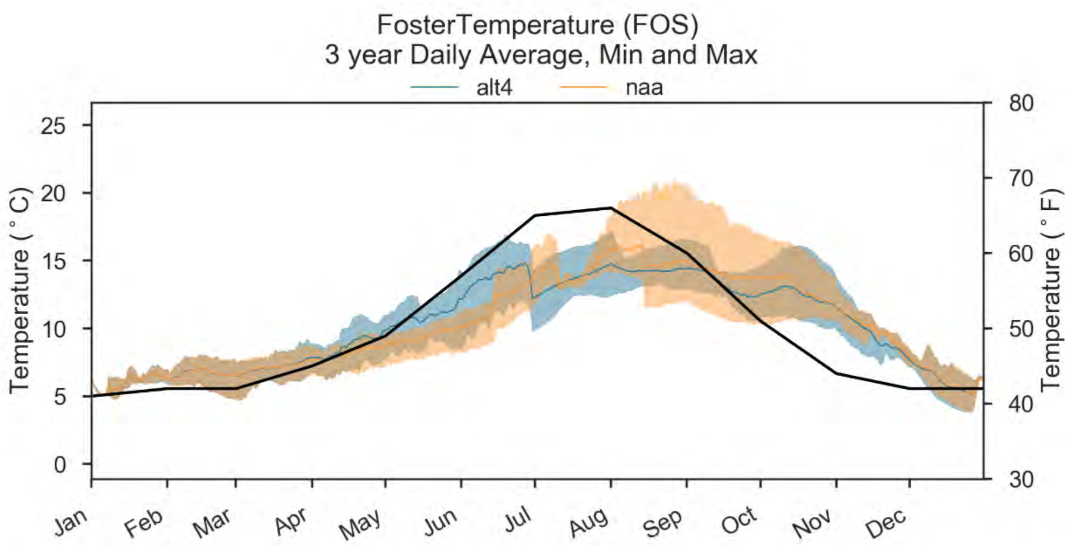

Figure 1-329. Comparison of FOS 3-year daily Daily Average, Min, Max Outflow Temperatures in NAA and Alternative 4. Black Line Indicates Temperature Target.

1.5.7.3 MCKENZIE DAMS

1.5.7.3.1 Cougar

RES-SIM Lake Levels and Outflows

Lake level and storage at Cougar Lake increased under Alternative 4 compared to NAA in 2015 and 2016 aside from September-November in 2015 where the power pool was utilized for downstream flow augmentation when available (Figure 1-330 and Figure 1-332). The increased storage coincided with reduced outflows during spring and increased outflows in summer (while the lake was above minimum lake elevation rules set in RES-SIM) during 2015 and 2016 (Figure 1-331). 2011 operations were generally similar in Alternative 1 and NAA at Cougar Lake.

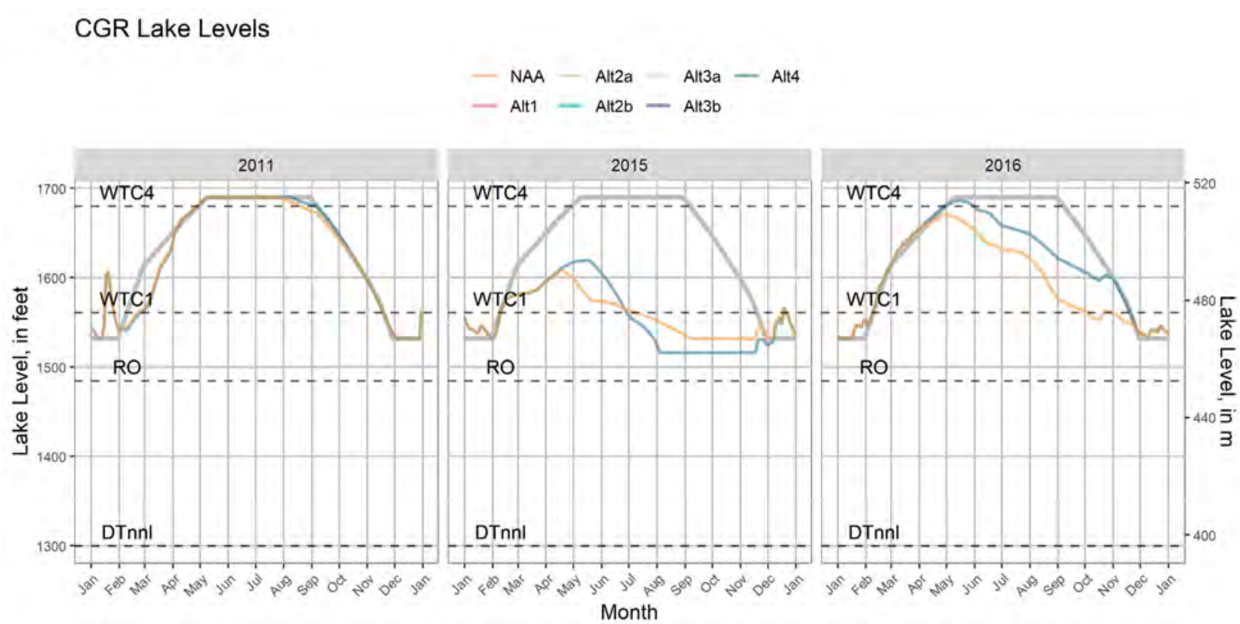

Figure 1-330. WV EIS RES-SIM Cougar Lake Levels in 2011, 2015, and 2016 Under Alternative 4 and NAA.

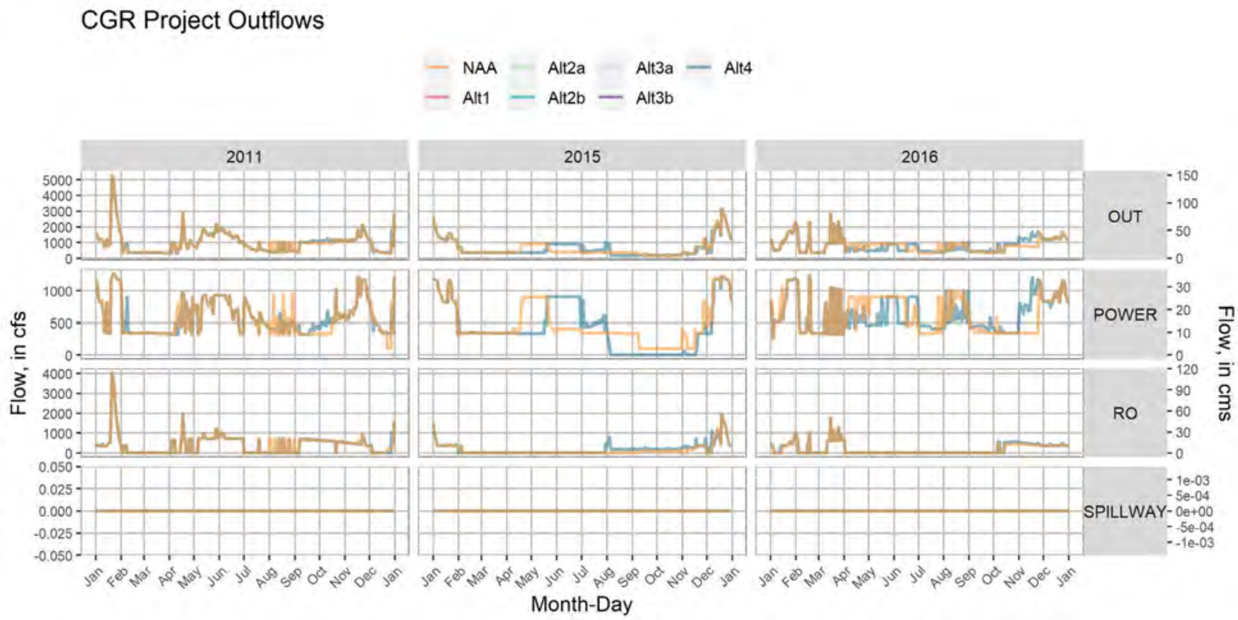

Figure 1-331. WV EIS RES-SIM Cougar Dam Gate-Specific Outflows in 2011, 2015, and 2016 under Alternative 4 and NAA.

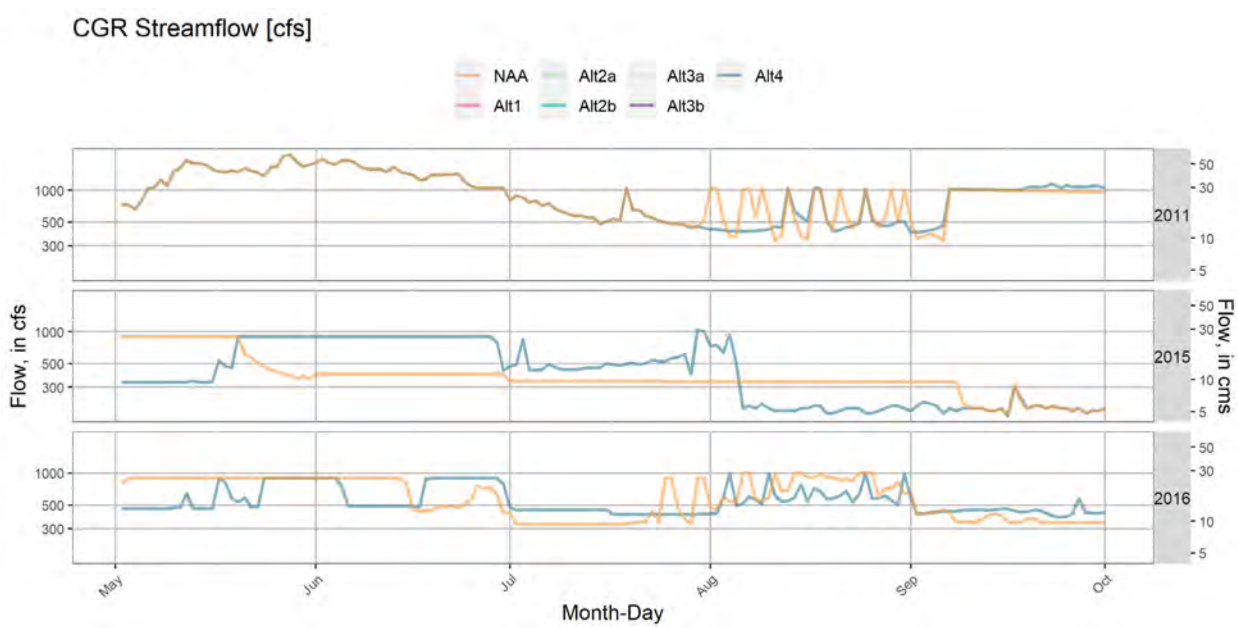

Figure 1-332. WV EIS RES-SIM Cougar Dam Total Outflow in 2011, 2015, and 2016 under Alternative 4 and NAA.

Lake Levels and Temperatures from CE-QUAL-W2

Depth-varying temperature, gate-specific outflows, and outflow temperatures through each calendar year scenario at Cougar Lake are shown in Figure 1-333, Figure 1-334, and Figure 1-335. Outflows from the existing temperature tower and proposed FSS resulted in similar tailwater temperature in Alternative 4 compared to NAA (Figure 1-336 and Figure 1-337) aside from minor differences in each calendar year scenario that were likely linked to differences in lake levels and the shift in timing of when the lake was drafted below the bottom usable elevation of the WTCT. The addition of a FSS structure in Alternative 4 is not expected to have a large effect on the ability of the existing WTCT functionality with respect to temperature management (USACE, 2019a).

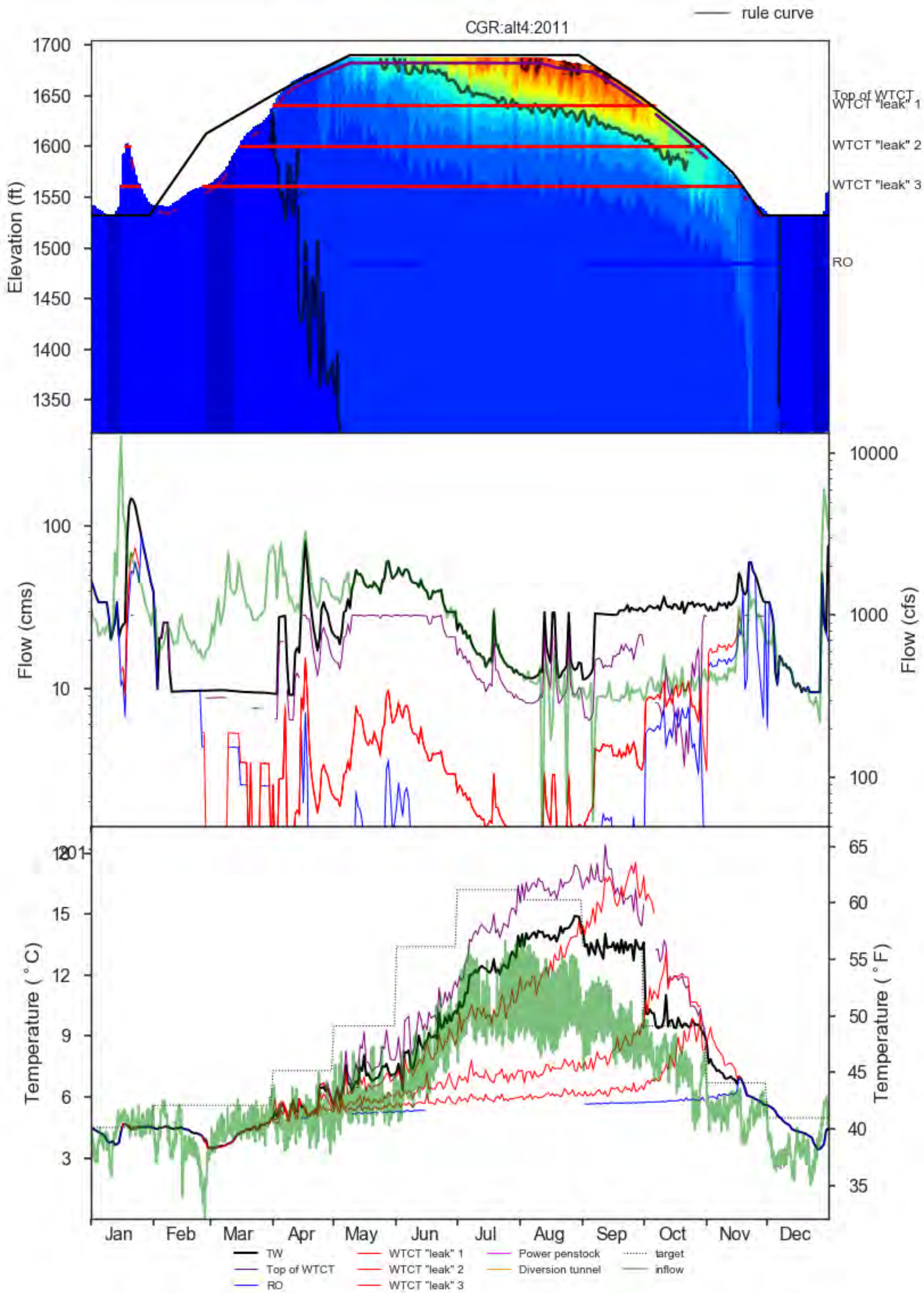

Figure 1-333. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at CGR under Alternative 4 in 2011.

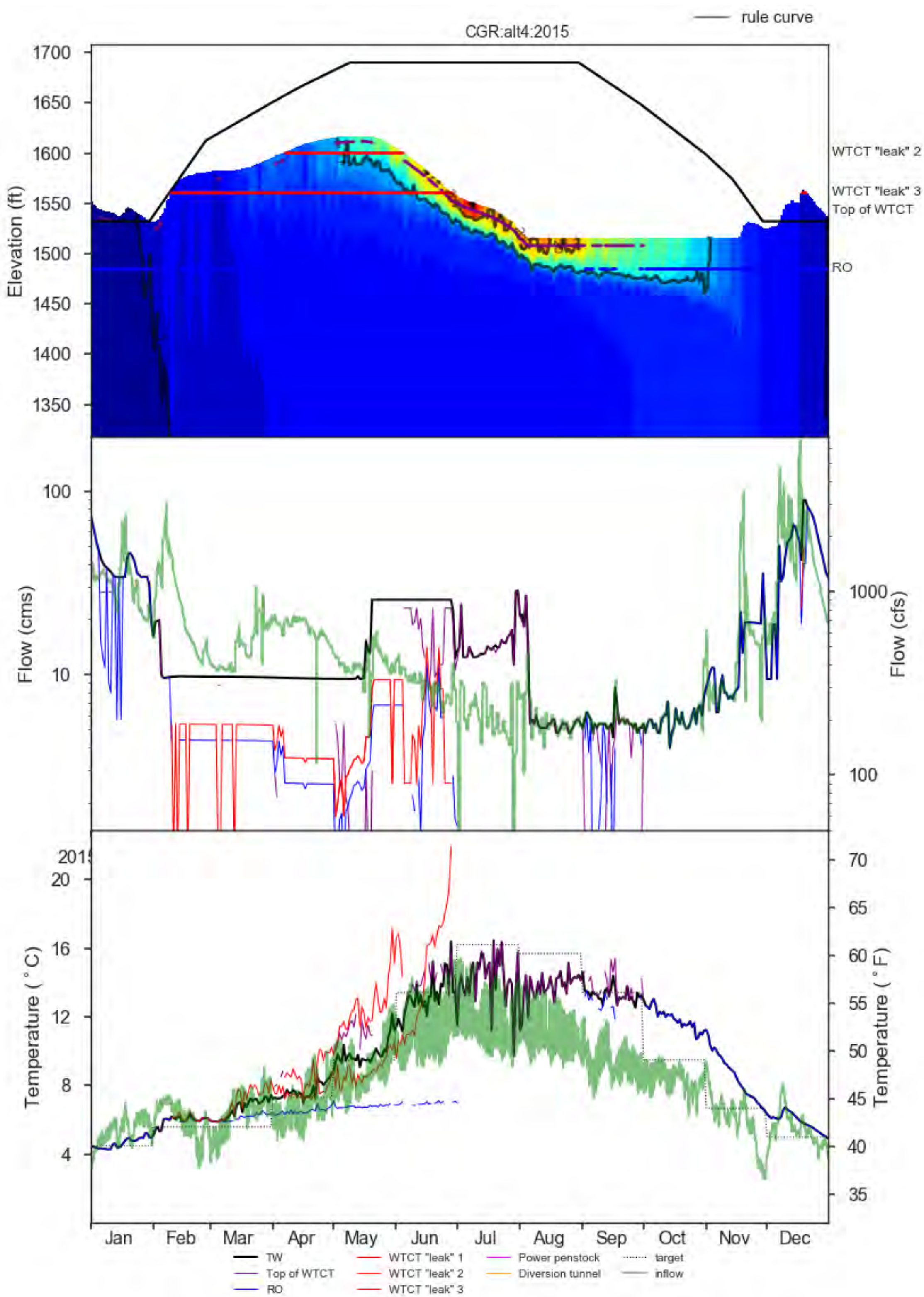

Figure 1-334. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at CGR under Alternative 4 in 2015.

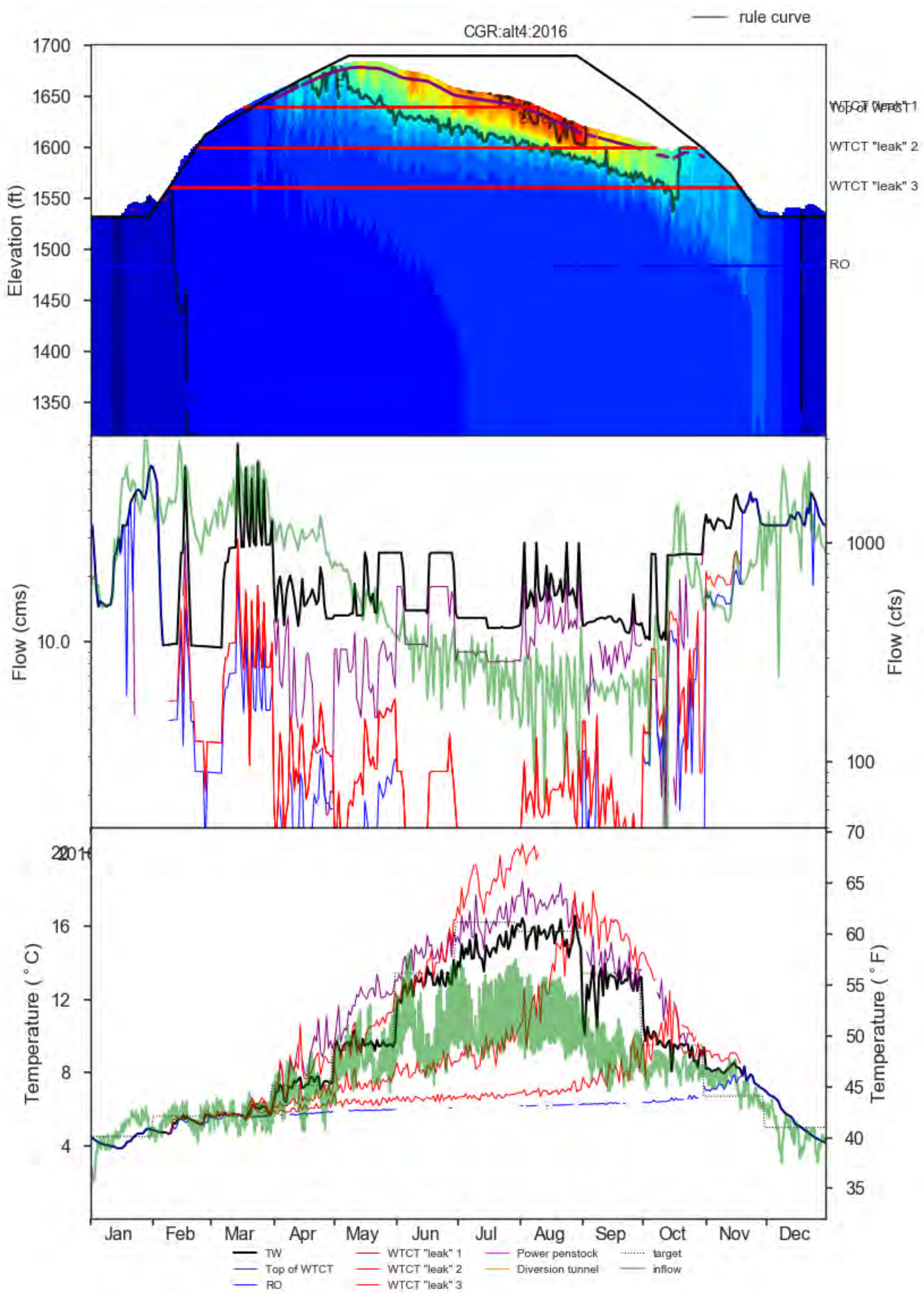

Figure 1-335. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at CGR under Alternative 4 in 2016.

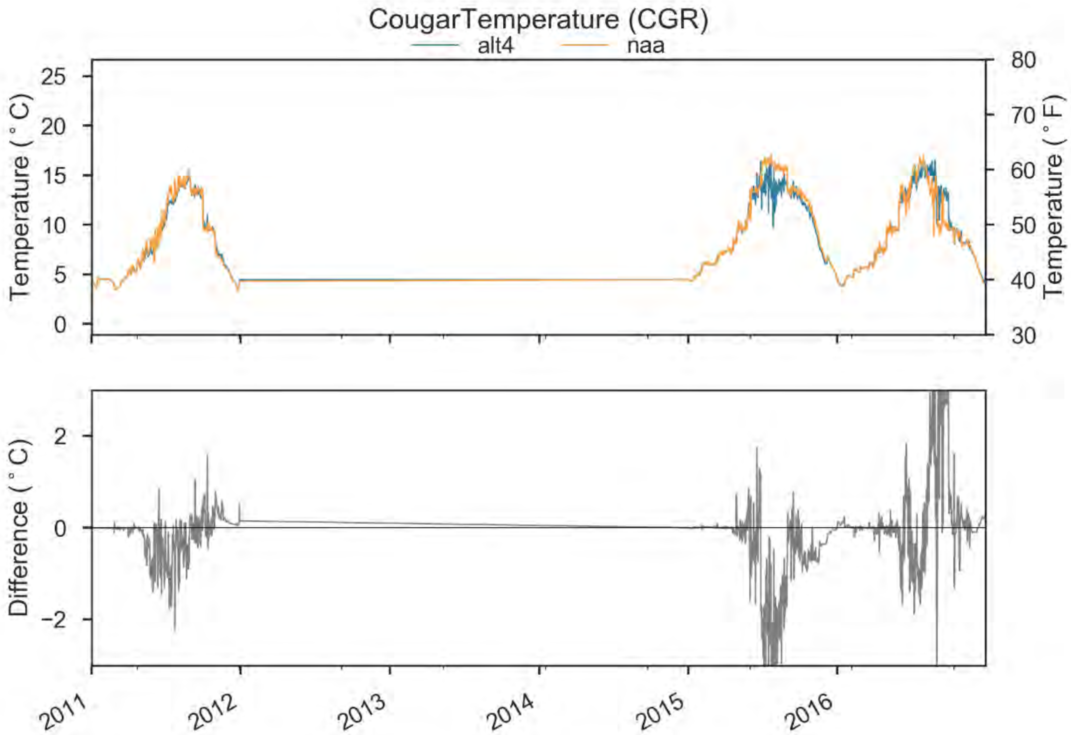

Figure 1-336. Comparison of CGR Outflow Temperatures in NAA and Alternative 4.

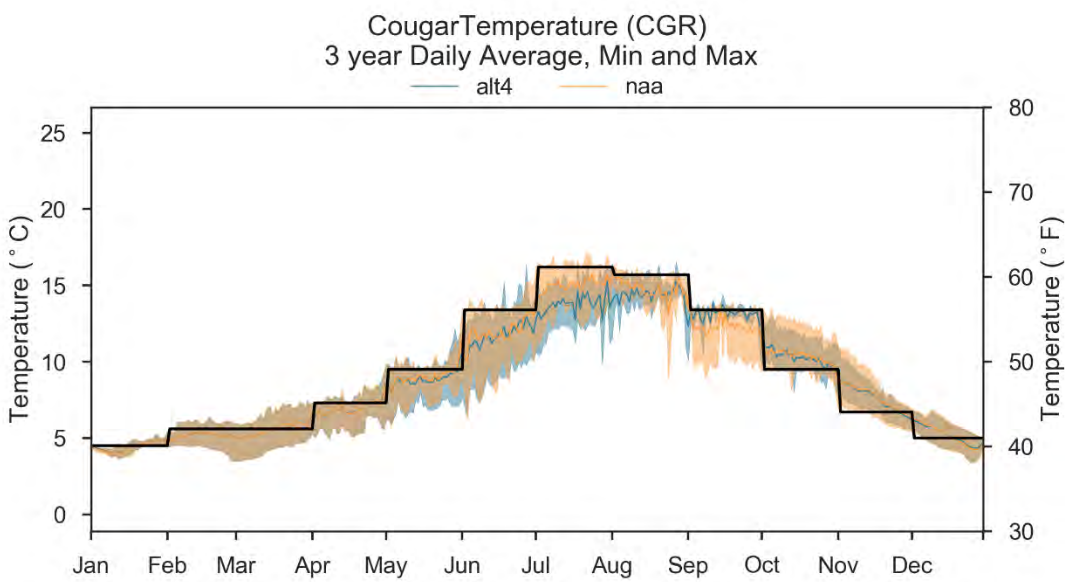

Figure 1-337. Comparison of CGR 3-year Daily Average, Min, Max Outflow Temperatures in NAA and Alternative 4. Black Line Indicates Temperature Target.

1.5.7.4 MIDDLE FORK WILLAMETTE DAMS

1.5.7.4.1 Hills Creek

RES-SIM Lake Levels and Outflows

Lake level and storage at Hills Creek Lake generally increased under Alternative 4 compared to NAA in 2015 and 2016 aside from August-November in 2015 where the power pool was utilized for downstream flow augmentation (Figure 1-338, Figure 1-340). The increased storage coincided with reduced outflows during spring and increased outflows in June-July during 2015 and July-October in 2016 (Figure 1-339). 2011 operations were similar in Alternative 4 and NAA at Hills Creek Lake.

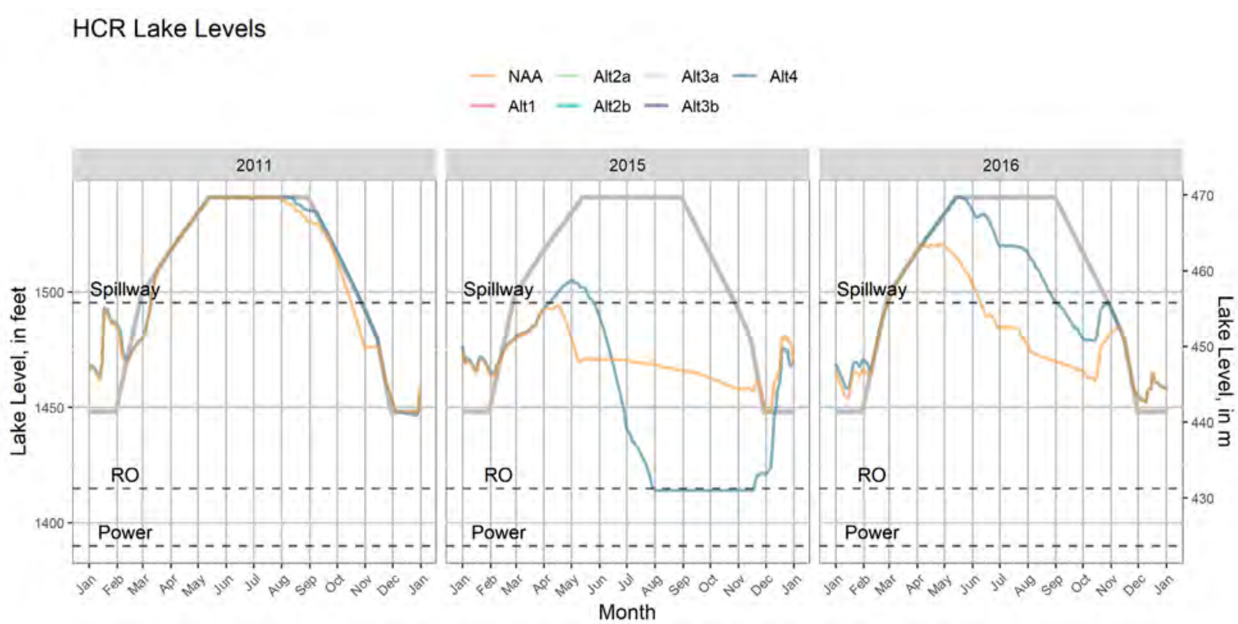

Figure 1-338. WV EIS RES-SIM Hills Creek Lake Levels in 2011, 2015, and 2016 Under Alternative 4 and NAA.

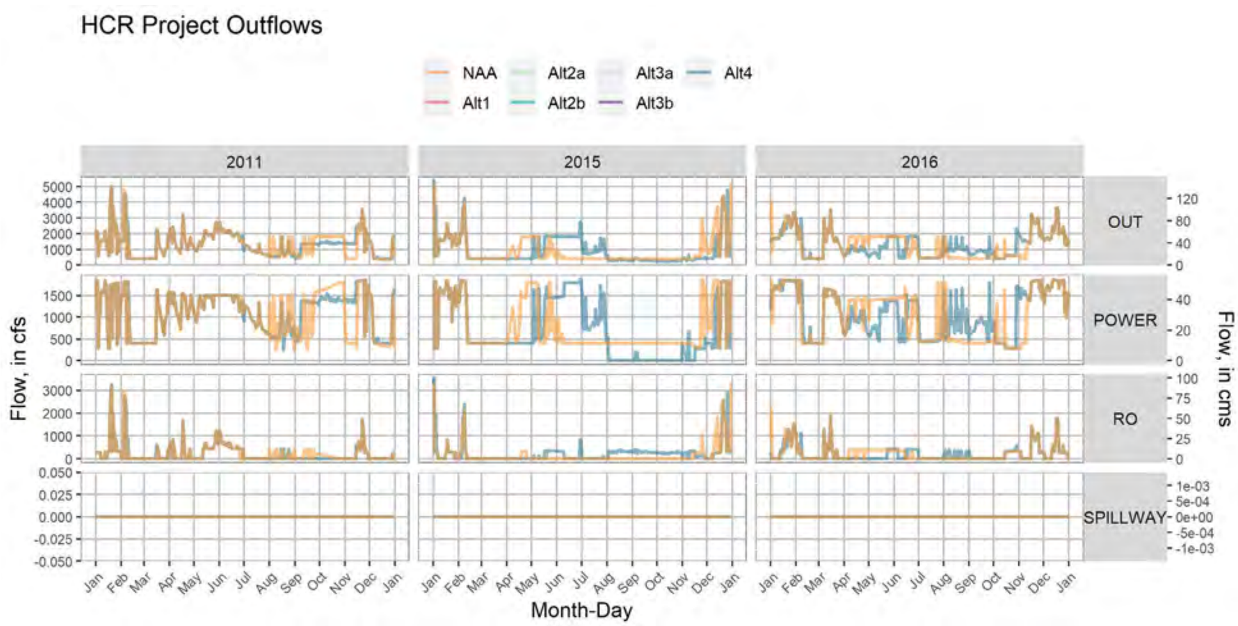

Figure 1-339. WV EIS RES-SIM Hills Creek Dam Gate-Specific Outflows in 2011, 2015, and 2016 under Alternative 4 and NAA.

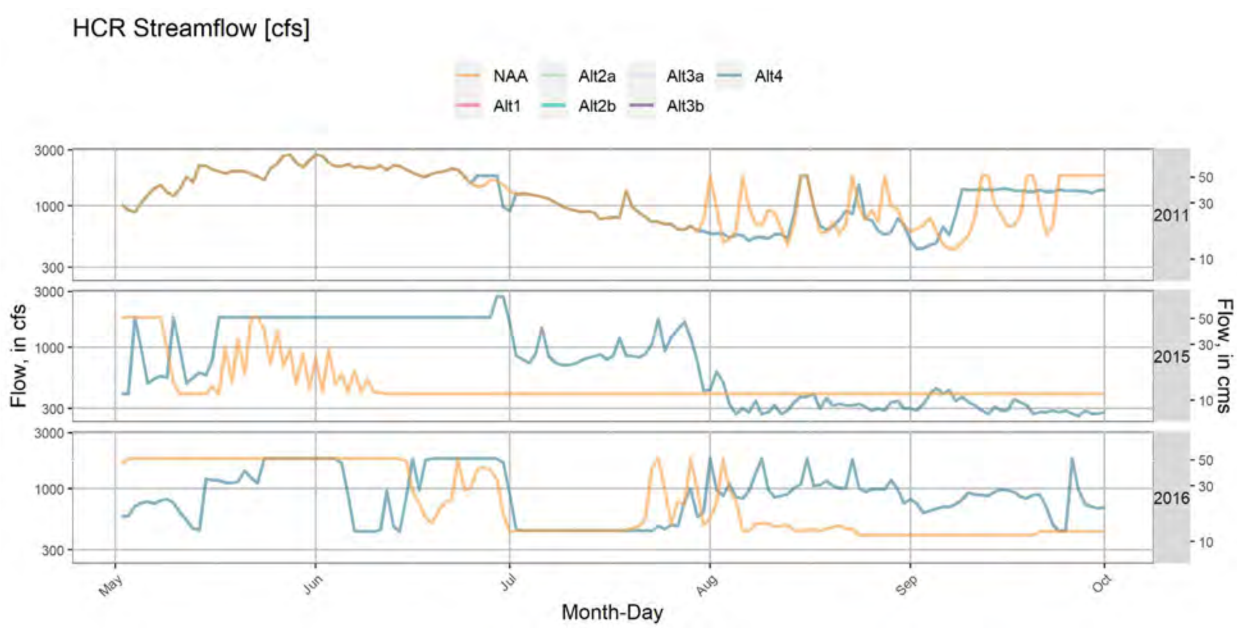

Figure 1-340. WV EIS RES-SIM Hills Creek Dam Total Outflow in 2011, 2015, and 2016 Under Alternative 4 and NAA.

Lake Levels and Temperatures from CE-QUAL-W2

Depth-varying temperature, gate-specific outflows, and outflow temperatures through each calendar year scenario in Alternative 4 at Hills Creek Lake are shown in Figure 1-341, Figure 1-342, and Figure 1-343. Temperature tower outflows blended between a floating outlet (25 feet below lake surface) and a deeper outlet at the elevation of the RO. Tailwater release temperatures generally matched the temperature target when sufficient warm or cool water was available. Generally, these proposed SWS-FSS structures allowed temperatures to be warmer than NAA in spring/summer and cooler than NAA in autumn in 2011, 2015, and 2016 (Figure 1-344, Figure 1-345).

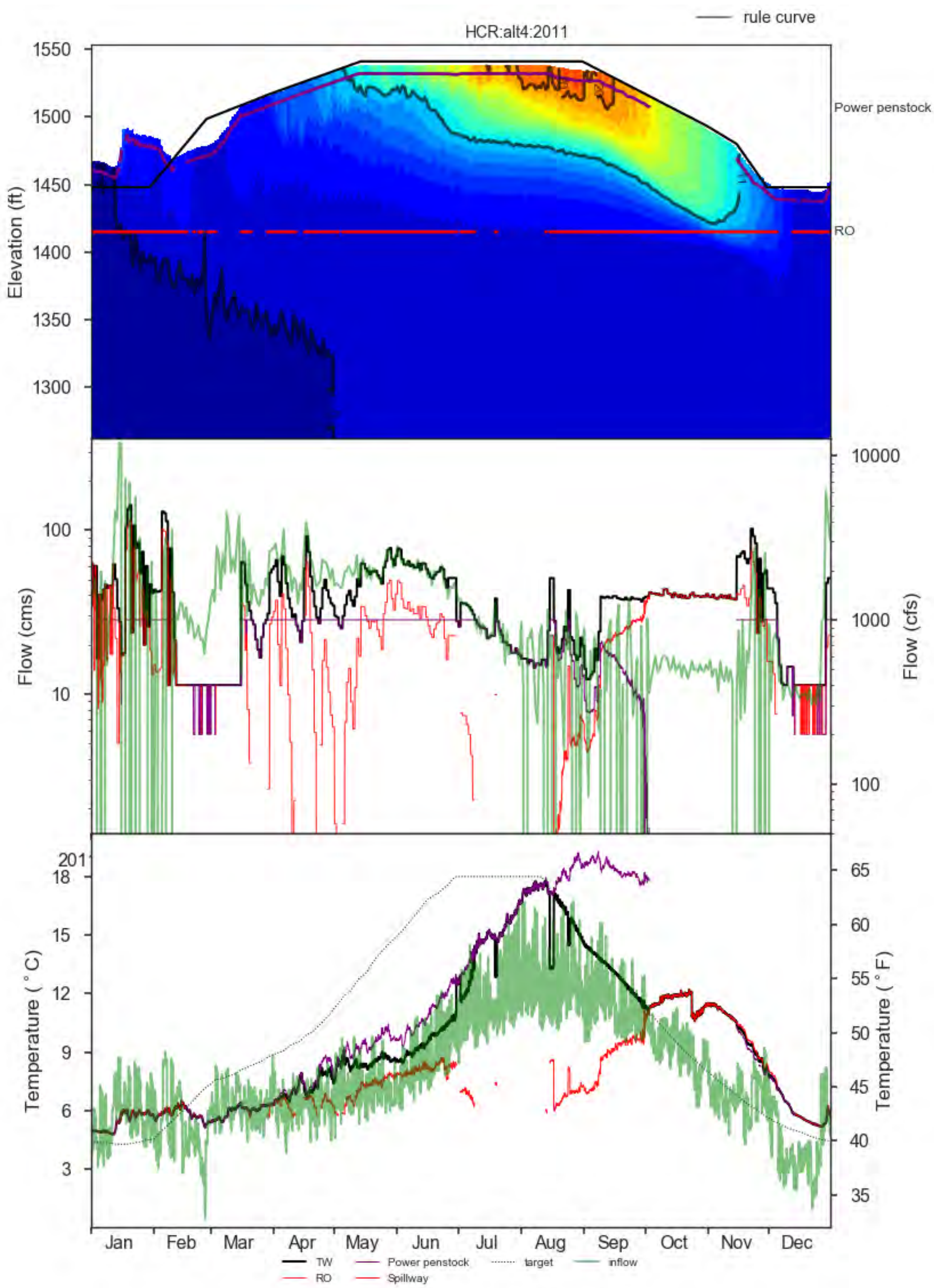

Figure 1-341. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at HCR under Alternative 4 in 2011.

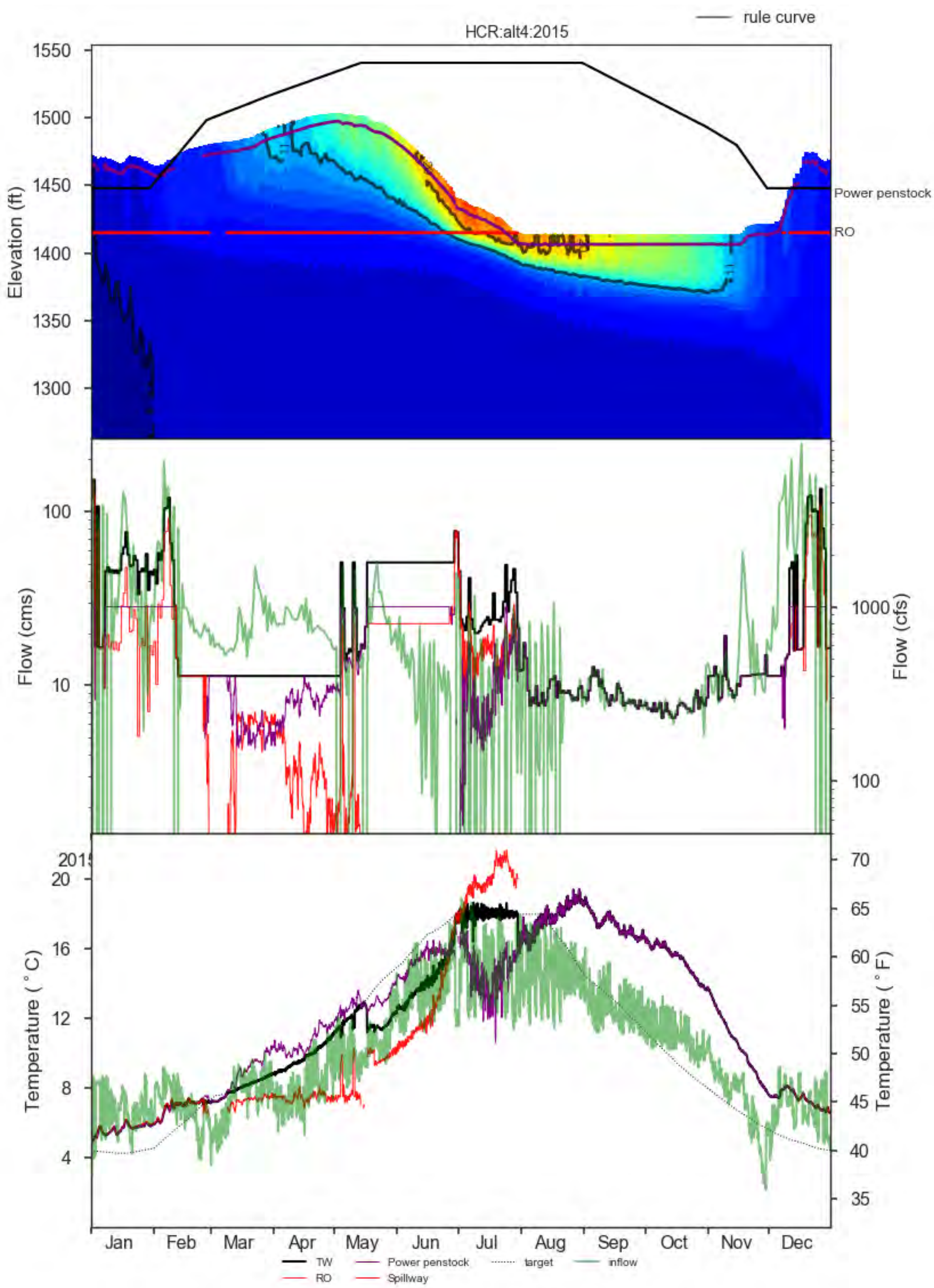

Figure 1-342. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at HCR under Alternative 4 in 2015.

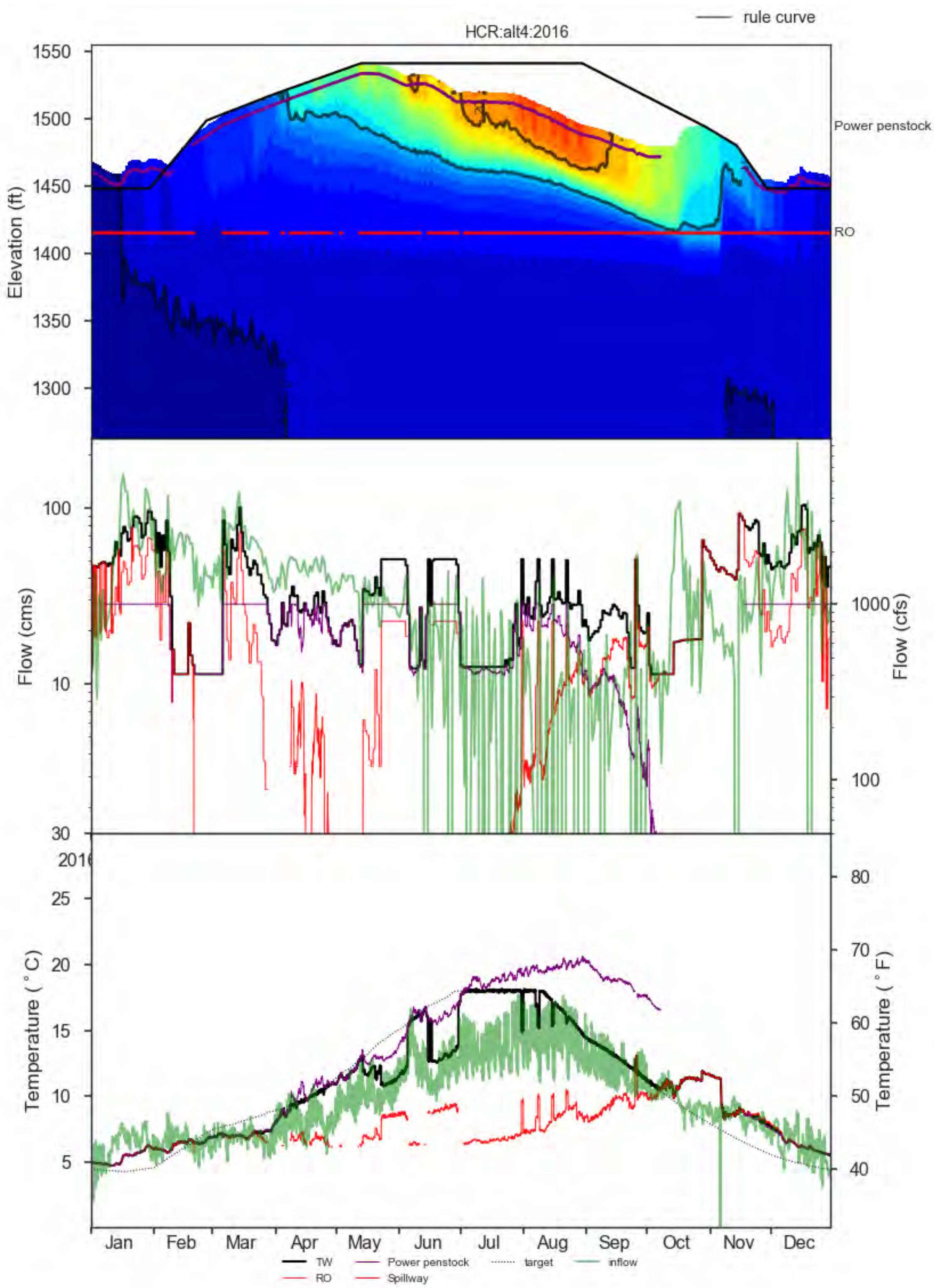

Figure 1-343. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at HCR under Alternative 4 in 2016.

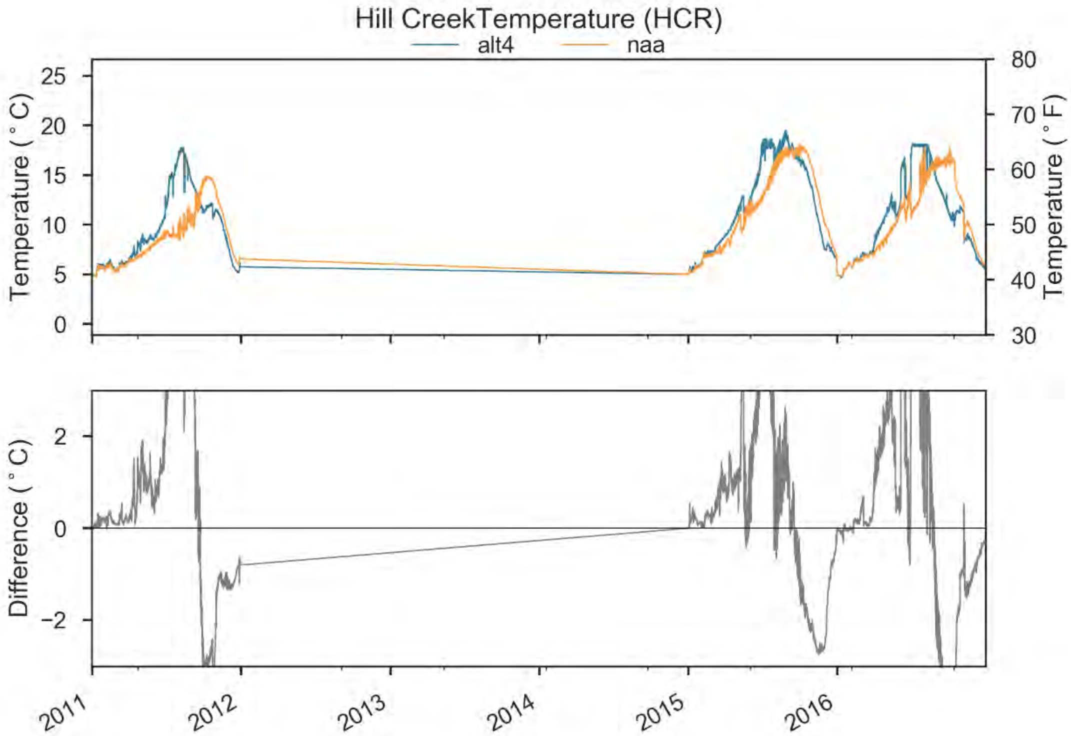

Figure 1-344. Comparison of HCR outflow temperatures in NAA and Alternative 4.

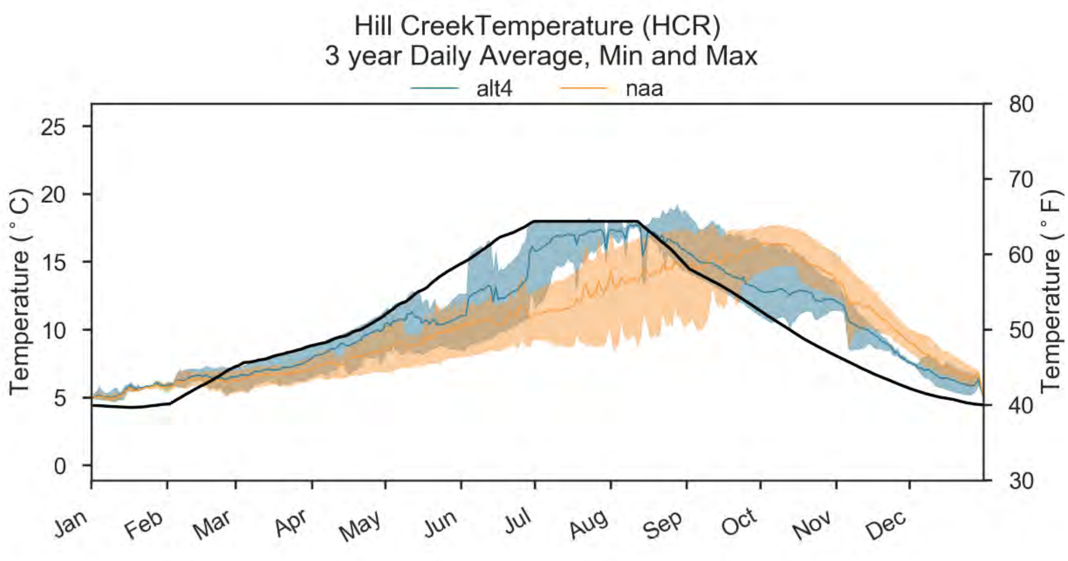

Figure 1-345. Comparison of HCR 3-year Daily Average, Min, Max Outflow Temperatures in NAA and Alternative 4. Black Line Indicates Temperature Target.

1.5.7.4.2 Lookout Point

RES-SIM Lake Levels and Outflows

Lake level and storage at Lookout Point Lake in Alternative 4 were generally similar to NAA in 2011, 2015, and 2016 (Figure 1-346, Figure 1-348) aside from minor differences in timing of refill and release rates that were associated with upstream HCR operations. The proposed SWS and FSS in Alternative 4 allowed all outflow within powerhouse capacity (assumed at 6000 cfs) to be routed from a floating outlet through the Power outlets for temperature management (Figure 1-347).

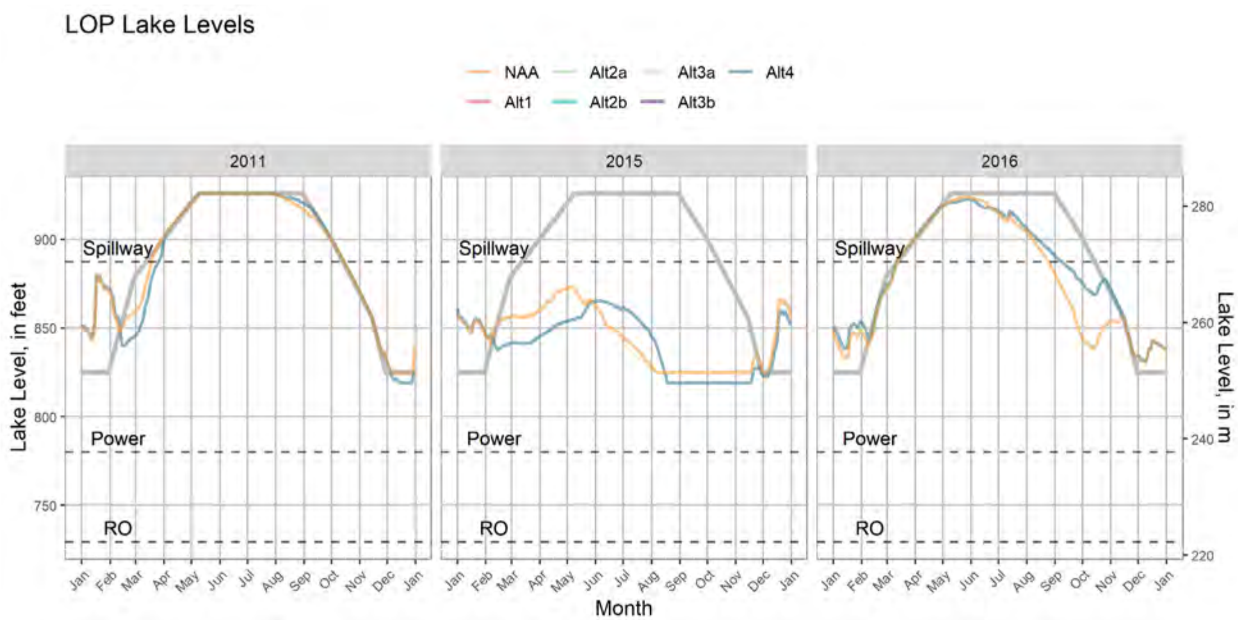

Figure 1-346. WV EIS RES-SIM Lookout Point Lake Levels in 2011, 2015, and 2016 Under Alternative 4 and NAA.

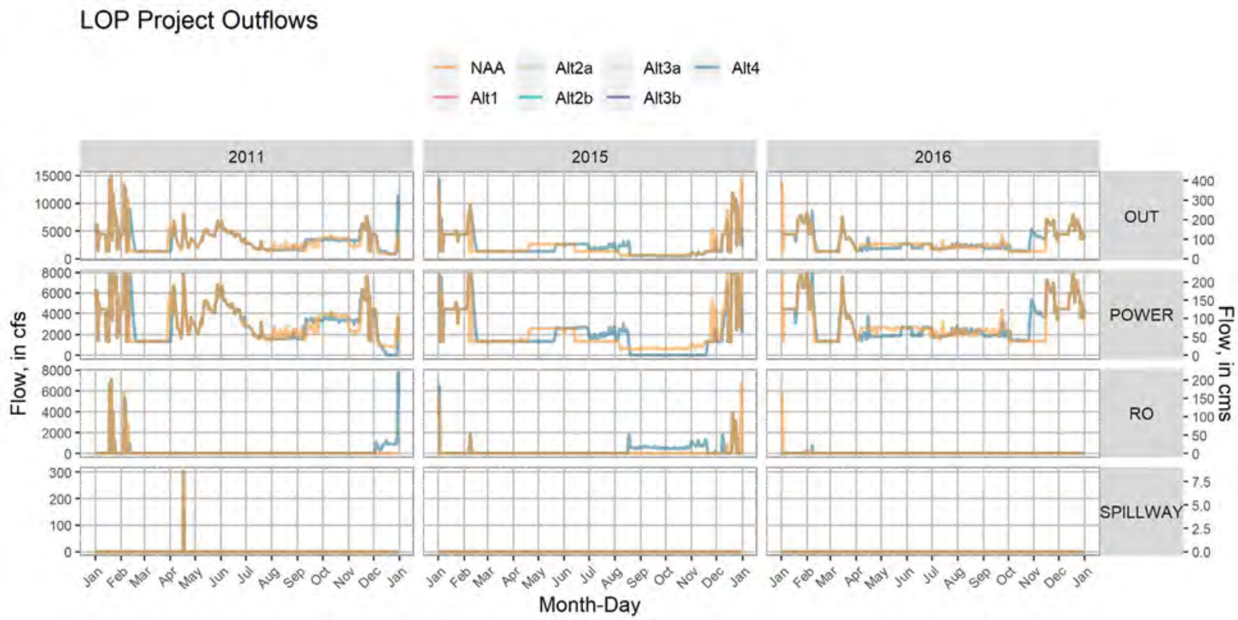

Figure 1-347. WV EIS RES-SIM Lookout Point Dam Gate-Specific Outflows in 2011, 2015, and 2016 under Alternative 4 and NAA.

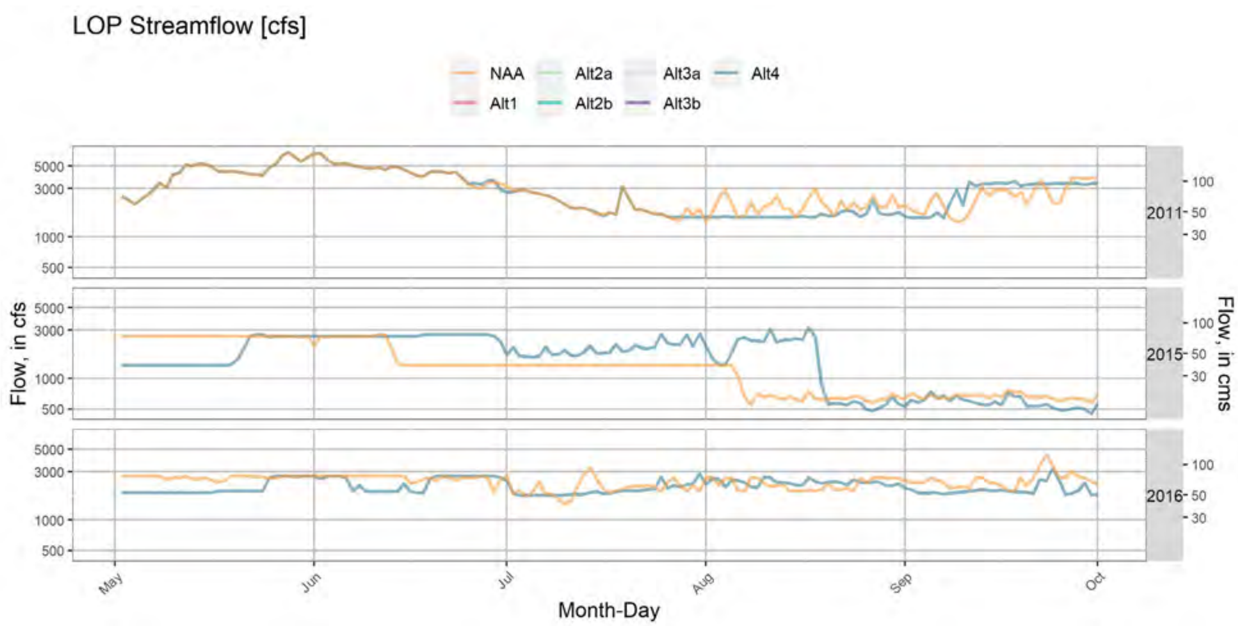

Figure 1-348. WV EIS RES-SIM Lookout Point Dam Total Outflow in 2011, 2015, and 2016 under Alternative 4 and NAA.

Lake Levels and Temperatures from CE-QUAL-W2

Depth-varying temperature, gate-specific outflows, and outflow temperatures through each calendar year scenario at Lookout Point Lake in Alternative 4 are shown in Figure 1-349, Figure 1-350, and Figure 1-351. Temperature tower outflows blended between a floating outlet (25 feet below lake surface) and a deeper outlet at the elevation of the RO. Tailwater release temperatures generally matched the temperature target when sufficient warm or cool water was available. Generally, these proposed SWS-FSS structures allowed temperatures to be warmer than NAA in spring/summer and cooler than NAA in autumn in 2011, 2015, and 2016 (Figure 1-352, Figure 1-353) as measured below Dexter Dam.

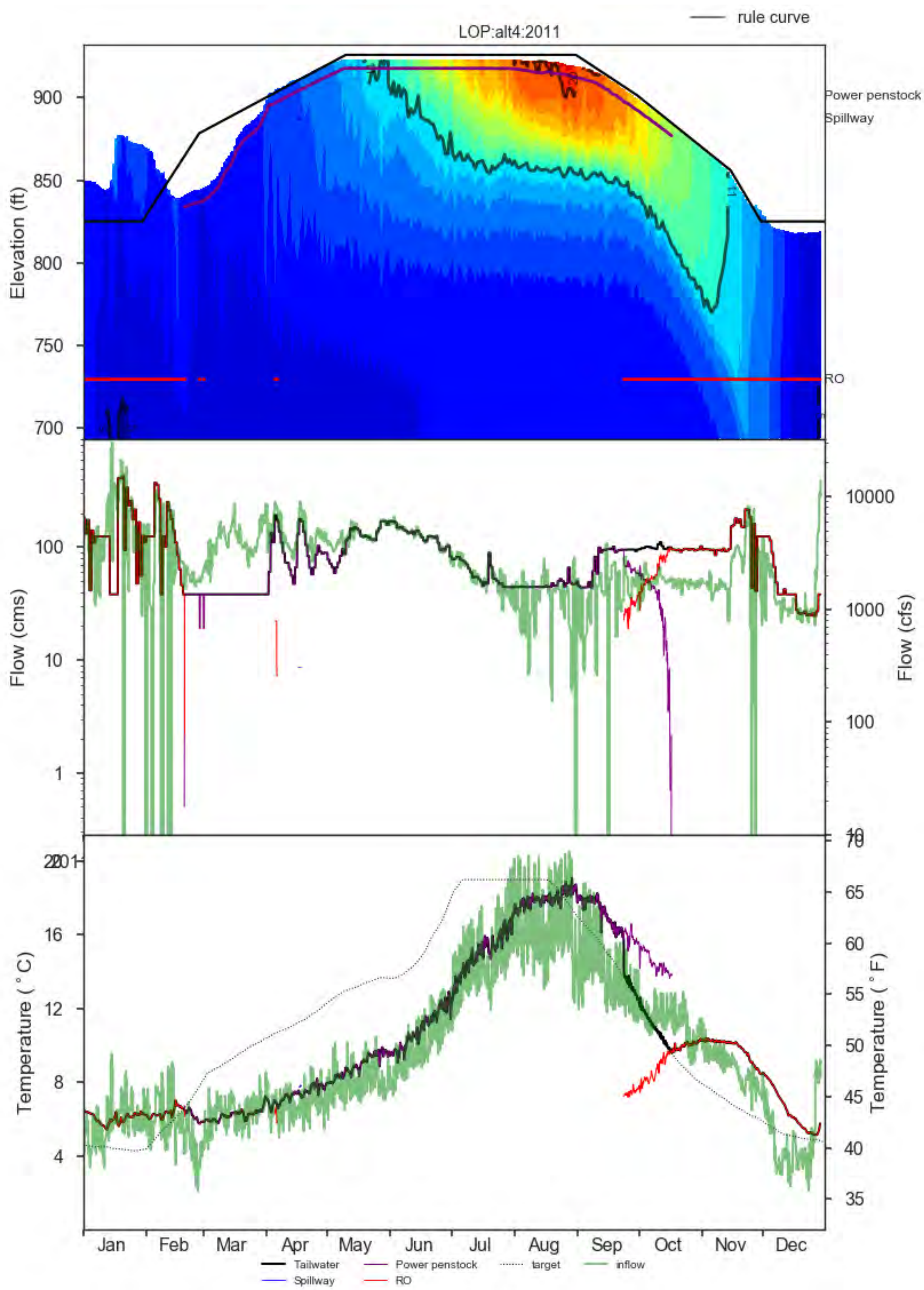

Figure 1-349. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at LOP under Alternative 4 in 2011.

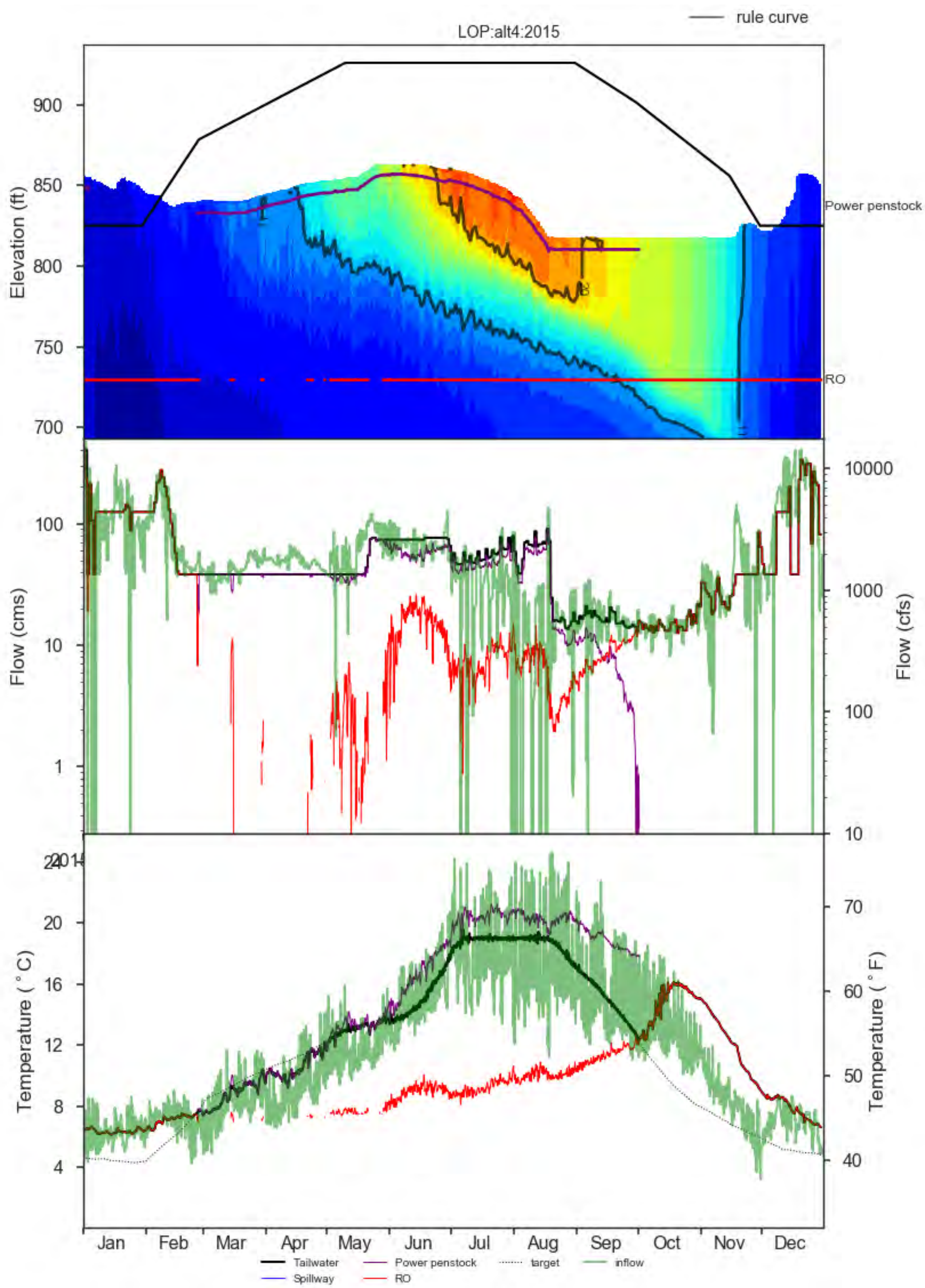

Figure 1-350. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at LOP under Alternative 4 in 2015.

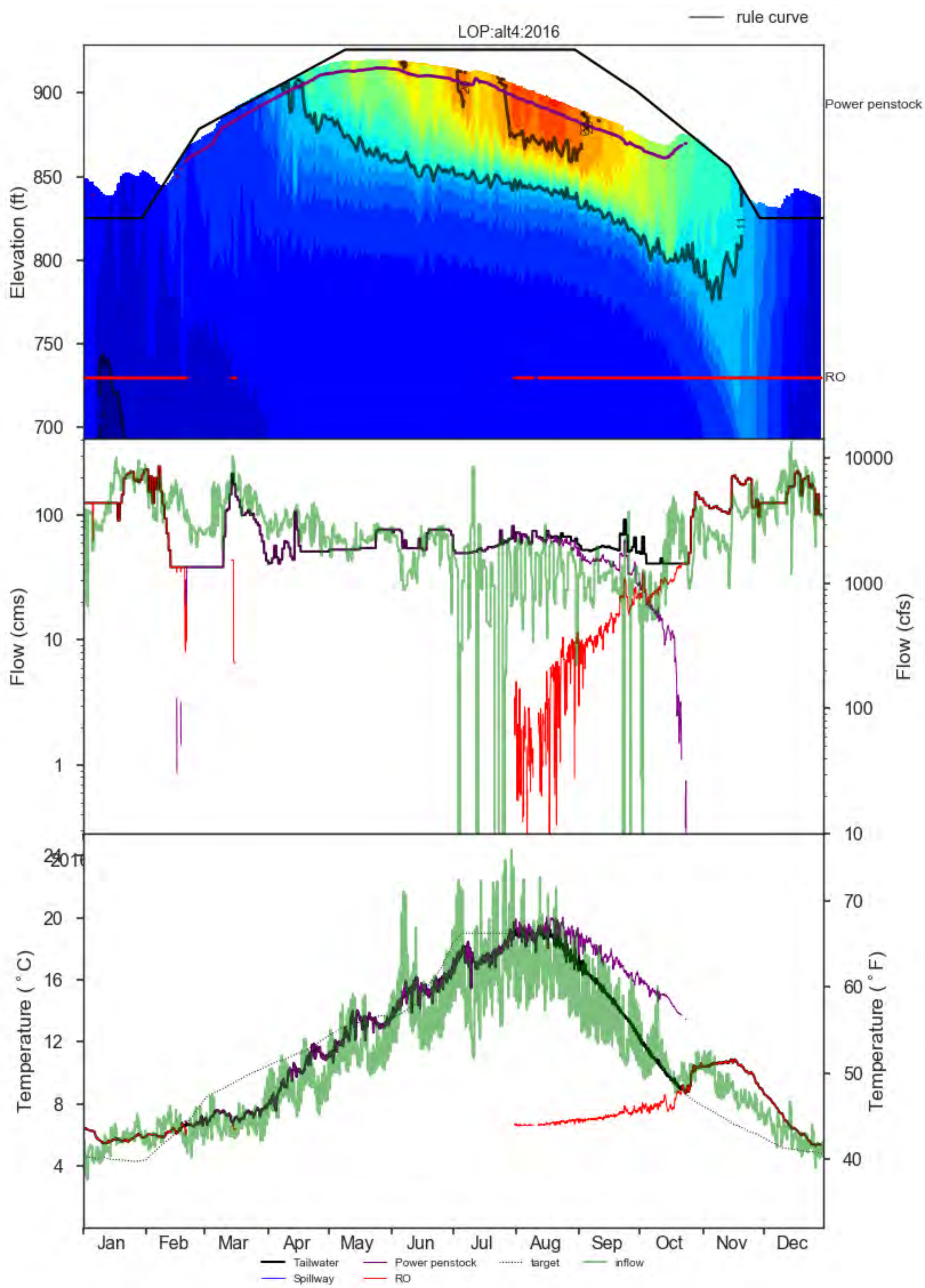

Figure 1-351. Temperature-Elevation Isopleth (top), Gate Outflows (middle), and Outflow Temperatures (bottom) at LOP under Alternative 4 in 2016.

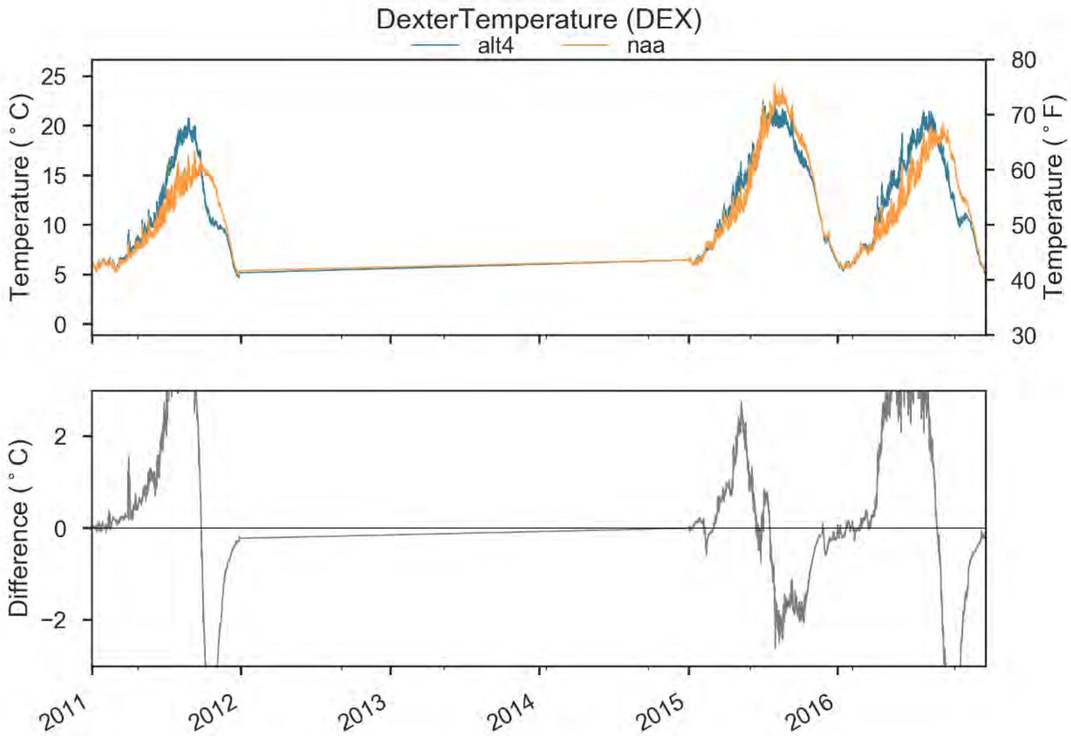

Figure 1-352. Comparison of DEX Outflow Temperatures in NAA and Alternative 4.

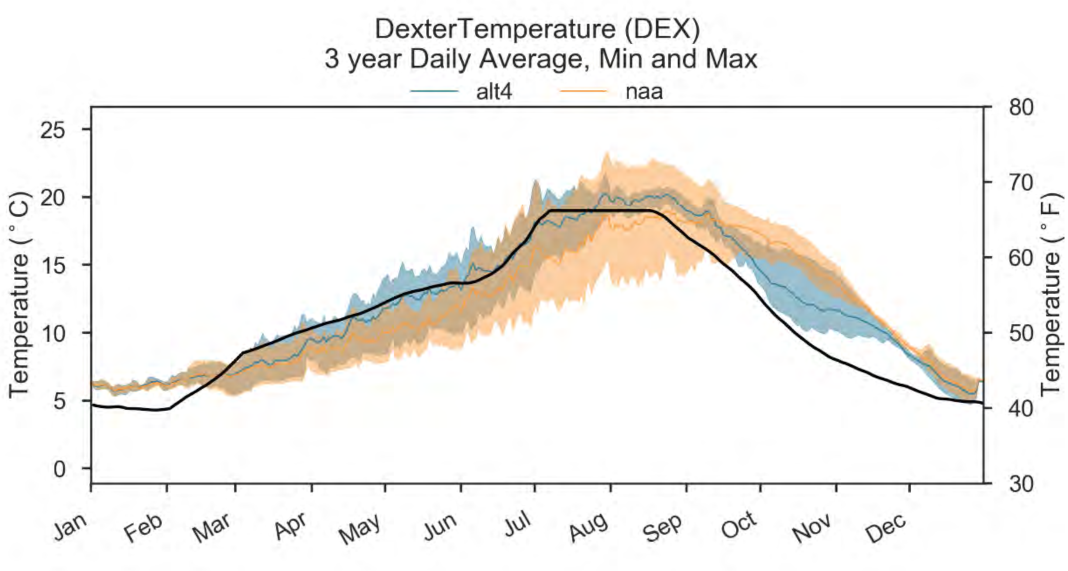

Figure 1-353. Comparison of DEX 3-year Daily Average, Min, Max Outflow Temperatures in NAA and Alternative 4. Black Line Indicates Temperature Target.

1.5.7.5 Mainstem Willamette River

Streamflow in the mainstem Willamette River under Alternative 4 was generally lower from April to mid-June and higher from mid-June to mid-September compared with NAA (Figure 1-354). However, these flow differences were primarily in 2015 and responsive to the Measure 30 rules that increase dam outflows in advance of heat wave events (Figure 1-355). These flow changes resulted in warmer water temperatures April to mid-June and cooler water temperatures from mid-June to mid-September compared with NAA in 2015 (Figure 1-356). Water temperatures at Salem were also affected by upstream dam operations and proposed SWS-FSS structures, which likely contributed to warmer temperatures seen in 2011 and 2015 (Figure 1-356, Figure 1-357). Water temperature differences between Alternative 4 and NAA were less than 2 degrees Celsius.

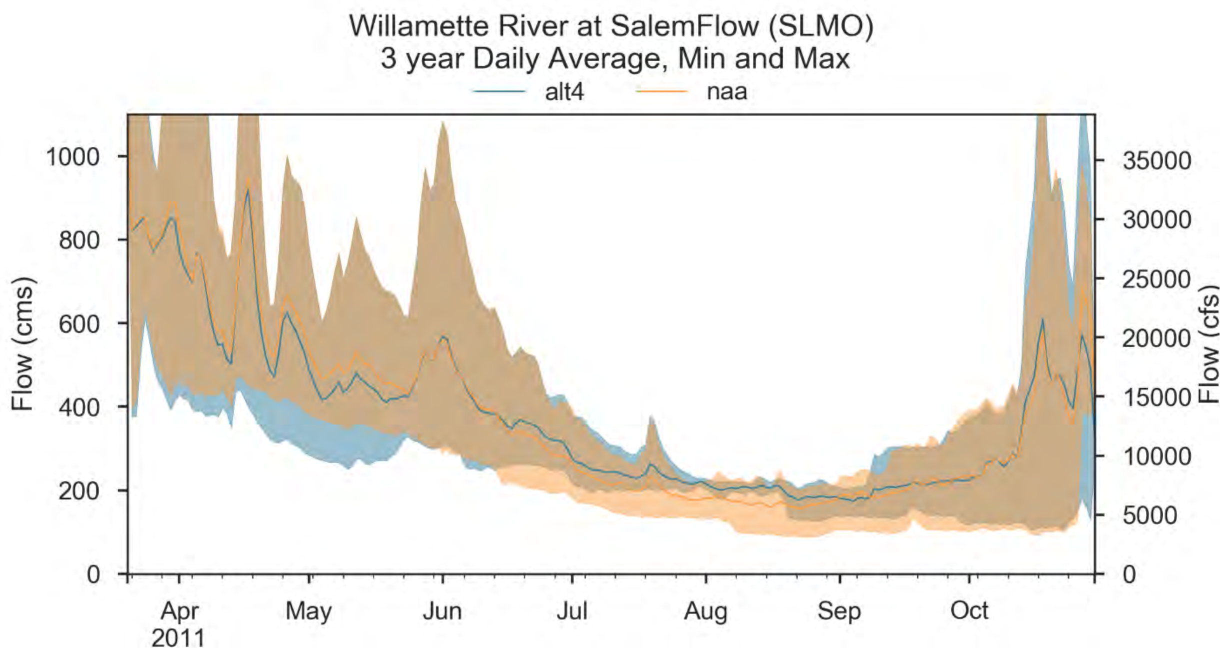

Figure 1-354. Streamflow Comparison of Daily Average, Min, Max Willamette River at SLMO under NAA and Alternative 4 Conditions.

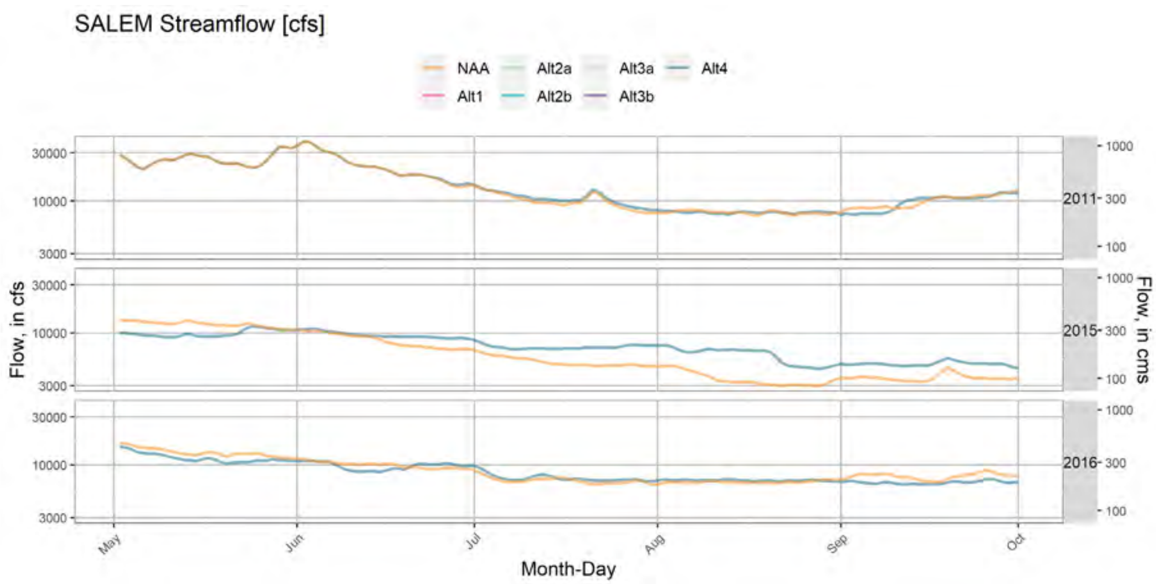

Figure 1-355. Streamflow Comparison Between Alternative 4 and NAA at Willamette River at SLMO.

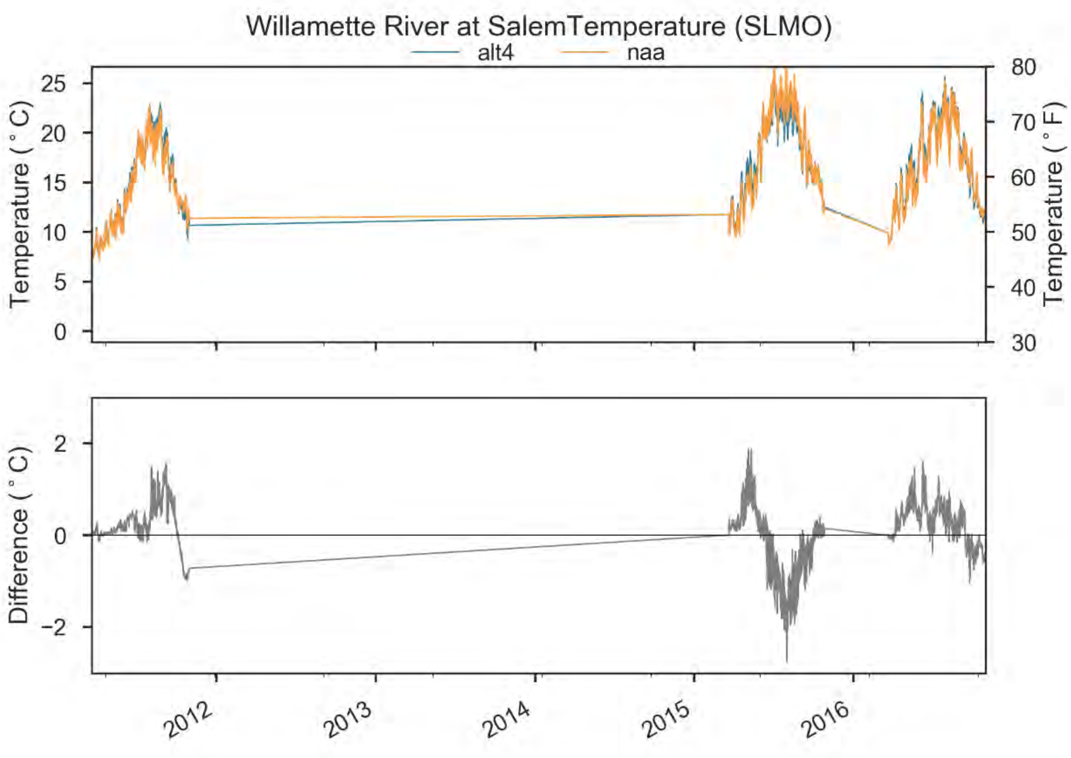

Figure 1-356. Comparison of Willamette River at SLMO Water Temperatures in NAA and Alternative 4.

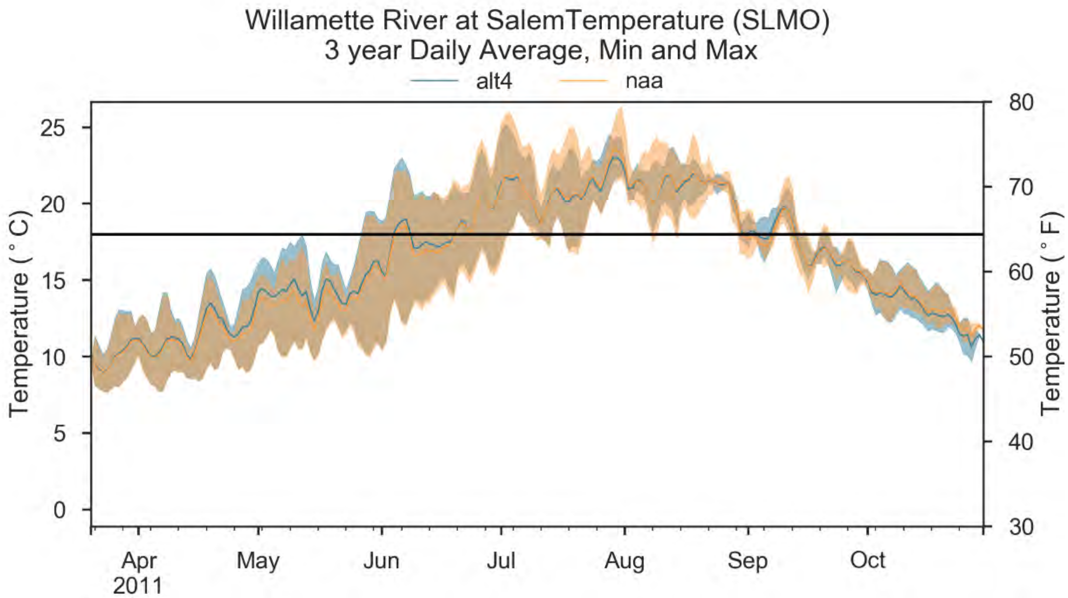

Figure 1-357. Comparison of Willamette River at SLMO 3-year Daily Average, Min, Max Outflow Temperatures in NAA and Alternative 4.

1.5.8 Alternative 5– Preferred Alternative

Alternative 5 is based on Alternative 2b, which had the following measures that affected operations, lake storage, and water temperature:

- Changes to tributary targets below Foster, Detroit, Lookout Point, and Cougar that are higher than the NAA BiOp targets when those reservoirs are more than 90% full and less than the NAA BiOp when those reservoirs are less than 90% full.
- Changes to baseline mainstem targets at Salem and Albany while adding a Salem flow target tied to forecasted air temperature.
- Construct temperature control structure at Detroit.
- Deep fall drawdown to 35’ over the regulating outlet at Green Peter, use of RO in fall, use spillway for surface spill in spring and summer
- Deep spring and fall drawdown to 30 feet over the diversion tunnel at Cougar, with a limited refill window between June 15th and November 15th (essentially a delayed refill).
- Modifications to existing outlets at Foster Dam that would allow releases at varying depths for temperature control by modifying the Facility Warm Water Supply (FWWS) pipe and fish weirs.

RES-SIM simulations of lake levels and dam outflows were used as a basis for assessing the water temperature effects of Alternative 5 in 2011, 2015, and 2016 and are discussed in this section. The underlying assumptions in Alternative 5 were similar to Alternative 2b aside from changes to the spring flow targets at Salem that are lower than BiOp dry year targets in years when water supply forecasted flows at Salem are projected to be less than 25% of normal. This provides additional spring storage in dry years allowing for targets that closely resemble BiOp flow targets to be met in dry summers.

A full explanation of the RES-SIM analysis and findings can be found in the Section 3.2 Hydrologic Processes and Technical Appendix B Hydrology and Hydraulics . Unlike the other alternatives, water temperature simulations were not available in Alternative 5, so a qualitative assessment of potential water temperature downstream of WV dams is provided in Section 1.6.8 Alternative 5 – Preferred Alternative Qualitative Assessments of this Appendix.

1.5.8.1 NORTH SANTIAM DAMS

1.5.8.1.1 Detroit

RES-SIM Lake Levels and Outflows

Lake level and storage at Detroit Lake in Alternative 5 was identical to Alternative 2b in 2011, 2015, and 2016. Compared to NAA, Alternative 5 lake levels were generally higher in 2015 and 2016 aside from September-November in 2015 where the power pool was utilized for downstream flow augmentation (Figure 1-358, Figure 1-359, and Figure 1-360). The increased storage compared to NAA coincided with reduced outflows during spring and increased outflows in summer during 2015 and 2016 under Alternative 5. Total outflow in 2011 was generally similar in Alternative 5 and NAA at Detroit Lake. The proposed SWS and FSS in Alternative 5 allowed all outflow within powerhouse capacity (assumed at 4600 cfs) to be routed from a floating outlet through the Power outlets for temperature management, rather than the Spillway or URO flow for temperature management that was used in NAA (Figure 1-359).

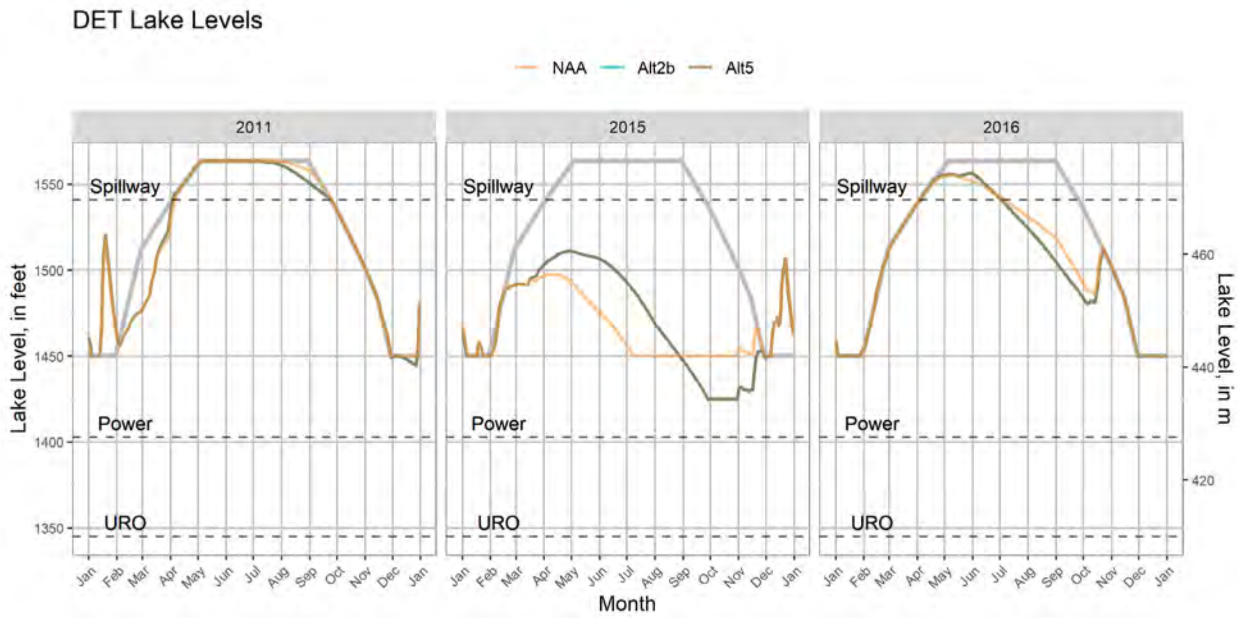

Figure 1-358. WV EIS RES-SIM Detroit Lake Levels in 2011, 2015, and 2016 under Alternative 5, Alternative 2b, and NAA.

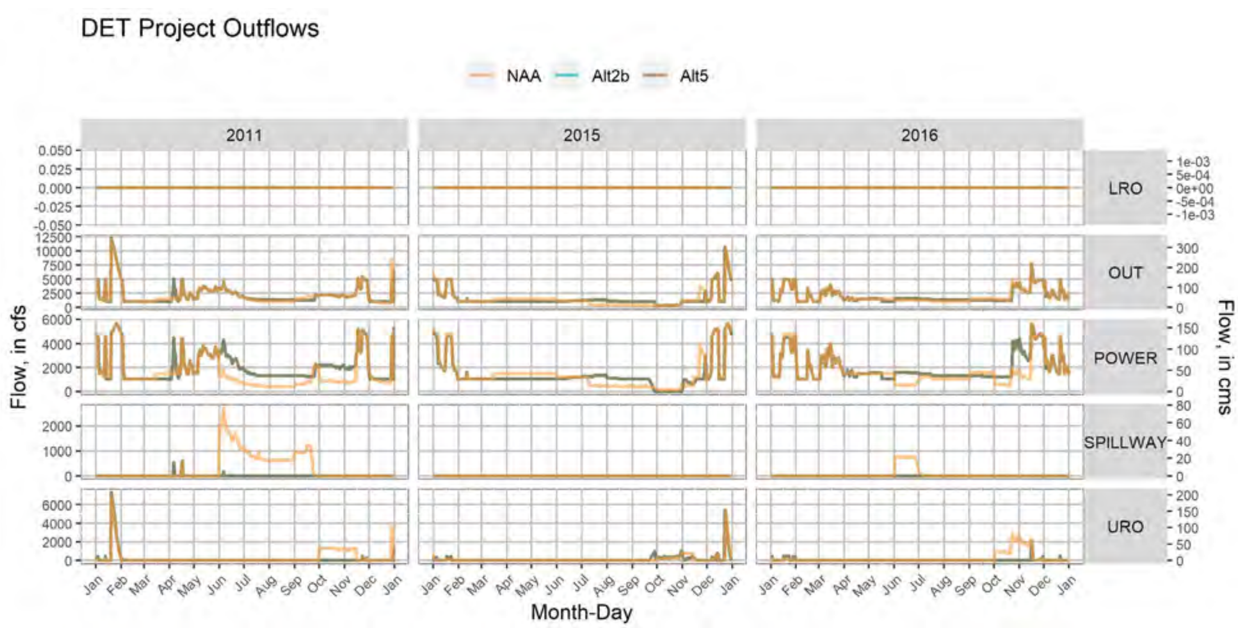

Figure 1-359. WV EIS RES-SIM Gate-Specific Outflows in 2011, 2015, and 2016 under Alternative 5, Alternative 2b, and NAA.

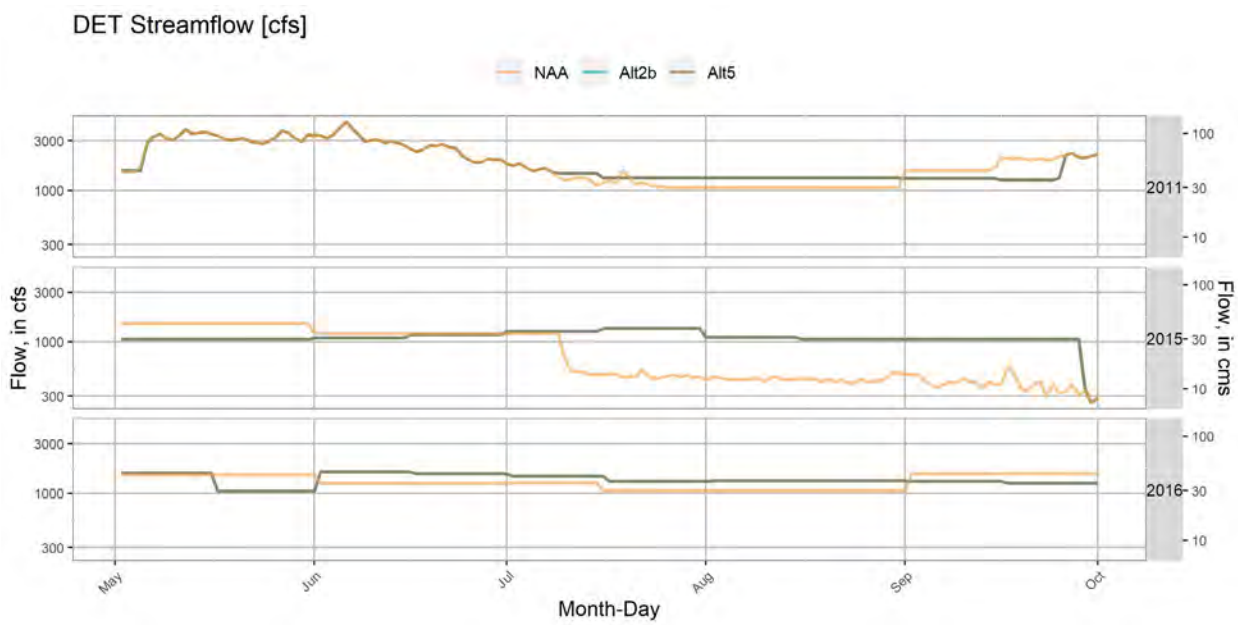

Figure 1-360. WV EIS RES-SIM Detroit Total Outflow in 2011, 2015, and 2016 under Alternative 5, Alternative 2b, and NAA.

1.5.8.2 SOUTH SANTIAM DAMS

1.5.8.2.1 Green Peter

<u>RES-SIM Lake Levels and Outflows</u>

Lake level and storage at Green Peter in Alternative 5 was nearly identical to Alternative 2b in 2011, 2015, and 2016. Compared to NAA, Alternative 5 lake levels were generally higher in 2011, 2015, and 2016 aside from October-November during RO drawdown for fish passage (Figure 1-361, Figure 1-362, and Figure 1-363). Some increased storage in 2015 coincided with reduced outflows during spring and increased outflows in July-October comparing Alternative 5 to NAA. 2011 and 2016 operations were generally similar in Alternative 5 and NAA at Green Peter Lake January-June but followed increased outflows in July-October to draft the lake for fish passage operations through the ROs in autumn. The proposed operational temperature management through the spillway (during spring/summer) and RO (during autumn) in Alternative 5 led to increased outflow from these outlets and decreased power outflow compared to NAA (Figure 1-362).

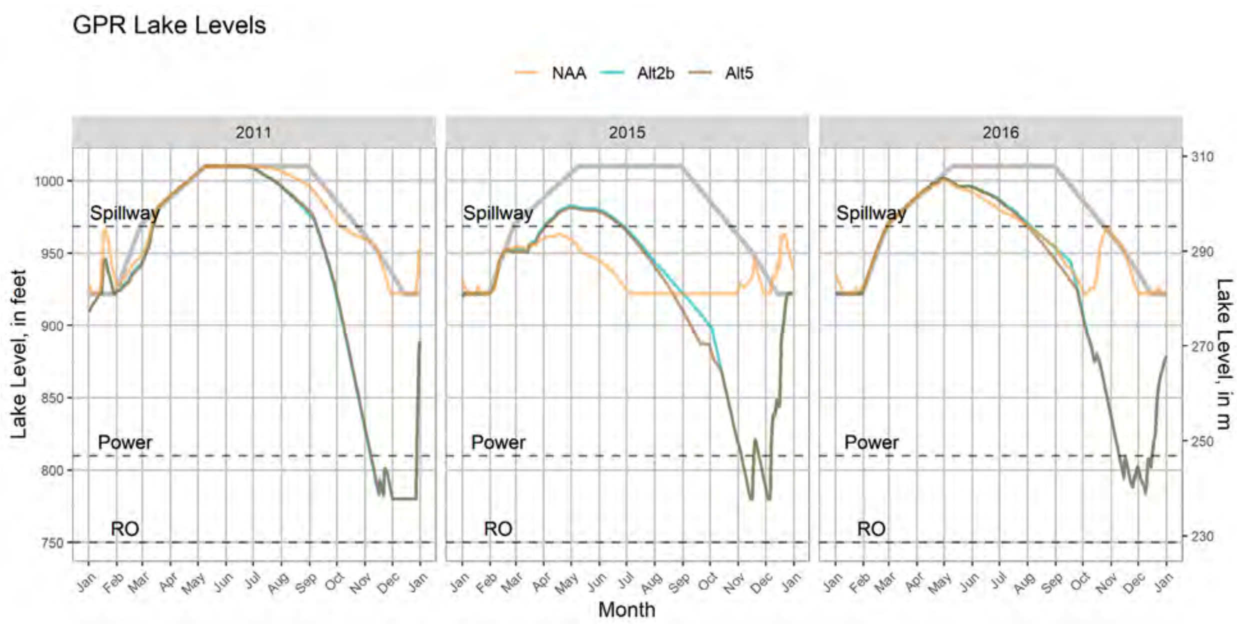

Figure 1-361. WV EIS RES-SIM Green Peter Lake Levels in 2011, 2015, and 2016 under Alternative 5, Alternative 2b, and NAA.

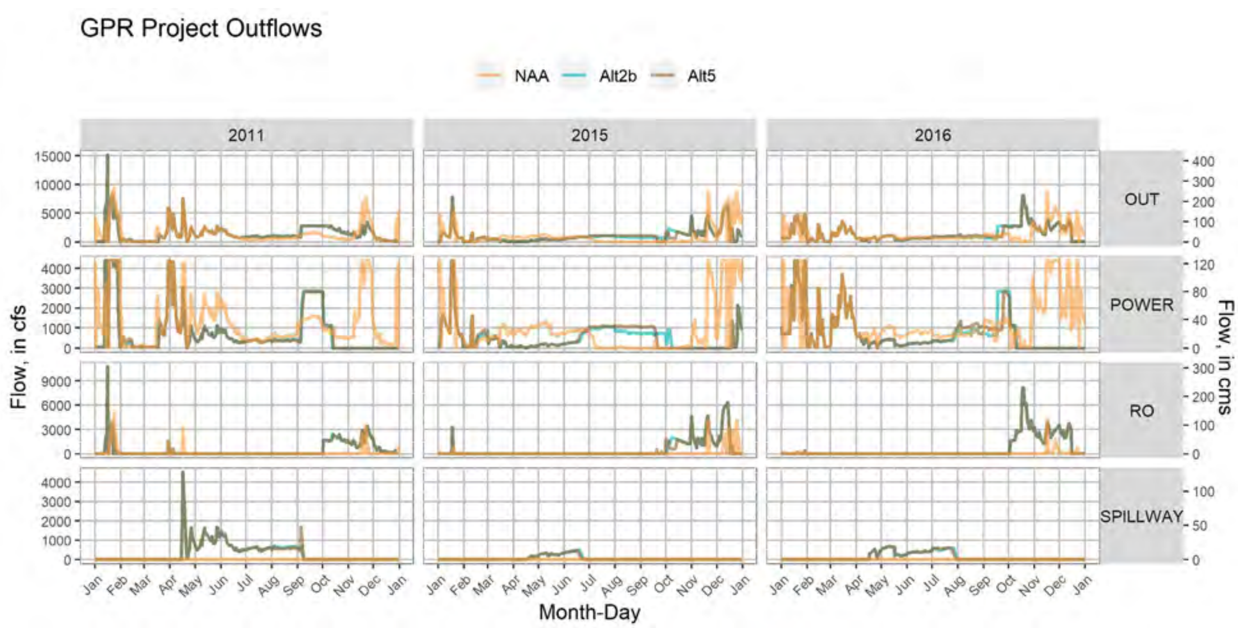

Figure 1-362. WV EIS RES-SIM Green Peter Dam Gate-Specific Outflows in 2011, 2015, and 2016 under Alternative 5, Alternative 2b, and NAA.

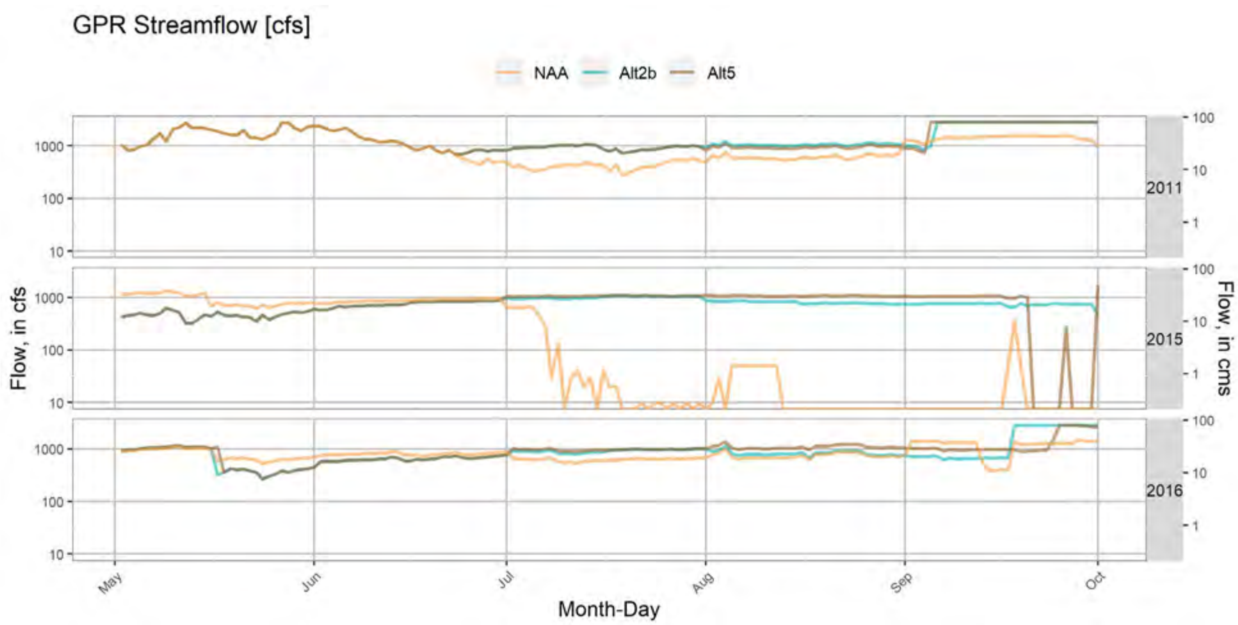

Figure 1-363. WV EIS RES-SIM Green Peter Dam Total Outflow in 2011, 2015, and 2016 under Alternative 5, Alternative 2b, and NAA.

1.5.8.2.2 Foster

RES-SIM Lake Levels and Outflows

Lake level and storage at Foster in Alternative 5 was nearly identical to Alternative 2b in 2011, 2015, and 2016. Compared to NAA, Alternative 5 lake levels were generally similar in 2011 and 2016 but increased in 2015 under Alternative 5 compared to NAA (Figure 1-364, Figure 1-365, and Figure 1-366). Total outflow from Foster Dam was affected by upstream operations at Green Peter Dam. The proposed modifications to the fish weir and FWWS in Alternative 5 resulted in lower outflow routed through the Power outlets for temperature management, especially during spring and summer, compared to NAA (Figure 1-365).

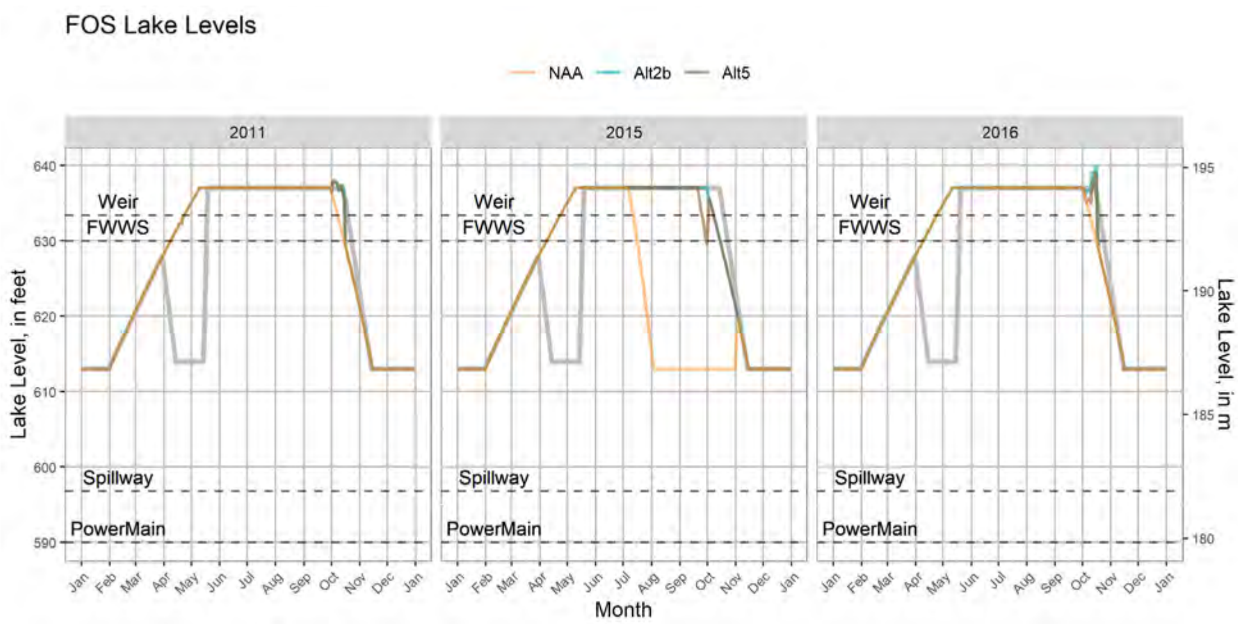

Figure 1-364. WV EIS RES-SIM Foster Lake Levels in 2011, 2015, and 2016 Under Alternative 5, Alternative 2b, and NAA.

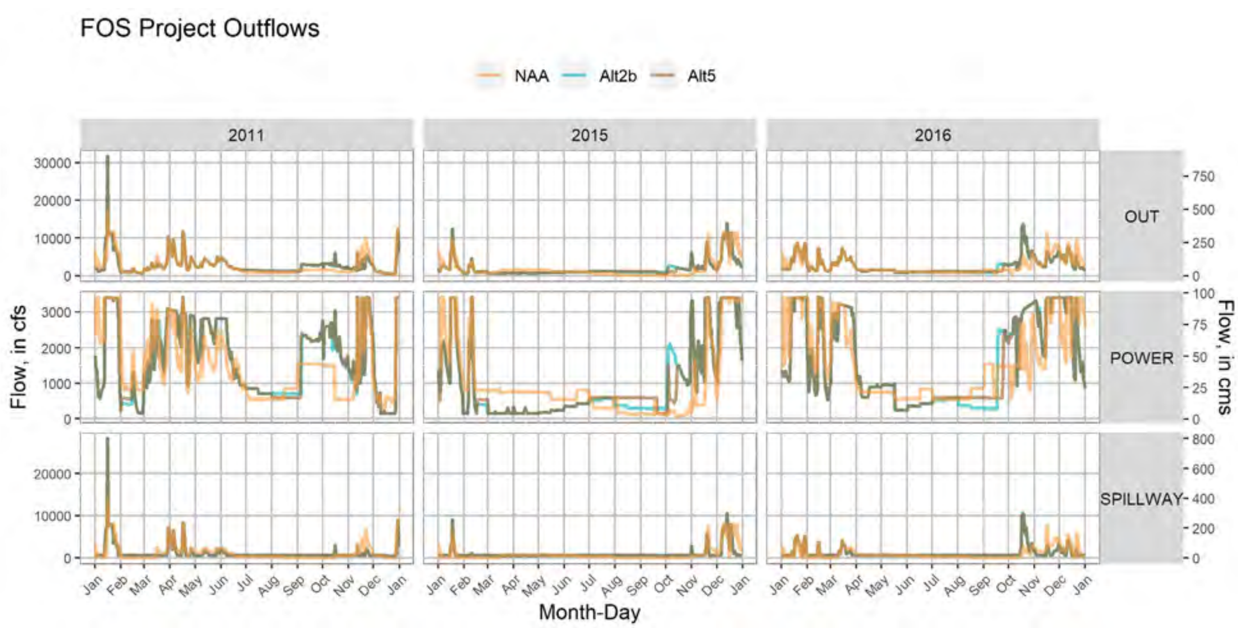

Figure 1-365. WV EIS RES-SIM Foster Dam Gate-Specific Outflows in 2011, 2015, and 2016 under Alternative 5, Alternative 2b, and NAA.

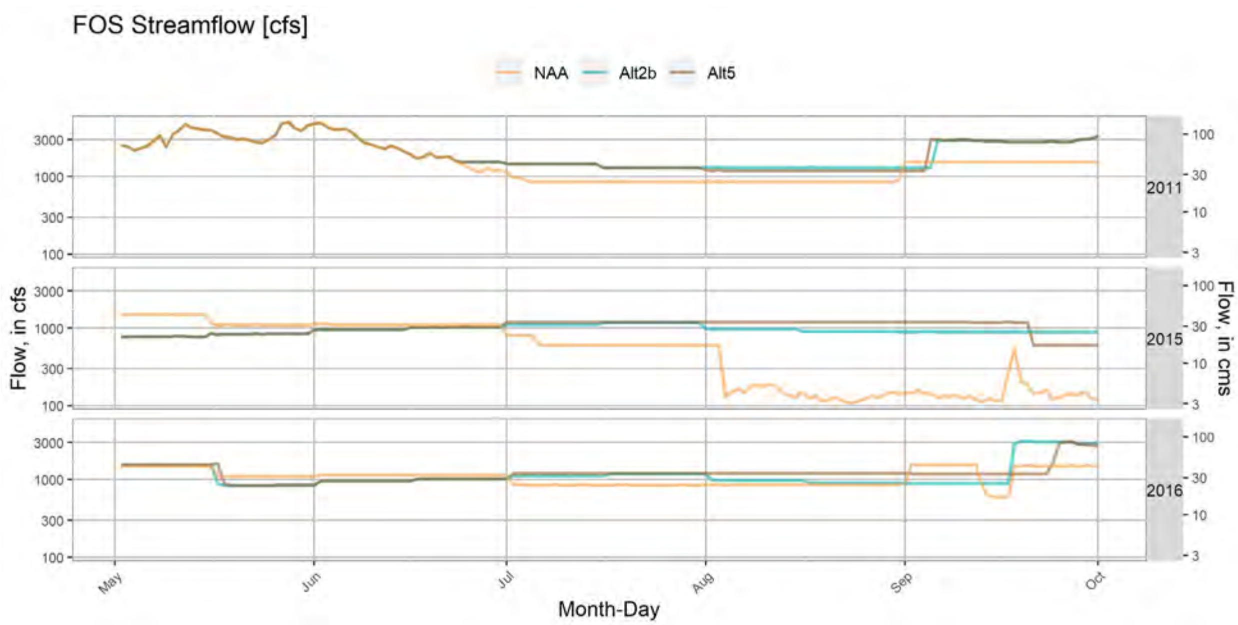

Figure 1-366. WV EIS RES-SIM Foster Dam Total Outflow in 2011, 2015, and 2016 under Alternative 5, Alternative 2b, and NAA.

1.5.8.3 MCKENZIE DAMS

1.5.8.3.1 Cougar

<u>RES-SIM Lake Levels and Outflows</u>

Lake level and storage at Cougar in Alternative 5 was nearly identical to Alternative 2b in 2011, 2015, and 2016. Compared to NAA, Alternative 5 lake levels were lower in 2011, 2015, and 2016 to allow for proposed fish passage operations through the diversion tunnel (Figure 1-367, Figure 1-368, Figure 1-369). The decreased storage coincided with reduced outflows during spring and summer (Figure 1-367). Outflows were primarily routed through the diversion tunnel in Alternative 5, except when the lake refilled to about 30 feet above the RO intake (e.g., 2011).

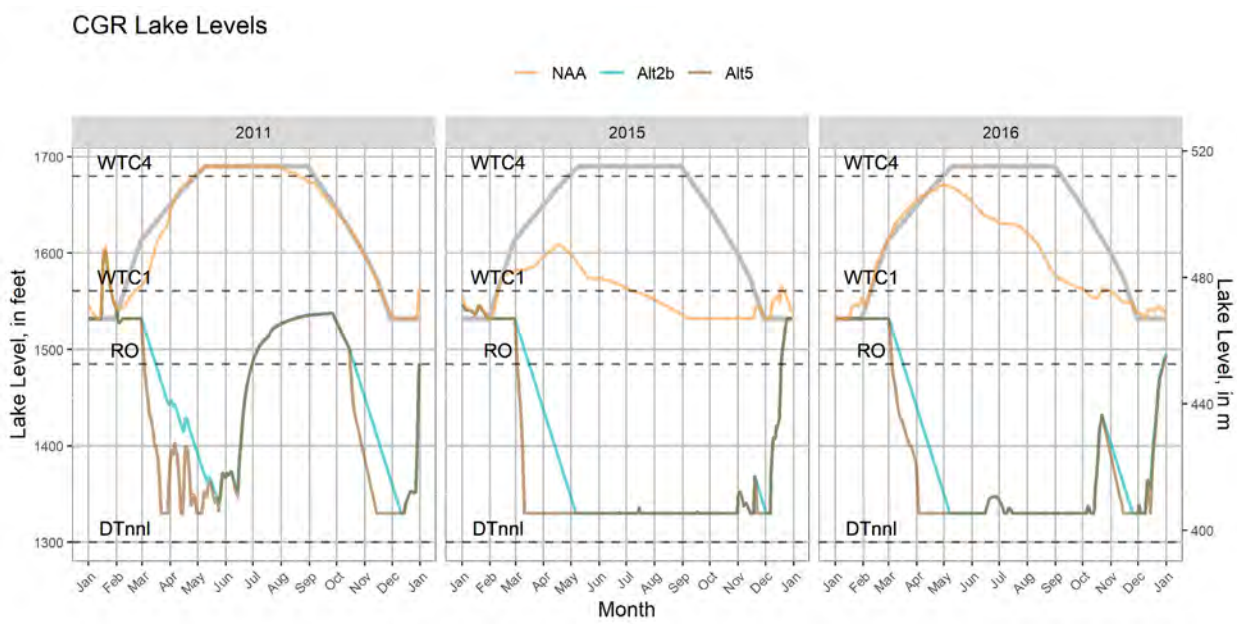

Figure 1-367. WV EIS RES-SIM Cougar Lake Levels in 2011, 2015, and 2016 Under Alternative 5, Alternative 2b, and NAA.

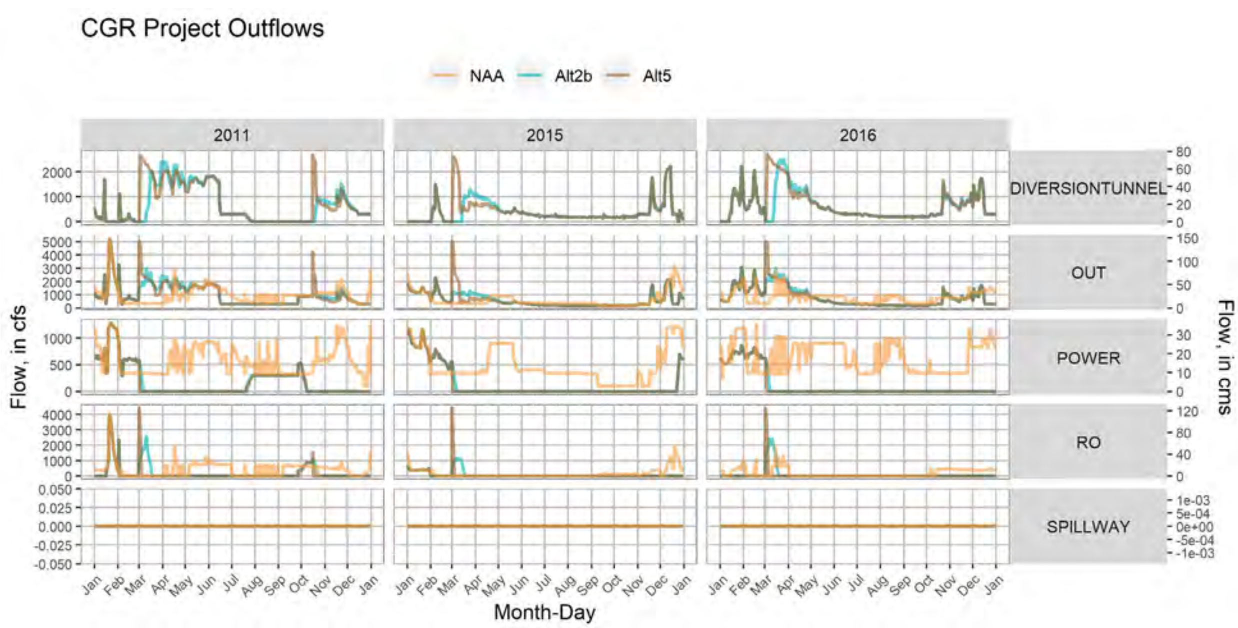

Figure 1-368. WV EIS RES-SIM Cougar Dam Gate-Specific Outflows in 2011, 2015, and 2016 under Alternative 5, Alternative 2b, and NAA.

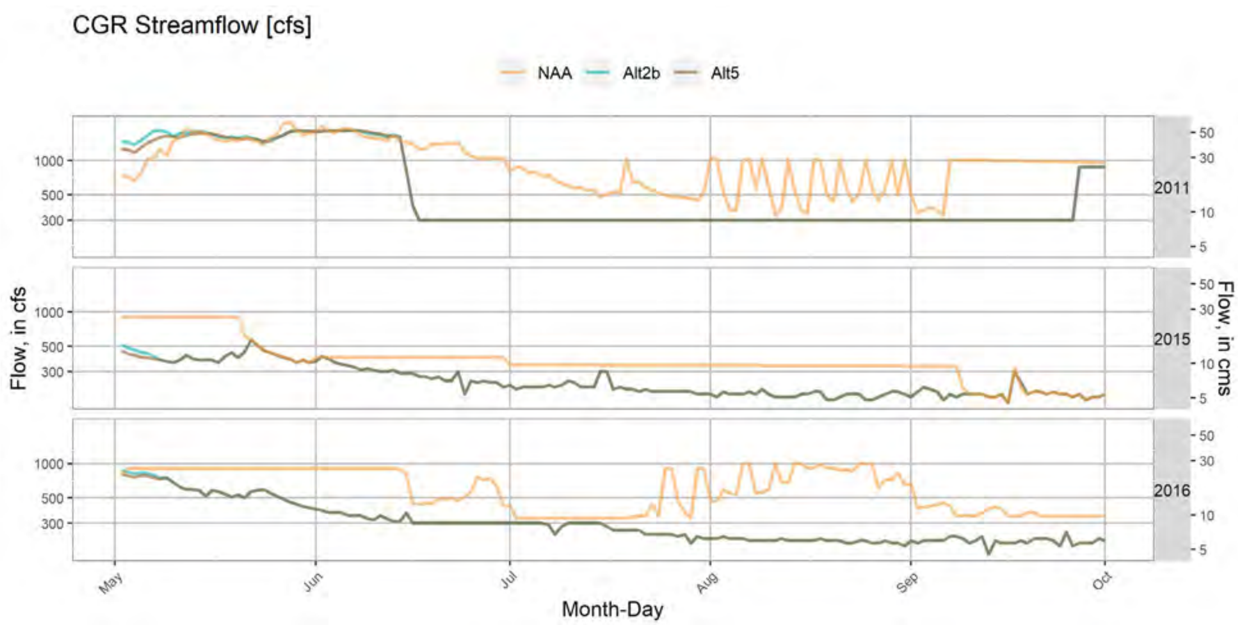

Figure 1-369. WV EIS RES-SIM Cougar Dam Total Outflow in 2011, 2015, and 2016 under Alternative 5, Alternative 2b, and NAA.

1.5.8.4 MIDDLE FORK WILLAMETTE DAMS

1.5.8.4.1 Hills Creek

<u>RES-SIM Lake Levels and Outflows</u>

Lake level and storage at Hills Creek in Alternative 5 were nearly identical to Alternative 2b in 2011 and 2015. Operational differences between Alternative 5 and Alternative 2b in 2016 are likely a result of RES-SIM using Hills Creek to meet mainstem flow targets at Salem during September. Compared to NAA, Alternative 5 lake levels were generally increased in the refill periods of 2015 and 2016 (early summer) before the lake was drafted and the power pool was utilized for downstream flow augmentation (Figure 1-370, Figure 1-371, and Figure 1-372). The increased storage coincided with reduced outflows during spring and increased outflows in May-June during 2015 and August-October in 2016 (Figure 1-371). 2011 operations were generally similar in Alternative 5, Alternative 2b, and NAA at Hills Creek Lake.

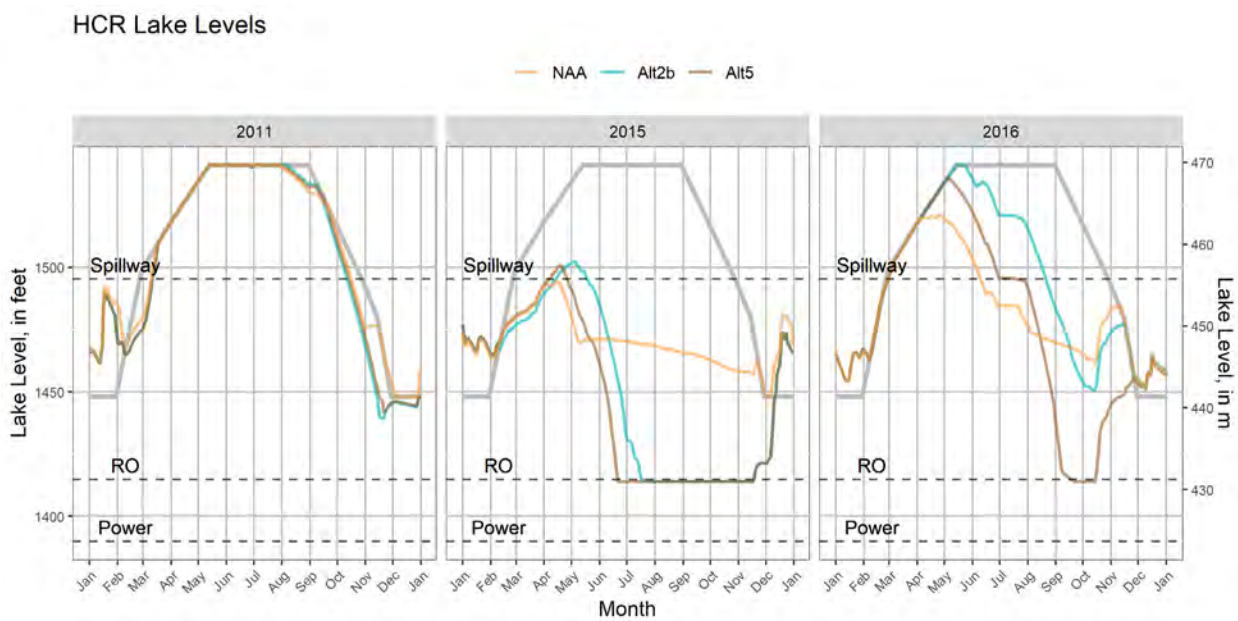

Figure 1-370. WV EIS RES-SIM Hills Creek Lake Levels in 2011, 2015, and 2016 Under Alternative 5, Alternative 2b, and NAA.

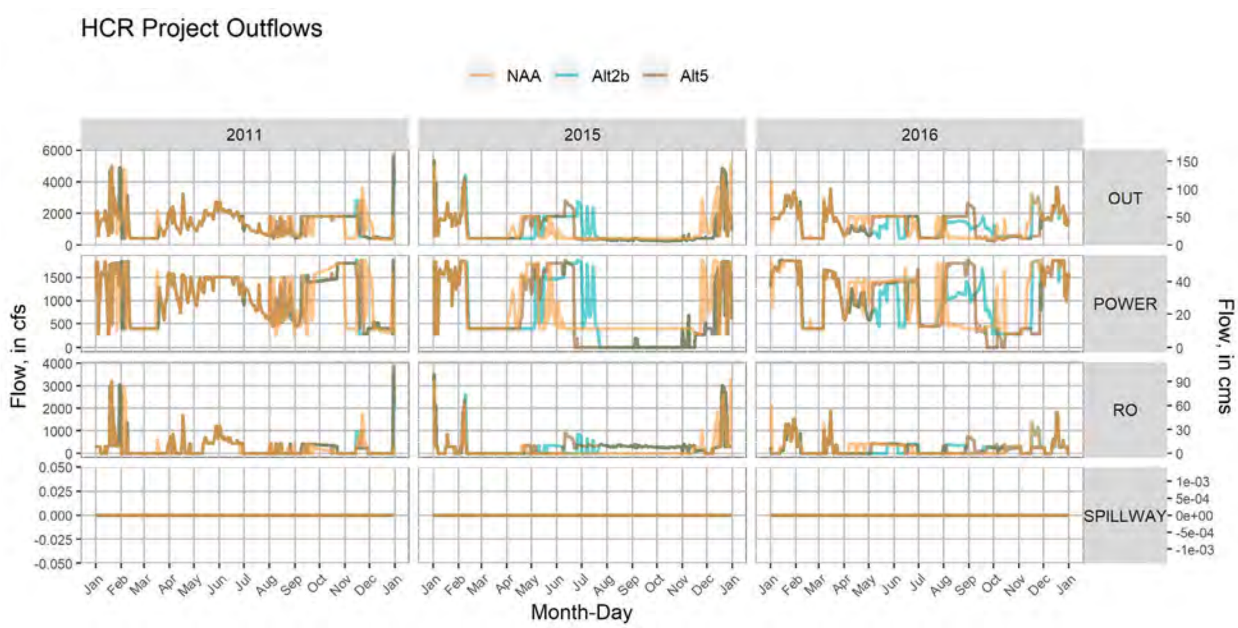

Figure 1-371. WV EIS RES-SIM Hills Creek Dam Gate-Specific Outflows in 2011, 2015, and 2016 under Alternative 5, Alternative 2b, and NAA.

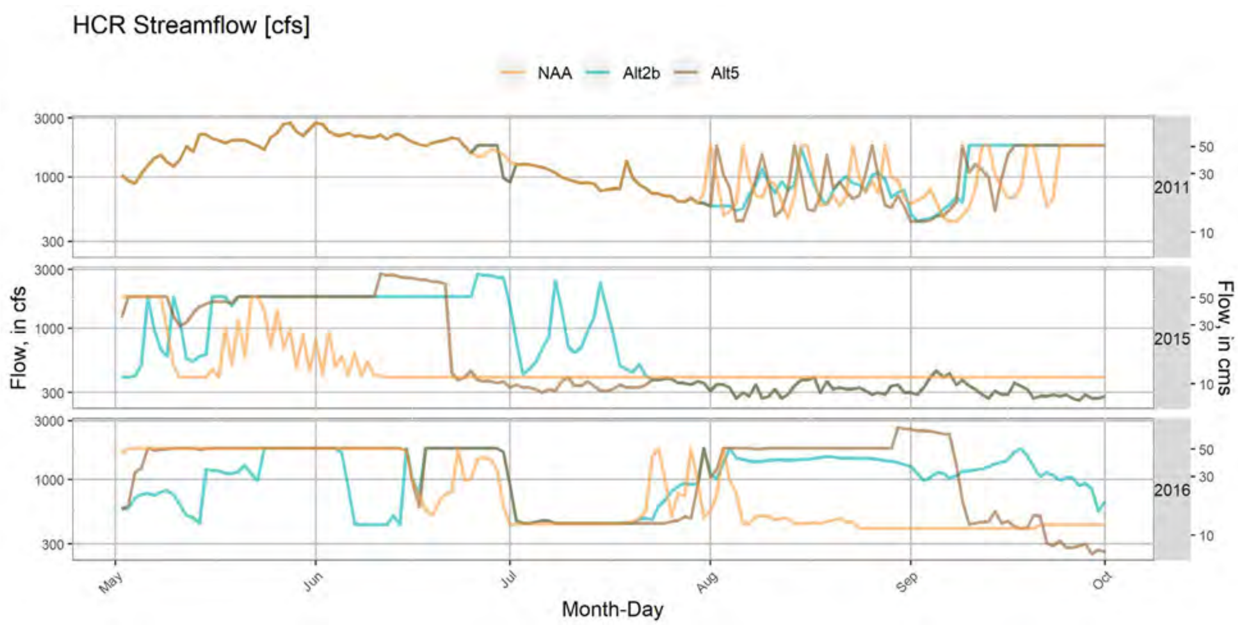

Figure 1-372. WV EIS RES-SIM Hills Creek Dam Total Outflow in 2011, 2015, and 2016 Under Alternative 5, Alternative 2b, and NAA.

1.5.8.4.2 Lookout Point

<u>RES-SIM Lake Levels and Outflows</u>

Lake level and storage at Lookout Point in Alternative 5 were similar to Alternative 2b and NAA in 2011, 2015, and 2016 (Figure 1-373, Figure 1-374, and Figure 1-375) aside from minor differences in timing of refill and release rates that were associated with upstream Hills Creek Dam operations.

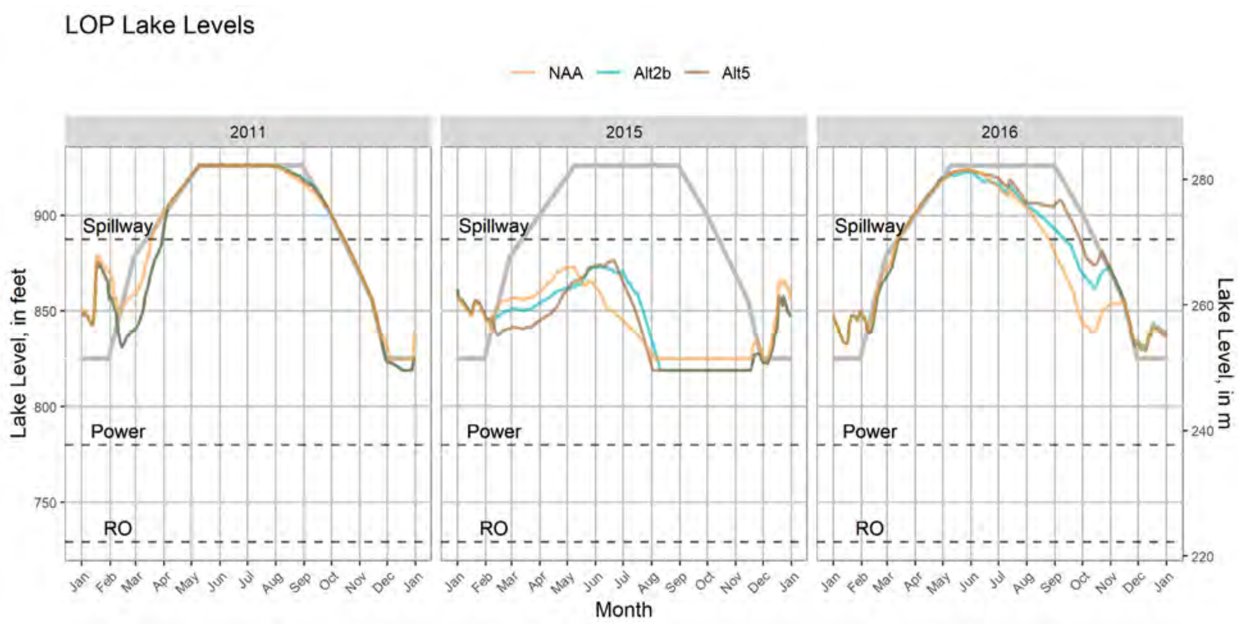

Figure 1-373. WV EIS RES-SIM Lookout Point Lake Levels in 2011, 2015, and 2016 Under Alternative 5, Alternative 2b, and NAA.

Figure 1-374. WV EIS RES-SIM Lookout Point Dam Gate-Specific Outflows in 2011, 2015, and 2016 Alternative 5, Alternative 2b, and NAA.

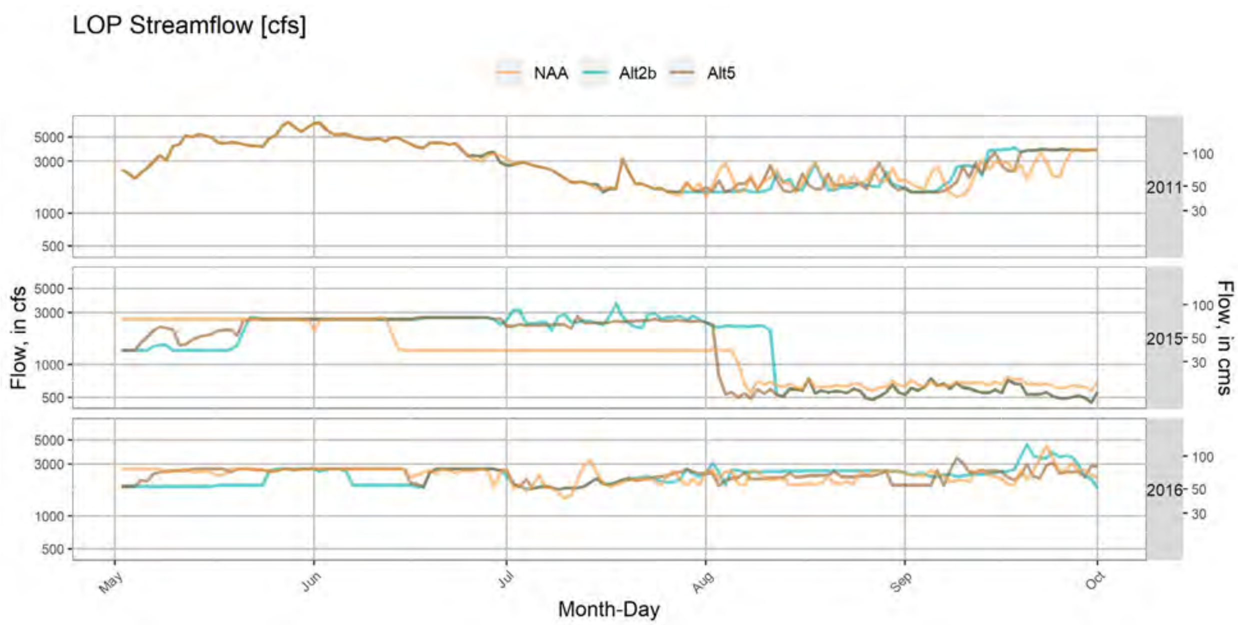

Figure 1-375. WV EIS RES-SIM Lookout Point Dam Total Outflow in 2011, 2015, and 2016 under Alternative 5, Alternative 2b, and NAA.

1.5.8.5 Mainstem Willamette River

Streamflow in Alternative 5 was nearly identical to Alternative 2b and NAA in 2011 and 2016. In 2015, alternative 5 streamflow was generally lower from April to mid-June and higher from mid-June to mid-September compared with NAA (Figure 1-1-376). Streamflow at Salem was generally similar May-September in Alternative 5 compared to Alternative 2b aside from a two-week period in August of 2015, where Alternative 5 resulted in lower streamflow than Alternative 2b. Similar to Alternative 2b, flow differences between Alternative 5 and NAA were primarily in 2015 and responsive to the Measure 30 dam outflow increases in advance of heat wave events (Figure 1-1-376). While temperature simulations are not available for Alternative 5, results would likely be similar to those in Alternative 2b, aside from differences provided in this section (Middle Fork Willamette operation changes in 2015 and 2016) and the two-week period in August of 2015. It is flow changes resulted in warmer water temperatures April to mid-June and cooler water temperatures from mid-June to mid-September compared with NAA in 2015 (Figure 1-200, Figure 1-201). Water temperatures at Salem were also affected by upstream dam operations and the proposed SWS-FSS structure at Detroit Dam, which likely contributed to warmer temperatures seen in 2011 and 2015 comparing Alternative 2b to NAA. Overall water temperature differences between Alternative 2b and NAA were less than 2 degrees Celsius.

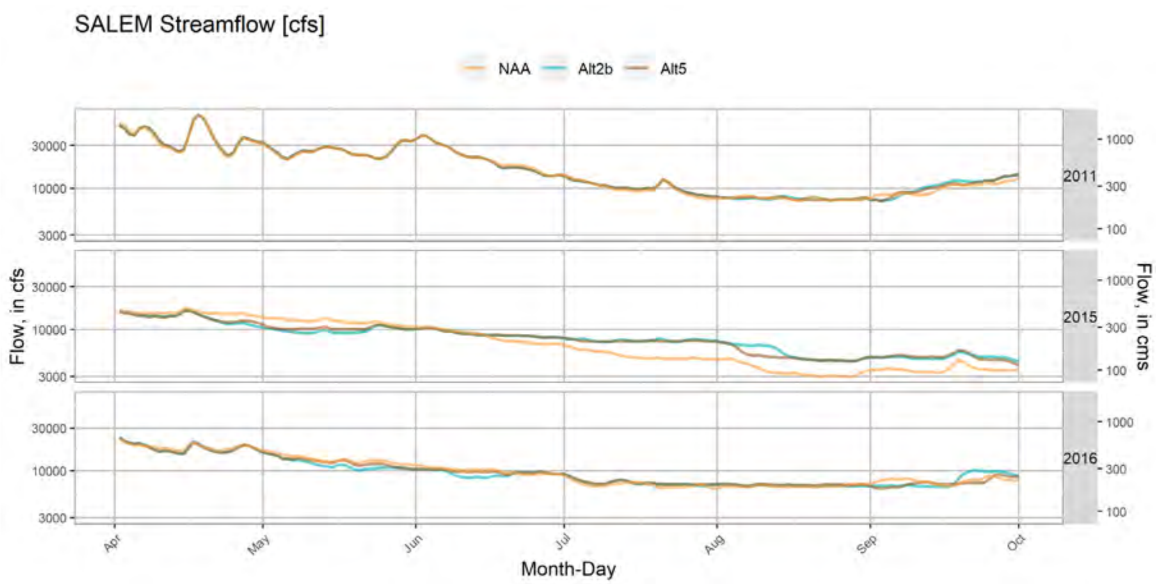

Figure 1-1-376. Streamflow Comparison Between Alternative 5, Alternative 2b, and NAA at Willamette River at SLMO.

1.6 SUPPORTING DATA FOR WATER QUALITY EFFECTS ANALYSIS

This section provides the figures and tables that represent the water temperature results for the WV EIS Chapter 3.6.3 Water Quality Effects Analysis. Refer to that chapter and section for explanations and interpretation of results for each alternative.

To assess impacts under each Alternative, the hourly water temperature below each dam was used to calculate the 7-day Average of the Daily Max (7dADM) water temperature. The 7dADM water temperature was then compared to the temperature targets at each location. Simulated water temperatures were evaluated and compared relative to NAA using the following metrics based on the 3-year average of 2011, 2015, and 2016 (the calendar years available from CE-QUAL-W2 modeling):

- **Summer Extremes:** Number of days in which the 7dADM water temperature is below 18 °C or 64.4 °F. The 18 °C thresholds corresponds to the Oregon State biologically based numeric Water Quality Temperature Standard for salmon and trout rearing and migration (OAR 340-041-0028) and represents "Optimal" conditions for juveniles and adult Chinook salmon in Koch, et al., (2020). See Figure 1-378 for values at each location, year, and alternative.
- **Days Near Temperature Target:** Number of days in which the 7dADM water temperature was within 2 F of the temperature target during **two** time frames: April-August and September-March. Temperature targets used in this analysis are those applied in the CE-QUAL-W2 model (discussed in Section 2.1.1) except for the Cougar (CGRO) target, where the temperature target defined in the Oregon State TMDL was used. The Oregon TMDL temperature target for Cougar is cooler than the target used in the CE-QUAL-W2 model and allowed for a more appropriate baseline for comparing the wide range of temperatures

across the Alternatives. This allowed a comparison of alternatives at Cougar that did not inappropriately penalize the relatively cool temperatures (downstream of the dam) that resulted during deep drafting of Cougar Reservoir in some alternatives and better aligns with the needs of ESA-listed cold water fish species being considered in this EIS. See Figure 1-379 for annual values at each location, year, and alternative.

Simulated water temperatures were also used to calculate the estimated chinook egg emergence relative to NAA in 2011, 2015, and 2016 based on accumulated thermal units (ATUs; "degree-days"). While this metric was not used to evaluate thermal effects in the WV EIS, it is provided here for context. Early emergence has been known to lead to mortality due to the excessive flows, abundant predators, or insufficient resources experienced by juvenile salmon that hatch early (Jensen and Johnsen 1999; Einum and Flemming, 2000). The ATU calculation begins on the presumed day when eggs are in the gravel (Sep 01, Sep 20, Oct 1) and is accumulated until the degree-day reaches 1750°F—day ATUs. For determining impacts under each WV EIS alternative, averages of the three spawn dates (Sep 01, Sep 20, and Oct 1) were used (Figure 1-377).

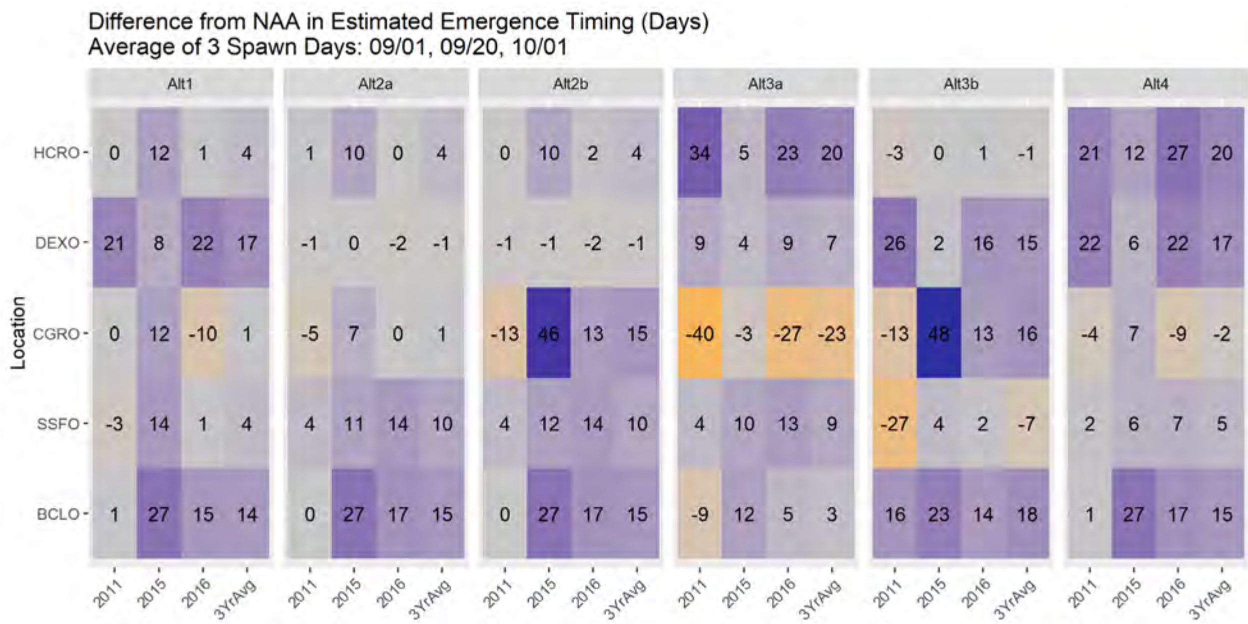

Figure 1-377. Difference in estimated chinook egg emergence timing relative to NAA (Alternative - NAA), in days.

Categorical water temperature evaluation criteria thresholds were assigned based on the aforementioned metrics at each location and alternative using criteria in Table 1. These categorical thresholds were chosen to represent the distribution of the summary data shown in Figure 1-378 and Figure 1-379. The results from each alternative were summarized by each metric and then categorized based on tangible time frames that are easily relatable, i.e., 5, 10, 15, 20, 50 days. Impacts at each location are summarized in Table 1-5, Table 1-6, and Table 1-7.

Table 1. Water Temperature Evaluation Criteria Thresholds Level Definitions

Evaluation Criteria Thresholds	Days Below 18 deg C (64.4 F)	Days Within 2 Deg F of Temperature Target (April-August)	Days Within 2 Deg F of Temperature Target (September - March)
Major Beneficial	15	50	50
Moderate Beneficial	10	20	20
Minor Beneficial	5	10	10
Negligible	0	0	0
Minor Adverse	-5	-10	-10
Moderate Adverse	-10	-20	-20
Major Adverse	-15	-50	-50

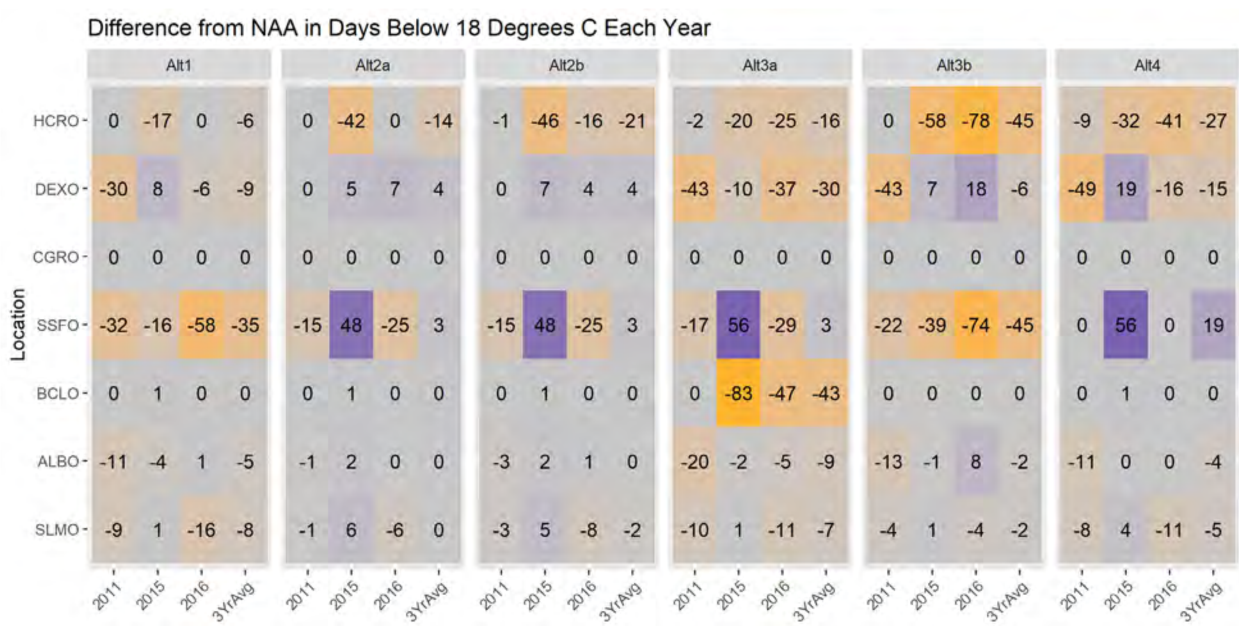

Figure 1-378. Difference, compared to NAA, in annual number of days below 18°C in each year, location, and alternative.

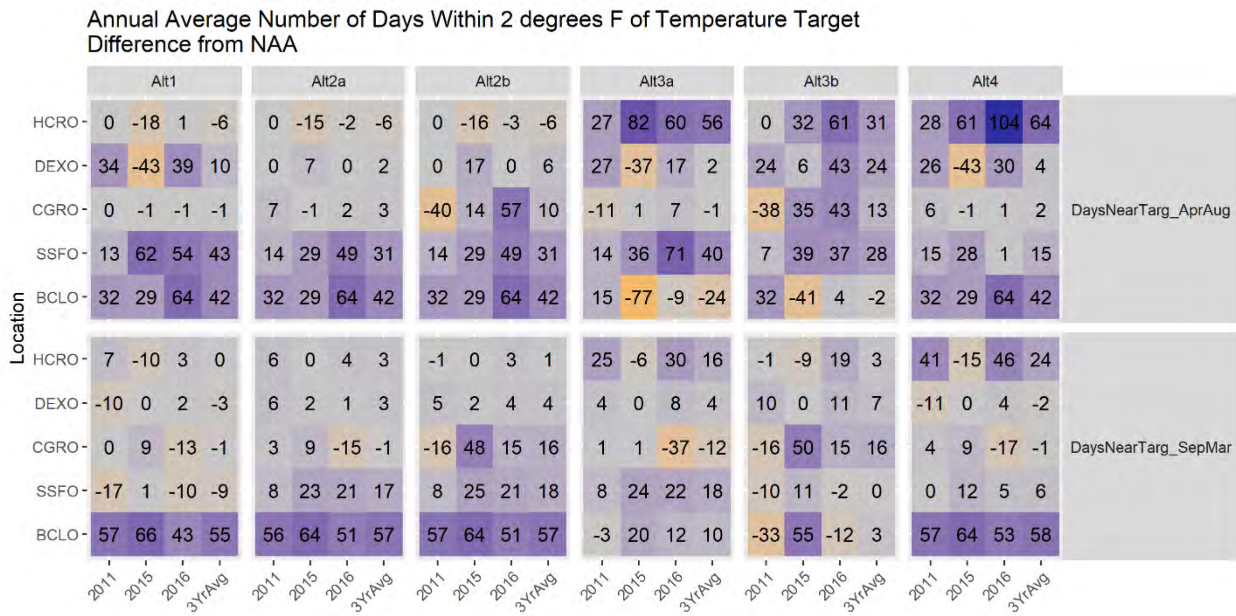

Figure 1-379. Difference, compared to NAA, in annual average number of days within 2°F of Temperature target April-August (top row of tables) and September-March (bottom row of tables).

Table 1-5. Water Temperature Effects based on Number of Days below 18°C (64.4°F).

Location	Alt1	Alt2a	Alt2b	Alt3a	Alt3b	Alt4
HCRO	Minor Adv	Moderate Adv	Major Adv	Major Adv	Major Adv	Major Adv
DEXO	Moderate Adv	Negligible	Negligible	Major Adv	Minor Adv	Major Adv
CGRO	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible
SSFO	Major Adv	Negligible	Negligible	Negligible	Major Adv	Major Ben
BCLO	Negligible	Negligible	Negligible	Major Adv	Negligible	Negligible
ALBO	Minor Adv	Negligible	Negligible	Minor Adv	Negligible	Negligible
SLMO	Minor Adv	Negligible	Negligible	Minor Adv	Negligible	Minor Adv

Table 1-6. Water Temperature Effects based on Difference from NAA in Number of Days within 2°F of Temperature Targets (April-August).

Location	Alt1	Alt2a	Alt2b	Alt3a	Alt3b	Alt4
HCRO	Negligible	Negligible	Negligible	Major Ben	Moderate Ben	Major Ben
DEXO	Minor Ben	Negligible	Negligible	Negligible	Moderate Ben	Negligible
CGRO	Negligible	Negligible	Minor Ben	Negligible	Minor Ben	Negligible
SSFO	Moderate Ben	Moderate Ben	Moderate Ben	Moderate Ben	Moderate Ben	Minor Ben
BCLO	Moderate Ben	Moderate Ben	Moderate Ben	Moderate Adv	Negligible	Moderate Ben

Table 1-7. Water Temperature Effects Based on Difference from NAA in Number of Days within 2°F of Temperature Targets (September-March).

Location	Alt1	Alt2a	Alt2b	Alt3a	Alt3b	Alt4
HCRO	Negligible	Negligible	Negligible	Minor Ben	Negligible	Moderate Ben
DEXO	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible
CGRO	Negligible	Negligible	Minor Ben	Minor Adv	Minor Ben	Negligible
SSFO	Negligible	Minor Ben	Minor Ben	Minor Ben	Negligible	Negligible
BCLO	Major Ben	Major Ben	Major Ben	Minor Ben	Negligible	Major Ben

1.6.1 No Action Alternative

Summary tables of NAA monthly mean water temperature is shown for each of the three simulated years in Figure 1-380.

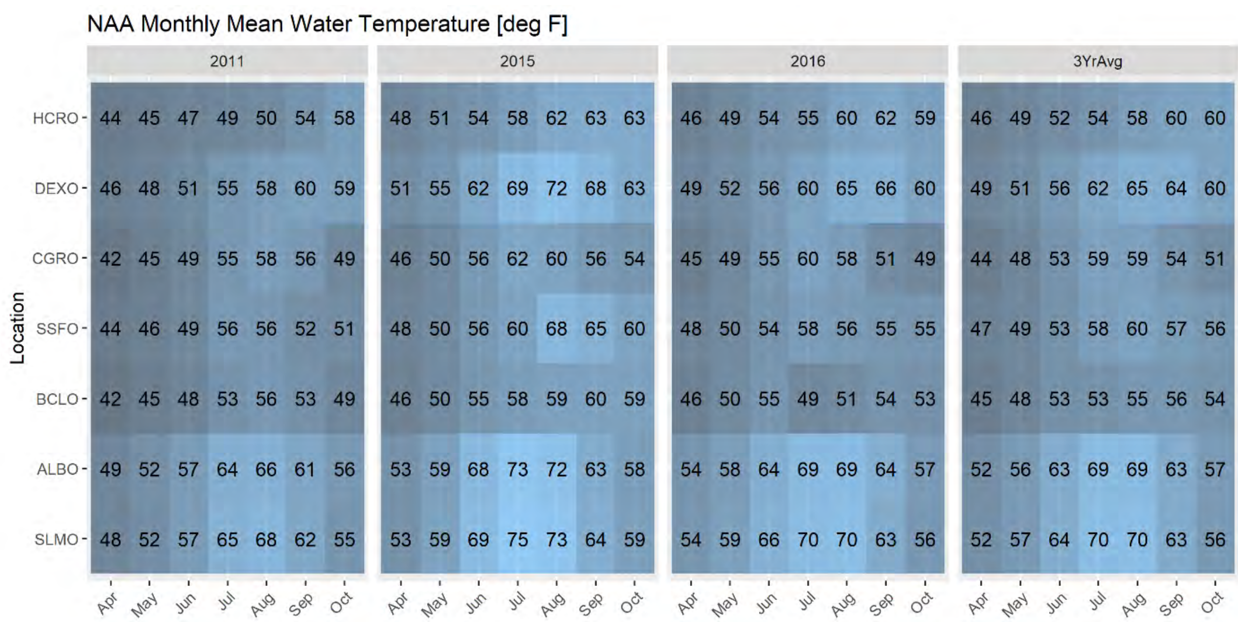

Figure 1-380. Simulated No Action Alternative Monthly Mean Water Temperature (deg F) in 2011, 2015, 2016, and average of these 3 years (3YrAvg).

1.6.2 Alternative 1 – Project Storage Alternative

Summary tables of Alternative 1 monthly mean water temperature and monthly mean difference between Alternative 1 and NAA for each of the three simulated years are shown in Figure 1-381 and Figure 1-382, respectively.

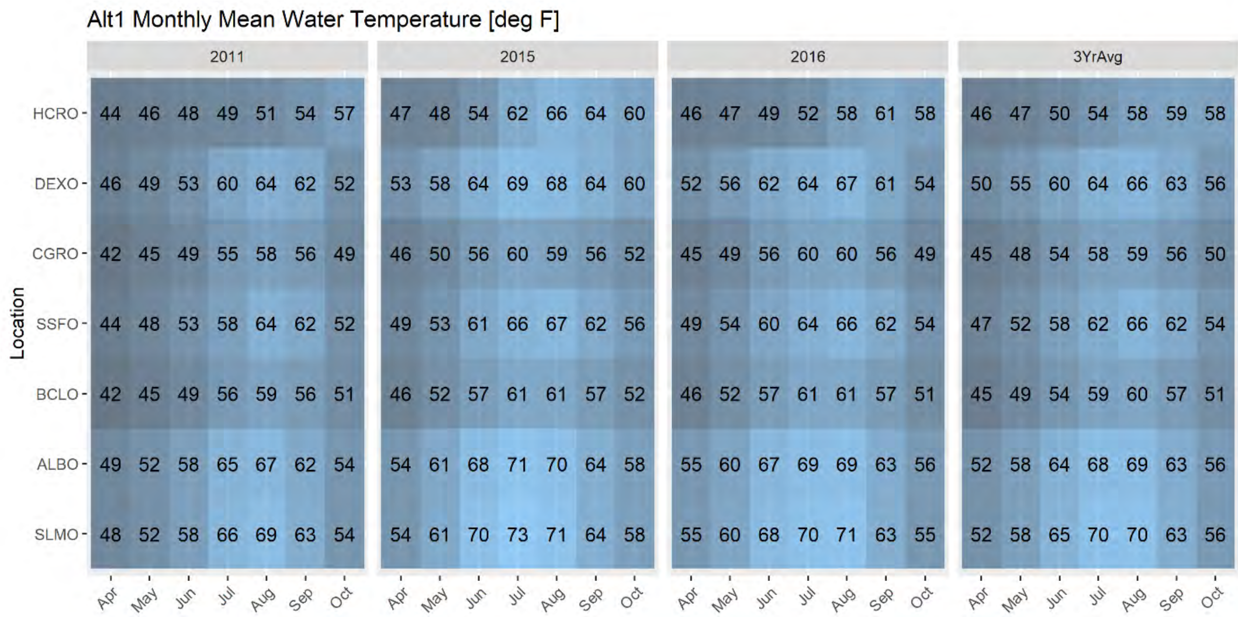

Figure 1-381. Monthly Mean of Water Temperatures (Fahrenheit) for Alternative 1.

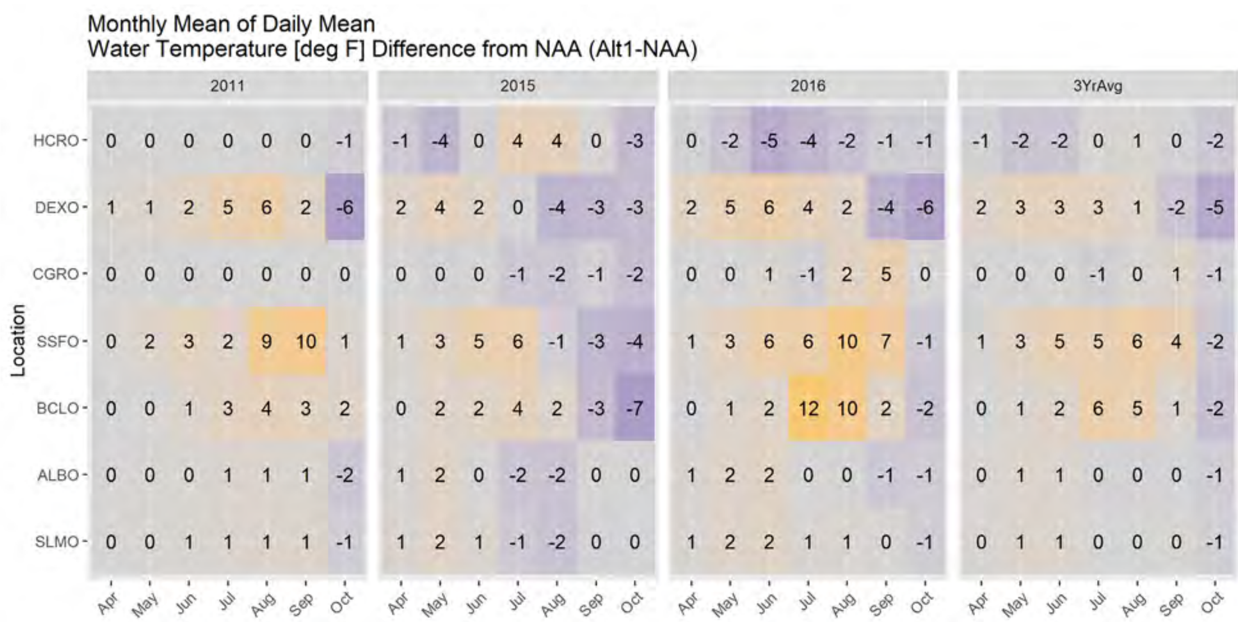

Figure 1-382. Monthly Mean of Daily Mean Water Temperatures (Fahrenheit) difference from NAA to Alternative 1.

1.6.2.1 NORTH SANTIAM DAMS

Alternative 1 as compared to the NAA (Figure 1-381; Figure 1-382*)* downstream of Detroit and Big Cliff dams (BCLO) would in the 2011-year scenario see water temperature increase up to 4 degrees starting in June through October (Figure 1-383). In the 2015-year scenario, water temperatures would increase 2 to 3 degrees from May to August and then decrease of 4 to 7 degrees in September to October. In the 2016-year scenario water temperatures would increase 2 to 12 degrees from May to September and then decrease by 2 degrees in October. For the Average of the three years water temperatures would increase 1 to 6 degrees from May to September and then decrease by 2 degrees in October.

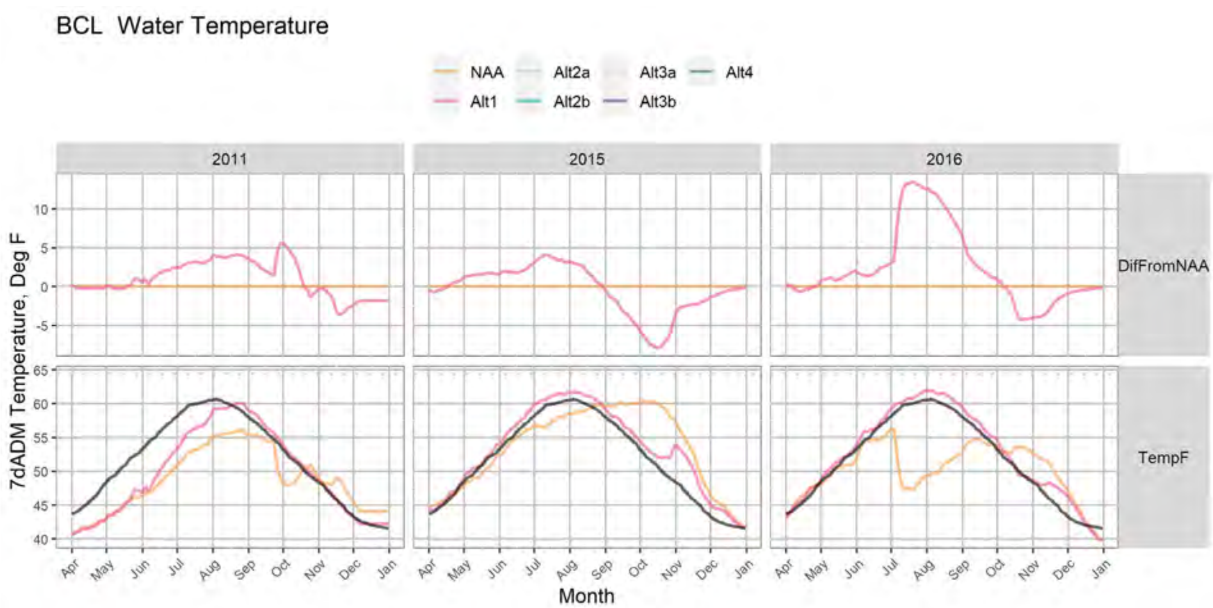

Figure 1-383. Comparison of Alternative 1 for 2011,2015,2016 with 7dADM temperatures (Degrees F) and difference from the NAA downstream of Big Cliff dam. Black line indicates temperature target.

1.6.2.2 SOUTH SANTIAM DAMS

Results are compared to the NAA the Monthly Mean of Daily Mean water temperatures at the South Santiam River near Foster gaging site (SSFO; Figure 1-384; Figure 1-382) in the 2011-year scenario would see an increase starting in May through October up to 10 degrees. In the 2015-year scenario, water temperatures increase of 1 to 5 degrees from April to July and then decrease from 2 to 4 degrees from August to October. In the 2016-year scenario water temperatures increase up to 10 degrees from April to September and then decrease by 1 degree in October. For the Average of the three years (2011, 2015, 2016) water temperatures increase 1 to 6 degrees from April through September and then decrease by 2 degrees in October.

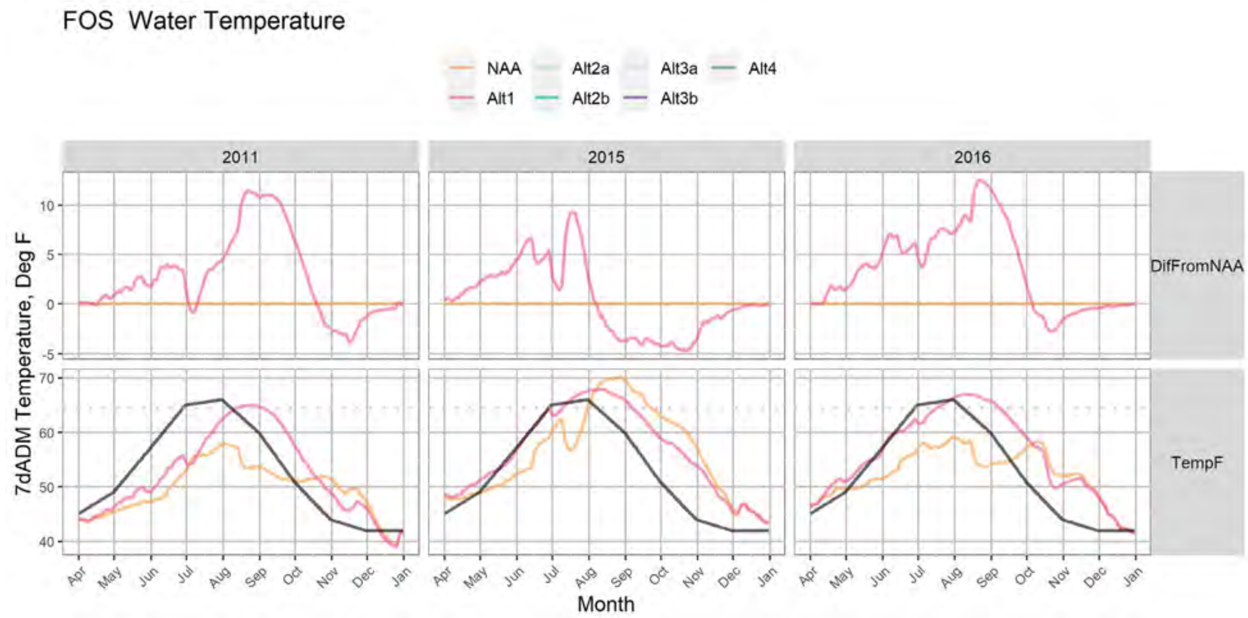

Figure 1-384 Comparison of Alternative 1 for 2011,2015,2016 with 7dADM temperatures (Degrees F) and difference from the NAA downstream of Foster dam. Black line indicates temperature target.

1.6.2.3 MCKENZIE DAMS

In the 2011-year scenario there would be no temperature difference at the South Fork McKenzie River near Rainbow site (CGRO; Figure 1-381; Figure 1-382; Figure 1-385) compared to the NAA. In the 2015-year scenario a decrease up to 2 degrees from July to October would occur under Alternative 1. In the 2016-year scenario a decrease is observed up to 1 degree in July and increase of 5 degrees in September is observed. For the Average of the three years (2011, 2015, 2016) a 1 degree temperature decrease is observed in July and October, an increase of 1 degree is observed in September.

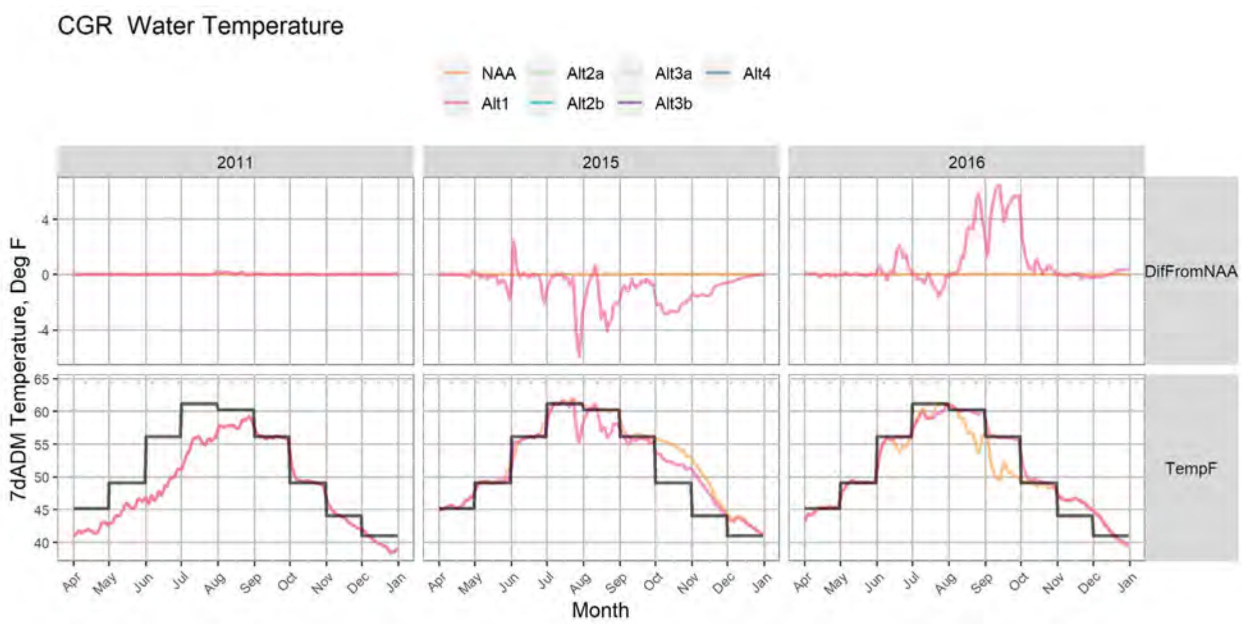

Figure 1-385. Comparison of Alternative 1 for 2011,2015,2016 with 7dADM temperatures (Degrees F) and difference from the NAA downstream of Cougar dam. Black line indicates temperature target.

1.6.2.4 MIDDLE FORK WILLAMETTE DAMS

Alternative 1 includes a Water Temperature Control tower at Lookout Point to better regulate downstream temperatures to Dexter reservoir. Results are also compared to the NAA the Monthly Mean water temperatures (deg F) at the Middle Fork Willamette River near Dexter gaging site (DEXO; Figure 1-381; Figure 1-382) In the 2011-year scenario, temperatures increase starting in May through September up to 6 degrees (Figure 1-387) and decrease by 6 degrees in October. In the 2015-year scenario: increase up to 4 degrees from April to June and then decrease by 4 degrees from July to October. In the 2016-year scenario an increase up to 6 degrees from April to August and then decrease by 6 degrees in October. For the Average of the three years (2011, 2015, 2016): increase up to 3 degrees from April to August and then decrease by 5 degrees in October.

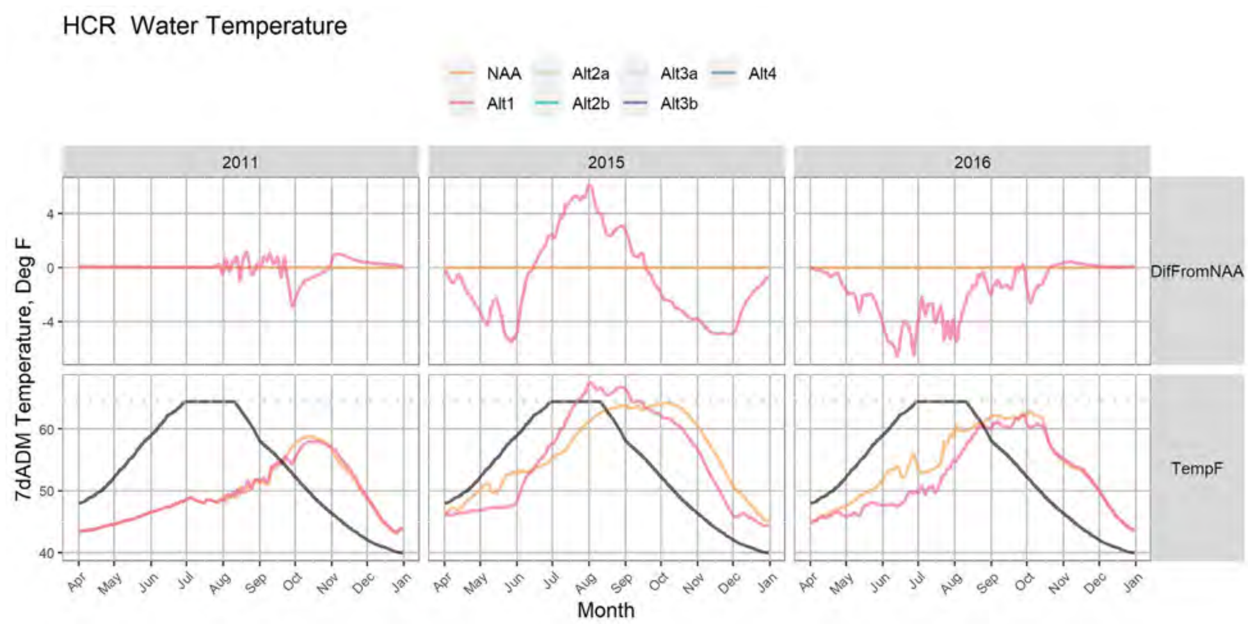

Figure 1-386. Comparison of Alternative 1 for 2011,2015,2016 with 7dADM temperatures (Degrees F) and difference from the NAA downstream of Hills Creek dam. Black line indicates temperature target.

Daily Mean water temperatures (deg F) at the Middle Fork Willamette River above Salt Creek gaging site (HCRO; Figure 1-381;Figure 1-382) in the 2011-year scenario would be similar to NAA from April until September and decrease by 1 degree in October. In the 2015-year scenario, Alternative 1 would produce a decrease by 3 degrees from April to June, increase by 3 degrees in July to September, decrease by 3 degrees in October. In the 2016-year scenario there would be no temperature change observed in April and then a decrease observed up to 5 degrees from May until October. For the three year average (2011, 2015, 2016) a temperature decrease up to 2 degrees is observed in May, June, and October under Alternative 1.

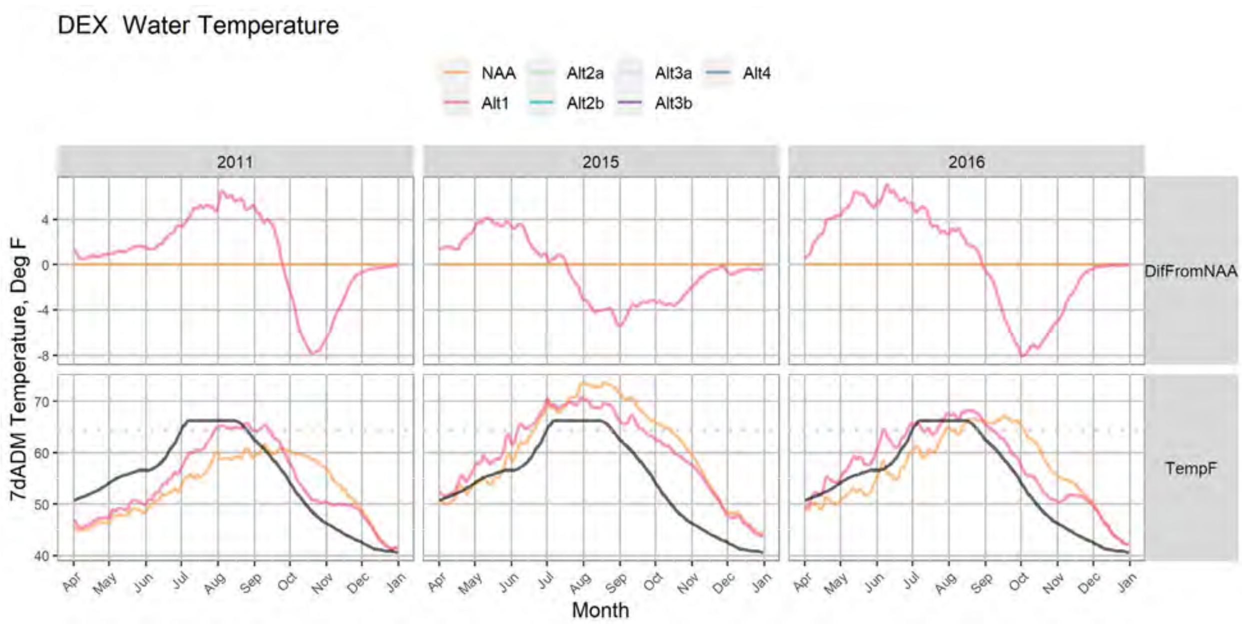

Figure 1-387. Comparison of Alternative 1 for 2011,2015,2016 with 7dADM temperatures (Degrees F) and difference from the NAA downstream of Dexter Dam. Black line indicates temperature target.

1.6.2.5 Mainstem Willamette River

Mainstem Willamette River Alternative 1 results are compared to the NAA using the Monthly Mean of Daily Mean water temperatures at the Willamette River near Salem gaging site (SLMO; Figure 1-382). In the 2011-year scenario there would be no change in temperature in April and May; a 1 degree temperature increase from June until September and then a 1 degree decrease in October. In the 2015-year scenario, water temperature increases up to 2-degree from April until June and then decreases up to 3 degrees from July until September under Alternative 1. In the 2016-year scenario, water temperature increases up to 2 degrees from April until August and then 1 degree decreases in October. For the average of the three years (2011, 2015, 2016) a 2-degree temperature increase is observed in May and June with a 1 degree decrease in October.

Mainstem Willamette River Alternative 1 results are compared to the NAA using the Monthly Mean of Daily Mean water temperatures at the Willamette River at Albany gaging site (ALBO; Figure 1-382). In the 2011-year scenario a water temperature increase up to 1 degree is observed from July until September with a 2 degree decrease in October. In the 2015-year scenario, water temperature increases up to 2 degree in April and May with a 1 degree decrease in July and August. In the 2016-year scenario, water temperature increases up to 2-degree from April until June followed by a 1-degree temperature decrease in September and October. For the average of the three years (2011, 2015, 2016) a water temperature increases up to 1-degree is observed from April until June with a 1-degree decrease in October.

1.6.3 Alternative 2a -- Hybrid Alternative

Alternative 2a improvement measures for water temperature include:

- Deep fall drawdown to 35' over the regulating outlet at Green Peter, use of RO in fall, use spillway for surface spill in spring and summer
- Modifications to existing outlets at Foster Dam that would allow releases at varying depths for temperature control by modifying the Facility Warm Water Supply (FWWS) pipe and fish weirs.
- Water temperature control tower at Detroit reservoir
- Use the RO's to discharge colder water during fall and winter drawdown operations at Green Peter reservoir
- Use of the spillway for surface spill in the summer at Green Peter Reservoir
- Modifying existing outlets to allow releases at varying depths for temperature control specifically at Foster reservoir with a modification to the Facility Warm Water Supply (FWWS) pipe and fish weirs.

Summary tables of Alternative 2a monthly mean water temperature and monthly mean difference between Alternative 2a and NAA for each of the three simulated years are shown in and Figure 1-388 and Figure 1-389, respectively.

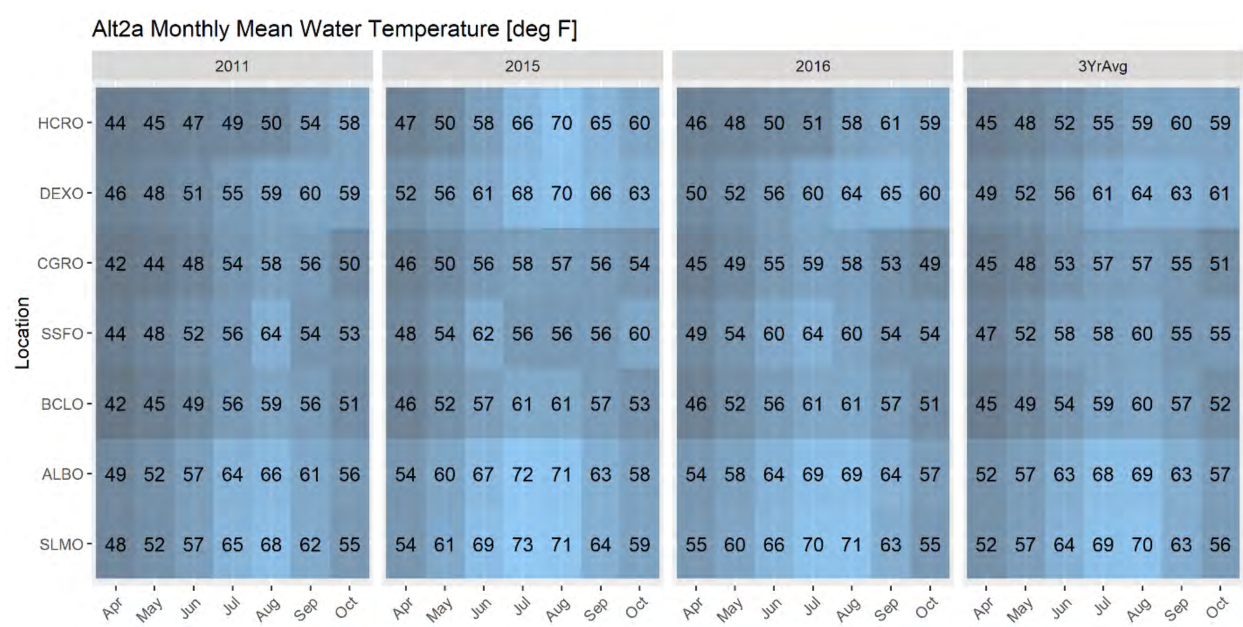

Figure 1-388. Monthly Mean of Daily Mean Water Temperatures (Fahrenheit) for Alternative 2a.

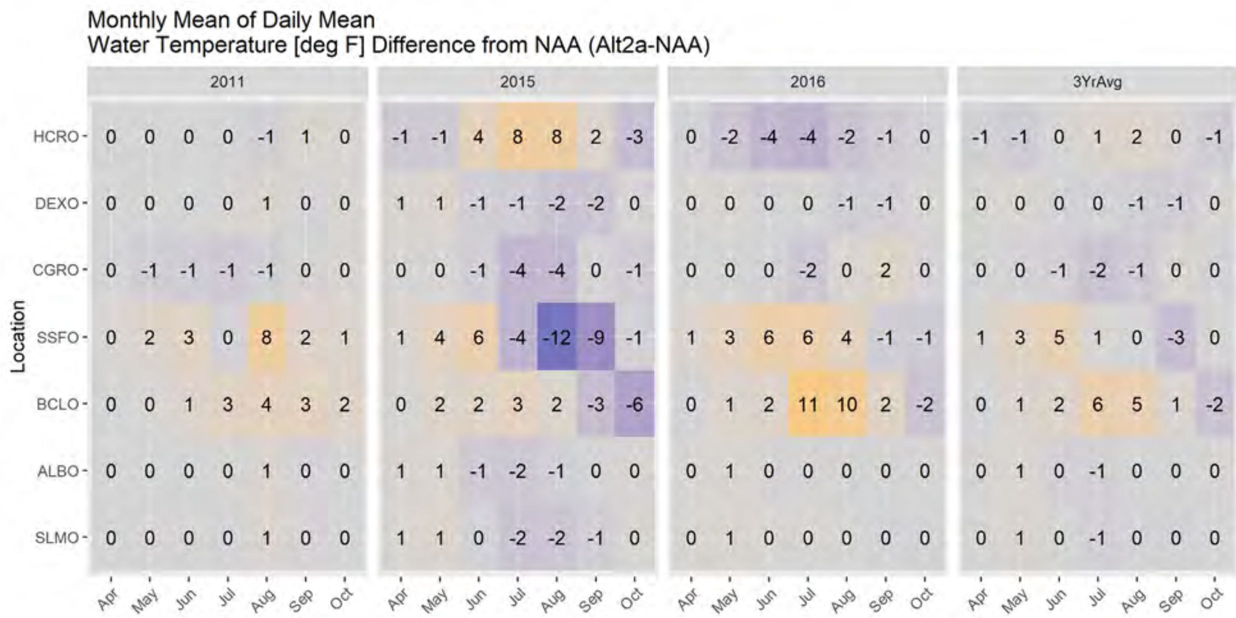

Figure 1-389. Monthly Mean of Daily Mean Water Temperatures (Fahrenheit) difference from NAA to Alternative 2a.

1.6.3.1 NORTH SANTIAM DAMS

Alternative 2a results as compared to the NAA the Monthly Mean of Daily Mean water temperatures at the North Santiam at Niagara gaging site (BCLO; Figure 1-388; Figure 1-389) in the 2011-year scenario would increase in water temperatures up to 4 degrees from June to October. In the 2015-year scenario water temperatures would increase up to 3 degrees from May until August and then a 4–6-degree decrease is observed in September and October. In the 2016-year scenario water temperatures increase up to 11 degrees from May to September and then a 2-degree decrease is observed in October. For the Average of the three years a water temperature increase up to 6 degrees is observed May to September and then a 2 degree decrease is observed in October.

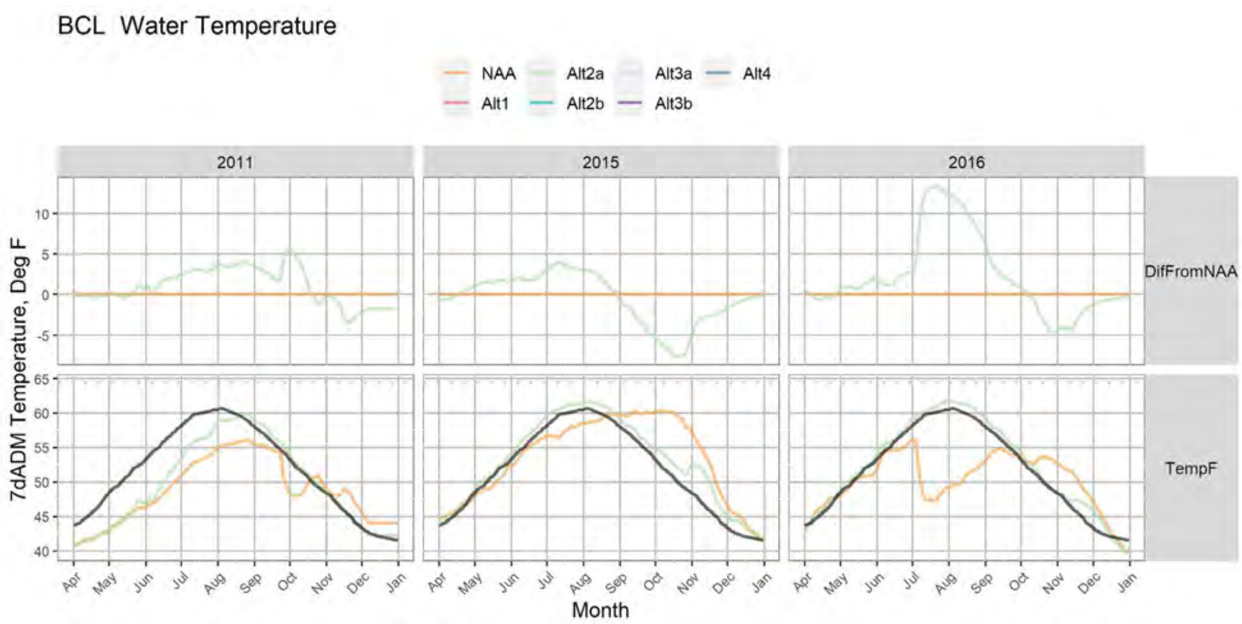

Figure 1-389. Comparison of Alternative 2a for 2011,2015,2016 with 7dADM temperatures (Degrees F) and difference from the NAA downstream of Big Cliff dam.

1.6.3.2 SOUTH SANTIAM DAMS

Results are compared to the NAA the Monthly Mean of Daily Mean water temperatures at the South Santiam River near Foster gaging site (SSFO; Figure 1-388; Figure 1-390) in the 2011-year scenario would see an increase starting in May through October up to 10 degrees. In the 2015-year scenario an increase of 1 to 5 degrees from April to July and then decrease from 2 to 4 degrees from August to October. In the 2016-year scenario an increase up to 10 degrees from April to September and then decrease by 1 degree in October. For the Average of the three years (2011, 2015, 2016) an increase 1 to 6 degrees from April through September and then decrease by 2 degrees in October.

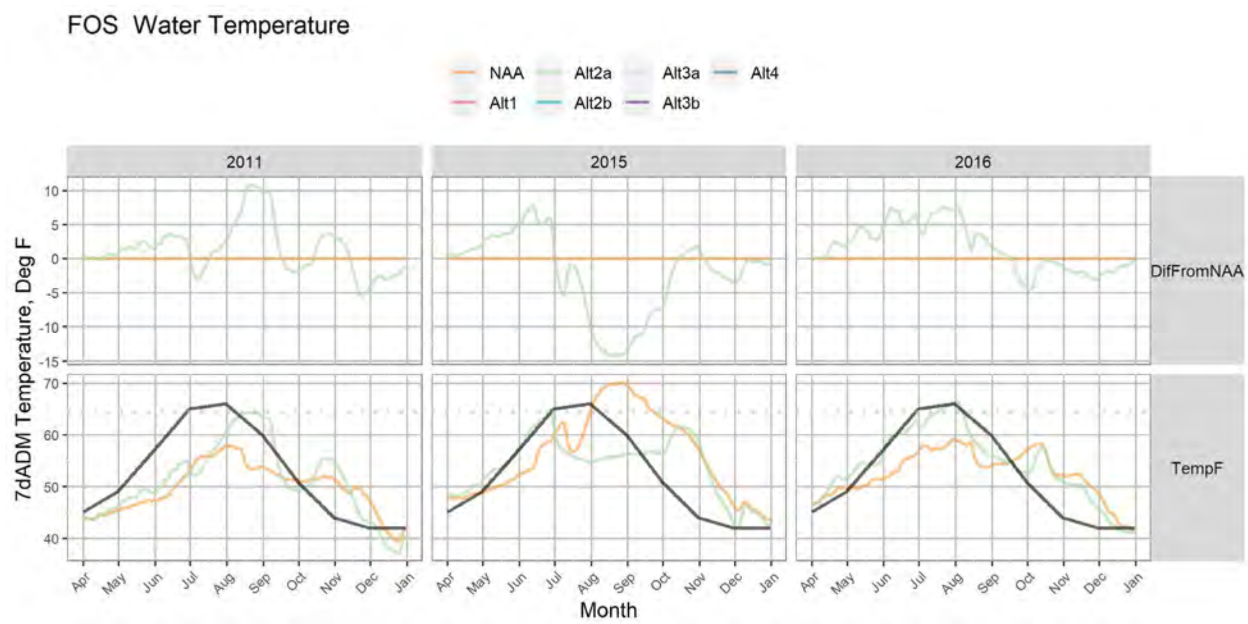

Figure 1-391. Comparison of Alternative 2a and NAA for 2011,2015,2016 with 7dADM temperatures (degrees F) and difference from the NAA downstream of Foster dam. Black line indicates temperature target.

1.6.3.3 MCKENZIE DAMS

Results are compared to the NAA the Monthly Mean of Daily Mean water temperatures at the South Fork McKenzie River near Rainbow gaging site (CGRO; Figure 1-388;Figure 1-392) in the 2011-year scenario there would be a decrease of 1-degree observed from May until August as compared to the NAA. In the 2015-year scenario a decrease up to 3-degrees is observed from June until August, as compared to the NAA. In the 2016-year scenario a decrease is observed up to 2 degrees in June and July, an increase is observed in September as compared to the NAA. For the Average of the three years (2011, 2015, 2016) a decrease up to 2-degrees is observed from June until August as compared to the NAA.

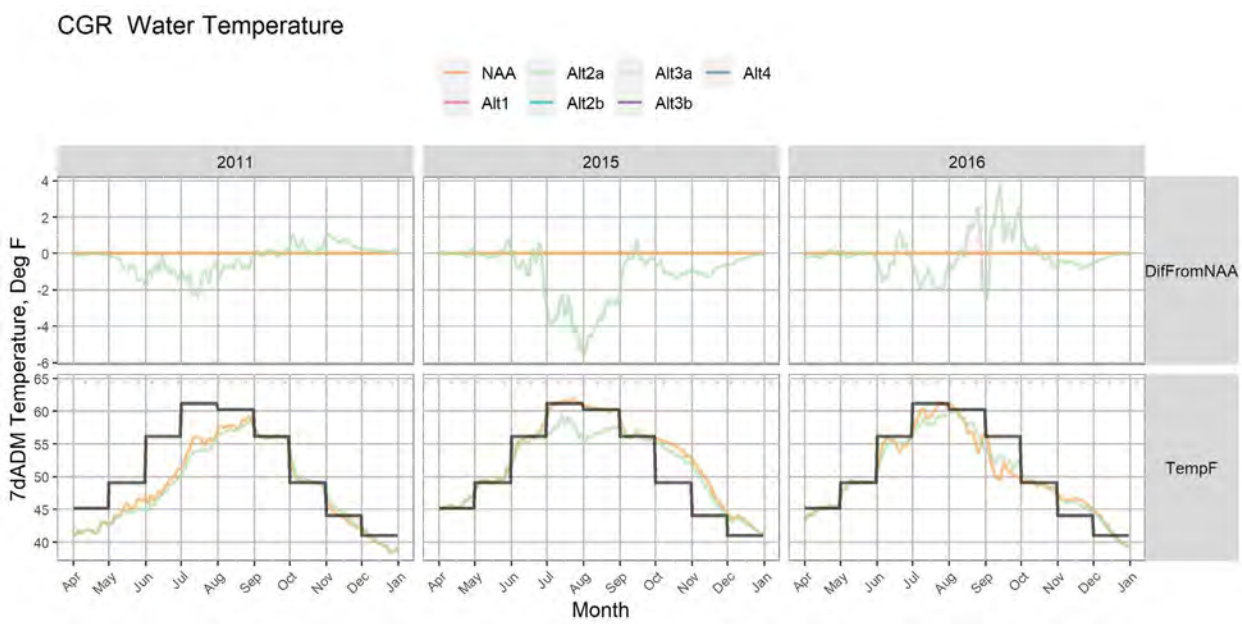

Figure 1-392. Comparison of Alternative 2a and NAA for 2011,2015,2016 with 7dADM temperatures (Degrees F) and difference from the NAA downstream of Cougar dam. Black line indicates temperature target.

1.6.3.4 MIDDLE FORK WILLAMETTE DAMS

Results are compared to the NAA the Monthly Mean of Daily Mean water temperatures at the Middle Fork Willamette River near Dexter gaging site (DEXO; Figure 1-388;Figure 1-393) in the 2011-year scenario would see an increase starting in May through September up to 6 degrees and decrease by 6 degrees in October. In the 2015-year scenario: increase up to 4 degrees from April to June and then decrease by 4 degrees from July to October. In the 2016-year scenario an increase up to 6 degrees from April to August and then decrease by 6 degrees in October. For the Average of the three years (2011, 2015, 2016): increase up to 3 degrees from April to August and then decrease by 5 degrees in October.

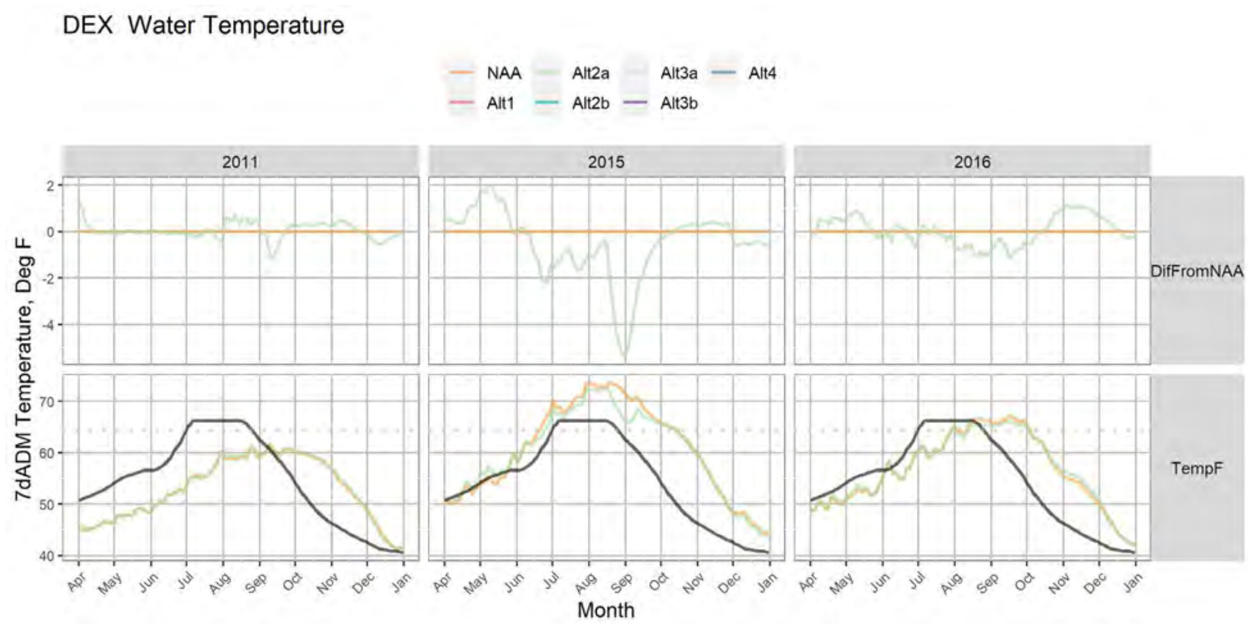

Figure 1-393. Comparison of Alternative 2a and NAA for 2011,2015,2016 with 7dADM temperatures (Degrees F) and difference from the NAA downstream of Dexter dam. Black line indicates temperature target.

As compared to the NAA the Monthly Mean of Daily Mean water temperatures (deg F) at the Middle Fork Willamette River above Salt Creek gaging site (HCRO; Figure 1-388; Figure 1-394) in the 2011-year scenario there would be no temperature difference from April until September and decrease by 1 degree in October as compared to the NAA. In the 2015-year scenario a decrease by 3 degrees from April to June, increase by 3 degrees in July to September, decrease by 3 degrees in October. In the 2016-year scenario there would be no temperature change observed in April and then a decrease observed up to 5 degrees from May until October. For the Average of the three years (2011, 2015, 2016) a temperature decrease up to 2 degrees is observed in May, June, and October.

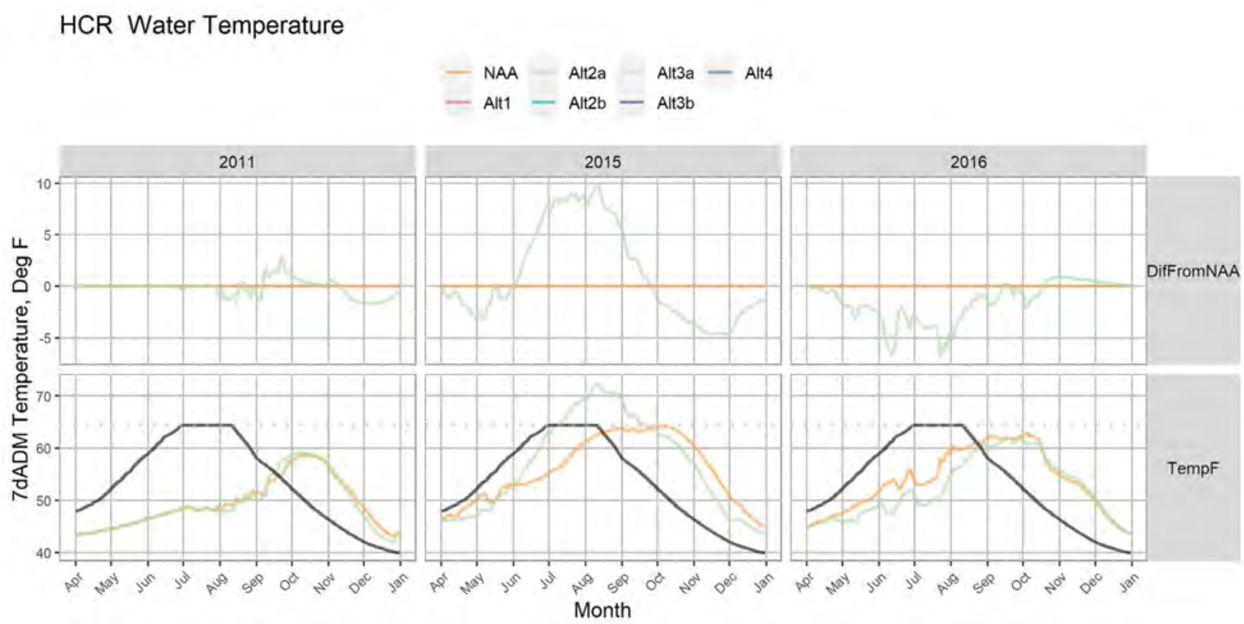

Figure 1-394. Comparison of Alternative 2a and NAA for 2011,2015,2016 with 7dADM temperatures (Degrees F) and difference from the NAA downstream of Hills Creek dam. Black line indicates temperature target.

1.6.3.5 Mainstem Willamette River

Mainstem Willamette River Alternative 2a results are compared to the NAA using the Monthly Mean of Daily Mean water temperatures at the Willamette River near Salem gaging site (SLMO; Figure 1-389). In the 2011-year scenario there would be a 1-degree water temperature increase in August. In the 2015-year scenario water temperatures increase up to 2-degree in April and May and then decrease up to 2 degrees from July until September. In the 2016-year scenario a water temperature increase of 1 degree is observed in May. For the Average of the three years (2011, 2015, 2016) water temperature increases 1-degree in May and then decreases by 1 degree in July and September.

Mainstem Willamette River Alternative 2a results are compared to the NAA using the Monthly Mean of Daily Mean water temperatures at the Willamette River at Albany gaging site (ALBO; Figure 1-389). In the 2011-year scenario a water temperature increase up to 1 degree is observed in August. In the 2015-year scenario a water temperature increase of 1 degree is observed in April and May and then 1 degree decrease in June and July. In the 2016-year scenario a water temperature increase of 1-degree is observed in May. For the Average of the three years (2011, 2015, 2016) a water temperature increase up to 1-degree is observed in May.

1.6.4 Alternative 2b -- Hybrid Alternative

Alternative 2b improvement measures for water temperature include:

- Water temperature control tower at Detroit reservoir
- Use the RO's to discharge colder water during fall and winter drawdown operations at Green Peter reservoir
- Use of the spillway for surface spill in the summer at Green Peter Reservoir
- Modifying existing outlets to allow releases at varying depths for temperature control specifically at Foster reservoir with a modification to the Facility Warm Water Supply (FWWS) pipe and fish weirs.

Summary tables of Alternative 2b monthly mean water temperature and monthly mean difference between Alternative 2b and NAA for each of the three simulated years are shown in and Figure 1-395 and Figure 1-396, respectively.

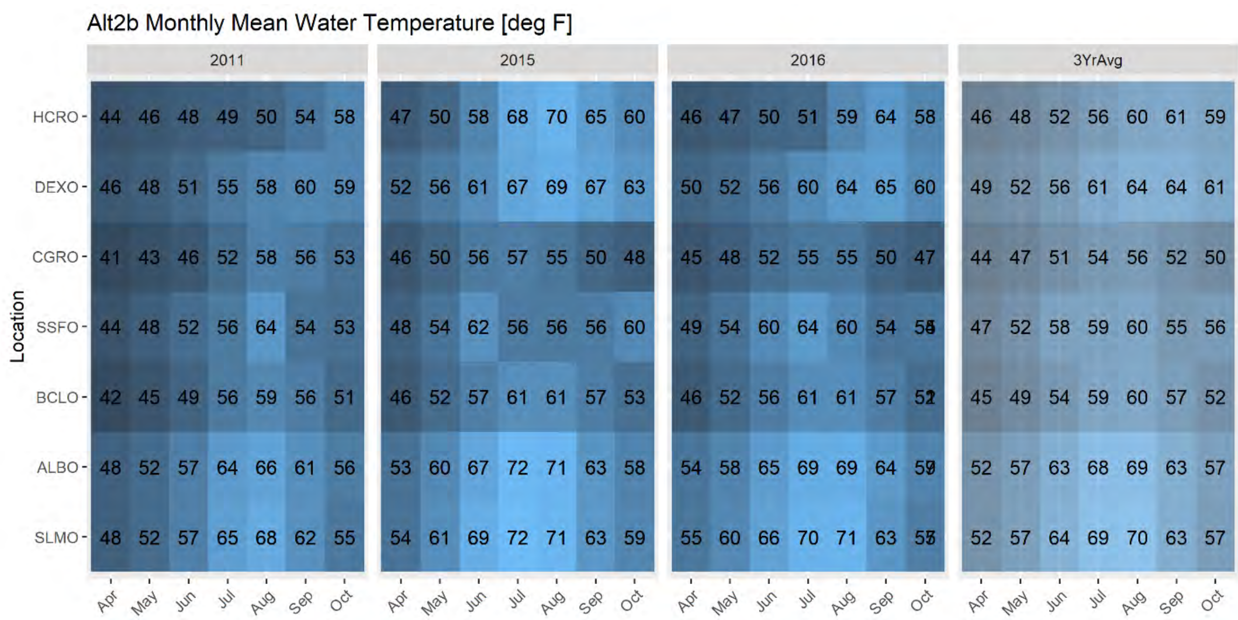

Figure 1-395. Monthly Mean of Water Temperatures (Fahrenheit) for Alternative 2b.

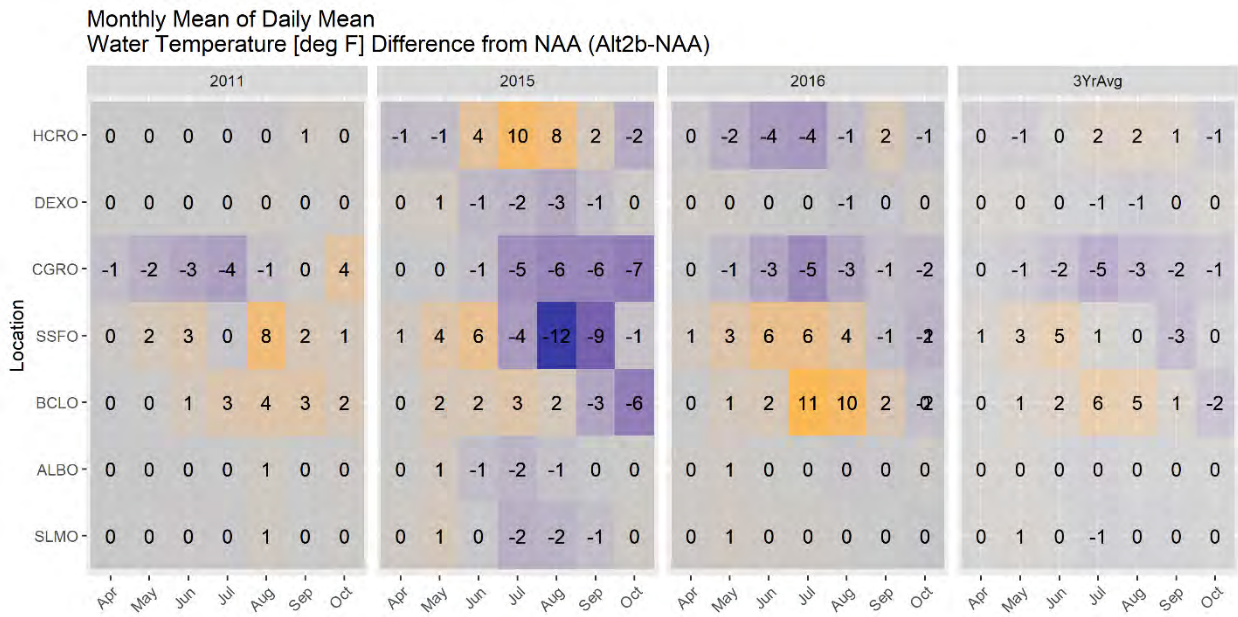

Figure 1-396. Monthly Mean of Daily Mean Water Temperatures (Fahrenheit) difference from NAA to Alternative 2b.

1.6.4.1 NORTH SANTIAM DAMS

Alternative 2b includes a Water Temperature Control tower at Detroit reservoir for water temperature management. Alternative 2b as compared to the NAA the Monthly Mean of Daily Mean water temperatures at the North Santiam at Niagara gaging site (BCLO in Figure 1-395, Figure 1-397) in the 2011-year scenario an increase up to 3-degrees is observed from June until October as compared to the NAA. In the 2015-year scenario an increase up to 3-degrees is observed from May until August and then decreases up to 6 degrees in September and October. In the 2016-year scenario an increase up to 11-degrees is observed from May until September as compared to the NAA. For the Average of the three years an increase up to 6-degrees is observed from May until September and then a decrease of 2-degrees in October as compared to the NAA.

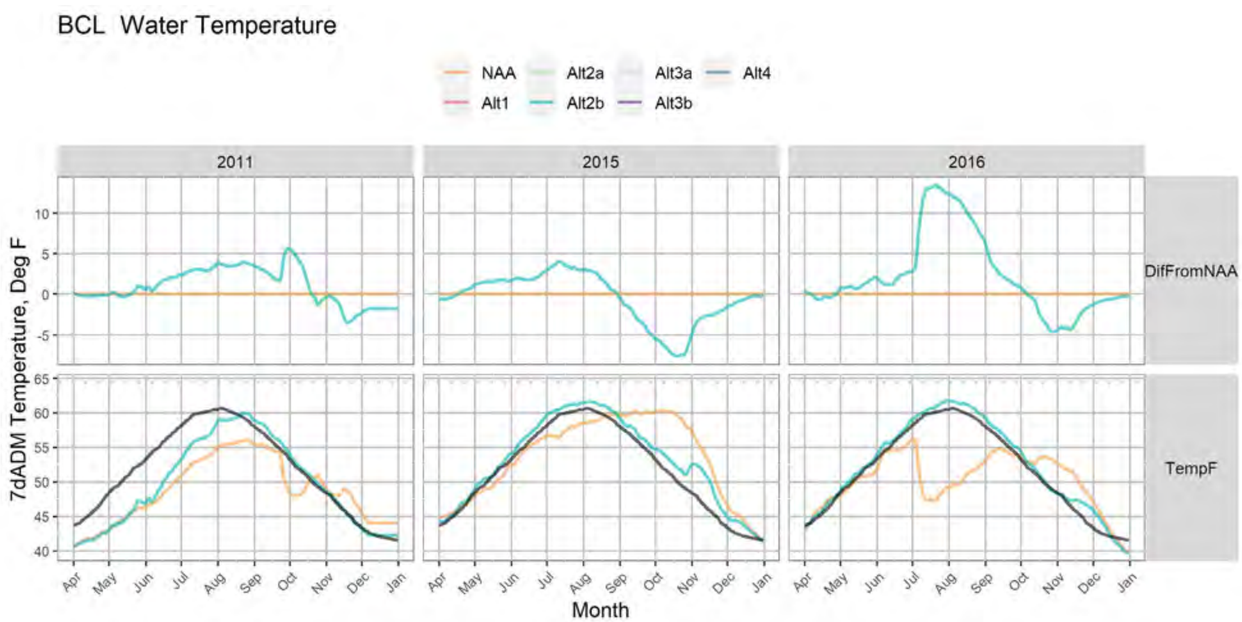

Figure 1-397. Comparison of Alternative 2b and NAA for 2011,2015,2016 with 7dADM temperatures (Degrees F) and difference from the NAA downstream of Big Cliff dam.

1.6.4.2 SOUTH SANTIAM DAMS

Alternative 2b includes the use of the RO's to discharge colder water during fall and winter drawdown operations at Green Peter reservoir. An additional measure includes the use of the spillway for surface spill in the summer at Green Peter reservoir. Also a measure to modify existing outlets to allow releases at varying depths for temperature control specifically at Foster reservoir with a modification to the Facility Warm Water Supply (FWWS) pipe and fish weirs.

Results are compared to the NAA the Monthly Mean of Daily Mean water temperatures at the South Santiam River near Foster gaging site (SSFO in Figure 1-396, Figure 1-398) in the 2011-year scenario would see an water temperature increase starting in May through October up to 8 degrees, although July observed a 1-degree temperature decrease. In the 2015-year scenario an increase in water temperatures of 1 to 6 degrees from April to June, a decrease in temperatures from 1 to 13 degrees is observed from July to October. In the 2016-year scenario an increase up to 6 degrees from April to August and then decrease by 2 degree in September and October. For the Average of the three years (2011, 2015, 2016) an increase 1 to 5 degrees from April through June and then decrease up to 3 degrees from August until October.

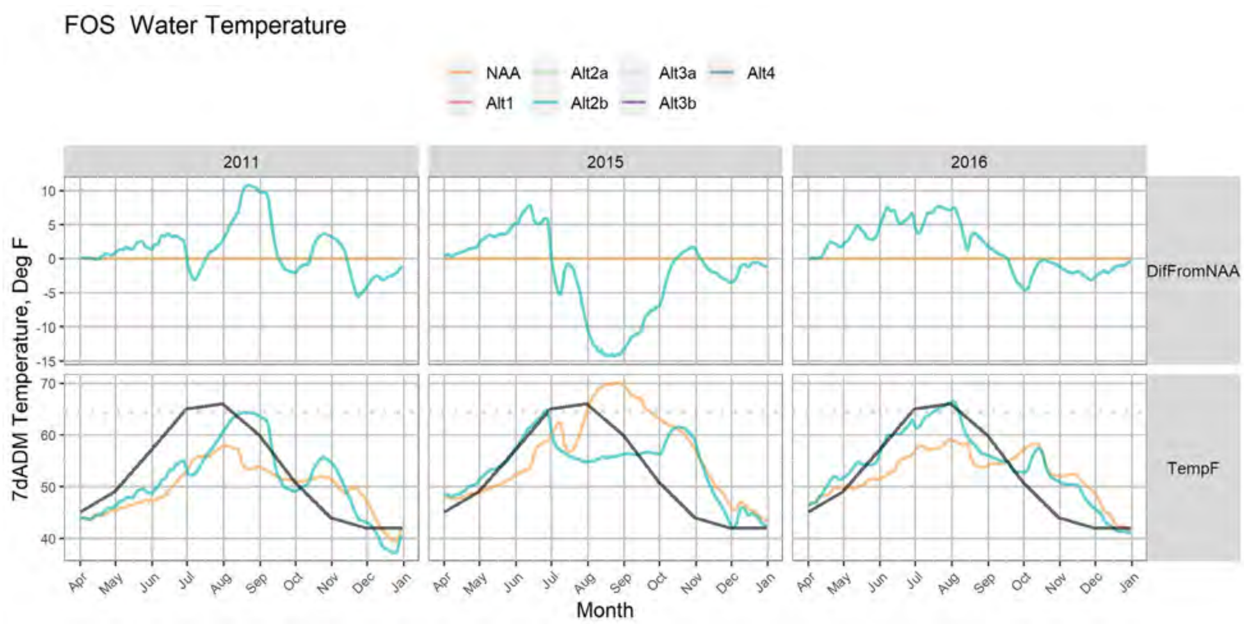

Figure 1-398. Comparison of Alternative 2b for 2011,2015,2016 with 7dADM temperatures (Degrees F) and difference from the NAA downstream of Foster dam.

1.6.4.3 MCKENZIE DAMS

There are no water temperature measures for Cougar or Blue River dams under Alternative 2b. Results are compared to the NAA the Monthly Mean of Daily Mean water temperatures at the South Fork McKenzie River near Rainbow gaging site (CGRO; Figure 1-396; Figure 1-399) in the 2011-year scenario there would be a water temperature decrease up to 3-degrees from April through July and a 4-degree increase in October as compared to the NAA. In the 2015-year scenario a water temperature decrease up to 7-degrees is observed from June until October, as compared to the NAA. In the 2016-year scenario a temperature decrease is observed up to 5 degrees from May until October as compared to the NAA. For the Average of the three years (2011, 2015, 2016) a temperature decrease up to 4-degrees is observed from May until October as compared to the NAA. These water temperature decreases relative to NAA are a result of the deep drawdown, decreased residence time in Cougar Lake (reduced heating in the reservoir), and use of the diversion tunnel as the primary outlet.

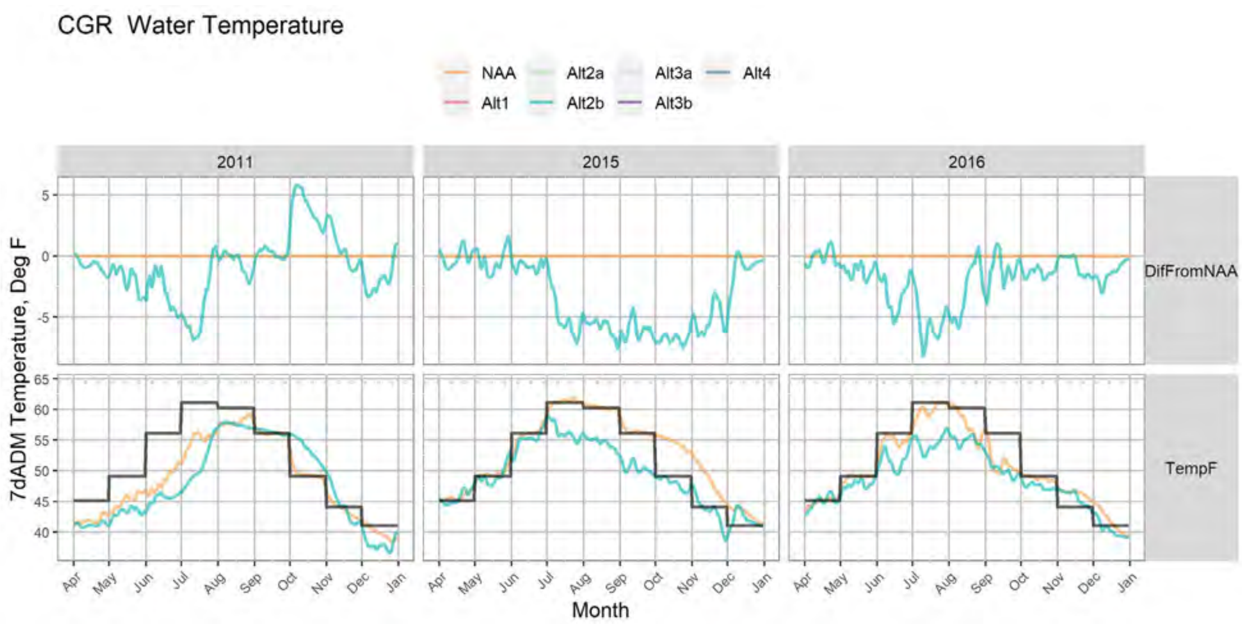

Figure 1-399. Comparison of Alternative 2b for 2011,2015,2016 with 7dADM temperatures (Degrees F) and difference from the NAA downstream of Cougar dam. Black Line indicates temperature target.

1.6.4.4 MIDDLE FORK WILLAMETTE DAMS

Alternative 2b has no water temperature measures for the Middle Fork sub-basin. Results are compared to the NAA the Monthly Mean of Daily Mean water temperatures at the Middle Fork Willamette River near Dexter gaging site (DEXO; Figure 1-400) in the 2011-year scenario there would be no temperature difference from April to October. In the 2015-year scenario observes a 1-degree increase in May, a water temperature decrease up to 3-degrees is observed from June until September. In the 2016-year scenario most months see no change in water temperatures except for August which decreases by 1 degree as compared to the NAA. For the Average of the three years (2011, 2015, 2016) a water temperature decrease by 1 degrees is observed from July through September.

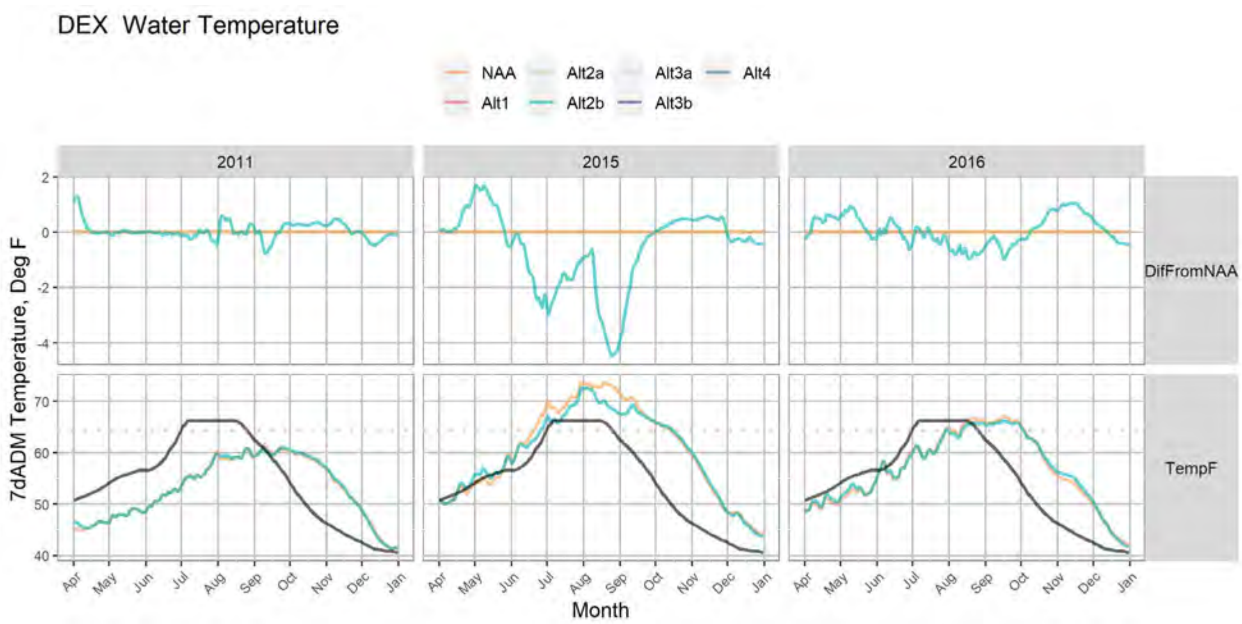

Figure 1-400. Comparison of Alternative 2b for 2011,2015,2016 with 7dADM temperatures (Degrees F) and difference from the NAA downstream of Dexter dam. Black Line indicates temperature target.

As compared to the NAA the Monthly Mean of Daily Mean water temperatures (deg F) at the Middle Fork Willamette River above Salt Creek gaging site (HCRO; Figure 1-396; Figure 1-401) in the 2011-year scenario there would be no temperature difference from April to October as compared to the NAA. In the 2015-year scenario a decrease up to 2 degrees are observed in May and October, water temperature increases up to 9 degrees in June through September as compared to the NAA. In the 2016-year scenario water temperature decrease is observed up to 4 degrees from May until October, although September would increase by 1 degree. For the Average of the three years (2011, 2015, 2016) a water temperature decrease up to 1 degrees is observed in May and October, a temperature increase up to 2-degrees occurs in July through September.

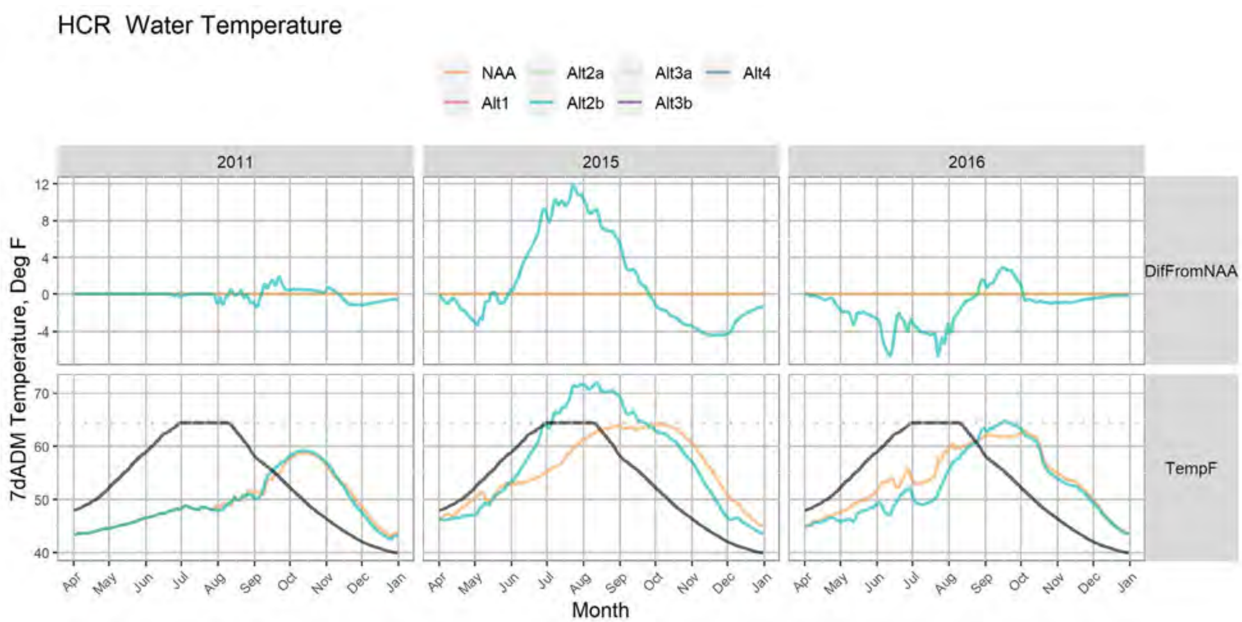

Figure 1-401. Comparison of Alternative 2b for 2011,2015,2016 with 7dADM temperatures (Degrees F) and difference from the NAA downstream of Hills Creek dam. Black Line indicates temperature target.

1.6.4.5 Mainstem Willamette River

Mainstem Willamette River Alternative 2b results are compared to the NAA using the Monthly Mean of Daily Mean water temperatures at the Willamette River near Salem gaging site (SLMO; Figure 1-396). In the 2011-year scenario there would be a 1-degree water temperature increase in August. In the 2015-year scenario water temperatures decrease by 2-degree from July through September. In the 2016-year scenario a water temperature increase of 1 degree is observed in May. For the Average of the three years (2011, 2015, 2016) water temperature increases 1-degree in May and then decreases by 1 degree in July.

Mainstem Willamette River Alternative 2b results are compared to the NAA using the Monthly Mean of Daily Mean water temperatures at the Willamette River at Albany gaging site (ALBO; Figure 1-396). In the 2011-year scenario a water temperature increase up to 1 degree is observed in August. In the 2015-year scenario a water temperature decreases by 2-degrees from June through August. In the 2016-year scenario a water temperature increase of 1-degree is observed in May. For the Average of the three years (2011, 2015, 2016) no temperature change is observed.

1.6.5 Alternative 3a – Operations-Focused Fish Passage

Alternative 3a would utilize operation-based measures for fish passage survivability within the WVS dams and compared to the NAA. Operational improvements for water temperature measures include:

- Utilizing the RO's to discharge cold water during drawdown operations in the fall and winter to reduce water temperatures below Detroit, Green Peter, and Lookout Point dams
- Utilizing the spillway for surface spill in the summer at Detroit, Green Peter, Foster, Blue River, Hills Creek, and Lookout point dams
- Spreading spill would be conducted at Dexter and Lookout Point
- Modify existing outlets to allow releases at varying depths for temperature control by modifying the spillway to allow releases at varying depths for temperature control at Blue River and Hills Creek dams
- Lining of the lower RO tunnels to limit cavitation effects and to assist in temperature control at Detroit dam.

Summary tables of Alternative 3a monthly mean water temperature and monthly mean difference between Alternative 3a and NAA for each of the three simulated years are shown in and Figure 1-402 and Figure 1-403, respectively.

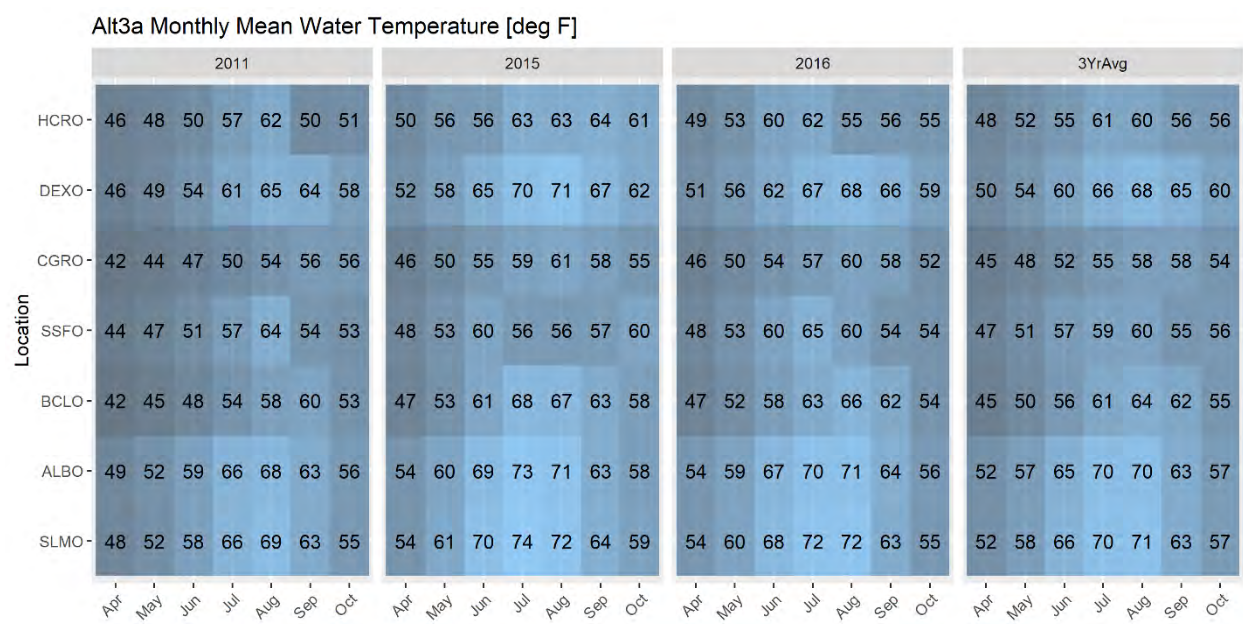

Figure 1-402. Monthly Mean of Water Temperatures (Fahrenheit) for Alternative 3a

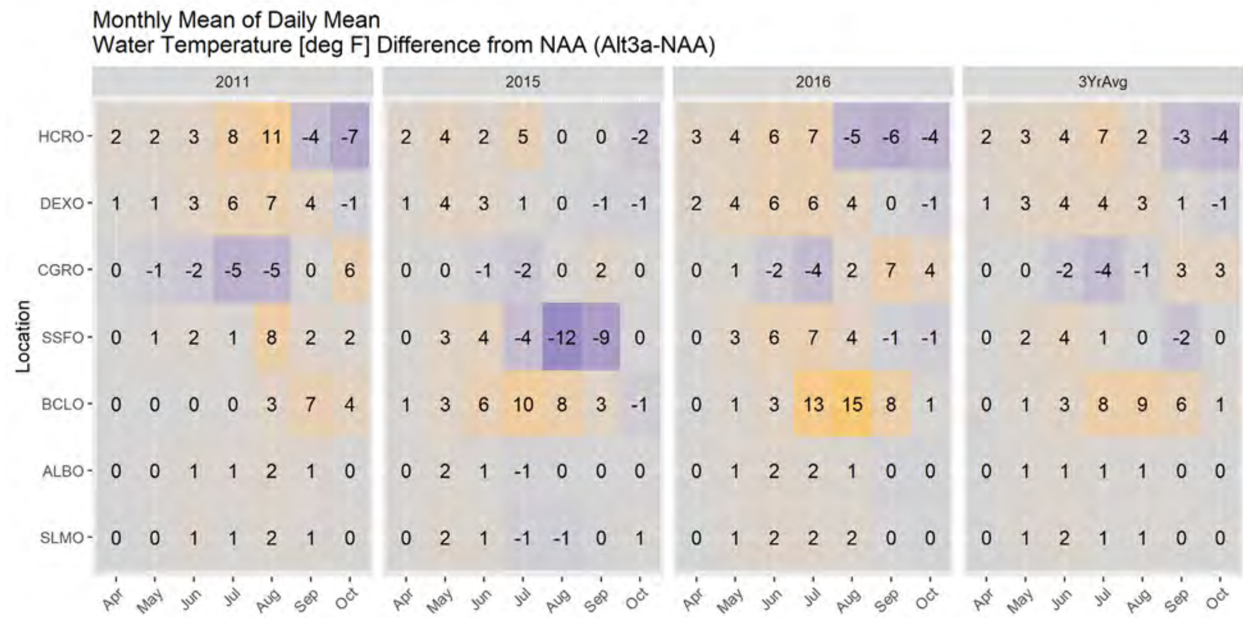

Figure 1-403. Monthly Mean of Daily Mean Water Temperatures (Fahrenheit) difference from NAA to Alternative 3a.

1.6.5.1 NORTH SANTIAM DAMS

Water temperature measures under Alternative 3a include Detroit reservoir utilizing the RO's to discharge colder water during drawdown operations in the fall and winter to reduce downstream water temperatures. The Detroit spillway would be utilized for surface spill in the summer which would assist in blending water temperatures below in Big Cliff. The lower RO's would be lined to limit cavitation effects and assist in releasing cooler water in the late fall at Detroit reservoir.

Alternative 3a as compared to the NAA the Monthly Mean of Daily Mean water temperatures at the North Santiam at Niagara gaging site (BCLO; Figure 1-403; Figure 1-404) the 2011-year scenario indicates an increase in water temperatures up to 7-degrees from August through October . Monthly Mean of Daily Max, Water Temperature difference from NAA (Alt3a-NAA). In the 2015-year scenario water temperatures increase up to 10 degrees from April until September, a 1-degree temperature decrease occurs in October. In the 2016-year scenario a water temperature increase up to 15-degrees is observed from May until October as compared to the NAA. For the average of the three years water temperatures increase up to 9-degrees from May until October.

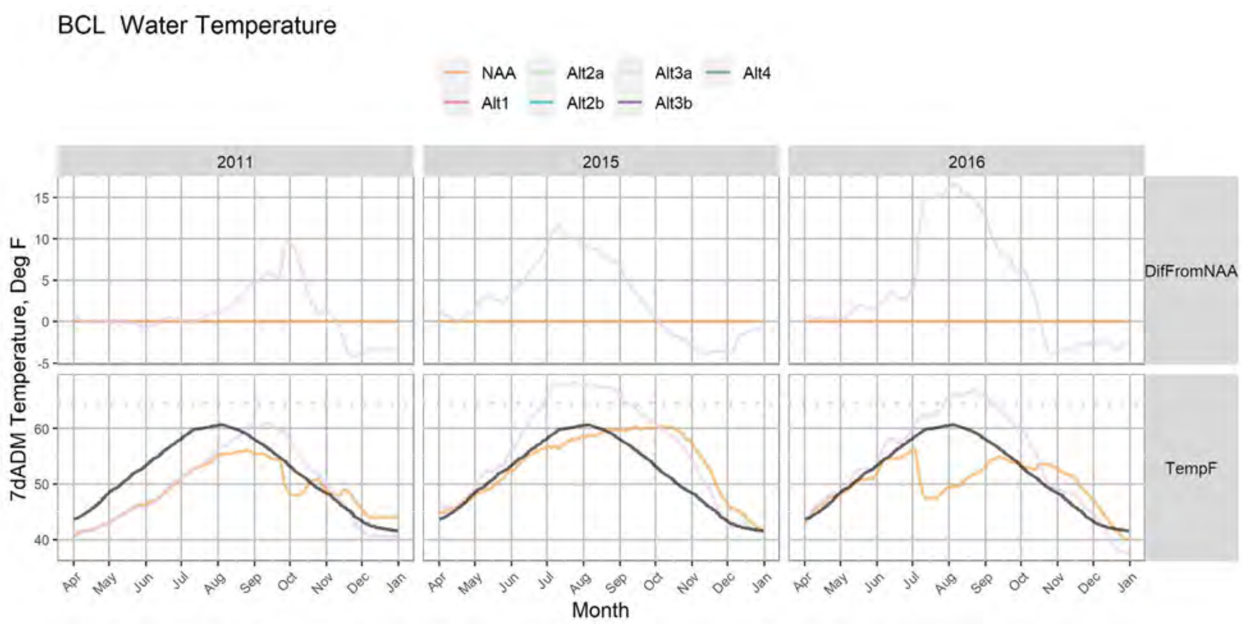

Figure 1-404. Comparison of Alternative 3a for 2011,2015,2016 with 7dADM temperatures (Degrees F) and difference from the NAA downstream of Big Cliff dam. Black line indicates temperature target.

1.6.5.2 SOUTH SANTIAM DAMS

Water temperature measures under Alternative 3a include Green Peter utilizing the RO's to discharge colder water during drawdown operations in the fall and winter to reduce downstream water temperatures and volitional downstream fish passage. The Green Peter and Foster dam spillways would be utilized in the summer for surface spill.

Alternative 3a results are compared to the NAA the Monthly Mean of Daily Mean water temperatures at the South Santiam River near Foster gaging site (SSFO; Figure 1-403; Figure 1-405)the 2011-year scenario would see a water temperature increase starting in May through October up to 8 degrees, although July has no temperature change as compared to the NAA. In the 2015-year scenario water temperatures increase from 1 to 4 degrees in April through June, a decrease in temperatures from 4 to 13 degrees is observed from July to September. In the 2016-year scenario water temperatures increase up to 7 degrees from May to August and then decrease by 1 degree in September and October. For the Average of the three years (2011, 2015, 2016) an increase 1 to 4 degrees from May through June and then decrease up to 2 degrees from August and September.

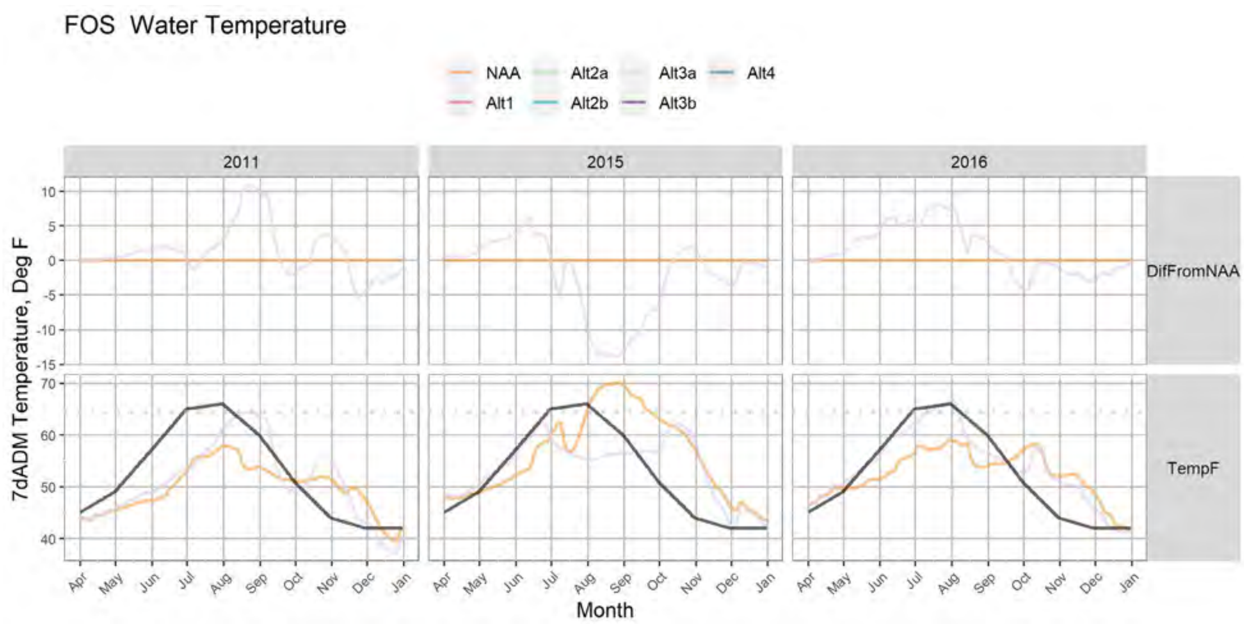

Figure 1-405. Comparison of Alternative 3a for 2011,2015,2016 with 7dADM temperatures (Degrees F) and difference from the NAA downstream of Foster dam. Black line indicates temperature target.

1.6.5.3 MCKENZIE DAMS

Water temperature measures under Alternative 3a include a modification to the spillway at Blue River reservoir to provide better water temperature management. The spillway would be used in the summer for surface spill. Not a direct water temperature measure but equally as important is Cougar reservoir implementing spring and fall drawdown operations for volitional downstream fish passage. And Blue River implementing a fall drawdown 15 ft below minimum conservation (1180 ft).

Temperature results for Alt 3a effects are compared to the NAA the Monthly Mean of Daily Mean water temperatures at the South Fork McKenzie River near Rainbow gaging site (CGRO; Figure 1-403; Figure 1-406) in the 2011-year scenario there would be a water temperature decrease from 1 to 5-degrees from April through August, a 6-degree water temperature increase would occur in October as compared to the NAA. In the 2015-year scenario a water temperature increase of 1 to 2 degrees is observed in May, August, and September. A temperature decrease of 1-2 degrees is observed in June and July for the 2015-year scenario. In the 2016-year scenario a temperature increase is observed up to 6 degrees from April until July, a temperature decrease of up to 6 degrees occurs from August until October as compared to the NAA. For the Average of the three years (2011, 2015, 2016) a temperature increase up to 7-degrees is observed from April until August, a temperature decrease of 3-4 degrees occurs in September and October as compared to the NAA.

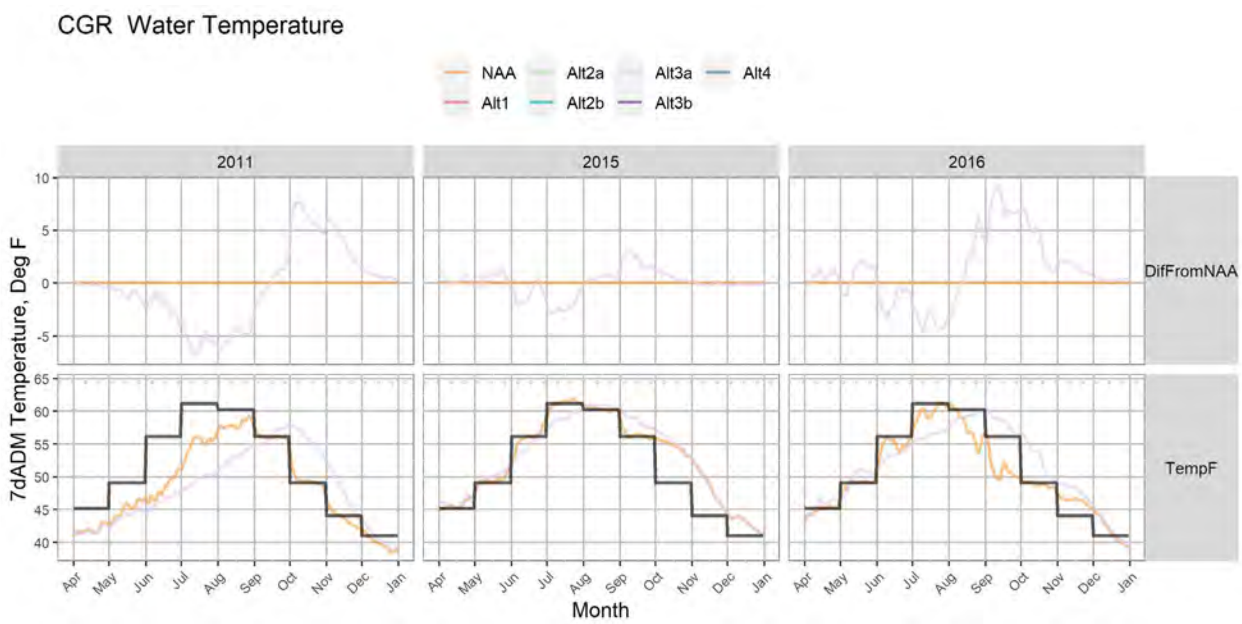

Figure 1-406. Comparison of Alternative 3a for 2011,2015,2016 with 7dADM temperatures (Degrees F) and difference from the NAA downstream of Cougar dam. Black line indicates temperature target.

1.6.5.4 MIDDLE FORK WILLAMETTE DAMS

Water temperature measures under Alternative 3a include Hills Creek reservoir modification to the spillway and use the spillway for surface spill in the summer. Lookout point reservoir would utilize the RO's to discharge colder water during drawdown operations in fall and winter to reduce downstream water temperatures. The Lookout Point spillway would be utilized in the summer for surface spill. Dexter spillway would be utilized in order to spread surface spill.

Water temperature results are compared to the NAA the Monthly Mean of Daily Mean water temperatures at the Middle Fork Willamette River near Dexter gaging site (DEXO; Figure 1-403;Figure 1-407) in the 2011-year scenario water temperature increase from 1 to 6 degrees is observed from April to September. In the 2015-year scenario observes a 1-3 degree increase from April through July, then decrease of 1 degree in September. In the 2016-year scenario a 2 to 6-degree water temperature increase is observed from April through August, and decrease by 1 degree in October as compared to the NAA. For the Average of the three years (2011, 2015, 2016) a water temperature increases from 1-4 degrees in April through September and decreases by 1 degrees in October.

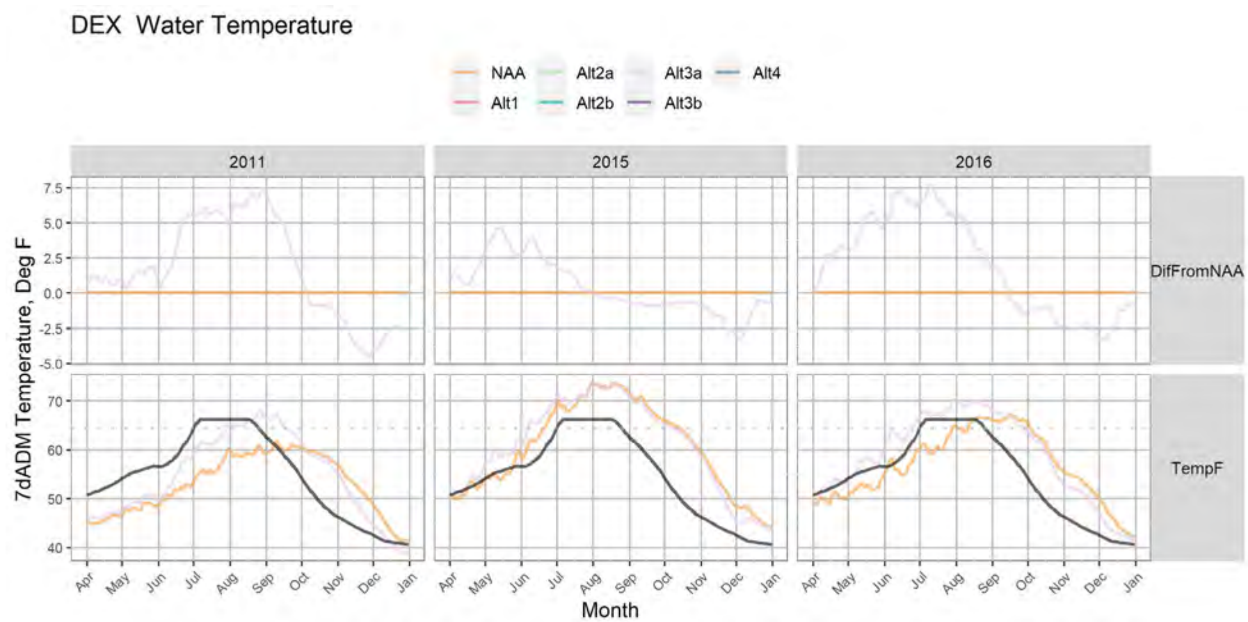

Figure 1-407. Comparison of Alternative 3a for 2011,2015,2016 with 7dADM temperatures (Degrees F) and difference from the NAA downstream of Dexter dam. Black line indicates temperature target.

As compared to the NAA the Monthly Mean of Daily Mean water temperatures at the Middle Fork Willamette River above Salt Creek gaging site (HCRO; Figure 1-403; Figure 1-407) in the 2011-year scenario water temperature increase from 2 to 11 degrees is observed from April to August, a decrease from 4 to 6 degrees occurs in September and October. In the 2015-year scenario observes a 1-6 degree increase from April through July, then decrease of 1 degree in October as compared to the NAA. In the 2016-year scenario water temperature increase 3-6 degrees from April through July, and decrease up to 6 degrees from August to October as compared to the NAA. For the Average of the three years (2011, 2015, 2016) a water temperatures increase 2 to 7 degrees from April through August and then decrease up to 4 degrees in September and October.

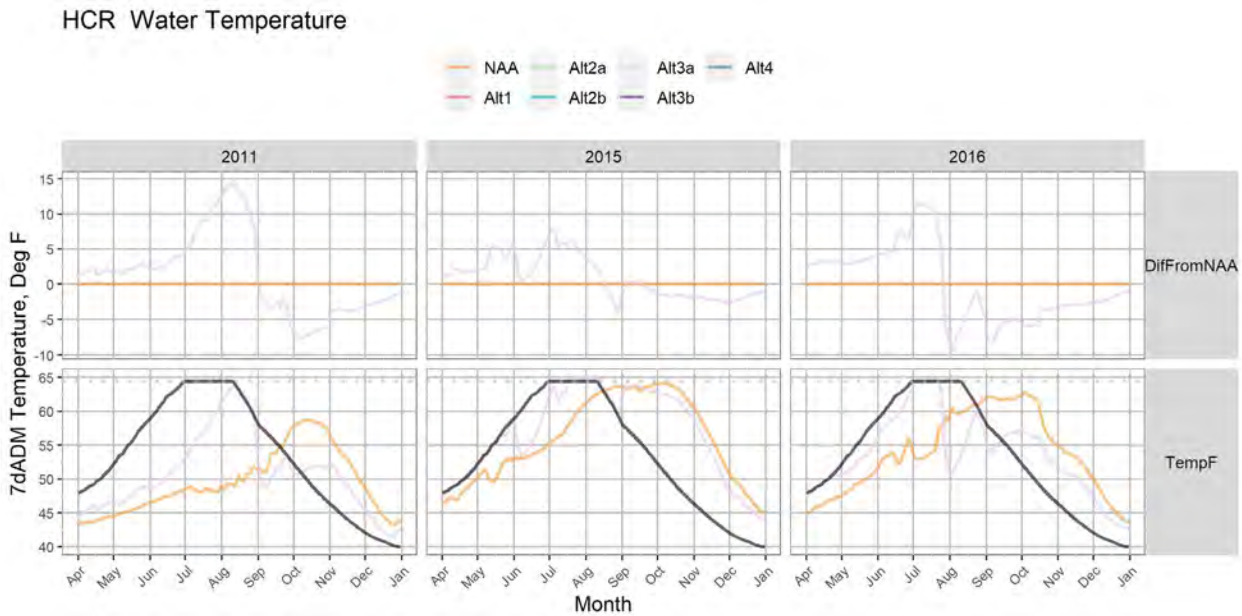

Figure 1-408. Comparison of Alternative 3a for 2011,2015,2016 with 7dADM temperatures (Degrees F) and difference from the NAA downstream of Hills Creek Dam. Black line indicates temperature target.

1.6.5.5 Mainstem Willamette River

Mainstem Willamette River Alternative 3a results are compared to the NAA using the Monthly Mean of Daily Mean water temperatures at the Willamette River near Salem gaging site (SLMO; Figure 1-403). In the 2011-year scenario, water temperature increases by 1 degree from June through September as compared to the NAA. In the 2015-year scenario temperature increases 1 to 2 degrees in April through June and then decreases by 1 degree in July and August as compared to the NAA. In the 2016-year scenario water temperatures increase up to 2-degrees from May until August as compared to the NAA. For the average of the three years (2011,2015, 2016) water temperature increases up to 2 degrees from May until July as compared to the NAA.

Mainstem Willamette River Alternative 3a results are compared to the NAA using the Monthly Mean of Daily Mean water temperatures at the Willamette River at Albany gaging site (ALBO; Figure 1-403). In the 2011-year scenario water temperatures increase up to 2 degrees from June through September as compared to the NAA. In the 2015-year scenario water temperatures increase up to 2-degrees in May and June as compared to the NAA. In the 2016-year scenario water temperatures increase up to 2-degrees from May until August as compared to the NAA. For the average of the three years (2011,2015, 2016) water temperatures increase up to 2-degrees from May until August as compared to the NAA.

1.6.6 Alternative 3b – Operations-Focused Fish Passage Alternative (using diversion tunnel at Cougar)

Alternative 3b measures include operational improvements for water temperature

- Utilizing the RO's to discharge cold water during drawdown operations in the fall and winter to reduce water temperatures below Detroit, Green Peter, and Lookout Point dams
- Utilizing the spillway for surface spill in the summer at Detroit, Green Peter, Foster, Blue River, Hills Creek, and Lookout point dams
- Modifying the spillway to allow releases at varying depths for temperature control at Blue River and Hills Creek dams
- Lining of the lower RO tunnels to limit cavitation effects and to assist in temperature control at Detroit dam
- Modifying the Cougar dam diversion tunnel for water temperature control and complying with dam safety

Summary tables of Alternative 3b monthly mean water temperature and monthly mean difference between Alternative 3b and NAA for each of the three simulated years are shown in and Figure 1-409 and Figure 1-410, respectively.

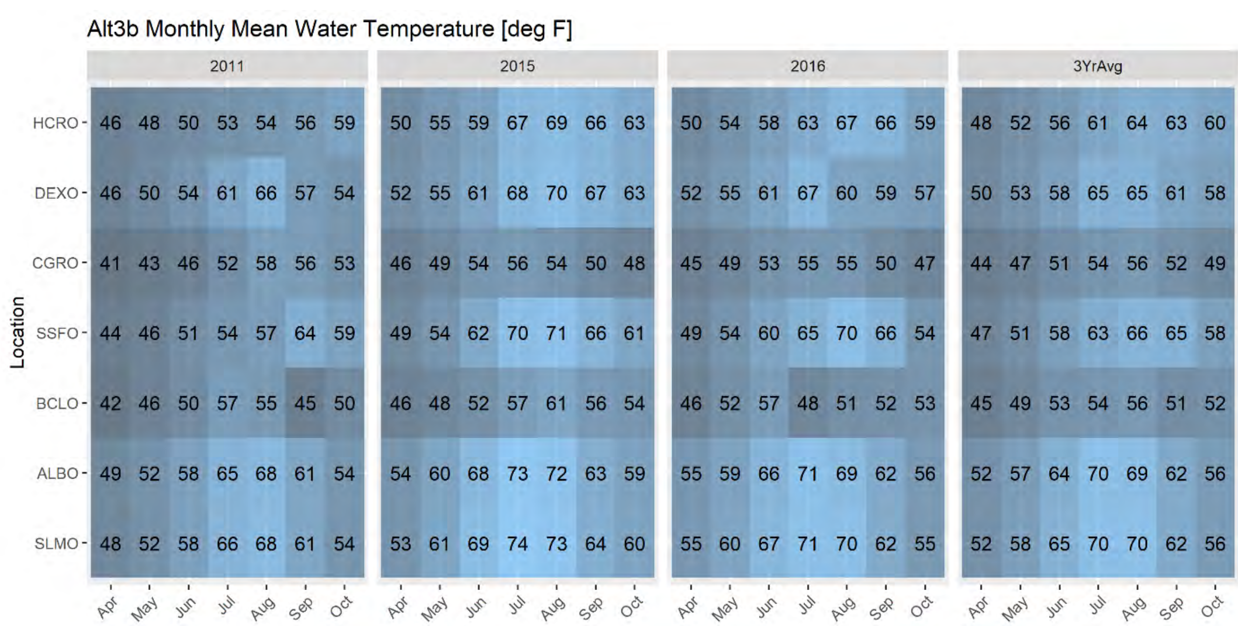

Figure 1-409. Monthly Mean of Water Temperatures (Fahrenheit) for Alternative 3b.

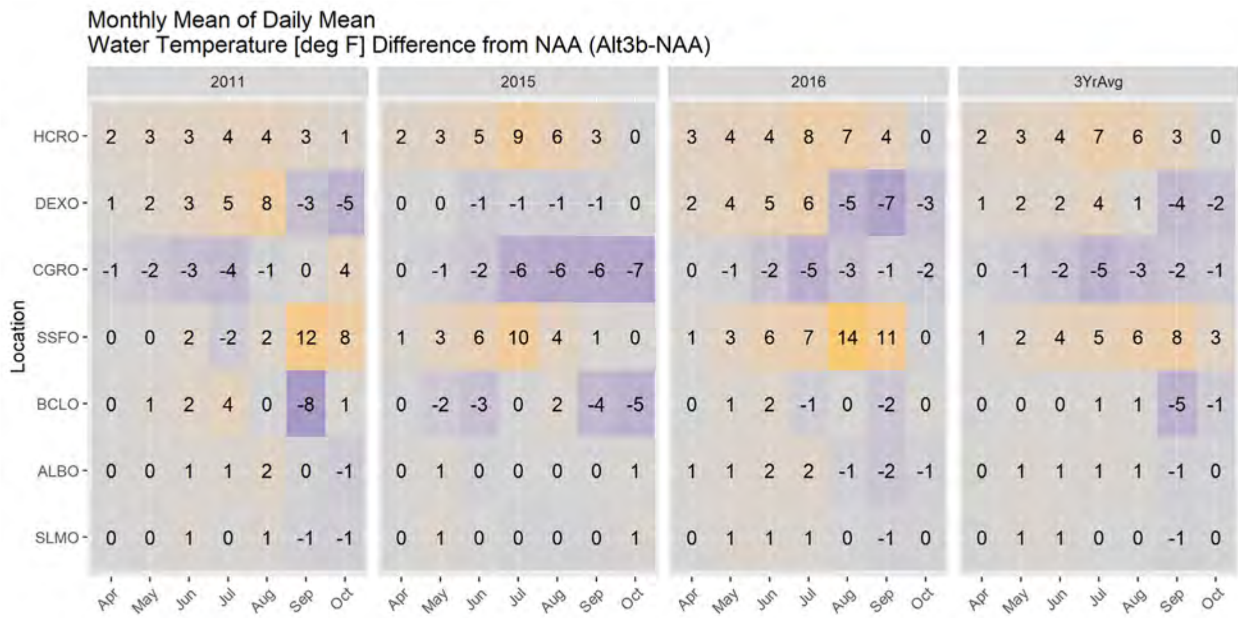

Figure 1-410. Monthly Mean of Daily Mean Water Temperatures (Fahrenheit) difference from NAA to Alternative 3b.

1.6.6.1 NORTH SANTIAM DAMS

Water temperature measures under Alternative 3b include Detroit reservoir utilizing the RO's to discharge colder water during drawdown operations in the fall and winter to reduce downstream water temperatures. The Detroit spillway would be utilized for surface spill in the summer which would assist in blending water temperatures below in Big Cliff. The lower RO's would be lined to limit cavitation effects and assist in releasing cooler water in the late fall at Detroit reservoir.

Alternative 3b as compared to the NAA the Monthly Mean of Daily Mean water temperatures at the North Santiam at Niagara gaging site (BCLO; Figure 1-410; Figure 1-411) the 2011-year scenario indicates an increase in water temperatures up to 4-degrees from May through July, an 8 degree temperature decrease is observed in September as compared to the NAA . Monthly Mean of Daily Max, Water Temperature difference from NAA (Alt3b-NAA). In the 2015-year scenario water temperatures decrease up to 5 degrees from May until October, although a 1-degree temperature increase is observed in August. In the 2016-year scenario a water temperature increase up to 2-degrees is observed in May and June, a temperature decrease of 1 to 2 degrees occurs in July and September. For the average of the three years water temperatures increase by 1-degrees in July, and then decrease up to 5 degrees in September and October as compared to the NAA.

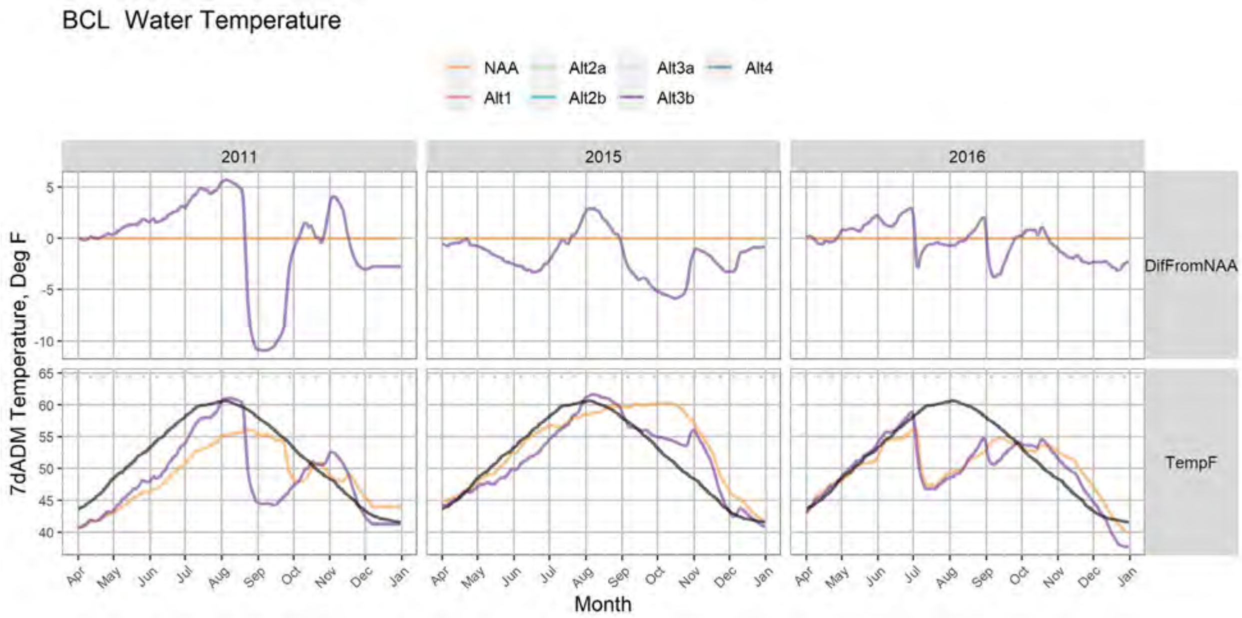

Figure 1-411. Comparison of Alternative 3b for 2011,2015,2016 with 7dADM temperatures (Degrees F) and difference from the NAA downstream of Big Cliff Dam. Black line indicates temperature target.

1.6.6.2 SOUTH SANTIAM DAMS

Water temperature measures under Alternative 3b include Green Peter utilizing the RO's to discharge colder water during drawdown operations in the fall and winter to reduce downstream water temperatures and volitional downstream fish passage. The Green Peter and Foster dam spillways would be utilized in the summer for surface spill.

Alternative 3b results are compared to the NAA the Monthly Mean of Daily Mean water temperatures at the South Santiam River near Foster gaging site (SSFO; Figure 1-410; Figure 1-412) the 2011-year scenario would see a water temperature increase starting in June through October up to 12 degrees, although July would have a 2-degree temperature decrease as compared to the NAA. In the 2015-year scenario water temperatures increase from 1 to 10 degrees in April through September as compared to the NAA. In the 2016-year scenario water temperatures increase up to 15 degrees from April through September as compared to the NAA. For the Average of the three years (2011, 2015, 2016) an increase 1 to 8 degrees from April through October as compared to the NAA.

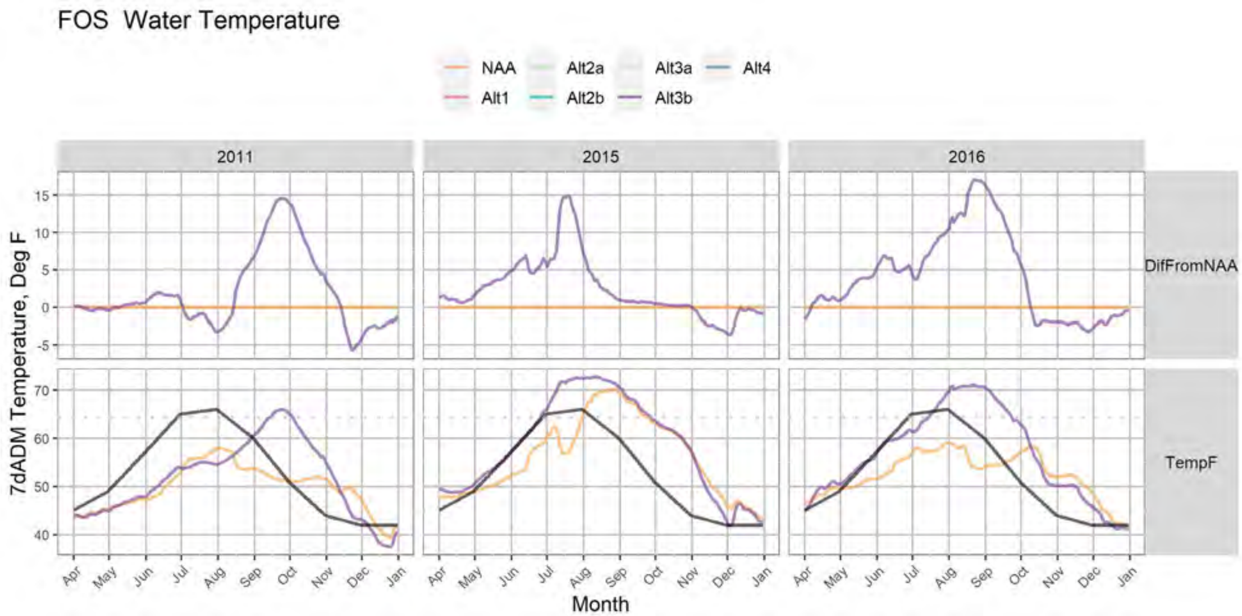

Figure 1-412. Comparison of Alternative 3b for 2011,2015,2016 with 7dADM temperatures (Degrees F) and difference from the NAA downstream of Foster Dam. Black line indicates temperature target.

1.6.6.3 MCKENZIE DAMS

Water temperature measures under Alternative 3b include modifying the diversion tunnel at Cougar reservoir to provide better temperature control. Measures for Blue River include a modification to the spillway to provide better water temperature management. The Blue River spillway would be used in the summer for surface spill

Temperature results for Alt 3b effects are compared to the NAA the Monthly Mean of Daily Mean water temperatures at the South Fork McKenzie River near Rainbow gaging site (CGRO; Figure 1-410; Figure 1-413) in the 2011-year scenario there would be a water temperature decrease from 1 to 3-degrees from April through July, a 4-degree water temperature increase would occur in October as compared to the NAA. In the 2015-year scenario a water temperature decrease of 1 to 7 degrees is observed in May through October as compared to the NAA. In the 2016-year scenario a temperature decrease is observed up to 5 degrees from June through October as compared to the NAA. For the Average of the three years (2011, 2015, 2016) a temperature decrease up to 5-degrees is observed from May through October as compared to the NAA.

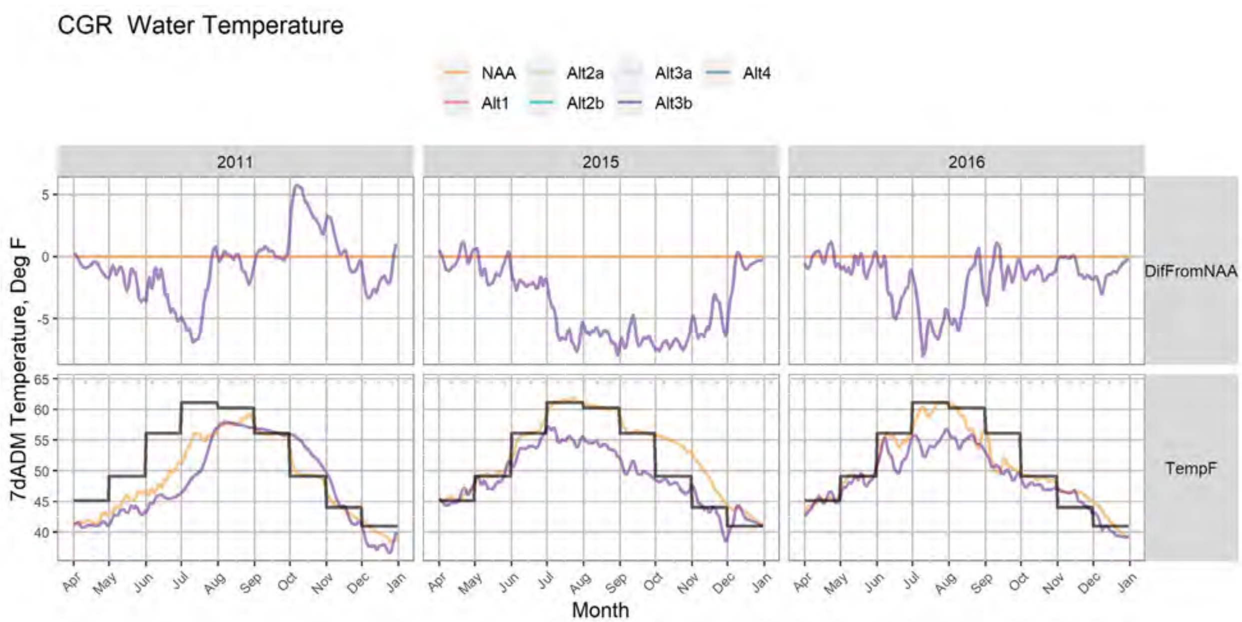

Figure 1-413. Comparison of Alternative 3b for 2011,2015,2016 with 7dADM temperatures (Degrees F) and difference from the NAA downstream of Foster Dam. Black line indicates temperature target.

1.6.6.4 MIDDLE FORK WILLAMETTE DAMS

Water temperature measures under Alternative 3b include Hills Creek reservoir modification to the spillway and use the spillway for surface spill in the summer. Lookout point reservoir would utilize the RO's to discharge colder water during drawdown operations in fall and winter to reduce downstream water temperatures. The Lookout Point spillway would be utilized in the summer for surface spill. Dexter spillway would be utilized in order to spread surface spill.

Water temperature results are compared to the NAA the Monthly Mean of Daily Mean water temperatures at the Middle Fork Willamette River near Dexter gaging site (DEXO; Figure 1-410; Figure 1-414) in the 2011-year scenario water temperature increase from 1 to 8 degrees is observed from April to August. In the 2015-year scenario observes a 1 degree decrease from June through September as compared to the NAA. In the 2016-year scenario a 2 to 6-degree water temperature increase is observed from April through July and decrease up to 7-degrees from August until October as compared to the NAA. For the Average of the three years (2011, 2015, 2016) a water temperature increases from 1-4 degrees in April through August and decreases up to 3-degrees in September and October.

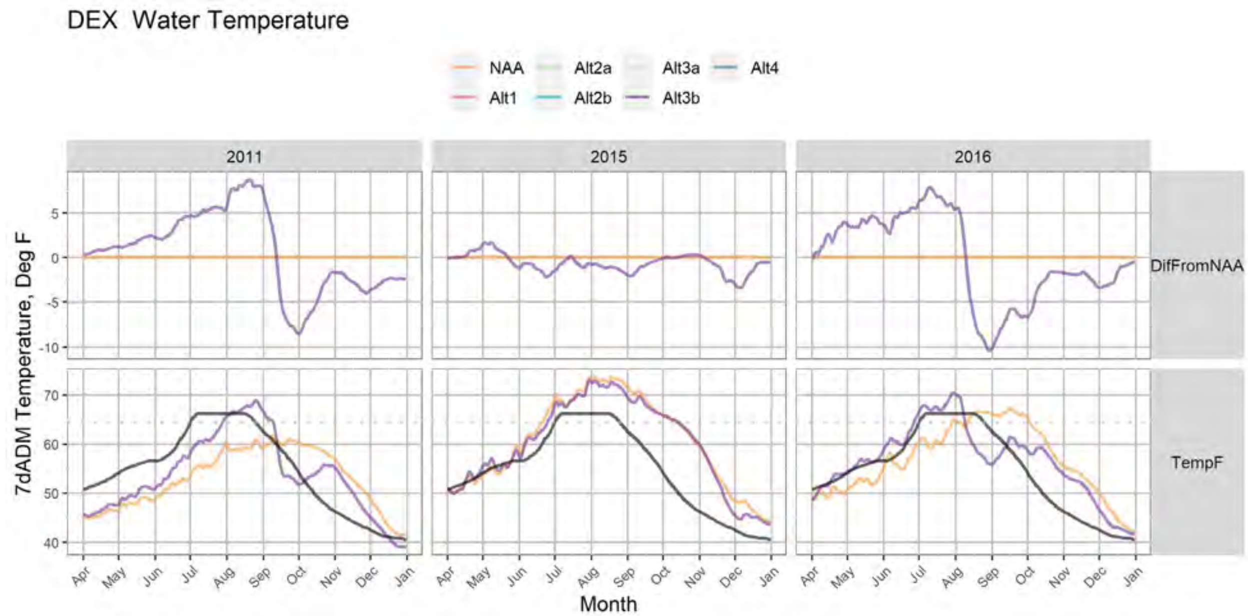

Figure 1-414. Comparison of Alternative 3b for 2011,2015,2016 with 7dADM temperatures (Degrees F) and difference from the NAA downstream of Dexter Dam. Black line indicates temperature target.

As compared to the NAA the Monthly Mean of Daily Mean water temperatures (deg F) at the Middle Fork Willamette River above Salt Creek gaging site (HCRO Figure 1-410;Figure 1-415) in the 2011-year scenario water temperature increase from 1 to 5 degrees is observed from April to October (Fig XX). In the 2015-year scenario observes a 2-9 degree increase from April through September as compared to the NAA. In the 2016-year scenario water temperature increase 3-8 degrees from April through September as compared to the NAA. For the Average of the three years (2011, 2015, 2016) water temperatures increase 2 to 7 degrees from April through September as compared to the NAA.

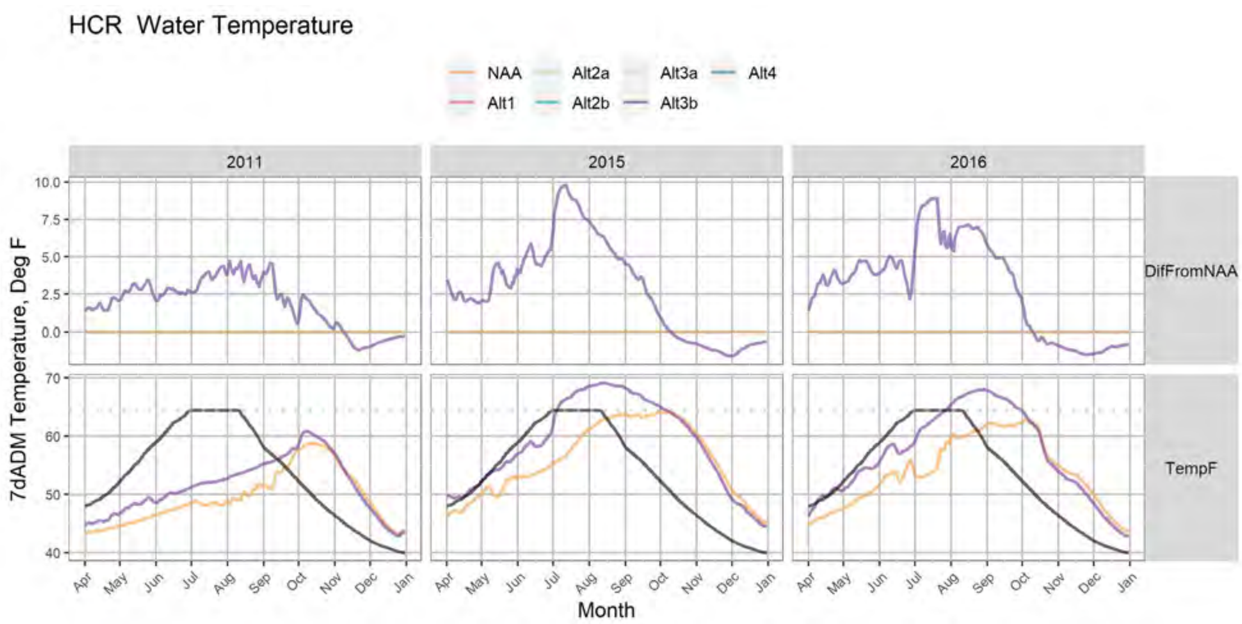

Figure 1-415. Comparison of Alternative 3b for 2011,2015,2016 with 7dADM temperatures (Degrees F) and difference from the NAA downstream of Hills Creek Dam. Black line indicates temperature target.

1.6.6.5 Mainstem Willamette River

Mainstem Willamette River Alternative 3b results are compared to the NAA using the Monthly Mean of Daily Mean water temperatures at the Willamette River near Salem gaging site (SLMO; Figure 1-410) 2011-year scenario water temperature increases by 1 degree from May through August and decreases by 1 degree in September and October as compared to the NAA. In the 2015-year scenario temperature increases by 1 degrees in May and October and decreases by 1 degree in July and September as compared to the NAA. In the 2016-year scenario water temperatures increase up to 2-degrees from May until July and then decreases by 1 degree in September as compared to the NAA. For the average of the three years (2011,2015, 2016) water temperature increases by 1 degrees in May and June and then decreases by 1 degree in September as compared to the NAA.

Mainstem Willamette River Alternative 3b results are compared to the NAA using the Monthly Mean of Daily Mean water temperatures at the Willamette River at Albany gaging site (ALBO; Figure 1-410) in the 2011-year scenario water temperatures increase up to 2 degrees from June through August and then decreases by 1 degree in October as compared to the NAA. In the 2015-year scenario water temperatures increase by 1-degrees in May and October as compared to the NAA. In the 2016-year scenario water temperatures increase up to 2-degrees from April through July and then decreases up to 2 degrees from August until October as compared to the NAA. For the average of the three years (2011,2015, 2016) water temperatures increase by 1-degrees from May until July and then decrease by 1-degree in September as compared to the NAA.

1.6.7 Alternative 4 – Structures-Based Fish Passage Alternative

Alternative 4 structural improvements for water temperature measures include:

- Water temperature control towers at Detroit, Hills Creek, and Lookout Point dams
- Modify existing outlets to allow releases at varying depths for temperature control at Foster reservoir by modifying the Facility Warm Water Supply (FWWS) pipe and fish weirs
- Utilizing the RO's to discharge cold water during drawdown operations in the fall and winter to reduce water temperatures below Green Peter dam
- Utilizing the spillway for surface spill in the summer at Green Peter dam.

Summary tables of Alternative 4 monthly mean water temperature and monthly mean difference between Alternative 4 and NAA for each of the three simulated years are shown in and Figure 1-416 and Figure 1-417, respectively.

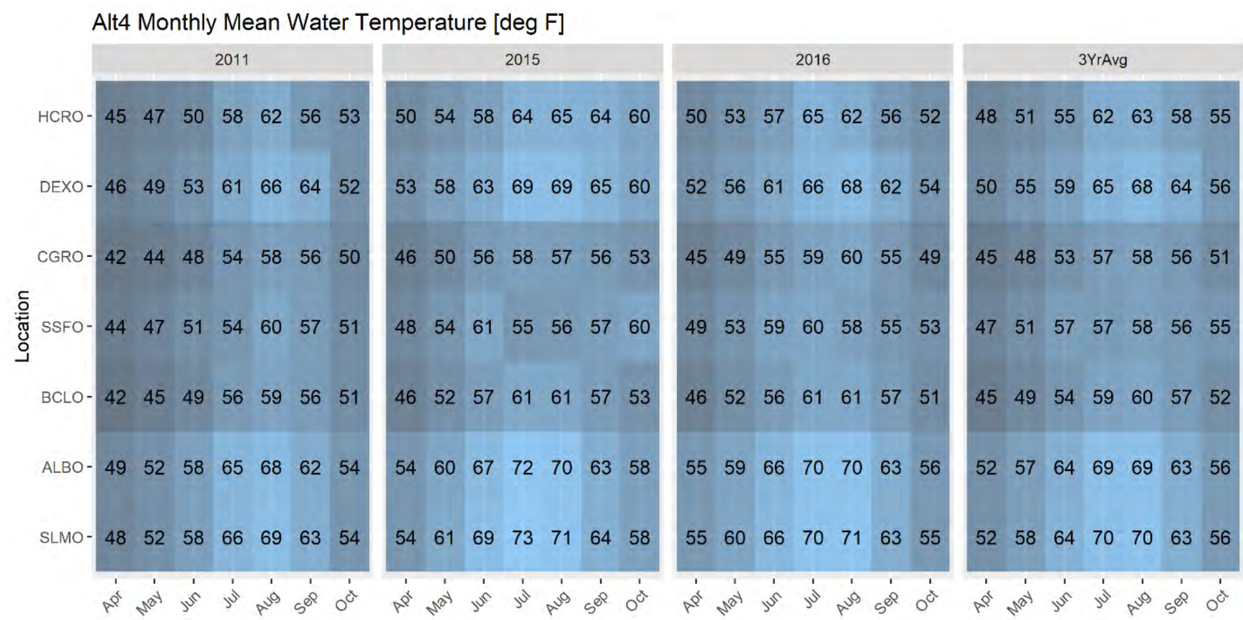

Figure 1-416. Monthly Mean of Water Temperatures (Fahrenheit) for Alternative 4.

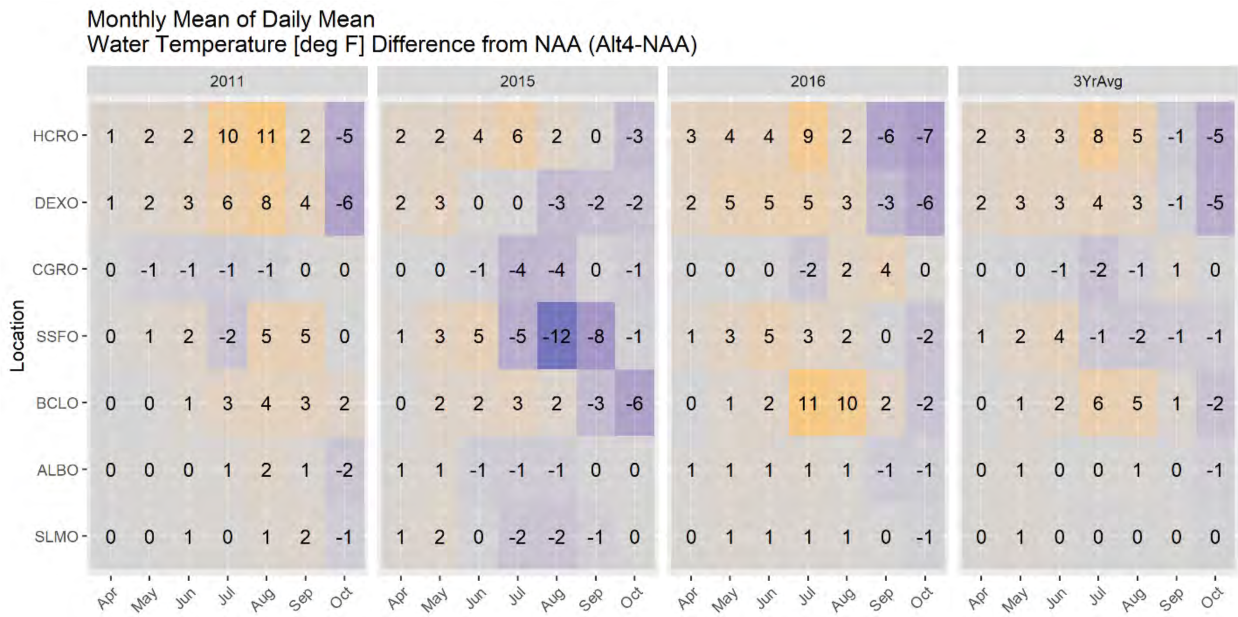

Figure 1-417. Monthly Mean of Daily Mean Water Temperatures (Fahrenheit) difference from NAA to Alternative 4.

1.6.7.1 NORTH SANTIAM DAMS

Alternative 4 measure at Detroit reservoir includes a water temperature control tower. Alternative 4 results as compared to the NAA the Monthly Mean of Daily Mean water temperatures at the North Santiam at Niagara gaging site (BCLO; Figure 1-417; Figure 1-418) in the 2011-year scenario see water temperature increase up to 3 degrees starting in June through October. In the 2015-year scenario water temperatures would increase 2 to 3 degrees from May to August and then decrease up to 6 degrees in September and October. In the 2016-year scenario water temperatures would increase up to 11 degrees from May to September and then decrease by 2 degrees in October. For the average of the three years (2011,2015,2016) water temperatures would increase up to 6 degrees from May until September and then decrease by 2 degrees in October.

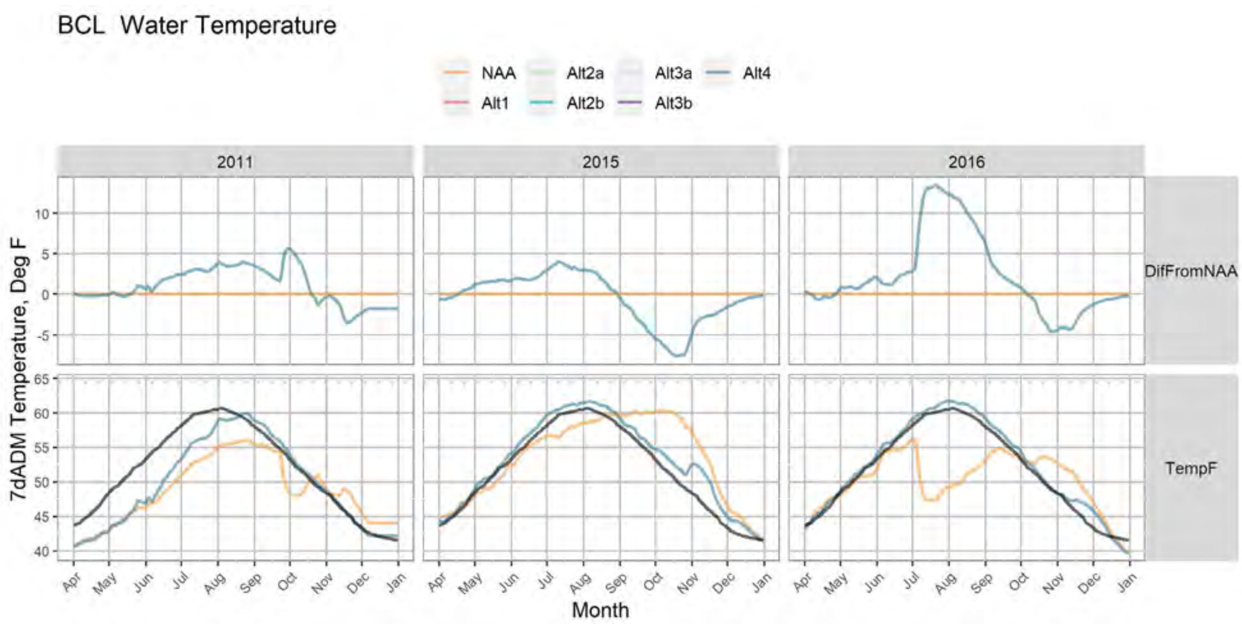

Figure 1-418. Comparison of Alternative 4 for 2011,2015,2016 with 7dADM temperatures (Degrees F) and difference from the NAA downstream of Big Cliff Dam. Black line indicates temperature target.

1.6.7.2 SOUTH SANTIAM DAMS

Alternative 4 measures at Green Peter reservoir include utilizing the RO's to discharge colder water during drawdown operation in the fall and winter to reduce downstream water temperatures. The Green Peter spillway is used for surface spill in the summer. At Foster reservoir the existing outlets would be modified to allow releases at varying depths for temperature control at the Facility Warm Water Supply (FWWS) pipe and fish weirs.

Alternative 4 results as compared to the NAA the Monthly Mean of Daily Mean water temperatures at the South Santiam River near Foster gaging site (SSFO; Figure 1-417; Figure 1-419) in the 2011-year scenario water temperatures would increase up to 5 degrees from May until September, although a 2-degree decrease occurs in July. In the 2015-year scenario water temperatures would increase up to 5 degrees from April to June and then decrease up to 13 degrees from July through October. In the 2016-year scenario water temperatures would increase up to 5 degrees from April to August and then decrease by 2 degrees in October. For the average of the three years water temperatures would increase up to 4 degrees from April until June and decrease up to 2 degrees from July through October.

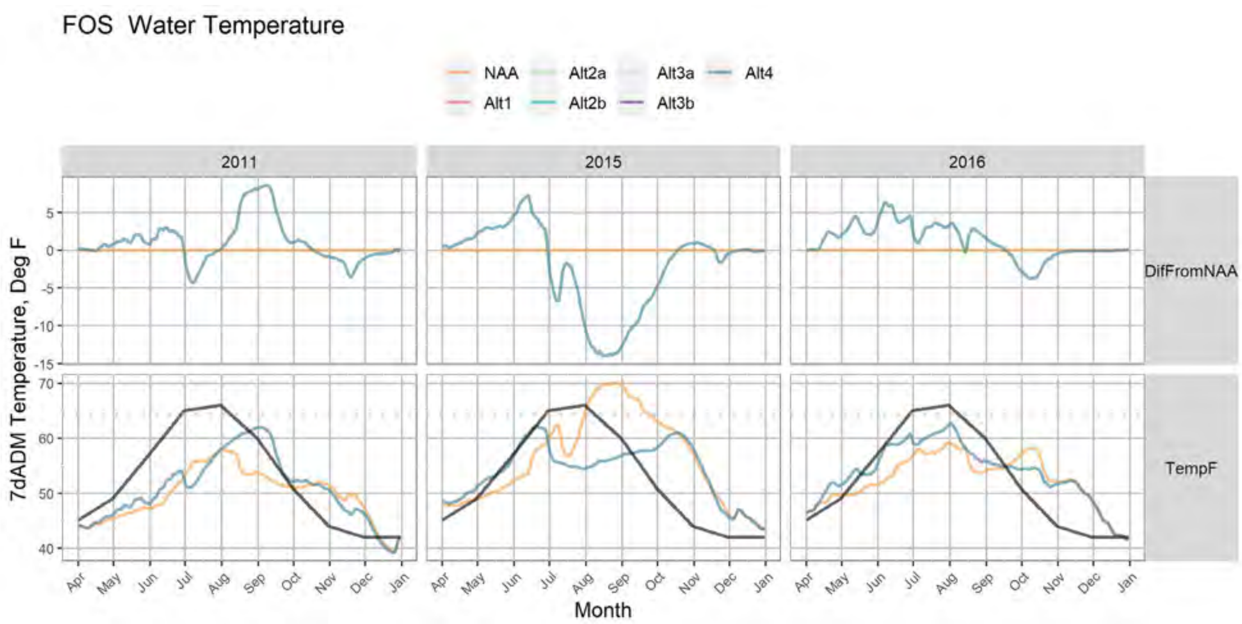

Figure 1-419. Comparison of Alternative 4 for 2011,2015,2016 with 7dADM temperatures (Degrees F) and difference from the NAA downstream of Foster Dam. Black line indicates temperature target.

1.6.7.3 MCKENZIE DAMS

Results are compared to the NAA the Monthly Mean of Daily Mean water temperatures at the South Fork McKenzie River near Rainbow gaging site (CGRO; Figure 1-417; Figure 1-420) in the 2011-year scenario water temperature would decrease by 1 degree from May until August. In the 2015-year scenario a decrease up to 3 degrees from July to October. In the 2016-year scenario a decrease is observed up to 2 degree in July and increase of 4 degrees in August and September. For the Average of the three years (2011, 2015, 2016) water temperature decreases up to 2 degrees from June until August and then increase by 1 degree in September.

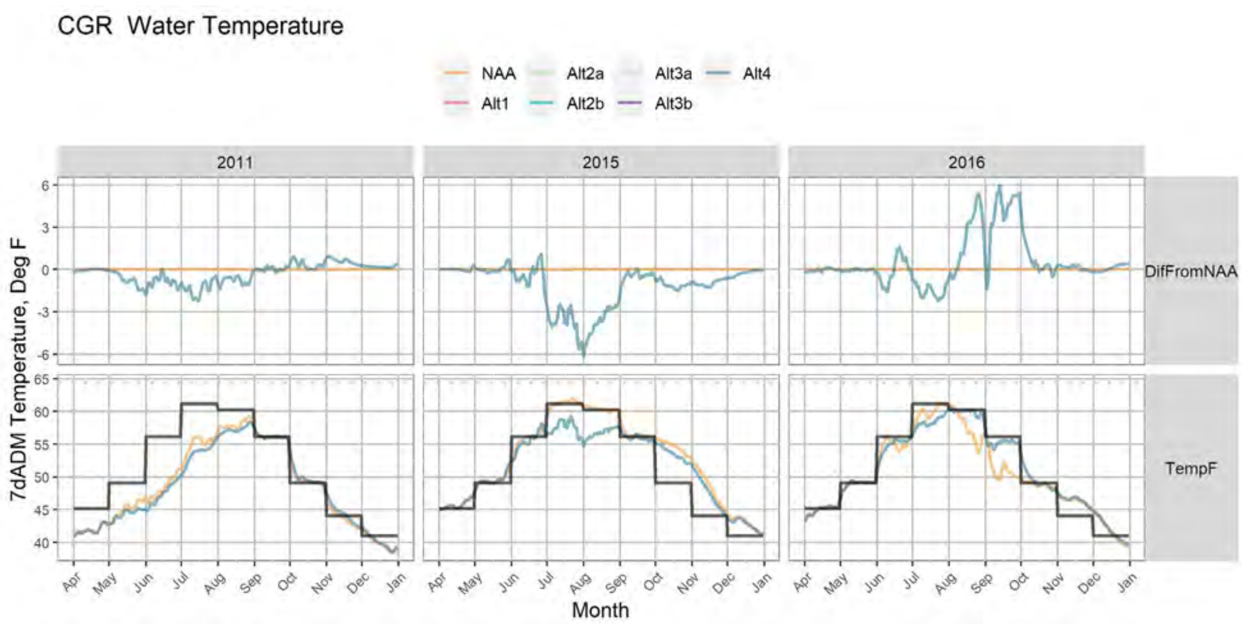

Figure 1-420. Comparison of Alternative 4 for 2011,2015,2016 with 7dADM temperatures (Degrees F) and difference from the NAA downstream of Cougar Dam. Black line indicates temperature target.

1.6.7.4 MIDDLE FORK WILLAMETTE DAMS

Alternative 4 measures at Hills Creek and Lookout Point dams include water temperature control towers to better regulate downstream water temperatures. There are no Alternative 4 temperature measures for Dexter or Fall Creek reservoirs.

As compared to the NAA the Monthly Mean of Daily Mean water temperatures at the Middle Fork Willamette River near Dexter gaging site (DEXO; Figure 1-417;Figure 1-421) in the 2011-year scenario water temperature would increase starting in April through September up to 8 degrees and decrease by 6 degrees in October. In the 2015-year scenario water temperature would increase up to 3 degrees in April and May and then decrease up to 3 degrees from August to October. In the 2016-year scenario water temperatures would increase up to 5 degrees from April to August and then decrease up to 6 degrees in September and October. For the average of the three years water temperatures would increase up to 4 degrees from April through August and then decrease up to 5 degrees in September and October.

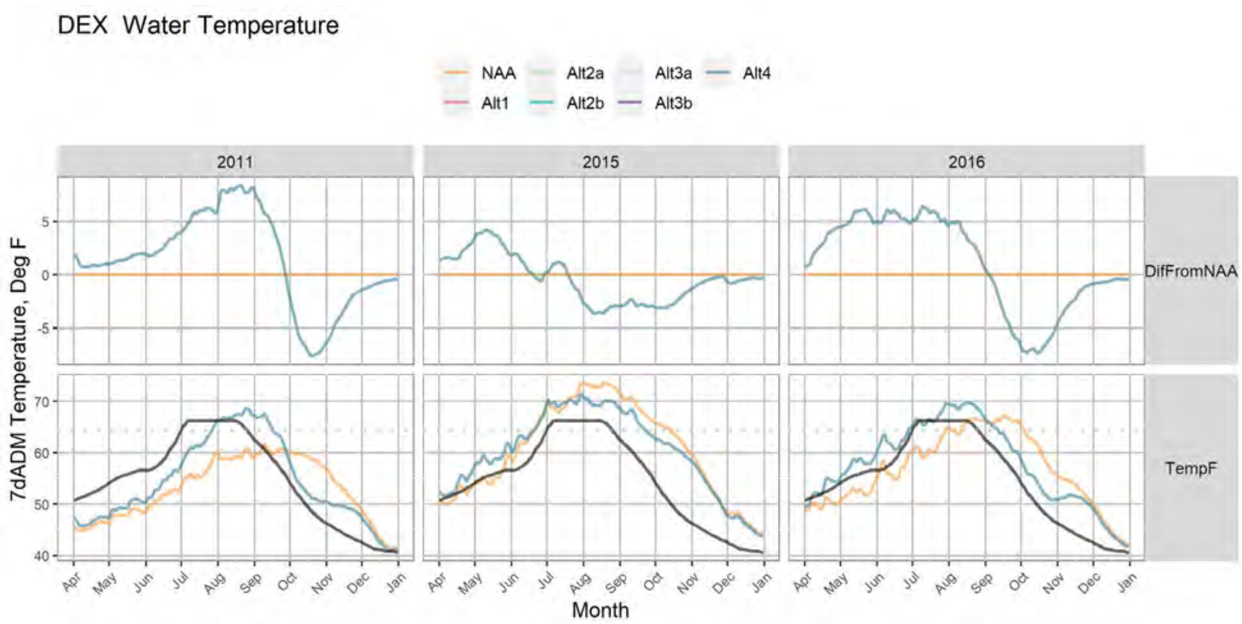

Figure 1-421. Comparison of Alternative 4 for 2011,2015,2016 with 7dADM temperatures (Degrees F) and difference from the NAA downstream of Dexter Dam. Black line indicates temperature target.

As compared to the NAA the Monthly Mean of Daily Mean water temperatures at the Middle Fork Willamette River above Salt Creek gaging site (HCRO; Figure 1-417; Figure 1-422) in the 2011-year scenario water temperatures would increase up to 12 degrees from April through September and then decrease by 5 degrees in October. In the 2015-year scenario water temperatures would increase up to 6 degrees from April through August and then decrease by 3 degrees in October. In the 2016-year scenario water temperatures would increase up to 9 degrees from April through August and then decrease by 7 degrees in September and October. For the average of the three years (2011,2015,2016) water temperatures would increase up to 8 degrees from April through August and then decrease up to 5 degrees in September and October.

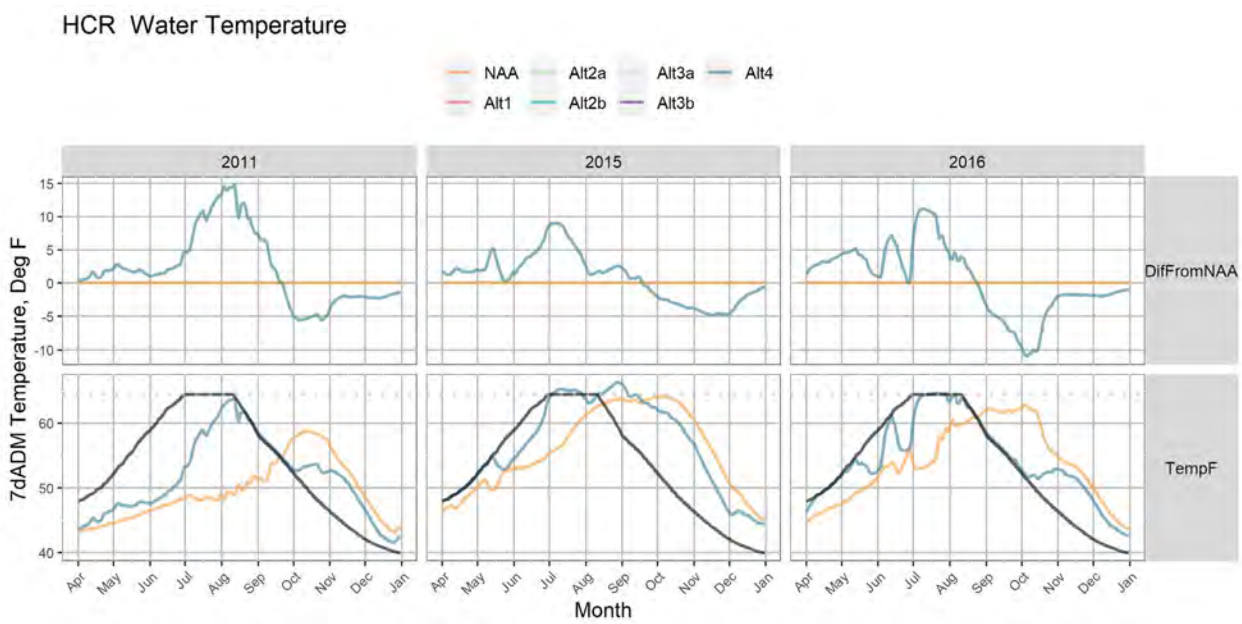

Figure 1-422. Comparison of Alternative 4 for 2011,2015,2016 with 7dADM temperatures (Degrees F) and difference from the NAA downstream of Hills Creek Dam. Black line indicates temperature target.

1.6.7.5 Mainstem Willamette River

Mainstem Willamette River Alternative 4 results are compared to the NAA using the Monthly Mean of Daily Mean water temperatures at the Willamette River near Salem gaging site (SLMO; Figure 1-417) 2011-year scenario water temperature increases by 1 degree in June and August to September and decreases by 1 degree in October as compared to the NAA. In the 2015-year scenario temperature increases up to 2 degrees from April to May and decreases up to 2 degrees in July and September as compared to the NAA. In the 2016-year scenario water temperatures increase by 1-degrees from May until July and then decreases by 1 degree in October as compared to the NAA. For the average of the three years (2011,2015, 2016) water temperature increases by 1 degrees in May as compared to the NAA.

Mainstem Willamette River Alternative 4 results are compared to the NAA using the Monthly Mean of Daily Mean water temperatures at the Willamette River at Albany gaging site (ALBO; Figure 1-417) in the 2011-year scenario water temperatures increase up to 2 degrees from July through September and then decreases by 2 degrees in October as compared to the NAA. In the 2015-year scenario water temperatures increase by 1-degrees in April and May and then decreases by 1 degree in July and August as compared to the NAA. In the 2016-year scenario water temperatures increase up to 2-degrees from April through August and then decreases by 1 degree from September through October as compared to the NAA. For the average of the three years (2011,2015, 2016) water temperatures increase by 1-degrees in April through May and August and then decrease by 1-degree in October as compared to the NAA.

1.6.8 Alternative 5 – Preferred Alternative Qualitative Assessments

Given the similarities between Alternative 5 and Alternative 2b in the measures, operations, and structural assumptions for Detroit, Green Peter, Foster, and Cougar Dams, it is reasonable to assume any water temperature differences between Alternative 5 and Alternative 2b would be due to model instabilities or processing errors in RES-SIM or CE-QUAL-W2 at those locations. Refer to section 1.6.4 for details regarding the differences between Alternative 2b and NAA for a description of Alternative 5 water temperature effects. Therefore, this section will focus on the differences in the Middle Fork Willamette, where minor differences in lake level at Hills Creek may lead to negligible differences in downstream water temperature.

1.6.8.1 NORTH SANTIAM DAMS

Alternative 5 includes a Water Temperature Control tower at Detroit reservoir for water temperature management. Because of the similarities in operations and structural assumptions for Alternative 5 and Alternative 2b in the North Santiam, refer to Section 1.6.4.1 for a comparison of Alternative 2b and NAA water temperature effects at Detroit and Big Cliff Dams.

1.6.8.2 SOUTH SANTIAM DAMS

Alternative 5 includes the use of the RO's to discharge colder water during fall and winter drawdown operations at Green Peter reservoir. Additional measures include use of the spillway for surface spill in the summer at Green Peter reservoir and a measure to modify existing outlets to allow releases at varying depths for temperature control specifically at Foster reservoir with a modification to the Facility Warm Water Supply (FWWS) pipe and fish weirs. Because of the similarities in operations and structural assumptions for Alternative 5 and Alternative 2b in the South Santiam, refer to Section 1.6.4.2 for a comparison of Alternative 2b and NAA water temperature effects at Green Peter and Foster Dams.

1.6.8.3 MCKENZIE DAMS

There are no water temperature measures for Cougar or Blue River dams under Alternative 2b. Because of the similarities in operations and structural assumptions for Alternative 5 and Alternative 2b in the Mckenzie River, refer to Section 1.6.4.3 for a comparison of Alternative 2b and NAA water temperature effects at Cougar Dam.

1.6.8.4 MIDDLE FORK WILLAMETTE DAMS

Hills Creek

Alternative 5 has no water temperature measures for Hills Creek Dam. The primary differences related to the expected water temperature below Hills Creek Dam in Alternative 5 and Alternative 2b are related to the timing and extent of the lake drafting in 2015 and 2016. The differences compared to Alternative 2b in the drawdown are limited to about 2 weeks in 2015 and 2-4 weeks in 2016 (Figure 1-370). The downstream temperature associated with these differences would likely be minor and represented by a minor to negligible temporal shift (backward in time) of the temperature signal (Figure 1-188) during June-July of 2015 and July-September of 2016. The deeper draft and use of the RO at Hills Creek in Alternative 5 during September of 2016 compared to Alternative 2b may result in warmer surface water releases during September followed by cooler releases in October as the lake is allowed to equilibrate with the ambient air sooner in the autumn. Given the brief and variable (relatively warmer and cooler) periods in which these differences from Alternative 2b occur, it is expected that Alternative 5 water temperature impacts would likely be negligibly different than the metrics shown for Alternative 2b.

Lookout Point and Dexter

Alternative 5 has no water temperature measures for Lookout Point Dam and operations in Alternative 5 closely resemble those in Alternative 2b (Section 0). It is likely that the negligible temperature effects from Hills Creek operations would be negligible, relatively short-lived (days to weeks) when incorporated into the proposed Alternative 5 operations at Lookout Point and Dexter Dams.   Because of the similarities in operations and structural assumptions for Alternative 5 and Alternative 2b at Lookout Point, refer to Section 1.6.4.4 for a comparison of Alternative 2b and NAA water temperature effects.

1.7 SUPPLEMENTAL MATERIAL

1.7.1 Comparison of NAA with Measurements

Simulating dam operations and water temperatures for the WV EIS involved the application of rules and assumptions that simplified the complex human-based water management decisions (i.e., minimum flow negotiations, flood operations), special operations (i.e., power/maintenance outages, fish passage, temperature management), and environmental factors (i.e., evaporation) that occur day-to-day and are encompassed in the measured values at each streamgage. Therefore, it is expected that the comparison of measurements with NAA results would not match identically but provide context for the potential range that could occur in each of the 3 years simulated in the CE-QUAL-W2 temperature models.

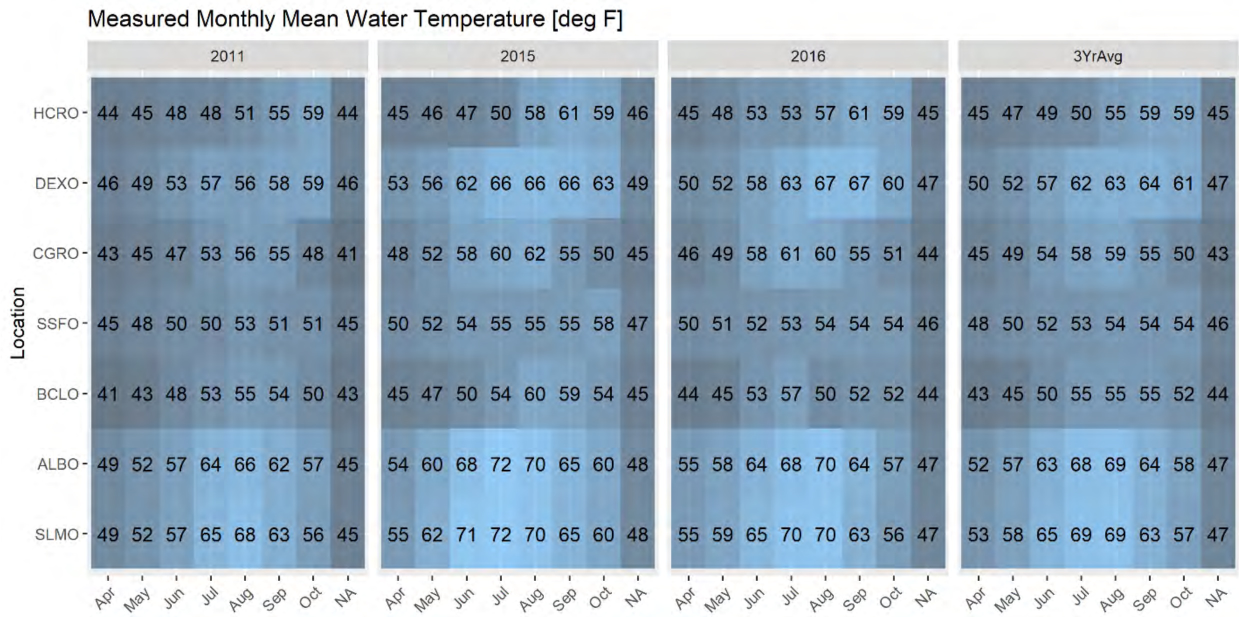

Figure 1-423. Monthly Mean of Measured Water Temperatures (Fahrenheit).

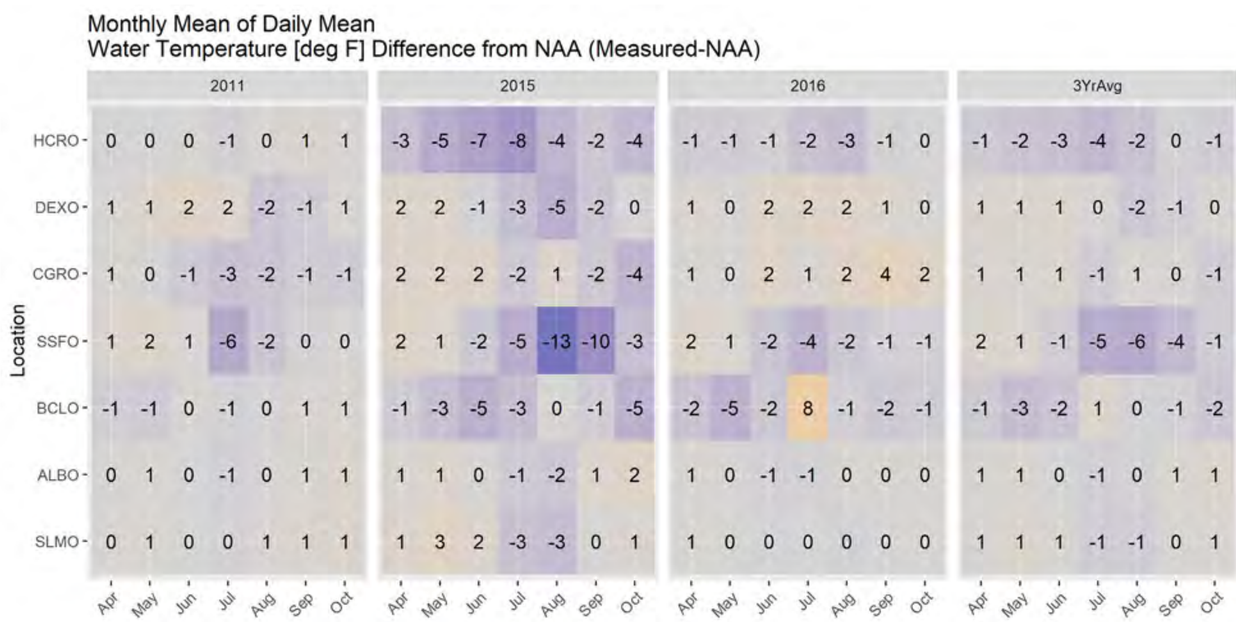

Figure 1-424. Monthly Mean of Daily Mean Water Temperatures (Fahrenheit) difference from Measurements to NAA.

1.7.1.1 NORTH SANTIAM DAM

Monthly Mean of Daily Mean Measured water temperatures were compared to the NAA at the North Santiam at Niagara gaging site (BCLO; Figure 1-423; Figure 1-426). The 2011-year measurements were generally within 1 degree of NAA. The 2015-year measurements were 3 to 5 degrees cooler than NAA from May to July and then up to 5 degrees cooler than NAA in September and October. The 2016-year measurements were 3 to 5 degrees cooler than NAA from April to June and then up to 8 degrees warmer than NAA in July, and finally up to 2 degrees cooler than NAA in September and October. For the average of the three years (2011,2015,2016) water temperatures measurements were generally up to 3 degrees cooler in May-June and up to 2 degrees cooler in October as compared to NAA. These differences can be linked to different dam operations imposed in NAA in comparison to measurements (Figure 1-425).

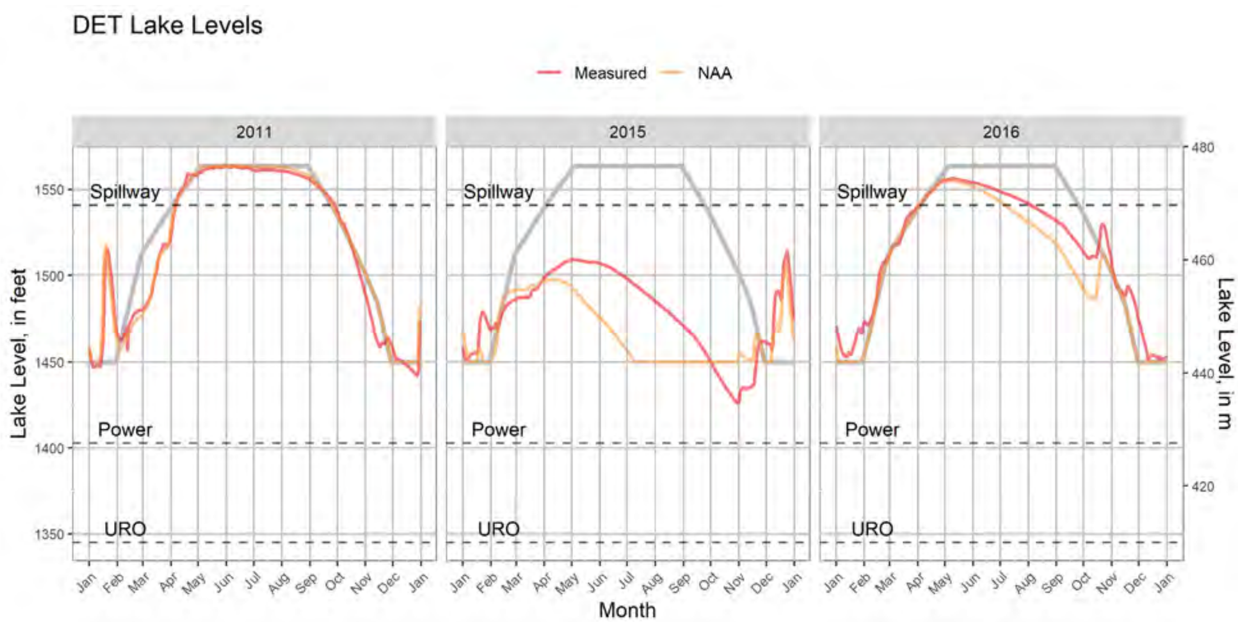

Figure 1-425. Detroit Lake Level Comparison of Measurements and NAA in 2011, 2015, and 2016. Grey Line Represents the Rule Curve.

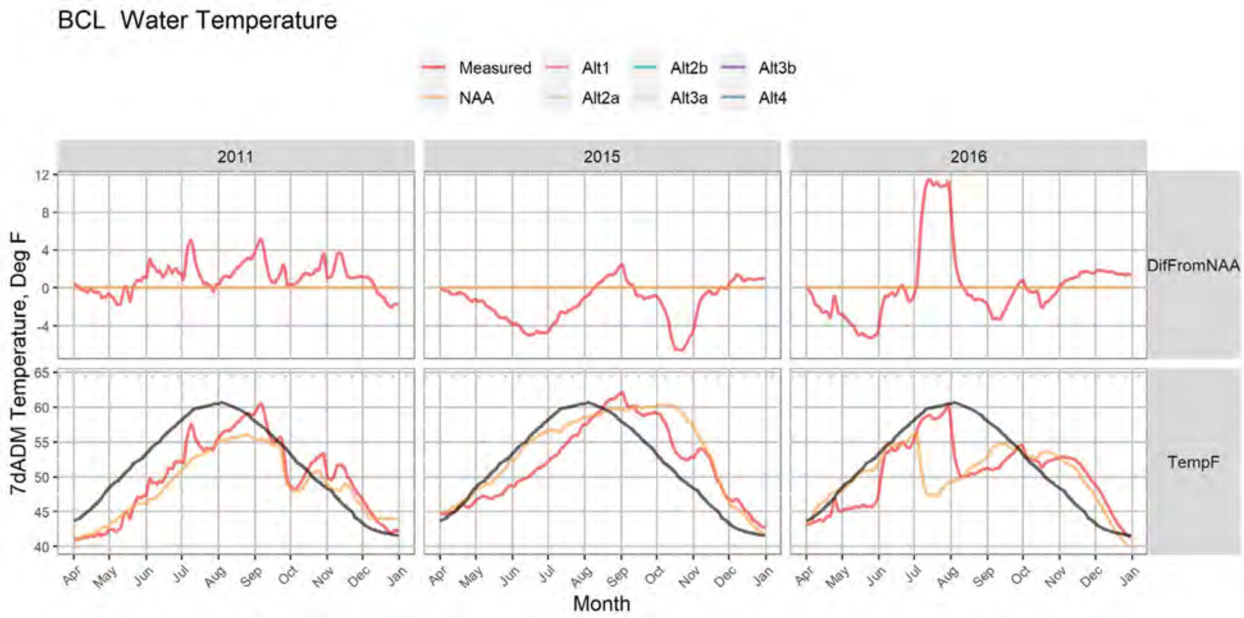

Figure 1-426. Comparison of 7dADM (Degrees F) Water Temperature Measurements for 2011, 2015, 2016 and Difference From NAA Downstream of Big Cliff Dam. Black Line Indicates Temperature Target.

1.7.1.2 SOUTH SANTIAM DAMS

Monthly Mean of Daily Mean Measured water temperatures were compared to NAA at the South Santiam below Foster gaging site (SSFO; Figure 1-424; Figure 1-429). The 2011-year measurements were generally within 2 degrees of NAA, aside from the month of July when measurements were up to 5 degrees cooler. The 2015-year measurements were 2 to 13 degrees cooler than NAA from June to October. The 2016-year measurements were 2 to 4 degrees cooler than NAA from June to August. For the average of the three years (2011,2015,2016) water temperatures measurements were generally up to 4 to 6 degrees cooler in July-September compared to NAA. These differences can be linked to different dam operations imposed in NAA in comparison to measurements (Figure 1-427, Figure 1-428).

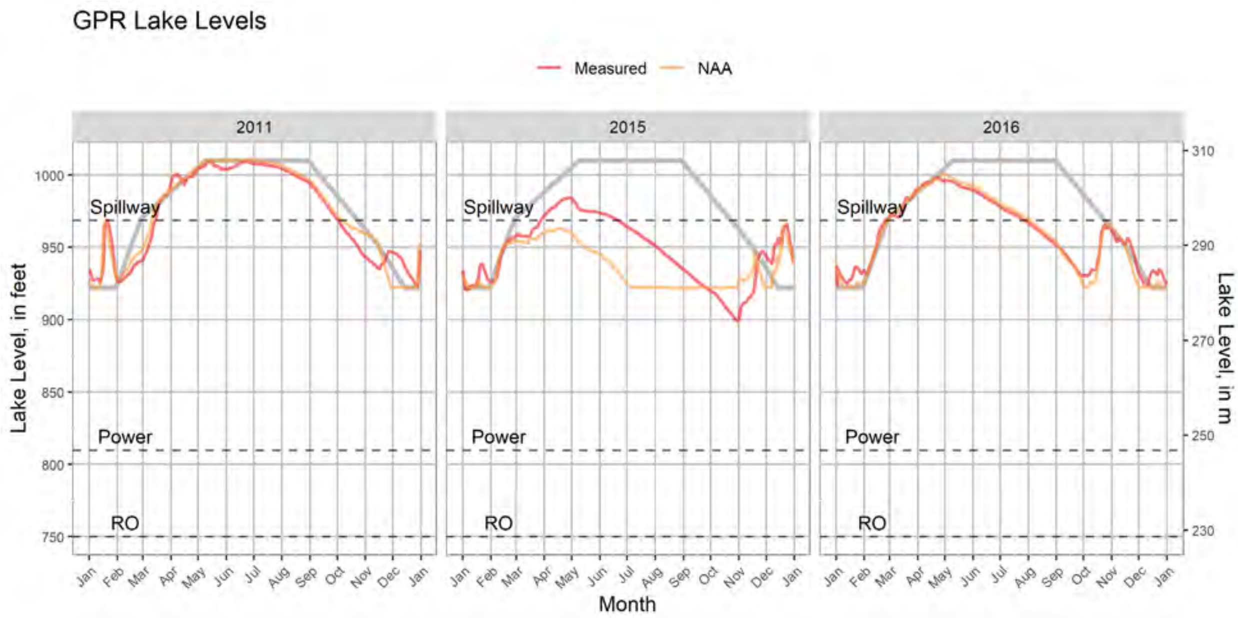

Figure 1-427. Green Peter Lake Level Comparison of Measurements and NAA in 2011, 2015, and 2016. Grey Line Represents the Rule Curve.

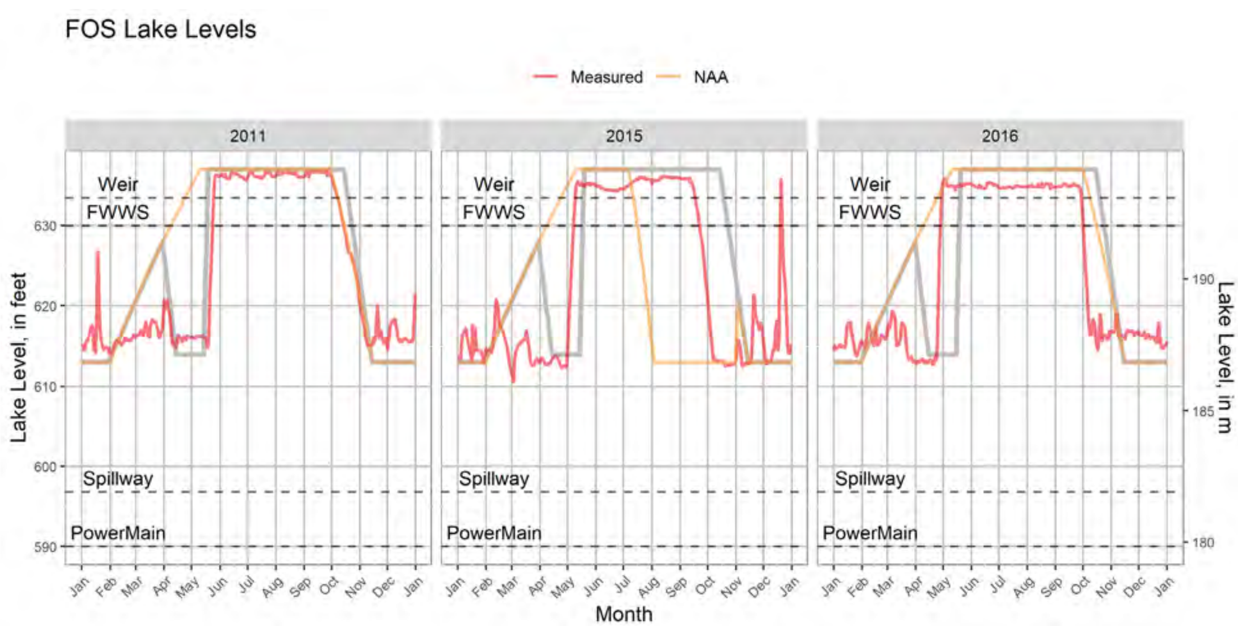

Figure 1-428. Foster Lake Level Comparison of Measurements and NAA in 2011, 2015, and 2016. Grey Line Represents the Rule Curve.

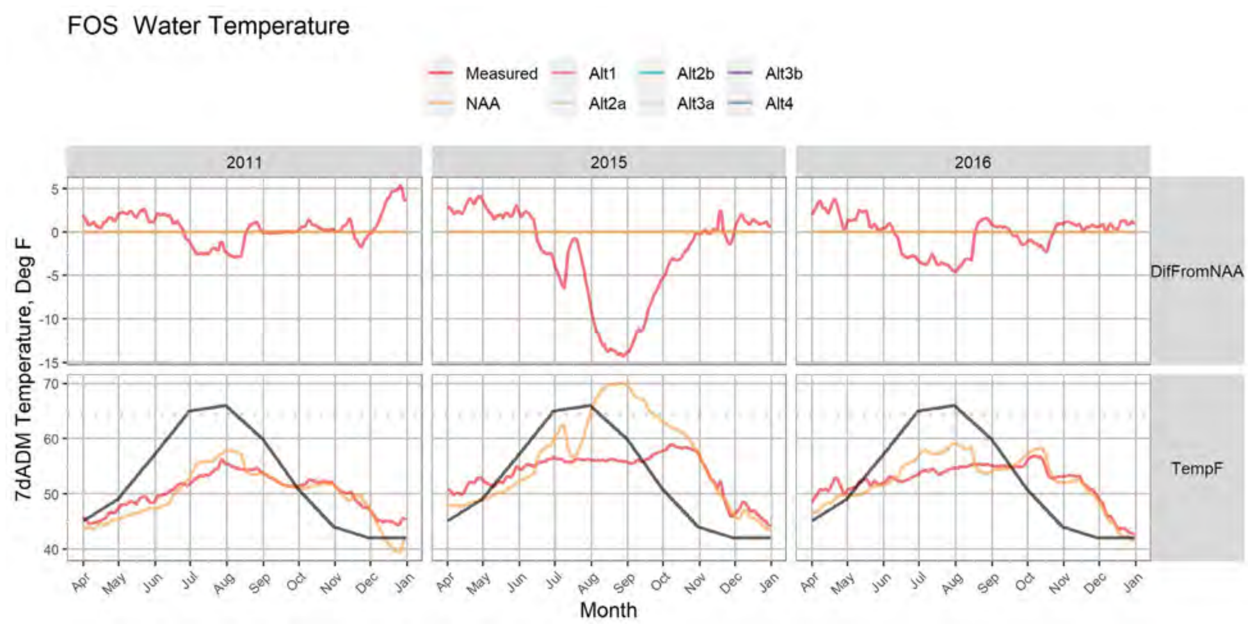

Figure 1-429. Comparison of 7dADM (Degrees F) Water Temperature Measurements for 2011, 2015, 2016 and Difference From NAA Downstream of Foster Dam. Black Line Indicates Temperature Target.

1.7.1.3 MCKENZIE DAMS

Monthly Mean of Daily Mean Measured water temperatures were compared to NAA at the South Fork McKenzie River near Rainbow gaging site (CGRO; Figure 1-424; Figure 1-431). The 2011-year measurements were generally within 1 degrees of NAA, aside from the month of June-July when measurements were up to 3 degrees cooler. The 2015-year measurements were generally within 2 degrees from NAA aside from October when measurements were 4 degrees cooler than NAA. The 2016-year measurements were generally within 2 degrees from NAA aside from September when measurements were 4 degrees warmer than NAA. These differences can be linked to different dam operations imposed in NAA in comparison to measurements (Figure 1-430).

For the average of the three years (2011, 2015, 2016) water temperatures measurements were within 1 degrees of NAA.

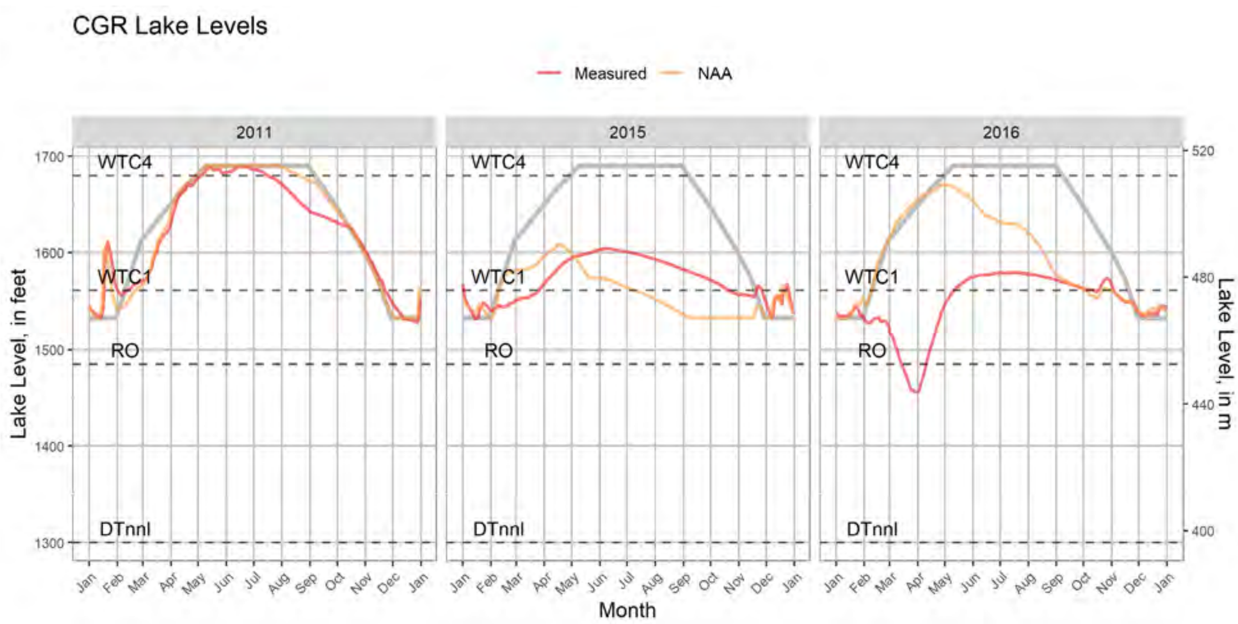

Figure 1-430. Cougar Lake Level Comparison of Measurements, NAA in 2011, 2015, and 2016.

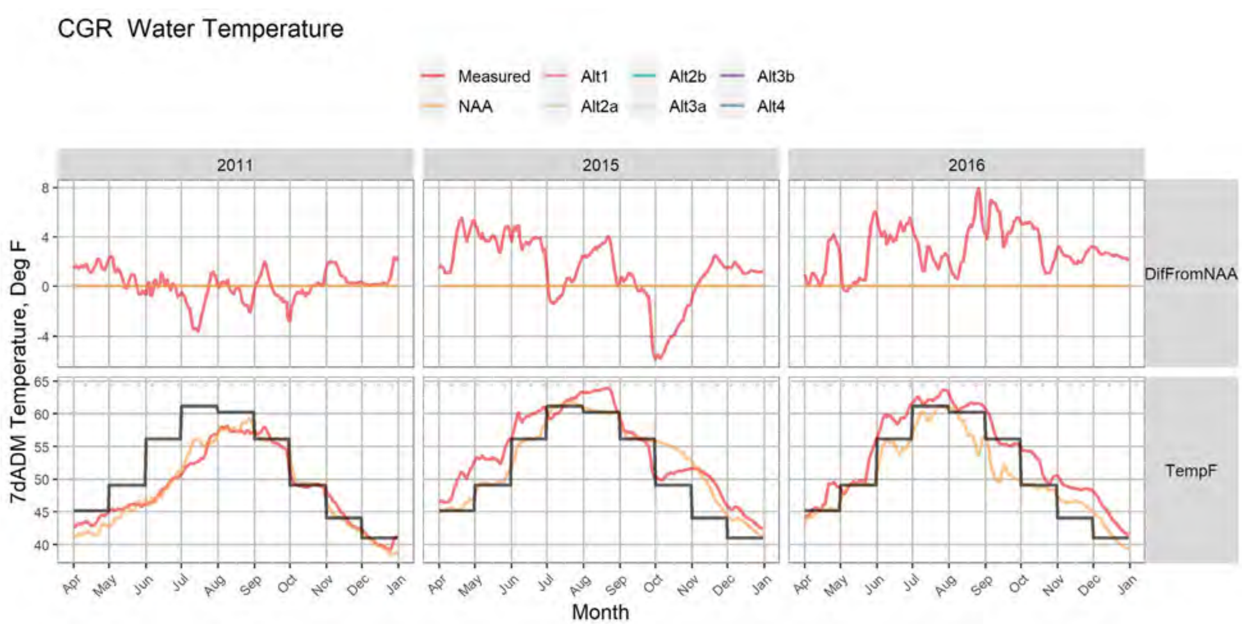

Figure 1-431. Comparison of 7dADM (Degrees F) Water Temperature Measurements for 2011, 2015, 2016 and Difference From NAA Downstream of Cougar Dam. Black Line Indicates Temperature Target.

1.7.1.4 MIDDLE FORK WILLAMETTE DAMS

Monthly Mean of Daily Mean Measured water temperatures were compared to NAA at the Middle Fork Willamette River near Dexter gaging site (DEXO; Figure 1-424; Figure 1-433). The 2011 and 2016 year measurements were generally within 2 degrees of NAA. The 2015-year measurements were generally within 2 degrees of NAA except July-August when measurements were 3 to 5 degrees cooler than NAA. For the average of the three years (2011,2015,2016) water temperatures measurements were generally within 2 degrees of NAA. These differences can be linked to different dam operations imposed in NAA in comparison to measurements.

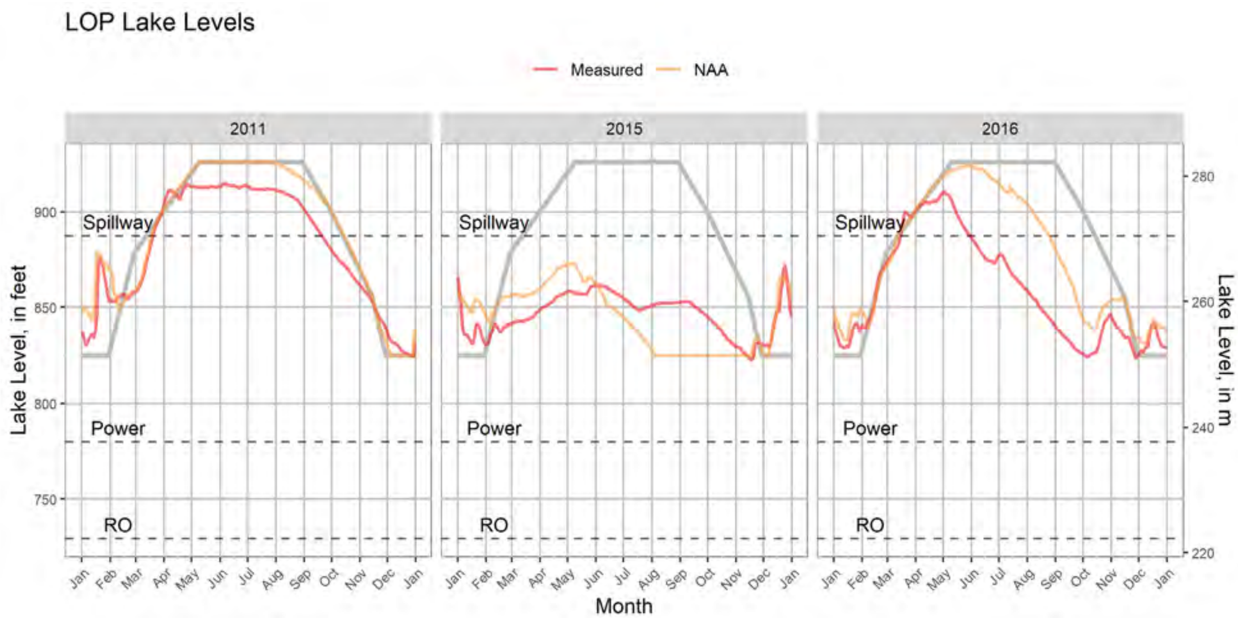

Figure 1-432. Lookout Point Lake Level Comparison of Measurements and NAA in 2011, 2015, and 2016.

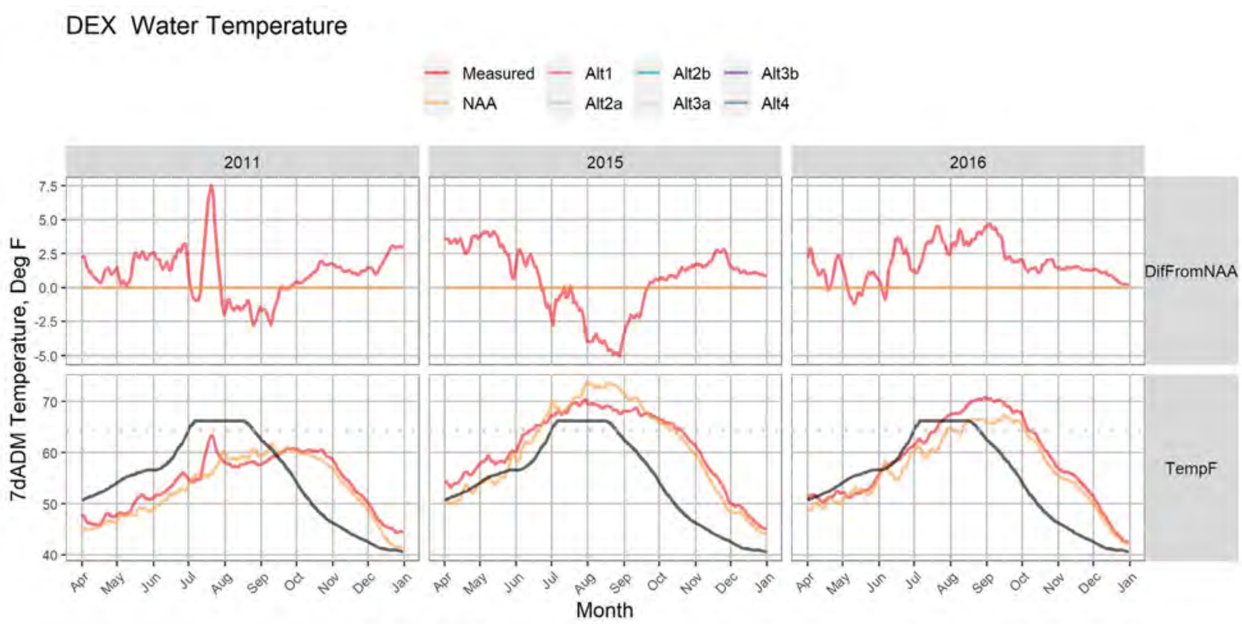

Figure 1-433. Comparison of 7dADM (Degrees F) Water Temperature Measurements for 2011, 2015, 2016 and Difference From NAA Downstream of Dexter Dam. Black Line Indicates Temperature Target.

Monthly Mean of Daily Mean Measured water temperatures were compared to NAA at the Middle Fork Willamette River above Salt Creek gaging site (HCRO; Figure 1-424; Figure 1-434). The 2011-year measurements were generally within 1 degrees of NAA. The 2015-year measurements were 2 to 8 degrees cooler than NAA from April to October. The 2016-year measurements were generally within 1 degree from NAA except July-August, when measurements were 2 to 3 degrees cooler than NAA. For the average of the three years (2011,2015,2016) water temperatures measurements were within 1 degree of NAA outside of May-August when measurements were up to 4 degrees cooler compared to NAA. These differences can be linked to different dam operations imposed in NAA in comparison to measurements.

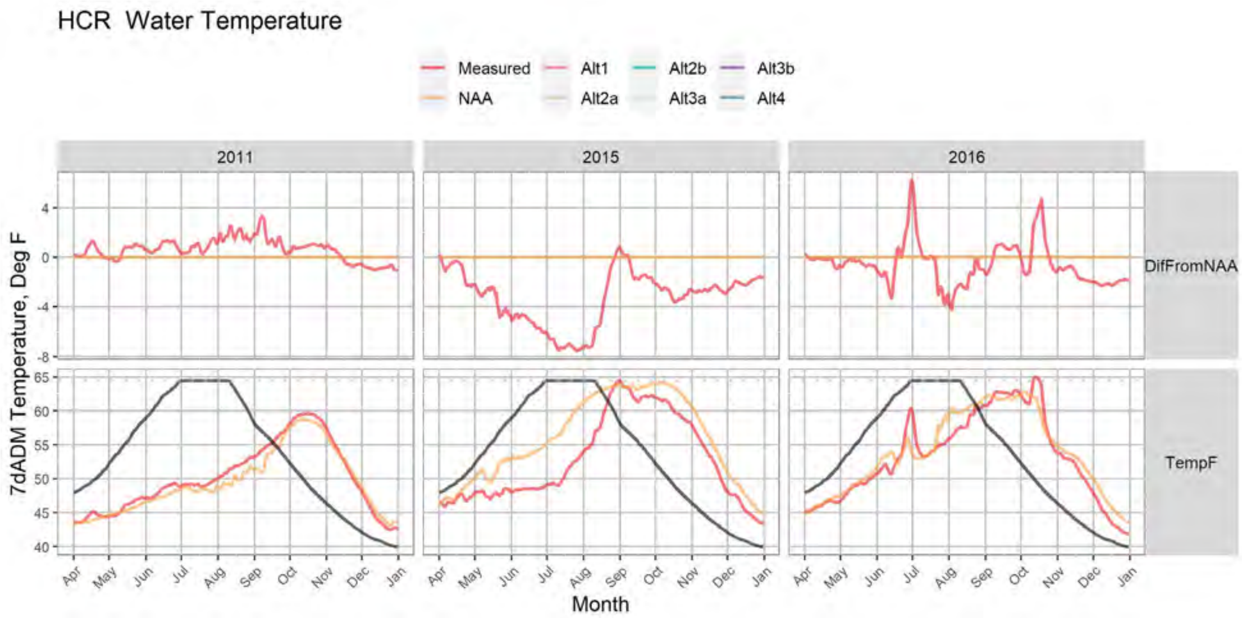

Figure 1-434. Comparison of 7dADM (Degrees F) Water Temperature Measurements for 2011, 2015, 2016 and Difference From NAA Downstream of Hills Creek Dam. Black Line Indicates Temperature Target.

1.8 CITATIONS

Annear, R.L., McKillip, M.L., Khan, S.J., Berger, C.J., and Wells, S.A., 2004, Willamette River Basin temperature TMDL model—Boundary conditions and model setup: Portland, Oreg., Portland State University, Department of Civil and Environmental Engineering, Technical Report EWR-01-04, 530 p.

Berger, C.J., McKillip, M.L., Annear, R.L., Khan, S.J., and Wells, S.A., 2004, Willamette River Basin temperature TMDL model—Model calibration: Portland, Oreg., Portland State University, Department of Civil and Environmental Engineering, Technical Report EWR-02-04, 341 p.

Buccola, N.L., Rounds, S.A., Sullivan, A.B., and Risley, J.C., 2012, Simulating potential structural and operational changes for Detroit Dam on the North Santiam River, Oregon, for downstream temperature management: U.S. Geological Survey Scientific Investigations Report 2012-5231, 68 p.

Buccola, N.L., Stonewall, A.J., and Rounds, S.A., 2015, Simulations of a hypothetical temperature control structure at Detroit Dam on the North Santiam River, northwestern Oregon: U.S. Geological Survey Open-File Report 2015–1012, 30 p., http://dx.doi.org/10.3133/ofr20151012

Buccola, N.L., Stonewall, A.J., Sullivan, A.B., Kim, Yoonhee, and Rounds, S.A., 2013, Development of CE-QUAL-W2 models for the Middle Fork Willamette and South

Santiam Rivers, Oregon: U.S. Geological Survey Open-File Report 2013-1196, 55 p. [Also available at https://dx.doi.org/10.3133/ofr20131186.]

Buccola, N.L., Turner, D.F., and Rounds, S.A., 2016, Water temperature effects from simulated dam operations and structures in the Middle Fork Willamette River, western Oregon: U.S. Geological Survey Open-File Report 2016-1159, 39 p. [Also available at https://dx.doi.org/10.3133/ofr20161159.]

Buccola, N.L., 2017, Water temperature effects from simulated changes to dam operations and structures in the Middle and South Santiam Rivers, Oregon: U.S. Geological Survey Open-File Report 2017–1063, 19 p., https://doi.org/10.3133/ofr20171063.

Cole, T.M., Wells, S.A., 2020. CE-QUAL-W2—A Two-dimensional, Laterally Averaged, Hydrodynamic and Water-quality Model, Version 4.2: Department of Civil and Environmental Engineering, Portland State University, Portland, OR 97207-0751.

Einum, S. and I.A. Fleming. 2000. Selection against late emergence and small offspring in Atlantic salmon (Salmo salar). Evolution 54: 628-639.

Jensen, A.J. & Johnsen, B.O. 1999. The functional relationship between peak spring floods and survival and growth of juvenile Atlantic salmon (Salmo salar) and brown trout (Salmo trutta). Functional Ecology 13: 778-785.

Keefer, M.L., Clabough, T.S., Jepson, M.A., Blubaugh, T., Naughton, G.P., and Caudill, C.C., 2019, Potential Effects Of Changes To Temperature Targets In The North Santiam River On Adult Chinook Salmon Behavior And Survival, Department of Fish and Wildlife Sciences, University of Idaho, Moscow, Idaho 83844-1136.

Koch, T., Perry, R., Hansen, G., 2020, Water Temperature Thresholds for a Chinook Salmon Habitat Assessment in the Willamette River, Oregon, March 2020.

Moore A.G, 1964, Compilation of Water-Temperature Data for Oregon Streams, USGS Open-file Report, Portland, Oregon.

NOAA, 2008, Endangered Species Act Section 7(a)(2) Consultation Biological Opinion & Magnuson-Stevens Fishery Conservation & Management Act Essential Fish Habitat Consultation, NOAA's National Marine Fisheries Service (NMFS) Northwest Region, July 11, 2008.

NOAA, 2020, National Centers for Environmental Information, accessed at https://www.ncdc.noaa.gov/cdo-web/ on August 13, 2020.

Rounds, S.A., 2007, Temperature effects of point sources, riparian shading, and dam operations on the Willamette River, Oregon: U.S. Geological Survey Scientific Investigations Report 2007-5185, 34 p. (Also available at http://pubs.usgs.gov/sir/2007/5185.)

Rounds, S.A., 2010, Thermal effects of dams in the Willamette River Basin, Oregon: U.S. Geological Survey Scientific Investigations Report 2010-5153, 64 p., available at https://doi.org/10.3133/sir20105153.

Rounds, S.A., and Buccola, N.L., 2015, Improved algorithms in the CE–QUAL–W2 water-quality model for blending dam releases to meet downstream water-temperature targets: U.S. Geological Survey Open-File Report 2015-1027, 36 p. [Also available at https://dx.doi.org/10.3133/ofr20151027.]

Rounds, S.A., 2021, Electronic Communication of CE-QUAL-W2 model code changes titled “README for edition 7 of USGS version 4_2 of CE-QUAL-W2”, December 1, 2021.

Rounds, S.A., and Stratton Garvin, L.E., 2022, Tracking heat in the Willamette River system, Oregon: U.S. Geological Survey Scientific Investigations Report 2022–5006, 47 p., https://doi.org/10.3133/sir20225006.

Stonewall, A.J., and Buccola, N.L., 2015, Development of a HEC-RAS temperature model for the North Santiam River, northwestern Oregon: U.S. Geological Survey Open-File Report 2015-1006, 26 p., http://dx.doi.org/10.3133/ofr20151006.

Stratton Garvin, L.E., Rounds, S.A., and Buccola, N.L., 2021, Estimating stream temperature in the Willamette River Basin, northwestern Oregon—A regression-based approach: U.S. Geological Survey Scientific Investigations Report 2021–5022, 40 p., https://doi.org/10.3133/sir20215022.

Stratton Garvin, L.E., Rounds, S.A., and Buccola, N.L., 2022a, Updates to models of streamflow and water temperature for 2011, 2015, and 2016 in rivers of the Willamette River Basin, Oregon: U.S. Geological Survey Open-File Report 2022–1017, 73 p., https://doi.org/10.3133/ofr20221017.

Stratton Garvin, L.E., and Rounds, S.A., 2022b, The thermal landscape of the Willamette River—Patterns and controls on stream temperature and implications for flow management and cold-water salmonids: U.S. Geological Survey Scientific Investigations Report 2022–5035, 43 p., https://doi.org/10.3133/sir20225035.

Sullivan, A.B., and Rounds, S.A., 2004, Modeling streamflow and water temperature in the North Santiam and Santiam Rivers, Oregon, 2001-02: U.S. Geological Survey Scientific Investigations Report 2004-5001, 35 p. (Also available at http://pubs.usgs.gov/sir/2004/5001.)

Sullivan, A.B., Rounds, S.A., Sobieszczyk, S., and Bragg, H.M., 2007, Modeling hydrodynamics, water temperature, and suspended sediment in Detroit Lake, Oregon: U.S. Geological Survey Scientific Investigations Report 2007-5008, 40 p., available at https://doi.org/10.3133/sir20075008.

Sullivan, A.B., and Rounds, S.A., 2021, Modeling water temperature response to dam operations and water management in Green Peter and Foster Lakes and the South Santiam River, Oregon: U.S. Geological Survey Scientific Investigations Report 2020–5145, 27 p., https://doi.org/10.3133/sir20205145.

Threadgill, Tammy L., Smith, David L., Tillman, Dorothy H., Nicholas, Laurie, A., and Roy, Elizabeth W. 2012, Temperature Modeling of Cougar Reservoir Using CE-QUAL-W2, A

Report on the Development, Calibration, Verification and Application of the Model, USACE Engineering and Development Center, Environmental Lab, Letter Report.

USACE, 2015, Middle Fork Willamette Downstream Fish Passage and Water Quality/Temperature Control 60% Engineering Documentation Report, U.S. Army Corps of Engineers Portland District, April 2015.

USACE, 2009, Willamette Valley Projects Configuration/Operation Plan, Phase I Report: Appendix D Proposed Structural And Operational Measures, U.S. Army Corps of Engineers Portland District, October, 2009.

USACE, 2009, Detroit / Big Cliff Dams Interim Temperature Operations Study, Phase I Technical Report, Portland District, March 27.

USACE, 2017, Willamette Fish Operations Plan Willamette Valley Project. U.S. Army Corps of Engineers, Portland, OR. Accessed on June 3, 2021 at: http://pweb.crohms.org/tmt/documents/FPOM/2010/Willamette_Coordination/WFOP/2017/final/2017%20WFOP%20Chapter%201%20Overview.pdf

USACE, 2019a, Cougar Dam Downstream Fish Passage Willamette River Basin South Fork Mckenzie River 90% Final Design Documentation Report, Oregon, US Army Corps of Engineers Portland District, 5 April 2019.

USACE, 2019b, Detroit Dam And Reservoir Willamette River Basin North Santiam River, Oregon, Phase 1 Downstream Fish Passage – Selective Withdrawal Structure Design Documentation Report, US Army Corps of Engineers Portland District, July 2019.

USACE, 2019c. Willamette Basin Annual Water Quality Report for 2018. U.S. Army Corps of Engineers, Portland, OR.

USACE, 2020a, Dataquery 2.0; Query Timeseries from USACE Northwestern Division, available online at: https://www.nwd-wc.usace.army.mil/dd/common/dataquery/www/

USACE. 2020b, Willamette Fish Operations Plan Willamette Valley Project. U.S. Army Corps of Engineers, Portland, OR.

USACE, 2020c, Foster Dam And Reservoir Willamette River Basin South Santiam River, Oregon 90% Design Documentation Report No. 17, US Army Corps of Engineers Portland District, December 2020.

West Consultants, Inc., 2004a, Development of a CE-QUAL-W2 Model for Hills Creek Reservoir: Seattle, Washington, prepared for U.S. Army Corps of Engineers under contract DACW57-02-D-0005, 42 p.

West Consultants, Inc., 2004b, Development of a CE-QUAL-W2 Model for Lookout Point/Dexter Reservoirs: Seattle, Washington, prepared for U.S. Army Corps of Engineers under contract DACW57-02-D-0005, 40 p.

West Consultants, Inc., 2005, Development of a CE-QUAL-W2 model for Green Peter and Foster reservoirs: Seattle, Washington, prepared for U.S. Army Corps of Engineers under contract DACW57-02-D-0005, 43 p.

Willamette Fish Passage Operations and Maintenance (W-FPOM) Coordination Team, 2017, "17DET02 North Santiam Temperature Targets" accessed at http://pweb.crohms.org/tmt/documents/FPOM/2010/Willamette_Coordination/MOCs%20and%20MFRs/North%20Santiam/ on Dec 28, 2020.

CHAPTER 2 - TOTAL DISSOLVED GAS (TDG)

2.1 BACKGROUND

This section describes the TDG model development and application for the WV EIS. Empirical models were developed based on measured TDG and operations data within recent timeframes with respect to the writing of this document. The TDG models were then used to provide TDG estimates for the WV EIS for the Period of Record (1936 – 2019).

2.1.1 TDG Model Development

Total Dissolved Gas (TDG) production was empirically estimated as a function of spill rate at Detroit / Big Cliff dams, Green Peter / Foster dams, Lookout Point / Dexter dams and Cougar dam (Table 2-1).

Spill can occur via a spillway (SW) or regulating outlet (RO) and typically results in TDG supersaturation (equation 1, from Cole and Wells, 2018). Downstream TDG was calculated using the mixing equation with flow and TDG from each outlet. Powerhouse (PH) TDG was assumed to equal upstream TDG levels or a constant value at approximately 100% TDG. TDG calculated using daily average flows was compared to the daily average observed TDG to account for travel time and dispersion. TDG was estimated as a function of spill rate via the spillway (SW) or regulating outlets (RO) at Detroit / Big Cliff dams. The form of this equation is as follows (Equation 2, from Cole and Wells, 2018):

$$\%\boldsymbol{TDG} = \boldsymbol{a} + \boldsymbol{b}\boldsymbol{e}^{\boldsymbol{c}\boldsymbol{Q}_{\boldsymbol{s}}} \qquad \text{Eq. 1}$$

Where:

a, **b**, and **c** are empirical coefficients

$\mathbf{Q_s}$ = total spill, in cfs (except Big Cliff)

The spill rate (Q_s, Equation 2) for Big Cliff Dam tailwater is represented using the flow-weighted specific spillbay discharge (Equation 2) borrowed from SYSTDG methods used on the lower Snake and Columbia River projects (USACE, 2020). Total spill rate alone could not explain the variable TDG production rates which were noted during the initial model calibration. At Big Cliff, individual spillbay flow rates were calculated by proportioning the total spill based on the reported opening of each spillbay.

$$\boldsymbol{Q}_{\boldsymbol{s}} = \frac{\sum_{i=1}^{nb} \boldsymbol{Q}_i^{C}}{\sum_{i=1}^{nb} \boldsymbol{Q}_i^{(C-1)}} \qquad \text{Eq. 2}$$

Where:

$\boldsymbol{Q_i}$ = discharge through spillbay i (use measured discharge or spill pattern lookup values)

nb = the number of project spillbays

C = Project and spill pattern specific constant

Estimated TDG caused by spill from 1, 2, and 3 spillway gates is compared with Detroit Spill only (Spillway and RO) in Figure 2-6. This analysis assumes a minimum spillway gate flow of 1000 cfs. Reductions in TDG occur with additional spillway gates, however, this effect diminishes as total flow increases. The average TDG reduction realized by spreading spill across spillway gates can be summarized with respect to total spill as follows: 2000 to 3000 cfs (2 gates): 14%, 3000 to 6000 cfs (3 gates): 10%, greater than 6000 cfs (3 gates): 1%. While it is feasible to use all three spillway gates at BCL, the WV EIS limited spill to 2 gates to incorporate the current dam safety concern that the third gate be operated only under emergency conditions as the automatic operating mechanisms were designed.

TDG models were developed at other WV dams using similar methodology as that used at DET-BCL with parameters shown in Table 2-1 and Table 2-2. The empirical coefficients and upstream TDG were estimated using trial and error and basing fit on visual error analysis with an emphasis on representing higher values of TDG based on professional judgment. The models were calibrated by adjusting the coefficients in Equations 1 and 2 and setting a minimum value for TDG production, as needed (Table 2-2). The goal of calibration was to minimize error statistics (Table 2-3) and follow the patterns of observed TDG and spill relationships (Figure 2-1 to Figure 2-25). For Cougar, there is no TDG data that has been observed for the diversion tunnel operation, so all TDG estimation for alternatives with diversion tunnel flow were assumed to be equivalent to powerhouse outflow (TDG = 102%).

Table 2-1. Representation of project outlets and configuration

Project	Abbreviation	Outlets	Spillway use criteria	Downstream Project	Tailrace gauge	Data range
Detroit	DET	SW, RO, PH	Forebay > 1541 ft	BCL	--	--
Big Cliff	BCL	3 spillbays, PH	--	--	BCLO	2011 - 2020
Green Peter	GPR	SW, RO, PH	5/28 to 6/19/2020	FOS	--	--
Foster	FOS	SW, PH	--	--	SSFO	2015 - 2020
Hills Creek	HCR	RO, PH	--	--	HCRO	2012
Lookout Point	LOP	SW, RO, PH	Forebay > 888 ft	DEX	--	--
Dexter	DEX	SW, PH	--	--	DEXO	2015 - 2020

Project	Abbreviation	Outlets	Spillway use criteria	Downstream Project	Tailrace gauge	Data range
Cougar	CGR	RO, PH	--	--	CGRO	2015 - 2020

Additionally, model error was compared to tailwater elevations but no further model parameterization was deemed necessary. Higher TDG values were weighted above lower TDG values when matching patterns. Given the complexity of multiple outlets and multiple projects in series, the model was able to adequately reproduce the pattern and magnitude of observed TDG. The models are appropriate to be used to predict changes in operations, given spill rates are within range used to calibrate the model and there no structural changes.

Table 2-2. Empirical coefficients for TDG production. If the a, b, c coefficient set results in TDG production less than 100%, then a floor was set.

Outlet	a	b	c	C, eq. 2 (nbays)	Minimum TDG (%)
DET SW	117	0	-0.005	--	--
DET RO	135	-50	-0.001	--	115
BCL SW	130	-80	-0.0015	2	100
GPR SW	130	-10	-0.001	--	103
GPR RO	130	-70	-0.0005	--	103
FOS SW	122	-70	-0.0005	--	110
CGR RO	120	-19	-0.001	--	102
LOP SW	120	-20	-0.0002	--	--
LOP RO	105	-5	-0.001	--	100
DEX SW	119	-17	-0.0003	--	--
HCR RO	123	-57	-0.0012	--	102

Table 2-3. SYS-TDG Error statistics

Gauge	Number of daily average values	mean error	absolute mean error	root mean square error
BCLO	3215	-0.4	2.4	3.8
SSFO	1943	1.7	2.3	3.0
HCRO	38	-0.6	3.4	4.4
DEXO	1909	-0.2	1.5	2.0
CGRO	2035	1.6	2.4	3.1

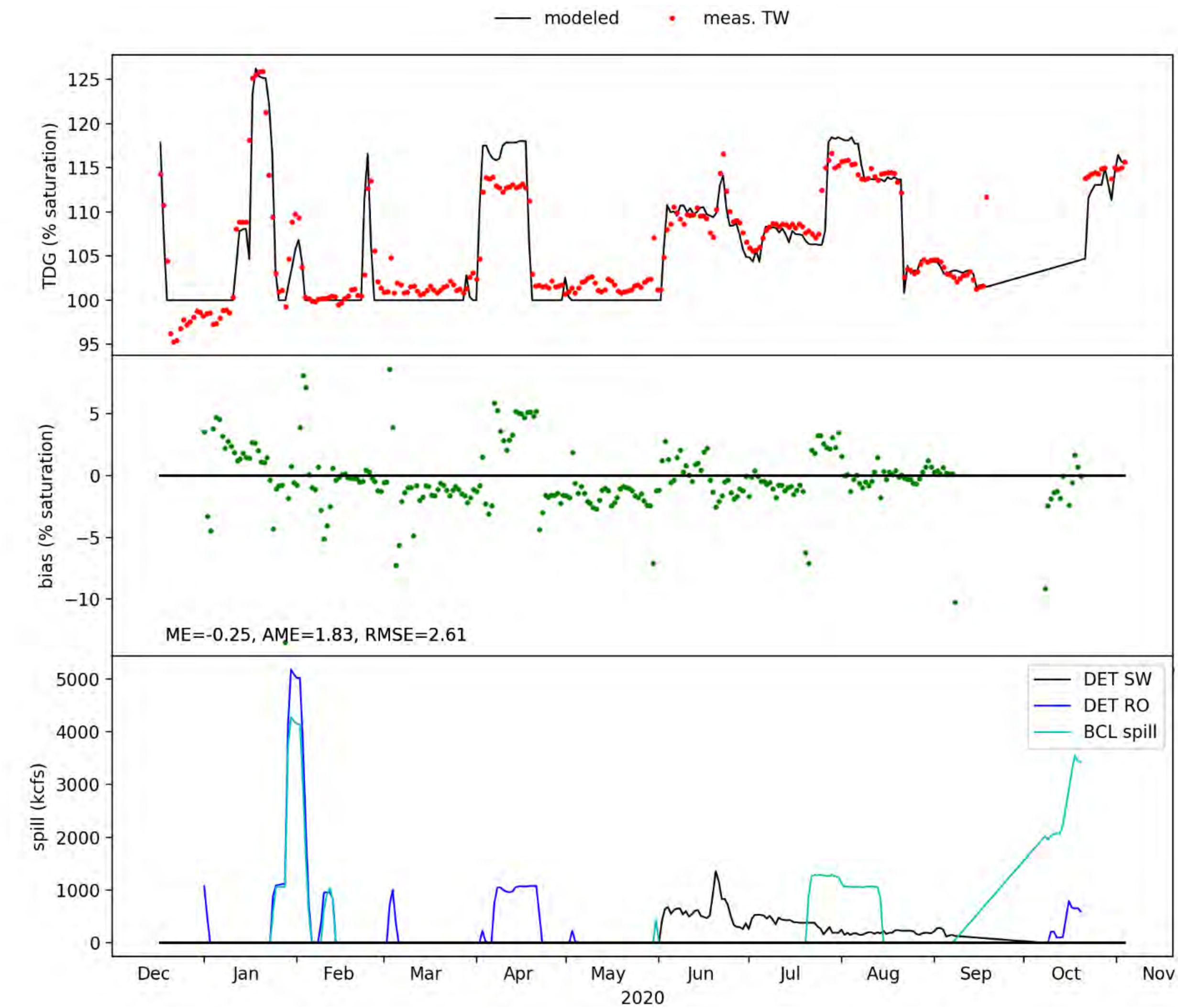

Figure 2-1. Example Time series of North Santiam model results at BCLO.

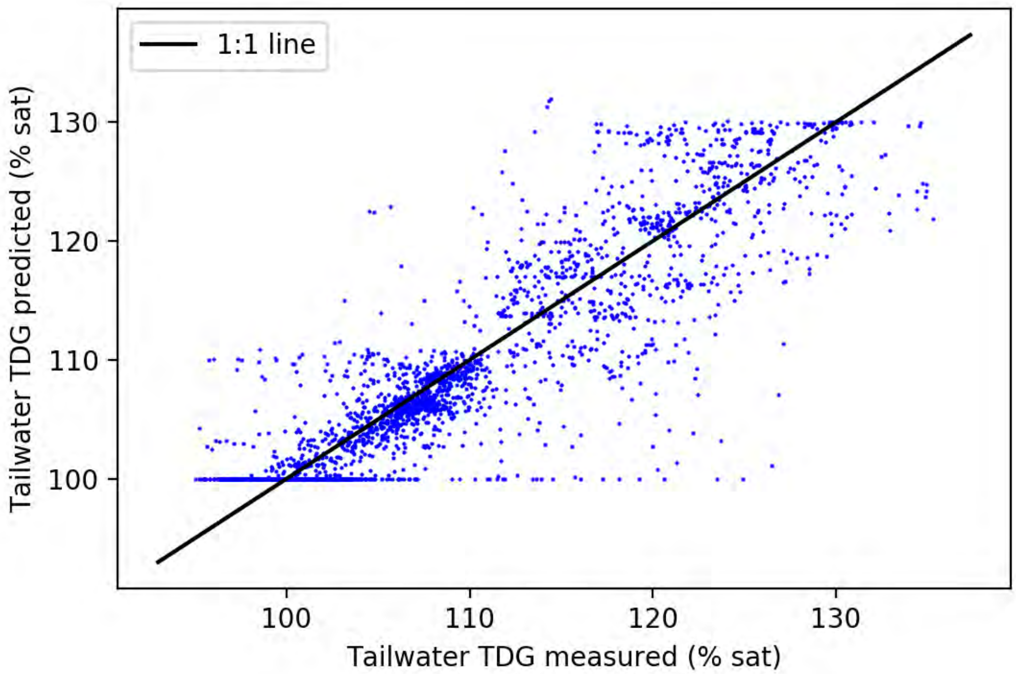

Figure 2-2. Model estimation of TDG compared to measurements at BCLO.

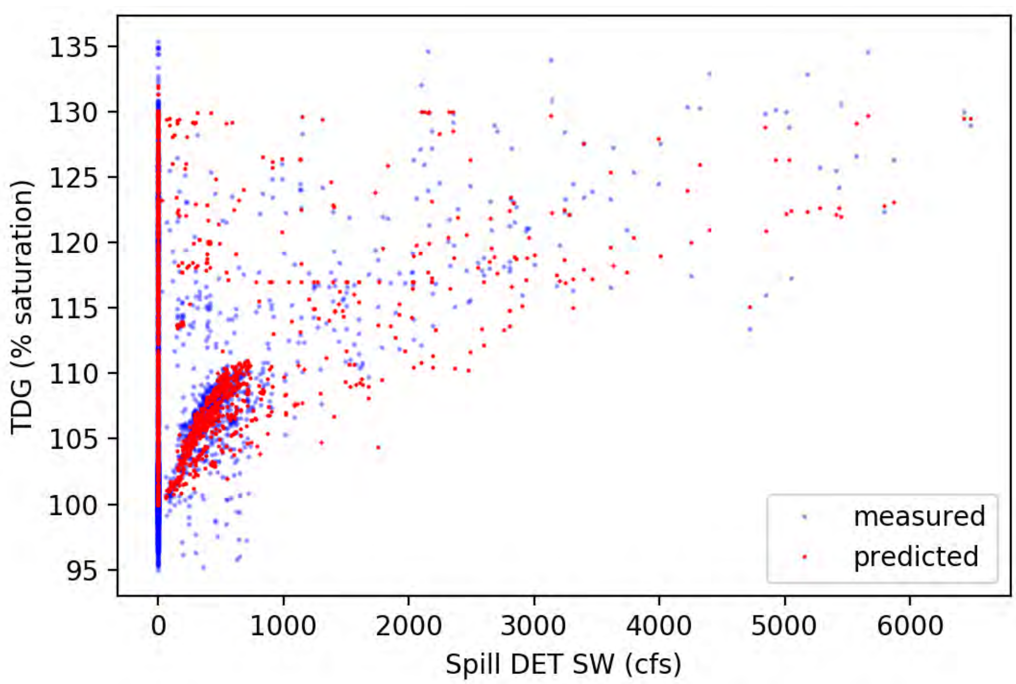

Figure 2-3. Model estimation and measurements of TDG compared to spill at Detroit spillway.

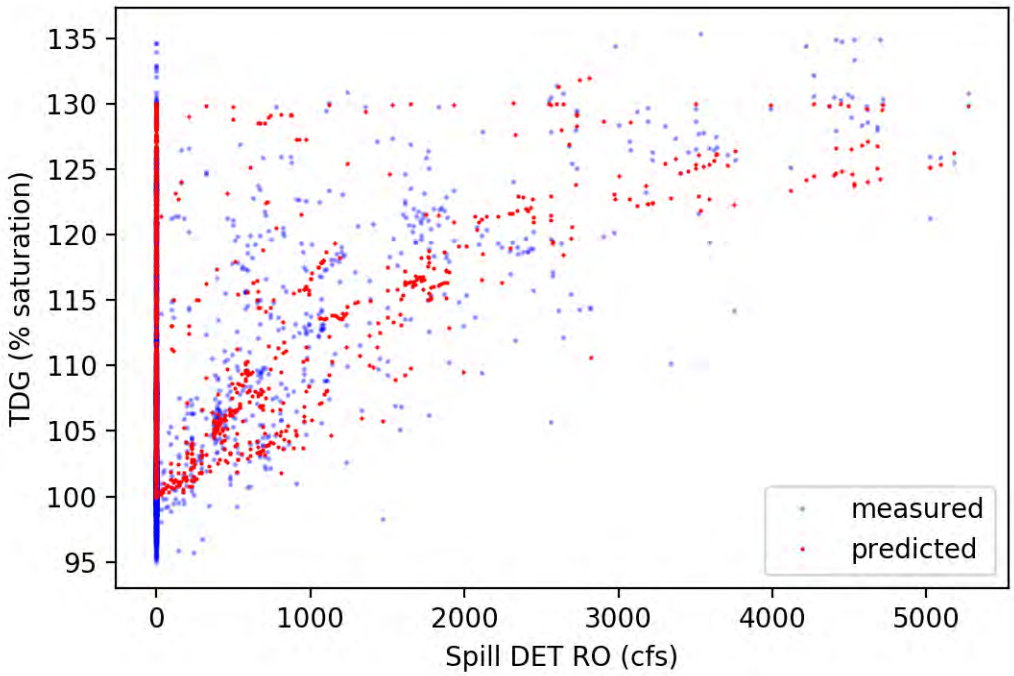

Figure 2-4. Model estimation and measurements of TDG compared to spill at Detroit regulating outlet.

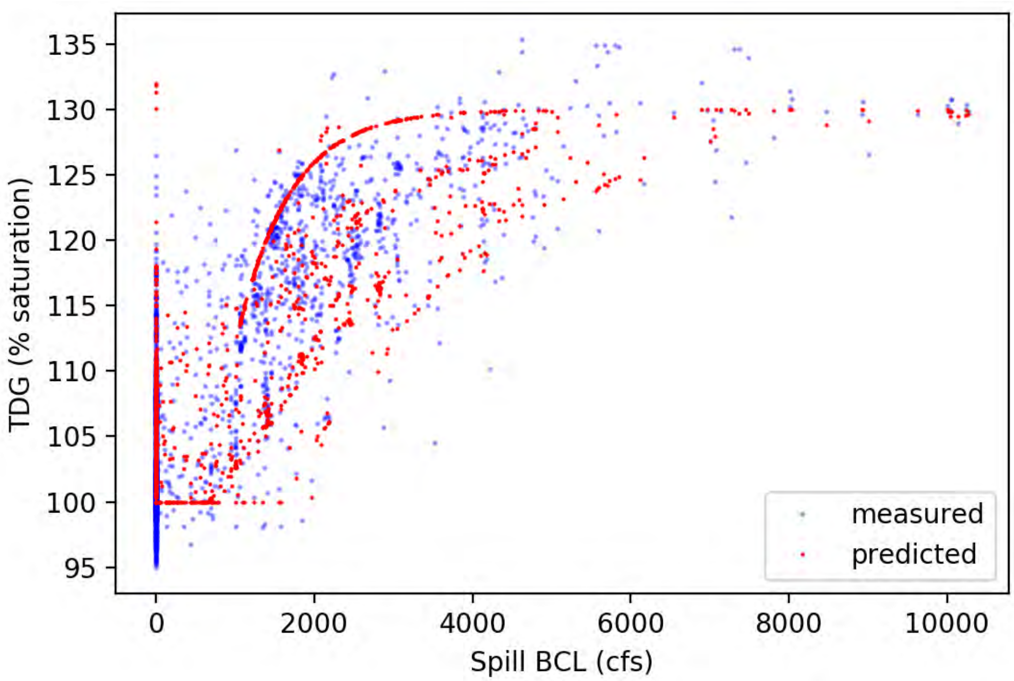

Figure 2-5. Model estimation and measurements of TDG compared to spill at Big Cliff spillway.

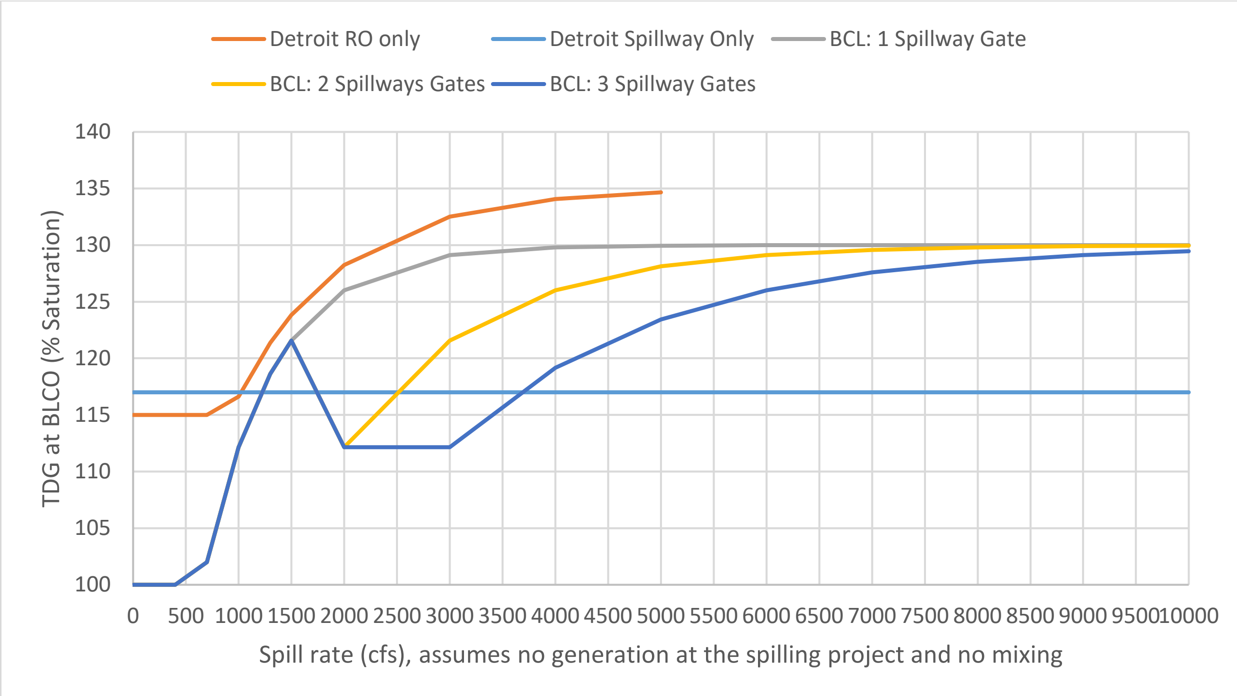

Figure 2-6. Model predictions of TDG downstream of Big Cliff Dam. Assumes that there is only one spill source and there is no mixing with generation flow.

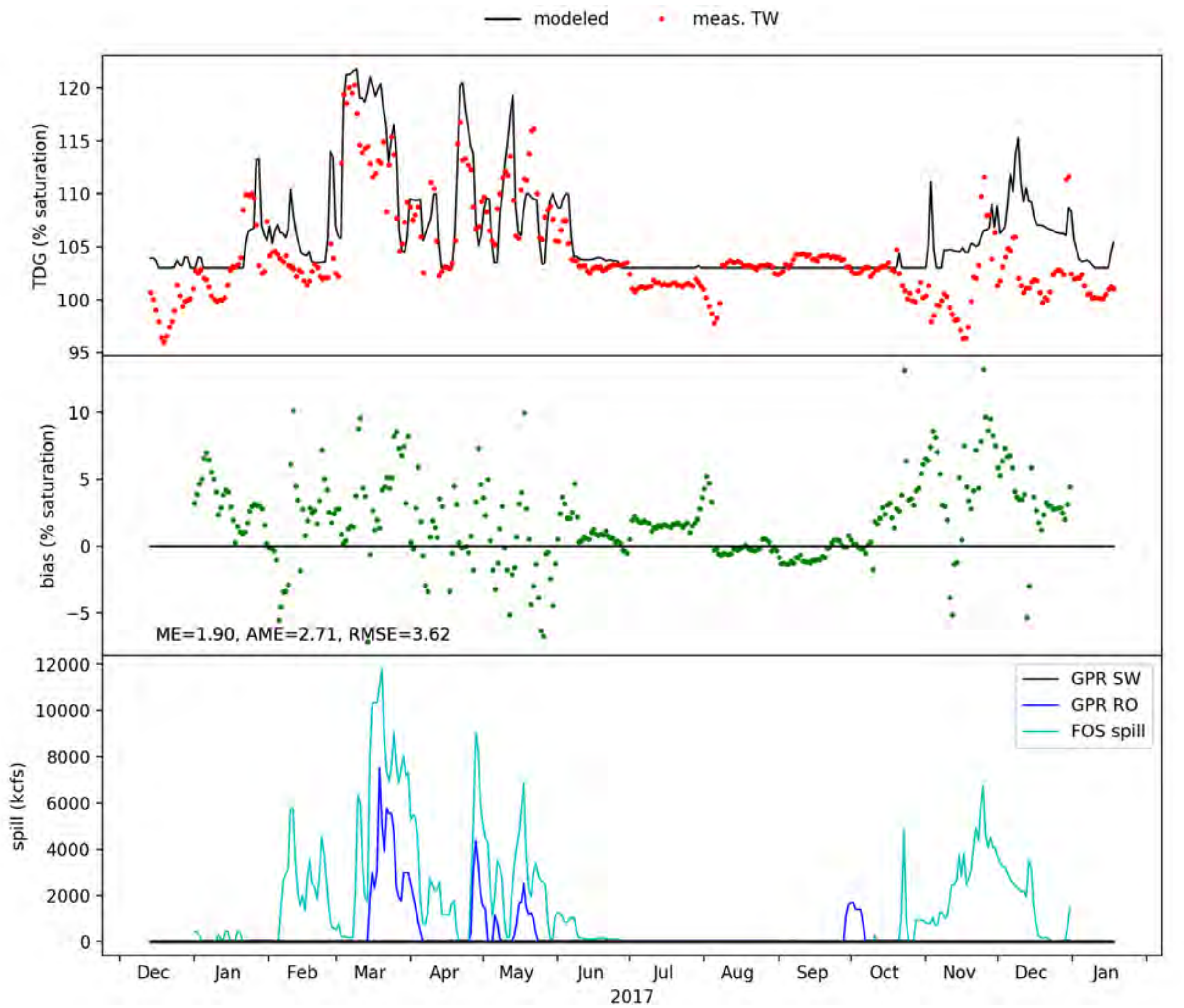

Figure 2-7. Example time series of South Santiam model results at SSFO.

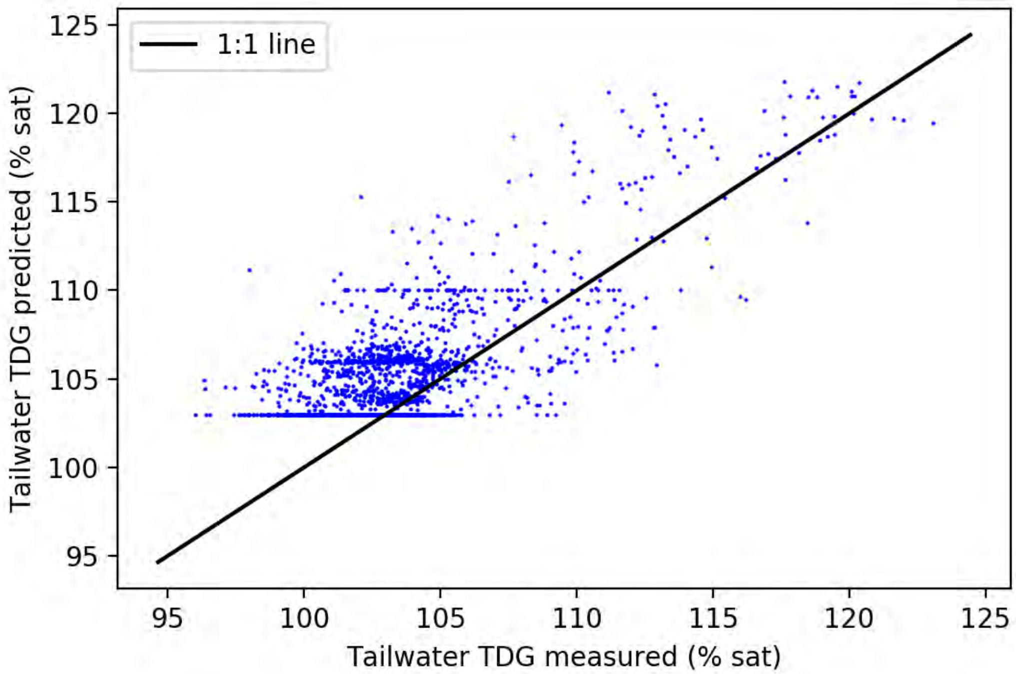

Figure 2-8. Model estimation of TDG compared to measurements at SSFO.

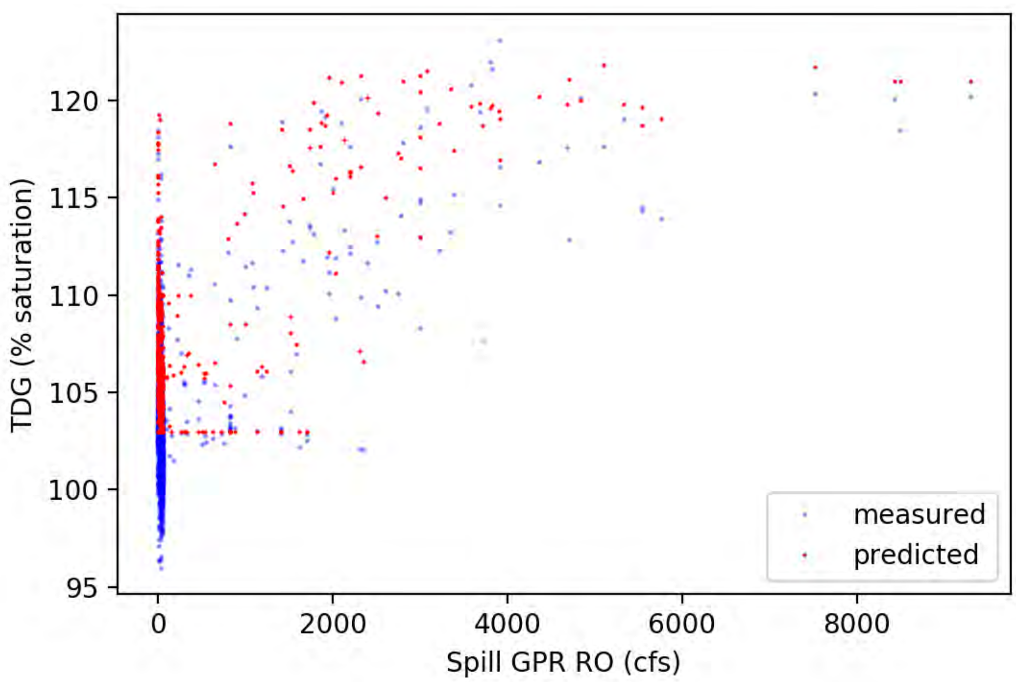

Figure 2-9. Model estimation and measurements of TDG compared to spill at Green Peter regulating outlet.

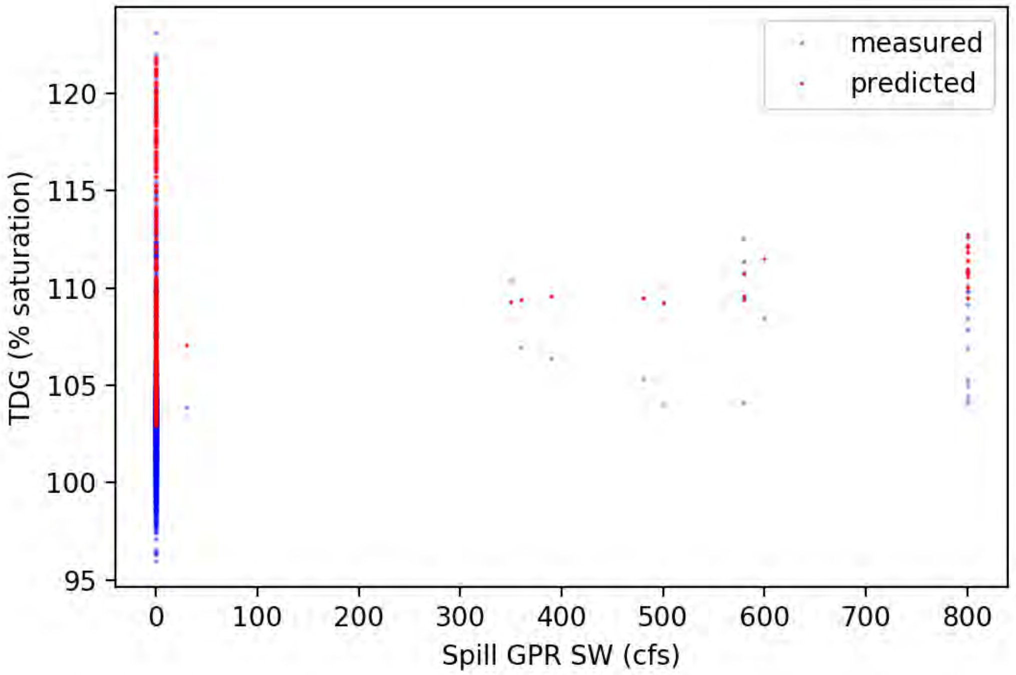

Figure 2-10. Model estimation and measurements of TDG compared to spill at Green Peter spillway.

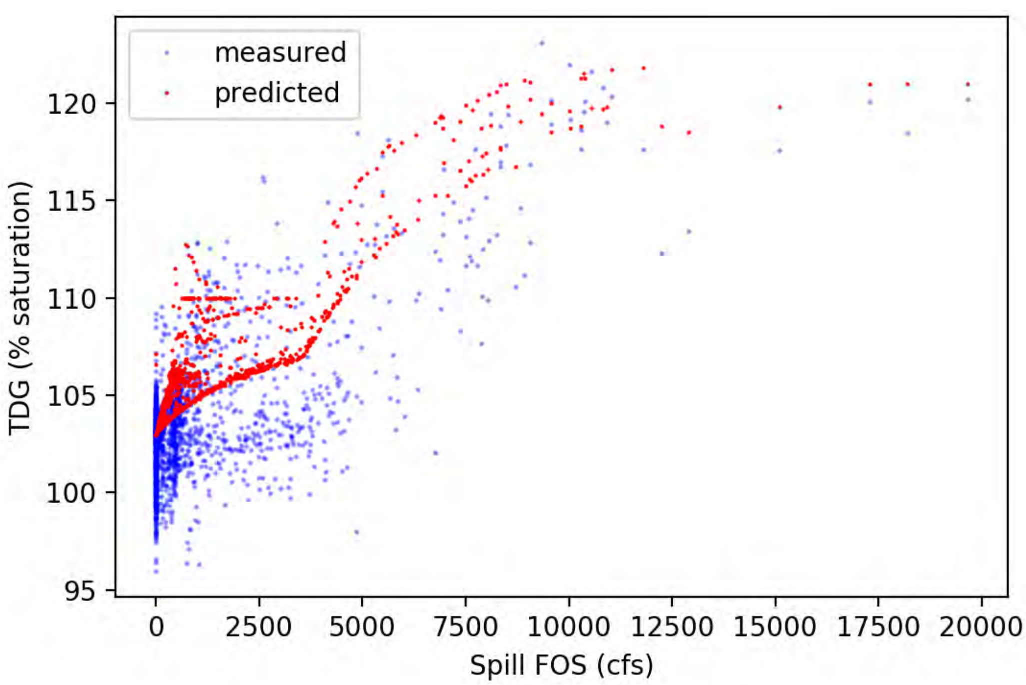

Figure 2-11. Model estimation and measurements of TDG compared to spill at Foster spillway.

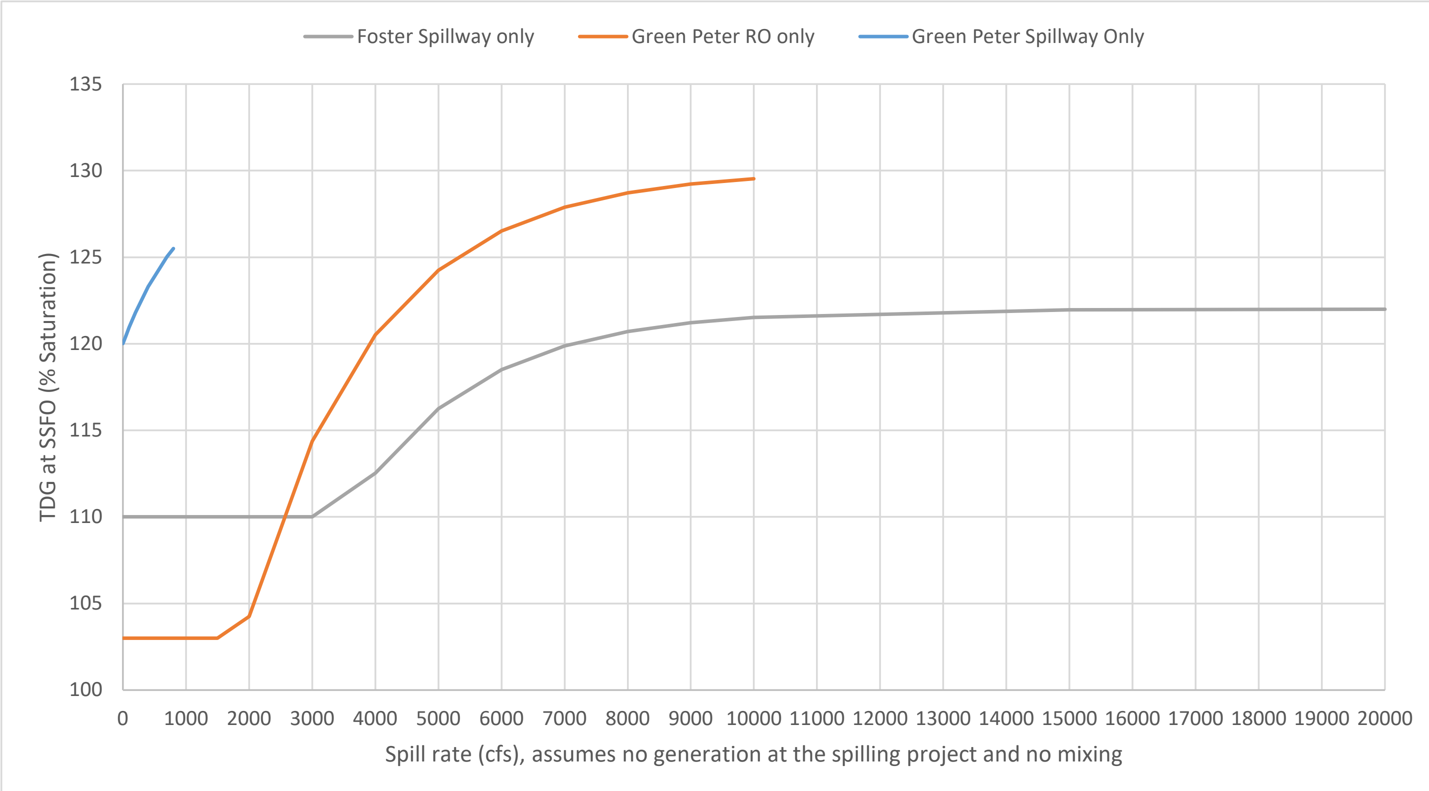

Figure 2-12. Model predictions of TDG at Green Peter and Foster Dams. Only one spill source and no mixing with generation flow assumed at Green Peter Dam due to absence of spillway data.

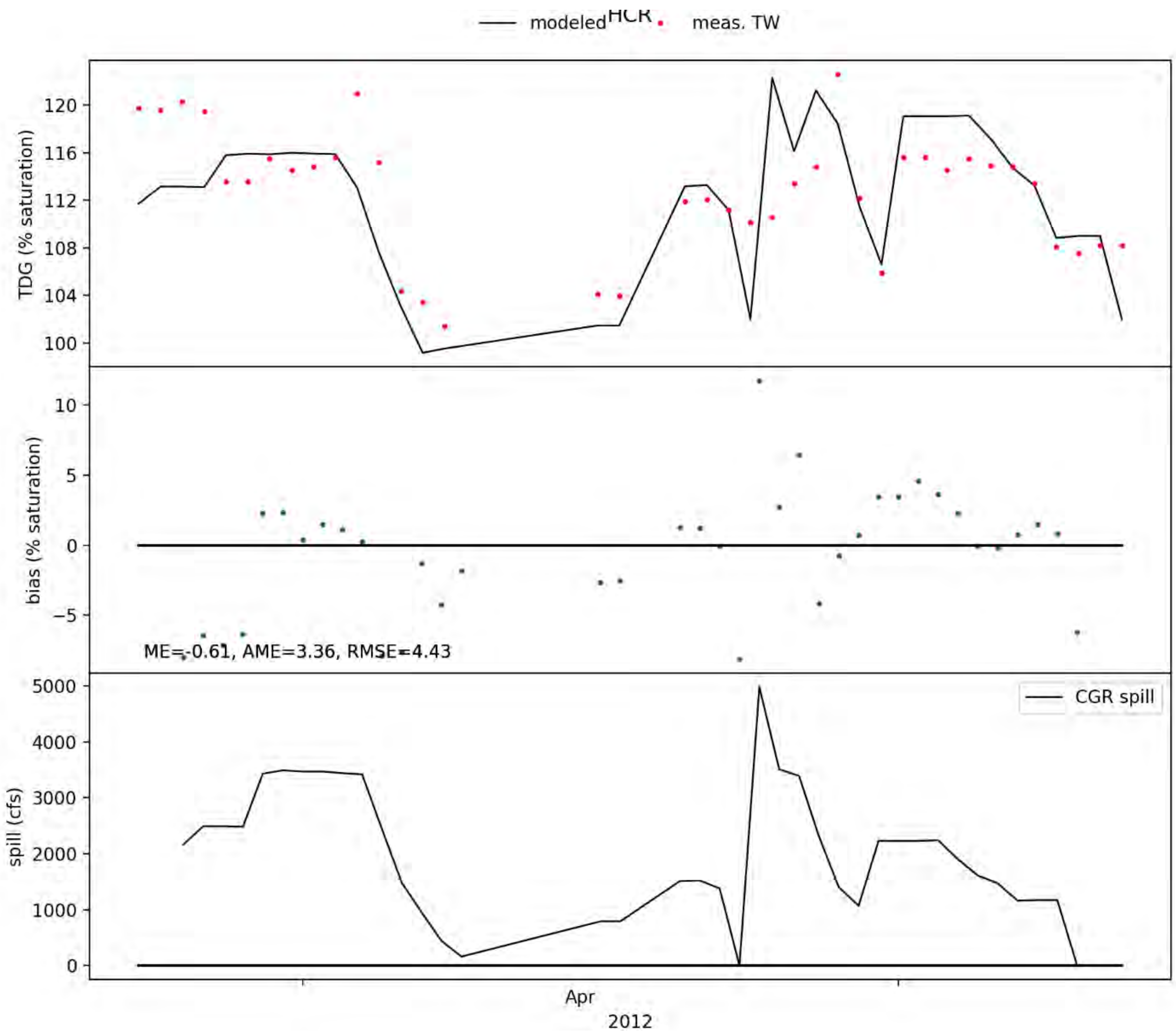

Figure 2-13. Example time series of Middle Fork Willamette model results at HCRO.

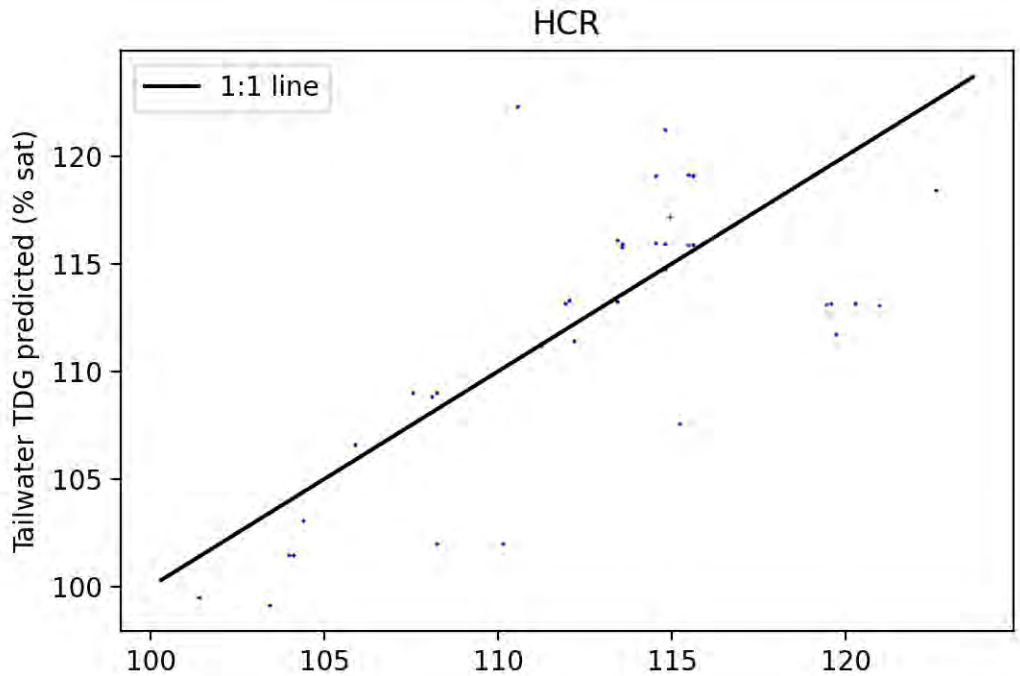

Figure 2-14. Model estimation of TDG compared to measurements at HCRO.

Spill HCR (cfs)

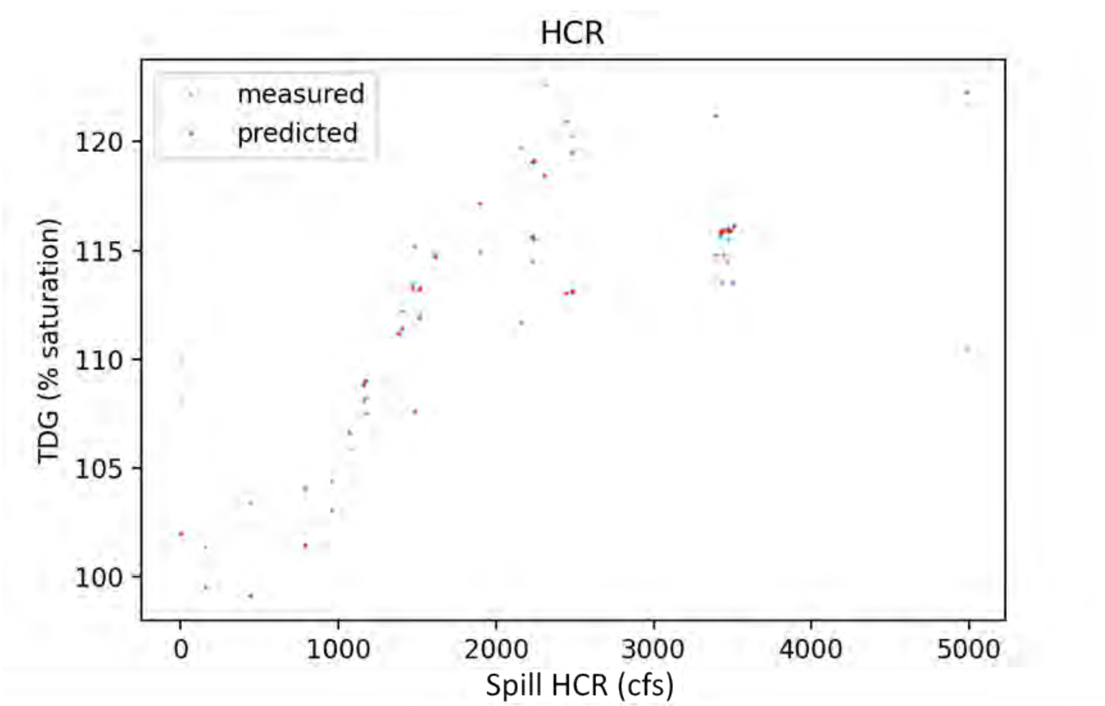

Figure 2-15. Model estimation and measurements of TDG compared to spill at Hills Creek regulating outlet.

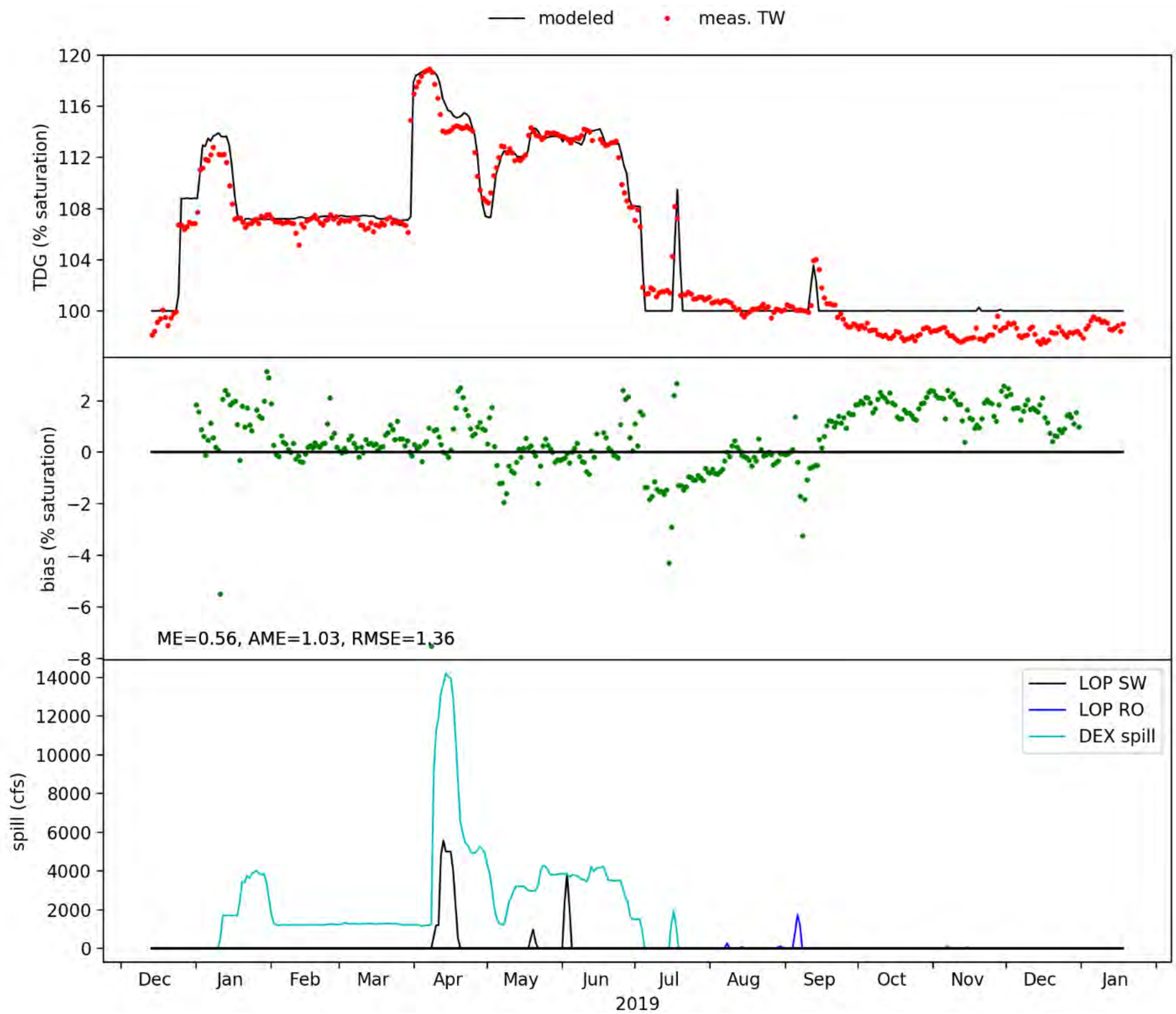

Figure 2-16. Example time series of Middle Fork Willamette model results at DEXO.

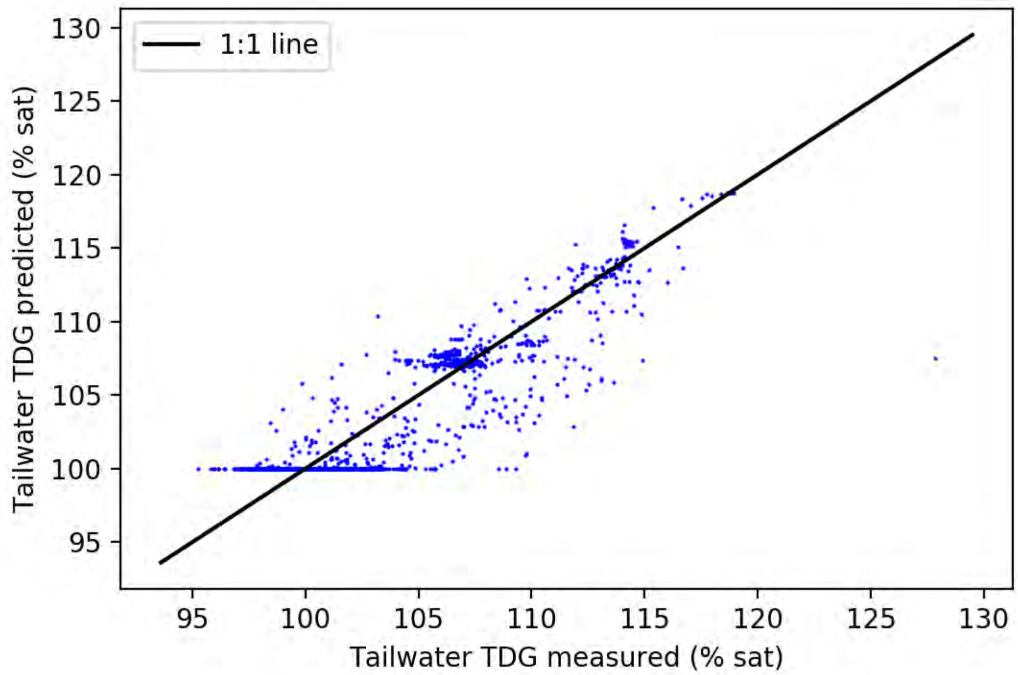

Figure 2-17. Model estimation of TDG compared to measurements at DEXO.

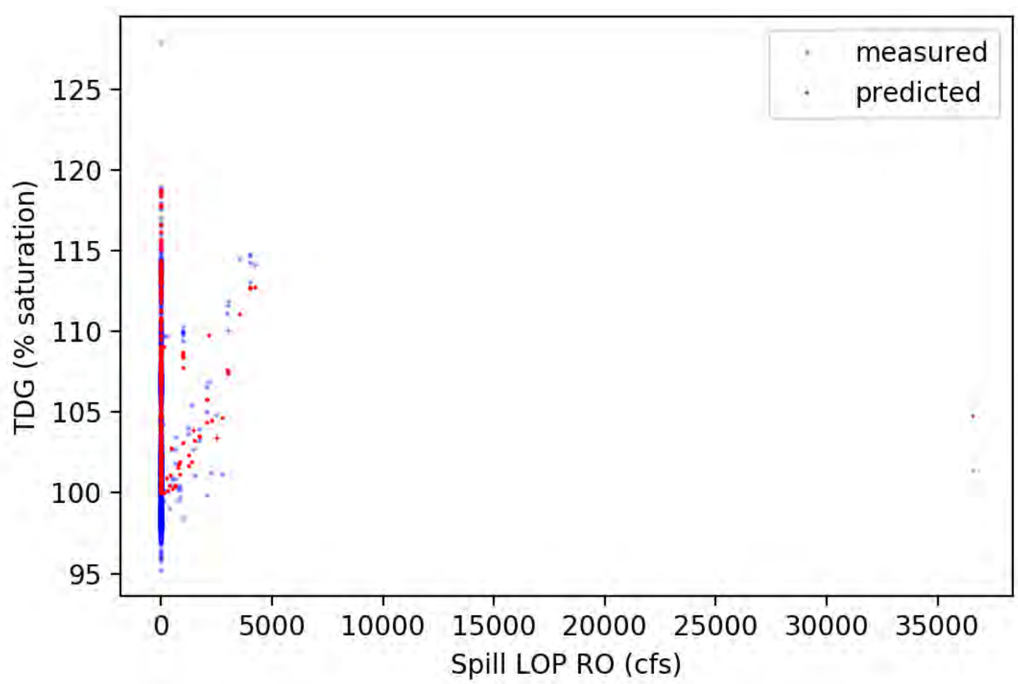

Figure 2-18. Model estimation and measurements of TDG compared to spill at Lookout Point regulating outlet.

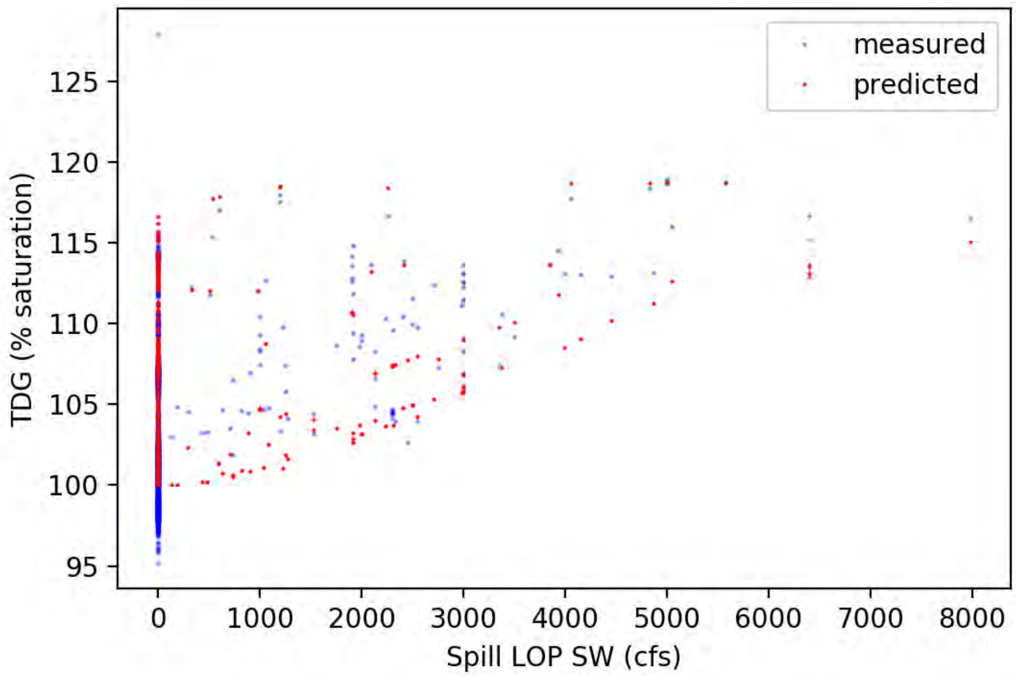

Figure 2-19. Model estimation and measurements of TDG compared to spill at Lookout Point spillway.

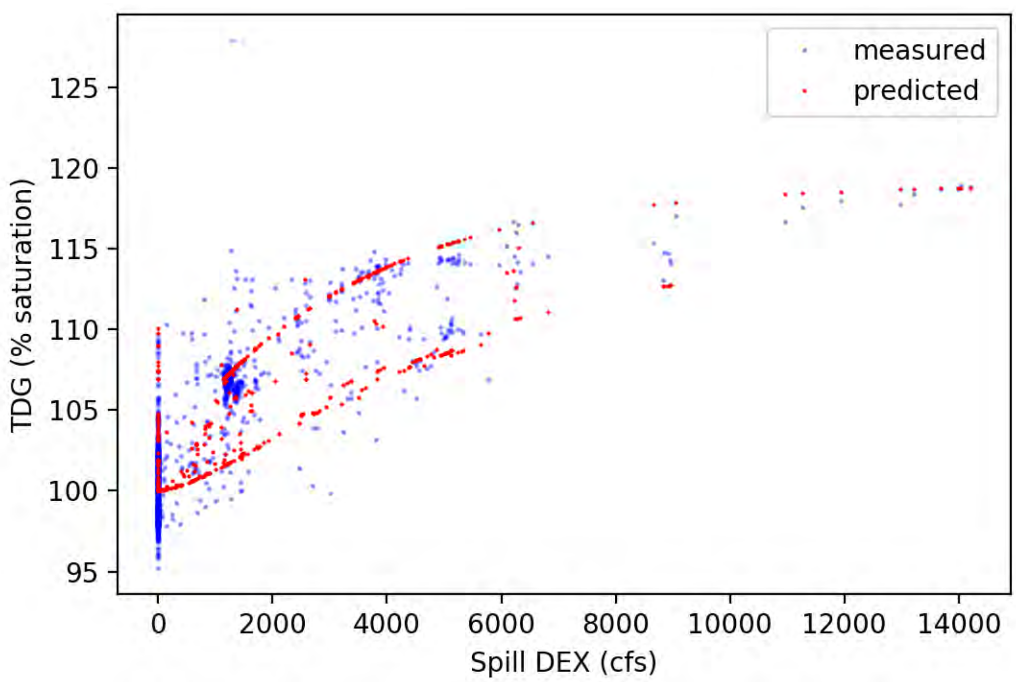

Figure 2-20. Model estimation and measurements of TDG compared to spill at Dexter spillway.

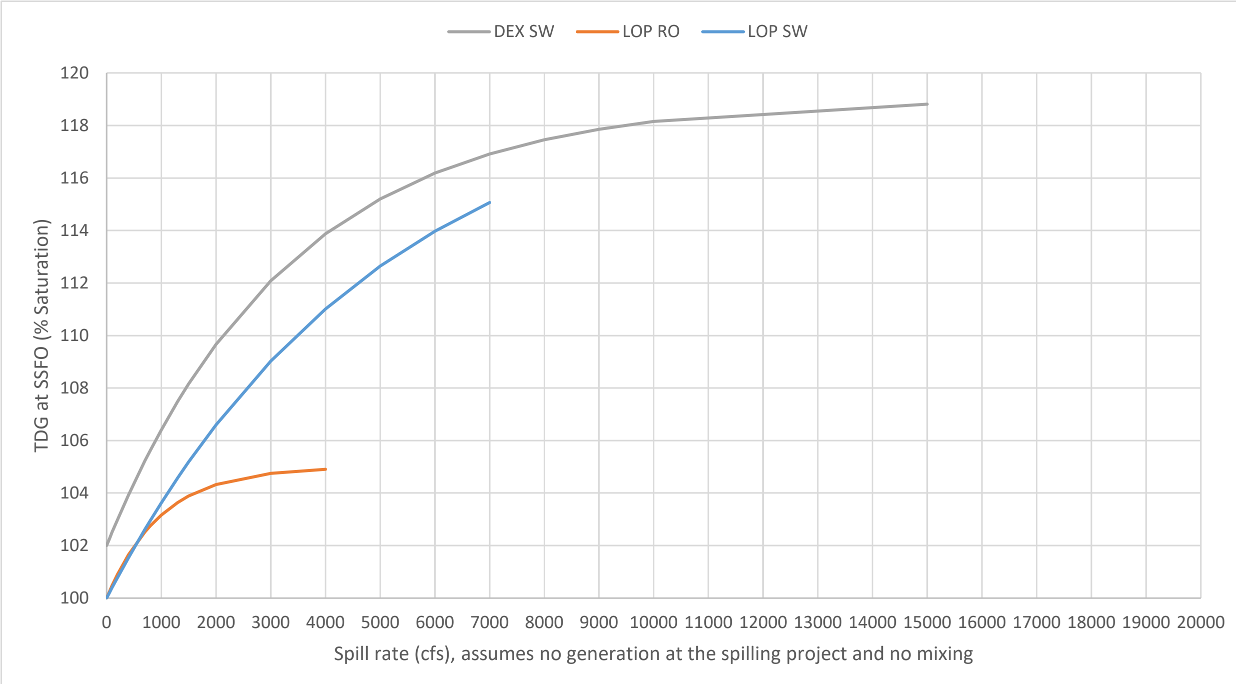

Figure 2-21. Model predictions of TDG below Lookout Point-Dexter Dams. Only one spill source and no mixing with generation flow assumed at Lookout Point Dam due to absence of spillway data.

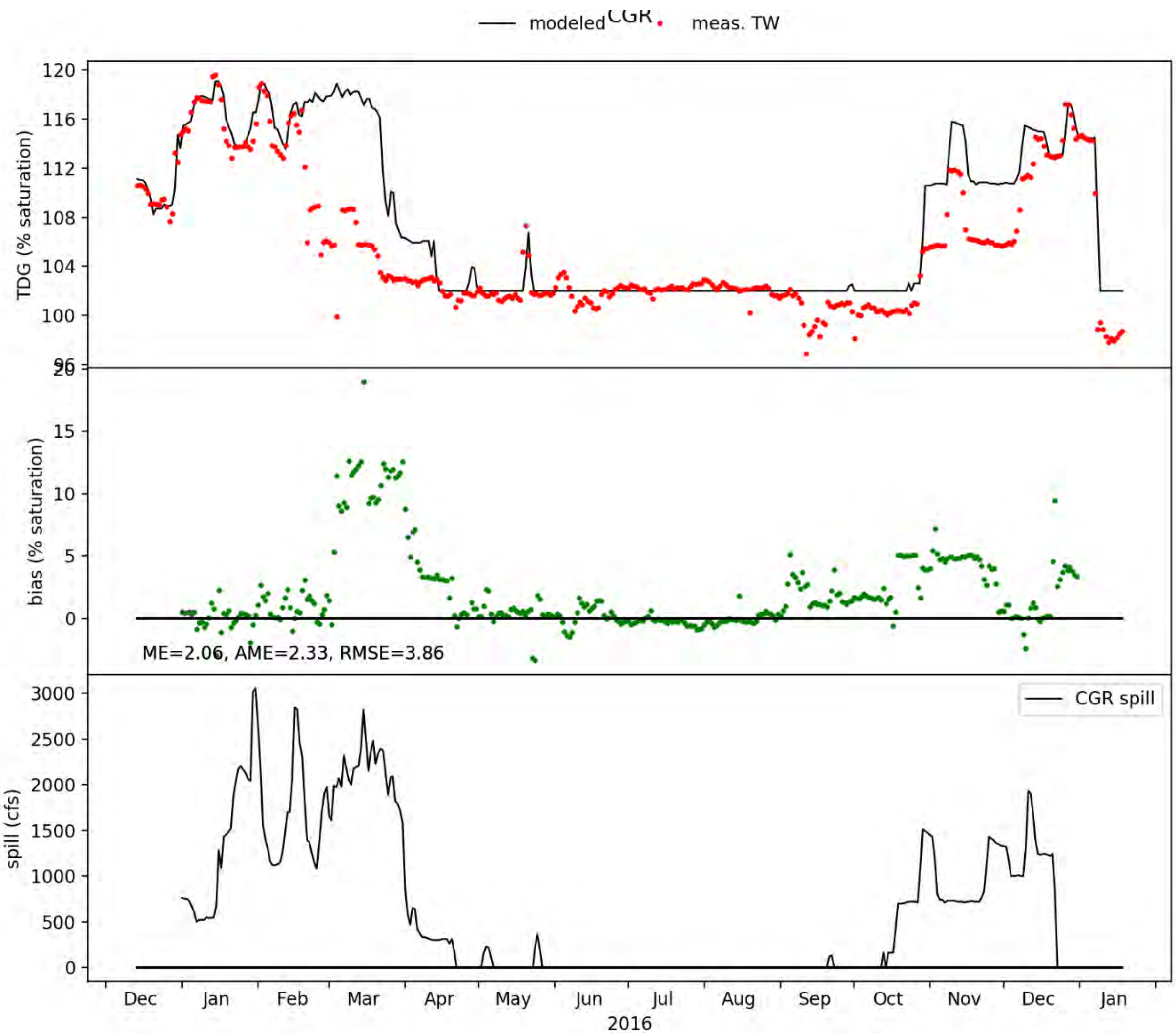

Figure 2-22. Example time series of South Fork McKenzie model results at CGRO.

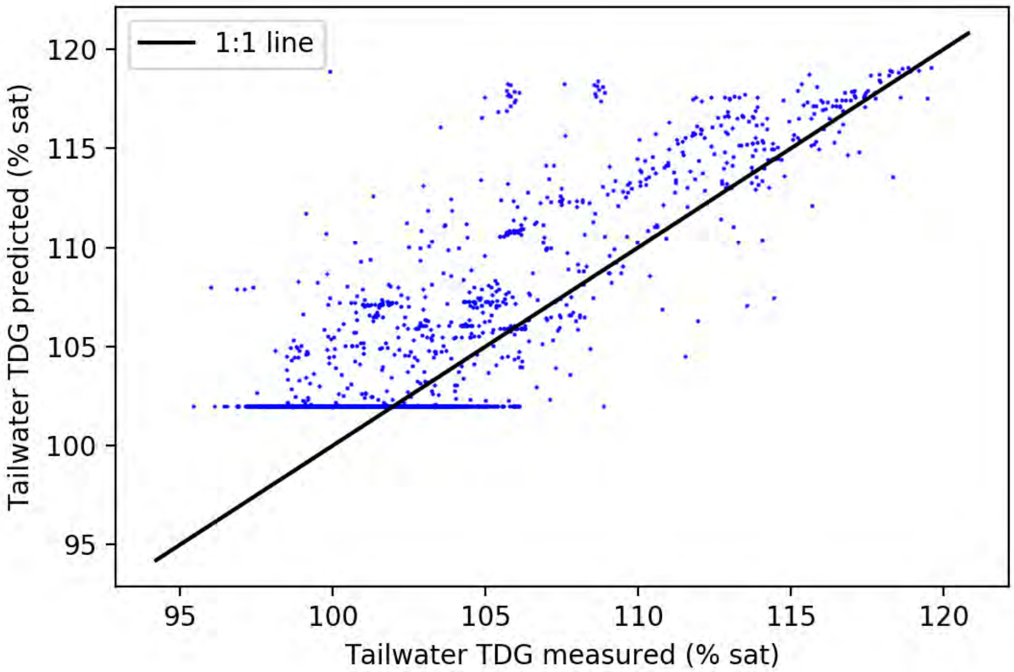

Figure 2-23. Model estimation of TDG compared to measurements at CGRO.

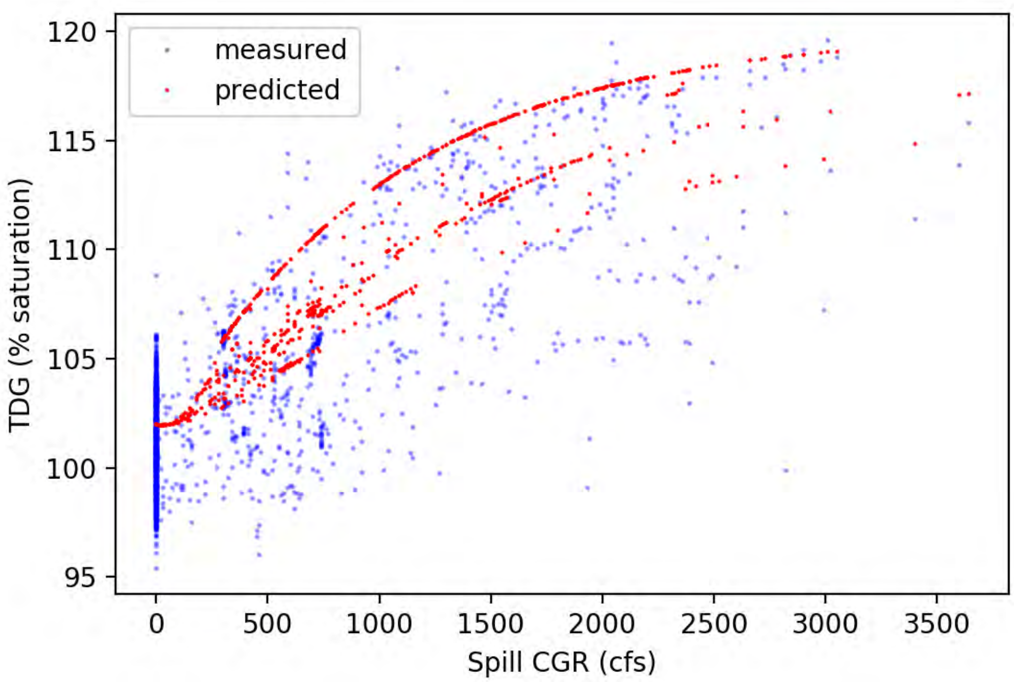

Figure 2-24. Model estimation and measurements of TDG compared to spill at Cougar regulating outlet.

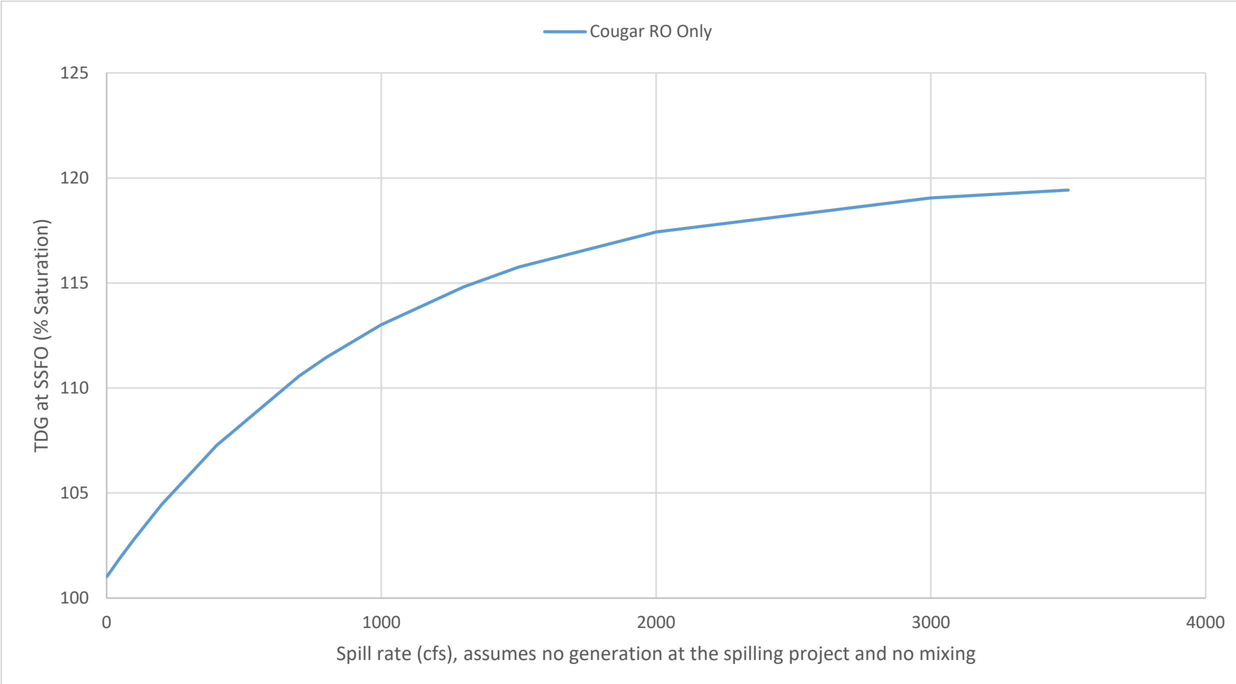

Figure 2-25. Model predictions of TDG below Cougar Dam. Only one spill source and no mixing with generation flow assumed below Cougar Dam.

2.1.2 Imposed Turbine Outages

Turbine outages caused by lack of energy demand, maintenance, or emergency safety measures can lead to spillway or regulating outlet usage and TDG exceedances of 110% below Willamette Valley Project Dams. Turbine outages were not included in RES-SIM simulations, so a method to introduce those outages into the TDG estimation was included here. To assess an average turbine outage rate per year for each WVP project, the observed turbine outages during 2009-2020 were used in combination with upcoming planned maintenance (Table 2-4). Estimated annual turbine outage rates as a percentage were applied to dam releases provided by the RES-SIM model in each alternative (e.g., NAA, Alternative 1) on random days during the year to recreate "forced" (i.e., unplanned) turbine outages. An additional 3% outage rate per year at all projects was imposed to recreate "planned" outages (e.g., maintenance) on random days during the winter months (December, January, February), aligning with planned outage periods described in the 2008 BiOp (NOAA, 2008) and Willamette Fish Operations Plan (USACE, 2017). For each day in which a turbine outage was imposed in each RES-SIM simulation (84-year simulation spanning 1936 – 2019), project power outflow was re-allocated to the appropriate spill outlet (spillway or RO, depending on lake level) outflow. A comparison of TDG over the entire period of record show a relatively close fit to the historic observations (Figure 2-26), especially at higher TDG levels (95th% TDG in Figure 2-27). The annual number of days in which spill and TDG exceedances (greater than 110%) occurred were similar in NAA and the observed record (Figure 2-28). A comparison of NAA and observed operations/TDG below each major TDG-producing WVP projects during separate wet winters are shown in Figure 2-29, Figure 2-30, Figure 2-31, and Figure 2-32. While the simulated high spill described here does not always align with the observed record, the number of spill events that were imposed using the random turbine outages method described here led to general agreement of the TDG exceedance trends in the historical record while allowing a projection of turbine outages into the period of record and in each alternative.

Table 2-4. Projected Annual Turbine Outage (percentage of days per year) Applied to RES-SIM WVP Outflow Data in WV EIS Alternatives for Estimating TDG.

Project	Estimated Annual Turbine Outage (Percentage Days)
DET	7%
BCL	3%
GPR	2%
FOS	2%
LOP	2%
DEX	6%
CGR	8%
HCR	3%

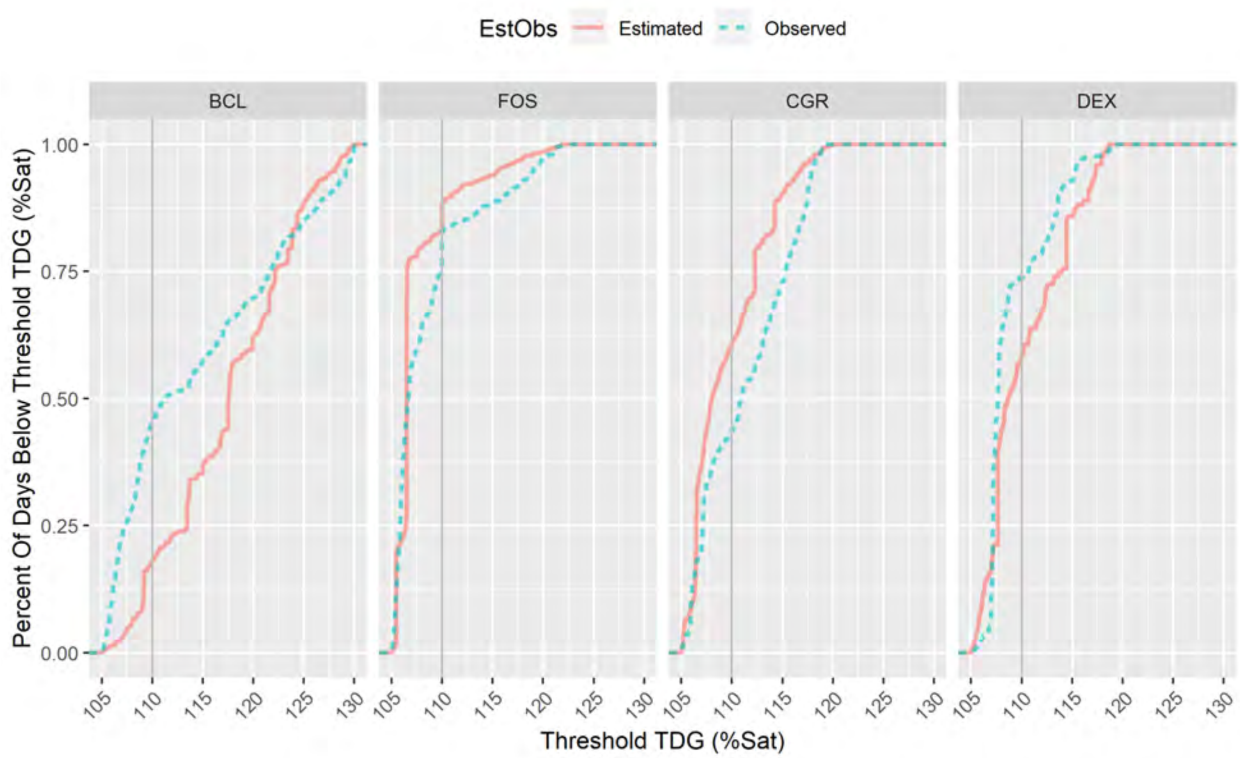

Figure 2-26. Percentage of Days Below a Given Threshold TDG (non-exceedance cumulative distribution function) as Estimated below Big Cliff (BCL), Foster (FOS), Cougar (CGR), and Dexter (DEX) Dams.

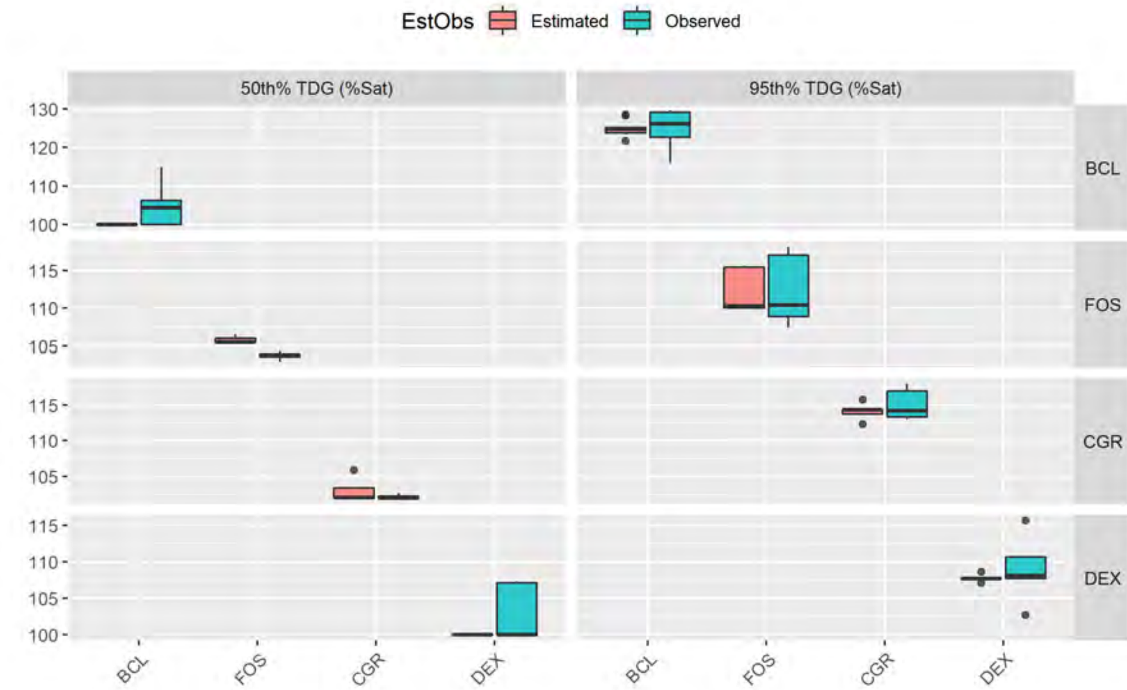

Figure 2-27. 50th and 95th percentile non-exceedance of estimated TDG under NAA (Estimated) compared to observed historical data (Observed) below Big Cliff (BCL), Foster (FOS), Cougar (CGR), and Dexter (DEX) Dams.

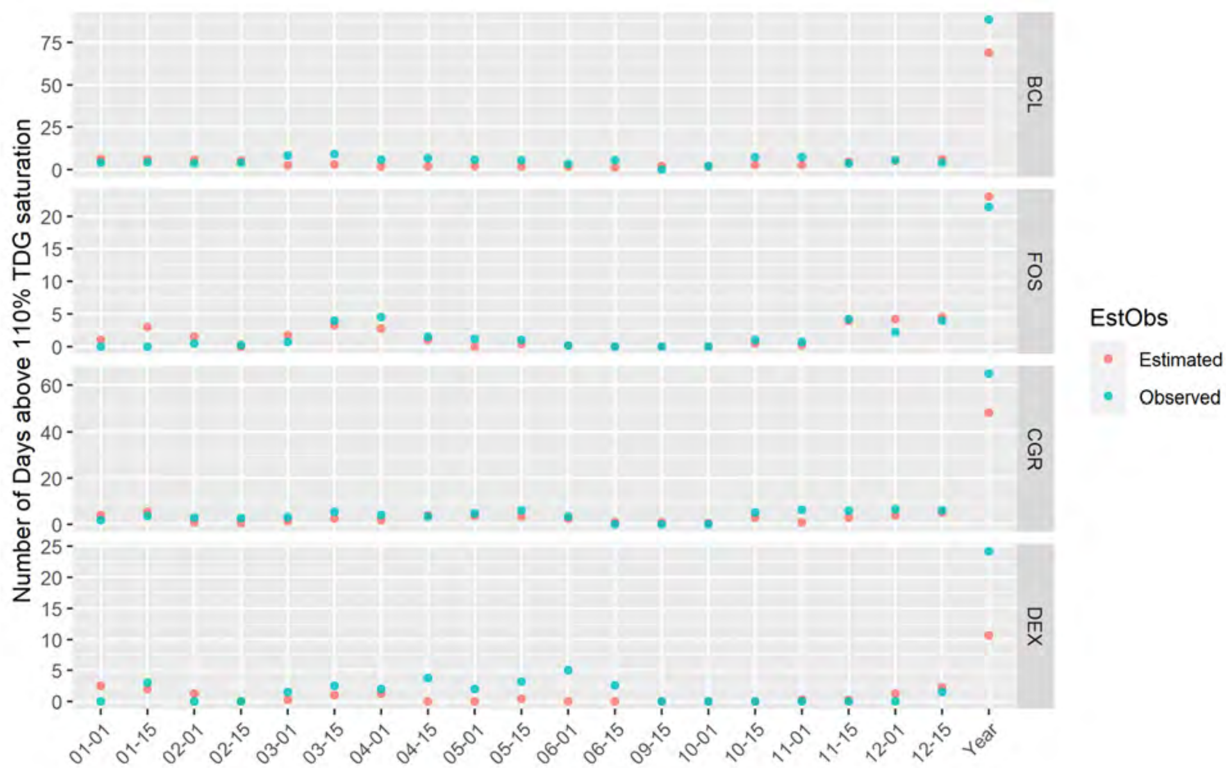

Figure 2-28. Number of days above 110% TDG in each bi-monthly period as estimated under NAA (Estimated) compared to observed historical data (Observed) below Big Cliff (BCL), Foster (FOS), Cougar (CGR), and Dexter (DEX) Dams.

Figure 2-29. Simulated operations and TDG at Detroit (DET) and Big Cliff (BCL) During three relatively large spring-time flow events comparing NAA (Estimated) to observed historical data (Observed). Abbreviations: spillRO; Regulating Outlet spill flow, spillSW; Spillway outlet flow, spilltotal; Total outflow.

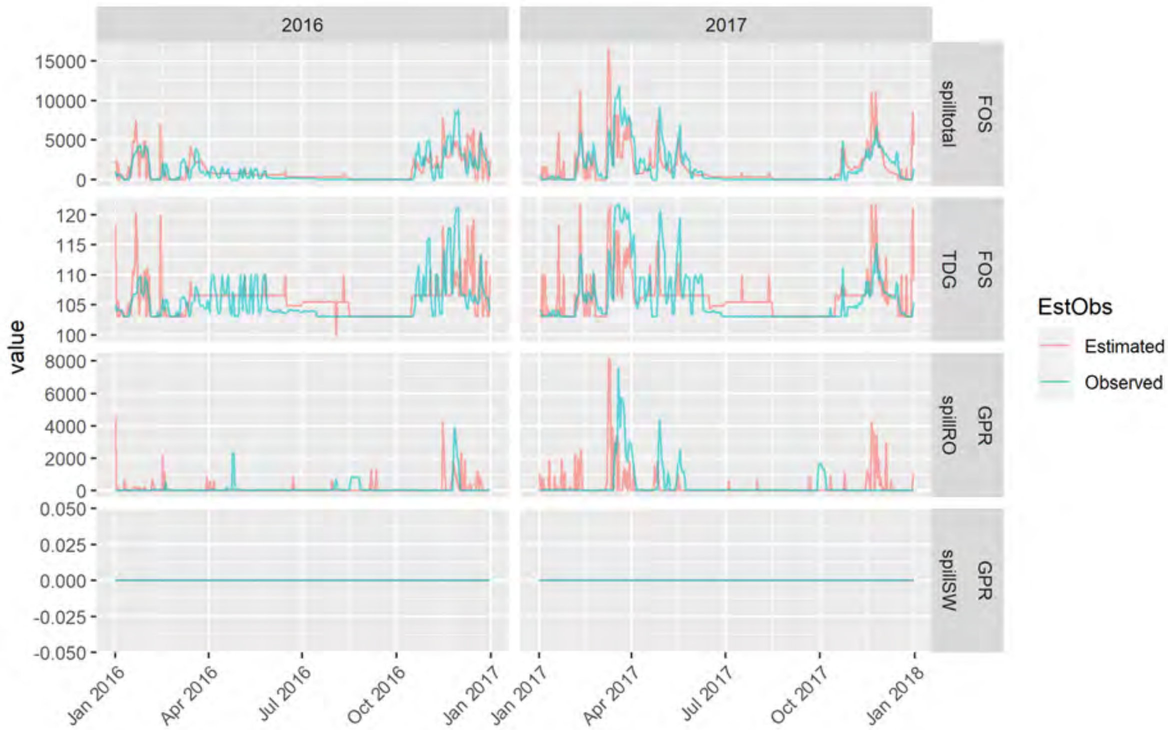

Figure 2-30. Simulated operations and TDG at Green Peter (GPR) and Foster (FOS) During Two relatively large spring-time flow events comparing NAA (Estimated) to observed historical data (Observed). Abbreviations: spillRO; Regulating Outlet spill flow, spillSW; Spillway outlet flow, spilltotal; Total outflow.

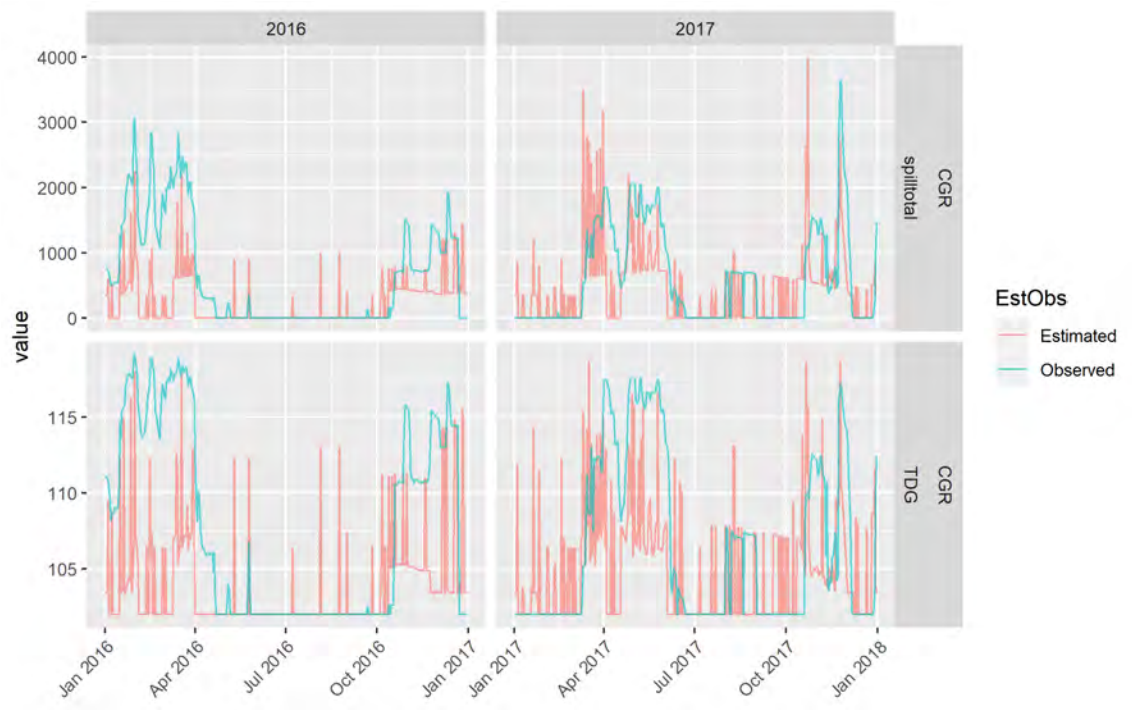

Figure 2-31. Simulated operations and TDG at Cougar (CGR) During Two relatively large spring-time flow events comparing NAA (Estimated) to observed historical data (Observed). Abbreviations: spillRO; Regulating Outlet spill flow, spillSW; Spillway outlet flow, spilltotal; Total outflow.

Figure 2-32. Simulated operations and TDG at Lookout Point (LOP) and Dexter (DEX) During two relatively large spring-time flow events comparing NAA (Estimated) to observed historical data (Observed). Abbreviations: spillRO; Regulating Outlet spill flow, spillSW; Spillway outlet flow, spilltotal; Total outflow.

2.1.3 Structural TDG Abatement Modeling Assumptions

Measure 174: Structural Improvements to reduce tailwater TDG where needed.

This measure describes structural modifications of current outlets, spillways or stilling basins to reduce tailwater TDG at Detroit, Big Cliff, Green Peter, Foster, Cougar, Lookout Point and Dexter Dams in the WVP. Previous work summarizing the monitoring efforts to compare structural and operational solutions for reducing TDG below Columbia River dams has shown varying degrees of success across different projects depending on flowrate per spillbay, number of spillbays, and spillway gate geometry/elevation/construction (USACE, 1996). A comparison of observed TDG reductions across studies is shown in Table 2-5. The following solutions have been evaluated in previous studies (USACE, 1996; USACE, 2002; USACE, 2009):

- **Spillway deflectors**, also called flip lips, have been installed at many Snake/Columbia River projects and are the most common structural solution for TDG abatement in the Columbia River. Spillway deflectors serve to redirect the spill jet from a plunging flow that transports air bubbles deep into the stilling basin to a horizontal jet that maintains entrained air much closer to the water surface (Figure 2-33). These deflectors are designed so that as the spillway discharge volumes increase (such as in a high river flow condition), the spillway discharges will eventually become high enough to override the spillway deflectors and begin the deep plunging action necessary for adequate energy dissipation. When projects operate outside of the spillway deflector design range, the spillway deflectors are less effective and may cause even higher TDG concentrations due to increased plunging depths in the stilling basin.

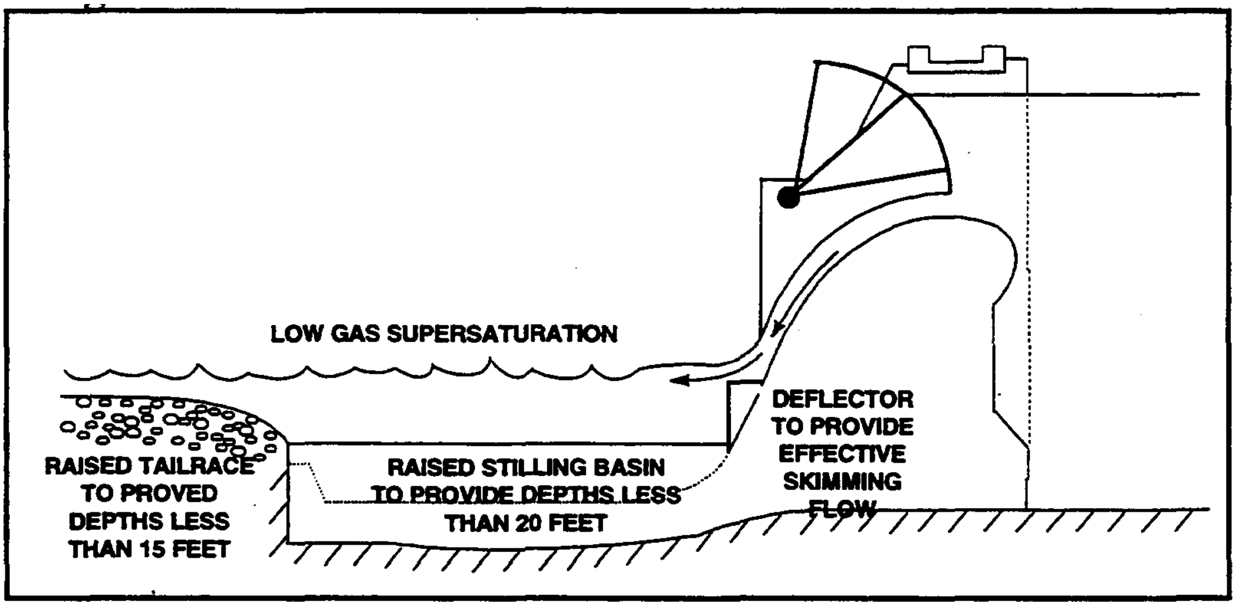

Figure 2-33. Conceptual Diagram of Potential Structural TDG Gas Abatement Structures (Figure 3.06.1 in USACE, 1996).

- **Raised tailrace or raised stilling basin** consists of added rock fill near the dam, contained by concrete cap to help reduce the plunging effect. This could result in a longer zone of turbulence and potentially increased erosion downstream of the dam. This may reduce the dam's structural integrity. Fish mortality from such structures is unknown.
- **Flip Bucket or Roller Bucket spillways** are intended to reduce the plunge depth. During low voluntary spillway discharges, the hydraulic jump will form in the flip bucket. During higher discharges the flip bucket will sweep out, and the discharge will plunge into the stilling basin below the flip bucket, which may produce high gas concentrations. A roller bucket looks somewhat like a flip bucket except that a roller bucket is submerged. Instead of dissipating energy by sweeping out during higher discharges, the roller bucket forms two horizontal rollers to dissipate energy.
- **Boulder augmentation or debris jams** could help create more natural riffles downstream of USACE projects and help degas supersaturated water. Little is known regarding the design and construction of riffles and debris jams and how effective these man-made structures may be for TDG abatement.
- **Spill patterns** that distribute spillbay flows uniformly across the entire spillway could help reduce downstream TDG. Dam safety protocols in the Willamette Valley Project limit the possibility of implementation during some higher flow conditions

- **Constructed pipe extensions** on the downstream side of ROs to submerge releases in the stilling basin could reduce jet impact on the tailwater surface.

Table 2-5. Summary of literature regarding observed TDG reduction associated with TDG abatement strategies.

Site	Details of TDG abatement structure	Approximate TDG % reduction downstream	Source and Notes
Rock Island Dam	Spillbay 29 flow deflector installed in 2000	4.5%	Carroll et al., 2001
Rock Island Dam	Spillbay 16 flow deflector installed in 2001	<6.0% (no values above 110%)	Carroll et al., 2002
Wanapum Dam	Deflectors installed at all spill bays in 2000	3-4% at flows < 60kcfs 1-2% at flow >100kcfs	USACE, 2001
Wanapum Dam	Deflectors installed at all spill bays in 2000	At Beverly Bridge: 9% at spill of 120kcfs 6% at spill of 150kcfs	Juul (2003) compared 2000-2001 to 1996-1997 data
Ice Harbor Dam	10 spillway flow deflectors installed in 1998	20% overall; peak reduction from 170 to 125 TDG	Schneider and Wilhelms, 2016
John Day Dam	18 spillway flow deflectors installed in 1999	Peak reduction from 170% to 125% TDG	DGAS Phase 2 (USACE, 2002)
Chief Joseph	Spillway flow deflectors installed 2006-2008	15% at flows >38kcfs	Schneider, 2012

The Dissolved Gas Abatement Study (DGAS) for the USACE Columbia River Dams determined that a combination of Spillway deflectors and/or a raised tailrace/stilling basin has the best opportunity to reduce TDG through structural solutions on the Columbia-Snake system (USACE, 1996). Following those findings, additional spillway deflectors were installed at the USACE Lower Snake and Columbia River Dams. The observed reductions to TDG in the studies shown in Table 2-5 are based on Columbia/Snake River flow, which can be roughly 10 times larger than the Willamette.

A reduction factor TDG estimation for alternatives that incorporated Measure 174 was considered given the following information:

- While there is a large difference in hydrology, dam configuration, and spillway gate sizes between the Columbia and Willamette Dams, the potential TDG reductions due to structural improvements generally ranged between 3% to 9%; higher TDG reductions within the normal range of spill. i

- Reductions in TDG realized through SYSTDG modeling of spreading spill across multiple spillway gates at Big Cliff Dam were about 10% (assuming 3000-6000 cfs range; see Figure 2-6).

Given this information (and lack of 3-dimensional computational fluid dynamics and dissolved gas modeling), a reduction factor of 5% was imposed for TDG estimates at BCL, FOS, CGR, and DEX exceeding 110 % in WV EIS Measure 174.

2.2 TDG RESULTS AND EFFECTS ANALYSIS

Available data from Detroit/Big Cliff, Green Peter/Foster, Lookout Point/Dexter, Hills Creek, and Cougar Dams was utilized to simulate TDG with the SYSTDG model. This model was adapted from the Columbia River System TDG model, SYSTDG, an empirical (data-driven) model depending primarily on spill outflow (non-turbine releases) and power outflow (turbine releases) at each dam. The period of record used by the RES-SIM modeling was applied to SYSTDG at the locations listed above for each alternative. For a complete listing of the measures included in each alternative, see Chapter 3.

The SYSTDG model output includes estimated TDG based on project operations and the annual number of days above 110% (Appendix D). TDG results are compared to the State of Oregon water quality standards in the Oregon Administrative Record (OAR) 340-041-0031: "Except when stream flow exceeds the ten-year, seven-day average flood, the concentration of total dissolved gas relative to atmospheric pressure at the point of sample collection may not exceed 110% of saturation".

Dam releases from non-turbine outlets (defined as "spill" in this EIS) are known to produce elevated TDG. The average number of days with spill per year are compared in each Alternative and dam (Figure 2-34) and help to explain locations and alternatives with relatively higher TDG. Generally, TDG is generated initially at the high-head dam when spill occurs (e.g., Detroit Dam) and can increase downstream if spill occurs at the downstream re-regulating dam (e.g., Big Cliff Dam). TDG estimates from SYSTDG were then tabulated as the average number of days exceeding 110% TDG per year (Figure 2-35). The annual number of days above 110% TDG is compared to the NAA for each alternative and summarized utilizing the TDG evaluation criteria (Figure 2-36). Effects are determined at the stream gage locations immediately downstream of the dams.

Due to timing of WV EIS alternative modeling prior to court-mandated injunction measures, TDG abatement modifications in Alternatives 1 and 4 represent an under-estimate of the expected TDG when incorporated into reasonably foreseeable actions over the planning horizon of the WV EIS. Correct estimates of TDG downstream of Big Cliff Dam would likely be 5% TDG points higher in Alternatives 1 and 4 than stated in this modeling effort. See the Cumulative Effects Section of this EIS for more information.

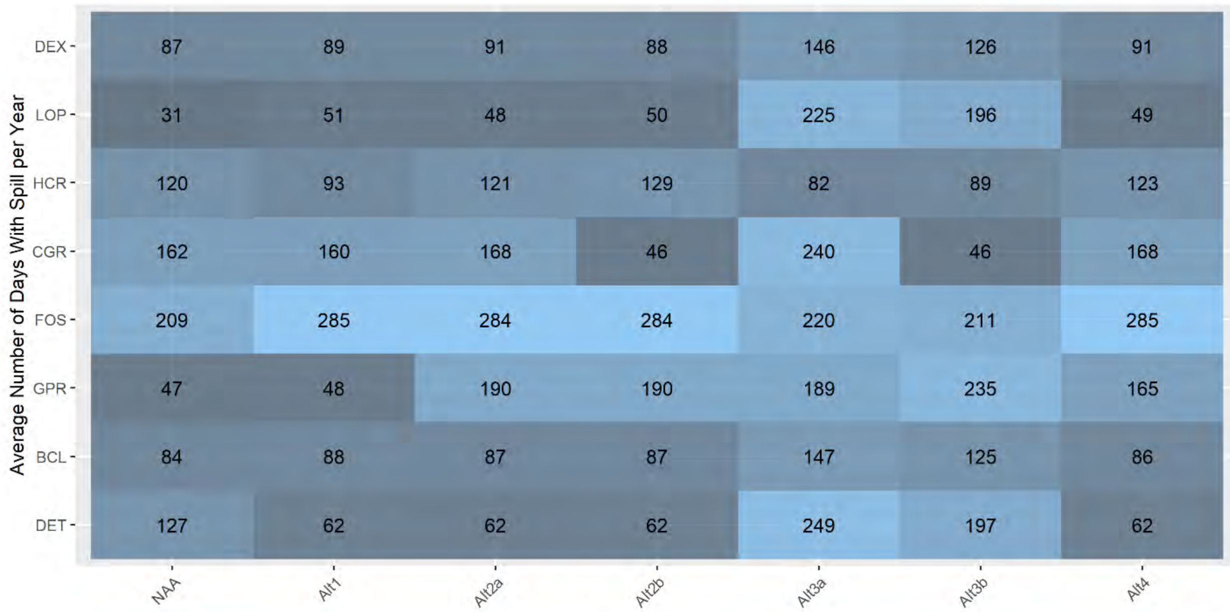

Figure 2-34. Average Number of Days with Spill per Year Under Each Alternative

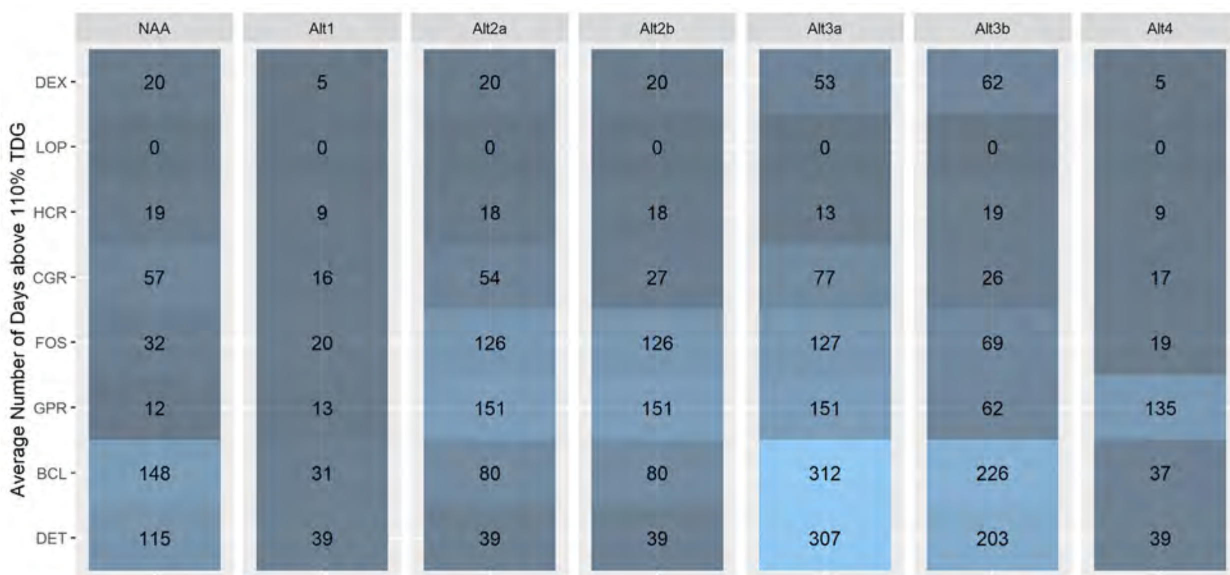

Figure 2-35. Average Number of Days above 110% TDG in Dam Tailraces Under Each Alternative

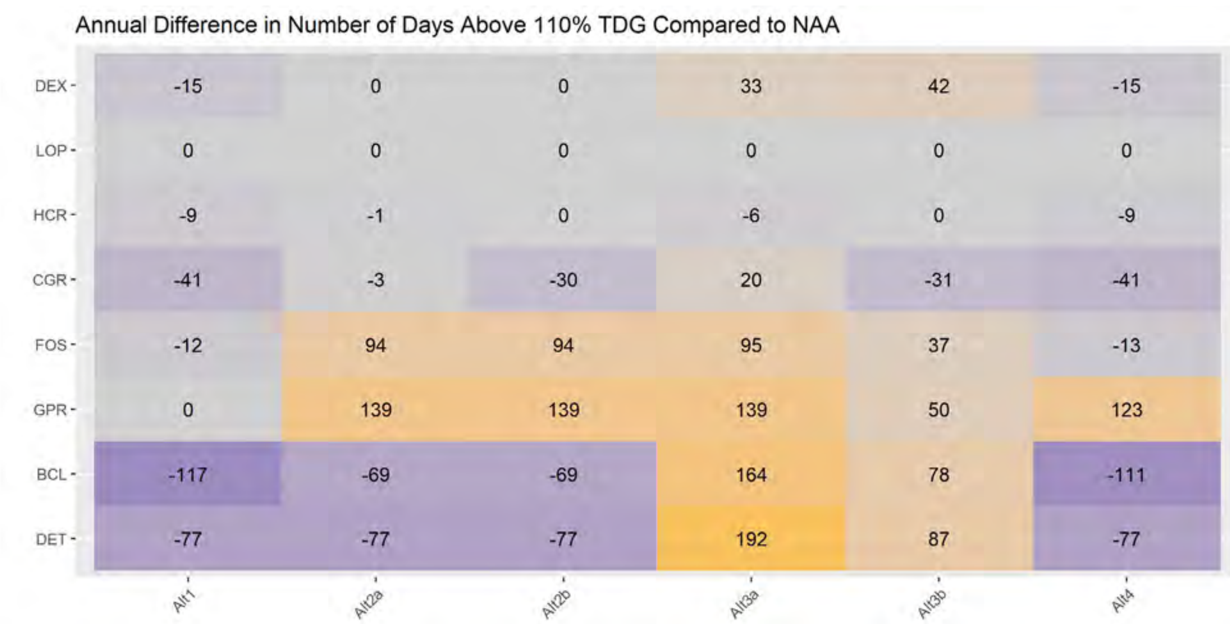

Figure 2-36. Annual Difference in Number of Days Above 110% TDG Compared to the No Action Alternative

The categorical TDG impacts at each location and alternative relative to NAA were developed based on the annual difference in number of days above 110% TDG compared to NAA (Table 2-6). These categorical thresholds were chosen to represent the distribution of the summary data shown in Table 2-7. The results from each alternative were summarized by each metric and then categorized based on tangible time frames that are easily relatable, i.e., increments of 25, 50, 100 days.

Table 2-6. Categorical TDG Impact Criteria Minimum Values

WV EIS Total Dissolved Gas Impact Criteria Minimum Values	
	Annual Average
Effect Criteria Thresholds	**Difference, in number of days, where TDG exceeds 110% compared to NAA**
Major Beneficial	-100
Moderate Beneficial	-50
Minor Beneficial	-25
Negligible	0
Minor Adverse	+25
Moderate Adverse	+50
Major Adverse	+100

Table 2-7. TDG Effects Based on Annual Number of Days above 110% TDG Levels Compared to the No Action Alternative

Location	Alt1	Alt2a	Alt2b	Alt3a	Alt3b	Alt4	Alt5
DET	Moderate Ben	Moderate Ben	Moderate Ben	Major Adv	Moderate Adv	Moderate Ben	Moderate Ben
BCL	Major Ben	Moderate Ben	Moderate Ben	Major Adv	Moderate Adv	Major Ben	Major Ben
GPR	Negligible	Major Adv	Major Adv	Major Adv	Minor Adv	Major Adv	Moderate Adv
FOS	Negligible	Moderate Adv	Moderate Adv	Moderate Adv	Minor Adv	Negligible	Negligible
CGR	Minor Ben	Negligible	Minor Ben	Negligible	Minor Ben	Minor Ben	Minor Ben
HCR	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible
LOP	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible
DEX	Negligible	Negligible	Negligible	Minor Adv	Minor Adv	Negligible	Negligible

2.2.1 No Action Alternative

A comparison of NAA with measurements is shown in Imposed Turbine Outages. Further information on NAA is available in Measure Assumptions.

2.2.1.1 NORTH SANTIAM DAMS

With current operations the same as stated in Section 3.6 Water Quality Affected Environment, exceedances of the 110% TDG water quality standard would continue to occur frequently downstream of Big Cliff (up to 148 days per year) and below Detroit Dam (up to 115 days per year; Figure 2-35). The Average Number of Days of Spill per Year would remain 127 at Detroit and 84 at Big Cliff (Figure 2-34).

2.2.1.2 SOUTH SANTIAM DAMS

Under the No Action Alternative operations would remain as described in the Section 3.6 Water Quality Affected Environment. Although no TDG measurements exist immediately downstream of Green Peter, it is estimated that the 110% TDG level would be exceeded 12 days per year on average based on the frequency of spill under NAA. Foster would be above 110% TDG for 32 days on average (Figure 2-35). The Average Number of Days of Spill per year would remain 47 days at Green Peter and 209 days at Foster (Figure 2-34).

2.2.1.3 MCKENZIE DAMS

Cougar reservoir would remain as described in the Section 3.6 Water Quality Affected Environment with an average of 57 days above 110% TDG levels (Figure 2-35). The Average Number of Days of Spill per year at Cougar would remain 162 days (Figure 2-34).

2.2.1.4 MIDDLE FORK WILLAMETTE DAMS

Hills Creek TDG would continue to exceed the 110% TDG water quality standard for an average of 19 days per year under NAA. Although no TDG measurements exist immediately downstream of Lookout Point, it is estimated that the 110% TDG level would not be exceeded. TDG immediately below Dexter would continue above 110% for an average of 20 days per year (Figure 2-35). The Average Number of Days of Spill per year would continue at Hills Creek with 120 days, Lookout Point would continue to be 31 days and Dexter would continue to be 87 days (Figure 2-34).

2.2.2 Alternative 1 – Project Storage Alternative

Alternative 1 includes structural improvement measures to reduce TDG at Detroit, Big Cliff, Green Peter, Foster, Lookout Point, Dexter, and Cougar dams. Measure 174 in Alternative 1 applied to LOP-DEX, CGR, GPR-FOS, and DET-BCL and resulted in an estimated 5% reduction in TDG values above 110% at the control point immediately below the lowest dam in each sub-basin (Figure 2-37, Figure 2-38, Figure 2-39).

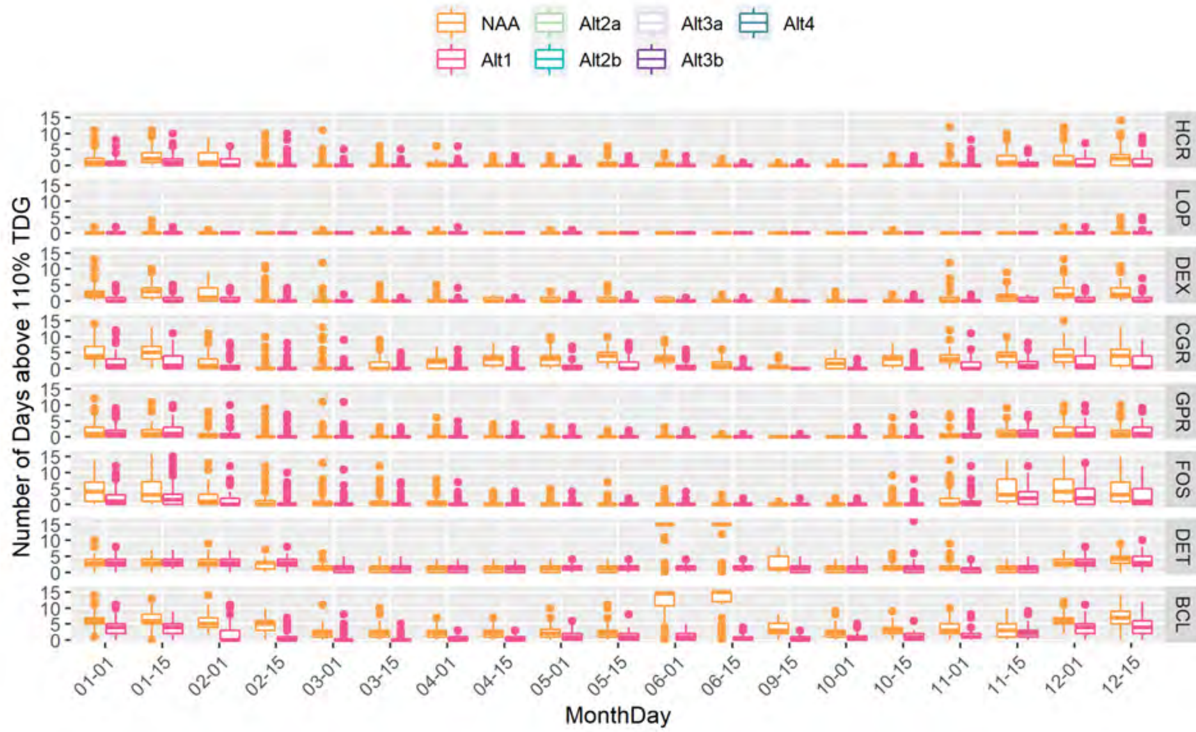

Figure 2-37. Number of days in each half-month period over the period of record (1936-2019) based on SYS-TDG estimated TDG for Alternative 1 and NAA.

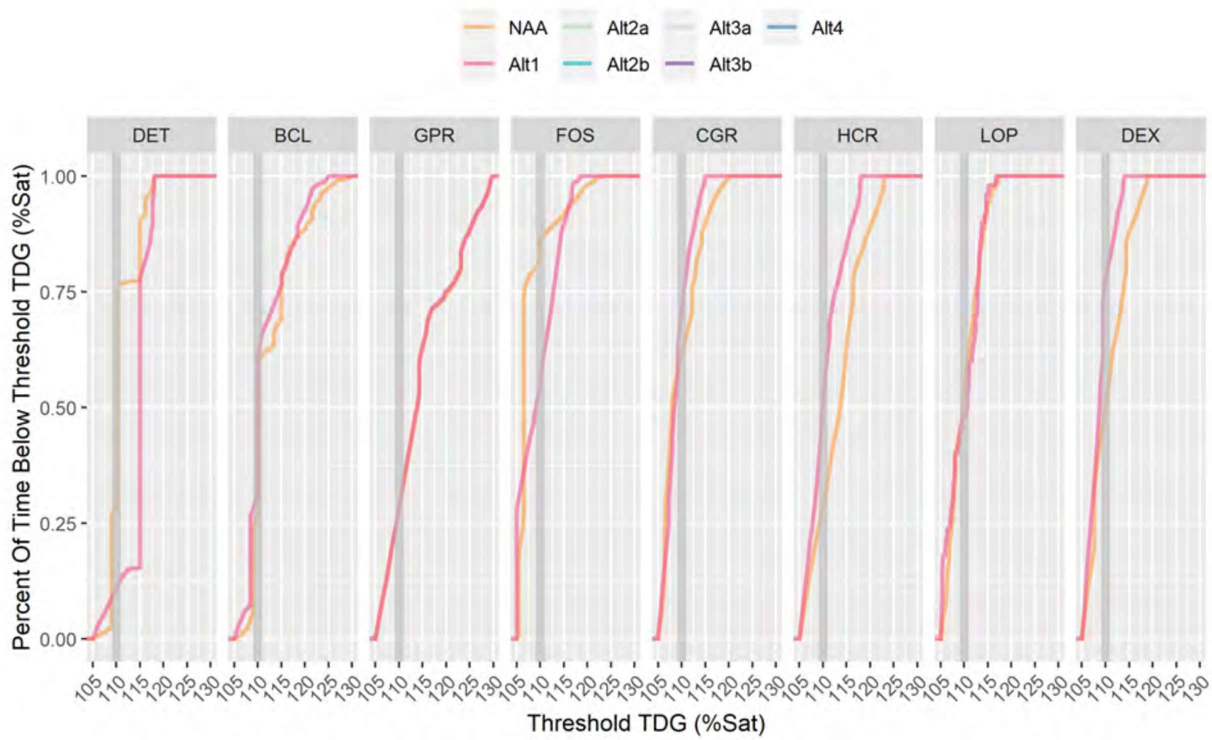

Figure 2-38. Cumulative distribution curves showing percent of time below a threshold TDG (% Saturation) in the period of record (1927-2018) based on SYS-TDG estimated TDG for Alternative 1 and NAA.

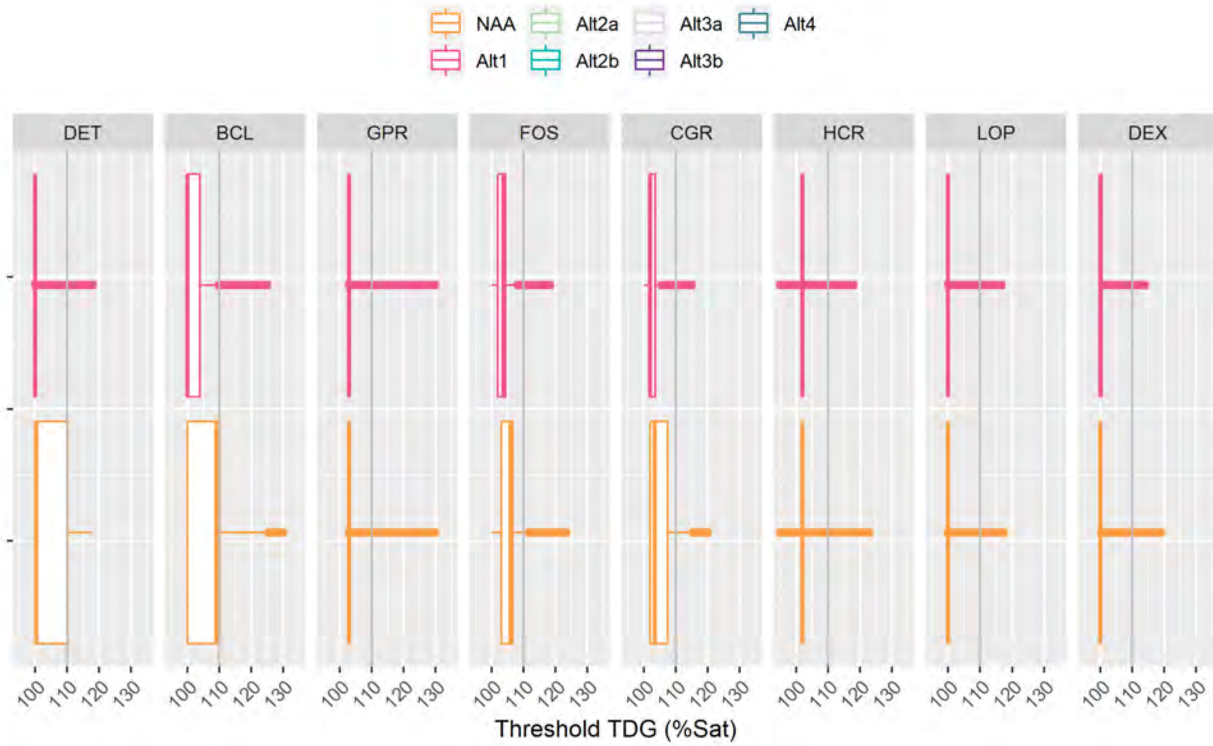

Figure 2-39. Boxplots of TDG (% Saturation) over the period of record (1936-2019) based on SYS-TDG estimated TDG for Alternative 1 and NAA. Boxes represent the first and third quantile (25th and 75th percentiles).

2.2.2.1 NORTH SANTIAM DAMS

Under Alternative 1, the average number of days above 110% TDG levels at Big Cliff is 31 and Detroit is 39 (Figure 2-35). This equates to a reduction in TDG below Big Cliff of 117 annually. Annual differences in number of days above 110% of TDG exceedances and below Detroit is reduced to 77 days as compared to the No Action Alternative (Figure 2-36). The Average Number of Days of Spill per year at Detroit is 62 days and Big Cliff is 88 days (Figure 2-34).

2.2.2.2 SOUTH SANTIAM DAMS

Under Alternative 1, Green Peter reservoir results in 13 average number of days above 110% TDG levels, whereas Foster would be 20 average number of days above 110% (Figure 2-35). Green Peter has a reduction of 0 days of TDG exceedances and Foster is reduced by 12 days as compared to the No Action Alternative (Figure 2-36). The Average Number of Days of Spill per year at Green Peter is 48 days and Foster is 285 days (Figure 2-34).

2.2.2.3 MCKENZIE DAMS

Under Alternative 1, the average number of days above 110% TDG levels would be 16 at Cougar reservoir (Figure 2-35). Cougar reservoir has a reduction of 41 days of TDG exceedances as compared to the No Action Alternative (Figure 2-36). The Average Number of Days of Spill per year at Cougar is 160 days under Alternative 1 (Figure 2-34). Blue River is expected to have similar operations as stated in the Affected Environment and NAA. As the RO's are routinely utilized and not turbines TDG levels would not be expected to change.

2.2.2.4 MIDDLE FORK WILLAMETTE DAMS

Under Alternative 1, the Average number of days above 110% TDG levels at Hills Creek is 9 average days, Lookout Point is 0, and Dexter is 5 average days (Figure 2-35). Hills Creek has a reduction of 9 days of TDG exceedances, Lookout Point has 0 days reduction, and Dexter is reduced by 15 days as compared to the No Action Alternative (Figure 2-36). The Average Number of Days of Spill per year at Hills Creek is 93 days, Lookout Point is 51 days and Dexter is 89 days (Figure 2-34). Fall Creek is expected to have similar operations as stated in the Affected Environment and NAA, as such there would not be expected TDG levels to change.

2.2.3 Alternative 2a - Hybrid Alternative

There are no measures to reduce TDG at the WVS dams in Alternative 2a. Boxplots in each half-month period, cumulative distribution curves, and annual boxplots comparing Alternative 2a and NAA are shown in Figure 2-40, Figure 2-41, and Figure 2-42 respectively.

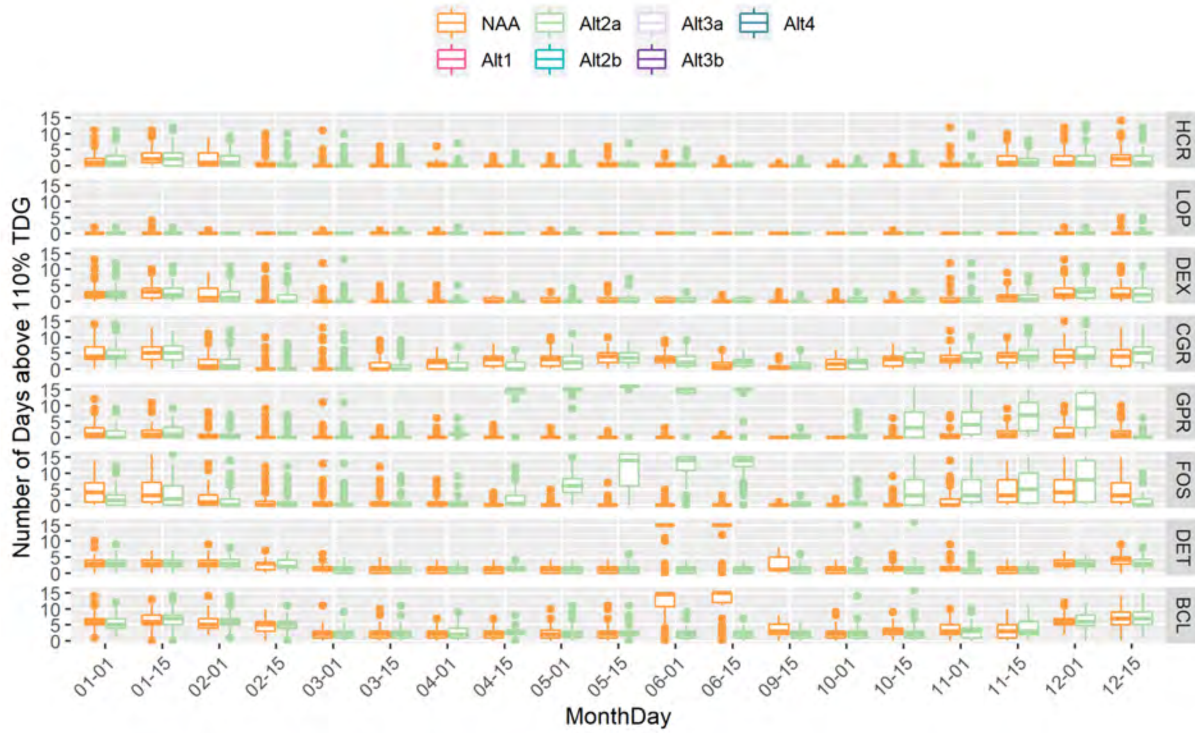

Figure 2-40. Number of days in each half-month period over the period of record (1936-2019) based on SYS-TDG estimated TDG for Alternative 2a and NA

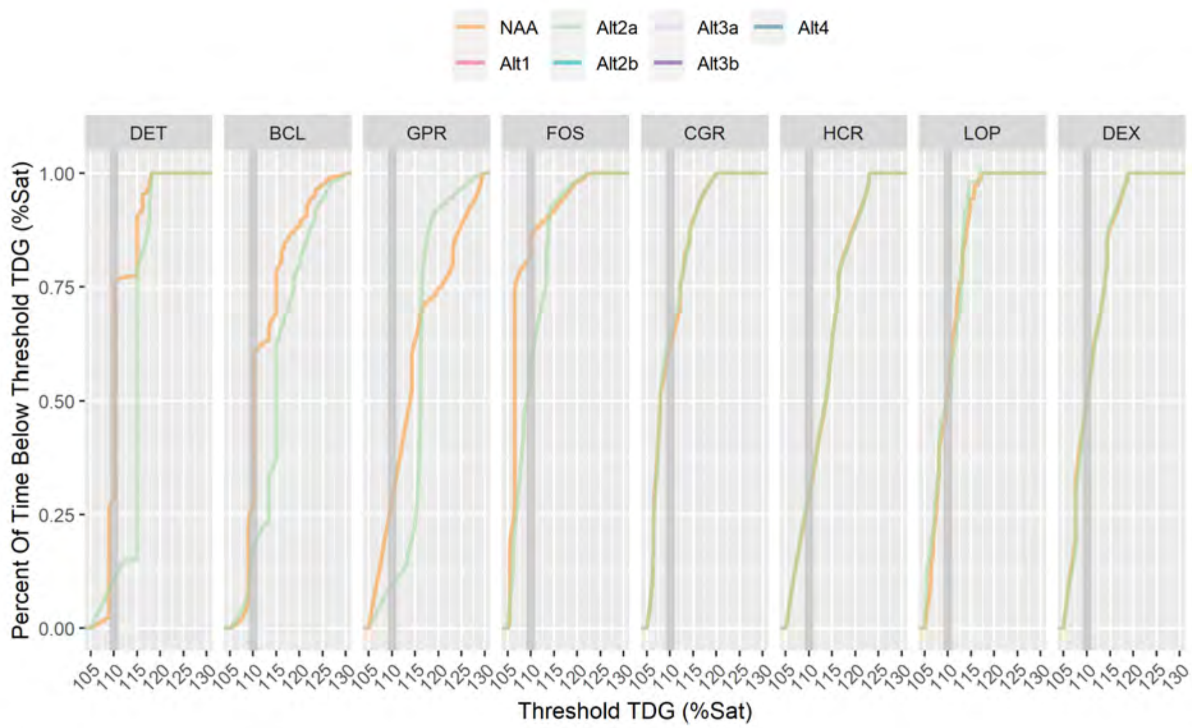

Figure 2-41. Cumulative distribution curves showing percent of time below a threshold TDG (% Saturation) in the period of record (1927-2018) based on SYS-TDG estimated TDG for Alternative 2a and NAA.

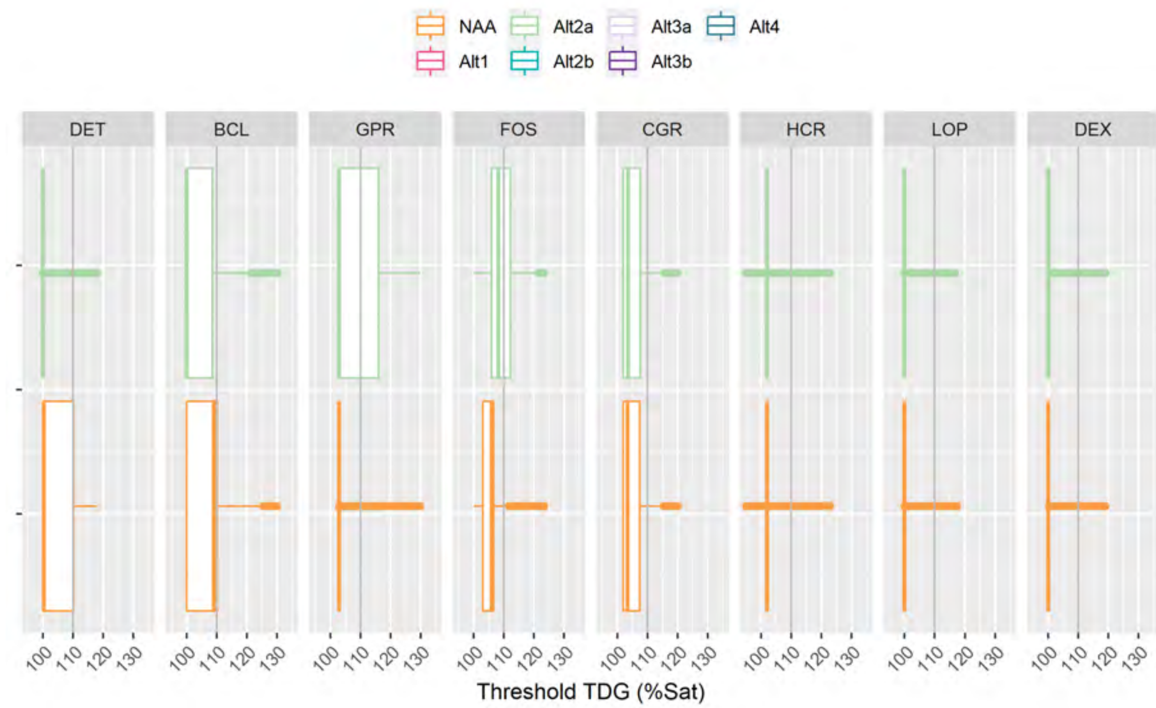

Figure 2-42. Boxplots of TDG (% Saturation) over the period of record (1936-2019) based on SYS-TDG estimated TDG for Alternative 2a and NAA. Boxes represent the first and third quantile (25th and 75th percentiles).

2.2.3.1 NORTH SANTIAM DAMS

Under Alternative 2a, Detroit reservoir is observed to have 39 average number of days above 110% TDG levels and Big Cliff is 80 average number of days (Figure 2-35). Detroit reservoir is reduced by 77 days and Big Cliff has a reduction in 69 Annual difference in number of days above 110% of TDG exceedances as compared to the No Action Alternative (Figure 2-36). The Average Number of Days of Spill per year at Detroit is 62 days and Big Cliff is 87 days (Figure 2-34).

2.2.3.2 SOUTH SANTIAM DAMS

Under Alternative 2a, the average number of days above 110% TDG levels at Green Peter is 151 days and Foster is 126 days (Figure 2-35). Green Peter has an increase of 139 days of TDG exceedances and Foster is increased by 94 days as compared to the No Action Alternative (Figure 2-36). The Average Number of Days of Spill per year at Green Peter is 190 days and Foster is 284 days (Figure 2-34).

2.2.3.3 MCKENZIE DAMS

There are no TDG management measures for Cougar or Blue River Reservoirs. Under Alternative 2a, the average number of days above 110% TDG levels at Cougar is 54 days (Figure

2-35). Observing the Annual difference in number of days above 110% of TDG exceedance Cougar is decreased by 3 days as compared to the No Action Alternative (Figure 2-36). The Average Number of Days of Spill per year at Cougar is 168 days (Figure 2-34).

In Table 3.2-3 Hydrologic Processes states “slightly lower flow in spring of dry years as reservoir fills. Higher summer flow in dry years”. TDG exceedance may occur if water is released through the non-turbine outlets of dams, spill and maintenance operations.

2.2.3.4 MIDDLE FORK WILLAMETTE DAMS

Under Alternative 2a, Lookout Point has reduction of 0 days and on average 0 days of TDG exceedance for the year (Figure 2-35). Dexter dam is reduced by 0 days and exceeds TDG by 20days by average number of days (Figure 2-36). Hills Creek dam has a reduction of 1 day of Annual Difference in Number of Days above 110% and on average number of days exceeds TDG by 18 days as compared to the No Action Alternative. The Average Number of Days of Spill per year at Hills Creek is 121 days, Lookout Point is 48 days, and Dexter is 91 days (Figure 2-34).

2.2.4 Alternative 2b -- Hybrid Alternative

Alternative 2b has no measures to reduce TDG although modelling results are included. Boxplots in each half-month period, cumulative distribution curves, and annual boxplots comparing Alternative 2b and NAA are shown in Figure 2-43, Figure 2-44, and Figure 2-45 respectively.

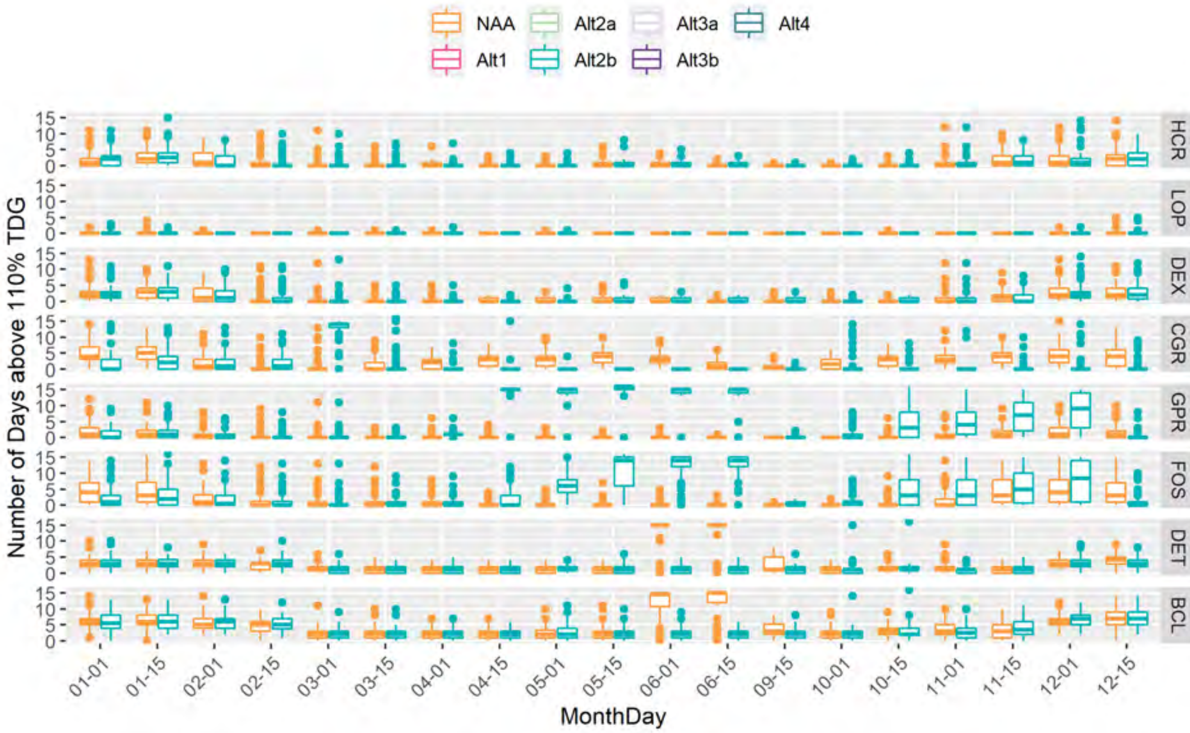

Figure 2-43. Number of days in each half-month period over the period of record (1936-2019) based on SYS-TDG estimated TDG for Alternative 2b and NAA.

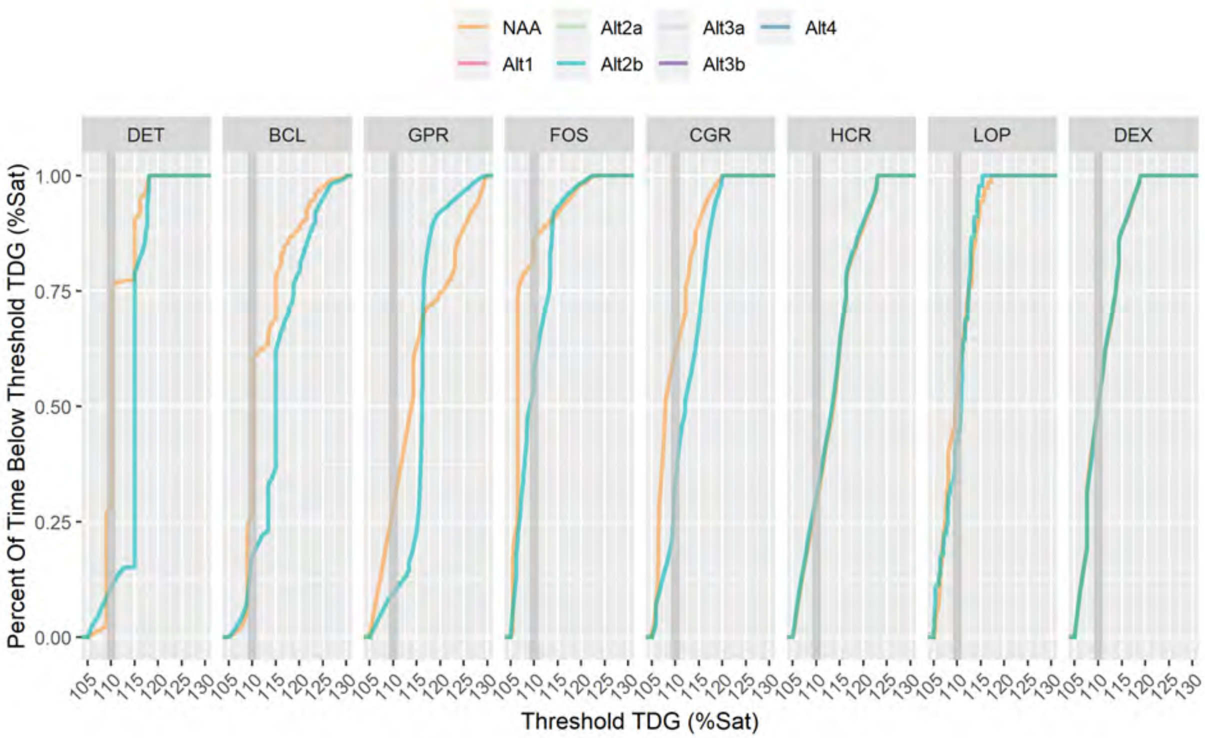

Figure 2-44. Cumulative distribution curves showing percent of time below a threshold TDG (% Saturation) in the period of record (1936-2019) based on SYS-TDG estimated TDG for Alternative 2b and NAA.

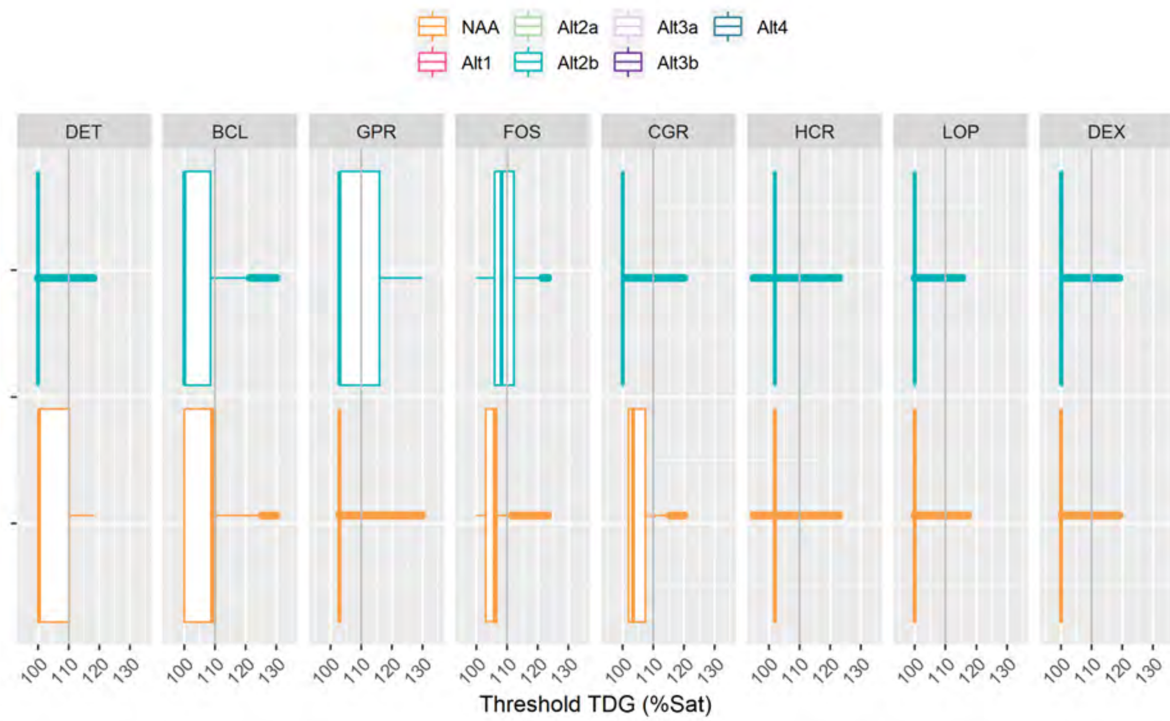

Figure 2-45. Boxplots of TDG (% Saturation) over the period of record (1936-2019) based on SYS-TDG estimated TDG for Alternative 2b and NAA. Boxes represent the first and third quantile (25th and 75th percentiles).

2.2.4.1 NORTH SANTIAM DAM

Under Alternative 2b, the average number of days above 110% TDG levels at Big Cliff is 80 and Detroit is 39 (Figure 2-35). Big Cliff has a reduction in 69 Annual difference in number of days above 110% of TDG exceedances and Detroit is reduced by 77 days as compared to the No Action Alternative (Figure 2-36). The Average Number of Days of Spill per year at Detroit is 62 days and Big Cliff is 87 days (Figure 2-34).

2.2.4.2 SOUTH SANTIAM DAMS

There are no TDG measures within Alternative 2b for Green Peter and Foster reservoirs.

Under Alternative 2b, the average number of days above 110% TDG levels at Green Peter is 151 days and Foster is 126 days (Figure 2-35). Green Peter has an increase of 139 days of TDG exceedances and Foster is increased by 94 days as compared to the No Action Alternative (Figure 2-36). The Average Number of Days of Spill per year at Green Peter is 190 days and Foster is 284 days (Figure 2-34).

2.2.4.3 MCKENZIE DAMS

There are no TDG management measures for Alternative 2b for Cougar Reservoir. Under Alternative 2b, the average number of days above 110% TDG levels at Cougar is 27 days (Figure 2-35). Observing the Annual difference in number of days above 110% of TDG exceedance Cougar is decreased by 30 days as compared to the No Action Alternative (Figure 2-36). The Average Number of Days of Spill per year at Cougar is 46 days (Figure 2-34).

2.2.4.4 MIDDLE FORK WILLAMETTE DAMS

There are no TDG measures for Hills Creek, Lookout Point and Dexter dams although model analysis has determined effects to the sub-basin. Under Alternative 2b, Lookout Point has reduction of 0 days and on average 0 days of TDG exceedance for the year (Figure 2-35). Dexter dam TDG is reduced by 0 days and exceeds TDG by 20 days as compared to the average number of days (Figure 2-36). Hills Creek dam has a reduction of 0 days of Annual Difference in Number of Days above 110% and on average number of days exceeds TDG by 18 days as compared to the No Action Alternative. The Average Number of Days of Spill per year at Hills Creek is 129 days, Lookout Point is 50 days, and Dexter is 88 days (Figure 2-34).

2.2.5 Alternative 3a – Operations-Focused Fish Passage

A summary of Alternative 3a measures include operation based TDG spreading of water over the spillway in order to reduce TDG % exceedances at Detroit, Big Cliff, Foster, Lookout Point, and Dexter dams. Boxplots in each half-month period, cumulative distribution curves, and annual boxplots comparing Alternative 3a and NAA are shown in Figure 2-46, Figure 2-47, and Figure 2-48 respectively.

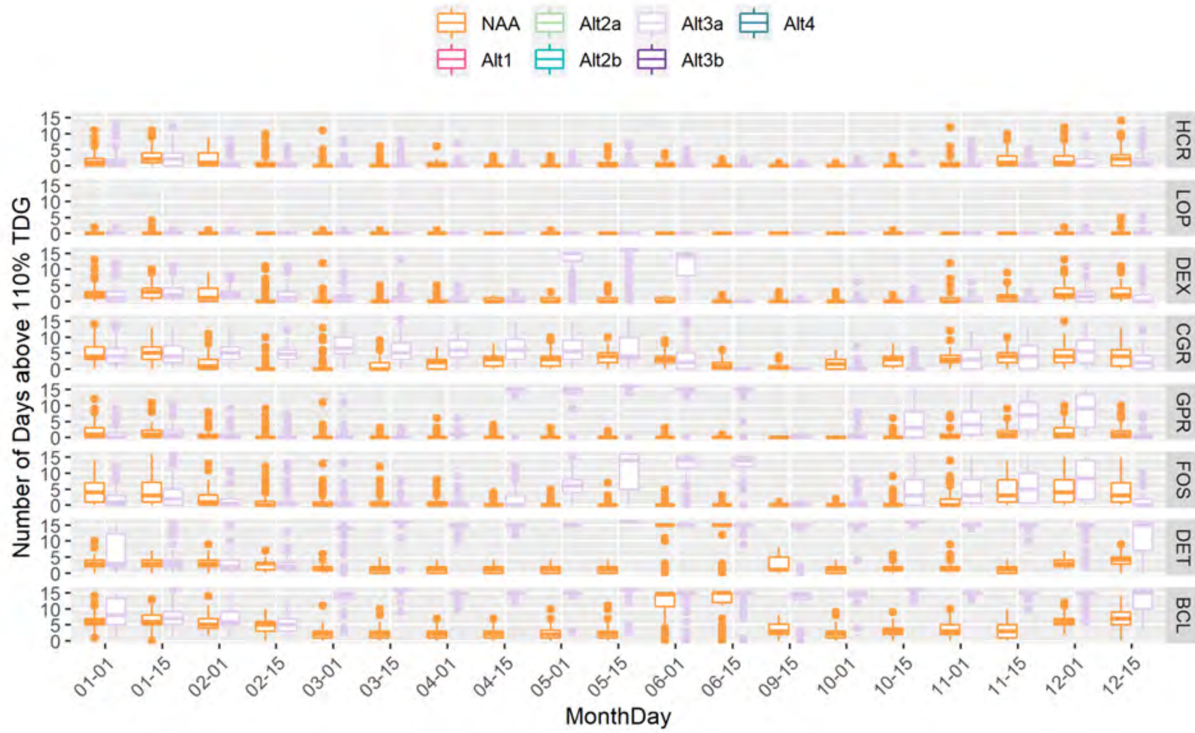

Figure 2-46. Number of days in each half-month period over the period of record (1936-2019) based on SYS-TDG estimated TDG for Alternative 3a and NAA.

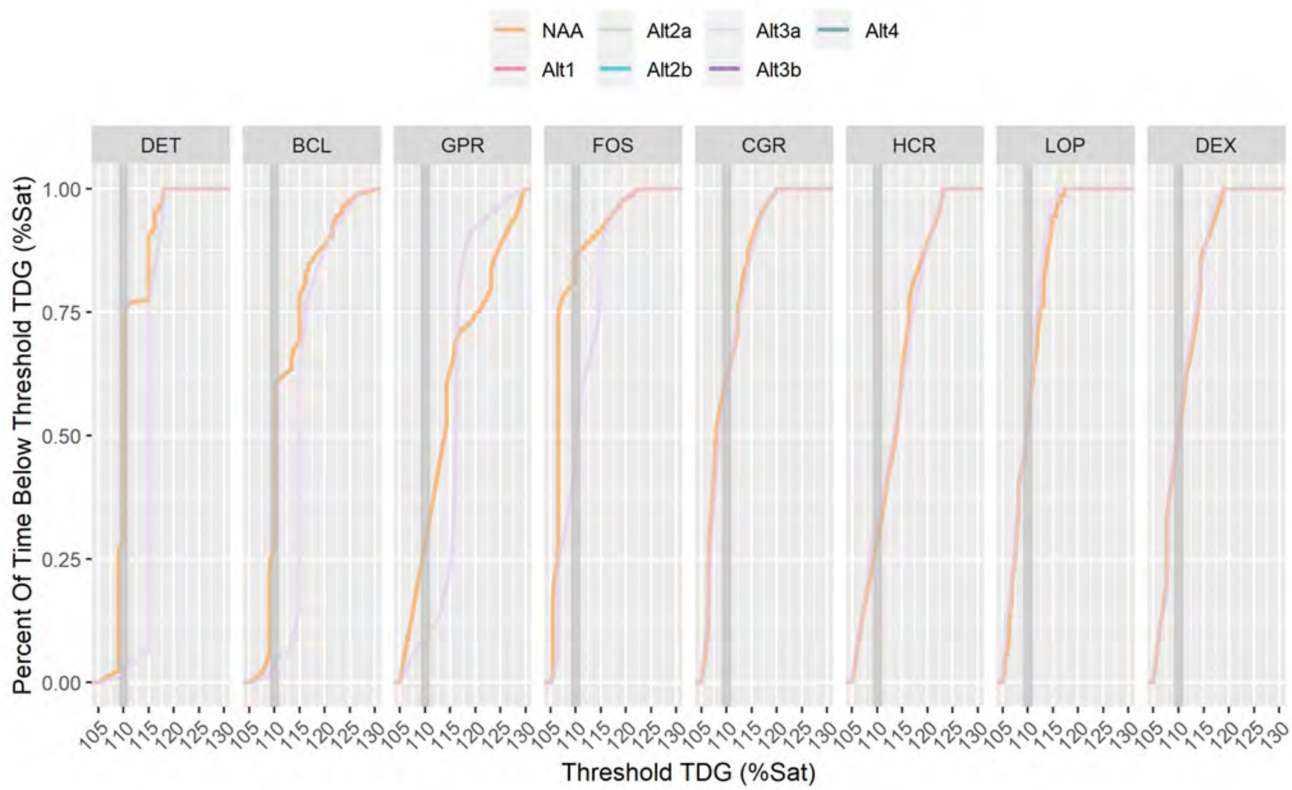

Figure 2-47. Cumulative distribution curves showing percent of time below a threshold TDG (% Saturation) in the period of record (1936-2019) based on SYS-TDG estimated TDG for Alternative 3a and NAA.

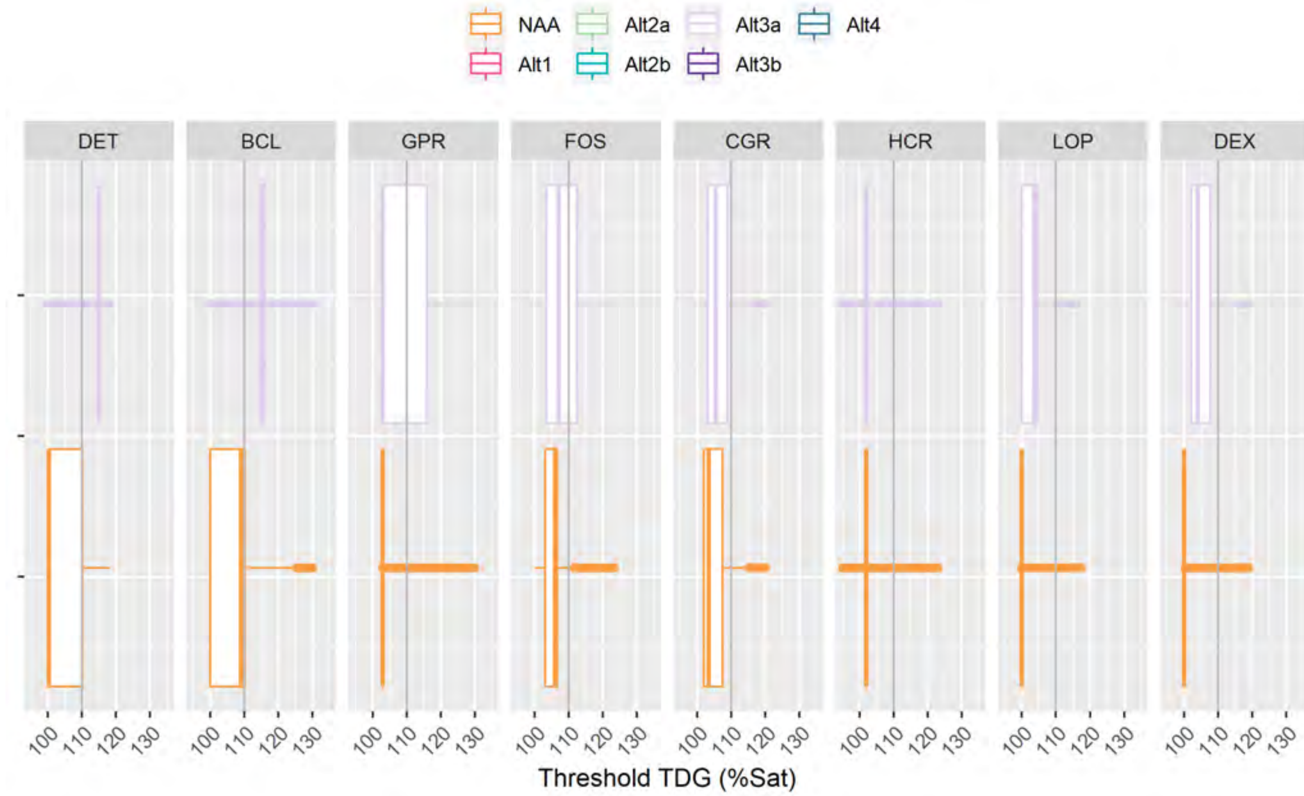

Figure 2-48. Boxplots of TDG (% Saturation) over the period of record (1936-2019) based on SYS-TDG estimated TDG for Alternative 3a and NAA. Boxes represent the first and third quantile (25th and 75th percentiles).

2.2.5.1 NORTH SANTIAM DAM

Under Alternative 3a, the average number of days above 110% TDG levels at Big Cliff is 312 and Detroit is 307 (Figure 2-35). Observing the Annual difference in number of days above 110% of TDG exceedances Big Cliff has an increase of 164 days and Detroit is increased by 192 days as compared to the No Action Alternative (Figure 2-36). The Average Number of Days of Spill per year at Big Cliff is 147 days and Detroit is 249 (Figure 2-34).

2.2.5.2 SOUTH SANTIAM DAMS

Under Alternative 3a, the average number of days above 110% TDG levels at Green Peter is 151 days and Foster is 127 days (Figure 2-35). Observing the Annual difference in number of days above 110% of TDG exceedances Green Peter has an increase of 139 days and Foster is 95 days as compared to the No Action Alternative (Figure 2-36). The Average Number of Days of Spill per year at Green Peter is 189 days and Foster is 220 days (Figure 2-34).

2.2.5.3 MCKENZIE DAMS

There are no TDG measures under Alternative 3a for Cougar Reservoir. Under Alternative 3a, the average number of days above 110% TDG levels at Cougar is 77 days (Figure 2-35). Observing the Annual difference in number of days above 110% of TDG exceedance Cougar is 20 days as compared to the No Action Alternative (Figure 2-36). The Average Number of Days of Spill per year at Cougar is 240 days (Figure 2-34).

2.2.5.4 MIDDLE FORK WILLAMETTE DAMS

TDG measures under Alternative 3a are to spread spill across the dam for TDG management at Lookout Point and Dexter dams. Under Alternative 3a, the average number of days above 110% TDG levels at Hills Creek is 13 days, Lookout Point is 0 days, and Dexter is 53 days (Figure 2-35). Observing the Annual difference in number of days above 110% of TDG exceedances Hills Creek is decreased by 6 days, Lookout Point is 0 days, and Dexter is increased to 33 days as compared to the No Action Alternative (Figure 2-36). The Average Number of Days of Spill per year at Hills Creek is 82 days, Lookout Point is 225 days, and Dexter is 146 days (Figure 2-34).

2.2.6 Alternative 3b – Operations-Focused Fish Passage Alternative (using diversion tunnel at COU)

Alternative 3b includes operation based TDG measures by spreading of water over the spillway to reduce TDG % exceedances at Detroit, Big Cliff, Foster, Lookout Point, and Dexter dams. Boxplots in each half-month period, cumulative distribution curves, and annual boxplots comparing Alternative 3b and NAA are shown in Figure 2-49, Figure 2-50, and Figure 2-51 respectively.

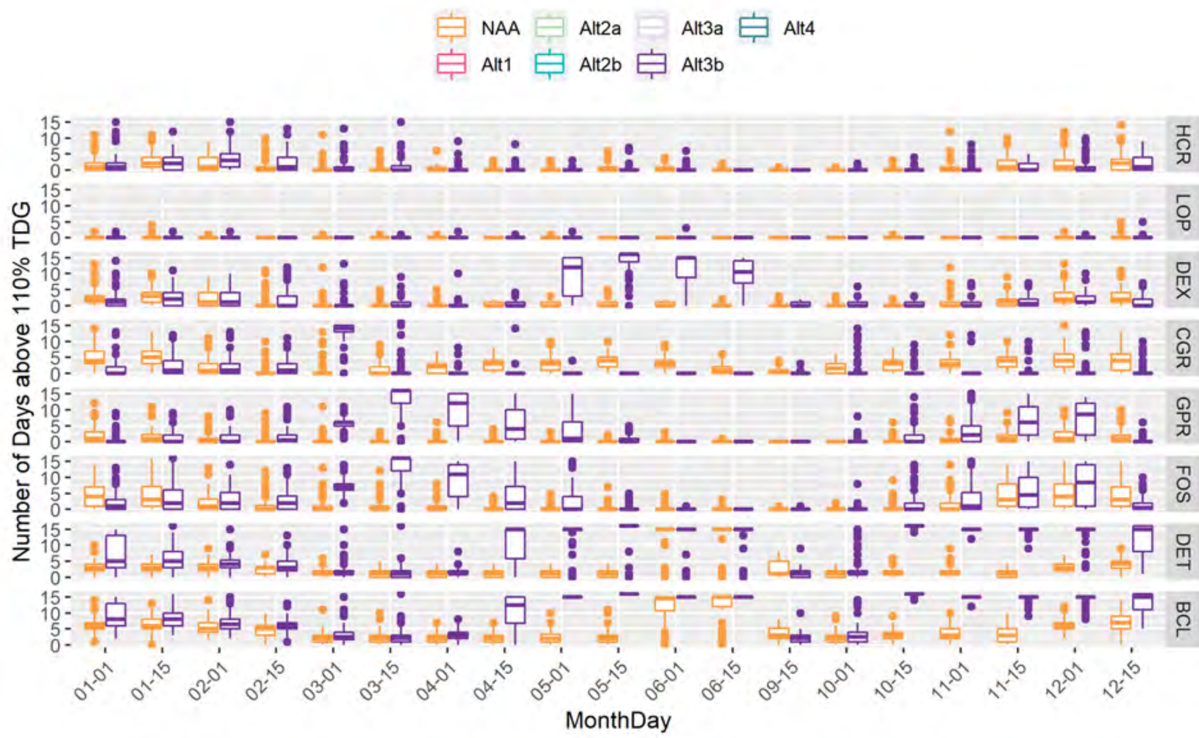

Figure 2-49. Number of days in each half-month period over the period of record (1936-2019) based on SYS-TDG estimated TDG for Alternative 3b and NAA.

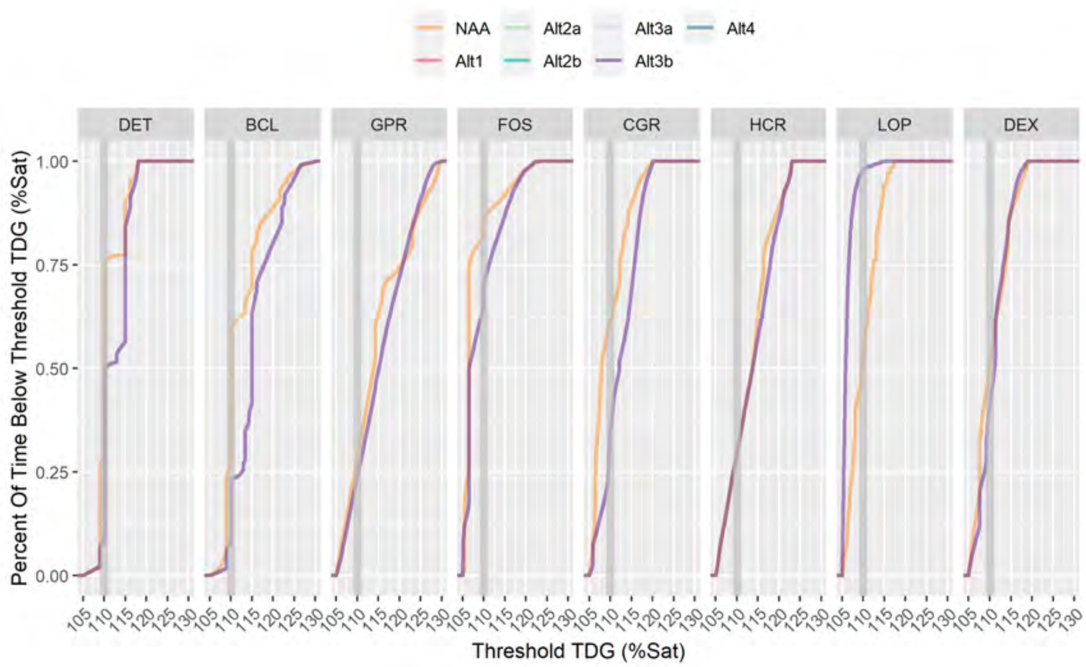

Figure 2-50. Cumulative distribution curves showing percent of time below a threshold TDG (% Saturation) in the period of record (1936-2019) based on SYS-TDG estimated TDG for Alternative 3b and NAA.

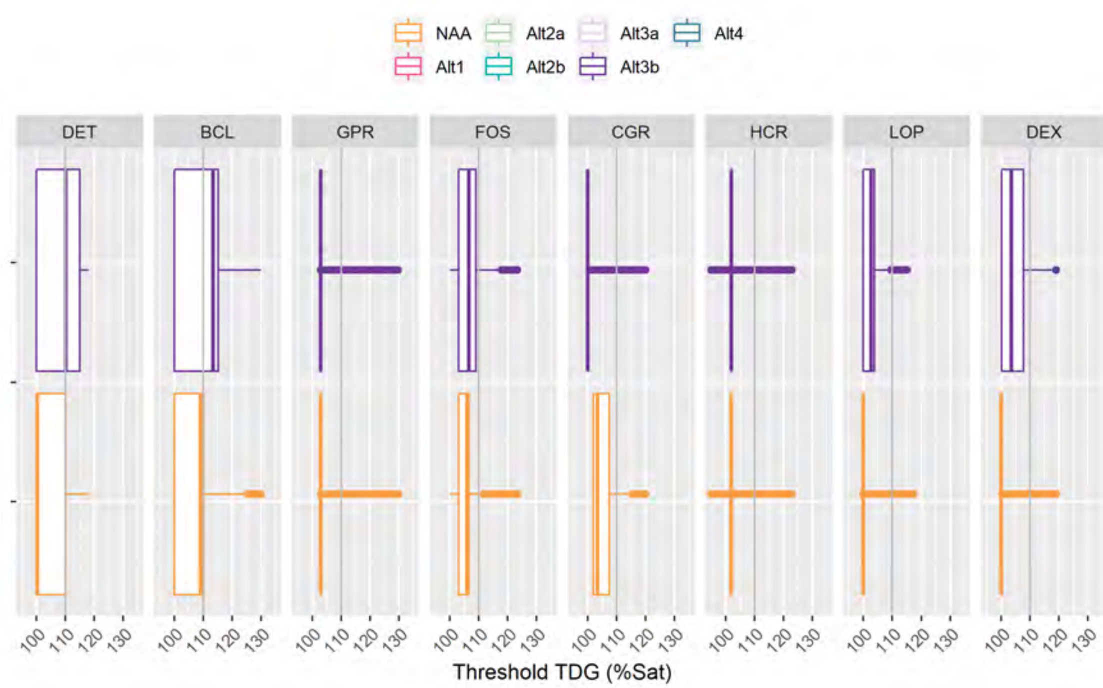

Figure 2-51. Boxplots of TDG (% Saturation) over the period of record (1936-2019) based on SYS-TDG estimated TDG for Alternative 3b and NAA. Boxes represent the first and third quantile (25th and 75th percentiles).

2.2.6.1 NORTH SANTIAM DAM

Under Alternative 3b, the average number of days above 110% TDG levels at Big Cliff is 226 and Detroit is 203 (Figure 2-35). Observing the Annual difference in number of days above 110% of TDG exceedances Big Cliff has an increase of 78 days and Detroit is increased by 87 days as compared to the No Action Alternative (Figure 2-36). The Average Number of Days of Spill per year at Big Cliff is 125 days and Detroit is 197 (Figure 2-34).

2.2.6.2 SOUTH SANTIAM DAMS

A measure to spread spill is included for Foster reservoir for TDG management. Under Alternative 3b, the average number of days above 110% TDG levels at Green Peter is 62 days and Foster is 69 days (Figure 2-35). Observing the Annual difference in number of days above 110% of TDG exceedances Green Peter has an increase of 50 days and Foster is 37 days as compared to the No Action Alternative (Figure 2-36). The Average Number of Days of Spill per year at Green Peter is 235 days and Foster is 211 days (Figure 2-34).

2.2.6.3 MCKENZIE DAMS

Under Alternative 3b, the average number of days above 110% TDG levels at Cougar is 26 days (Figure 2-35). Observing the Annual difference in number of days above 110% of TDG exceedance Cougar is decreased to 31 days as compared to the No Action Alternative (Figure 2-36). The Average Number of Days of Spill per year at Cougar is 46 days (Figure 2-34).

2.2.6.4 MIDDLE FORK WILLAMETTE DAMS

Measures for Alternative 3b are to spread spill across the dam for TDG management at Lookout Point and Dexter dams. Under Alternative 3b, the average number of days above 110% TDG levels at Hills Creek is 19 days, Lookout Point is 0 days, and Dexter is 62 days (Figure 2-35). Observing the Annual difference in number of days above 110% of TDG exceedances Hills Creek is 0 days, Lookout Point is 0 days, and Dexter is increased to 42 days as compared to the No Action Alternative (Figure 2-36). The Average Number of Days of Spill per year at Hills Creek is 89 days, Lookout Point is 196 days, and Dexter is 126 days (Figure 2-34).

2.2.7 Alternative 4 – Structures-Based Fish Passage Alternative

Alternative 4 includes structural improvement measures to reduce TDG at Detroit, Big Cliff, Green Peter, Foster, Lookout Point, Dexter, and Cougar dams. Detroit and Lookout Point dams TDG measure would be incorporated into the water temperature control tower design. Measure 174 was included in Alternative 4 at LOP-DEX, CGR, GPR-FOS, and DET-BCL and resulted in an estimated 5% reduction in TDG values above 110% at the control point immediately below the lowest dam in each sub-basin (Figure 2-52, Figure 2-53, Figure 2-54).

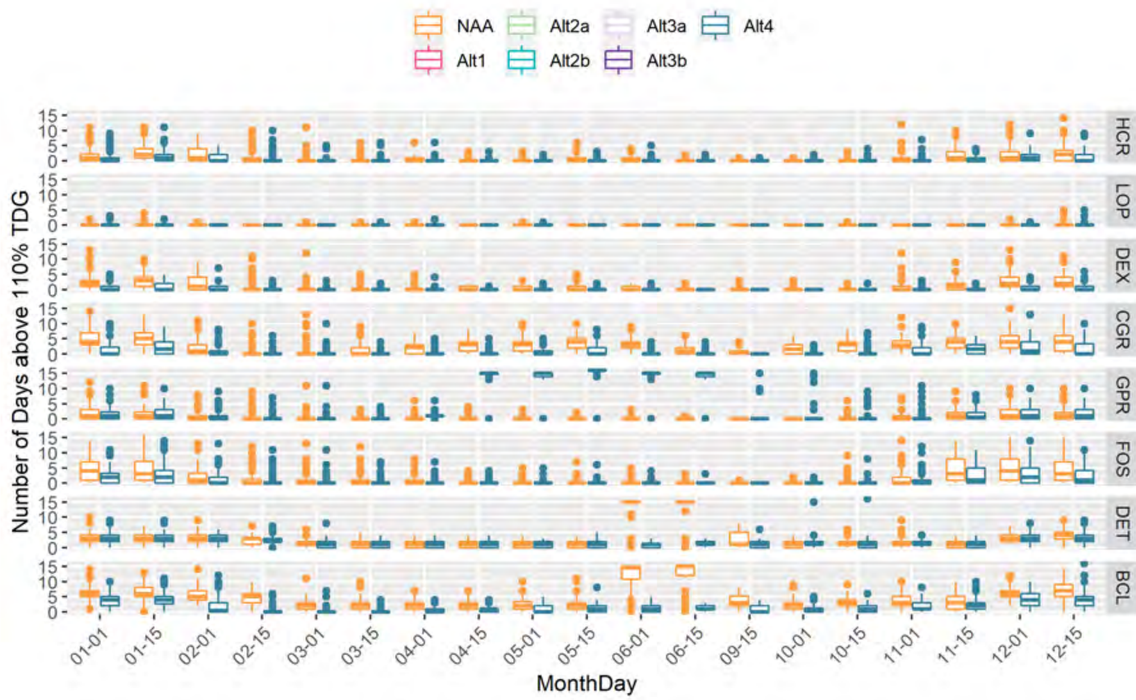

Figure 2-52. Number of days in each half-month period over the period of record (1936-2019) based on SYS-TDG estimated TDG for Alternative 4 and NAA.

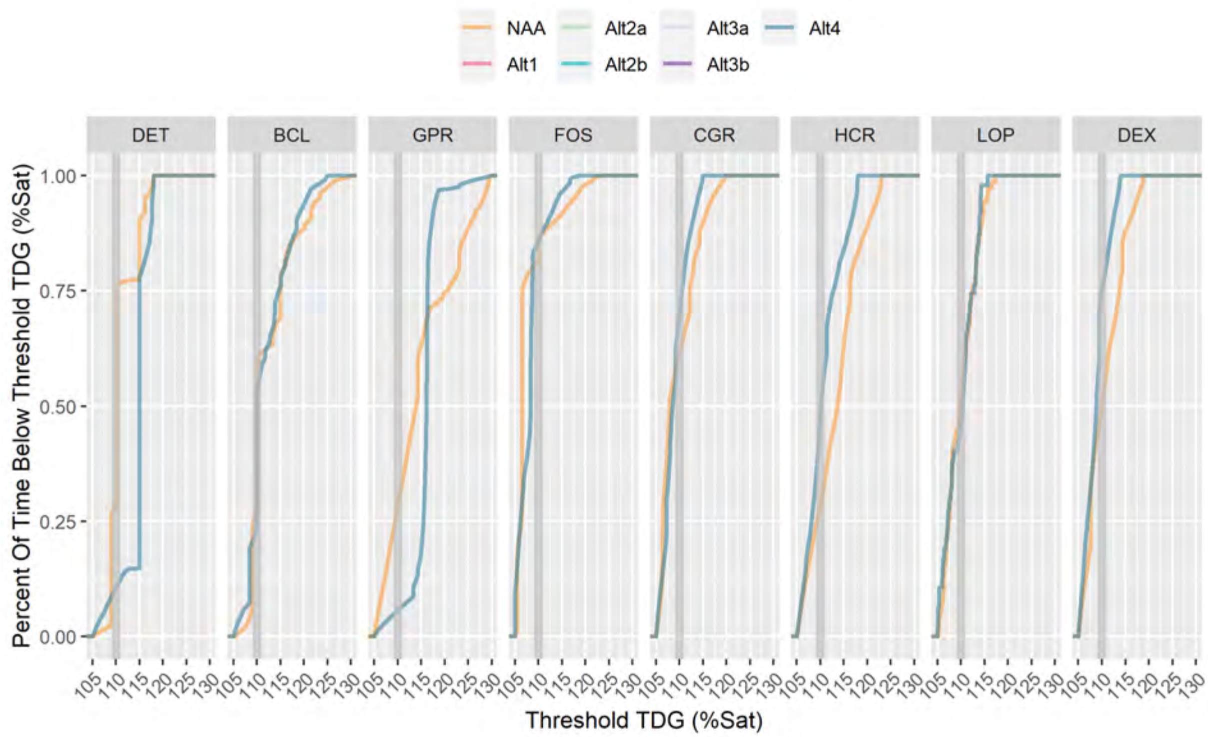

Figure 2-53. Cumulative distribution curves showing percent of time below a threshold TDG (% Saturation) in the period of record (1936-2019) based on SYS-TDG estimated TDG for Alternative 4 and NAA.

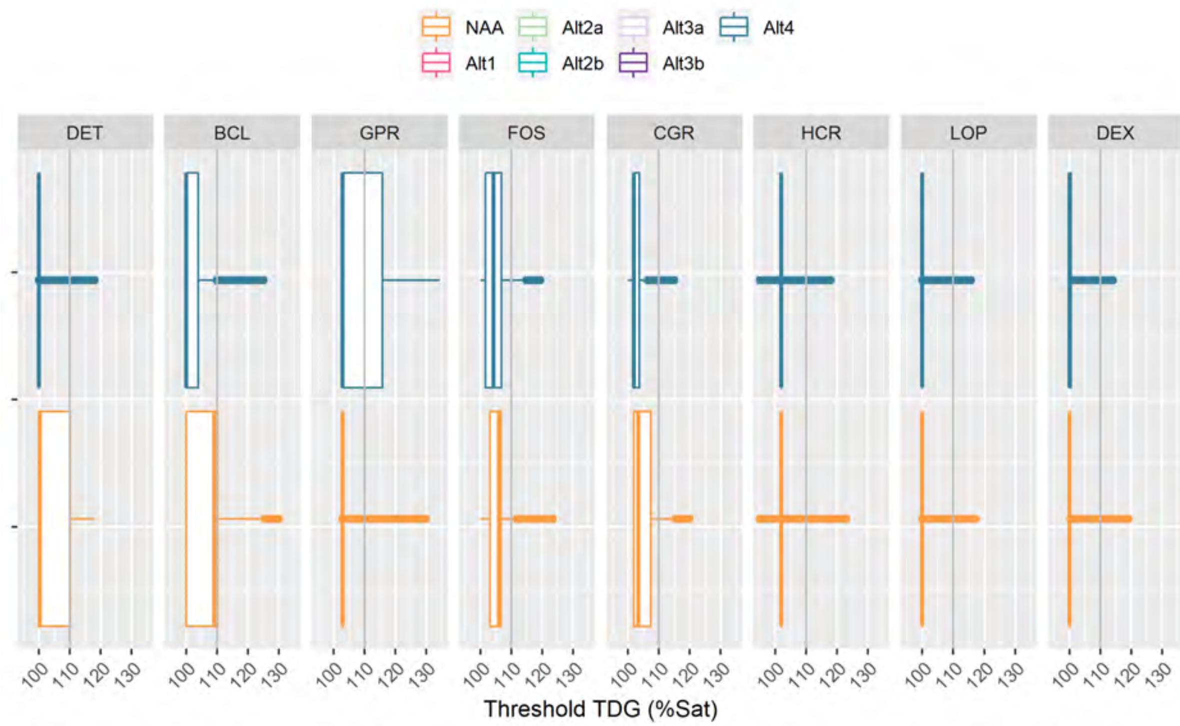

Figure 2-54. Boxplots of TDG (% Saturation) over the period of record (1936-2019) based on SYS-TDG estimated TDG for Alternative 4 and NAA. Boxes represent the first and third quantile (25th and 75th percentiles).

2.2.7.1 NORTH SANTIAM DAM

Structural improvement measures to improve TDG at Detroit reservoir is included in the design of the proposed water temperature control tower under Alternative 4. Under Alternative 4, the average number of days above 110% TDG levels at Big Cliff is 37 and Detroit is 39 (Figure 2-35). Observing the Annual difference in number of days above 110% of TDG exceedances Big Cliff has a reduction of 111 days and Detroit has a reduction of 77 days as compared to the No Action Alternative (Figure 2-36). The Average Number of Days of Spill per year at Big Cliff is 86 days and Detroit is 62 (Figure 2-34).

2.2.7.2 SOUTH SANTIAM DAMS

Structural improvement measures to improve TDG at Foster reservoir are included at the Foster adult fish collection facility. Under Alternative 4, the average number of days above 110% TDG levels at Green Peter is 135 days and Foster is 19 days (Figure 2-35). Observing the Annual difference in number of days above 110% of TDG exceedances Green Peter has an increase of 123 days and Foster is decreased to 13 days as compared to the No Action Alternative (Figure 2-36). The Average Number of Days of Spill per year at Green Peter is 185 days and Foster is 211 days (Figure 2-34).

2.2.7.3 MCKENZIE DAMS

Under Alternative 4, the average number of days above 110% TDG levels at Cougar is 17 days (Figure 2-35). Observing the Annual difference in number of days above 110% of TDG exceedance Cougar is decreased to 41 days as compared to the No Action Alternative (Figure 2-36). The Average Number of Days of Spill per year at Cougar is 168 days (Figure 2-34).

2.2.7.4 MIDDLE FORK WILLAMETTE DAMS

Under Alternative 4, the Average number of days above 110% TDG levels at Hills Creek is 9 average days, Lookout Point is 0, and Dexter is 5 average days (Figure 2-35). Hills Creek has a reduction of 9 days of TDG exceedances, Lookout Point has 0 days reduction, and Dexter is reduced by 15 days as compared to the No Action Alternative (Figure 2-36). The Average Number of Days of Spill per year at Hills Creek is 93 days, Lookout Point is 51 days and Dexter is 89 days (Figure 2-34).

2.2.8 Alternative 5 – Preferred Alternative

Alternative 5 has no specific measures to reduce TDG. Alternative 5 is based on Alternative 2b, which had the following measures that affected operations total outflow and spill rates that contributes to TDG:

- Changes to tributary targets below Foster, Detroit, Lookout Point, and Cougar that are higher than the NAA BiOp targets when those reservoirs are more than 90% full and less than the NAA BiOp when those reservoirs are less than 90% full.
- Changes to baseline mainstem targets at Salem and Albany while adding a Salem flow target tied to forecasted air temperature.
- Construct temperature control structure at Detroit.
- Deep fall drawdown to 35’ over the regulating outlet at Green Peter, use of RO in fall, use spillway for surface spill in spring and summer
- Deep spring and fall drawdown to 30 feet over the diversion tunnel at Cougar, with a limited refill window between June 15th and November 15th (essentially a delayed refill).
- Modifications to existing outlets at Foster Dam that would allow releases at varying depths for temperature control by modifying the Facility Warm Water Supply (FWWS) pipe and fish weirs.

RES-SIM simulations of lake levels and dam outflows were provided as inputs to the SYS-TDG model to estimate TDG over the period of record in Alternative 5 and is discussed in this section. The underlying assumptions in Alternative 5 were similar to Alternative 2b aside from changes to the spring flow targets at Salem that are lower than BiOp dry year targets in years when water supply forecasted flows at Salem are projected to be less than 25% of normal. This provides additional spring storage in dry years allowing for targets that closely resemble BiOp flow targets to be met in dry summers. A full explanation of the RES-SIM analysis and findings can be found in the Section 3.2 Hydrologic Processes and Technical Appendix B Hydrology and Hydraulics. Boxplots of TDG in each half-month period, cumulative distribution curves of TDG, and annual boxplots of TDG comparing Alternative 5, Alternative 2b, and NAA are shown in Figure 2-43, Figure 2-44, and Figure 2-45 respectively.

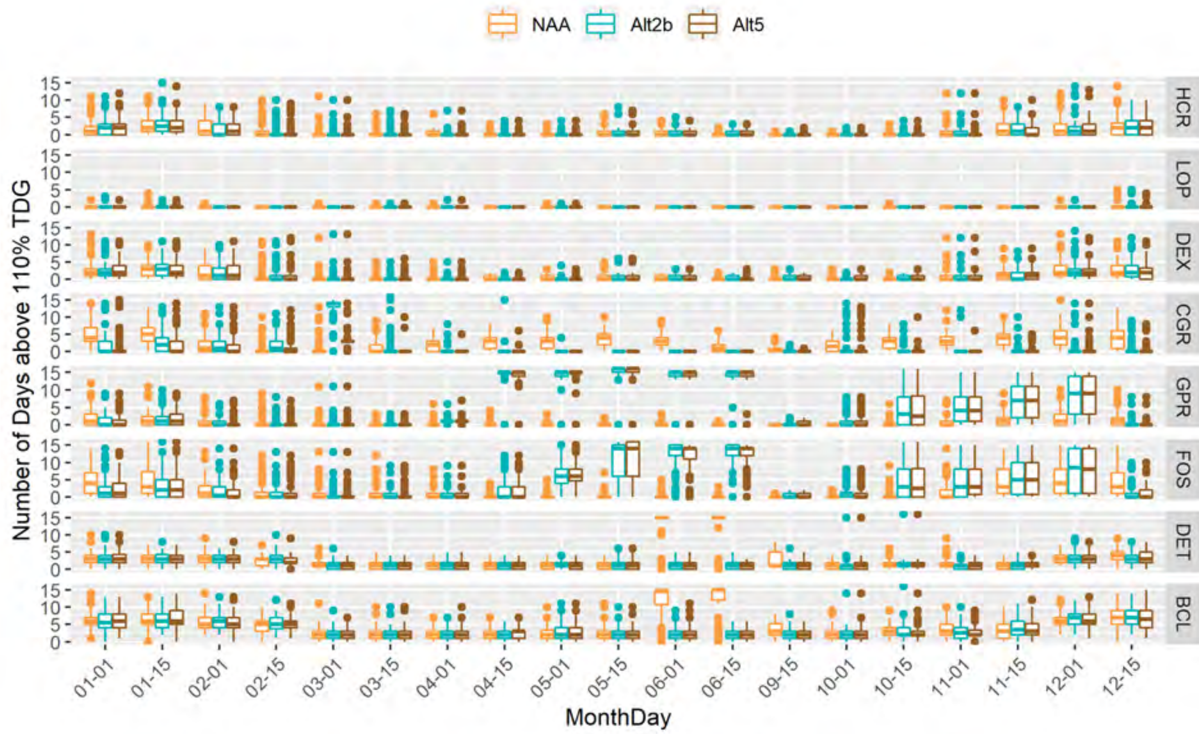

Figure 2-55. Number of days in each half-month period over the period of record (1936-2019) based on SYS-TDG estimated TDG for Alternative 5 and NAA.

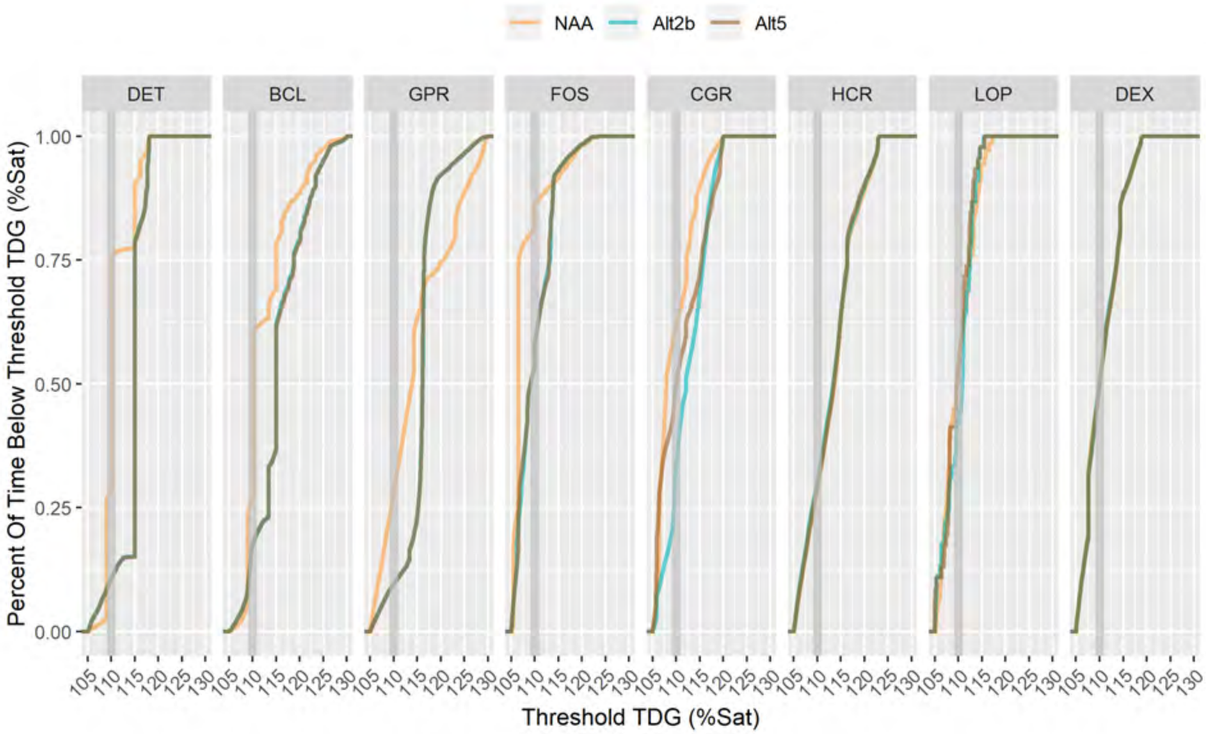

Figure 2-56. Cumulative distribution curves showing percent of time below a threshold TDG (% Saturation) in the period of record (1936-2019) based on SYS-TDG estimated TDG for Alternative 5 and NAA.

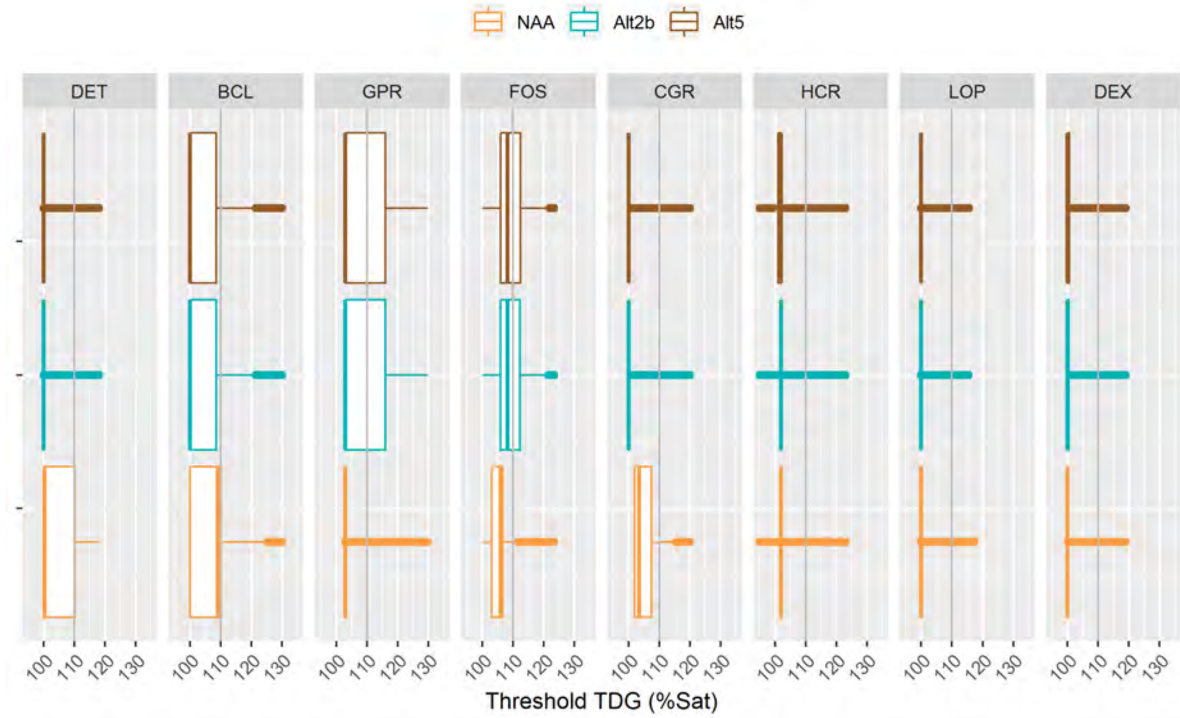

Figure 2-57. Boxplots of TDG (% Saturation) over the period of record (1936-2019) based on SYS-TDG estimated TDG for Alternative 5 and NAA. Boxes represent the first and third quantile (25th and 75th percentiles).

2.2.8.1 NORTH SANTIAM DAM

Under Alternative 5, the average number of days above 110% TDG levels at Big Cliff is 79 and Detroit is 39 (Figure 2-35). North Santiam Alternative 5 TDG effects essentially match those in Alternative 2b with Big Cliff resulting in a reduction of 69 number of days in annual difference the above 110% TDG and Detroit reduced by 77 days as compared to the No Action Alternative (Figure 2-36). The Average Number of Days of Spill per year at Detroit is 62 days and Big Cliff is 86 days (Figure 2-34).

2.2.8.2 SOUTH SANTIAM DAMS

There are no TDG measures within Alternative 5 for Green Peter and Foster reservoirs.

South Santiam Alternative 5 TDG effects match those in Alternative 2b, with the average number of days above 110% TDG levels at Green Peter 151 days and Foster at 126 days (Figure 2-35). Green Peter results in an increase of 139 days of TDG exceedances and Foster is increased by 94 days as compared to the No Action Alternative (Figure 2-36). The Average Number of Days of Spill per year at Green Peter is 190 days and Foster is 284 days (Figure 2-34).

2.2.8.3 MCKENZIE DAMS

There are no TDG management measures for Alternative 5 for Cougar Reservoir. Under Alternative 5, the average number of days above 110% TDG levels at Cougar is 13 days (Figure 2-35). The minimal change from Alternative 5 to Alternative 2b is likely due to differences in the draft rate during the spring drawdown at Cougar (for more information, see section 0 and Section 3.2 Hydrologic Processes and Technical Appendix B Hydrology and Hydraulics). Observing the Annual difference in number of days above 110% of TDG exceedance Cougar is decreased by 49 days as compared to the No Action Alternative (Figure 2-36). The Average Number of Days of Spill per year at Cougar is 29 days (Figure 2-34).

2.2.8.4 MIDDLE FORK WILLAMETTE DAMS

There are no TDG measures for Hills Creek, Lookout Point and Dexter dams although model analysis has determined effects to the sub-basin. Middle Fork Willamette Alternative 5 TDG effects essentially match those in Alternative 2b, with Lookout Point resulting in a reduction of 0 days and on average 0 days of TDG exceedance for the year (Figure 2-35) compared to NAA. Dexter dam has reduction of 16 days and on average 5 days of TDG exceedance for the year (Figure 2-35) compared to NAA. Hills Creek dam has a reduction of 3 days of Annual Difference in Number of Days above 110% and on average number of days exceeds TDG by 18 days as compared to the No Action Alternative. The Average Number of Days of Spill per year at Hills Creek is 138 days, Lookout Point is 52 days, and Dexter is 87 days (Figure 2-34).

2.3 CITATIONS

Carroll, J.H., M.L. Schneider, J.W. Lemons, and L.M. Gunter, 2001. Data Summary for Rock Island Dam Single Spillway Bay Performance Testing, Total Dissolved Gas Exchange, August 21-22 and October 9-10, 2000. CEERDC-ES-P, Memorandum for Record dated 3 May 2001, U.S. Army Corps of Engineers, Engineer Research and Development Center, Dallesport, WA.

Carroll, J.H., M.L. Schneider, L.M. Gunter, and J.W. Lemons, 2002. Pre- and Post-Deflector Total Dissolved Gas Exchange of a Notched Spillway Operation at Rock Island Dam, 12-15 October and 2-6 December 2001. CEERDC-EP-P, Memorandum for Record dated 3 April 2002, U.S. Army Corps of Engineers, Engineer Research and Development Center, Dallesport, WA.

Ebel, W.J. 1969. Supersaturation of nitrogen in the Columbia River and its effect on salmon and steelhead trout. United States Fisheries Service Fishery Bulletin 68:1-11.

Juul, S.T.J. 2003. An assessment of selected water quality parameters for the Priest Rapids Hydroelectric Project. Report prepared for Public Utility District No. 2 of Grant County, Ephrata, WA.

NOAA, 2008, Endangered Species Act Section 7(a)(2) Consultation Biological Opinion & Magnuson-Stevens Fishery Conservation & Management Act Essential Fish Habitat

Consultation, NOAA's National Marine Fisheries Service (NMFS) Northwest Region, July 11, 2008.

Scheibe, T. D. and M. C. Richmond. 2002. Fish individual-based numerical simulator (FINS): as particle-based model of juvenile salmonid movement and dissolved gas exposure history in the Columbia River basin. Ecological Modelling 147:233-252.

Schneider, M.L., 2012, Total Dissolved Gas Exchange at Chief Joseph Dam Post Spillway Flow Deflectors, April 28-May 1, 2009, Coastal and Hydraulic Laboratory U.S. Army Engineer Research and Development Center, Vicksburg ,MS, April 2012.

Schneider, M.L., and Wilhelms, S.C., 2016, Ice Harbor Spillway Dissolved Gas Field Studies: Before and After Spillway Deflectors, Coastal And Hydraulics Laboratory U.S. Army Engineer Research and Development Center, Vicksburg, Mississippi, July 2016. Accessed at https://apps.dtic.mil/dtic/tr/fulltext/u2/1013510.pdf

USACE, 1996, Dissolved Gas Abatement Study Phase I Technical Report, U.S. Army Corps of Engineers North Pacific Division Portland District and Walla Walla District, April 1996.

USACE, 2002, Dissolved Gas Abatement Study Phase II, Technical Report - Final May 2002 Volume I Report: Corps Of Engineers Plan Of Action For Dissolved Gas Monitoring In 2001. U.S. Army Corps of Engineers, Northwest Division, Portland, OR.

USACE, 2009, Willamette Valley Projects Configuration/Operation Plan, Phase I Report: Appendix D Proposed Structural And Operational Measures, U.S. Army Corps of Engineers Portland District, October, 2009.

USACE, 2012, Willamette Basin Annual Water Quality Report for 2011: U.S. Army Corps of Engineers Final Report, April 2012, 123 p.

USACE. 2017, Willamette Fish Operations Plan Willamette Valley Project. U.S. Army Corps of Engineers, Portland, OR. Accessed on June 3, 2021 at: http://pweb.crohms.org/tmt/documents/FPOM/2010/Willamette_Coordination/WFOP/2017/final/2017%20WFOP%20Chapter%201%20Overview.pdf

USACE, 2020a, Dataquery 2.0; Query Timeseries from USACE Northwestern Division, available online at: https://www.nwd-wc.usace.army.mil/dd/common/dataquery/www/

USACE. 2020b, Willamette Fish Operations Plan Willamette Valley Project. U.S. Army Corps of Engineers, Portland, OR.

Washington State Department of Ecology, 2004, Total Maximum Daily Load for Total Dissolved Gas in the Mid-Columbia River and Lake Roosevelt Submittal Report, Washington State Department of Ecology, June 2004. Accessed at https://apps.ecology.wa.gov/publications/documents/0403002.pdf.

Weitkamp, D. E. and Katz, M. 1980. A review of dissolved gas supersaturation literature. Transactions of the American Fisheries Society 109:659-702.

CHAPTER 3 - CLIMATE CHANGE ASSESSMENT FOR WATER TEMPERATURE AND TDG

This appendix to the Willamette Valley EIS describes the methodology for developing qualitative assessments of the effects of climate change on the water temperature and TDG at each listed control point. The qualitative effects of dam operations/structures described in each WV EIS Alternative (Chap 3) have been integrated with qualitative interpretations of unregulated flow and air temperature from the River Joint Operating Committee (RMJOC II) climate projections (representing an 80 Global Circulation Model [GCM] ensemble; Chapter 3.2 (Effects Analysis – Hydrology and Hydraulics) and Technical Appendix B (Hydrology and Hydraulics)). For this assessment, the climate impacts are based on RCP8.5 projections to the 2030's and 2070's. Storage/flow determinations from the hydrologic impacts due to climate change section were integrated into the water quality qualitative assessments (Chap 3.6).

3.1 WATER TEMPERATURE

Projected increases in summer water temperatures for Columbia River tributaries by the end of the century span a wide range, from 1.8 to 9.0 degrees Fahrenheit (1 to 5 degrees Celsius) (e.g., Cristea and Burges 2010; Mantua, Tohver, and Hamlet 2010; Wu et al. 2012; Beechie et al. 2013; Caldwell et al. 2013; Isaak et al. 2017). Previous research on the relationship between air temperature and water temperature have documented a 0.6-0.8°C increase in water temperature for every 1°C increase in air temperature (Morrill, et al., 2005). Similarly, a study on future climate impacts in the North Santiam Basin, Oregon found a 2°C annual air temperature increase translated to a water temperature increase of 1.5°C downstream of Detroit Dam under current operational rules (annual average water-to-air temperature ratio of 0.75)(Buccola, et al., 2016). Determinations of air temperature from the Northwest Climate Toolbox (https://climatetoolbox.org/) at Salem, Oregon (Figure 3-1) indicated a warming of maximum Jun-July-Aug air temperature of 4.7-7.9^{o}F (comparing ensemble 5th and 95th percentiles from 1971-2010, with 2010-2039 and 2040-2069 periods assuming Higher Emissions (RCP 8.5) scenarios in Table 3-1). Applying water-to-air temperature ratio of 0.75 to these air temperature projections to the Willamette Valley, water temperatures downstream of the dams could increase annually 3.5^{o}F – 5.9^{o}F under the 2040-2069 period or 1.9^{o}F – 2.9^{o}F under the 2010-2039 period under current operation regimes. Based on these ranges, an annual warming of 3.5-5.9^{o}F was assigned to "Much Warmer" qualitative assessments, and 1.9^{o}F – 2.9^{o}F assigned to "Warmer" qualitative assessments for the purpose of this EIS.

Table 3-1. Projected air temperature summary at Salem, Oregon based on RCP8.5 (climatetoolbox.org)

Model Statistic	HIST Historical Scenario: 1971-2010	Future Scenario 1: 2010-2039 (Higher Emissions (RCP 8.5))	*Difference* btwn 2010-2039 Future and 1971-2010 Historical	Future Scenario 2: 2040-2069 (Higher Emissions (RCP 8.5))	*Difference* btwn 2040-2069 Future and 1971-2010 Historical
Minimum from Models	78.8	80.9	2.1	82.4	3.6
5 Percentile from Models	79.0	81.5	2.5	83.7	4.6
Mean from Models	79.3	82.3	3.0	85.6	6.2
95 percentile from Models	79.6	83.4	3.8	87.5	7.9
Maximum from Models	79.8	83.7	3.9	88.5	8.8

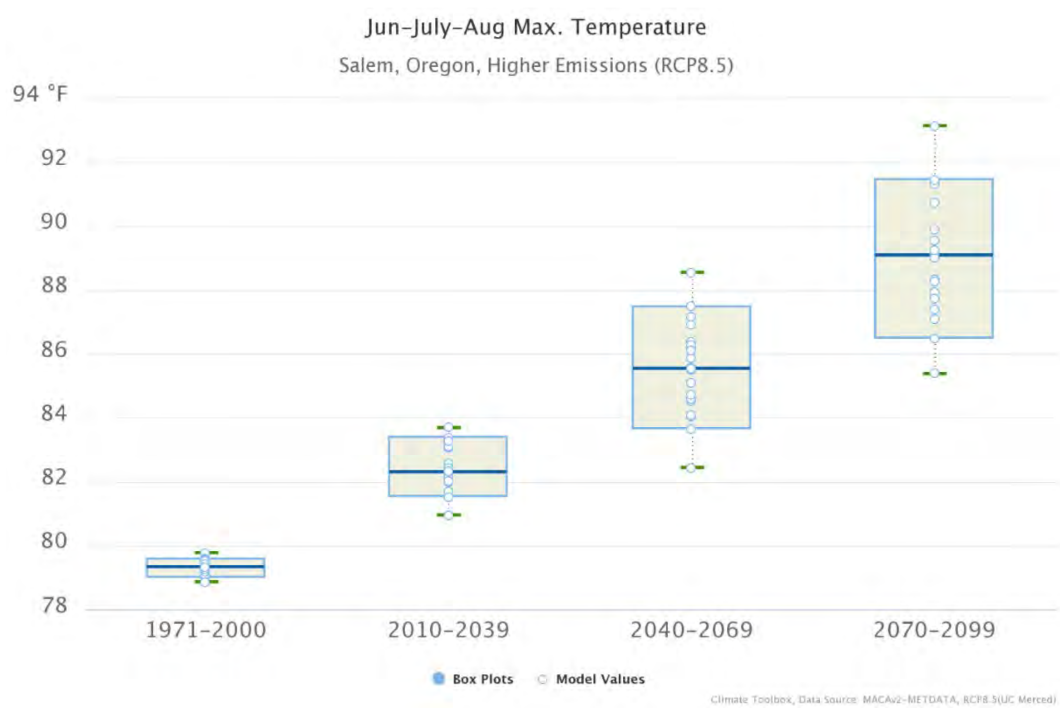

Figure 3-1. Summer Maximum air temperature boxplots at Salem, Oregon. (Source: Northwest Climate Toolbox: https://climatetoolbox.org/tool/Future-Boxplots).

Reservoir storage volume is the primary driver for providing augmentation flows in summer and autumn. Immediately downstream of each dam, water temperature is dependent on temperature management (the ability to mix cooler, deeper lake water with warmer, surface lake water). For alternatives with proposed SWS, the downstream water temperature is less dependent on lake volume as long as the SWS is accessible (wet). For alternatives that rely on existing structures for temperature control, downstream water temperature is dependent on: 1) Whether the lake fills above the spillway crest in spring and early summer, and 2) What outlets are available in the autumn to access deeper/cooler water. In-lake temperatures, i.e., the amount of heat stored in the lake during summer, depends on how much lake surface water is released during spring and summer. This directly affects autumn temperatures, as the warmer lake surface water is drawn towards the deeper outlets as the lake is drafted in autumn. Simulated climate change effects on potential operations and structures at Detroit Dam have been shown to exacerbate the dependence of autumn temperature on spring and summer temperature control earlier in a given year (Buccola, et al., 2016). Further downstream, extreme water temperatures can be mitigated to some extent with increased flow that can buffer incoming heat from solar radiation.

3.1.1 Methodology

Assignment of a qualitative category was derived through a combination of the expected climate change impacts to water storage developed in the hydrologic section (Chap 3.2) as well as the water temperature impacts presented in Chap 3.6 for each sub-basin control point. Determinations in the expected climate change impacts to water storage in the Effects Analysis – Hydrology and Hydraulics (Chapter 3.2) and Technical Appendix B (Hydrology and Hydraulics) of *Summer* category *"less"* were replaced with *"warmer"*. Determinations were located and generally dependent on the site immediately below the lowest dam in each sub-basin as follows: Middle Fork Willamette (Lookout Point-Dexter at DEXO), Mckenzie (Cougar at CGRO), South Santiam (Foster at SSFO), North Santiam (Detroit-Big Cliff at BCLO). The mainstem Willamette was determined at Salem (SLMO). The following changes were made to sites immediately below dams:

1. Climate change impacts in alternatives and locations with "*Moderate Beneficial"* or *Major Beneficial*" impacts to either of the "Days Near the Temperature target" water temperature criteria in the WQ Impacts section of the EIS were assigned a climate change impact one step closer to *"Similar".* For example, a determination of "*Much Warmer*" would be moved to "*Warmer*".
2. Climate change impacts in alternatives and locations with "*Moderate Detrimental*" or "*Major Detrimental*" impacts to either of the "Days Near the Temperature target" water temperature criteria in the WQ Impacts section of the EIS were assigned a climate change impact one step closer to *"Similar".* For example, a determination of "*Similar*" would be moved to "*Warmer*".
3. Climate change impacts in alternatives and locations with "*Minor*" or "*Negligible*" impacts to both of the "Days Near the Temperature target" water temperature criteria in the WQ

Impacts section of the EIS were assigned the same change provided in the Hydrologic climate impact analysis (Chapter 3.2).

*Note: Due to the existence of a water temperature control tower (WTCT) at Cougar, it was assumed that climate change impacts on temperature below Cougar would be one step closer to *"Similar"* in all alternatives that allow the lake to fill to the operable WTCT lake elevations (Alt 1, 2a, 4). For Alt 2b, 3a, and 3b, the above rules applied.

For sites further downstream at Salem and Albany, no changes were made to those assigned in the Hydrologic climate impact analysis (Chapter 3.2) as there were only "*Minor*" or "*Negligible*" impacts to the "Days Above 18 degrees C" water temperature criteria in the WQ Impacts section of the EIS.

3.2 TOTAL DISSOLVED GAS (TDG)

TDG increases when non-turbine releases, such as RO's or spillway releases increase. These types of releases occur when powerhouse capacity has been exceeded, a non-power outlet is used (e.g., for fish passage or temperature management), or turbine outages (e.g., repair).

3.2.1 Methodology

Determinations were located and generally dependent on the site immediately below the lowest dam in each sub-basin as follows: Middle Fork Willamette (Lookout Point-Dexter at DEXO), McKenzie (Cougar at CGRO), South Santiam (Foster at SSFO), North Santiam (Detroit-Big Cliff at BCLO). Using the expected climate change impacts to flow volume developed in the hydrologic section (Chapter 3.2), determinations in *Winter* category were used in combination with the effects described in the Water Quality TDG effects section:

1. Climate change impacts in alternatives and locations with "*Moderate Beneficial"* or *Major Beneficial*" impacts to the "Number of Days Above 110% TDG" criteria in the WQ Impacts section of the EIS were assigned a climate change impact one step closer to *"Much Less".* For example, a determination of "*Much More*" would be moved to "*More*".
2. Climate change impacts in alternatives and locations with "*Moderate Detrimental*" or "*Major Detrimental*" impacts to the "Number of Days Above 110% TDG" criteria in the WQ Impacts section of the EIS were assigned a climate change impact one step closer to *"Much More".* For example, a determination of "*Much Less*" would be moved to "*Less*".
3. Climate change impacts in alternatives and locations with "*Minor*" or "*Negligible*" impacts to the "Number of Days Above 110% TDG" criteria in the WQ Impacts section of the EIS were assigned the same change provided in the Hydrologic climate impact analysis.

3.3 ASSESSMENTS BY ALTERNATIVE

3.3.1 No Action Alternative

Please reference Technical Appendices B and F for Climate Change qualitative effects. Water Quality parameters such as Water Temperature and TDG would be influenced by refill timing, storage volume, and outflow at each dam. Climate change projections for the 2030s and 2070s under RCP 8.5 show higher project inflow December-March and lower inflow April-November for the Willamette Basin. Higher winter flow may increase TDG levels if no TDG management is in place, as turbine capacity at power projects would likely be exceeded more often and result in “spill” releases through non-power outlets. Higher winter flows occurring in December-January would not be stored, as the guide curves for Willamette Projects generally begin February 1. Therefore, climate change will likely lead to a decreased release volumes in spring and summer compared to the Affected Environment. Decreased storage will likely decrease the ability to manage dam releases from different outlets for temperature management, leading to less normative release temperatures (cooler in spring-early summer; warmer in autumn).

In the No Action Alternative, Detroit dam, Green Peter dam, Foster dam, Cougar dam, Hills Creek dam, Lookout Point dam, and Mainstem Willamette river would potentially have less flow during the summer which may cause and increase downstream water temperatures.

3.3.2 Alternative 1 - Project Storage Alternative

Please reference Technical Appendices B and F for Climate Change qualitative effects. Compared to NAA, Alternative 1 would potentially increase resiliency against climate change impacts on water temperature and TDG (increased water temperature control) below Detroit and Green Peter as a result of the proposed SWS and TDG abatement measures at each location. Parameters such as Turbidity and Mercury will likely experience similar effects as those described under NAA. Increased releases from the lake surface via the proposed SWS at Detroit, Green Peter, and Lookout Point combined with reduced summer flow volumes under Alternative 1 could lead to increased phytoplankton (algae) compared to NAA (Technical Appendix B Hydrology and Hydraulics).

3.3.3 Alternative 2a - Hybrid Alternative

Please reference Technical Appendices B and F for Climate Change qualitative effects. Compared to NAA, Alternative 2a would potentially increase resiliency against climate change impacts on water temperature (increased water temperature control) below Detroit and Green Peter as a result of the proposed SWS and operational temperature control measures at those locations. TDG impacts immediately below Detroit would likely be more resilient to climate change under Alternative 2a due to the proposed SWS (reducing the need for operational temperature control). Parameters such as Turbidity and Mercury will likely experience similar effects as those described under NAA. Increased releases from the lake surface via the proposed SWS at Detroit combined with reduced summer flow volumes under Alternative 2a could lead to increased phytoplankton (algae) compared to NAA (Technical Appendix B Hydrology and Hydraulics).

3.3.4 Alternative 2b - Hybrid Alternative

Please reference Technical Appendices B and F for Climate Change qualitative effects. Compared to NAA, Alternative 2b would potentially increase resiliency against climate change impacts on water temperature and TDG (increased water temperature control) below Detroit as a result of the proposed SWS and TDG abatement measures at each location. Parameters such as Turbidity and Mercury will likely experience similar effects as those described under NAA. Increased releases from the lake surface via the proposed SWS at Detroit combined with reduced late summer flow volumes under Alternative 2b could lead to increased phytoplankton (algae) compared to NAA (Technical Appendix B Hydrology and Hydraulics).

3.3.5 Alternative 3a – Operations-Focused Fish Passage

Please reference Technical Appendices B and F for Climate Change qualitative effects. Compared to NAA, Alternative 3b would potentially reduce resiliency against climate change impacts on water temperature (decreased water temperature control) below Detroit, Hills Creek, and Lookout Point, and lower on the mainstem Willamette at Salem as a result of the lower storage and outflows at each location. However, Alternative 3b would potentially increase resiliency against climate change impacts on water temperature (more normative water temperature) below Green Peter-Foster due to the elevation of the summer lake levels at that project. Resiliency against climate change impacts to TDG would likely increase below Lookout Point-Dexter due to the reduced reservoir storage and expected hydrologic impacts shown in the Hydraulics and Hydrology Appendix. Parameters such as Turbidity, HAB's, and Mercury will likely experience similar effects as those described under NAA.

3.3.6 Alternative 3b – Operations-Focused Fish Passage

Please reference Technical Appendices B and F for Climate Change qualitative effects. Compared to NAA, Alternative 3b would potentially reduce resiliency against climate change impacts on water temperature (decreased water temperature control) below Detroit, Hills Creek, and Lookout Point, and lower on the mainstem Willamette at Salem as a result of the lower storage and outflows at each location. However, Alternative 3b would potentially increase resiliency against climate change impacts on water temperature (more normative temperatures) below Lookout Point-Dexter due to operational lake elevations. Resiliency against climate change impacts to TDG would likely increase below Lookout Point-Dexter due to the reduced reservoir storage and expected hydrologic impacts shown in the Hydraulics and Hydrology Appendix. Parameters such as Turbidity, HAB's, and Mercury will likely experience similar effects as those described under NAA.

3.3.7 Alternative 4– Structures-Based Fish Passage Alternative

Please reference Technical Appendices B and F for Climate Change qualitative effects. Compared to NAA, Alternative 4 would potentially increase resiliency against climate change impacts on water temperature and TDG (increased water temperature control) below Detroit, Lookout Point, and Hills Creek as a result of the proposed SWS and TDG abatement measures at each location. Parameters such as Turbidity and Mercury will likely experience similar impacts as those described under NAA. Increased releases from the lake surface via the proposed SWS at Detroit, Lookout Point, and Hills Creek combined with reduced summer flow volumes under

Alternative 1 could lead to increased phytoplankton (algae) compared to NAA (Technical Appendix B Hydrology and Hydraulics).

3.3.8 Alternative 5 – Preferred Alternative

Please reference Technical Appendices B and F for Climate Change qualitative effects closely matched to Alternative 2b. Compared to the No Action Alternative, Alternative 5 would potentially increase resiliency against climate change impacts on water temperature and TDG (increased water temperature control) below Detroit as a result of the proposed SWS and TDG abatement measures at each location.

3.4 CITATIONS

Beechie, T., H. Imaki, J. Greene, A. Wade, H. Wu, G. Pess, P. Roni, J. Kimball, J. Stanford, P. Kiffney, and N. Mantua. 2013. "Restoring Salmon Habitat for a Changing Climate." *River Research and Applications* 29(8):939–960.

Buccola, N.L., Risley, J.C., Rounds, S.A., 2016, Simulating future water temperatures in the North Santiam River, Oregon, Journal of Hydrology, Volume 535, April 2016, Pages 318-330, ISSN 0022-1694, http://dx.doi.org/10.1016/j.jhydrol.2016.01.062.

Caldwell, R. J., S. Gangopadhyay, J. Bountry, Y. Lai, and M. M. Elsner. 2013. "Statistical Modeling of Daily and Subdaily Stream Temperatures: Application to the Methow River Basin, Washington." *Water Resources Research* 49(7):4346–4361.

Cristea, N. C., and S. J. Burges. 2010. "An Assessment of the Current and Future Thermal Regimes of Three Streams Located in the Wenatchee River Basin, Washington State: Some Implications for Regional River Basin Systems." Climatic Change 102(3-4):493–520.

Isaak, D. J., S. J. Wenger, E. E. Peterson, J. M. Ver Hoef, D. E. Nagel, C. H. Luce, S. W. Hostetler, J. B. Dunham, B. B. Roper, S. P. Wollrab, and G. L. Chandler. 2017. "The NorWeST Summer Stream Temperature Model and Scenarios for the Western US: A Crowd-Sourced Database and New Geospatial Tools Foster a User Community and Predict Broad Climate Warming of Rivers and Streams." *Water Resources Research* 53(11):9181–9205.

Mantua, N., I. Tohver, and A. Hamlet. 2010. "Climate Change Impacts on Streamflow Extremes and Summertime Stream Temperature and Their Possible Consequences for Freshwater Salmon Habitat in Washington State*." Climatic Change* 102(1-2):187–223.

Morrill, J.C., Roger C. Bales, R.C., Conklin, M.H., 2005, Estimating Stream Temperature from Air Temperature: Implications for Future Water Quality, Journal of Environmental Engineering Vol. 131, Issue 1 (January 2005) accessed at https://doi.org/10.1061/(ASCE)0733-9372(2005)131:1(139) on February 3, 2022.

University of California Merced and University of Washington, 2022, Climate Toolbox, accessed at https://climatetoolbox.org/ on February 3, 2022.

USACE, 2020, Columbia River System Operations Environmental Impact Statement, U.S. Army Corps of Engineers Northwest Division, Bureau of Reclamation, and Bonneville Power Administration, accessed at https://www.nwd.usace.army.mil/CRSO on March 23, 2022.

Wu, H., J. S. Kimball, M. M. Elsner, N. Mantua, R. F. Adler, and J. Stanford. 2012. "Projected Climate Change Impacts on the Hydrology and Temperature of Pacific Northwest Rivers." *Water Resources Research* 48(11).