testing. First, the tested Chinook salmon were larger individuals (e.g., 110-140-mm fork length in 2011), which may result in better swimming ability and effectiveness of the BAFF relative to the smaller sizes of winter-run and spring-run Chinook salmon that would encounter the BAFF. Second, all fish were hatchery-raised, and therefore may have behaved differently than wild fish would in relation to a BAFF. Last, river flow in 2011 was very high, resulting in largely unidirectional, downstream flow, which could have improved BAFF effectiveness; however, the more variable flow conditions in 2012, including periods of reverse flow, illustrated that the BAFF has potential to be effective across a variety of environmental conditions if an engineering solution is desired.

Effects of nonphysical barrier construction and near-field predation are discussed in Section 5.5.3, *Georgiana Slough Nonphysical Fish Barrier*.

5.4.1.3.1.2.1.3 Through-Delta Survival

Various analytical tools were used to provide greater biological context for the previously described operations-related differences in Delta hydrodynamics between the NAA and PA. These included the Delta Passage Model, analyses based on Newman (2003) and Perry (2010), and the winter-run Chinook salmon life cycle models, IOS and OBAN. This section describes the principal results of these analyses. The tools were all focused on Chinook salmon, but the inferences from the results may be applicable to juvenile steelhead, given that there are similarities between Chinook salmon and steelhead with respect to at least some features of their Delta ecology (e.g., losses in Clifton Court Forebay [Gingras 1997; Clark et al. 2009] and relative loss by migration pathways through the Delta [Singer et al. 2013]) and their migration timing overlaps that of the listed juvenile Chinook salmon.

5.4.1.3.1.2.1.3.1 Delta Passage Model: Winter-Run and Spring-Run Chinook Salmon

The Delta Passage Model (DPM) integrates operational effects of the NAA and PA that could influence survival of migrating juvenile winter-run and spring-run Chinook salmon through the Delta: differences in channel flows (flow-survival relationships), differences in routing based on flow proportions (e.g., entry into the interior Delta, where survival is lower), and differences in south Delta exports (export-survival relationships). Details of the DPM analysis are provided in Appendix 5.D, *Quantitative Methods and Detailed Results for Effects Analysis of Chinook Salmon, Central Valley Steelhead, Green Sturgeon, and Killer Whale*, Section 5.D.1.2.2, *Delta Passage Model*. As with all such modeling tools, the DPM does not account for the results of the coordinated monitoring and research under Collaborative Science and Adaptive Management program, including real-time operational adjustments that would occur in relation to fish presence, for example.

For winter-run Chinook salmon, the DPM results suggested that total through-Delta survival would be similar or lower under the PA than the NAA (Figure 5.4-7 and Figure 5.4-8). Mean total through-Delta survival under the PA ranged from 0.24 in critical years to 0.43 in wet years, with a range of 2% less than NAA in wet and above normal years to 7% less in dry years (Table 5.4-12). Mean survival down the mainstem Sacramento River route under the PA ranged from 0.26 in critical years to 0.46 in wet years, and the difference from NAA ranged from 4% less in critical years to 8% less in below normal and dry years, reflecting the influence of less river flow downstream of the NDD under the PA. As would be expected given that both scenarios assumed a notched Fremont Weir, Yolo Bypass entry was very similar between NAA and PA scenarios, and survival was identical (because the random draws from the route-specific survival distribution [Appendix 5.D, *Quantitative Methods and Detailed Results for Effects Analysis of Chinook Salmon, Central Valley Steelhead, Green Sturgeon, and Killer Whale*, Section 5.D.1.2.2.2.5.4, *Route-Specific Survival*] were the same for NAA and PA). A marginally (1-2%) lower proportion of fish entered Sutter and Steamboat Sloughs under the PA compared to NAA (reflecting the flow routing into junctions; see Table 5.4-11 in Section 5.4.1.3.1.2.1.2.1, *Flow Routing into Channel Junctions*), and the difference in mean survival for this route between PA and NAA was similar to that of the mainstem Sacramento River, reflecting the similar flow-survival relationships in the relevant reaches (see Appendix 5.D, *Quantitative Methods and Detailed Results for Effects Analysis of Chinook Salmon, Central Valley Steelhead, Green Sturgeon, and Killer Whale*, Section 5.D.1.2.2.2.5.5, *Flow-Dependent Survival*). A slightly greater (1-2%) proportion of fish used the interior Delta migration route under the PA compared to NAA (again reflecting the flow routing into junctions; see Table 5.4-11- in Section 5.4.1.3.1.2.1.2.1, *Flow Routing into Channel Junctions*), and mean survival in this route was appreciably greater (19-28%) in wet and above normal years, which reflected appreciably less south Delta exports under the PA[15].

Seventy-five randomized iterations of the DPM allowed 95% confidence intervals to be calculated for the annual estimates of through-Delta survival (Appendix 5.D, *Quantitative Methods and Detailed Results for Effects Analysis of Chinook Salmon, Central Valley Steelhead, Green Sturgeon, and Killer Whale*, Section 5.D.1.2.2.4, *Randomization to Illustrate Uncertainty*); of the 81 years in the simulation, the PA and NAA had non-overlapping confidence intervals in 10 years and all were lower under the PA (Figure 5.4-9). Of the 10 years, 3 were wet years (12% of all wet years), 1 was an above normal year (8% of all above normal years), 2 were below normal years (18% of all below normal years), 4 were dry years (20% of all dry years), and none were critical years. This suggests that the magnitudes of difference observed from the DPM would be mostly likely to be statistically detectable in below normal or dry years, although it is acknowledged that the DPM incorporates flow-survival and other relationships from a variety of studies and its measures of uncertainty are drawn from these relationships; an integrated field study of through-Delta survival during PA implementation would not necessarily have similar uncertainty in survival estimates. In addition, the operations modeling included a wider range of conditions than occurred during the field studies upon which the DPM model relationships were based, which contributes to the uncertainty. To provide insight into the conditions leading to years with non-overlapping confidence intervals, mean flow into reach Sac 3 (Sacramento River downstream of Georgiana Slough)[16] and south Delta exports, both weighted by proportion of the population entering the Delta, were plotted in relation to years with overlapping confidence intervals. This illustrated that years with non-overlapping confidence intervals were found in the range of weighted mean Sacramento River flow into reach Sac3 of ~7,000-12,500 cfs for NAA and ~5,500-10,000 cfs for PA (Figure 5.4-10). This corresponds

[15] In addition, the DPM's export-survival relationship does not calculate absolute survival, but a ratio of survival in the interior Delta to survival in reach Sac3 (Appendix 5.D, *Quantitative Methods and Detailed Results for Effects Analysis of Chinook Salmon, Central Valley Steelhead, Green Sturgeon, and Killer Whale*, Section 5.D.1.2.2.2.5.6, *Export-Dependent Survival*), and in wetter years the difference in survival in reach Sac3 between NAA and PA begins to level off as the flow-survival relationship begins to asymptote (Figure 5.D-45 in Appendix 5.D), so that less south Delta exports have a greater effect on survival at greater Sacramento River flows.

[16] This reach was chosen because it is the basis for the Sacramento River flow-survival relationships in the DPM, from Perry (2010).

closely with weighted mean flows in below normal years (NAA: 7,826 cfs; PA: 6,687 cfs) and dry years (NAA: 7,116 cfs; PA: 6,048 cfs), which is logical given that these had the greatest differences in survival (Table 5.4-12). In years with less flow, there are greater constraints on north Delta exports, whereas in wetter years, the rate of change in survival per unit of river flow decreases (Figure 5.D-45 in Appendix 5.D, *Quantitative Methods and Detailed Results for Effects Analysis of Chinook Salmon, Central Valley Steelhead, Green Sturgeon, and Killer Whale*). Therefore, there would be the greatest potential for adverse effects in below normal and dry years. As previously stated this analysis does not account for the results of the coordinated monitoring and research under Collaborative Science and Adaptive Management program, including real-time operational adjustments that would be made in response to fish presence, which would seek to maximize water supplies while limiting potential adverse effects as appropriate to avoid jeopardy.

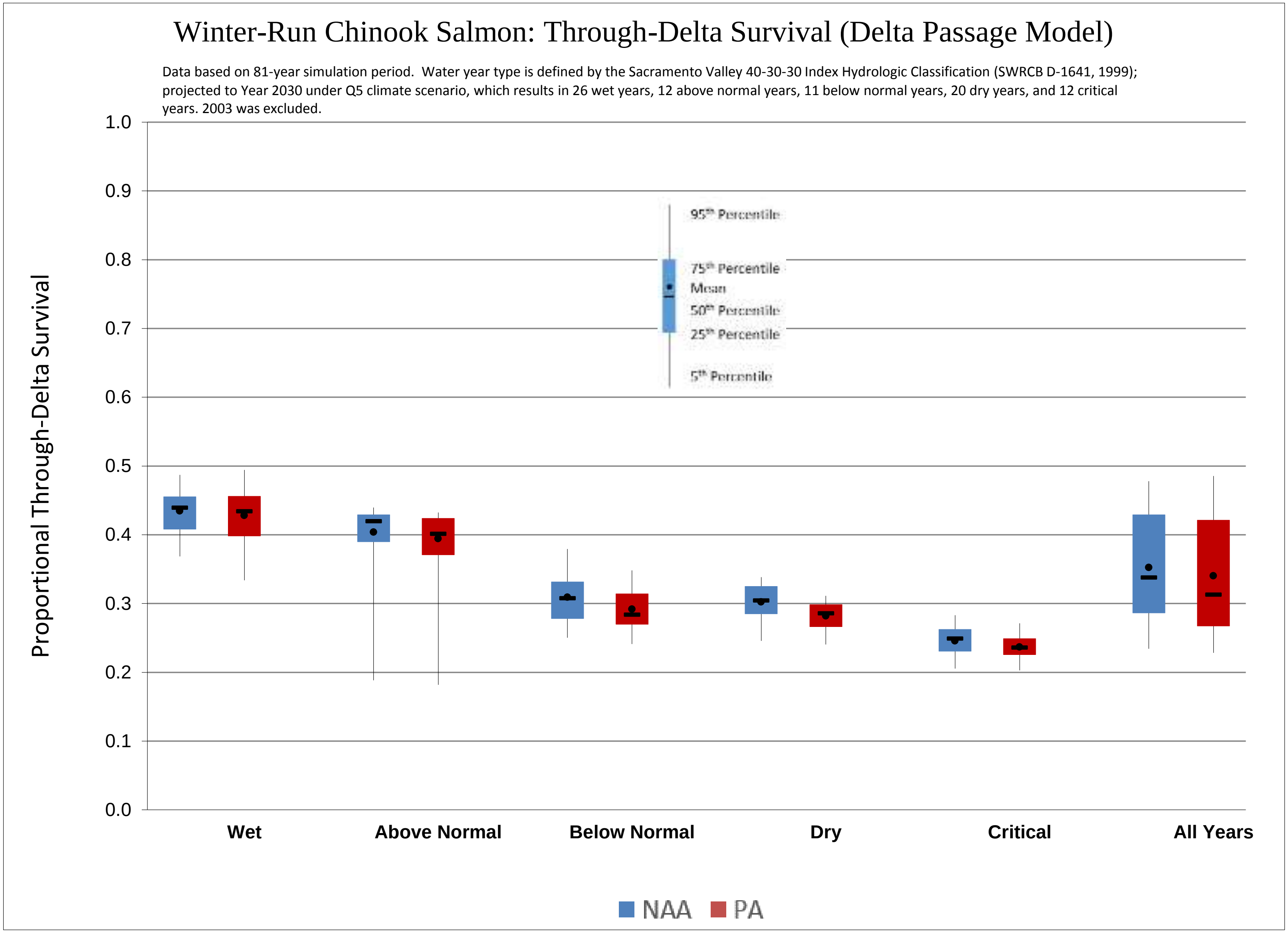


Figure 5.4-7. Box Plots of Winter-Run Chinook Salmon Annual Through-Delta Survival Estimated from the Delta Passage Model, Grouped by Water Year Type.

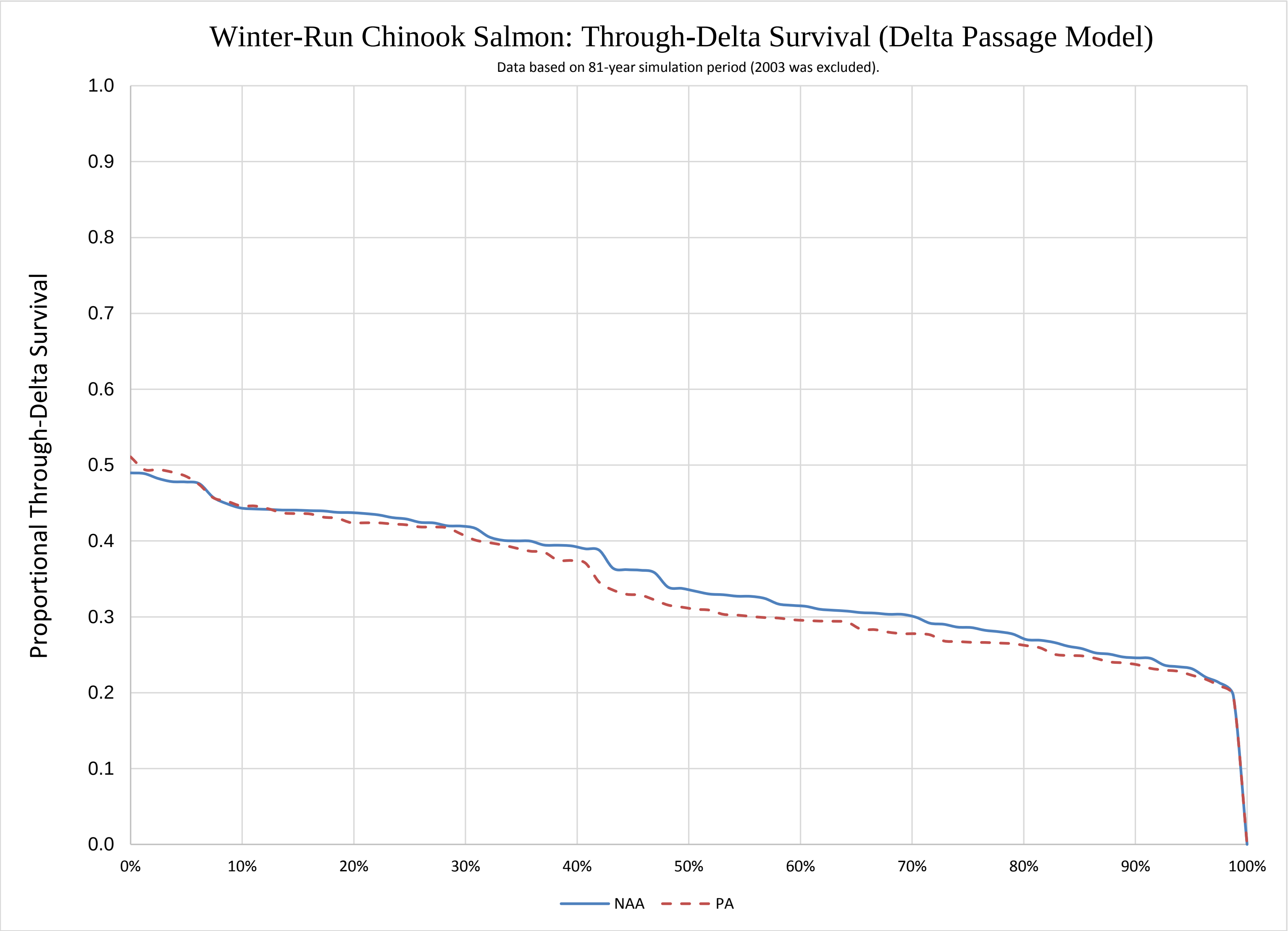
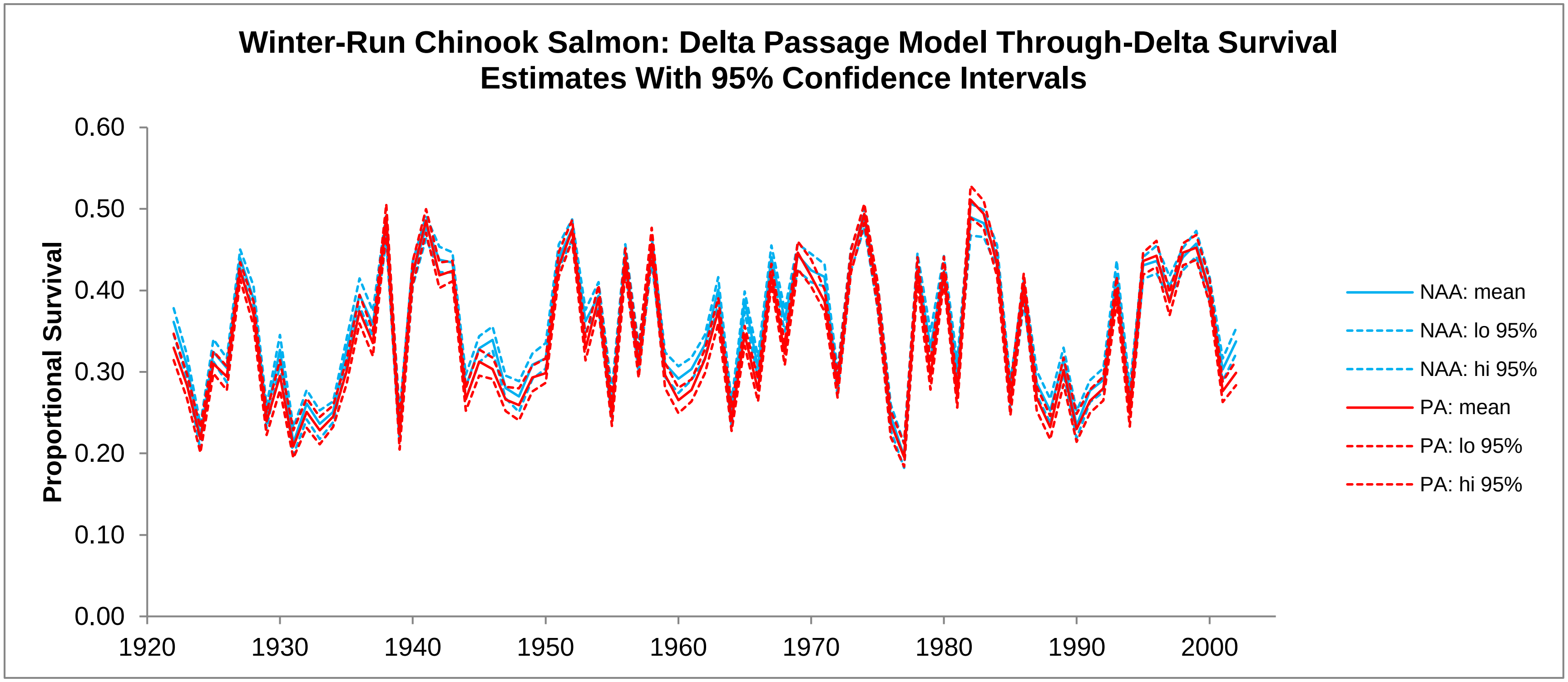


Figure 5.4-8. Exceedance Plot of Winter-Run Chinook Salmon Annual Through-Delta Survival Estimated from the Delta Passage Model.

Table 5.4-12. Delta Passage Model: Winter-Run Chinook Salmon Mean Through-Delta (Total) Survival, Mainstem Sacramento River survival, and Proportion Using and Surviving Other Migration Routes.

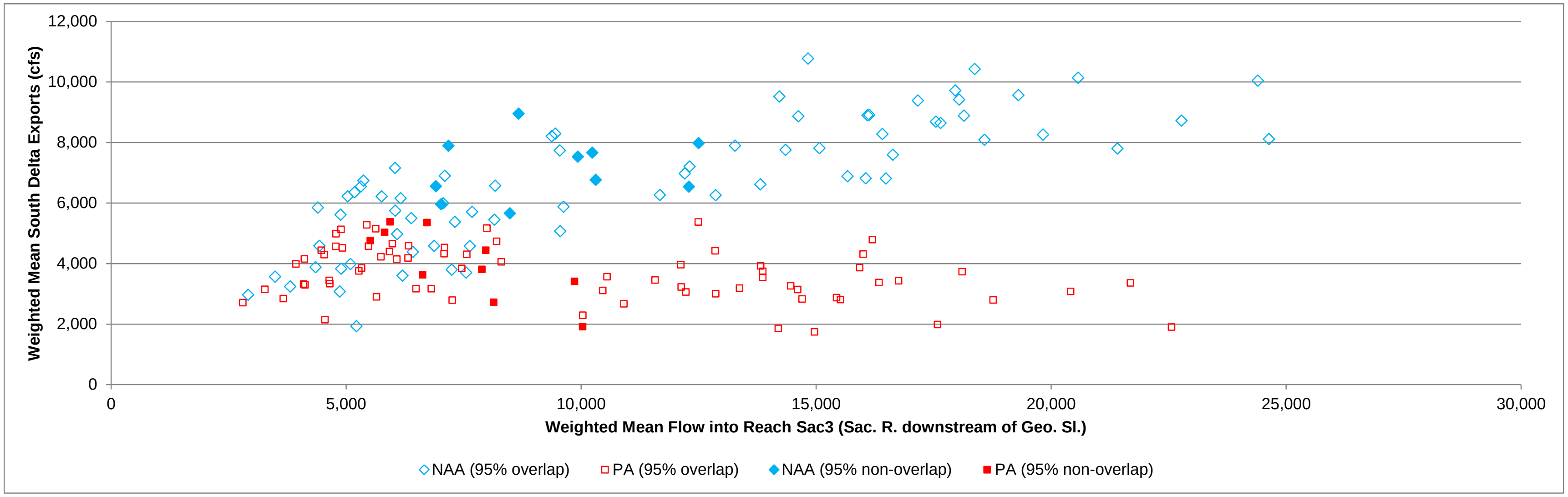
WY	Total Survival			Mainstem Sacramento River Survival			Yolo Bypass					
							Proportion Using Route			Survival		
	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
W	0.43	0.43	-0.01 (-2%)	0.48	0.46	-0.02 (-5%)	0.22	0.22	0.00 (1%)	0.47	0.47	0.00 (0%)
AN	0.40	0.39	-0.01 (-2%)	0.44	0.42	-0.02 (-6%)	0.16	0.17	0.00 (1%)	0.47	0.47	0.00 (0%)
BN	0.31	0.29	-0.02 (-6%)	0.34	0.31	-0.03 (-8%)	0.06	0.06	0.00 (2%)	0.47	0.47	0.00 (0%)
D	0.30	0.28	-0.02 (-7%)	0.33	0.30	-0.03 (-8%)	0.06	0.06	0.00 (2%)	0.47	0.47	0.00 (0%)
C	0.25	0.24	-0.01 (-4%)	0.27	0.26	-0.01 (-4%)	0.03	0.03	0.00 (0%)	0.47	0.47	0.00 (0%)
WY	Sutter/Steamboat Sloughs						Interior Delta (Via Georgiana Slough/DCC)					
	Proportion Using Route			Survival			Proportion Using Route			Survival		
	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
W	0.29	0.28	-0.01 (-2%)	0.52	0.50	-0.02 (-4%)	0.26	0.26	0.00 (2%)	0.18	0.23	0.05 (28%)
AN	0.30	0.29	-0.01 (-2%)	0.49	0.46	-0.02 (-5%)	0.26	0.27	0.01 (2%)	0.17	0.20	0.03 (19%)
BN	0.31	0.30	-0.01 (-2%)	0.38	0.35	-0.03 (-7%)	0.27	0.28	0.01 (2%)	0.14	0.15	0.01 (5%)
D	0.30	0.30	-0.01 (-2%)	0.37	0.34	-0.03 (-8%)	0.27	0.28	0.01 (2%)	0.14	0.14	0.00 (0%)
C	0.29	0.29	0.00 (-1%)	0.31	0.30	-0.01 (-4%)	0.29	0.29	0.00 (1%)	0.13	0.12	0.00 (-1%)

Note: Survival in Sutter/Steamboat Sloughs and Interior Delta routes includes survival in the Sacramento River prior to entering the channel junctions.



Note: Broken lines indicate 95% confidence intervals from the 75 iterations of the DPM.

Figure 5.4-9. Time Series of Mean (With 95% Confidence Interval) Annual Juvenile Winter-Run Chinook Salmon Through-Delta Survival Estimated from the Delta Passage Model.



Note: 95% overlap and non-overlap refers to years with overlapping and non-overlapping confidence intervals from DPM.

Figure 5.4-10. Delta Passage Model: Annual mean Sacramento River Flow into Reach Sac3 (Downstream of Georgiana Slough) and South Delta Exports, Weighted by Proportional Entry into the Delta of Winter-Run Chinook Salmon, Classified into Years of Overlapping and Non-overlapping Through-Delta Survival 95% Confidence Intervals.

For spring-run Chinook salmon, the DPM results suggested that through-Delta survival under the PA would be similar to or lower than the NAA (Figure 5.4-11 and Figure 5.4-12), with the differences being less than those for winter-run Chinook salmon. Mean total through-Delta survival under the PA ranged from 0.22 in critical years to 0.42 in wet years, with a range of 1% less than NAA in wet and critical years to 4% less in dry years (Table 5.4-13). Mean survival down the mainstem Sacramento River route under the PA ranged from 0.23 in critical years to 0.44 in wet years, and the difference from NAA ranged from 1% less in critical years to 5% less in above normal and dry years, reflecting the influence of less river flow downstream of the NDD under the PA. Yolo Bypass entry was similar between NAA and PA scenarios (both assumed a notched weir), and survival was identical (because the random draws from the route-specific survival distribution [Appendix 5.D, *Quantitative Methods and Detailed Results for Effects Analysis of Chinook Salmon, Central Valley Steelhead, Green Sturgeon, and Killer Whale,* Section 5.D.1.2.2.2.5.4, *Route-Specific Survival*] were the same for NAA and PA). A marginally (0-2%) lower proportion of fish entered Sutter and Steamboat Sloughs under the PA compared to NAA (reflecting the flow routing into junctions; see Table 5.4-11 in Section 5.4.1.3.1.2.1.2.1, *Flow Routing into Channel Junctions*), and the difference in mean survival for this route between PA and NAA was similar to that of the mainstem Sacramento River, reflecting the similar flow-survival relationships in the relevant reaches (Appendix 5.D, *Quantitative Methods and Detailed Results for Effects Analysis of Chinook Salmon, Central Valley Steelhead, Green Sturgeon, and Killer Whale,* Section 5.D.1.2.2.2.5, *Flow-Dependent Survival*). A similar or marginally greater (1-2%) proportion of fish used the interior Delta migration route under the PA compared to NAA (again reflecting the flow routing into junctions; see Table 5.4-11 in Section 5.4.1.3.1.2.1.2.1, *Flow Routing into Channel Junctions*), and mean survival in this route was greater (11–19%) in wet and above normal years, which reflected appreciably less south Delta exports under the PA.

As noted for winter-run Chinook salmon, seventy-five randomized iterations of the DPM allowed 95% confidence intervals to be calculated for the annual estimates of through-Delta survival (Appendix 5.D, *Quantitative Methods and Detailed Results for Effects Analysis of Chinook Salmon, Central Valley Steelhead, Green Sturgeon, and Killer Whale,* Section 5.D.1.2.2.4, *Randomization to Illustrate Uncertainty*). The 95% confidence intervals for NAA and PA overlapped in all years (Figure 5.4-13), illustrating that the magnitude of differences may be difficult to detect statistically if field studies were undertaken during PA implementation to assess effects[17]. The spring-run Chinook salmon DPM results suggested very small differences in survival under the PA compared to NAA, whereas the analysis based on Newman (2003) (discussed in the next section) suggested that there would essentially be no difference in survival (despite the Delta same entry timing being used for both). This reflects model differences (with further discussion being provided for the analysis based on Newman [2003] in the next section): in the DPM, the benefits of less south Delta exports under the PA are only experienced by the proportion of the population entering the interior Delta (0.25-0.30 take this route), whereas for the analysis based on Newman (2003), the effect of exports is applied to the entire population; and in the DPM, the export-survival effect is weaker than the flow-survival effect (Model

[17] As noted for winter-run Chinook salmon, it is acknowledged that the DPM incorporates flow-survival and other relationships from a variety of studies and its measures of uncertainty are drawn from these relationships; an integrated field study of through-Delta survival during PA implementation would not necessarily have similar uncertainty in survival estimates.

Demonstration results in Appendix 5.D, *Quantitative Methods and Detailed Results for Effects Analysis of Chinook Salmon, Central Valley Steelhead, Green Sturgeon, and Killer Whale*, Section 5.D.1.2.2.5.2.3, *Model Demonstration*) and is calculated as a ratio of survival in reach Sac3 (which is lower because of the NDD), whereas as discussed in the following section, in the analysis based on Newman (2003) the export-survival effect is similar in magnitude to the flow-survival effect—the “offsetting” of south and north Delta exports results in similar survival under PA and NAA for the analysis based on Newman (2003). Further discussion of these issues and the Sacramento River flow and south Delta exports during the spring-run Chinook salmon migration period used for the DPM are provided in the analysis based on Newman (2003), which is found in the next section. Overall, the DPM results suggested the potential for a marginal adverse effect on spring-run Chinook salmon juveniles from the PA but, as previously stated for winter-run Chinook salmon, this analysis does not account for the results of the coordinated monitoring and research under the Collaborative Science and Adaptive Management program, including the real-time operational adjustments that would be made in response to fish presence, which would seek to maximize water supplies while limiting potential adverse effects as appropriate to avoid jeopardy.

Table 5.4-13. Delta Passage Model: Spring-Run Chinook Salmon Mean Through-Delta (Total) Survival, Mainstem Sacramento River survival, and Proportion Using and Surviving Other Migration Routes.

WY	Total Survival			Mainstem Sacramento River Survival			Yolo Bypass					
							Proportion Using Route			Survival		
	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
W	0.42	0.42	0.00 (-1%)	0.46	0.44	-0.02 (-4%)	0.19	0.19	0.00 (1%)	0.47	0.47	0.00 (0%)
AN	0.37	0.36	-0.01 (-2%)	0.39	0.37	-0.02 (-5%)	0.13	0.14	0.01 (5%)	0.47	0.47	0.00 (0%)
BN	0.27	0.26	-0.01 (-3%)	0.29	0.28	-0.01 (-4%)	0.04	0.04	0.00 (-2%)	0.47	0.47	0.00 (0%)
D	0.28	0.27	-0.01 (-4%)	0.30	0.28	-0.01 (-5%)	0.05	0.05	0.00 (-1%)	0.47	0.47	0.00 (0%)
C	0.22	0.22	0.00 (-1%)	0.24	0.23	0.00 (-1%)	0.03	0.03	0.00 (-2%)	0.47	0.47	0.00 (0%)
WY	Sutter/Steamboat Sloughs						Interior Delta (Via Georgiana Slough/DCC)					
	Proportion Using Route			Survival			Proportion Using Route			Survival		
	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
W	0.29	0.28	0.00 (-1%)	0.50	0.48	-0.02 (-4%)	0.26	0.26	0.00 (1%)	0.21	0.25	0.04 (19%)
AN	0.29	0.29	-0.01 (-2%)	0.43	0.41	-0.02 (-4%)	0.27	0.27	0.00 (1%)	0.19	0.21	0.02 (11%)
BN	0.30	0.30	0.00 (-1%)	0.32	0.31	-0.01 (-4%)	0.28	0.28	0.00 (1%)	0.15	0.15	0.00 (2%)
D	0.30	0.29	0.00 (-1%)	0.34	0.32	-0.01 (-4%)	0.28	0.28	0.00 (1%)	0.15	0.15	0.00 (1%)
C	0.28	0.28	0.00 (0%)	0.28	0.27	0.00 (-1%)	0.30	0.30	0.00 (0%)	0.13	0.13	0.00 (1%)
Note: Survival in Sutter/Steamboat Sloughs and Interior Delta routes includes survival in the Sacramento River prior to entering the channel junctions.												

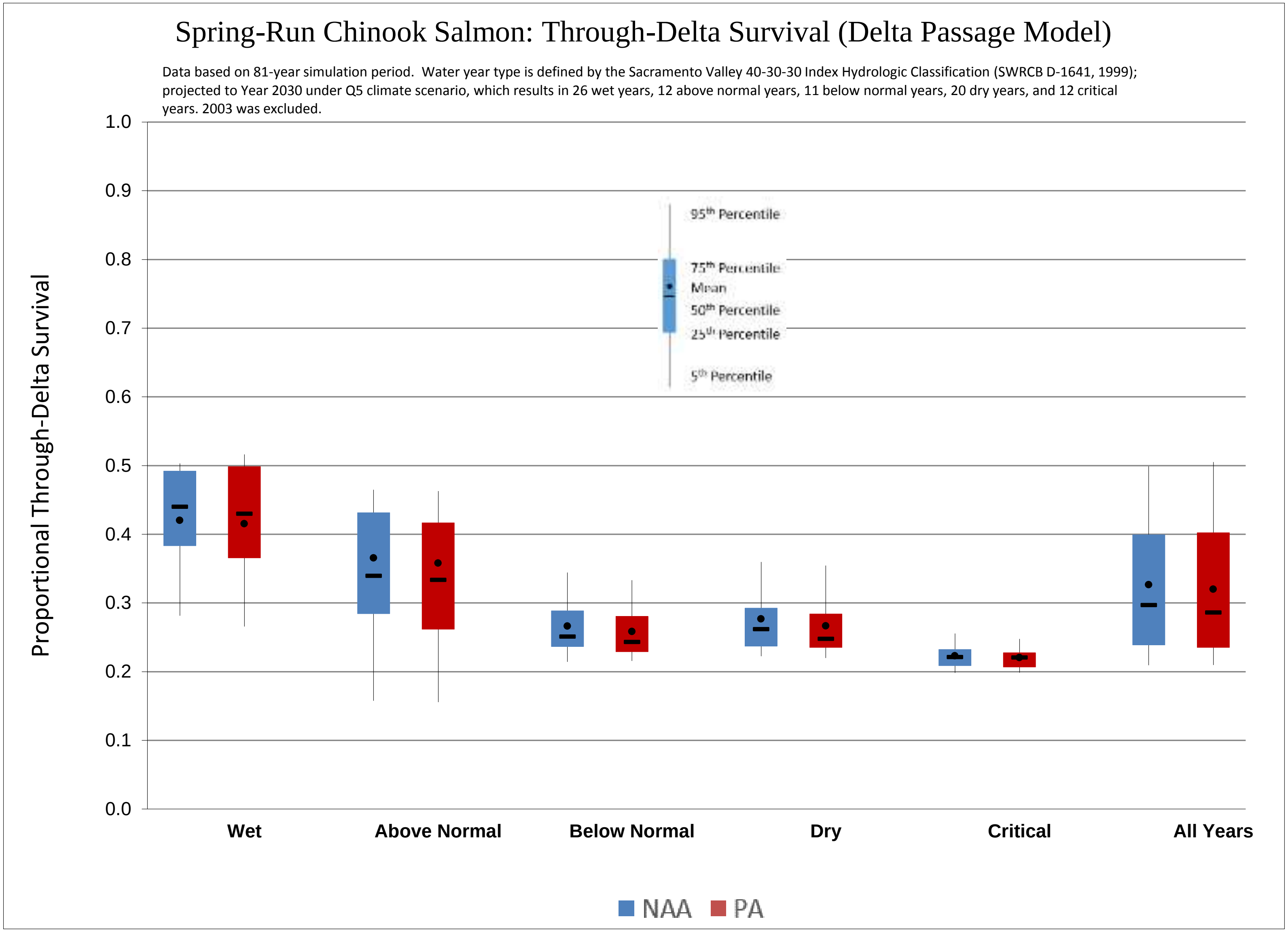


Figure 5.4-11. Box Plots of Spring-Run Chinook Salmon Annual Through-Delta Survival Estimated from the Delta Passage Model, Grouped by Water Year Type.

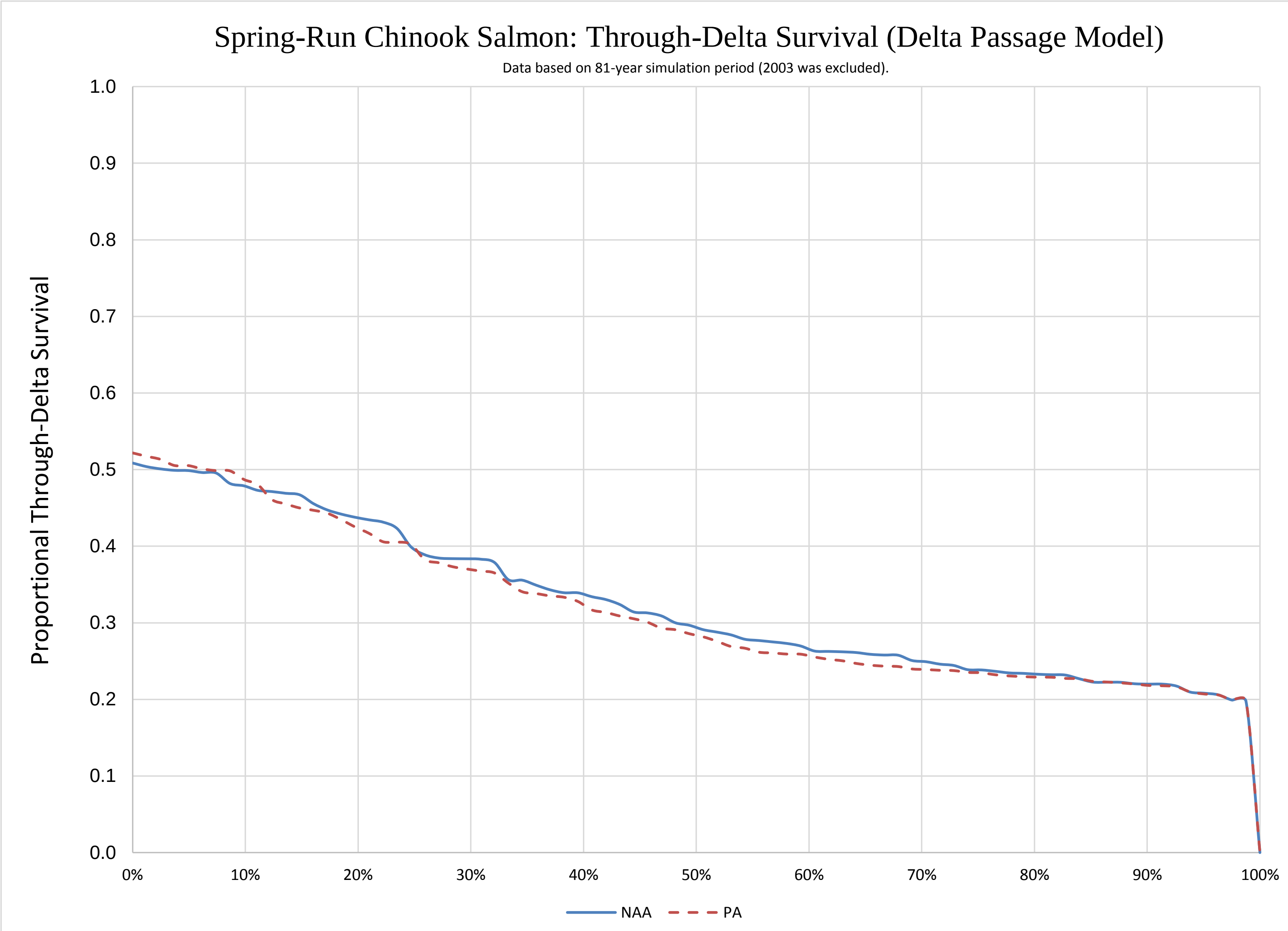
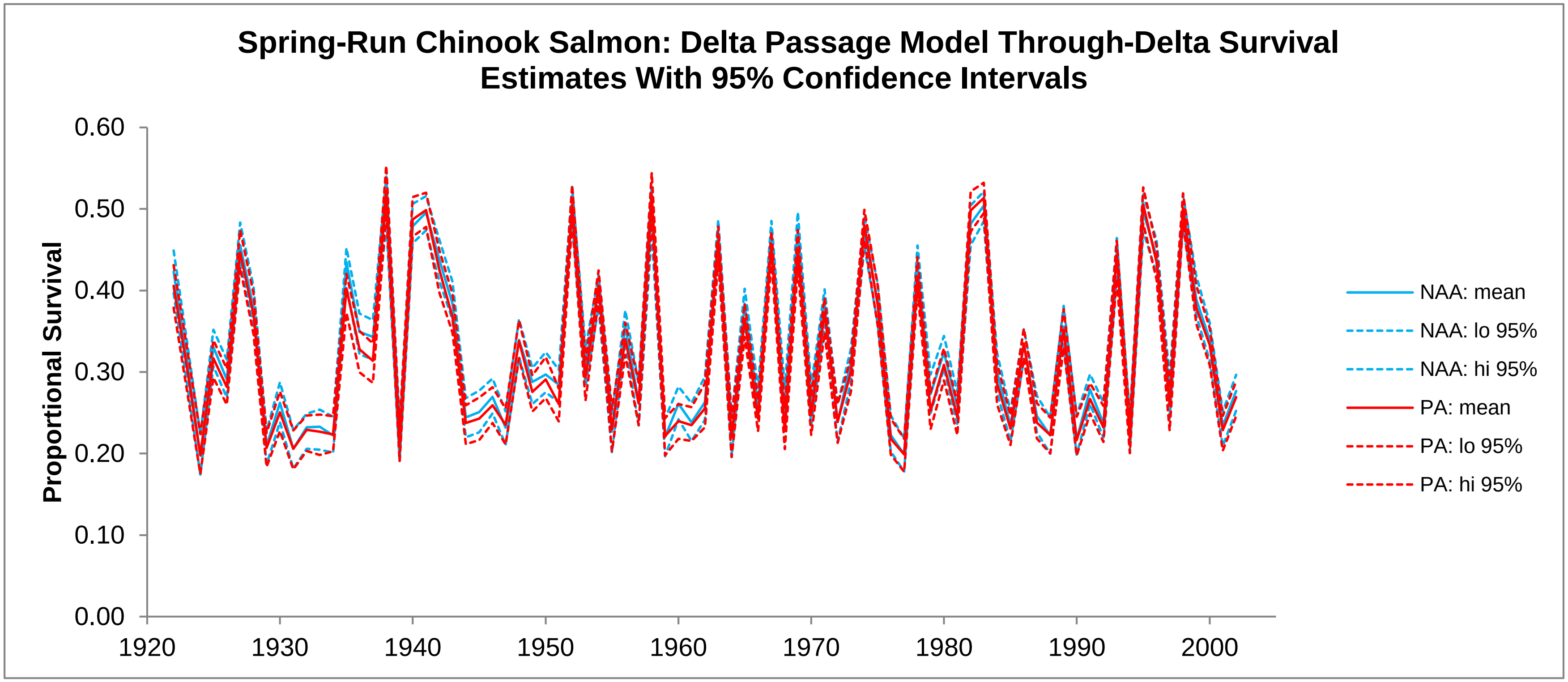


Figure 5.4-12. Exceedance Plot of Spring-Run Chinook Salmon Annual Through-Delta Survival Estimated from the Delta Passage Model.



Note: Broken lines indicate 95% confidence intervals from the 75 iterations of the DPM.

Figure 5.4-13. Time Series of Mean (With 95% Confidence Interval) Annual Juvenile Spring-Run Chinook Salmon Through-Delta Estimated from the Delta Passage Model.

5.4.1.3.1.2.1.3.2 Analysis Based on Newman (2003): Spring-Run Chinook Salmon

In addition to the DPM, an analysis based on Newman (2003) was undertaken to assess the potential effects of the PA on juvenile spring-run Chinook salmon migrating through the Delta. The method is described further in Appendix 5.D, *Quantitative Methods and Detailed Results for Effects Analysis of Chinook Salmon, Central Valley Steelhead, Green Sturgeon, and Killer Whale*, Section 5.D.1.2.3, *Analysis Based on Newman (2003)*, but essentially allows estimation of through-Delta survival as a function of river flow (Sacramento River below the NDD, to capture flow-survival effects), south Delta exports, and other covariates, including salinity, turbidity, DCC position, and water temperature. As noted in Appendix 5.D, the analysis does not include winter-run Chinook salmon because the data used by Newman (2003) were derived from studies of smolts released during the main fall-run/spring-run Chinook salmon migration period, which is after the main winter-run migration period, and the method requires water temperature data. Note that the analysis based on Newman (2003) does not include representation of near-field mortality effects from the NDD (e.g., predation or impingement at the NDD), but instead focuses on far-field effects.

The results of the analysis based on Newman (2003) suggested that there would be very little difference in overall mean survival between the NAA and PA for spring-run Chinook salmon across all water year types (Figure 5.4-14; Figure 5.4.1-15; Figure 5.4-16). When examined by NDD bypass flow level, the minor differences between NAA and PA were also apparent (Table 5.4-14)[18].

The results are driven by several factors. The timing of spring-run Chinook salmon entry into the Delta was assumed to be the same as that used for the DPM, for which entry occurs during spring (March–May), with a pronounced unimodal peak in April (Figure 5.D-42 in Appendix 5.D, *Quantitative Methods and Detailed Results for Effects Analysis of Chinook Salmon, Central Valley Steelhead, Green Sturgeon, and Killer Whale*). During April under the PA, south Delta exports and Sacramento River flow downstream of the NDD are very similar in their absolute differences from the NAA (Table 5.4-15; for additional south Delta exports information, see also Figures 5.A.6-27-1 to 5.A.6-27-6, Figures 5.A.6-27-7 to 5.A.6-27-19, and Table 5.A.6-27 in Appendix 5.A, *CalSim II Modeling and Results*). In other words, less Sacramento River flow downstream of the NDD is offset by less south Delta exports. The analysis based on Newman (2003) includes a rate of change in juvenile Chinook salmon survival per unit of flow that is similar for the Sacramento River and south Delta exports (see Figure 5.D-61 in Appendix 5.D), so that a similar change in Sacramento River flows (less) and exports (less) results in similar survival, as the analysis showed.[19] As noted in the previous section describing the DPM results, this results in differences in the results compared to DPM results, for which survival under PA

[18] Based on agency request, an unweighted version of these data is presented in Appendix 5.D, *Quantitative Methods and Detailed Results for Effects Analysis of Chinook Salmon, Central Valley Steelhead, Green Sturgeon, and Killer Whale*, Section 5.D.1.2.3.3, *Results* (Table 5.D-46), which again shows the similarity between NAA and PA.

[19] The relative effect of south Delta exports and Sacramento River flow downstream of the NDD are illustrated in Figure 5.D-64 in Appendix 5.D, Section 5.D.1.2.3, *Analysis Based on Newman (2003)*.

was marginally lower than under NAA.

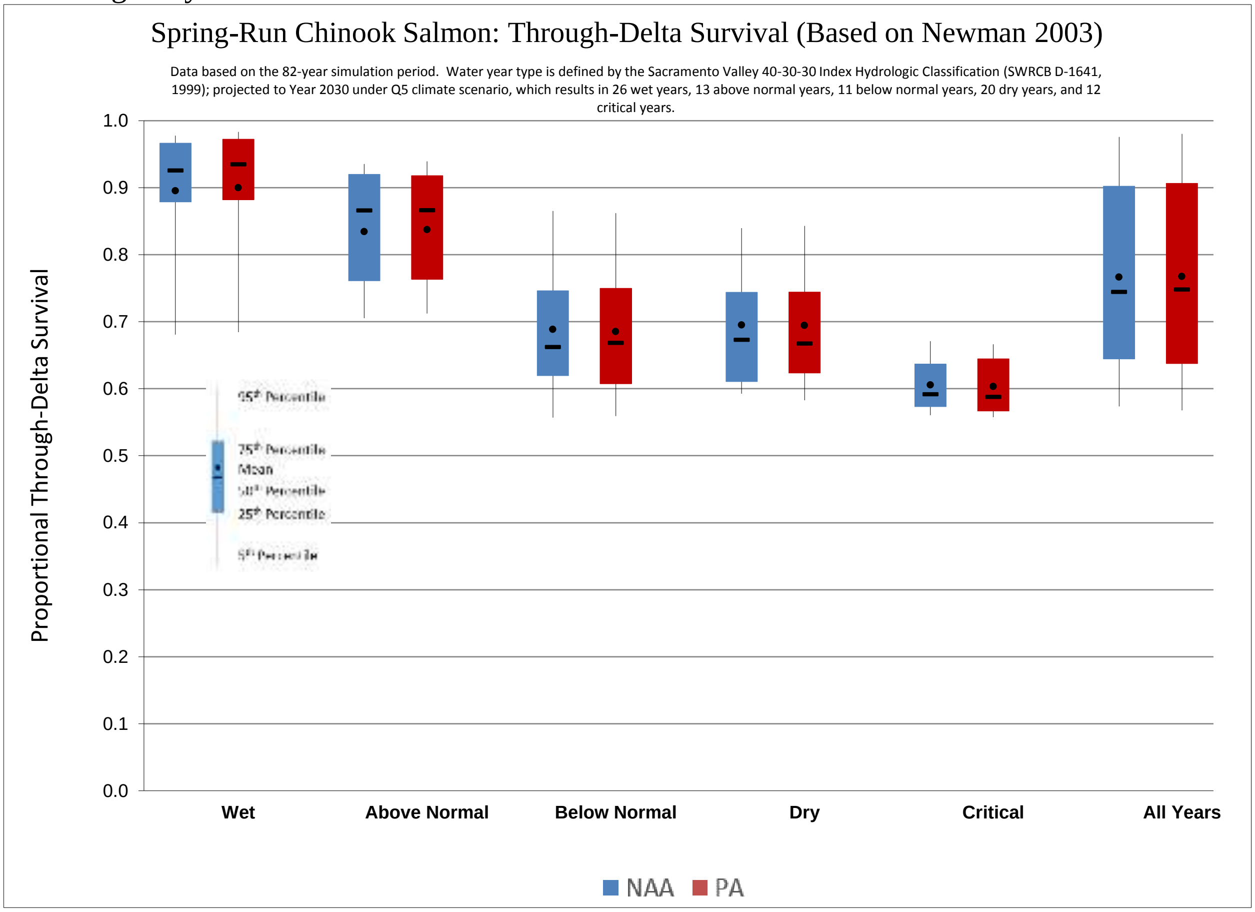


Figure 5.4-14. Box Plots of Spring-Run Chinook Salmon Annual Through-Delta Survival Estimated from the Analysis Based on Newman (2003), Grouped by Water Year Type.

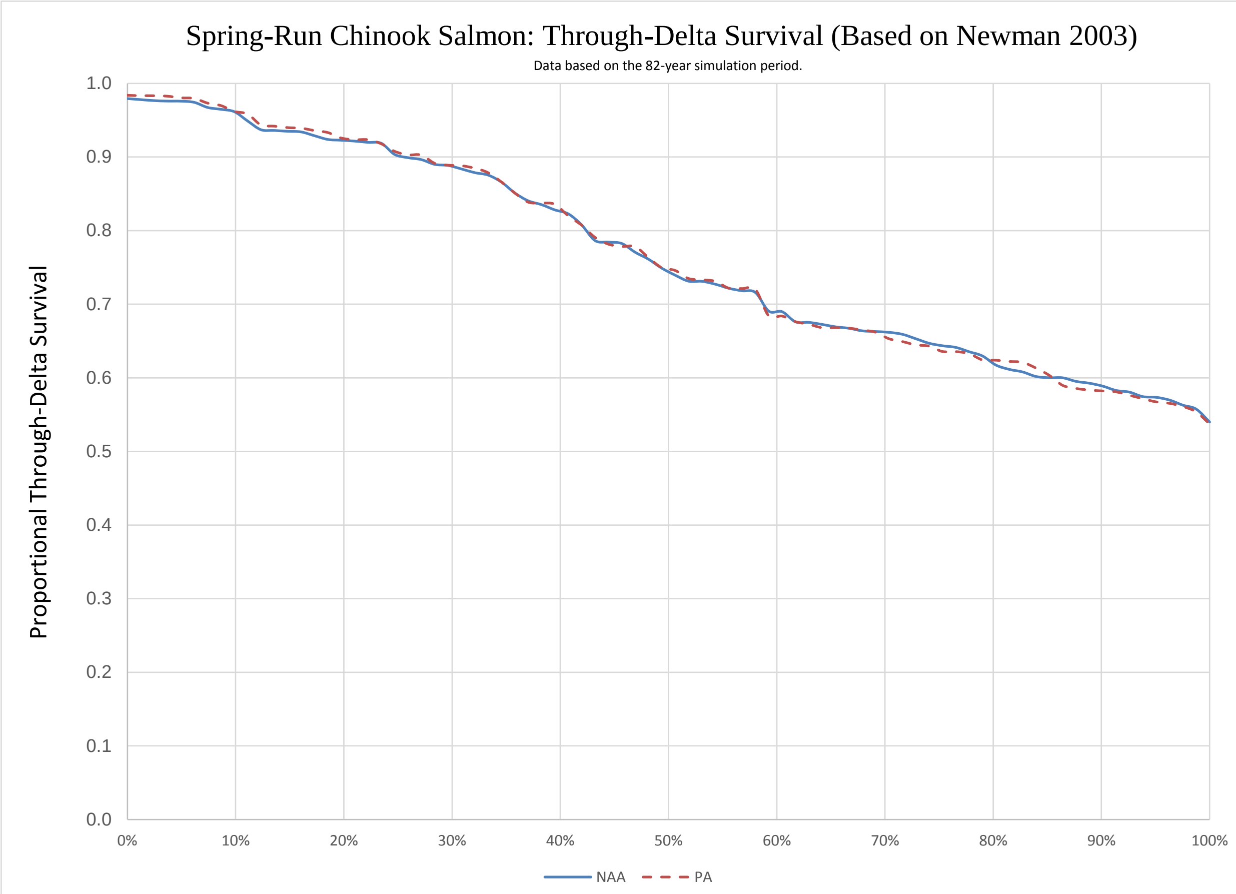


Figure 5.4-15. Exceedance Plot of Spring-Run Chinook Salmon Annual Through-Delta Survival Estimated from the Analysis Based on Newman (2003).

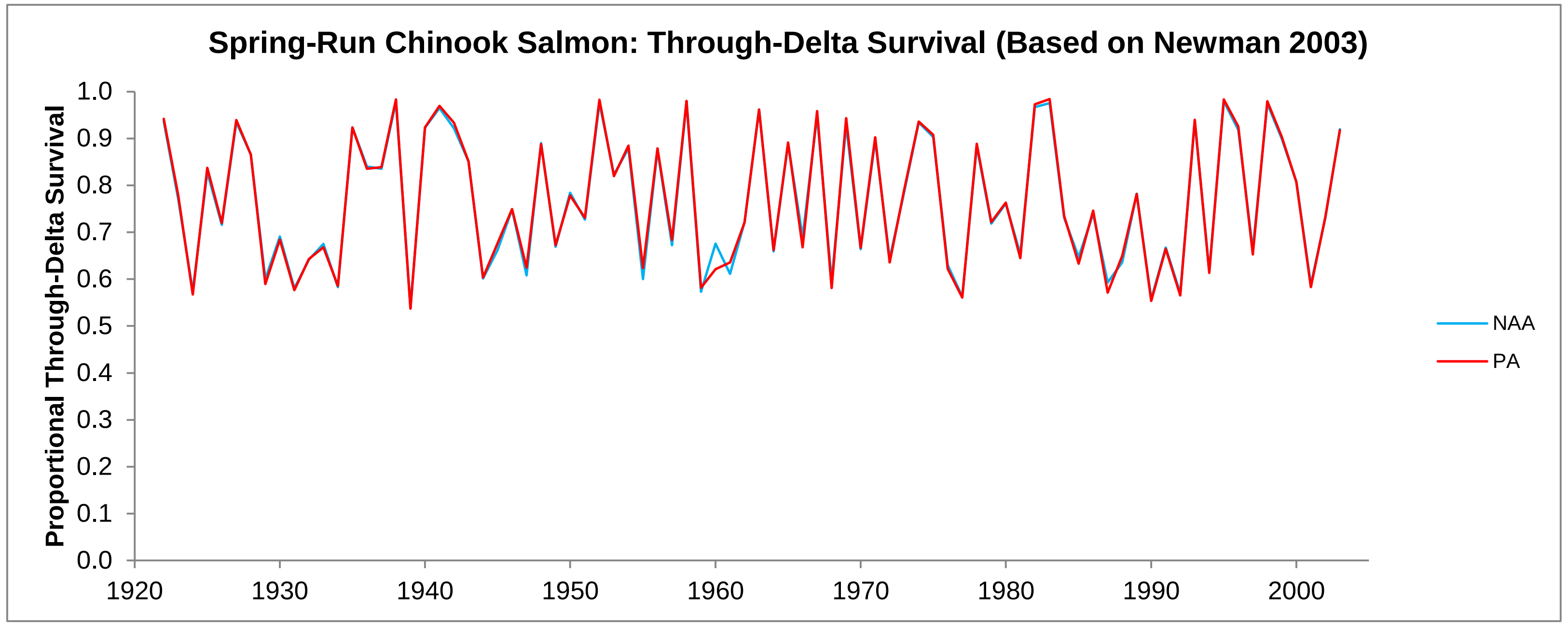


Figure 5.4-16. Time Series of Spring-Run Chinook Salmon Annual Through-Delta Survival Estimated from the Analysis Based on Newman (2003).

Table 5.4-14. Mean Annual Spring-Run Chinook Salmon Weighted Annual Through-Delta Survival Estimated from the Analysis Based on Newman (2003), Divided into Each NDD Bypass Flow Level.

WY	Pulse protection flows			Level 1 bypass flows			Level 2 bypass flows			Level 3 bypass flows			Total		
	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
W	0.00	0.00	0.00 (0%)	0.00	0.00	0.00 (2%)	0.04	0.04	0.00 (1%)	0.85	0.85	0.00 (0%)	0.90	0.90	0.00 (0%)
AN	0.00	0.00	0.00 (1%)	0.01	0.01	0.00 (0%)	0.06	0.06	0.00 (2%)	0.77	0.77	0.00 (0%)	0.83	0.84	0.00 (0%)
BN	0.00	0.00	0.00 (0%)	0.25	0.24	0.00 (-1%)	0.31	0.31	0.00 (0%)	0.13	0.13	0.00 (-1%)	0.69	0.69	0.00 (0%)
D	0.00	0.00	0.00 (-1%)	0.21	0.21	0.00 (0%)	0.39	0.39	0.00 (0%)	0.09	0.09	0.00 (0%)	0.69	0.69	0.00 (0%)
C	0.01	0.01	0.00 (-1%)	0.51	0.50	0.00 (-1%)	0.09	0.09	0.00 (1%)	0.00	0.00	0.00 (0%)	0.61	0.60	0.00 (0%)

Table 5.4-15. Mean South Delta Exports and Sacramento River Flow Downstream of the NDD in March-May, by Water-Year Type.

WY	South Delta Exports									Sacramento River Flow Downstream of the NDD (Bypass Flows)								
	March			April			May			March			April			May		
	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
W	9,461	1,706	-7,755 (-82%)	2,977	395	-2,582 (-87%)	3,378	570	-2,808 (-83%)	47,988	40,145	-7,844 (-16%)	34,998	32,406	-2,592 (-7%)	29,839	26,747	-3,092 (-10%)
AN	7,826	902	-6,924 (-88%)	1,801	369	-1,432 (-80%)	1,720	411	-1,309 (-76%)	40,801	34,100	-6,700 (-16%)	24,080	22,944	-1,136 (-5%)	16,711	15,444	-1,266 (-8%)
BN	6,089	3,825	-2,264 (-37%)	1,774	1,340	-435 (-24%)	1,624	1,034	-590 (-36%)	18,542	15,051	-3,492 (-19%)	14,076	13,607	-469 (-3%)	12,460	12,027	-433 (-3%_
D	4,868	3,619	-1,249 (-26%)	2,052	1,493	-559 (-27%)	2,054	1,337	-717 (-35%)	21,284	17,259	-4,025 (-19%)	14,895	14,348	-547 (-4%)	11,633	11,382	-251 (-2%_
C	2,701	2,139	-561 (-21%)	1,430	1,267	-163 (-11%)	1,415	1,207	-208 (-15%)	12,529	11,683	-846 (-7%)	10,290	10,144	-147 (-1%)	8,214	8,031	-184 (-2%)

5.4.1.3.1.2.1.3.3 Analysis Based on Perry (2010): Winter-Run and Spring-Run Chinook Salmon

In addition to the DPM and the analysis based on Newman (2003), which both allow consideration of the through-Delta juvenile Chinook salmon survival changes in relation to the far-field effects of both north and south Delta exports simultaneously, a focused analysis based on Perry (2010) was undertaken to focus solely on the potential flow-survival effects of the PA's proposed NDD on juvenile winter-run and spring-run Chinook salmon survival, particularly with respect to Sacramento River flows bypassing the NDD (i.e., pulse protection flows and level 1-3 bypass flows). The method is described further in Appendix 5.D, *Quantitative Methods and Detailed Results for Effects Analysis of Chinook Salmon, Central Valley Steelhead, Green Sturgeon, and Killer Whale*, Section 5.D.1.2.4, and allows estimation of through-Delta survival from the Sacramento River at Georgiana Slough to Chipps Island, based on the implementation of the Perry (2010) flow-survival relationship from the DPM. The analysis based on Perry (2010) does not include representation of near-field mortality effects from the NDD (e.g., predation or impingement at the NDD), but instead focuses on far-field effects.

The results of the analysis based on Perry (2010) suggested that annual through-Delta survival in the Sacramento River from Georgiana Slough to Chipps Island would be slightly lower under the PA relative to the NAA for both juvenile winter-run Chinook salmon (Figure 5.4-17 and Figure 5.4-18; Table 5.4-16; see also Figure 5.D-71 in Appendix 5.D, *Quantitative Methods and Detailed Results for Effects Analysis of Chinook Salmon, Central Valley Steelhead, Green Sturgeon, and Killer Whale*) and juvenile spring-run Chinook salmon (Figure 5.4-19 and Figure 5.4-20; Table 5.4-17; see also Figure 5.D-77 in Appendix 5.D, *Quantitative Methods and Detailed Results for Effects Analysis of Chinook Salmon, Central Valley Steelhead, Green Sturgeon, and Killer Whale*). As would be expected, for winter-run Chinook salmon the relative difference between NAA and PA scenarios in weighted survival generally was greater with the progression from pulse protection flows (0–2% relative difference), to level 1 bypass flows (2–5% relative difference), to level 2 bypass flows (3-7% relative difference), to level 3 bypass flows (2–12%) (Table 5.4-16). For winter-run Chinook salmon, the greatest differences in overall survival (4–5% less under PA) were in above normal, below normal, and dry years, a pattern that generally was also true for spring-run Chinook salmon (Table 5.4-17). However, the relative differences between NAA and PA for through-Delta survival of spring-run Chinook salmon (1–3% less under the PA, depending on water year type) were less than for winter-run (2–5% less under the PA).

Note that there is appreciable variability in the underlying relationship between Sacramento River flow and survival, as represented in the analysis based on Perry (2010) (Figure 5.D-65 in Appendix 5.D, *Quantitative Methods and Detailed Results for Effects Analysis of Chinook Salmon, Central Valley Steelhead, Green Sturgeon, and Killer Whale*). Plots of annual estimated weighted survival and 95% confidence intervals presented in Appendix 5.D show considerable overlap in the estimate for the NAA and PA scenarios: for both winter-run and spring-run Chinook salmon, the estimates of weighted survival for pulse-protection flows, level 1-3 bypass flows, and overall survival overlap in all pairs of NAA and PA scenarios across the 82 years that were included in the analysis (see Figures 5.D-66 to 5.D-70 and Figures 5.D-72 to 5.D-76 in Appendix 5.D). This suggests that although the results discussed above show potentially less survival under the PA relative to the NAA, it might be challenging to statistically detect this small magnitude of difference during PA monitoring, for example.

Given that the analyses described above were for fixed winter-run and spring-run Chinook salmon entry distributions, it also was of interest to examine the differences in juvenile Chinook salmon survival based on Perry (2010) when assuming an equal daily weighting for entry distribution during December-June, the main juvenile Chinook salmon Delta entry period (Table 5.4.1-18). Although the entry distribution to the Delta was assumed to be the same on each day (i.e., equal daily weighting), the patterns from this analysis were similar to those observed for winter-run and spring-run Chinook salmon: lower survival under the PA relative to NAA (Figure 5.4-21 and Figure 5.4-22), with the relative differences between PA and NAA increasing with the movement from pulse protection flows (0–2%), to level 1 bypass flows (1–4%), to level 2 bypass flows (2–4%), to level 3 bypass flows (3–6%). In addition, the 95% confidence intervals for through-Delta survival estimates under all flow levels overlapped in every year between the NAA and PA scenarios (see Figures 5.D-78 to 5.D-82 in Appendix 5.D, *Quantitative Methods and Detailed Results for Effects Analysis of Chinook Salmon, Central Valley Steelhead, Green Sturgeon, and Killer Whale*, Section 5.D.1.2.4.3, *Results*), again suggesting that it might be challenging to statistically detect the small magnitude of the PA effect during monitoring of implementation.

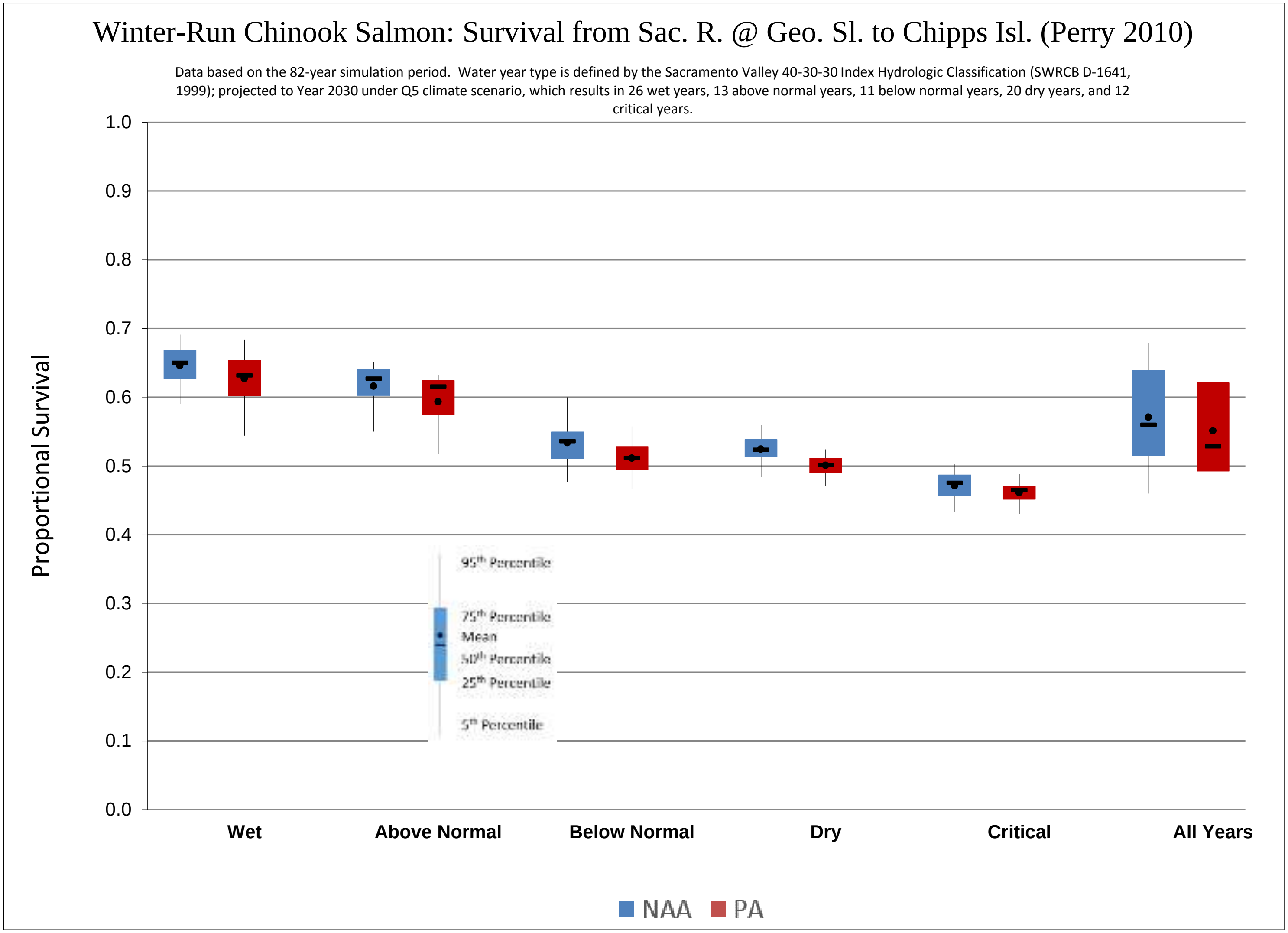


Figure 5.4-17. Box Plots of Juvenile Winter-Run Chinook Salmon Annual Total Survival from the Sacramento River at Georgiana Slough to Chipps Island, Estimated from the Analysis Based on Perry (2010), Grouped by Water Year Type.

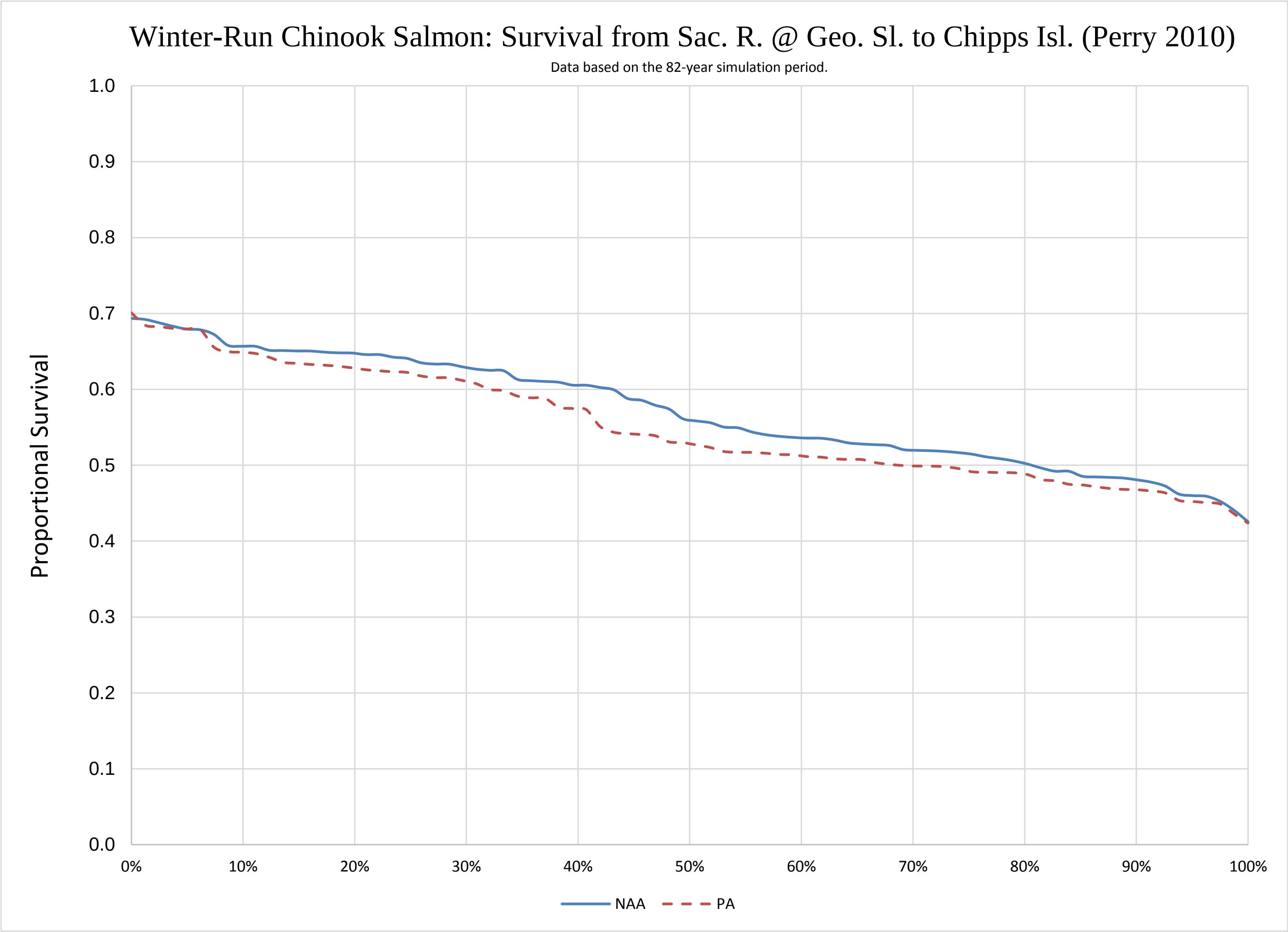


Figure 5.4-18. Exceedance Plot of Juvenile Winter-Run Chinook Salmon Annual Total Survival from the Sacramento River at Georgiana Slough to Chipps Island, Estimated from the Analysis Based on Perry (2010).

Table 5.4-16. Mean Annual Juvenile Winter-Run Chinook Salmon Weighted Survival from the Sacramento River at Georgiana Slough to Chipps Island By Water Year Type, Estimated from the Analysis Based on Perry (2010), Divided into Each NDD Bypass Flow Level.

WY	Pulse protection flows			Level 1 bypass flows			Level 2 bypass flows			Level 3 bypass flows			Total		
	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
W	0.05	0.05	0.00 (0%)	0.16	0.15	-0.01 (-5%)	0.08	0.08	0.00 (-5%)	0.35	0.34	-0.01 (-2%)	0.65	0.63	-0.02 (-3%)
AN	0.04	0.04	0.00 (-1%)	0.20	0.19	-0.01 (-3%)	0.09	0.09	0.00 (-3%)	0.29	0.27	-0.01 (-5%)	0.62	0.59	-0.02 (-4%)
BN	0.04	0.04	0.00 (-1%)	0.29	0.28	-0.01 (-3%)	0.15	0.14	-0.01 (-6%)	0.05	0.05	0.00 (-10%)	0.53	0.51	-0.02 (-4%)
D	0.03	0.03	0.00 (-2%)	0.35	0.34	-0.01 (-4%)	0.12	0.11	-0.01 (-7%)	0.03	0.02	0.00 (-12%)	0.52	0.50	-0.02 (-5%)
C	0.03	0.03	0.00 (-1%)	0.41	0.40	-0.01 (-2%)	0.03	0.03	0.00 (-4%)	NA	NA	NA	0.47	0.46	-0.01 (-2%)

Note: Survival for a given flow level is weighted by the proportion of the juvenile population occurring during that flow level. NA indicates there were no level 3 bypass flows in critical years.

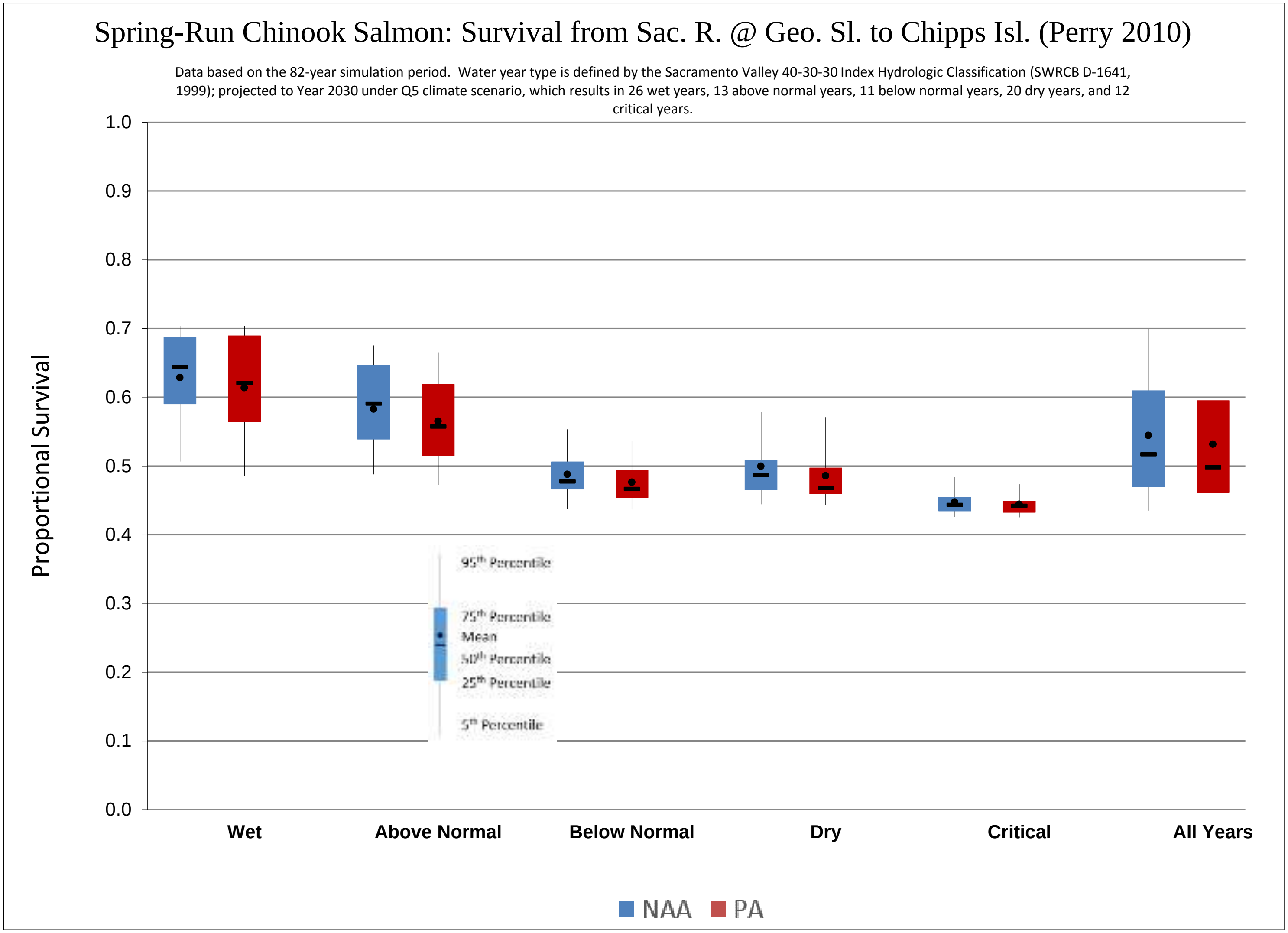


Figure 5.4-19. Box Plots of Juvenile Spring-Run Chinook Salmon Annual Total Survival from the Sacramento River at Georgiana Slough to Chipps Island, Estimated from the Analysis Based on Perry (2010), Grouped by Water Year Type.

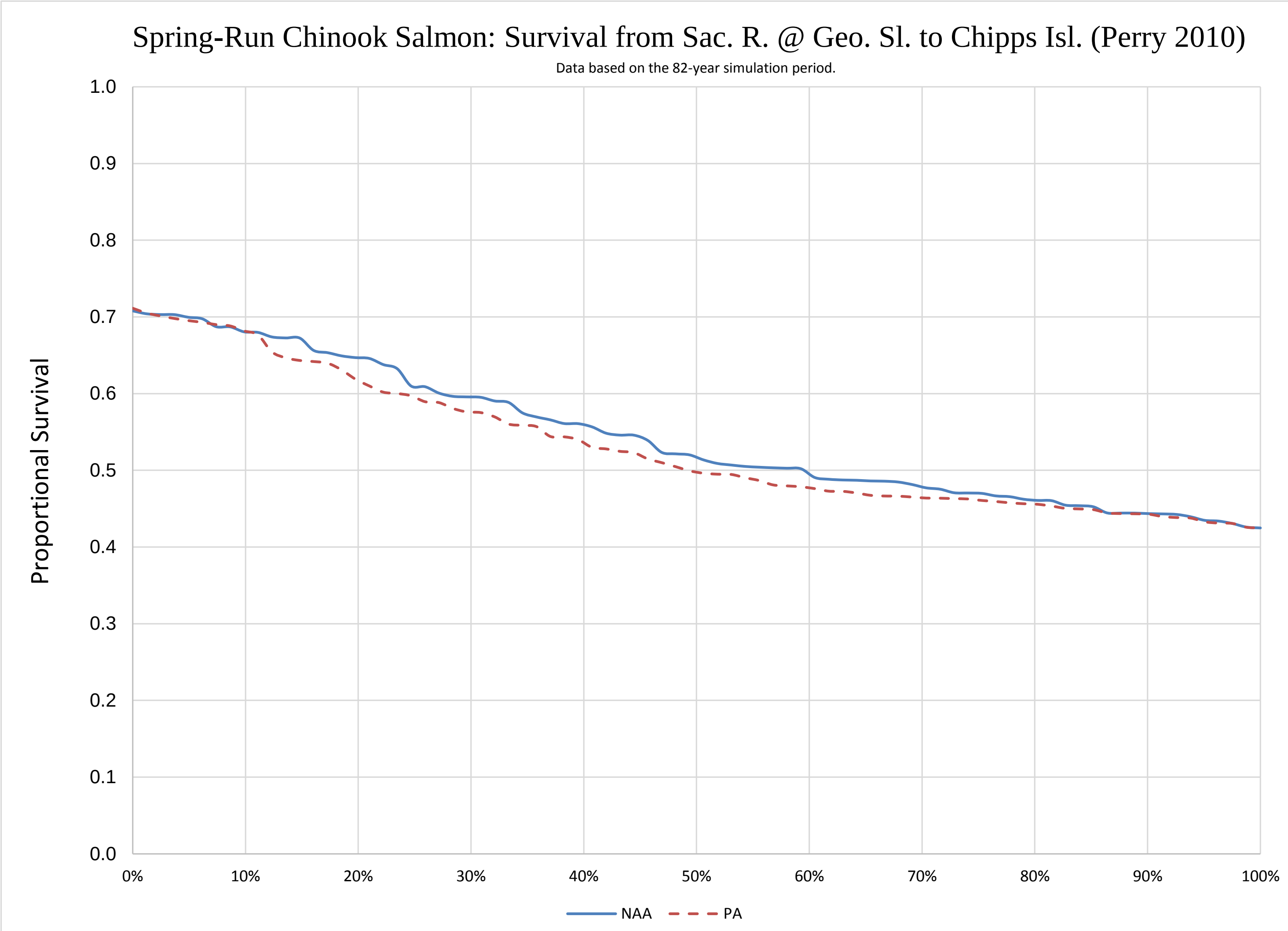


Figure 5.4-20. Exceedance Plot of Juvenile Spring-Run Chinook Salmon Annual Total Survival from the Sacramento River at Georgiana Slough to Chipps Island, Estimated from the Analysis Based on Perry (2010).

Table 5.4-17. Mean Annual Juvenile Spring-Run Chinook Salmon Weighted Survival from the Sacramento River at Georgiana Slough to Chipps Island By Water Year Type, Estimated from the Analysis Based on Perry (2010), Divided into Each NDD Bypass Flow Level.

WY	Pulse protection flows			Level 1 bypass flows			Level 2 bypass flows			Level 3 bypass flows			Total		
	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
W	0.04	0.04	0.00 (0%)	0.12	0.12	0.00 (-4%)	0.06	0.06	0.00 (-3%)	0.39	0.38	-0.01 (-3%)	0.62	0.60	-0.02 (-3%)
AN	0.03	0.03	0.00 (-1%)	0.15	0.15	0.00 (-3%)	0.07	0.07	0.00 (-2%)	0.32	0.31	-0.01 (-4%)	0.57	0.55	-0.02 (-3%)
BN	0.03	0.03	0.00 (0%)	0.25	0.24	-0.01 (-2%)	0.16	0.16	-0.01 (-4%)	0.06	0.05	0.00 (-5%)	0.50	0.48	-0.01 (-3%)
D	0.02	0.02	0.00 (-1%)	0.27	0.27	-0.01 (-3%)	0.16	0.15	0.00 (-3%)	0.04	0.04	0.00 (-6%)	0.49	0.48	-0.01 (-3%)
C	0.02	0.02	0.00 (-2%)	0.39	0.39	-0.01 (-1%)	0.04	0.04	0.00 (-2%)	NA	NA	NA	0.45	0.45	-0.01 (-1%)

Note: Survival for a given flow level is weighted by the proportion of the juvenile population occurring during that flow level. NA indicates there were no level 3 bypass flows in critical years.

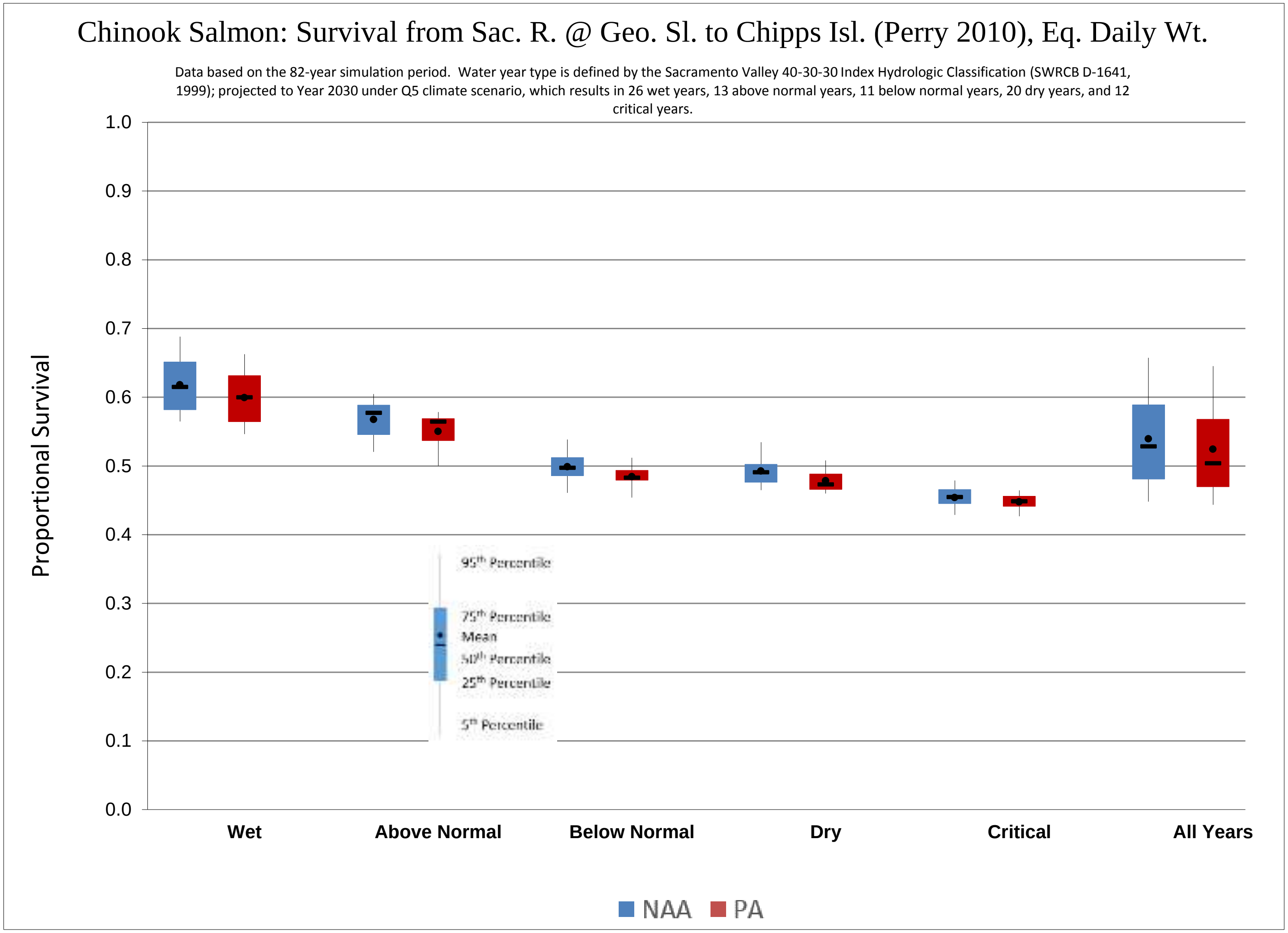


Figure 5.4-21. Box Plots of Juvenile Chinook Salmon Annual Total Survival from the Sacramento River at Georgiana Slough to Chipps Island, Estimated from the Analysis Based on Perry (2010), Grouped by Water Year Type, Assuming Equal Daily Weighting from December to June.

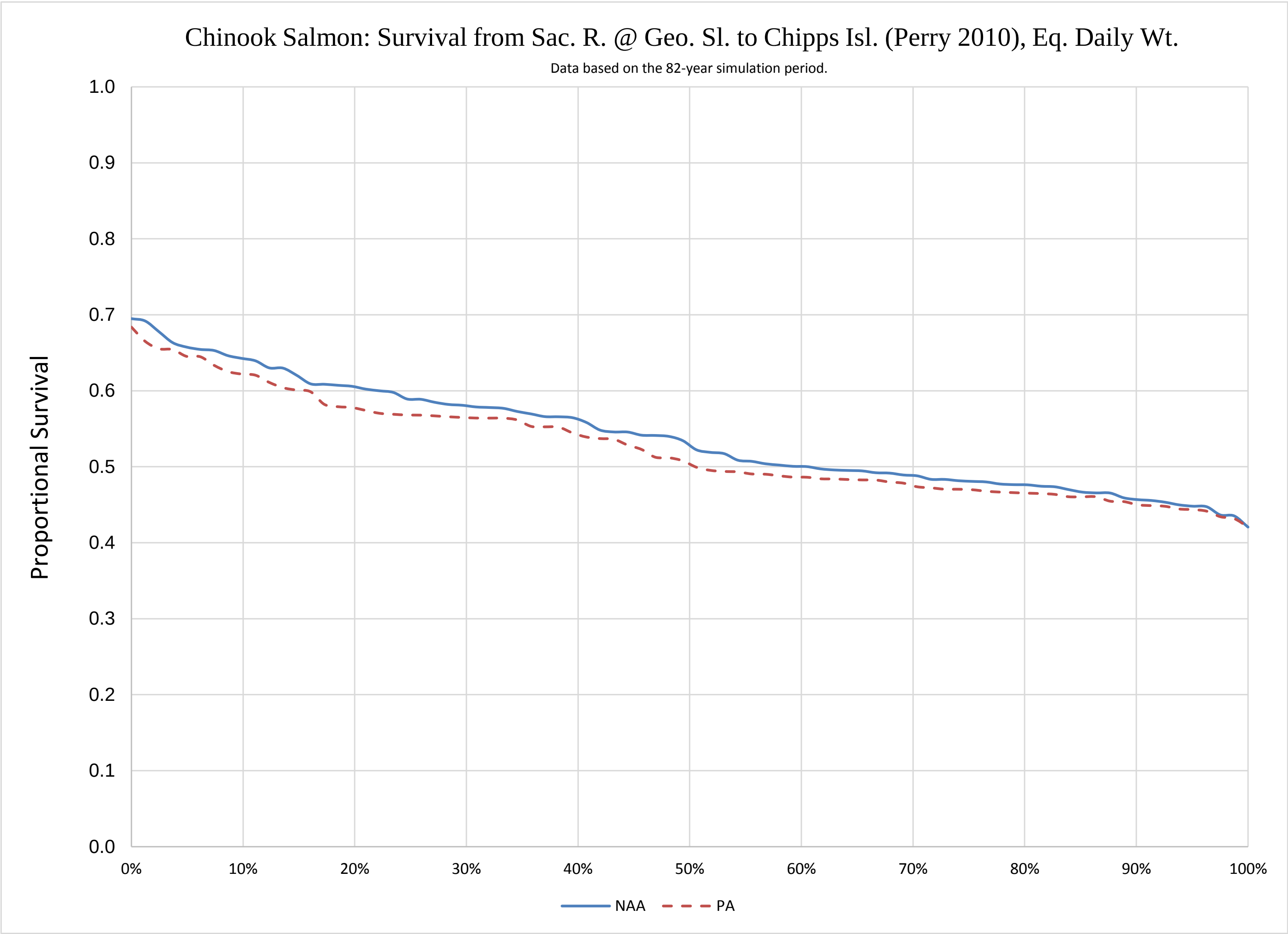


Figure 5.4-22. Exceedance Plot of Juvenile Chinook Salmon Annual Total Survival from the Sacramento River at Georgiana Slough to Chipps Island, Estimated from the Analysis Based on Perry (2010), Assuming Equal Daily Weighting from December to June.

Table 5.4-18. Mean Annual Juvenile Chinook Salmon Weighted Survival from the Sacramento River at Georgiana Slough to Chipps Island By Water Year Type, Estimated from the Analysis Based on Perry (2010), Divided into Each NDD Bypass Flow Level, Assuming Equal Daily Weighting from December to June.

WY	Pulse protection flows			Level 1 bypass flows			Level 2 bypass flows			Level 3 bypass flows			Total		
	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
W	0.04	0.04	0.00 (0%)	0.12	0.12	0.00 (-4%)	0.06	0.06	0.00 (-3%)	0.39	0.38	-0.01 (-3%)	0.62	0.60	-0.02 (-3%)
AN	0.03	0.03	0.00 (-1%)	0.15	0.15	0.00 (-3%)	0.07	0.07	0.00 (-2%)	0.32	0.31	-0.01 (-4%)	0.57	0.55	-0.02 (-3%)
BN	0.03	0.03	0.00 (0%)	0.25	0.24	-0.01 (-2%)	0.16	0.16	-0.01 (-4%)	0.06	0.05	0.00 (-5%)	0.50	0.48	-0.01 (-3%)
D	0.02	0.02	0.00 (-1%)	0.27	0.27	-0.01 (-3%)	0.16	0.15	0.00 (-3%)	0.04	0.04	0.00 (-6%)	0.49	0.48	-0.01 (-3%)
C	0.02	0.02	0.00 (-2%)	0.39	0.39	-0.01 (-1%)	0.04	0.04	0.00 (-2%)	NA	NA	NA	0.45	0.45	-0.01 (-1%)

Note: Survival for a given flow level is weighted by the proportion of the juvenile population occurring during that flow level. NA indicates there were no level 3 bypass flows in critical years.

5.4.1.3.1.2.1.3.4 Life Cycle Models (IOS and OBAN): Winter-run Chinook Salmon

The winter-run Chinook salmon life cycle models IOS and OBAN were also run to provide perspective on potential PA effects with respect to both in-Delta and upstream conditions. Methods and results are presented in Appendix 5.D, *Quantitative Methods and Detailed Results for Effects Analysis of Chinook Salmon, Central Valley Steelhead, Green Sturgeon, and Killer Whale*, Section 5.D.3, *Life Cycle Models*. In both models, ocean conditions were assumed not to differ between the NAA and PA, in order to focus the analysis on potential PA effects.

As described in Section 5.4.2, *Upstream Hydrologic Changes*, upstream differences between the NAA and PA were found to be small, so the main driver of differences in escapement between NAA and PA was differences in Delta survival. IOS's in-Delta component is the DPM, although with one important difference from the DPM results previously discussed in Section 5.4.1.3.1.2.1.3.1, *Delta Passage Model: Winter-Run and Spring-Run Chinook Salmon*: Delta entry in IOS consists of a unimodal peak, the timing of which depends on upstream fry/egg rearing, in contrast to the fixed nature of Delta entry for the standalone DPM; the unimodal peak generally occurs between the bimodal peaks from the fixed entry distribution (Appendix 5.D, *Quantitative Methods and Detailed Results for Effects Analysis of Chinook Salmon, Central Valley Steelhead, Green Sturgeon, and Killer Whale,* Section 5.D.3.1.1.5, *Delta Passage*). Whereas the DPM results showed that the 95% confidence intervals of annual through-Delta survival estimates for NAA and PA did not overlap in 10 of 81 years, the through-Delta survival confidence intervals overlapped in all but one year for IOS. This may have reflected a greater proportion of the through-Delta migration occurring earlier in the migration season for IOS, when NDD bypass flow restrictions would have been greater, with the result that there was greater overlap in survival estimates between NAA and PA for IOS compared to DPM.

In IOS, as with the DPM, in-Delta channel flow-survival relationships tend to have a greater effect on survival than the export-survival effect, as discussed in Section 5.4.1.3.1.2.1.3, *Through-Delta Survival*, for spring-run Chinook salmon. In contrast, OBAN's through-Delta survival component includes Yolo Bypass inundation (which was assumed the same for NAA and PA, based on both scenarios having a notched Fremont Weir) and south Delta exports, which would be appreciably less under the PA than NAA. In order to represent potential adverse effects of the NDD on through-Delta survival in OBAN, sensitivity analyses of additional mortality (1%, 5%, 10%, and 50%) were applied to the estimates of survival derived from Yolo Bypass inundation and south Delta exports. The OBAN results demonstrated that early ocean survival and the spreading of effects between age 3 and age 4 maturing adults has a significant buffering effect on through-Delta survival effects[20], so that estimates of escapement between sensitivity analysis scenarios did not directly reflect proportional differences in through-Delta survival. The sensitivity analysis results suggested that at 5% additional mortality because of the NDD, the number of years having greater than 50% probability of *equal or greater* escapement under the PA relative to the NAA would be the same as the number of years having less than 50% probability of *lower* escapement under the PA relative to the NAA. In simpler terms, 5%

[20] As discussed further in Appendix 5.D, *Quantitative Methods and Detailed Results for Effects Analysis of Chinook Salmon, Central Valley Steelhead, Green Sturgeon, and Killer Whale*, Section 5.D.3.2.8, *Results*, OBAN includes a lower bound on escapement to avoid numerical instability, which also contributed to less than expected differences between sensitivity analysis scenarios when escapement was low.