Appendix J, Winter and Spring Pulses and Delta Outflow

Attachment J.4 XT Model

J.4.1 Model Overview

In-river migration can be analyzed using the passage component ("Migration Model") of the SacPAS Fish Model. The model is a reconfiguration of the National Marine Fisheries Service Comprehensive Passage (NMFS COMPASS) smolt passage model, developed for Columbia River salmon and steelhead (Zabel et al. 2008). Water velocity in a reach is determined with a power curve relationship between flow and velocity in a free-flowing reach. Fish passage time through a reach is a function of water velocity. Fish survival through a reach is a function of distance travelled and travel time to complete that distance. Both water and fish properties (i.e., velocity, travel time) are computed on sub-daily time steps. The survival sub-model is calibrated from acoustically tagged fall-run Chinook salmon (Steel et al. 2020). The XT model (Anderson et al. 2005), which the SacPAS Fish Model utilizes, assumes fish are similar between cohorts but the environment they experience is different. Flow varies spatially and temporally and there is a trade-off between the distance (X) a fish travels and the time spent (T) for a fish in a reach when calculating survival.

J.4.2 Model Development

J.4.2.1 Methods

The SacPAS In-River Migration Fish Model was run using flow scenarios for each alternative at Keswick (KWK) and user-provided fish release inputs for a fixed location: Red Bluff Diversion Dam on Sacramento River at river kilometer 391 (RKM 391). The model outputs estimated survival and travel time through specified reaches to two locations: American River confluence with Sacramento River and the Delta Cross Channel.

J.4.2.1.1 Fish Release Inputs and Flow Scenarios

Red Bluff Diversion Dam (RBDD) passage estimates are used in this analysis. RBDD passage estimates used include all runs of juvenile Chinook salmon from 2005 – 2022. For the subset of Red Bluff rotary screw trap (RST) estimates between January 1st and June 15th, we removed any catch values greater than 80,000 and made a linear interpolation of missing RBDD sampling days. Catch values greater than 80,000 were considered to be indicative of a hatchery release prior to the date.

The XT model uses daily median flow from Keswick (KWK, Figure J.4-1) from the January 1st to June 15th spring period from the Upper Sacramento River Daily Operations Model (USRDOM, 1923 – 2021).

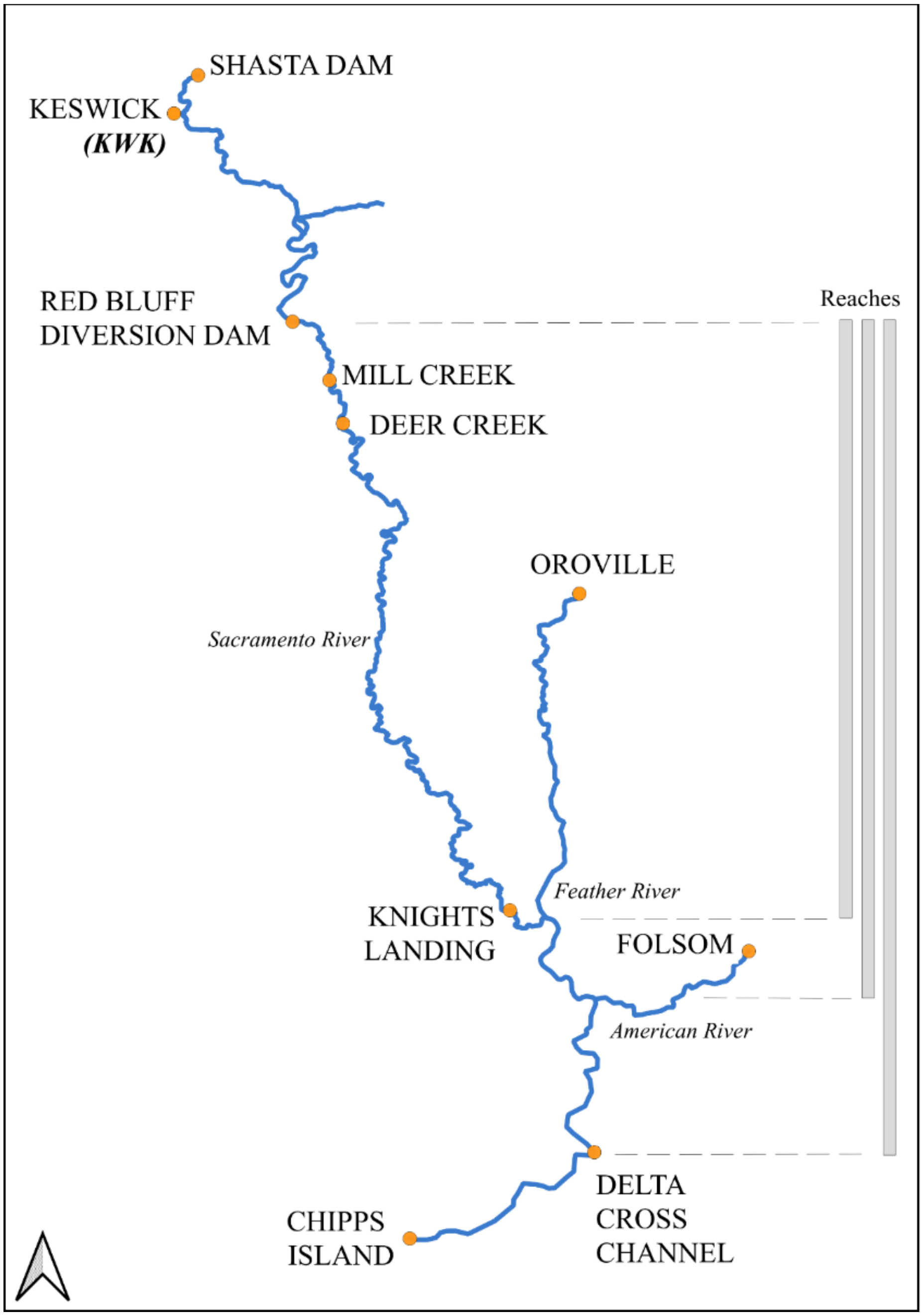

Figure J.4-1. Map of major features and reaches along the Sacramento River system used in the spatially explicit Migration Model.

J.4.2.1.2 Model Parameters

Migration parameters and brief explanations for linear migration rate equations and flow pulse rate equations used for specific juvenile fish migration rates (miles / day) are in Table J.4-1. Individual reach survival was set as a calculation of distance and travel time with the XT model (Anderson et al. 2005) using parameters in Table J.4-2. The analysis used a flow pulse rate equation.

Table J.4-1. Migration rate configuration: linear migration rate equation parameters for linear flow pulse rate equations.

Parameter	Value	Description
B0mig, above Red Bluff	1	Pre-pulse migration, above Red Bluff
B0mig, below Red Bluff	1	Pre-pulse migration, below Red Bluff
B1mig, above Red Bluff	0.05	Migration with river velocity, above Red Bluff
B1mig, below Red Bluff	0.07	Migration with river velocity, below Red Bluff

Table J.4-2. XT model parameters and values.

Parameter	Value	Description
xt0 intercept	0.01012	Free-Path length (1/miles)
xt1 flow-time scale parameter	1.5227	Encounter speed (miles/day)
xt2 flow parameter	0	[Disabled], set at 0

Mortality parameters were adjusted to fit results of radio-tagged fall-run Chinook salmon (Steel et al. 2020) and are built into the SacPAS In-River Migration Fish Model.

The XT model was applied to modeled alternatives using daily flows from the Upper Sacramento River Daily Operations Model (USRDOM): EXP1, EXP3, NAA, Alternative 1, four phases of Alternative 2 (Alternative 2 With TUCP Without VA, Alternative 2 Without TUCP Without VA, Alternative 2 Without TUCP Delta VA, Alternative 2 Without TUCP Systemwide VA), Alternative 3, and Alternative 4.

J.4.2.2 Assumptions / Uncertainty

This model estimates Chinook Salmon outmigration survival based on travel time and predation rates from the RBDD over a 3-month season, March 15th – June 15th, using the model described by Anderson et al. 2005. To account for fish that are in the system at the start of the season, it also includes those fish that passed RBDD between January 1st and March 15th. The model assumes that predators have a random uniform distribution and that both prey and predators can be described by a path described by velocity and a random component. The predicted probability of predation generally decreases when flows increase. These components were held at their defaults for the SacPAS program rather than adjusted based on empirical data on predator occurrence.

USRDOM does not incorporate functional flow pulses, it creates daily flow patterns utilizing tributary inflow information and averaged monthly Sacramento flows to simulate daily flows. Flow volumes, which are part of certain alternatives are not shaped to achieve functional flows. There is uncertainty about how the duration, intensity, or rates of changes, which may influence fish outmigration behavior, would be implemented in alternatives.

J.4.2.3 Code and Data Repository

Fish inputs, daily flow inputs, and R scripts are available upon request.

J.4.3 Results

Mean predicted survival was similar for each reach (RBDD to (1) confluence of the Sacramento River and American River or (2) Delta Cross Channel) across alternatives. Predicted travel time for both reaches varied across all alternatives, and predicted travel time increased with increasingly dry water year types. Predicted survival was lowest during the critical water year type.

J.4.3.1 Narrative: BA

Mean predicted survival from RBDD to the confluence of the Sacramento River and the American river was the same or similar among Proposed Action phases within each water year type. Between water year types, mean predicted survival was similar ranging from 13% in the drier water year types (below normal, dry, and critical) to 15% survival in a wet water year type (excluding EXP1 and EXP3 predicted survival estimates) (Table J.4-3, Figure J.4-2).

Mean predicted survival from RBDD to the DCC on the Sacramento River was the same or similar among alternative 2 phases within each water year type. Between water year types, mean predicted survival was similar ranging from 9% survival in the drier water year types (below normal, dry, and critical) to 11% survival in a wet water year type (excluding EXP1 and EXP3 predicted survival estimates) (Table J.4-5, Figure J.4-4).

Mean predicted travel time from RBDD to the confluence of the Sacramento River and the American river was the same (in a wet water year type) or similar among alternative 2 phases within each water year type. Depending on water year type, predicted travel time ranged widely from 22 days in a wet water year type (the No Action Alternative and four phases of the Alternative 2) to 52 days in a critical water year type (the No Action Alternative and Alternative 2 without TUCP All VA) (excluding EXP1 and EXP3 predicted travel time estimates) (Table J.4-7, Figure J.4-8).

Mean predicted travel time from RBDD to the DCC on the Sacramento River was the same (in a wet water year type) or similar among alternatives within each water year type. Depending on water year type, predicted mean travel time ranged widely from 27 days in a wet water year type (the No Action Alternative and four phases of alternative 2) to 62 days in a critical water year type (the No Action Alternative; excluding EXP 1 and EXP3 predicted travel time estimates) (Table J.4-9, Figure J.4-10).

Spring-run Chinook salmon outmigrate from the upper Sacramento River during the spring, and average 50% passage at Red Bluff Diversion Dam is March 6th (2008 – 2022, SacPAS online). The release of water from Shasta Reservoir can provide additional flows in the Sacramento River. Flows may cue juveniles to begin to move or provide benefits to juveniles already beginning the downstream migration through increased survival and decreased travel time. Travel and survival rates of Chinook in upper Sacramento River reaches are strongly correlated (Notch et al. 2020). Michel et al. (2021) identified an optimal flow threshold condition favorable for outmigration for juvenile Chinook salmon, 10,712 cfs, which could provide an additional 2.7-fold increase in survival. Authors hypothesize one mechanism for this flow threshold is faster outmigration rates due to higher flows decrease exposure to possible predation (Michel et al. 2021).

With the XT model, travel time was estimated to range widely, but outmigration survival did not vary much. Outmigrating juveniles may be exposed to predation and, as inflow decrease and tidal influence moves upstream, travel time and distance may increase leading to higher exposure to predators. In the XT model, outmigration survival is measured across the entire migration season, which is different than observations of tight correlation in travel time and survival in outmigrating acoustically tagged fish. In the XT model, predation influences survival and may be a more influential factor on outmigration survival than increased flows.

In wetter water year types (wet, above normal) and even in below normal water years, modeled daily flows (USRDOM, 1923 – 2021) on the Sacramento River below Keswick Dam exhibit a "pulse" followed by a steep decrease and a less steep increase trend from mid-March through mid-June (Figure J.4-6, Figure J.4-7). In drier water year types (dry and critical), modeled daily flows on the Sacramento River below Keswick Dam exhibit an increasing trend from mid-March through mid-June. Alternative 3 flows are generally the highest, particularly in the beginning of May through mid-June window in wet and above normal water year types. Lower flows can lead to increased travel time and decreased survival for juvenile Chinook. In other water year types (below normal, dry, and critical), Alternative 1 flows are generally the highest during certain periods. For the below normal water year type, Alternative 1 flows were higher than other alternatives from early April to early May and again in late May to mid-June. For the dry water year type, Alternative 1 flows where higher from early April to late April and again in early May to mid-June. For the critical water year type, Alternative 1 flows were highest from early May to mid-June. Increased flows can lead to decreased travel time and increased survival for juvenile Chinook (Michel et al. 2021). The other alternatives and the No Action Alternative have slight variation among modeled flows but largely follow a similar trend. The one exception is that Alternative 3 in wet and above normal water year types exhibits higher flows than all other modeled scenarios. EXP1 exhibits a decreasing trend in daily flows, with some small pulses, throughout the mid-April through mid-May window (Figure J.4-6). EXP3 generally follows the trend of other alternatives but is lower than other alternatives, particularly in wet and above normal water year types, in the second half window (Figure J.4-6).

J.4.3.2 Narrative: EIS

J.4.3.2.1 Survival: Red Bluff Diversion Dam to the confluence of the Sacramento and American rivers (Table J.4-4, Figure J.4-3)

During wet water year types, all alternatives had equal mean predicted survival from RBDD to the confluence of the Sacramento and American Rivers (14.7%). This value is equal to the No Action Alternative mean predicted survival in wet water year types.

During above normal water year types, Alternative 3 had 1% higher mean predicted survival than the No Action Alternative. All other alternatives had equal mean predicted survival from RBDD to the confluence of the Sacramento and American Rivers (14%). This value is equal to the No Action Alternative mean predicted survival in above normal water year types.

During below normal water year types, mean predicted survival under Alternative 1 was 1% greater than mean predicted survival under the No Action Alternative in below normal water year types. Alternative 2 with TUCP without VA, Alternative 2 without TUCP without VA, Alternative 2 without TUCP Delta VA, Alternative 2 without TUCP All VA, Alternative 3, and Alternative 4 had equal mean predicted survival as the No Action Alternative.

During dry water year types, mean predicted survival under Alternative 1 was 2% greater than mean predicted survival under the No Action Alternative in dry water year types. Mean predicted survival under Alternatives 2 with TUCP without VA and without TUCP without VA along with Alternative 4 were 1% greater than mean predicted survival under the No Action Alternative in dry water year types. Alternative 2 without TUCP Delta VA and all VA along with Alternative 3 had equal mean predicted survival as the No Action Alternative.

During critical water year types, mean predicted survival under Alternative 1 and Alternative 2 without TUCP without VA were 2% greater than the No Action Alternative and while Alternative 3 mean predicted survival was 1% less than the No Action Alternative in a critical water year type. Mean predicted survival under Alternative 2 without TUCP all VA was 1% greater than the No Action Alternative. Alternative 2 with TUCP without VA, Alternative 2 without TUCP Delta VA, and Alternative 4 had equal mean predicted survival as the No Action Alternative.

J.4.3.2.2 Survival: Red Bluff Diversion Dam to the DCC on the Sacramento River (Table J.4-6, Figure J.4-5)

During wet water year types, all alternatives had equal mean predicted survival from RBDD to the DCC on the Sacramento River (10.6%). This value is equal to the No Action Alternative mean predicted survival in wet water year types.

During above normal water year types, Alternative 2 with TUCP without VA, Alternative 2 without TUCP without VA, Alternative without TUCP Delta VA, Alternative 2 without TUCP All VA, and Alternative 4 had mean predicted survival equivalent to the No Action Alternative while Alternative 1and Alternative 3 had 1% greater mean predicted survival than the No Action Alternative in above normal water year types.

During below normal water year types, Alternative 2 with TUCP without VA, Alternative 2 without TUCP without VA, Alternative 2 without TUCP Delta VA, Alternative 3, and Alternative 4 had mean predicted survival equivalent to the No Action Alternative while Alternative 1 and Alternative 2 without TUCP All VA had 1% greater mean predicted survival than the No Action Alternative in below normal water year types.

During dry water year types, Alternative 3 had 1% lower mean predicted survival than the No Action Alternative. Alternative 1 and Alternative 2 without TUCP without VA had 2% greater mean predicted survival than the No Action Alternative. Alternative 2 with TUCP without VA and Alternative 3 had 1% higher predicted mean survival than the No Action Alternative. Alternatives 2 without TUCP Delta VA and without TUCP All VA had equal mean predicted survival as the No Action Alternative.

During critical water year types, Alternative 3 had 1% lower mean predicted survival than the No Action Alternative. Alternative 2 without TUCP without VA had 3% greater mean predicted survival than the No Action Alternative. Alternative 2 without TUCP Delta VA, Alternative 2 without TUCP All VA, and Alternative 4 had 1% greater mean predicted survival than the No Action Alternative. Alternative 1 had 2% greater mean predicted survival than the No Action Alternative. Alternative 2 with TUCP without VA had equal mean predicted survival as the No Action Alternative.

J.4.3.2.3 Travel Time: Red Bluff Diversion Dam to the confluence of the Sacramento and American rivers (Table J.4-8, Figure J.4-9)

During wet water year types, Alternative 2 without TUCP All VA had 1% shorter travel time to the confluence with the American River. All other alternatives had equal mean predicted travel time from RBDD to the confluence of the Sacramento and American Rivers (22 days). This value is equal to the No Action Alternative mean predicted travel time in the wet water year type.

During above normal water year types, the mean predicted travel time from RBDD to the confluence of the Sacramento and American Rivers ranged from 1-2% greater (Alternatives 2 without TUCP without VA, without TUCP Delta VA, and Alternative 4, 34 days) to 1-4% lower (32-33 days) in Alternative 1, Alternative 2 with TUCP without VA., Alternative 2 without TUCP All VA, and Alternative 3.

During below normal water year types, mean predicted travel time from RBDD to the confluence of the Sacramento and American Rivers ranged from 5% lower (Alternative 1, 43 days) to 1% greater (Alternative 2 without TUCP without VA and Alternative 3, 46 days) compared with the No Action Alternative (46 days).

During dry water year types, mean predicted travel time from RBDD to the confluence of the Sacramento and American Rivers ranged from 7% lower (Alternative 1, 48 days) to 2% greater (Alternative 3, 53 days) compared with the No Action Alternative (52 days).

During critical water year types, mean predicted travel time from RBDD to the confluence of the Sacramento and American Rivers ranged from 8-10% lower (Alternative 1 and Alternative 2 without TUCP without VA, 47 days) to 3% greater (Alternative 3, 54 days) than the No Action Alternative (62 days).

J.4.3.2.4 Travel Time: Red Bluff Diversion Dam to the DCC on the Sacramento River (Table J.4-10, Figure J.4-11)

During wet water year types, all alternatives had equal mean predicted travel time from RBDD to the DCC on the Sacramento River (27 days). This value is equal to the No Action Alternative mean predicted travel time in the wet water year type.

During above normal water year types, mean predicted travel time from RBDD to the DCC on the Sacramento River ranged from 1-2% greater (Alternatives 2 without TUCP without VA and without TUCP Delta VA, 40 days) to 5% lower (Alternative 3, 37 days) compared with the No Action Alternative in the above normal water year type.

During below normal water year types, mean predicted travel time from RBDD to the DCC on the Sacramento River ranged from 3-5% lower (Alternative 1 at a predicted 51 days and Alternative 2 without TUCP All VA at a predicted 53 days) compared to the No Action

Alternative to equal to the No Action Alternative (Alternative 2 without TUCP without VA, Alternative 2 without TUCP Delta VA, and Alternative 3 at a predicted 54 days).

During dry water year types, mean predicted travel time from RBDD to the DCC on the Sacramento River ranged from 5-8% lower (Alternative 2 without TUCP without VA at a predicted 57 days and Alternative 1 at a predicted 56 days) to 4% greater (Alternative 3, 63 days) compared to the No Action Alternative (60 days).

During critical water year types, mean predicted travel time from RBDD to the DCC on the Sacramento River ranged from 2-9% lower (Alternative 1 at a predicted 57 days and Alternative 2 without TUCP without VA at a predicted 56 days, Alternative 2 without TUCP all VA at 59 days, and Alternative2 without TUCP delta VA and Alternative 4 at a predicted 60 days) to 5% greater (Alternative 3, 65 days and Alternative 2 with TUCP without VA at 63 days) compared with the No Action Alternative (62 days) in the critical water year type.

J.4.3.3 Tables

Table J.4-3. Mean survival for outmigrating Chinook between Red Bluff Diversion Dam and the confluence of the Sacramento and American rivers by water year type for NAA, EXP1, EXP3, and four phases of Alternative 2 (BA scenarios).

WYT	NAA	EXP1	EXP3	Alt2wTUCP woVA	Alt2woTUCP woVA	Alt2woTUCP DeltaVA	Alt2woTUCP AllVA
W	14.7	15.5	14.5	14.7	14.7	14.7	14.7
AN	14.0	15.4	13.9	14.0	14.0	14.0	14.0
BN	13.3	15.0	13.0	13.3	13.3	13.3	13.4
D	12.8	14.7	12.7	12.9	12.9	12.8	12.8
C	12.9	14.0	12.6	12.9	13.2	13.0	12.9

Table J.4-4. Mean survival for outmigrating Chinook between Red Bluff Diversion Dam and the confluence of the Sacramento and American rivers by water year type for NAA, Alternative 1, four phases of Alternative 2, Alternative 3, and Alternative 4. Percent difference from NAA is in parentheses (EIS scenarios).

WYT	NAA	Alt1	Alt2wTUCP woVA	Alt2woTUCP woVA	Alt2woTUCP DeltaVA	Alt2woTUCP AllVA	Alt3	Alt4
W	14.71	14.72(0%)	14.71(0%)	14.71(0%)	14.71(0%)	14.72(0%)	14.72(0%)	14.72(0%)
AN	13.97	14.03(0%)	13.98(0%)	13.94(0%)	13.95(0%)	14.00(0%)	14.05(1%)	13.92(0%)
BN	13.29	13.41(1%)	13.28(0%)	13.25(0%)	13.27(0%)	13.33(0%)	13.26(0%)	13.29(0%)
D	12.83	13.04(2%)	12.93(1%)	12.94(1%)	12.81(0%)	12.82(0%)	12.80(0%)	12.91(1%)
C	12.85	13.07(2%)	12.79(0%)	13.09(2%)	12.88(0%)	12.94(1%)	12.77(-1%)	12.91(0%)

Table J.4-5. Mean survival for outmigrating Chinook between Red Bluff Diversion Dam and the Delta Cross Channel by water year type for NAA, EXP1, EXP3, and four phases of Alternative 2 (BA scenarios).

WYT	NAA	EXP1	EXP3	Alt2wTUCP woVA	Alt2woTUCP woVA	Alt2woTUCP DeltaVA	Alt2woTUCP AllVA
W	10.6	11.2	10.4	10.6	10.6	10.6	10.6
AN	10.0	11.2	9.9	10.0	10.0	10.0	10.1
BN	9.4	10.8	9.2	9.4	9.4	9.4	9.5
D	9.1	10.5	8.9	9.2	9.2	9.1	9.1
C	9.1	9.8	8.9	9.1	9.3	9.2	9.1

Table J.4-6. Mean survival for outmigrating Chinook between Red Bluff Diversion Dam and the Delta Cross Channel by water year type for NAA, Alternative 1, four phases of Alternative 2, Alternative 3, and Alternative 4. Percent difference from NAA is in parentheses (EIS scenarios).

WYT	NAA	Alt1	Alt2wTUCP woVA	Alt2woTUCP woVA	Alt2woTUCP DeltaVA	Alt2woTUCP AllVA	Alt3	Alt4
W	10.60	10.60(0%)	10.60(0%)	10.60(0%)	10.60(0%)	10.61(0%)	10.60(0%)	10.61(0%)
AN	10.00	10.08(1%)	10.01(0%)	9.96(0%)	9.98(0%)	10.05(0%)	10.08(1%)	9.98(0%)
BN	9.39	9.52(1%)	9.39(0%)	9.37(0%)	9.38(0%)	9.45(1%)	9.39(0%)	9.41(0%)
D	9.08	9.26(2%)	9.20(1%)	9.22(2%)	9.07(0%)	9.04(0%)	9.01(-1%)	9.19(1%)
C	9.05	9.26(2%)	9.02(0%)	9.29(3%)	9.10(1%)	9.14(1%)	8.93(-1%)	9.13(1%)

Table J.4-7. Mean travel time (days) for outmigrating Chinook between Red Bluff Diversion Dam and the confluence of the Sacramento and American rivers by water year type for NAA, EXP1, EXP3, and four phases of Alternative 2 (BA scenarios).

WYT	NAA	EXP1	EXP3	Alt2wTUCP woVA	Alt2woTUCP woVA	Alt2woTUCP DeltaVA	Alt2woTUCP AllVA
W	22.3	10.6	25.3	22.3	22.1	22.3	22.1
AN	33.4	12.2	33.8	33.4	33.8	33.9	32.4
BN	45.5	19.5	48.4	44.6	45.2	45.5	43.6
D	51.7	24.9	53.8	49.3	49.1	52.0	52.1
C	52.4	36.0	55.7	51.3	46.4	49.5	51.6

Table J.4-8. Mean travel time (days) for outmigrating Chinook between Red Bluff Diversion Dam and the confluence of the Sacramento and American rivers by water year type for NAA, Alternative 1, four phases of Alternative 2, Alternative 3, and Alternative 4. Percent difference from NAA is in parentheses (EIS scenarios).

WYT	NAA	Alt1	Alt2wTUCP woVA	Alt2woTUCP woVA	Alt2woTUCP DeltaVA	Alt2woTUCP AllVA	Alt3	Alt4
W	22.3	22.3(0%)	22.3(0%)	22.3(0%)	22.3(0%)	22.2(-1%)	22.2(0%)	22.3(0%)
AN	33.4	32.7(-2%)	33.2(-1%)	34.1(2%)	33.8(1%)	32.8(-2%)	32.1(-4%)	33.9(2%)
BN	45.5	43.4(-5%)	45.3(0%)	45.8(1%)	45.4(0%)	44.4(-3%)	45.8(1%)	45.3(-1%)
D	51.7	47.9(-7%)	49.4(-4%)	49.2(-5%)	52.2(1%)	52.4(1%)	52.8(2%)	49.6(-4%)
C	52.4	48.4(-8%)	53.1(1%)	47.3(-10%)	51.1(-3%)	50.3(-4%)	54.1(3%)	51.3(-2%)

Table J.4-9. Mean travel time (days) for outmigrating Chinook between Red Bluff Diversion Dam and the Delta Cross Channel by water year type for NAA, EXP1, EXP3, and four phases of Alternative 2 (BA scenarios).

WYT	NAA	EXP1	EXP3	Alt2wTUCP woVA	Alt2woTUCP woVA	Alt2woTUCP DeltaVA	Alt2woTUCP AllVA
W	27	14	31	27	27	27	27
AN	39	16	40	39	40	40	38
BN	54	25	58	53	54	54	52
D	60	32	63	57	57	61	61
C	62	46	65	61	55	58	61

Table J.4-10. Mean travel time (days) for outmigrating Chinook between Red Bluff Diversion Dam and the Delta Cross Channel by water year type for NAA, Alternative 1, four phases of Alternative 2, Alternative 3, and Alternative 4. Percent difference from NAA is in parentheses (EIS scenarios).

WYT	NAA	Alt1	Alt2wTUCP woVA	Alt2woTUCP woVA	Alt2woTUCP DeltaVA	Alt2woTUCP AllVA	Alt3	Alt4
W	27.0	26.8(-1%)	26.9(0%)	27.0(0%)	26.9(0%)	26.8(-1%)	26.6(-1%)	26.9(0%)
AN	39.3	38.4(-2%)	39.1(-1%)	40.2(2%)	39.7(1%)	38.9(-1%)	37.5(-5%)	39.8(1%)
BN	54.1	51.3(-5%)	54.0(0%)	54.5(1%)	54.1(0%)	52.7(-3%)	54.2(0%)	53.7(-1%)

WYT	NAA	Alt1	Alt2wTUCP woVA	Alt2woTUCP woVA	Alt2woTUCP DeltaVA	Alt2woTUCP AllVA	Alt3	Alt4
D	60.4	55.8(-8%)	57.2(-5%)	57.1(-5%)	61.0(1%)	61.6(2%)	62.6(4%)	57.3(-5%)
C	61.7	57.3(-7%)	62.5(1%)	55.9(-9%)	60.1(-3%)	59.3(-4%)	64.8(5%)	60.2(-2%)

J.4.3.4 Figures

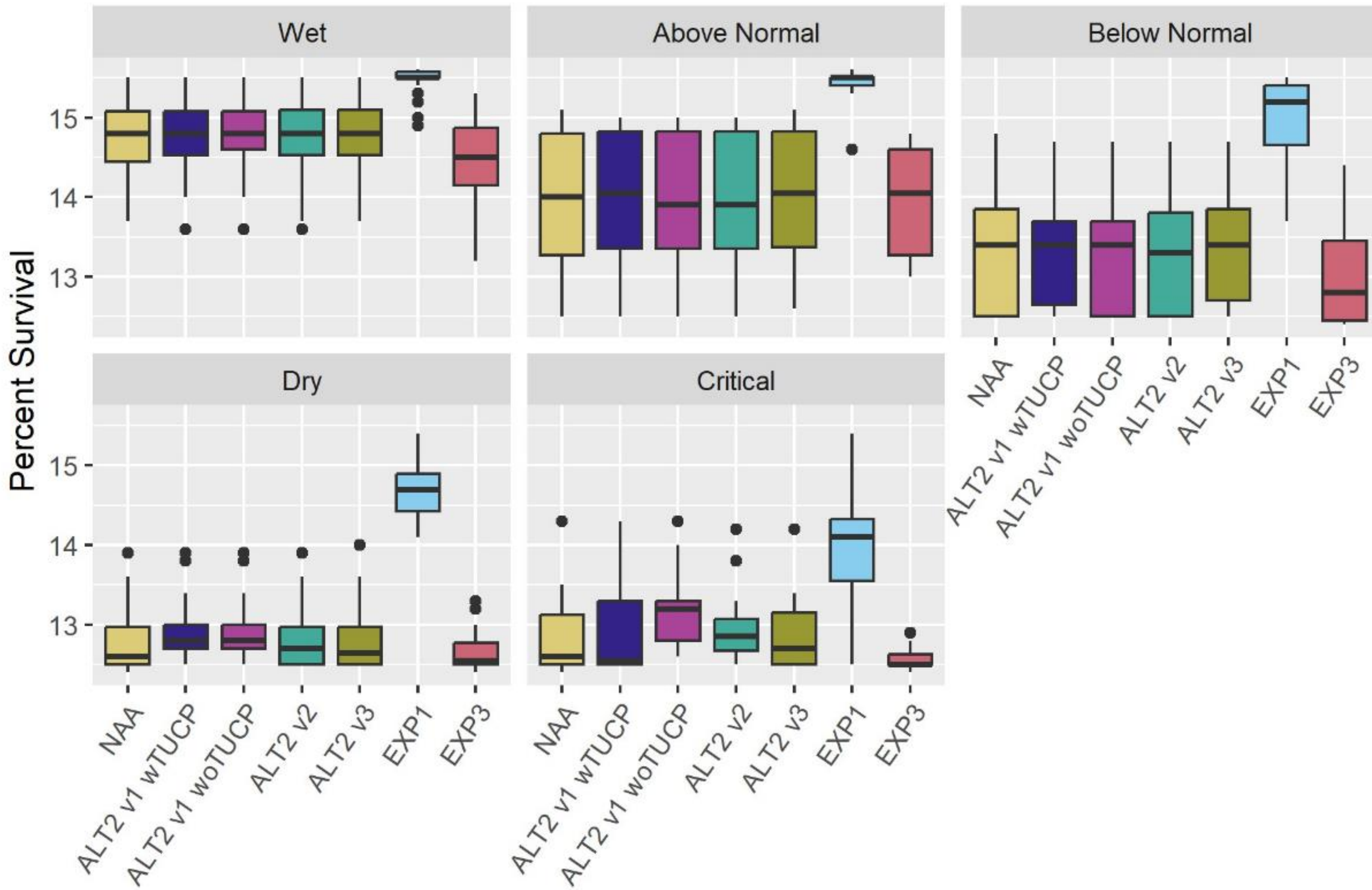

Figure J.4-2. Boxplots of mean survival between Red Bluff Diversion Dam and the confluence with the American River for different modeled scenarios by water year type (BA scenarios).

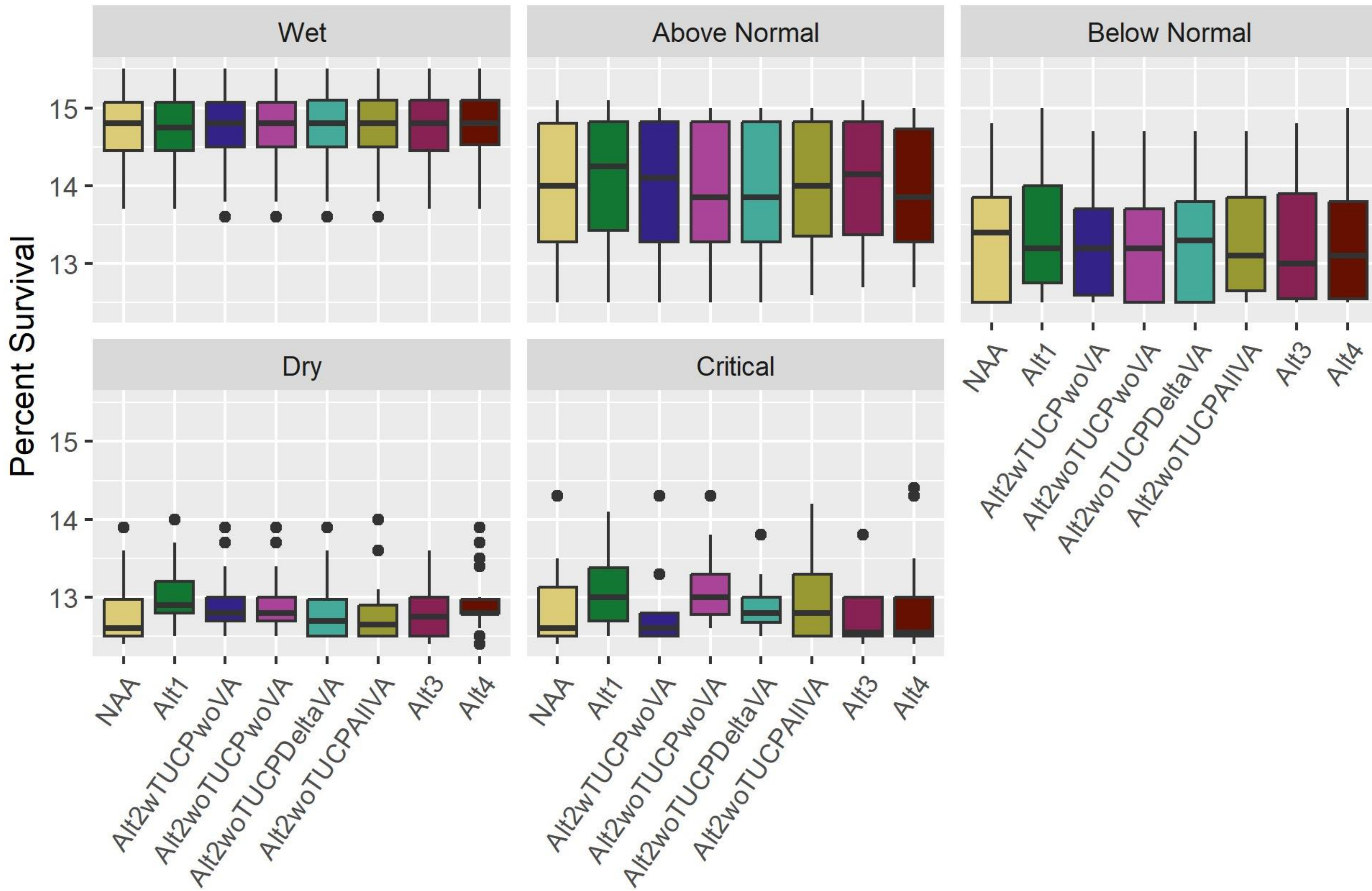

Figure J.4-3. Boxplots of mean survival between Red Bluff Diversion Dam and the confluence with the American River for different modeled scenarios by water year type (EIS scenarios).

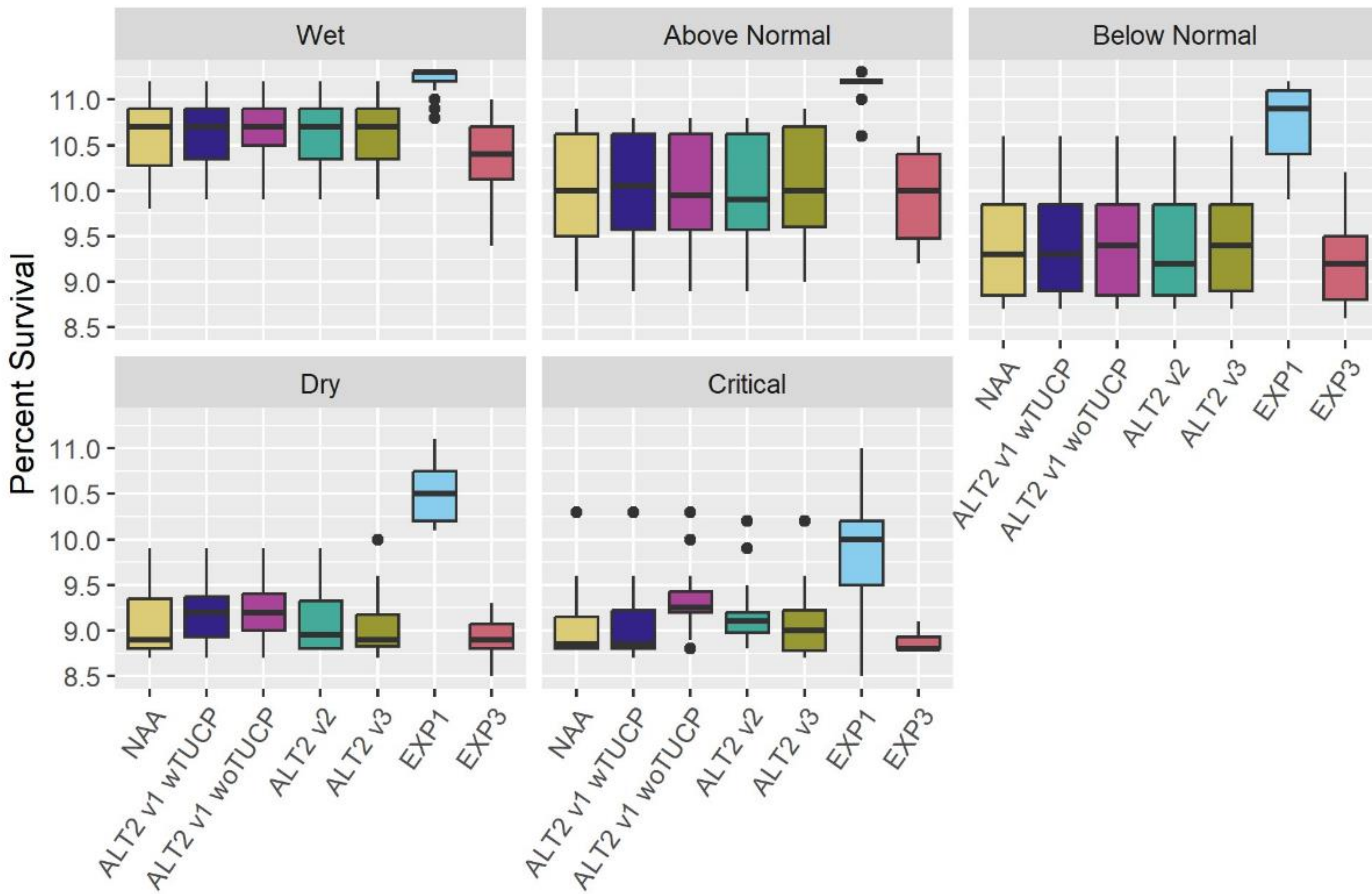

Figure J.4-4. Boxplots of mean survival between Red Bluff Diversion Dam and the Delta Cross Channel for different modeled scenarios by water year type (BA scenarios).

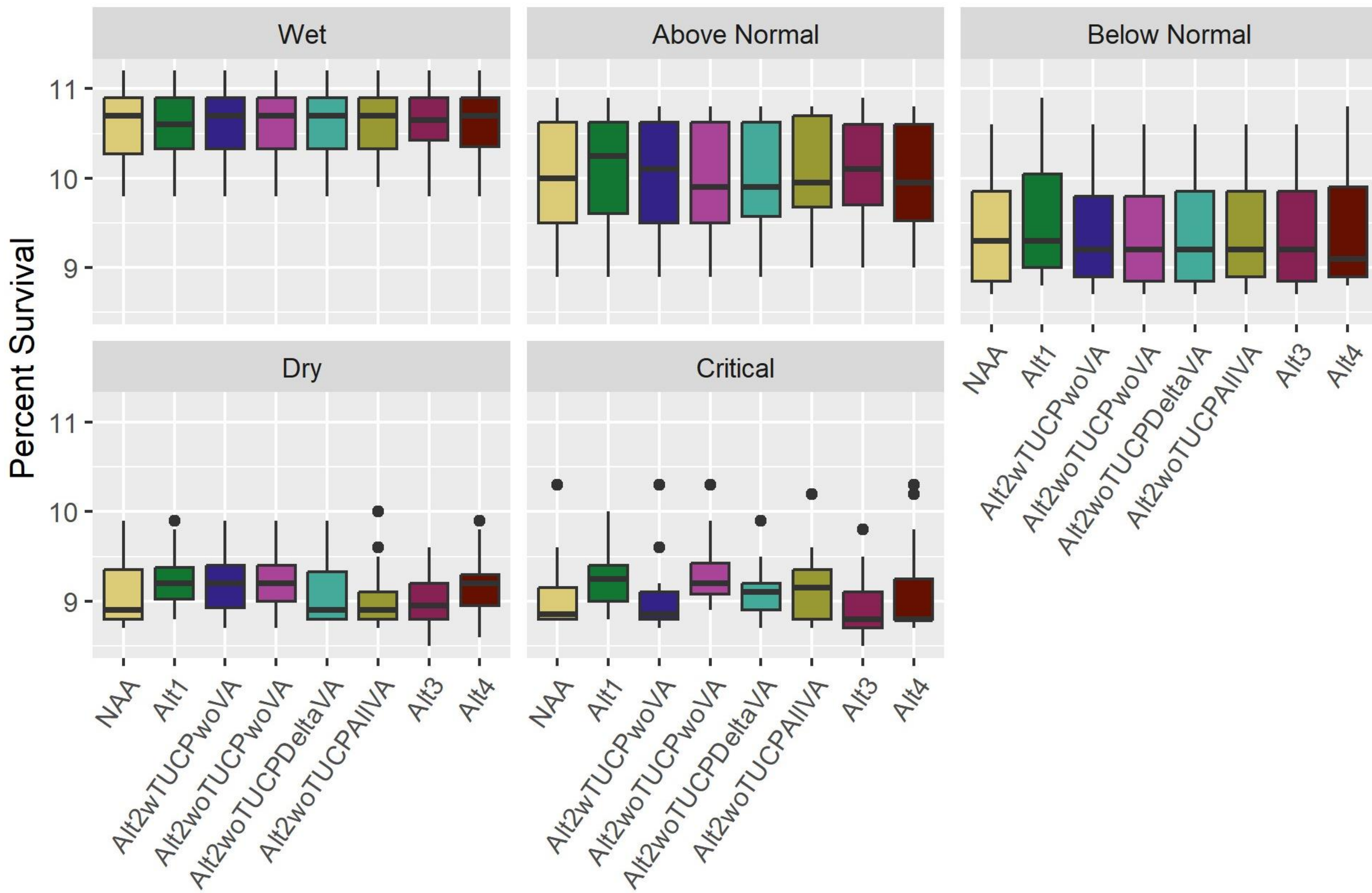

Figure J.4-5. Boxplots of mean survival between Red Bluff Diversion Dam and the Delta Cross Channel for different modeled scenarios by water year type (EIS scenarios).

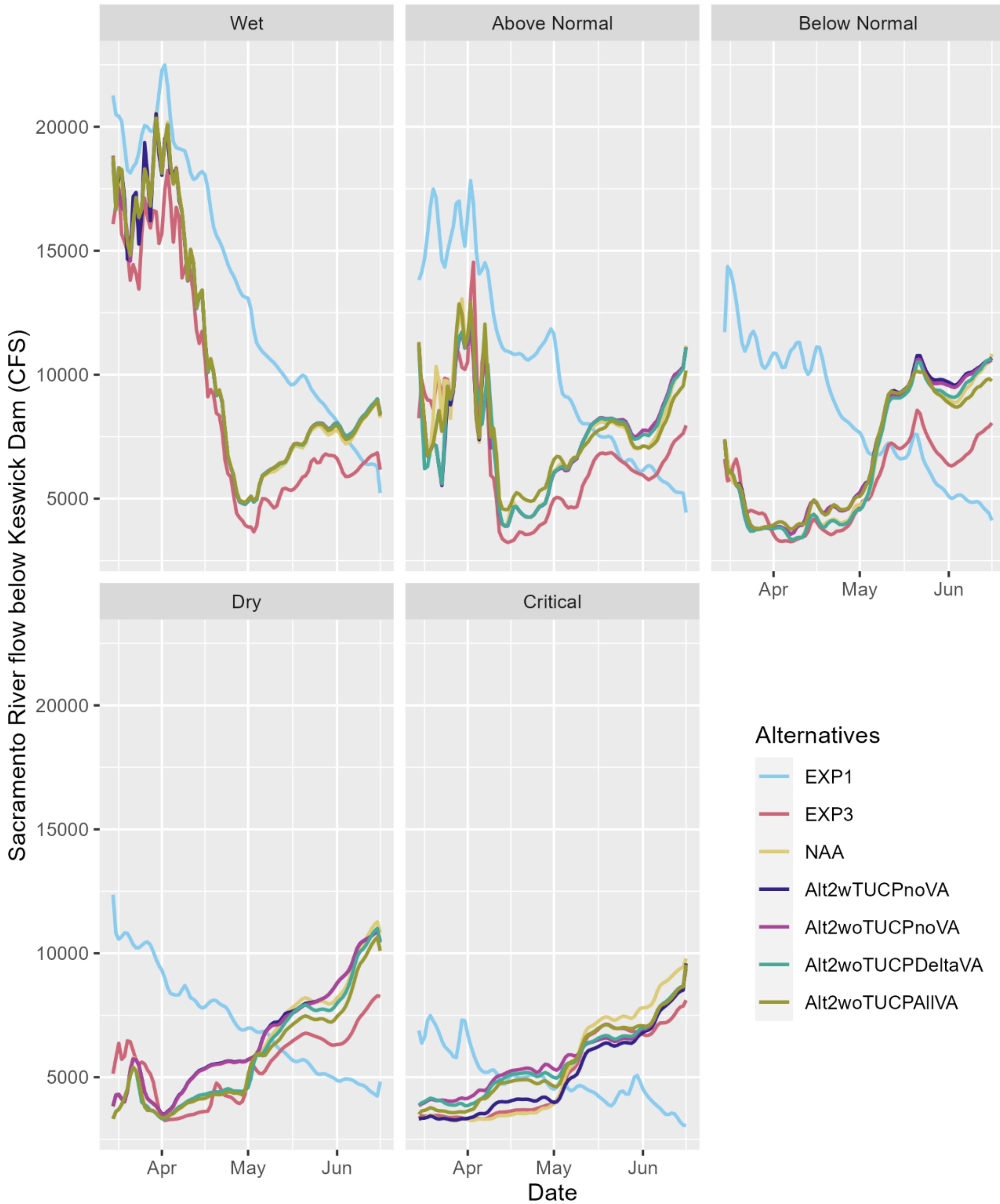

Figure J.4-6. Mean daily Sacramento River flow at Keswick (cfs) of different alternatives by date across water year types (USRDOM, 1922 – 2023) (BA scenarios).

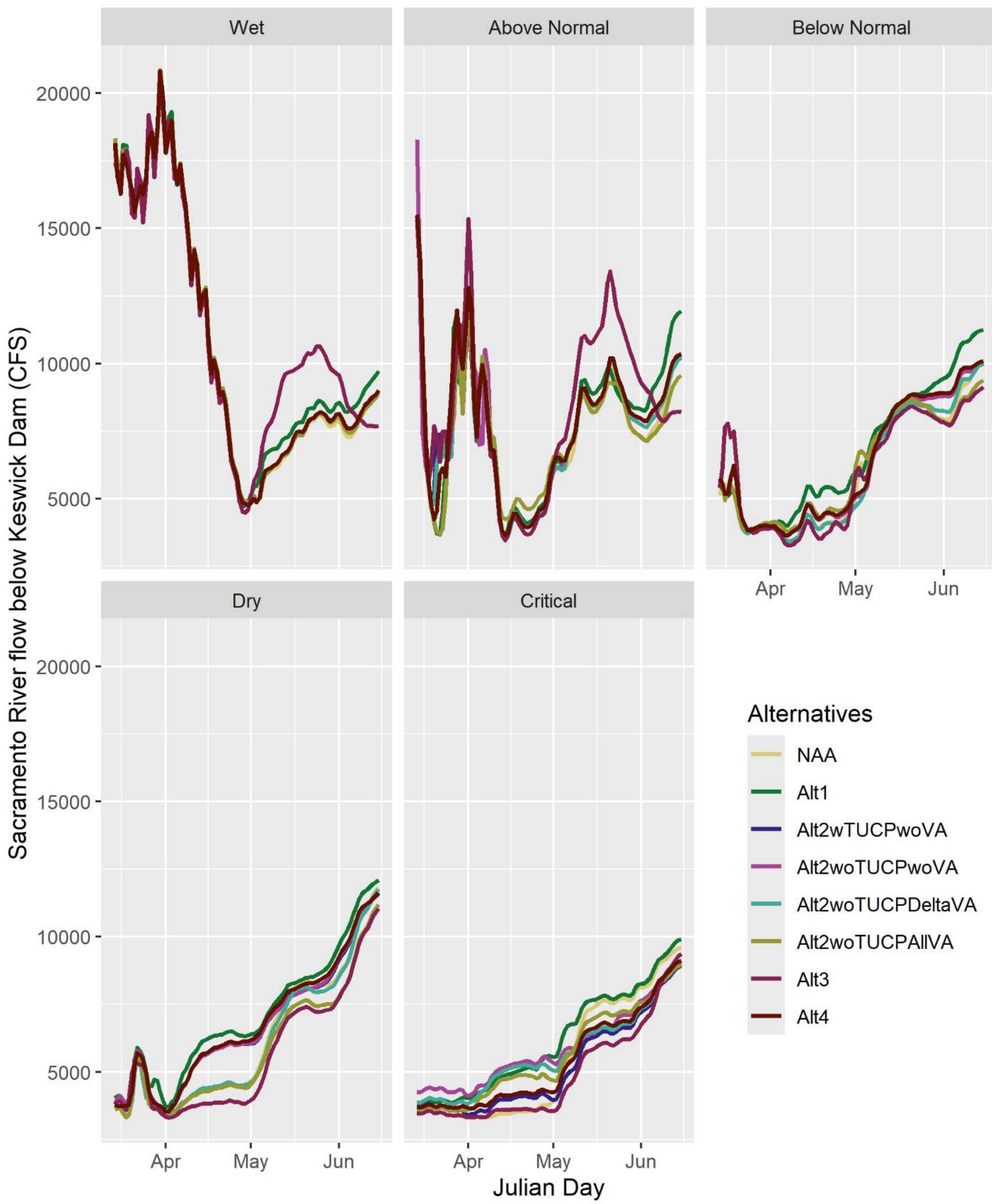

Figure J.4-7. Mean daily Sacramento River flow at Keswick (cfs) of different alternatives by date across water year types (USRDOM, 1922 – 2021) (EIS scenarios).

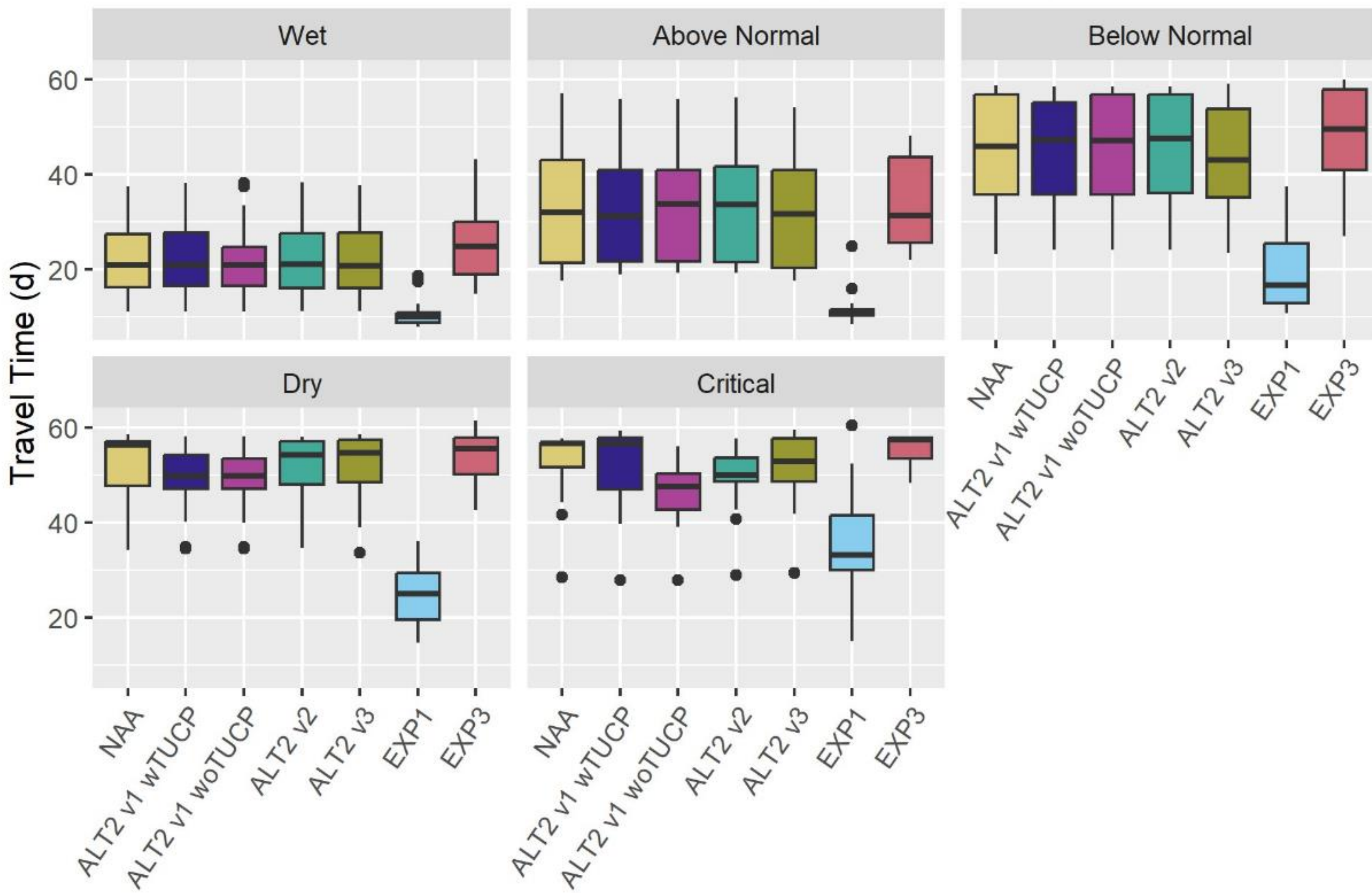

Figure J.4-8. Boxplots of mean travel time (days) between Red Bluff Diversion Dam and the confluence with the American River for different modeled scenarios by water year type (BA scenarios).

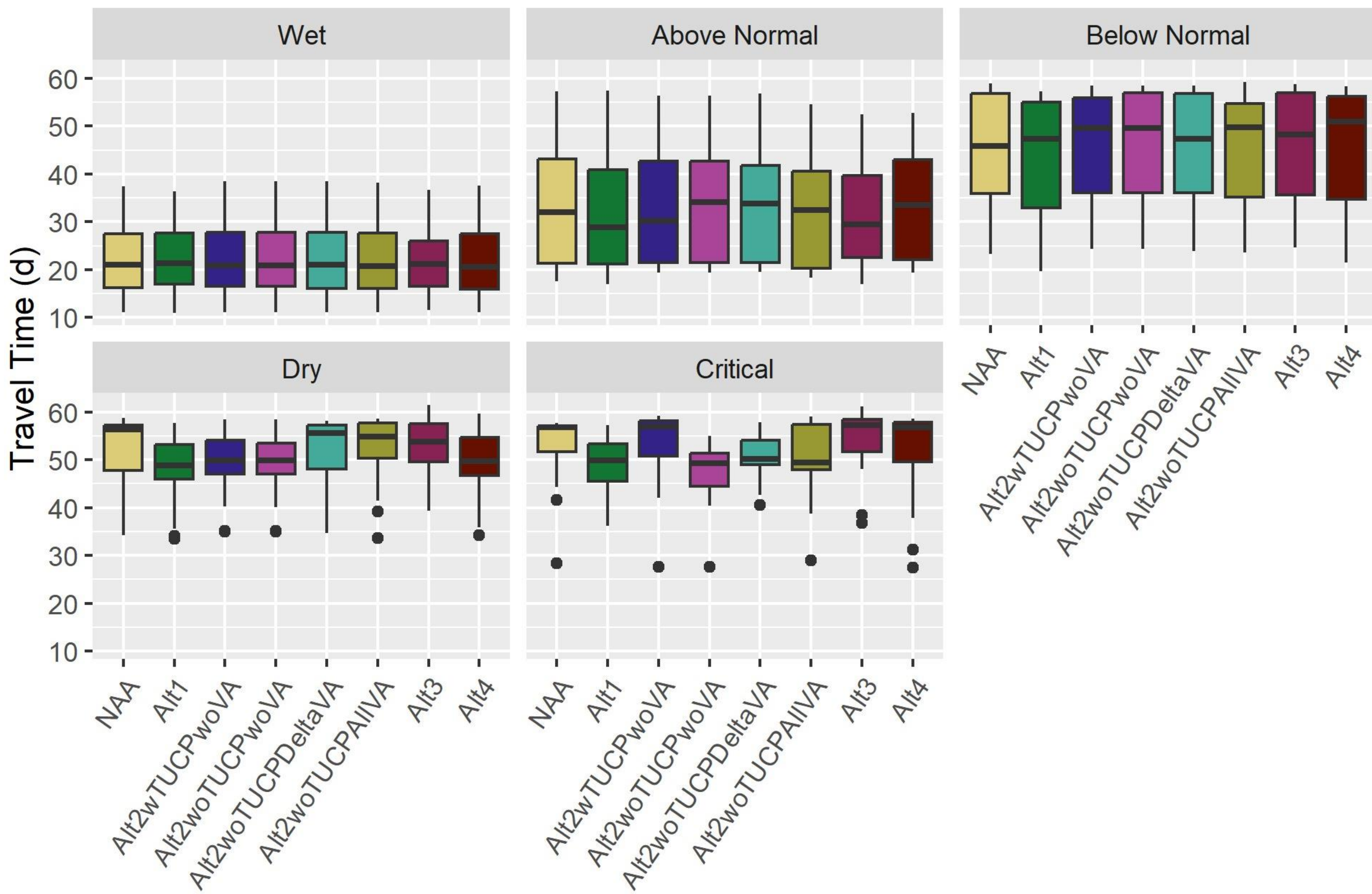

Figure J.4-9. Boxplots of mean travel time (days) between Red Bluff Diversion Dam and the confluence with the American River for different modeled scenarios by water year type (EIS scenarios).

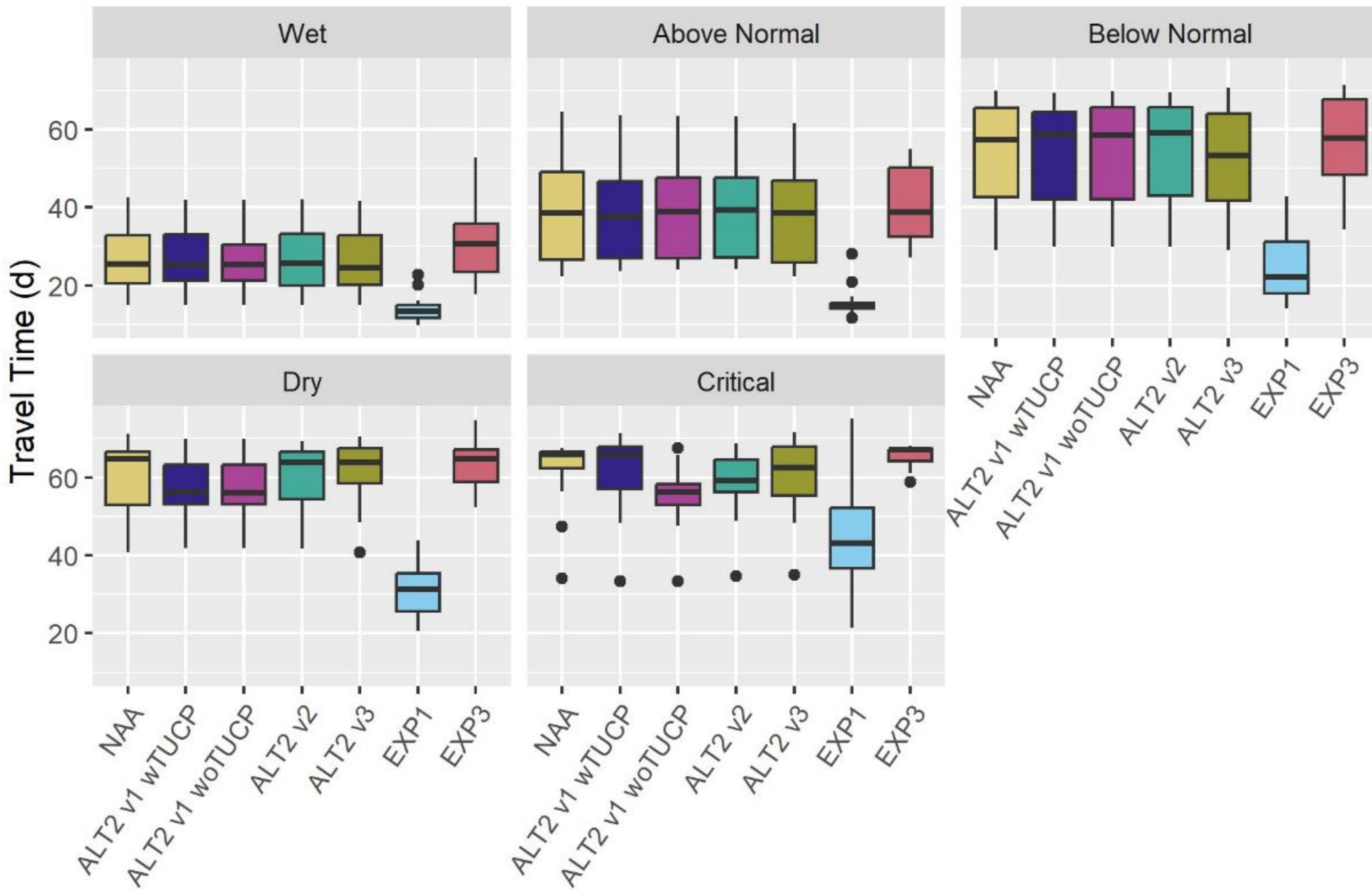

Figure J.4-10. Boxplots of mean travel time (days) between Red Bluff Diversion Dam and the Delta Cross Channel for different modeled scenarios by water year type (BA scenarios).

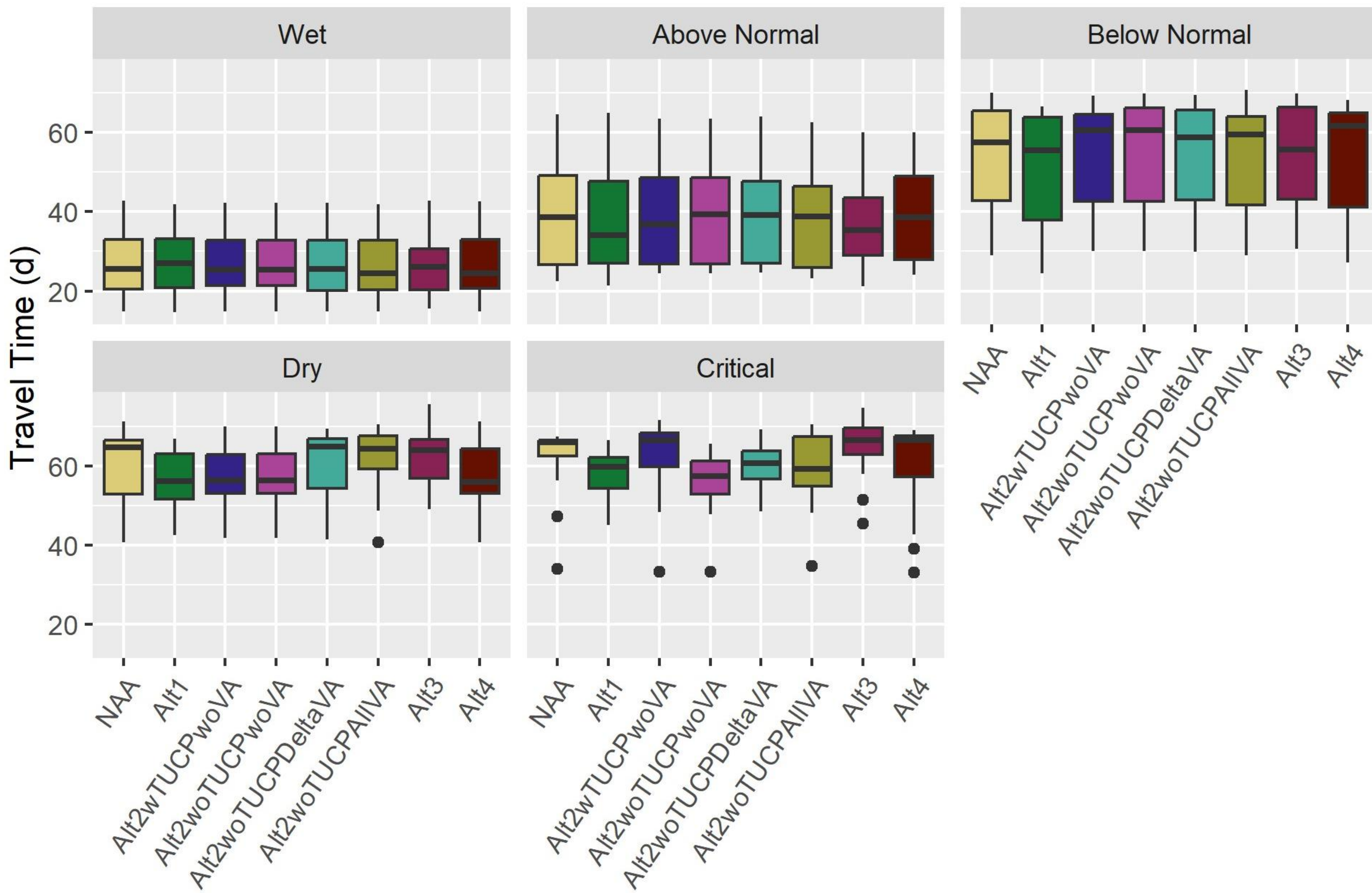

Figure J.4-11. Boxplots of mean travel time (days) between Red Bluff Diversion Dam and the Delta Cross Channel for different modeled scenarios by water year type (EIS scenarios).

J.4.4 References

Anderson JJ, Gurarie E, Zabel RW. Mean free-path length theory of predator-prey interactions: Application to juvenile salmon migration. Ecological Modelling. 2005;186(2):196-211. doi: DOI 10.1016/j.ecolmodel.2005.01.014. PubMed PMID: ISI:000230636400004

Beer, W.N., Anderson, J.J., Iltis, S.I., & Van Holmes, C. (2017). SacPAS Fish Model: A model for emergence, migration and survival of Sacramento River salmon. University of Washington.

Michel, C.J., Notch, J.J., Cordoleani, F., Ammann, A.J., Danner, E.M., 2021. Nonlinear survival of imperiled fish informs managed flows in a highly modified river. *Ecosphere* 12 (5), e03498. https://doi.org/10.1002/ecs2.3498.

Notch, J. J., A. S. McHuron, C. J. Michel, F. Cordoleani, M. Johnson, M. J. Henderson, and A. J. Ammann. 2020. Outmigration survival of wild Chinook salmon smolts through the Sacramento River during historic drought and high water conditions. *Environmental Biology of Fishes* 103: 561–576.

Steel, A. E., Anderson, J.J., Mulvey, B., Smith, D. L. (2020). Applying the mean free-path length model to juvenile Chinook salmon migrating in the Sacramento River, California. *Environ Biol Fish* 103:1603-1617

Zabel R.W., Faulkner J., Smith S., Anderson J., Van Holmes C., Beer W. N., Iltis S., Krinke J., Fredricks G., Bellerud B., Sweet J., Giorgi A. 2008. Comprehensive passage (COMPASS) model: a model of downstream migration and survival of juvenile salmonids through a hydropower system. *Hydrobiologia*. 609(1):289-300

This page intentionally left blank.