Mechanical removal of aquatic weeds in Clifton Court Forebay would occur on an as needed basis and therefore could coincide with occurrence of juvenile winter-run Chinook salmon, spring-run Chinook salmon, and steelhead. In assessing the potential for adverse effects of the 2013-2017 Water Hyacinth Control Program in the Delta, NMFS (2013b: 11) concluded that mechanical removal could have negative effects to listed species but that these would be discountable because of several factors, including that mechanical removal would be limited to dense water hyacinth mats where listed salmonids are not likely to be present. Presumably within Clifton Court Forebay there would be greater potential for juvenile salmonids to encounter mechanical removal of water hyacinth, given that hyacinth and fish may follow similar pathways across the Forebay toward the intake channel and the trash racks. However, any potential adverse effects from mechanical removal of water hyacinth or other aquatic weeds (e.g., injury from contact with cutting blades) possibly would be offset to some extent by the reduced probability of predation by weed-associated predatory fishes and increases in salvage efficiency at the Skinner Fish Delta Fish Protective Facility because of reduced smothering by weeds.

5.4.1.3.1.2 Far-Field Effects

5.4.1.3.1.2.1 Indirect Mortality Within the Delta

5.4.1.3.1.2.1.1 Channel Velocity (DSM2-HYDRO)

Delta channel flows have considerable importance for downstream migrating juvenile salmonids, as shown by studies in which through-Delta survival of Chinook salmon smolts positively correlated with flow (Newman 2003; Perry 2010) although one recent study by Zeug and Cavallo (2013) did not find evidence for effects of inflow on the probability of recovery of coded-wire-tagged Chinook salmon in ocean fisheries. Flow-related survival, in terms of the influence of downstream river (net) flow, may be more important in areas with largely unidirectional downstream flow and lesser tidal influence, as opposed to strong tidal influence, because tidal influence progressively becomes much greater with movement downstream. The Delta Passage Model, for example, does not include a net flow-survival relationship in the Sacramento River below Rio Vista, because such a relationship is not supported by existing data (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*). Further evidence of possible greater importance of flow in riverine reaches (as opposed to tidal reaches) comes from the recent study of Michel et al. (2015), who found that survival of acoustically tagged juvenile late fall-run Chinook salmon from the upper Sacramento River to the Golden Gate Bridge was greatest in 2011, the highest flow year, and that survival in the other years (2007-2010) was lower and did not differ greatly; the overall pattern was driven by in-river (upstream of Delta) survival being considerably greater in 2011 than the other years, whereas through-Delta survival was similar in all five years.

The PA has the potential to both adversely and beneficially change channel flows in the Delta, through changes in north and south Delta export patterns in relation to the NAA. Although north Delta exports would reduce Sacramento River flows downstream of the NDD, this would allow greater south and central Delta channel flows because of less south Delta exports.

As described 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.1.2.1.1.1, *Velocity*, velocity generally is a superior variable than flow for examining potential

effects on fish because its effects do not vary with channel size and velocity has a direct relationship with bioenergetics. However, for the present analysis, the summary is based only on velocity, without linkage to biological outcomes such as sustained fish swimming speed, and represents a somewhat new methodology in terms of assessing potential differences, having only recently been applied in Reclamation/DWR's Biological Review for Endangered Species Act Compliance with the WY 2015 Drought Contingency Plan April through September Project Description[11]. In addition, the behavior of juvenile salmonids, particularly with respect to selective tidal-stream transport (Delaney et al. 2014) means that simple differences in velocity may not translate into biological outcomes between scenarios and therefore indicates that there is uncertainty as to the significance of the velocity-based results to listed salmonids beyond general trends in differences. A comparison of hydrodynamic conditions in important Delta channels for the NAA and PA scenarios was undertaken based on 15-minute DSM2-HYDRO velocity outputs. Three velocity metrics were assessed: magnitude of channel velocity; magnitude of negative velocity; and proportion of time in each day that velocity was negative. Lower overall velocity, greater negative velocity, and a greater proportion of negative velocity are all indicators of potential adverse effects to juvenile salmonids, e.g., by delaying migration or causing advection into migration pathways with lower survival. As previously noted, the lack of an explicit biological outcome in the modeling means that there is some uncertainty in the biological significance of the results; other analyses used herein to assess effects, such as the Delta Passage Model and the analysis based on Perry (2010), provide more explicit context as to biological significance because differences in flow are converted to potential differences in survival. Note that the summary of velocity differences between NAA and PA does not account for real-time operations that would be done in order to limit potential operational effects by assessing flow conditions in the context of fish presence, e.g., by using monitoring data from at or upstream of the Delta periphery (e.g., Knights Landing on the Sacramento River or Mossdale on the San Joaquin River).

A comprehensive description of the results 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.1.2.1.2, *Results*. In this section, the detailed information presented with text and graphs in Appendix 5.D is summarized in color-coded tables, which highlight differences in medians of 5% or greater between PA and NAA. These differences are plotted and described across the full range of variability of the data in Appendix 5.D.

With respect to overall velocity, operational differences between NAA and PA led to differences in channel velocity. Within the south Delta and San Joaquin River, the changes would be beneficial to migrating juvenile salmonids, because channel velocity was generally greater under the PA (Table 5.4-8). In the San Joaquin River, this was caused by the closure of the HOR gate (assumed in the modeling to be open during days in October prior to the D-1641 San Joaquin River pulse, 100% closed during the pulse, 50% closed from January–June 15, and 100% open during the remaining months), and median channel 21 velocity downstream of the HOR was around 10–50% greater (0.02–0.08 ft/s greater). In Old River downstream of the south Delta export facilities, the differences were related to less south Delta exports; however, in April and May it was also apparent that in drier years median velocity was less positive under PA than

[11] Available at http://www.waterboards.ca.gov/waterrights/water_issues/programs/drought/docs/tucp/2015/biorev2_aprsep.pdf

NAA. Although the PA criteria are consistent with the OMR flows and San Joaquin I/E ratio requirements in the current BiOps, and south Delta export pumping is almost always lower (Appendix 5.A, *CALSIM Methods and Results*, Figures 5.A.6-27-1 to 5.A.6-27-19 and Table 5.A.6-27), in April and May the assumption of the HOR gate being 50% closed, combined with differing modeling assumptions for south Delta exports[12], results in Old River channel velocity that was slightly lower under PA than NAA (although both had positive median velocity). Channel velocity in Old River upstream of the south Delta export facilities was less positive under the PA than NAA, reflecting less south Delta exports under the PA (i.e., the export facilities exert some hydrodynamic influence by increasing velocity toward them) and the HOR gate, which blocks flow from entering 50% of the time during January–June 15.

In the north Delta, less flow in the Sacramento River downstream of the NDD (channel 418) under the PA led to lower median channel velocity under the PA relative to NAA (Table 5.4-8). Reflecting the fact that greater diversion would occur in wetter years, the difference in median velocity for channel 418 ranged from 10–24% less under PA in wet years to 4–11% less in critical years, which equated to absolute differences of 0.23–0.57 ft/s in wet years to 0.04–0.15 ft/s in critical years. Sacramento River channels farther downstream (421 and 423, upstream and downstream of Georgiana Slough) had similar patterns of difference, but with lower magnitude of change, reflecting greater tidal influence; this was also evident in Sutter Slough (channel 379) and Steamboat Slough (channel 383) (Table 5.4-8), with the latter being farther downstream than the former.

Considering only negative velocity estimates, under the PA the median negative velocity in the San Joaquin River downstream of Old River was greater (closer to zero) than under NAA, with the relative difference decreasing as water years became drier (Table 5.4-9); there was little difference farther downstream near the confluence with the Mokelumne River, reflecting greater tidal influence. Negative velocity estimates in Old River downstream of the south Delta export facilities under the PA were either less than or similar to those under NAA, whereas in Old River upstream of the facilities, the negative velocities were greater (again reflecting less south Delta exports and the influence of the HOR gate, both of which would increase the influence of flood tides in this channel). In the north Delta, the estimates of negative velocity must be interpreted with caution because in many cases negative velocity occurred for only a very small proportion of time (particularly in the more upstream channels such as Sutter Slough and the Sacramento River downstream of the NDD and upstream of Georgiana Slough; see Table 5.4-10). For the situations where an appreciable proportion of velocity estimates were negative under both scenarios, (e.g., Steamboat Slough and the Sacramento River downstream of Georgiana Slough), median negative velocity under PA was similar to or more negative than median negative velocity under NAA. This is consistent with less Sacramento River flow because of the NDD, increasing the flood tide influence on velocity. The absolute differences in median negative velocity were not large, however; for example, in the Sacramento River downstream of

[12] To some extent the results reflect the fact that there were differences in the CalSim modeling between the San Luis rule curves assumed for the NAA and PA: the NAA was more conservative in terms of being well below criteria for April-May San Luis reservoir filling, whereas the PA assumed a different curve and was much closer to criteria in some instances. Additional discussion of the rule curve differences is provided in Appendix 5.A, *CALSIM Methods and Results*, Section 5.A.4.4.

Georgiana Slough, differences in the periods during which there was a greater proportion of negative velocity (typically drier years) generally were much less than 0.1 ft/s (Table 5.4-9).

The median daily proportion of negative velocity again illustrated the effect of the HOR gate in the San Joaquin River downstream of HOR, where the proportion under the PA generally was moderately less than under NAA, although farther downstream near the confluence with the Mokelumne River the tidal influence resulted in little to no difference between PA and NAA (Table 5.4-10). The daily proportion of negative velocity in Old River downstream of the south Delta export facilities under PA was similar to or somewhat less than NAA, whereas upstream of the facilities, the greater tidal influence caused by the HOR gate and less south Delta exports led to an appreciably greater proportion of time with negative velocity. In the north Delta, as previously noted in the analysis of negative velocity, the farther upstream channels had little to no negative velocity much of the time (e.g., Sutter Slough and the Sacramento River downstream of the NDD) (Table 5.4-10). Of concern from the perspective of salmonids migrating down the Sacramento River was greater frequency of negative velocity in the Sacramento River downstream of Georgiana Slough under the PA relative to the NAA, with differences between medians ranging from little difference in a number of water-year types/months to >110% more (0.09 in absolute difference) in March of below normal years.

Overall, the results of the analysis of channel velocity suggest the potential for adverse effects to migrating juvenile winter-run and spring-run Chinook salmon and juvenile steelhead migrating downstream through the north Delta from the Sacramento River watershed caused by lower overall velocity, somewhat greater negative velocity, and a greater proportion of time with negative velocity, which may delay migration and result in greater repeated exposure to entry into migration routes with lower survival, particularly because of entry into Georgiana Slough (see also discussion of flow routing into channel junctions). Juvenile steelhead emigrating from the San Joaquin River watershed would be expected to benefit from the HOR gate, which would increase overall velocity and reduce negative velocity in the San Joaquin River, as well as reducing the daily proportion of negative velocity; these effects would be greatest farther upstream. Salmonids from both the Sacramento and San Joaquin River watersheds generally would be expected to benefit from interior Delta channel velocity (e.g., Old River downstream of the south Delta export facilities) that would be somewhat more positive and less frequently negative. As previously noted, the summary of Delta hydrodynamic conditions based on DSM2 does not account for the results of coordinated monitoring and research that will be done under the Collaborative Science and Adaptive Management Program, including real-time operations that would be done in order to limit potential operational effects to avoid jeopardy while maximizing water supplies, by assessing flow conditions in the context of fish presence, e.g., by using monitoring data from at or upstream of the Delta periphery (e.g., Knights Landing on the Sacramento River or Mossdale on the San Joaquin River).

Table 5.4-8. Median 15-minute Velocity in Important Delta Channels, from DSM2-HYDRO Modeling, with Green Shading Indicating PA is ≥ 5% More than NAA and Red Shading Indicating PA is ≥ 5% Less than NAA.

DSM2 Channel	Location	Water Year Type	December			January			February			March			April			May			June		
			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	NAA	PA	PA vs. NAA
21	San Joaquin River downstream of HOR	W	0.263	0.264	0.001 (0%)	0.378	0.433	0.054 (14%)	0.473	0.533	0.060 (13%)	0.482	0.548	0.066 (14%)	0.428	0.493	0.065 (15%)	0.407	0.462	0.055 (13%)	0.330	0.355	0.025 (8%)
		AN	0.182	0.185	0.003 (2%)	0.239	0.295	0.056 (23%)	0.308	0.371	0.064 (21%)	0.295	0.368	0.073 (25%)	0.271	0.351	0.081 (30%)	0.254	0.331	0.078 (31%)	0.152	0.196	0.045 (30%)
		BN	0.115	0.119	0.004 (4%)	0.131	0.202	0.071 (54%)	0.265	0.318	0.053 (20%)	0.169	0.251	0.082 (49%)	0.199	0.286	0.087 (44%)	0.166	0.245	0.079 (47%)	0.097	0.118	0.022 (22%)
		D	0.087	0.089	0.002 (3%)	0.112	0.171	0.059 (52%)	0.167	0.223	0.057 (34%)	0.172	0.228	0.056 (32%)	0.167	0.234	0.067 (40%)	0.155	0.217	0.061 (39%)	0.090	0.110	0.020 (22%)
		C	0.085	0.086	0.001 (1%)	0.087	0.128	0.041 (47%)	0.120	0.167	0.048 (40%)	0.104	0.142	0.038 (37%)	0.099	0.134	0.035 (35%)	0.092	0.128	0.035 (38%)	0.076	0.083	0.008 (11%)
45	San Joaquin River near the confluence with the Mokelumne River	W	0.240	0.251	0.011 (4%)	0.432	0.488	0.056 (13%)	0.471	0.554	0.083 (18%)	0.452	0.550	0.098 (22%)	0.439	0.474	0.034 (8%)	0.394	0.430	0.036 (9%)	0.232	0.293	0.061 (27%)
		AN	0.140	0.155	0.015 (11%)	0.269	0.300	0.031 (11%)	0.334	0.368	0.034 (10%)	0.293	0.385	0.092 (31%)	0.298	0.324	0.026 (9%)	0.247	0.270	0.022 (9%)	0.142	0.171	0.030 (21%)
		BN	0.061	0.081	0.020 (34%)	0.131	0.191	0.060 (45%)	0.237	0.260	0.023 (10%)	0.168	0.197	0.029 (17%)	0.213	0.222	0.009 (4%)	0.172	0.186	0.014 (8%)	0.130	0.139	0.008 (6%)
		D	0.068	0.076	0.008 (11%)	0.118	0.149	0.031 (27%)	0.184	0.198	0.013 (7%)	0.192	0.203	0.011 (6%)	0.195	0.208	0.014 (7%)	0.158	0.172	0.014 (9%)	0.134	0.143	0.010 (7%)
		C	0.085	0.087	0.002 (2%)	0.092	0.111	0.020 (21%)	0.148	0.150	0.002 (1%)	0.152	0.161	0.010 (6%)	0.144	0.148	0.004 (3%)	0.122	0.126	0.004 (3%)	0.124	0.124	0.000 (0%)
94	Old River downstream of the south Delta export facilities	W	-0.250	-0.175	0.075 (30%)	0.004	0.227	0.224 (5831%)	0.036	0.448	0.412 (1138%)	0.052	0.505	0.454 (877%)	0.350	0.486	0.136 (39%)	0.296	0.453	0.157 (53%)	-0.110	0.170	0.279 (255%)
		AN	-0.358	-0.272	0.087 (24%)	-0.121	0.008	0.129 (107%)	-0.062	0.087	0.149 (240%)	-0.146	0.265	0.411 (282%)	0.189	0.230	0.041 (22%)	0.164	0.197	0.032 (20%)	-0.181	-0.061	0.120 (66%)
		BN	-0.446	-0.363	0.083 (19%)	-0.200	0.003	0.203 (101%)	-0.108	-0.051	0.057 (53%)	-0.171	-0.100	0.071 (42%)	0.109	0.061	-0.048 (-44%)	0.088	0.061	-0.027 (-30%)	-0.131	-0.077	0.054 (41%)
		D	-0.368	-0.321	0.046 (13%)	-0.213	-0.134	0.079 (37%)	-0.133	-0.086	0.047 (35%)	-0.097	-0.074	0.024 (24%)	0.067	0.047	-0.020 (-30%)	0.039	0.043	0.004 (11%)	-0.112	-0.043	0.069 (61%)
		C	-0.266	-0.222	0.044 (16%)	-0.214	-0.190	0.023 (11%)	-0.107	-0.108	0.000 (0%)	-0.019	-0.016	0.003 (16%)	0.056	0.034	-0.022 (-39%)	0.045	0.029	-0.015 (-35%)	0.035	0.052	0.017 (48%)
212	Old River upstream of the south Delta export facilities	W	0.682	0.701	0.018 (3%)	0.946	0.867	-0.079 (-8%)	1.120	1.036	-0.084 (-8%)	1.199	1.075	-0.124 (-10%)	1.171	1.074	-0.097 (-8%)	1.161	1.069	-0.093 (-8%)	0.666	0.621	-0.045 (-7%)
		AN	0.574	0.558	-0.016 (-3%)	0.705	0.578	-0.127 (-18%)	0.794	0.689	-0.105 (-13%)	0.818	0.754	-0.064 (-8%)	0.814	0.640	-0.174 (-21%)	0.805	0.612	-0.193 (-24%)	0.301	0.159	-0.142 (-47%)
		BN	0.493	0.465	-0.028 (-6%)	0.503	0.362	-0.141 (-28%)	0.713	0.555	-0.158 (-22%)	0.583	0.350	-0.234 (-40%)	0.657	0.387	-0.269 (-41%)	0.589	0.327	-0.262 (-44%)	0.132	0.047	-0.085 (-64%)
		D	0.445	0.428	-0.017 (-4%)	0.452	0.287	-0.165 (-36%)	0.541	0.378	-0.162 (-30%)	0.575	0.387	-0.188 (-33%)	0.584	0.363	-0.221 (-38%)	0.546	0.346	-0.200 (-37%)	0.113	0.037	-0.076 (-67%)
		C	0.418	0.394	-0.024 (-6%)	0.393	0.248	-0.145 (-37%)	0.467	0.300	-0.167 (-36%)	0.410	0.251	-0.159 (-39%)	0.378	0.235	-0.143 (-38%)	0.359	0.200	-0.160 (-44%)	0.009	-0.011	-0.020 (-229%)
365	Delta Cross Channel	W	0.016	0.016	0.000 (0%)	0.013	0.013	0.000 (1%)	0.014	0.014	0.000 (0%)	0.015	0.015	0.000 (1%)	0.016	0.016	0.000 (2%)	0.016	0.016	0.000 (2%)	0.422	0.471	0.049 (12%)
		AN	0.025	0.027	0.001 (6%)	0.014	0.014	0.000 (1%)	0.015	0.015	0.000 (1%)	0.015	0.015	0.000 (2%)	0.014	0.014	0.000 (2%)	0.013	0.013	0.000 (2%)	0.662	0.576	-0.087 (-13%)
		BN	0.036	0.037	0.001 (3%)	0.011	0.012	0.001 (5%)	0.013	0.013	0.000 (1%)	0.012	0.012	0.000 (1%)	0.012	0.013	0.000 (1%)	0.011	0.011	0.000 (2%)	0.667	0.613	-0.053 (-8%)
		D	0.043	0.043	0.000 (-1%)	0.011	0.011	0.000 (2%)	0.012	0.012	0.000 (0%)	0.013	0.013	0.000 (0%)	0.012	0.012	0.000 (0%)	0.010	0.011	0.000 (2%)	0.675	0.609	-0.065 (-10%)
		C	0.040	0.039	-0.001 (-1%)	0.010	0.010	0.000 (1%)	0.011	0.011	0.000 (0%)	0.010	0.011	0.000 (2%)	0.010	0.010	0.000 (0%)	0.008	0.009	0.000 (2%)	0.535	0.518	-0.017 (-3%)

DSM2 Channel	Location	Water Year Type	December			January			February			March			April			May			June		
			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	NAA	PA	PA vs. NAA
379	Sutter Slough	W	1.691	1.478	-0.214 (-13%)	2.573	2.270	-0.304 (-12%)	3.045	2.765	-0.280 (-9%)	2.536	2.208	-0.327 (-13%)	1.763	1.648	-0.116 (-7%)	1.687	1.543	-0.143 (-8%)	1.036	0.807	-0.229 (-22%)
		AN	1.101	1.012	-0.089 (-8%)	1.866	1.578	-0.288 (-15%)	2.564	2.305	-0.259 (-10%)	2.052	1.769	-0.283 (-14%)	1.345	1.270	-0.075 (-6%)	1.022	0.958	-0.065 (-6%)	0.799	0.656	-0.143 (-18%)
		BN	0.996	0.902	-0.094 (-9%)	1.079	1.015	-0.064 (-6%)	1.327	1.192	-0.134 (-10%)	1.146	0.992	-0.154 (-13%)	0.937	0.922	-0.015 (-2%)	0.856	0.832	-0.023 (-3%)	0.763	0.681	-0.082 (-11%)
		D	0.875	0.823	-0.052 (-6%)	1.008	0.939	-0.069 (-7%)	1.202	1.090	-0.112 (-9%)	1.236	1.052	-0.185 (-15%)	0.956	0.946	-0.010 (-1%)	0.821	0.799	-0.022 (-3%)	0.758	0.659	-0.099 (-13%)
		C	0.766	0.721	-0.046 (-6%)	0.932	0.892	-0.040 (-4%)	1.006	0.909	-0.097 (-10%)	0.846	0.805	-0.041 (-5%)	0.751	0.734	-0.017 (-2%)	0.649	0.607	-0.042 (-6%)	0.610	0.562	-0.048 (-8%)
383	Steamboat Slough	W	1.972	1.789	-0.183 (-9%)	2.932	2.617	-0.315 (-11%)	3.448	3.120	-0.328 (-10%)	2.868	2.495	-0.373 (-13%)	2.021	1.903	-0.118 (-6%)	1.888	1.742	-0.146 (-8%)	1.346	1.140	-0.206 (-15%)
		AN	1.394	1.313	-0.081 (-6%)	2.161	1.916	-0.245 (-11%)	2.937	2.632	-0.305 (-10%)	2.346	2.042	-0.304 (-13%)	1.581	1.538	-0.044 (-3%)	1.275	1.206	-0.070 (-5%)	1.026	0.930	-0.095 (-9%)
		BN	1.235	1.156	-0.079 (-6%)	1.362	1.276	-0.086 (-6%)	1.631	1.518	-0.113 (-7%)	1.397	1.239	-0.158 (-11%)	1.169	1.140	-0.030 (-3%)	1.089	1.062	-0.027 (-2%)	0.972	0.941	-0.031 (-3%)
		D	1.115	1.066	-0.049 (-4%)	1.272	1.196	-0.076 (-6%)	1.493	1.384	-0.109 (-7%)	1.483	1.307	-0.177 (-12%)	1.204	1.177	-0.027 (-2%)	1.032	1.012	-0.020 (-2%)	0.964	0.918	-0.046 (-5%)
		C	0.987	0.936	-0.051 (-5%)	1.175	1.121	-0.054 (-5%)	1.249	1.143	-0.106 (-8%)	1.083	1.019	-0.064 (-6%)	0.960	0.942	-0.018 (-2%)	0.816	0.808	-0.008 (-1%)	0.779	0.776	-0.003 (0%)
418	Sacramento River downstream of proposed NDD	W	2.224	1.901	-0.323 (-15%)	3.416	2.884	-0.532 (-16%)	4.052	3.484	-0.568 (-14%)	3.347	2.775	-0.571 (-17%)	2.305	2.070	-0.235 (-10%)	2.191	1.939	-0.252 (-12%)	1.524	1.162	-0.362 (-24%)
		AN	1.494	1.351	-0.143 (-10%)	2.473	2.019	-0.453 (-18%)	3.409	2.918	-0.491 (-14%)	2.700	2.240	-0.460 (-17%)	1.752	1.615	-0.137 (-8%)	1.343	1.225	-0.119 (-9%)	1.206	0.982	-0.224 (-19%)
		BN	1.365	1.219	-0.145 (-11%)	1.432	1.312	-0.120 (-8%)	1.744	1.538	-0.206 (-12%)	1.508	1.279	-0.229 (-15%)	1.240	1.186	-0.054 (-4%)	1.140	1.081	-0.060 (-5%)	1.157	1.017	-0.140 (-12%)
		D	1.222	1.131	-0.091 (-7%)	1.349	1.227	-0.122 (-9%)	1.594	1.411	-0.183 (-11%)	1.623	1.353	-0.269 (-17%)	1.265	1.218	-0.047 (-4%)	1.096	1.041	-0.055 (-5%)	1.149	0.992	-0.157 (-14%)
		C	1.081	0.993	-0.088 (-8%)	1.245	1.163	-0.082 (-7%)	1.333	1.182	-0.151 (-11%)	1.134	1.059	-0.075 (-7%)	1.019	0.977	-0.042 (-4%)	0.885	0.814	-0.071 (-8%)	0.928	0.826	-0.102 (-11%)
421	Sacramento River upstream of Georgiana Slough	W	1.858	1.672	-0.186 (-10%)	2.737	2.445	-0.292 (-11%)	3.191	2.903	-0.288 (-9%)	2.679	2.337	-0.342 (-13%)	1.897	1.773	-0.124 (-7%)	1.786	1.637	-0.149 (-8%)	1.407	1.115	-0.292 (-21%)
		AN	1.322	1.241	-0.081 (-6%)	2.031	1.773	-0.258 (-13%)	2.736	2.467	-0.269 (-10%)	2.210	1.921	-0.288 (-13%)	1.472	1.418	-0.055 (-4%)	1.154	1.074	-0.080 (-7%)	1.114	0.955	-0.159 (-14%)
		BN	1.194	1.113	-0.082 (-7%)	1.251	1.167	-0.084 (-7%)	1.501	1.374	-0.127 (-8%)	1.295	1.139	-0.156 (-12%)	1.076	1.053	-0.023 (-2%)	0.986	0.954	-0.032 (-3%)	1.067	0.980	-0.087 (-8%)
		D	1.087	1.040	-0.047 (-4%)	1.173	1.099	-0.073 (-6%)	1.372	1.263	-0.109 (-8%)	1.381	1.198	-0.183 (-13%)	1.103	1.084	-0.020 (-2%)	0.944	0.914	-0.030 (-3%)	1.058	0.955	-0.103 (-10%)
		C	0.956	0.902	-0.054 (-6%)	1.080	1.039	-0.041 (-4%)	1.147	1.053	-0.094 (-8%)	0.989	0.945	-0.045 (-5%)	0.885	0.867	-0.018 (-2%)	0.756	0.733	-0.024 (-3%)	0.852	0.814	-0.039 (-5%)
423	Sacramento River downstream of Georgiana Slough	W	1.713	1.578	-0.134 (-8%)	2.467	2.211	-0.256 (-10%)	2.857	2.593	-0.265 (-9%)	2.429	2.129	-0.300 (-12%)	1.755	1.670	-0.085 (-5%)	1.623	1.522	-0.102 (-6%)	1.147	0.975	-0.171 (-15%)
		AN	1.229	1.161	-0.067 (-5%)	1.857	1.680	-0.177 (-10%)	2.463	2.205	-0.259 (-11%)	2.015	1.764	-0.251 (-12%)	1.402	1.368	-0.034 (-2%)	1.127	1.072	-0.055 (-5%)	0.824	0.739	-0.086 (-10%)
		BN	1.063	0.993	-0.070 (-7%)	1.199	1.121	-0.077 (-6%)	1.458	1.359	-0.100 (-7%)	1.235	1.091	-0.144 (-12%)	1.020	0.998	-0.022 (-2%)	0.947	0.927	-0.020 (-2%)	0.767	0.743	-0.024 (-3%)
		D	0.949	0.903	-0.046 (-5%)	1.120	1.055	-0.065 (-6%)	1.328	1.228	-0.100 (-8%)	1.313	1.150	-0.162 (-12%)	1.058	1.032	-0.025 (-2%)	0.890	0.877	-0.013 (-2%)	0.759	0.723	-0.037 (-5%)
		C	0.829	0.784	-0.046 (-6%)	1.023	0.973	-0.050 (-5%)	1.095	0.999	-0.096 (-9%)	0.945	0.883	-0.062 (-7%)	0.824	0.810	-0.014 (-2%)	0.674	0.669	-0.005 (-1%)	0.596	0.594	-0.001 (0%)

Table 5.4-9. Median 15-minute Negative Velocity in Important Delta Channels, from DSM2-HYDRO Modeling, with Green Shading Indicating PA is ≥ 5% More than NAA and Red Shading Indicating PA is ≥ 5% Less than NAA.

DSM2 Channel	Location	Water Year Type	December			January			February			March			April			May			June		
			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	NAA	PA	PA vs. NAA
21	San Joaquin River downstream of HOR	W	-0.298	-0.295	0.003 (1%)	-0.246	-0.194	0.052 (21%)	-0.182	-0.133	0.049 (27%)	-0.166	-0.121	0.045 (27%)	-0.154	-0.104	0.051 (33%)	-0.187	-0.124	0.063 (34%)	-0.222	-0.205	0.017 (7%)
		AN	-0.334	-0.332	0.002 (1%)	-0.284	-0.233	0.051 (18%)	-0.246	-0.187	0.059 (24%)	-0.225	-0.170	0.055 (25%)	-0.194	-0.132	0.062 (32%)	-0.215	-0.149	0.066 (31%)	-0.267	-0.249	0.017 (7%)
		BN	-0.321	-0.317	0.004 (1%)	-0.309	-0.251	0.058 (19%)	-0.281	-0.220	0.061 (22%)	-0.258	-0.198	0.060 (23%)	-0.229	-0.167	0.061 (27%)	-0.249	-0.190	0.059 (24%)	-0.299	-0.287	0.012 (4%)
		D	-0.333	-0.330	0.002 (1%)	-0.318	-0.259	0.059 (19%)	-0.306	-0.250	0.057 (18%)	-0.309	-0.254	0.054 (18%)	-0.277	-0.226	0.051 (18%)	-0.291	-0.239	0.052 (18%)	-0.312	-0.301	0.011 (4%)
		C	-0.338	-0.337	0.001 (0%)	-0.341	-0.294	0.047 (14%)	-0.317	-0.266	0.051 (16%)	-0.324	-0.282	0.042 (13%)	-0.327	-0.288	0.039 (12%)	-0.325	-0.284	0.041 (13%)	-0.322	-0.319	0.003 (1%)
45	San Joaquin River near the confluence with the Mokelumne River	W	-1.314	-1.307	0.008 (1%)	-1.223	-1.199	0.023 (2%)	-1.161	-1.118	0.043 (4%)	-1.196	-1.146	0.049 (4%)	-1.206	-1.188	0.018 (1%)	-1.231	-1.212	0.018 (1%)	-1.296	-1.264	0.032 (2%)
		AN	-1.343	-1.332	0.010 (1%)	-1.284	-1.268	0.016 (1%)	-1.255	-1.236	0.018 (1%)	-1.265	-1.219	0.045 (4%)	-1.285	-1.272	0.013 (1%)	-1.306	-1.297	0.010 (1%)	-1.340	-1.331	0.009 (1%)
		BN	-1.376	-1.364	0.012 (1%)	-1.341	-1.316	0.025 (2%)	-1.295	-1.283	0.012 (1%)	-1.321	-1.304	0.016 (1%)	-1.303	-1.297	0.005 (0%)	-1.316	-1.310	0.006 (0%)	-1.333	-1.330	0.003 (0%)
		D	-1.370	-1.365	0.005 (0%)	-1.348	-1.334	0.014 (1%)	-1.331	-1.321	0.010 (1%)	-1.323	-1.315	0.008 (1%)	-1.314	-1.310	0.004 (0%)	-1.328	-1.323	0.005 (0%)	-1.339	-1.336	0.003 (0%)
		C	-1.358	-1.355	0.002 (0%)	-1.351	-1.345	0.005 (0%)	-1.333	-1.329	0.004 (0%)	-1.337	-1.334	0.003 (0%)	-1.341	-1.339	0.002 (0%)	-1.336	-1.335	0.001 (0%)	-1.333	-1.334	0.000 (0%)
94	Old River downstream of the south Delta export facilities	W	-0.962	-0.953	0.009 (1%)	-0.895	-0.849	0.045 (5%)	-0.859	-0.775	0.084 (10%)	-0.873	-0.724	0.149 (17%)	-0.715	-0.706	0.009 (1%)	-0.733	-0.711	0.022 (3%)	-0.917	-0.815	0.102 (11%)
		AN	-0.977	-0.968	0.008 (1%)	-0.922	-0.884	0.038 (4%)	-0.910	-0.870	0.040 (4%)	-0.927	-0.812	0.115 (12%)	-0.821	-0.838	-0.017 (-2%)	-0.818	-0.834	-0.016 (-2%)	-0.963	-0.929	0.034 (4%)
		BN	-1.002	-0.996	0.006 (1%)	-0.956	-0.888	0.068 (7%)	-0.921	-0.889	0.031 (3%)	-0.940	-0.915	0.025 (3%)	-0.844	-0.877	-0.033 (-4%)	-0.843	-0.867	-0.024 (-3%)	-0.932	-0.923	0.009 (1%)
		D	-0.992	-0.987	0.006 (1%)	-0.965	-0.931	0.034 (4%)	-0.936	-0.919	0.017 (2%)	-0.929	-0.912	0.016 (2%)	-0.865	-0.882	-0.017 (-2%)	-0.851	-0.866	-0.014 (-2%)	-0.929	-0.917	0.012 (1%)
		C	-0.950	-0.952	-0.002 (0%)	-0.955	-0.943	0.012 (1%)	-0.916	-0.915	0.001 (0%)	-0.896	-0.905	-0.008 (-1%)	-0.888	-0.897	-0.009 (-1%)	-0.866	-0.878	-0.012 (-1%)	-0.898	-0.898	0.001 (0%)
212	Old River upstream of the south Delta export facilities	W	-0.451	-0.461	-0.010 (-2%)	-0.461	-0.698	-0.237 (-51%)	-0.377	-0.691	-0.314 (-83%)	-0.342	-0.661	-0.319 (-93%)	-0.418	-0.705	-0.288 (-69%)	-0.504	-0.766	-0.262 (-52%)	-0.261	-0.319	-0.058 (-22%)
		AN	-0.481	-0.465	0.016 (3%)	-0.531	-0.718	-0.187 (-35%)	-0.490	-0.678	-0.188 (-38%)	-0.431	-0.773	-0.342 (-79%)	-0.506	-0.767	-0.261 (-52%)	-0.550	-0.807	-0.257 (-47%)	-0.306	-0.348	-0.043 (-14%)
		BN	-0.433	-0.445	-0.012 (-3%)	-0.526	-0.761	-0.236 (-45%)	-0.501	-0.678	-0.177 (-35%)	-0.465	-0.675	-0.210 (-45%)	-0.548	-0.750	-0.202 (-37%)	-0.604	-0.798	-0.194 (-32%)	-0.369	-0.396	-0.027 (-7%)
		D	-0.472	-0.479	-0.008 (-2%)	-0.500	-0.699	-0.199 (-40%)	-0.544	-0.707	-0.163 (-30%)	-0.578	-0.723	-0.145 (-25%)	-0.620	-0.767	-0.147 (-24%)	-0.642	-0.793	-0.151 (-24%)	-0.400	-0.430	-0.030 (-8%)
		C	-0.591	-0.573	0.018 (3%)	-0.554	-0.700	-0.146 (-26%)	-0.596	-0.716	-0.121 (-20%)	-0.691	-0.797	-0.106 (-15%)	-0.735	-0.829	-0.094 (-13%)	-0.731	-0.830	-0.099 (-14%)	-0.473	-0.489	-0.016 (-3%)
365	Delta Cross Channel	W	-0.052	-0.052	0.000 (0%)	-0.050	-0.050	0.000 (0%)	-0.050	-0.049	0.000 (1%)	-0.051	-0.051	0.000 (1%)	-0.052	-0.052	0.000 (0%)	-0.052	-0.052	0.000 (0%)	-0.056	-0.060	-0.004 (-7%)
		AN	-0.052	-0.052	0.000 (0%)	-0.052	-0.052	0.000 (0%)	-0.052	-0.052	0.000 (0%)	-0.052	-0.052	0.000 (1%)	-0.052	-0.052	0.000 (0%)	-0.053	-0.053	0.000 (0%)	-0.059	-0.061	-0.002 (-3%)
		BN	-0.053	-0.053	0.000 (0%)	-0.052	-0.052	0.000 (0%)	-0.051	-0.051	0.000 (0%)	-0.052	-0.052	0.000 (0%)	-0.052	-0.052	0.000 (0%)	-0.052	-0.052	0.000 (0%)	-0.057	-0.059	-0.002 (-3%)
		D	-0.054	-0.054	0.000 (0%)	-0.052	-0.052	0.000 (0%)	-0.052	-0.052	0.000 (0%)	-0.052	-0.052	0.000 (0%)	-0.051	-0.052	0.000 (0%)	-0.052	-0.052	0.000 (0%)	-0.058	-0.060	-0.002 (-3%)
		C	-0.055	-0.055	0.000 (-1%)	-0.052	-0.052	0.000 (0%)	-0.051	-0.051	0.000 (0%)	-0.051	-0.051	0.000 (0%)	-0.051	-0.051	0.000 (0%)	-0.051	-0.051	0.000 (0%)	-0.099	-0.095	0.004 (4%)

DSM2 Channel	Location	Water Year Type	December			January			February			March			April			May			June		
			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	NAA	PA	PA vs. NAA
379	Sutter Slough	W	-0.120	-0.127	-0.007 (-6%)	-0.077	-0.073	0.003 (5%)	-0.025	-0.022	0.003 (12%)	NA*	NA	NA	-0.111	-0.119	-0.008 (-7%)	-0.124	-0.122	0.002 (2%)	-0.147	-0.135	0.011 (8%)
		AN	-0.224	-0.209	0.015 (7%)	-0.099	-0.062	0.037 (37%)	-0.206	-0.177	0.029 (14%)	NA	-0.027	NA	-0.154	-0.150	0.003 (2%)	-0.140	-0.123	0.017 (12%)	-0.135	-0.104	0.032 (24%)
		BN	-0.218	-0.199	0.019 (9%)	-0.173	-0.162	0.010 (6%)	-0.295	-0.271	0.025 (8%)	-0.096	-0.094	0.002 (2%)	-0.154	-0.142	0.012 (8%)	-0.132	-0.136	-0.005 (-3%)	-0.139	-0.145	-0.005 (-4%)
		D	-0.194	-0.180	0.014 (7%)	-0.136	-0.128	0.008 (6%)	-0.153	-0.143	0.010 (7%)	-0.127	-0.115	0.013 (10%)	-0.172	-0.163	0.009 (5%)	-0.149	-0.136	0.013 (9%)	-0.143	-0.156	-0.013 (-9%)
		C	-0.231	-0.240	-0.010 (-4%)	-0.192	-0.121	0.071 (37%)	-0.149	-0.173	-0.024 (-16%)	-0.166	-0.145	0.021 (12%)	-0.146	-0.144	0.002 (2%)	-0.249	-0.248	0.001 (1%)	-0.222	-0.230	-0.008 (-3%)
383	Steamboat Slough	W	-0.404	-0.399	0.005 (1%)	-0.362	-0.364	-0.002 (-1%)	-0.185	-0.250	-0.065 (-35%)	-0.160	-0.347	-0.187 (-117%)	-0.372	-0.397	-0.025 (-7%)	-0.410	-0.438	-0.028 (-7%)	-0.550	-0.579	-0.029 (-5%)
		AN	-0.492	-0.516	-0.025 (-5%)	-0.345	-0.340	0.005 (2%)	-0.525	-0.461	0.064 (12%)	-0.246	-0.324	-0.078 (-32%)	-0.367	-0.393	-0.027 (-7%)	-0.431	-0.456	-0.025 (-6%)	-0.567	-0.594	-0.026 (-5%)
		BN	-0.484	-0.512	-0.028 (-6%)	-0.457	-0.470	-0.014 (-3%)	-0.419	-0.435	-0.015 (-4%)	-0.392	-0.419	-0.027 (-7%)	-0.434	-0.463	-0.029 (-7%)	-0.480	-0.490	-0.010 (-2%)	-0.578	-0.547	0.030 (5%)
		D	-0.541	-0.559	-0.018 (-3%)	-0.439	-0.474	-0.035 (-8%)	-0.376	-0.421	-0.045 (-12%)	-0.384	-0.409	-0.025 (-7%)	-0.471	-0.474	-0.003 (-1%)	-0.472	-0.476	-0.004 (-1%)	-0.582	-0.578	0.003 (1%)
		C	-0.625	-0.648	-0.023 (-4%)	-0.499	-0.494	0.005 (1%)	-0.419	-0.485	-0.066 (-16%)	-0.487	-0.516	-0.029 (-6%)	-0.503	-0.516	-0.014 (-3%)	-0.613	-0.621	-0.007 (-1%)	-0.691	-0.696	-0.005 (-1%)
418	Sacramento River downstream of proposed NDD	W	-0.120	-0.136	-0.017 (-14%)	-0.091	-0.092	-0.002 (-2%)	NA	-0.073	NA	NA	0.000	NA	-0.168	-0.160	0.008 (5%)	-0.145	-0.154	-0.008 (-6%)	-0.156	-0.175	-0.019 (-12%)
		AN	-0.250	-0.242	0.008 (3%)	-0.065	-0.064	0.001 (2%)	-0.265	-0.220	0.046 (17%)	NA	-0.036	NA	-0.200	-0.183	0.017 (8%)	-0.150	-0.140	0.010 (7%)	-0.202	-0.156	0.046 (23%)
		BN	-0.254	-0.231	0.023 (9%)	-0.187	-0.180	0.007 (4%)	-0.374	-0.359	0.015 (4%)	-0.126	-0.114	0.012 (9%)	-0.175	-0.178	-0.002 (-1%)	-0.150	-0.160	-0.010 (-7%)	-0.135	-0.135	0.000 (0%)
		D	-0.233	-0.200	0.032 (14%)	-0.141	-0.139	0.002 (1%)	-0.154	-0.149	0.005 (3%)	-0.115	-0.119	-0.004 (-3%)	-0.194	-0.182	0.012 (6%)	-0.168	-0.158	0.010 (6%)	-0.157	-0.152	0.005 (3%)
		C	-0.272	-0.266	0.006 (2%)	-0.224	-0.146	0.078 (35%)	-0.155	-0.188	-0.033 (-21%)	-0.183	-0.169	0.014 (8%)	-0.166	-0.162	0.004 (3%)	-0.285	-0.281	0.005 (2%)	-0.271	-0.263	0.009 (3%)
421	Sacramento River upstream of Georgiana Slough	W	-0.074	-0.080	-0.006 (-8%)	-0.061	-0.052	0.008 (14%)	NA	-0.104	NA	NA	-0.033	NA	-0.123	-0.123	0.001 (0%)	-0.111	-0.147	-0.036 (-33%)	-0.152	-0.158	-0.006 (-4%)
		AN	-0.190	-0.187	0.003 (2%)	-0.047	-0.084	-0.037 (-78%)	-0.179	-0.139	0.040 (22%)	NA	-0.058	NA	-0.156	-0.137	0.019 (12%)	-0.110	-0.142	-0.032 (-29%)	-0.186	-0.147	0.038 (21%)
		BN	-0.218	-0.179	0.038 (18%)	-0.141	-0.141	0.000 (0%)	-0.304	-0.278	0.025 (8%)	-0.088	-0.096	-0.008 (-9%)	-0.133	-0.161	-0.028 (-21%)	-0.115	-0.146	-0.031 (-27%)	-0.113	-0.133	-0.020 (-18%)
		D	-0.178	-0.161	0.017 (10%)	-0.103	-0.105	-0.002 (-2%)	-0.106	-0.118	-0.012 (-11%)	-0.077	-0.092	-0.014 (-18%)	-0.149	-0.157	-0.008 (-5%)	-0.125	-0.145	-0.020 (-16%)	-0.162	-0.142	0.020 (12%)
		C	-0.223	-0.223	0.000 (0%)	-0.163	-0.108	0.054 (33%)	-0.113	-0.152	-0.039 (-35%)	-0.134	-0.139	-0.004 (-3%)	-0.122	-0.139	-0.018 (-15%)	-0.219	-0.234	-0.015 (-7%)	-0.247	-0.256	-0.009 (-4%)
423	Sacramento River downstream of Georgiana Slough	W	-0.347	-0.343	0.005 (1%)	-0.310	-0.297	0.013 (4%)	-0.225	-0.217	0.008 (4%)	-0.144	-0.286	-0.142 (-98%)	-0.317	-0.338	-0.021 (-7%)	-0.356	-0.384	-0.028 (-8%)	-0.545	-0.580	-0.035 (-6%)
		AN	-0.448	-0.468	-0.020 (-4%)	-0.297	-0.285	0.012 (4%)	-0.467	-0.402	0.065 (14%)	-0.213	-0.268	-0.054 (-25%)	-0.312	-0.333	-0.021 (-7%)	-0.377	-0.403	-0.026 (-7%)	-0.576	-0.610	-0.034 (-6%)
		BN	-0.449	-0.479	-0.030 (-7%)	-0.396	-0.414	-0.017 (-4%)	-0.354	-0.372	-0.018 (-5%)	-0.329	-0.363	-0.034 (-10%)	-0.385	-0.412	-0.026 (-7%)	-0.434	-0.443	-0.008 (-2%)	-0.582	-0.585	-0.002 (0%)
		D	-0.505	-0.520	-0.015 (-3%)	-0.389	-0.426	-0.037 (-9%)	-0.329	-0.369	-0.039 (-12%)	-0.334	-0.348	-0.014 (-4%)	-0.417	-0.419	-0.002 (0%)	-0.430	-0.435	-0.005 (-1%)	-0.589	-0.600	-0.011 (-2%)
		C	-0.587	-0.608	-0.021 (-4%)	-0.438	-0.444	-0.006 (-1%)	-0.373	-0.432	-0.059 (-16%)	-0.435	-0.463	-0.028 (-6%)	-0.460	-0.472	-0.012 (-3%)	-0.566	-0.576	-0.010 (-2%)	-0.678	-0.682	-0.004 (-1%)

Note: *NA denotes that there were no negative velocity estimates.

Table 5.4-10. Median Daily Proportion of Negative Velocity in Important Delta Channels, from DSM2-HYDRO Modeling, with Green Shading Indicating PA is ≥ 5% Less than NAA and Red Shading Indicating PA is ≥ 5% More than NAA.

DSM2 Channel	Location	Water Year Type	December			January			February			March			April			May			June		
			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	NAA	PA	PA vs. NAA
21	San Joaquin River downstream of HOR	W	0.438	0.438	0.000 (0%)	0.365	0.250	-0.115 (-31%)	0.219	0.083	-0.135 (-62%)	0.167	0.063	-0.104 (-63%)	0.234	0.094	-0.141 (-60%)	0.292	0.135	-0.156 (-54%)	0.385	0.323	-0.063 (-16%)
		AN	0.469	0.458	-0.010 (-2%)	0.438	0.406	-0.031 (-7%)	0.406	0.333	-0.073 (-18%)	0.396	0.260	-0.135 (-34%)	0.396	0.292	-0.104 (-26%)	0.406	0.323	-0.083 (-21%)	0.448	0.438	-0.010 (-2%)
		BN	0.469	0.469	0.000 (0%)	0.458	0.427	-0.031 (-7%)	0.438	0.396	-0.042 (-10%)	0.438	0.396	-0.042 (-10%)	0.427	0.385	-0.042 (-10%)	0.438	0.396	-0.042 (-10%)	0.458	0.458	0.000 (0%)
		D	0.469	0.469	0.000 (0%)	0.458	0.438	-0.021 (-5%)	0.458	0.427	-0.031 (-7%)	0.458	0.438	-0.021 (-5%)	0.448	0.417	-0.031 (-7%)	0.448	0.427	-0.021 (-5%)	0.469	0.458	-0.010 (-2%)
		C	0.469	0.469	0.000 (0%)	0.469	0.448	-0.021 (-4%)	0.458	0.438	-0.021 (-5%)	0.458	0.448	-0.010 (-2%)	0.458	0.448	-0.010 (-2%)	0.458	0.448	-0.010 (-2%)	0.469	0.469	0.000 (0%)
45	San Joaquin River near the confluence with the Mokelumne River	W	0.479	0.479	0.000 (0%)	0.458	0.448	-0.010 (-2%)	0.448	0.438	-0.010 (-2%)	0.448	0.438	-0.010 (-2%)	0.448	0.438	-0.010 (-2%)	0.448	0.448	0.000 (0%)	0.469	0.469	0.000 (0%)
		AN	0.490	0.490	0.000 (0%)	0.469	0.469	0.000 (0%)	0.458	0.458	0.000 (0%)	0.458	0.448	-0.010 (-2%)	0.458	0.458	0.000 (0%)	0.469	0.469	0.000 (0%)	0.479	0.479	0.000 (0%)
		BN	0.500	0.490	-0.010 (-2%)	0.490	0.479	-0.010 (-2%)	0.479	0.479	0.000 (0%)	0.479	0.479	0.000 (0%)	0.469	0.469	0.000 (0%)	0.479	0.469	-0.010 (-2%)	0.479	0.479	0.000 (0%)
		D	0.500	0.490	-0.010 (-2%)	0.490	0.479	-0.010 (-2%)	0.479	0.479	0.000 (0%)	0.479	0.479	0.000 (0%)	0.469	0.469	0.000 (0%)	0.479	0.479	0.000 (0%)	0.479	0.479	0.000 (0%)
		C	0.490	0.490	0.000 (0%)	0.490	0.490	0.000 (0%)	0.479	0.479	0.000 (0%)	0.479	0.479	0.000 (0%)	0.479	0.479	0.000 (0%)	0.479	0.479	0.000 (0%)	0.479	0.479	0.000 (0%)
94	Old River downstream of the south Delta export facilities	W	0.583	0.573	-0.010 (-2%)	0.531	0.490	-0.042 (-8%)	0.531	0.448	-0.083 (-16%)	0.531	0.438	-0.094 (-18%)	0.448	0.438	-0.010 (-2%)	0.458	0.448	-0.010 (-2%)	0.531	0.479	-0.052 (-10%)
		AN	0.583	0.583	0.000 (0%)	0.531	0.510	-0.021 (-4%)	0.531	0.500	-0.031 (-6%)	0.542	0.469	-0.073 (-13%)	0.469	0.469	0.000 (0%)	0.469	0.469	0.000 (0%)	0.542	0.521	-0.021 (-4%)
		BN	0.667	0.604	-0.063 (-9%)	0.552	0.490	-0.063 (-11%)	0.521	0.521	0.000 (0%)	0.542	0.531	-0.010 (-2%)	0.479	0.490	0.010 (2%)	0.479	0.490	0.010 (2%)	0.531	0.521	-0.010 (-2%)
		D	0.594	0.583	-0.010 (-2%)	0.552	0.531	-0.021 (-4%)	0.531	0.531	0.000 (0%)	0.521	0.521	0.000 (0%)	0.490	0.500	0.010 (2%)	0.490	0.490	0.000 (0%)	0.521	0.510	-0.010 (-2%)
		C	0.542	0.542	0.000 (0%)	0.552	0.552	0.000 (0%)	0.521	0.521	0.000 (0%)	0.500	0.500	0.000 (0%)	0.490	0.490	0.000 (0%)	0.490	0.490	0.000 (0%)	0.490	0.490	0.000 (0%)
212	Old River upstream of the south Delta export facilities	W	0.344	0.354	0.010 (3%)	0.292	0.396	0.104 (36%)	0.125	0.354	0.229 (183%)	0.094	0.297	0.203 (217%)	0.177	0.365	0.188 (106%)	0.229	0.396	0.167 (73%)	0.188	0.385	0.198 (106%)
		AN	0.344	0.365	0.021 (6%)	0.365	0.427	0.063 (17%)	0.313	0.406	0.094 (30%)	0.271	0.417	0.146 (54%)	0.344	0.427	0.083 (24%)	0.365	0.438	0.073 (20%)	0.438	0.464	0.026 (6%)
		BN	0.333	0.365	0.031 (9%)	0.385	0.448	0.063 (16%)	0.365	0.427	0.063 (17%)	0.354	0.438	0.083 (24%)	0.375	0.438	0.063 (17%)	0.396	0.448	0.052 (13%)	0.469	0.490	0.021 (4%)
		D	0.375	0.375	0.000 (0%)	0.385	0.448	0.063 (16%)	0.385	0.448	0.063 (16%)	0.396	0.448	0.052 (13%)	0.406	0.448	0.042 (10%)	0.417	0.458	0.042 (10%)	0.479	0.500	0.021 (4%)
		C	0.396	0.406	0.010 (3%)	0.406	0.458	0.052 (13%)	0.396	0.448	0.052 (13%)	0.438	0.469	0.031 (7%)	0.438	0.469	0.031 (7%)	0.438	0.469	0.031 (7%)	0.500	0.500	0.000 (0%)
365	Delta Cross Channel	W	0.448	0.448	0.000 (0%)	0.427	0.427	0.000 (0%)	0.427	0.417	-0.010 (-2%)	0.427	0.427	0.000 (0%)	0.438	0.427	-0.010 (-2%)	0.427	0.427	0.000 (0%)	0.073	0.083	0.010 (14%)
		AN	0.458	0.458	0.000 (0%)	0.448	0.448	0.000 (0%)	0.438	0.438	0.000 (0%)	0.438	0.438	0.000 (0%)	0.448	0.448	0.000 (0%)	0.458	0.458	0.000 (0%)	0.031	0.063	0.031 (100%)
		BN	0.458	0.448	-0.010 (-2%)	0.469	0.458	-0.010 (-2%)	0.458	0.458	0.000 (0%)	0.458	0.458	0.000 (0%)	0.458	0.458	0.000 (0%)	0.469	0.458	-0.010 (-2%)	0.042	0.063	0.021 (50%)
		D	0.458	0.458	0.000 (0%)	0.469	0.469	0.000 (0%)	0.458	0.458	0.000 (0%)	0.458	0.458	0.000 (0%)	0.458	0.458	0.000 (0%)	0.469	0.469	0.000 (0%)	0.042	0.073	0.031 (75%)
		C	0.458	0.458	0.000 (0%)	0.469	0.469	0.000 (0%)	0.469	0.469	0.000 (0%)	0.469	0.469	0.000 (0%)	0.469	0.469	0.000 (0%)	0.469	0.469	0.000 (0%)	0.146	0.156	0.010 (7%)

DSM2 Channel	Location	Water Year Type	December			January			February			March			April			May			June		
			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	NAA	PA	PA vs. NAA
379	Sutter Slough	W	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)
		AN	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.083	0.063	-0.021 (-25%)
		BN	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.052	0.063	0.010 (20%)	0.104	0.083	-0.021 (-20%)
		D	0.000	0.063	0.063 (Inf.)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.052	0.052	0.000 (0%)	0.104	0.104	0.000 (0%)
		C	0.167	0.203	0.036 (22%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.021	0.021 (Inf.)	0.083	0.094	0.010 (13%)	0.167	0.188	0.021 (12%)	0.240	0.250	0.010 (4%)
383	Steamboat Slough	W	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.198	0.302	0.104 (53%)
		AN	0.125	0.167	0.042 (33%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.031	0.031 (Inf.)	0.188	0.229	0.042 (22%)	0.302	0.333	0.031 (10%)
		BN	0.167	0.229	0.063 (37%)	0.115	0.146	0.031 (27%)	0.000	0.094	0.094 (Inf.)	0.042	0.146	0.104 (250%)	0.219	0.250	0.031 (14%)	0.281	0.281	0.000 (0%)	0.313	0.313	0.000 (0%)
		D	0.260	0.281	0.021 (8%)	0.182	0.224	0.042 (23%)	0.021	0.125	0.104 (500%)	0.000	0.125	0.125 (Inf.)	0.224	0.229	0.005 (2%)	0.271	0.271	0.000 (0%)	0.313	0.323	0.010 (3%)
		C	0.333	0.344	0.010 (3%)	0.219	0.250	0.031 (14%)	0.146	0.214	0.068 (46%)	0.281	0.292	0.010 (4%)	0.302	0.302	0.000 (0%)	0.344	0.354	0.010 (3%)	0.375	0.375	0.000 (0%)
418	Sacramento River downstream of proposed NDD	W	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)
		AN	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)
		BN	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.031	0.052	0.021 (67%)	0.000	0.000	0.000 (0%)
		D	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.021	0.042	0.021 (100%)	0.000	0.000	0.000 (0%)
		C	0.141	0.156	0.016 (11%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.005	0.005 (Inf.)	0.073	0.083	0.010 (14%)	0.156	0.167	0.010 (7%)	0.130	0.135	0.005 (4%)
421	Sacramento River upstream of Georgiana Slough	W	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)
		AN	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.031	0.031 (Inf.)	0.000	0.000	0.000 (0%)
		BN	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.042	0.073	0.031 (75%)	0.000	0.000	0.000 (0%)
		D	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.021	0.073	0.052 (250%)	0.000	0.000	0.000 (0%)
		C	0.135	0.156	0.021 (15%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.052	0.052 (Inf.)	0.083	0.104	0.021 (25%)	0.167	0.167	0.000 (0%)	0.125	0.135	0.010 (8%)
423	Sacramento River downstream of Georgiana Slough	W	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.281	0.333	0.052 (19%)
		AN	0.146	0.188	0.042 (29%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.063	0.063 (Inf.)	0.208	0.250	0.042 (20%)	0.344	0.365	0.021 (6%)
		BN	0.188	0.250	0.063 (33%)	0.135	0.167	0.031 (23%)	0.000	0.115	0.115 (Inf.)	0.083	0.177	0.094 (113%)	0.240	0.250	0.010 (4%)	0.292	0.292	0.000 (0%)	0.354	0.354	0.000 (0%)
		D	0.281	0.302	0.021 (7%)	0.198	0.240	0.042 (21%)	0.083	0.146	0.063 (75%)	0.000	0.146	0.146 (Inf.)	0.229	0.240	0.010 (5%)	0.281	0.281	0.000 (0%)	0.354	0.365	0.010 (3%)
		C	0.344	0.354	0.010 (3%)	0.240	0.260	0.021 (9%)	0.177	0.229	0.052 (29%)	0.292	0.292	0.000 (0%)	0.302	0.313	0.010 (3%)	0.354	0.354	0.000 (0%)	0.396	0.396	0.000 (0%)

5.4.1.3.1.2.1.2 Entry into Interior Delta

Juvenile salmonids may enter the interior Delta from the mainstem Sacramento and San Joaquin Rivers through junctions such as Georgiana Slough/Delta Cross Channel and the HOR. Survival through the interior Delta from the Sacramento River has been shown to be consistently appreciably lower than in the river mainstem (Perry et al. 2010, 2013; Brandes and McLain 2001; Singer et al. 2013), whereas some evidence supports higher main stem survival for the San Joaquin River (reviewed by Hankin et al. 2010) and other evidence does not (Buchanan et al. 2013, 2015[13]). Perry et al. (2013) found that, based on observed patterns for hatchery-origin late fall–run Chinook salmon, eliminating entry into the interior Delta through Georgiana Slough and the Delta Cross Channel would increase overall through-Delta survival by up to approximately one-third (10-35%); this represents an absolute increase in survival of 2-7%. The need to reduce entry into the interior Delta by juvenile salmonids was recognized in the NMFS (2009) BiOp, which requires that engineering solutions be investigated to lessen the issue; such solutions may include physical or nonphysical barriers.

The PA has the potential to result in changes in interior Delta entry on the Sacramento River and the San Joaquin River. Less flow in the Sacramento River (as would occur because of exports by the NDD) leads to a greater tidal influence at the Georgiana Slough/DCC junction (Perry et al. 2015) and a greater proportion of flow entering the junction (Cavallo et al. 2015); installation of a nonphysical barrier at the Georgiana Slough junction would aim to minimize the biological consequences of these changes in hydrodynamics by allowing flow to enter Georgiana Slough but preventing fish from entering the distributary [14]. Installation of the HOR gate under the PA would greatly reduce entry into Old River from the San Joaquin River. These factors are discussed in this section.

5.4.1.3.1.2.1.2.1 Flow Routing Into Channel Junctions

Perspective on potential differences in juvenile salmonid entry into the interior Delta between modeled operations of the NAA and PA was provided by assessing differences in the proportion of flow entering important channel junctions from the Sacramento River and the San Joaquin River based on DSM2-HYDRO modeling (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.1.2.1.1.2, *Flow Routing at Junctions*, for methods, with results in Section 5.D.1.2.1.2.2, *Flow Routing at Junctions*, of the same appendix). Assessment of the proportion of flow entering a junction generally is a reasonable proxy for the proportion of fish entering the junction (Cavallo et al. 2015). As noted previously in the analysis of velocity, the summary provided herein does not account for the results of the coordinated monitoring and research under the Collaborative Science and Adaptive Management Program, including real-time operations that would be done in order to limit potential operational effects to avoid jeopardy while maximizing water supplies, by assessing flow conditions in the context of fish

[13] The study of Buchanan et al. (2015) occurred in 2012, when a rock barrier was in place at HOR, resulting in very few fish entering Old River (presumably through the barrier culverts), giving high uncertainty in the estimates of survival via the Old River route (which was not significantly different from survival in the San Joaquin River mainstem route). See also discussion by Anderson et al. (2012) for the Report of the 2012 Delta Science Program Independent Review Panel (IRP) on the Long-term Operations Opinions (LOO) Annual Review.

[14] Note that there is essentially no effect of south Delta exports on the proportion of flow (and fish) entering Georgiana Slough (Cavallo et al. 2015).

presence, e.g., by using monitoring data from at or upstream of the Delta periphery (e.g., Knights Landing on the Sacramento River or Mossdale on the San Joaquin River).

For the Sacramento River, the junctions analyzed included Sutter and Steamboat Sloughs, for which less entry from the mainstem Sacramento River is actually a negative effect, as these are relatively high survival migration pathways that allow fish to avoid entry into the interior Delta (Perry et al. 2010; 2012), Georgiana Slough, and the DCC. The junctions off the mainstem San Joaquin River that were analyzed included the HOR, Turner Cut, Columbia Cut, Middle River, and mouth of Old River.

For the Sacramento River, the analysis of flow routing into channel junctions showed that at Sutter Slough, the most upstream junction, there generally would be little difference in proportion of flow entering the junction between NAA and PA, although in one case (December of critical years) the difference in median proportion was 5% less under PA (0.01 absolute difference) (Table 5.4-11). Slightly farther downstream at Steamboat Slough, there were more incidences of median proportion being >5% less under PA (0.01-0.02 less absolute difference in February and March of below normal and dry years). Differences in flow routing into the Delta Cross Channel in December to May are discountable because the gates are usually closed in these months, whereas there were negligible differences in June, when the gates are opened again (see summary of gate openings in Table 5.B.5-24 in Appendix 5.B, *DSM2 Methods and Results*). The proportion of flow entering Georgiana Slough under the PA was generally similar to or somewhat greater than the proportion entering under NAA, with the largest difference between medians in March of dry years (11% more under the PA, or 0.04 in absolute terms).

Table 5.4-11. Median Daily Proportion of Flow Entering Important Delta Channels, from DSM2-HYDRO Modeling, with Green Shading Indicating PA is ≥ 5% Less than NAA and Red Shading Indicating PA is ≥ 5% More than NAA(Except for Sutter/Steamboat Sloughs, where Entry is Considered Beneficial and the Color Scheme is Reversed).

Junction	Water Year Type	December			January			February			March			April			May			June		
		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	NAA	PA	PA vs. NAA
Sutter Slough (Entry is beneficial)	W	0.262	0.262	0.000 (0%)	0.264	0.263	-0.001 (0%)	0.267	0.265	-0.002 (-1%)	0.265	0.265	0.000 (0%)	0.263	0.263	0.000 (0%)	0.263	0.263	0.000 (0%)	0.219	0.193	-0.026 (-12%)
	AN	0.259	0.257	-0.002 (-1%)	0.261	0.261	0.000 (0%)	0.263	0.263	0.000 (0%)	0.262	0.263	0.001 (0%)	0.262	0.261	-0.001 (0%)	0.262	0.258	-0.004 (-2%)	0.181	0.174	-0.007 (-4%)
	BN	0.257	0.252	-0.005 (-2%)	0.259	0.258	-0.001 (0%)	0.261	0.261	0.000 (0%)	0.260	0.259	-0.001 (0%)	0.261	0.259	-0.002 (-1%)	0.240	0.238	-0.002 (-1%)	0.175	0.181	0.006 (3%)
	D	0.227	0.219	-0.008 (-4%)	0.256	0.254	-0.002 (-1%)	0.260	0.259	-0.001 (0%)	0.260	0.259	-0.001 (0%)	0.259	0.259	0.000 (0%)	0.242	0.239	-0.003 (-1%)	0.173	0.174	0.001 (1%)
	C	0.195	0.185	-0.010 (-5%)	0.254	0.247	-0.007 (-3%)	0.259	0.256	-0.003 (-1%)	0.249	0.239	-0.010 (-4%)	0.230	0.225	-0.005 (-2%)	0.199	0.195	-0.004 (-2%)	0.151	0.152	0.001 (1%)
Steamboat Slough (Entry is beneficial)	W	0.254	0.242	-0.012 (-5%)	0.278	0.272	-0.006 (-2%)	0.291	0.284	-0.007 (-2%)	0.277	0.270	-0.007 (-3%)	0.257	0.253	-0.004 (-2%)	0.252	0.249	-0.003 (-1%)	0.182	0.180	-0.002 (-1%)
	AN	0.207	0.203	-0.004 (-2%)	0.259	0.248	-0.011 (-4%)	0.279	0.272	-0.007 (-3%)	0.263	0.257	-0.006 (-2%)	0.238	0.229	-0.009 (-4%)	0.202	0.203	0.001 (0%)	0.164	0.169	0.005 (3%)
	BN	0.200	0.193	-0.007 (-4%)	0.213	0.209	-0.004 (-2%)	0.238	0.220	-0.018 (-8%)	0.218	0.205	-0.013 (-6%)	0.196	0.196	0.000 (0%)	0.192	0.194	0.002 (1%)	0.164	0.168	0.004 (2%)
	D	0.192	0.190	-0.002 (-1%)	0.199	0.197	-0.002 (-1%)	0.222	0.210	-0.012 (-5%)	0.232	0.212	-0.020 (-9%)	0.197	0.198	0.001 (1%)	0.192	0.194	0.002 (1%)	0.163	0.169	0.006 (4%)
	C	0.192	0.193	0.001 (1%)	0.198	0.196	-0.002 (-1%)	0.203	0.199	-0.004 (-2%)	0.193	0.194	0.001 (1%)	0.190	0.191	0.001 (1%)	0.191	0.193	0.002 (1%)	0.180	0.183	0.003 (2%)
Delta Cross Channel (Entry is adverse)	W	0.006	0.007	0.001 (17%)	0.004	0.004	0.000 (0%)	0.003	0.003	0.000 (0%)	0.004	0.004	0.000 (0%)	0.005	0.006	0.001 (20%)	0.006	0.006	0.000 (0%)	0.386	0.379	-0.007 (-2%)
	AN	0.009	0.010	0.001 (11%)	0.005	0.006	0.001 (20%)	0.004	0.004	0.000 (0%)	0.005	0.006	0.001 (20%)	0.007	0.008	0.001 (14%)	0.010	0.011	0.001 (10%)	0.432	0.426	-0.006 (-1%)
	BN	0.009	0.010	0.001 (11%)	0.009	0.009	0.000 (0%)	0.007	0.008	0.001 (14%)	0.008	0.009	0.001 (13%)	0.010	0.010	0.000 (0%)	0.011	0.011	0.000 (0%)	0.437	0.430	-0.007 (-2%)
	D	0.011	0.011	0.000 (0%)	0.010	0.010	0.000 (0%)	0.008	0.009	0.001 (13%)	0.008	0.009	0.001 (13%)	0.010	0.010	0.000 (0%)	0.011	0.011	0.000 (0%)	0.442	0.429	-0.013 (-3%)
	C	0.013	0.013	0.000 (0%)	0.010	0.010	0.000 (0%)	0.009	0.010	0.001 (11%)	0.011	0.011	0.000 (0%)	0.011	0.011	0.000 (0%)	0.012	0.013	0.001 (8%)	0.389	0.379	-0.010 (-3%)
Georgiana Slough (Entry is adverse)	W	0.314	0.342	0.028 (9%)	0.293	0.295	0.002 (1%)	0.291	0.292	0.001 (0%)	0.292	0.293	0.001 (0%)	0.302	0.304	0.002 (1%)	0.307	0.311	0.004 (1%)	0.396	0.393	-0.003 (-1%)
	AN	0.395	0.401	0.006 (2%)	0.304	0.327	0.023 (8%)	0.292	0.293	0.001 (0%)	0.299	0.302	0.003 (1%)	0.336	0.360	0.024 (7%)	0.417	0.405	-0.012 (-3%)	0.420	0.402	-0.018 (-4%)
	BN	0.411	0.418	0.007 (2%)	0.396	0.400	0.004 (1%)	0.339	0.379	0.040 (12%)	0.391	0.417	0.026 (7%)	0.424	0.416	-0.008 (-2%)	0.433	0.422	-0.011 (-3%)	0.414	0.412	-0.002 (0%)
	D	0.415	0.419	0.004 (1%)	0.421	0.423	0.002 (0%)	0.382	0.400	0.018 (5%)	0.366	0.406	0.040 (11%)	0.416	0.411	-0.005 (-1%)	0.432	0.423	-0.009 (-2%)	0.415	0.403	-0.012 (-3%)
	C	0.387	0.384	-0.003 (-1%)	0.412	0.428	0.016 (4%)	0.418	0.416	-0.002 (0%)	0.431	0.429	-0.002 (0%)	0.440	0.434	-0.006 (-1%)	0.404	0.397	-0.007 (-2%)	0.363	0.347	-0.016 (-4%)
Head of Old River (Entry is adverse)	W	0.649	0.642	-0.007 (-1%)	0.580	0.322	-0.258 (-44%)	0.537	0.282	-0.255 (-47%)	0.534	0.323	-0.211 (-40%)	0.525	0.259	-0.266 (-51%)	0.527	0.259	-0.268 (-51%)	0.515	0.497	-0.018 (-3%)
	AN	0.663	0.661	-0.002 (0%)	0.616	0.349	-0.267 (-43%)	0.577	0.280	-0.297 (-51%)	0.560	0.264	-0.296 (-53%)	0.529	0.253	-0.276 (-52%)	0.537	0.252	-0.285 (-53%)	0.530	0.474	-0.056 (-11%)
	BN	0.679	0.667	-0.012 (-2%)	0.635	0.342	-0.293 (-46%)	0.602	0.353	-0.249 (-41%)	0.611	0.289	-0.322 (-53%)	0.559	0.264	-0.295 (-53%)	0.581	0.279	-0.302 (-52%)	0.504	0.412	-0.092 (-18%)
	D	0.667	0.662	-0.005 (-1%)	0.647	0.362	-0.285 (-44%)	0.634	0.371	-0.263 (-41%)	0.629	0.385	-0.244 (-39%)	0.597	0.322	-0.275 (-46%)	0.602	0.335	-0.267 (-44%)	0.467	0.377	-0.090 (-19%)
	C	0.642	0.639	-0.003 (0%)	0.638	0.405	-0.233 (-37%)	0.622	0.383	-0.239 (-38%)	0.594	0.398	-0.196 (-33%)	0.567	0.393	-0.174 (-31%)	0.580	0.383	-0.197 (-34%)	0.367	0.307	-0.060 (-16%)

Junction	Water Year Type	December			January			February			March			April			May			June		
		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	NAA	PA	PA vs. NAA
Turner Cut (Entry is adverse)	W	0.176	0.173	-0.003 (-2%)	0.176	0.181	0.005 (3%)	0.191	0.187	-0.004 (-2%)	0.197	0.190	-0.007 (-4%)	0.180	0.189	0.009 (5%)	0.177	0.187	0.010 (6%)	0.190	0.183	-0.007 (-4%)
	AN	0.171	0.169	-0.002 (-1%)	0.167	0.174	0.007 (4%)	0.175	0.185	0.010 (6%)	0.182	0.185	0.003 (2%)	0.170	0.188	0.018 (11%)	0.167	0.186	0.019 (11%)	0.173	0.173	0.000 (0%)
	BN	0.177	0.172	-0.005 (-3%)	0.165	0.168	0.003 (2%)	0.169	0.181	0.012 (7%)	0.169	0.181	0.012 (7%)	0.164	0.182	0.018 (11%)	0.161	0.176	0.015 (9%)	0.163	0.164	0.001 (1%)
	D	0.168	0.167	-0.001 (-1%)	0.164	0.170	0.006 (4%)	0.161	0.170	0.009 (6%)	0.159	0.168	0.009 (6%)	0.157	0.170	0.013 (8%)	0.157	0.168	0.011 (7%)	0.160	0.160	0.000 (0%)
	C	0.161	0.161	0.000 (0%)	0.161	0.167	0.006 (4%)	0.158	0.166	0.008 (5%)	0.152	0.159	0.007 (5%)	0.150	0.157	0.007 (5%)	0.151	0.158	0.007 (5%)	0.153	0.153	0.000 (0%)
Columbia Cut (Entry is adverse)	W	0.169	0.166	-0.003 (-2%)	0.166	0.163	-0.003 (-2%)	0.171	0.161	-0.010 (-6%)	0.173	0.157	-0.016 (-9%)	0.155	0.157	0.002 (1%)	0.155	0.157	0.002 (1%)	0.169	0.161	-0.008 (-5%)
	AN	0.166	0.164	-0.002 (-1%)	0.161	0.162	0.001 (1%)	0.165	0.165	0.000 (0%)	0.166	0.158	-0.008 (-5%)	0.153	0.160	0.007 (5%)	0.151	0.159	0.008 (5%)	0.164	0.161	-0.003 (-2%)
	BN	0.171	0.167	-0.004 (-2%)	0.160	0.158	-0.002 (-1%)	0.162	0.165	0.003 (2%)	0.161	0.164	0.003 (2%)	0.151	0.160	0.009 (6%)	0.149	0.158	0.009 (6%)	0.157	0.156	-0.001 (-1%)
	D	0.164	0.163	-0.001 (-1%)	0.159	0.161	0.002 (1%)	0.156	0.160	0.004 (3%)	0.153	0.158	0.005 (3%)	0.149	0.156	0.007 (5%)	0.148	0.154	0.006 (4%)	0.154	0.152	-0.002 (-1%)
	C	0.158	0.157	-0.001 (-1%)	0.157	0.160	0.003 (2%)	0.152	0.158	0.006 (4%)	0.147	0.151	0.004 (3%)	0.144	0.148	0.004 (3%)	0.144	0.149	0.005 (3%)	0.147	0.147	0.000 (0%)
Middle River (Entry is adverse)	W	0.189	0.186	-0.003 (-2%)	0.183	0.178	-0.005 (-3%)	0.185	0.174	-0.011 (-6%)	0.184	0.168	-0.016 (-9%)	0.167	0.168	0.001 (1%)	0.169	0.169	0.000 (0%)	0.186	0.176	-0.010 (-5%)
	AN	0.190	0.187	-0.003 (-2%)	0.180	0.178	-0.002 (-1%)	0.182	0.180	-0.002 (-1%)	0.183	0.173	-0.010 (-5%)	0.170	0.175	0.005 (3%)	0.170	0.174	0.004 (2%)	0.183	0.180	-0.003 (-2%)
	BN	0.194	0.189	-0.005 (-3%)	0.182	0.175	-0.007 (-4%)	0.180	0.180	0.000 (0%)	0.181	0.179	-0.002 (-1%)	0.171	0.176	0.005 (3%)	0.170	0.175	0.005 (3%)	0.178	0.177	-0.001 (-1%)
	D	0.188	0.186	-0.002 (-1%)	0.181	0.180	-0.001 (-1%)	0.179	0.178	-0.001 (-1%)	0.177	0.178	0.001 (1%)	0.171	0.175	0.004 (2%)	0.170	0.174	0.004 (2%)	0.176	0.175	-0.001 (-1%)
	C	0.180	0.180	0.000 (0%)	0.179	0.179	0.000 (0%)	0.175	0.176	0.001 (1%)	0.171	0.172	0.001 (1%)	0.169	0.172	0.003 (2%)	0.169	0.172	0.003 (2%)	0.170	0.170	0.000 (0%)
Mouth of Old River (Entry is adverse)	W	0.178	0.174	-0.004 (-2%)	0.177	0.172	-0.005 (-3%)	0.181	0.170	-0.011 (-6%)	0.177	0.164	-0.013 (-7%)	0.162	0.161	-0.001 (-1%)	0.163	0.161	-0.002 (-1%)	0.174	0.167	-0.007 (-4%)
	AN	0.174	0.172	-0.002 (-1%)	0.173	0.171	-0.002 (-1%)	0.175	0.172	-0.003 (-2%)	0.173	0.164	-0.009 (-5%)	0.159	0.162	0.003 (2%)	0.159	0.161	0.002 (1%)	0.171	0.169	-0.002 (-1%)
	BN	0.177	0.173	-0.004 (-2%)	0.168	0.164	-0.004 (-2%)	0.169	0.169	0.000 (0%)	0.165	0.164	-0.001 (-1%)	0.158	0.162	0.004 (3%)	0.158	0.161	0.003 (2%)	0.167	0.167	0.000 (0%)
	D	0.171	0.170	-0.001 (-1%)	0.167	0.166	-0.001 (-1%)	0.165	0.165	0.000 (0%)	0.162	0.163	0.001 (1%)	0.158	0.161	0.003 (2%)	0.158	0.160	0.002 (1%)	0.166	0.164	-0.002 (-1%)
	C	0.166	0.165	-0.001 (-1%)	0.166	0.166	0.000 (0%)	0.163	0.163	0.000 (0%)	0.157	0.159	0.002 (1%)	0.155	0.156	0.001 (1%)	0.156	0.158	0.002 (1%)	0.161	0.161	0.000 (0%)

For the San Joaquin River, the assumption of 50% closure of the PA's HOR gate from January to June 15, subject to RTO adjustments, led to appreciably less flow (~30-50%) entering Old River under the PA compared to NAA (Table 5.4-11). For Turner Cut, the next downstream junction, the proportion of flow entering the junction generally was greater under PA than NAA (median by water year type up to 11% greater, or 0.02 in absolute value), reflecting more flow remaining in the river main stem because of the HOR gate; this is consistent the observations of Cavallo et al. (2015), who estimated (based on DSM2-HYDRO modeling) that more fish would enter the HOR with higher flow—for the PA, the flow that otherwise would have gone into Old River progresses to Turner Cut, thus producing a similar effect at that location. With movement downstream to other junctions, differences in flow routing into the junctions between NAA and PA were less which, as noted by Cavallo et al. (2015) reflects greater tidal influence; where lower proportions of flow entered the junctions under PA, this probably reflected less south Delta export pumping than NAA.

Overall, the analysis suggested that juvenile salmonids migrating down the Sacramento River would have somewhat greater potential to enter the interior Delta through Georgiana Slough, which may result in adverse effects from the relatively low survival probability in that migration route. Minimization of this adverse effect would be undertaken with the installation of a nonphysical barrier at the Georgiana Slough junction (discussed in the next section). As previously noted, the summary of Delta hydrodynamic conditions based on DSM2 does not account for real-time operations that would be done in order to limit potential operational effects, by assessing flow conditions in the context of fish presence. Juvenile steelhead migrating down the San Joaquin River would, based on flow routing, be expected to benefit from a HOR gate, which would considerably reduce entry into Old River and therefore reduce entrainment at the south Delta export facilities. Effects of the HOR gate in terms of near-field effects were discussed in Section 5.4.1.3.1.1.3, *Head of Old River Gate*.

5.4.1.3.1.2.1.2.2 Nonphysical Fish Barrier at Georgiana Slough

Installation of a nonphysical fish barrier at the Georgiana Slough junction would aim to minimize the potential for increased entry of fish into the junction caused by hydrodynamic changes because of the NDD, as described above. The two types of nonphysical barrier with greatest potential for use at this junction are the Bioacoustic Fish Fence (BAFF) and Floating Fish Guidance Structure (FFGS); both have been tested at this location, but only analyses for the former have been published, so the analysis here focuses on this technology. A BAFF consists of acoustic deterrence stimuli broadcast from loudspeakers and contained within a bubble curtain that is illuminated with strobe lights (to allow the fish to orient away from the sound stimulus better). A BAFF was tested at Georgiana Slough in 2011 and 2012, using acoustically tagged juvenile salmonids. It was found that BAFF operations in 2011 reduced entry of late fall-run Chinook salmon into Georgiana Slough from 22.1% (0.221) to 7.4% (0.074), a reduction of around two thirds, and that operations in 2012 reduced entry of late fall-run Chinook salmon from 24.2% (0.242) to 11.8% (0.118), or a reduction of approximately half, with a similar reduction for steelhead (26.4% to 11.6%) (see summary by California Department of Water Resources 2015b: 3-11 to 3-14). There is therefore potential to minimize adverse effects of hydrodynamic effects of the PA, given that the analysis of flow routing into Georgiana Slough based on DSM2-HYDRO data suggested potential increases in median proportional flow entry of up to 11-12% (see Table 5.4-11 in Section 5.4.1.3.1.2.1.2.1, *Flow Routing into Channel Junctions)*. However, it is important to consider several important limitations of the BAFF

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.

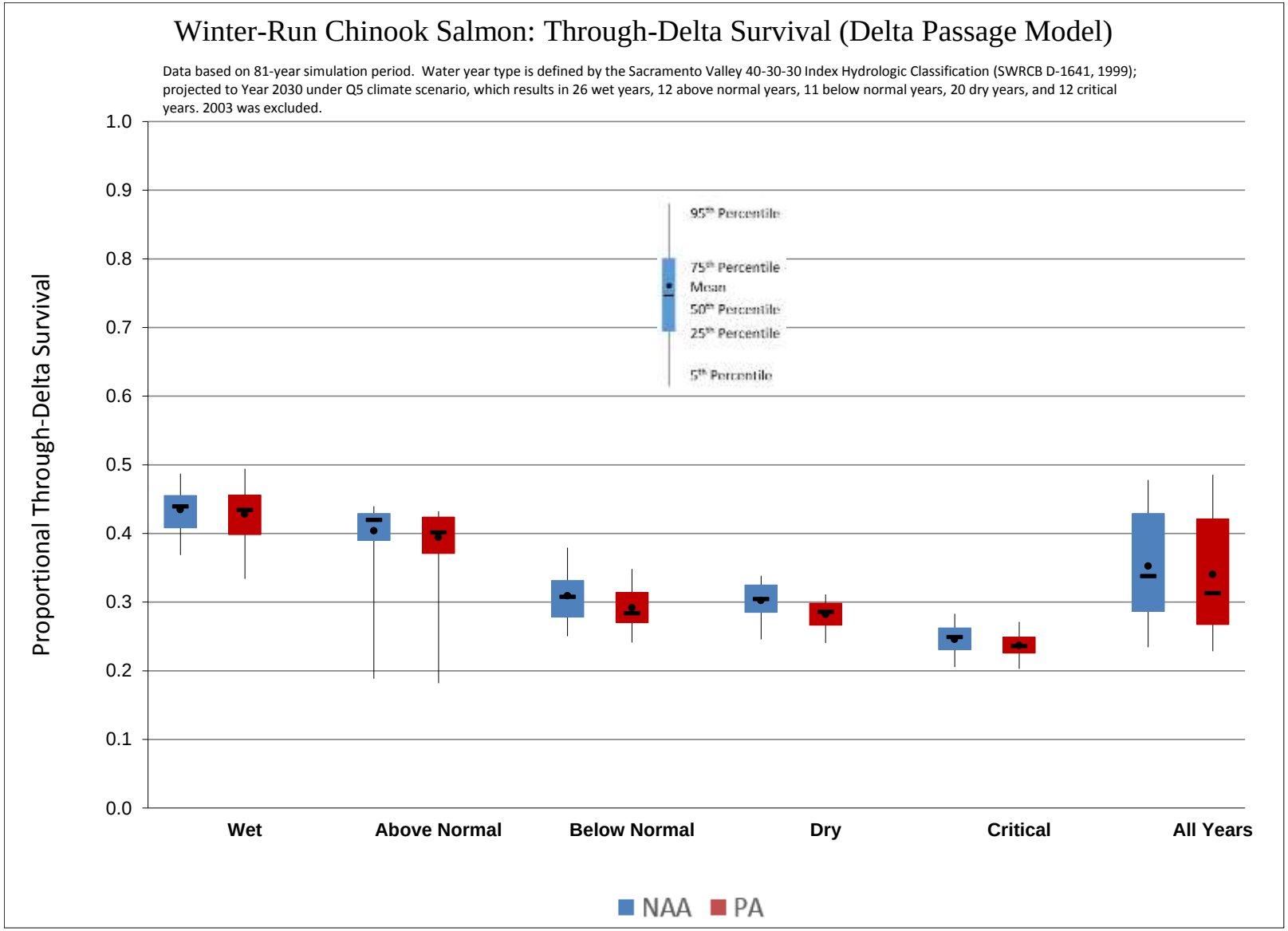


Figure 5.4-7. Box Plots of Winter-Run Chinook Salmon Annual Through-Delta Survival Estimated from the Delta Passage Model, Grouped by Water Year Type.

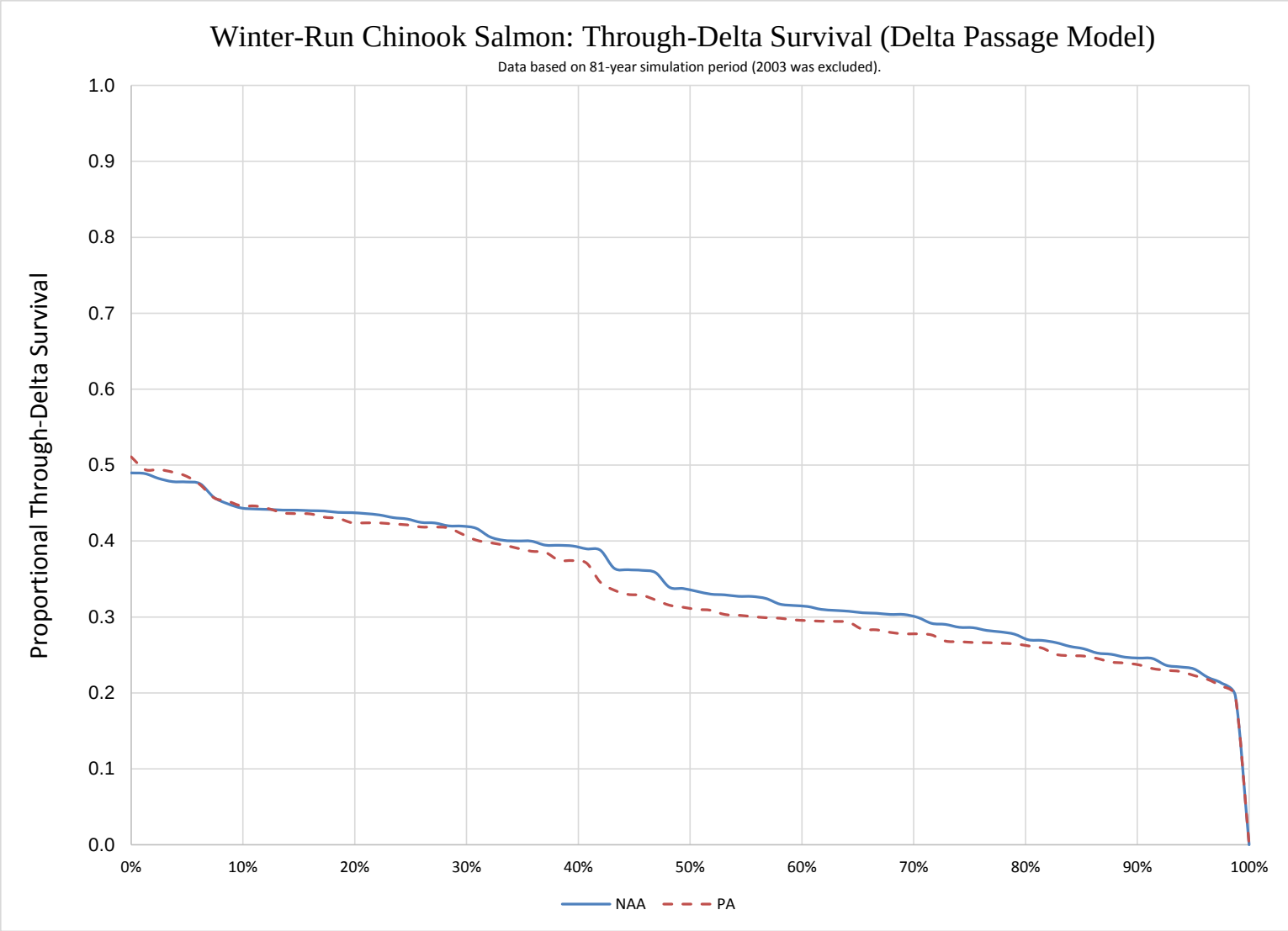
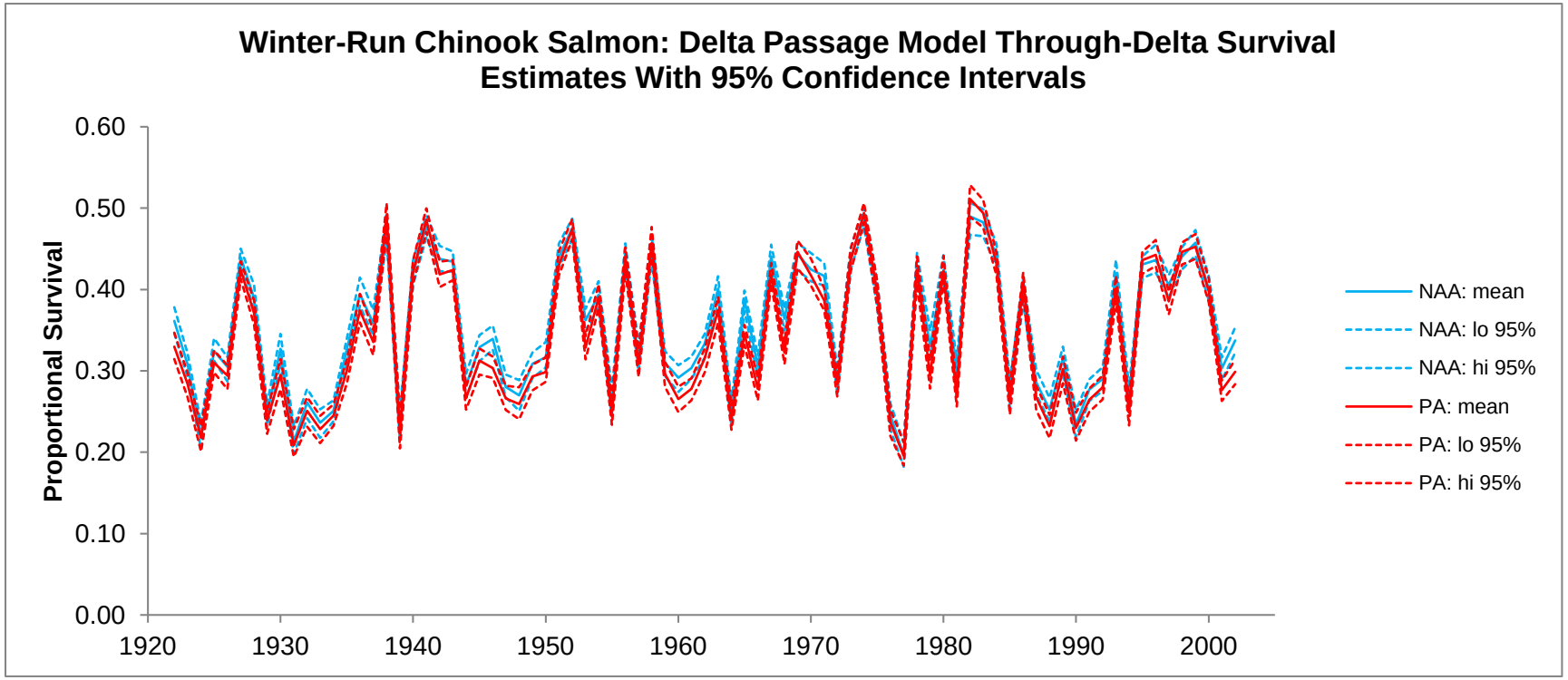


Figure 5.4-8. Exceedance Plot of Winter-Run Chinook Salmon Annual Through-Delta Survival Estimated from the Delta Passage Model.

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.

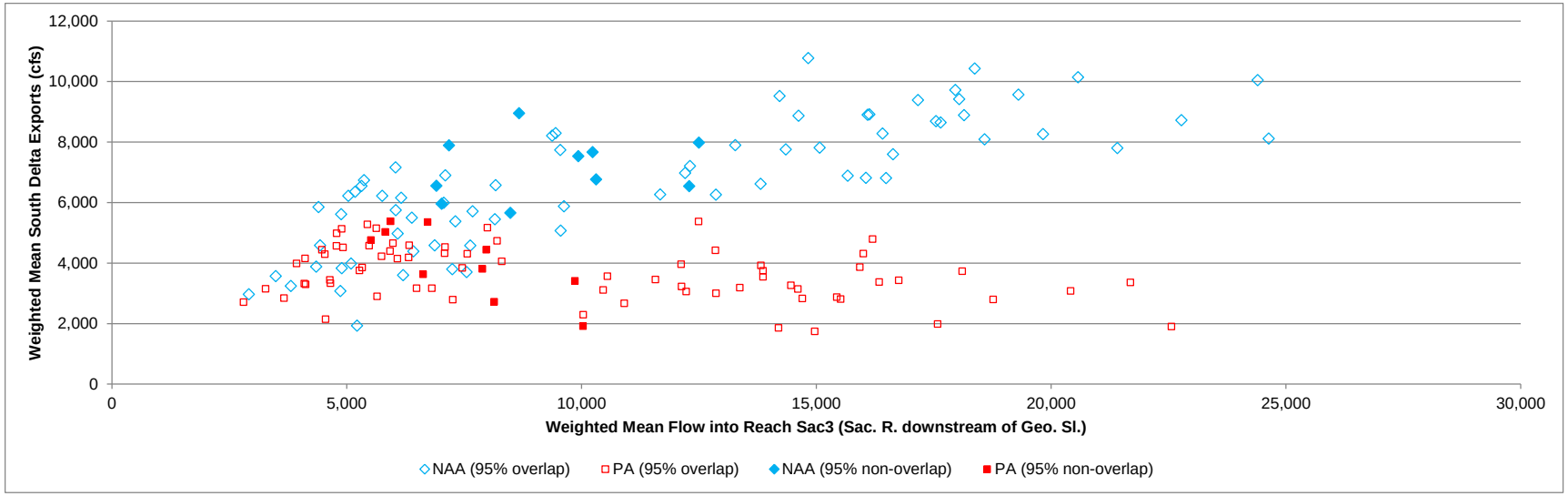
WY	Total Survival			Mainstem Sacramento River Survival			Yolo Bypass					
							Proportion Using Route			Survival		
	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
W	0.43	0.43	-0.01 (-2%)	0.48	0.46	-0.02 (-5%)	0.22	0.22	0.00 (1%)	0.47	0.47	0.00 (0%)
AN	0.40	0.39	-0.01 (-2%)	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.

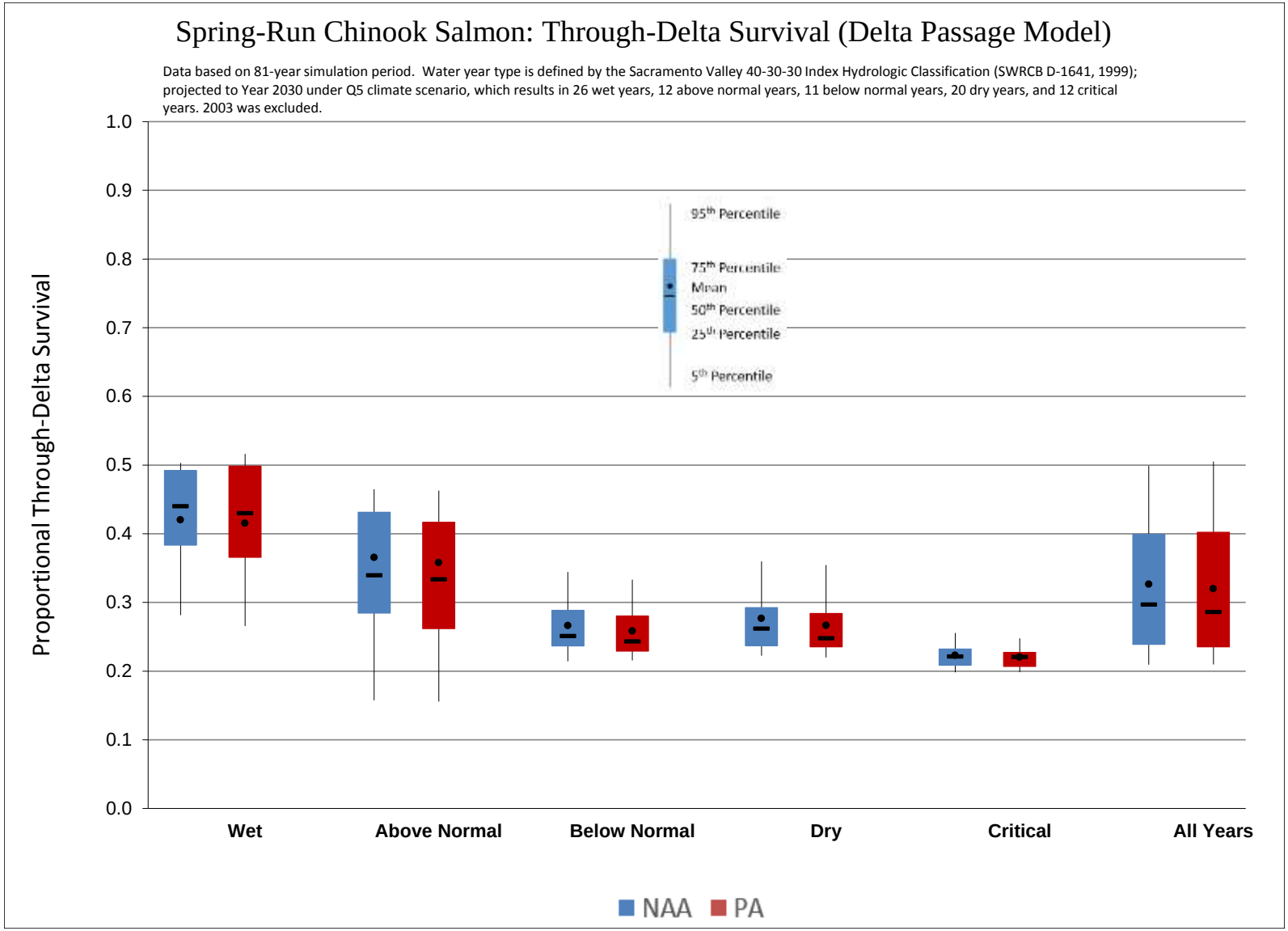


Figure 5.4-11. Box Plots of Spring-Run Chinook Salmon Annual Through-Delta Survival Estimated from the Delta Passage Model, Grouped by Water Year Type.

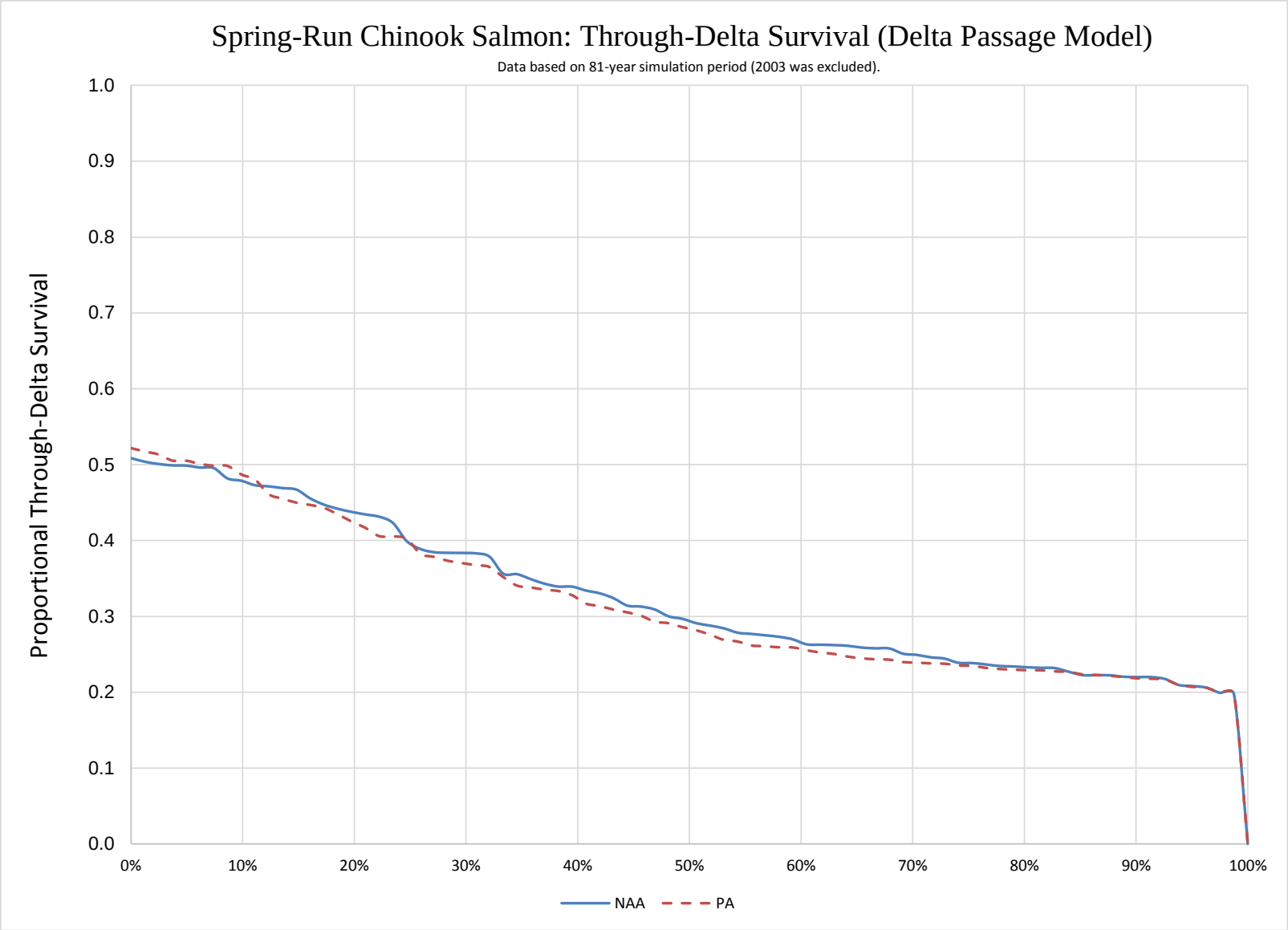
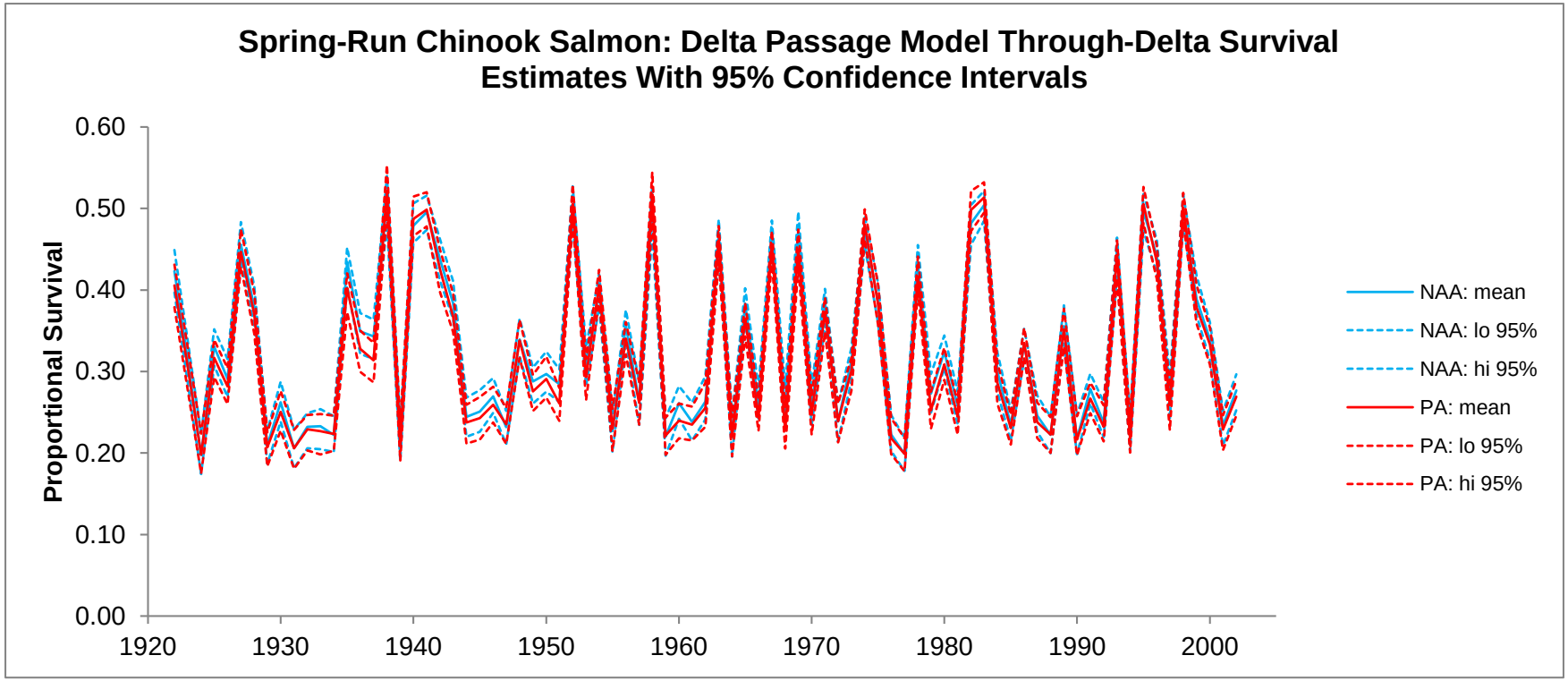


Figure 5.4-12. Exceedance Plot of Spring-Run Chinook Salmon Annual Through-Delta Survival Estimated from the Delta Passage Model.



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.

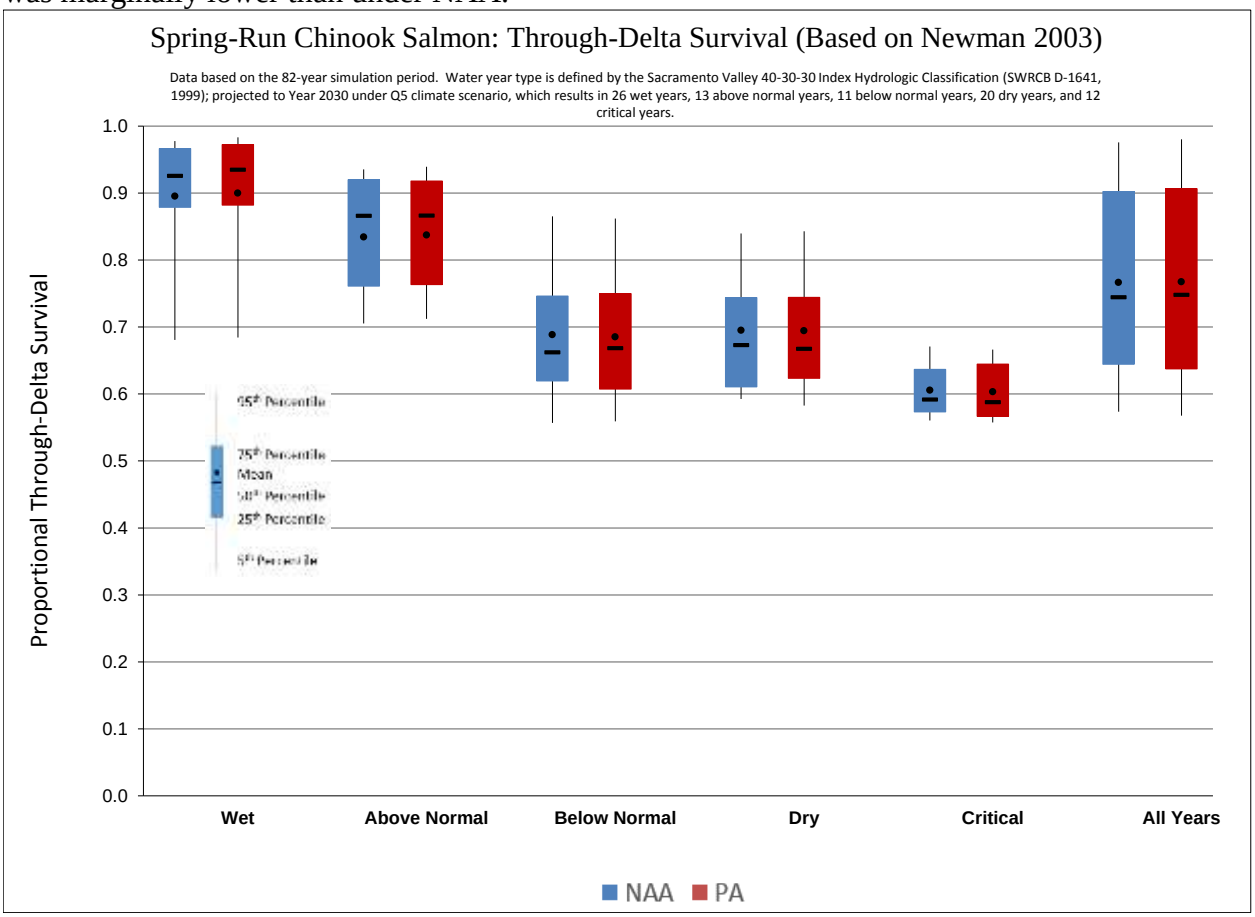


Figure 5.4-14. Box Plots of Spring-Run Chinook Salmon Annual Through-Delta Survival Estimated from the Analysis Based on Newman (2003), Grouped by Water Year Type.

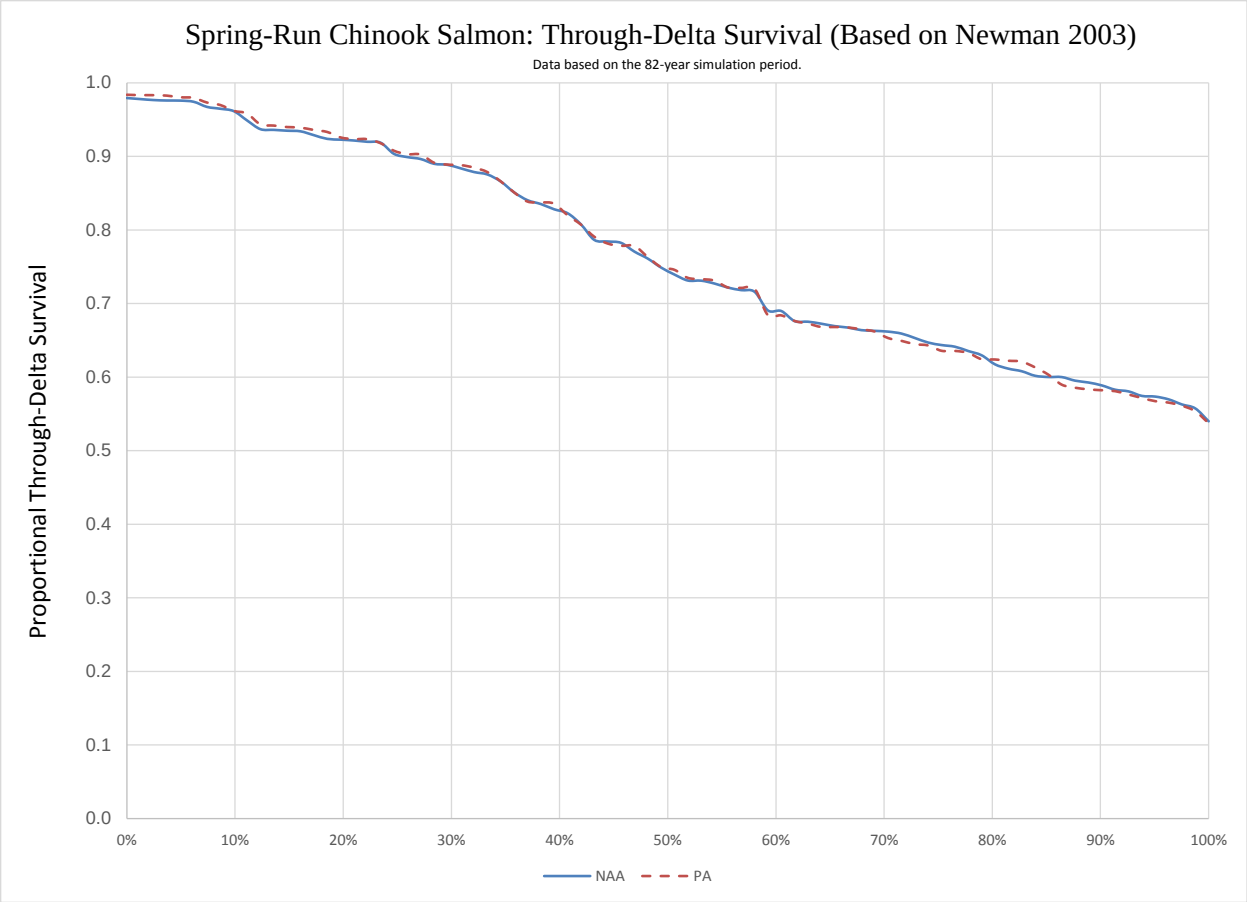


Figure 5.4-15. Exceedance Plot of Spring-Run Chinook Salmon Annual Through-Delta Survival Estimated from the Analysis Based on Newman (2003).

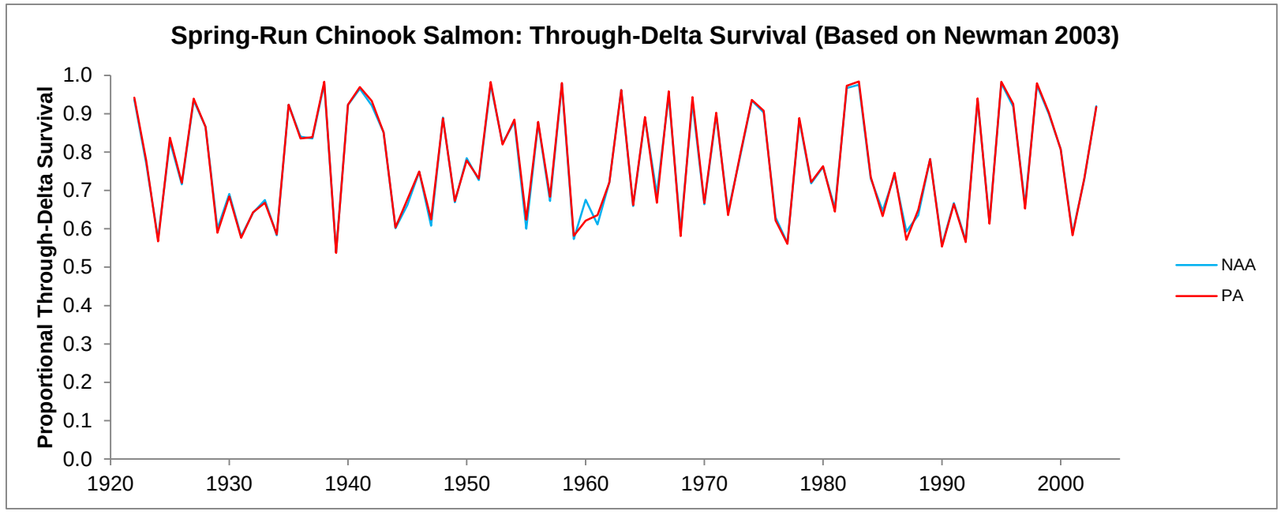


Figure 5.4-16. Time Series of Spring-Run Chinook Salmon Annual Through-Delta Survival Estimated from the Analysis Based on Newman (2003).

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.

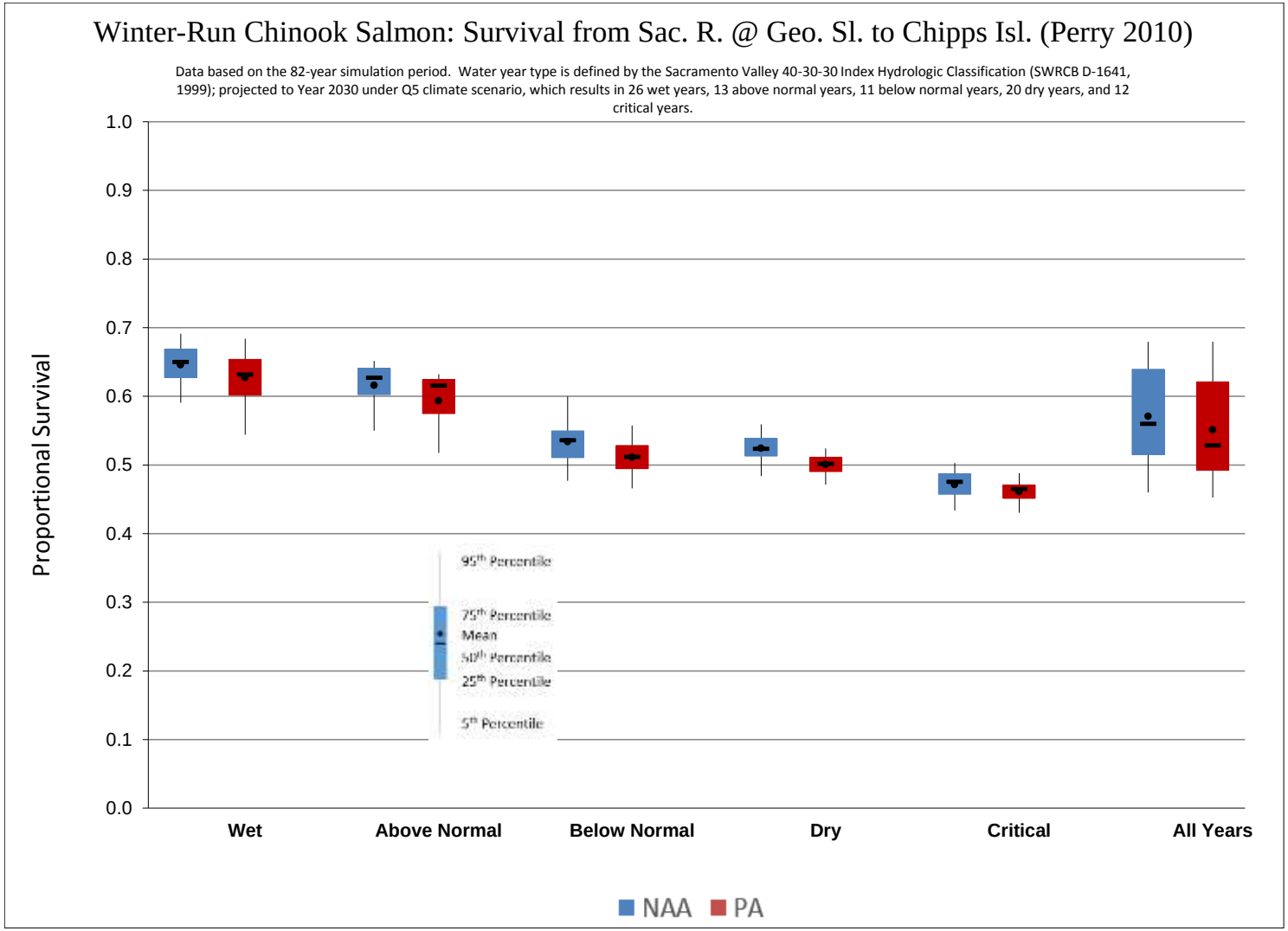


Figure 5.4-17. Box Plots of Juvenile Winter-Run Chinook Salmon Annual Total Survival from the Sacramento River at Georgiana Slough to Chipps Island, Estimated from the Analysis Based on Perry (2010), Grouped by Water Year Type.

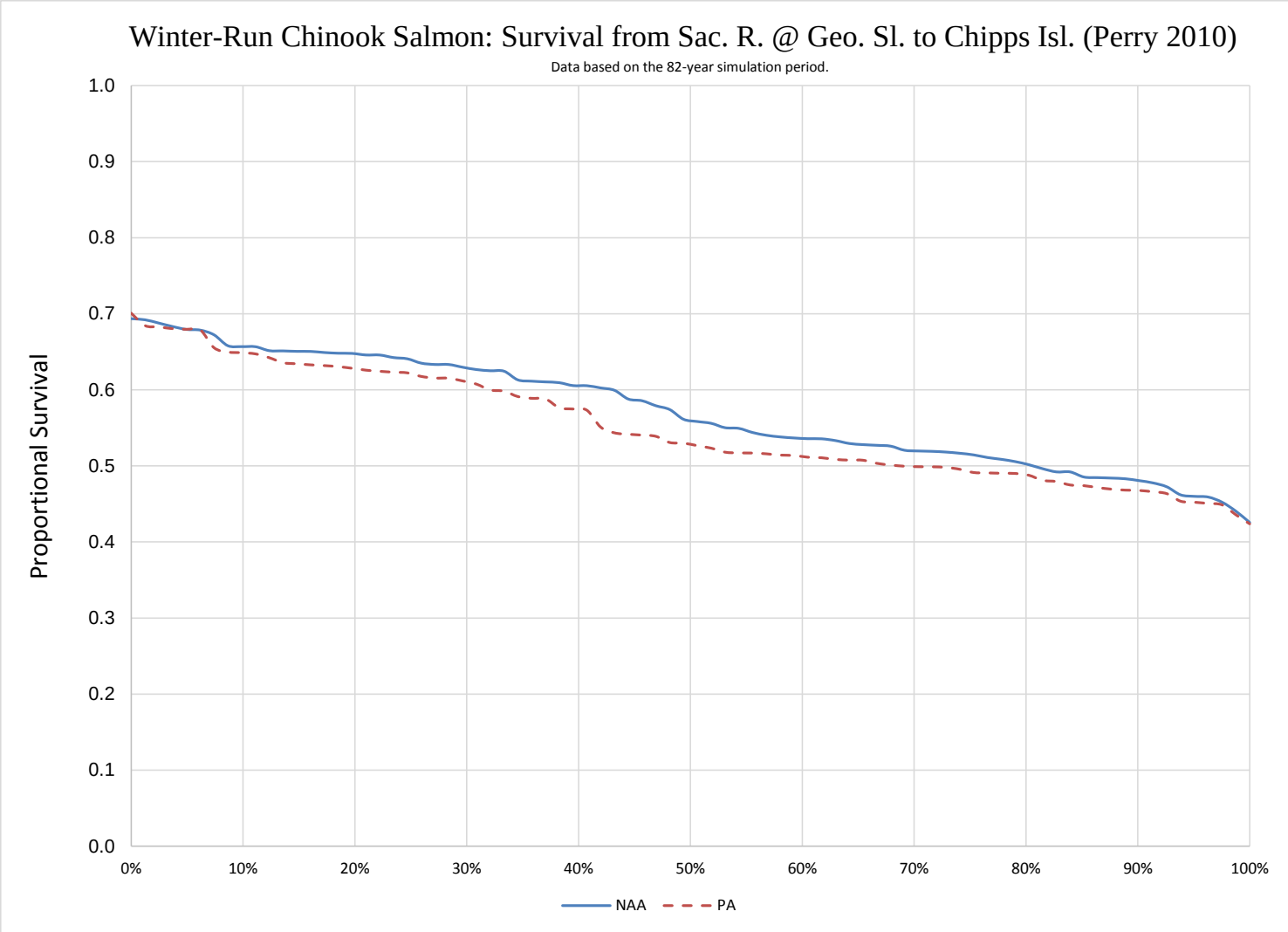


Figure 5.4-18. Exceedance Plot of Juvenile Winter-Run Chinook Salmon Annual Total Survival from the Sacramento River at Georgiana Slough to Chipps Island, Estimated from the Analysis Based on Perry (2010).

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.

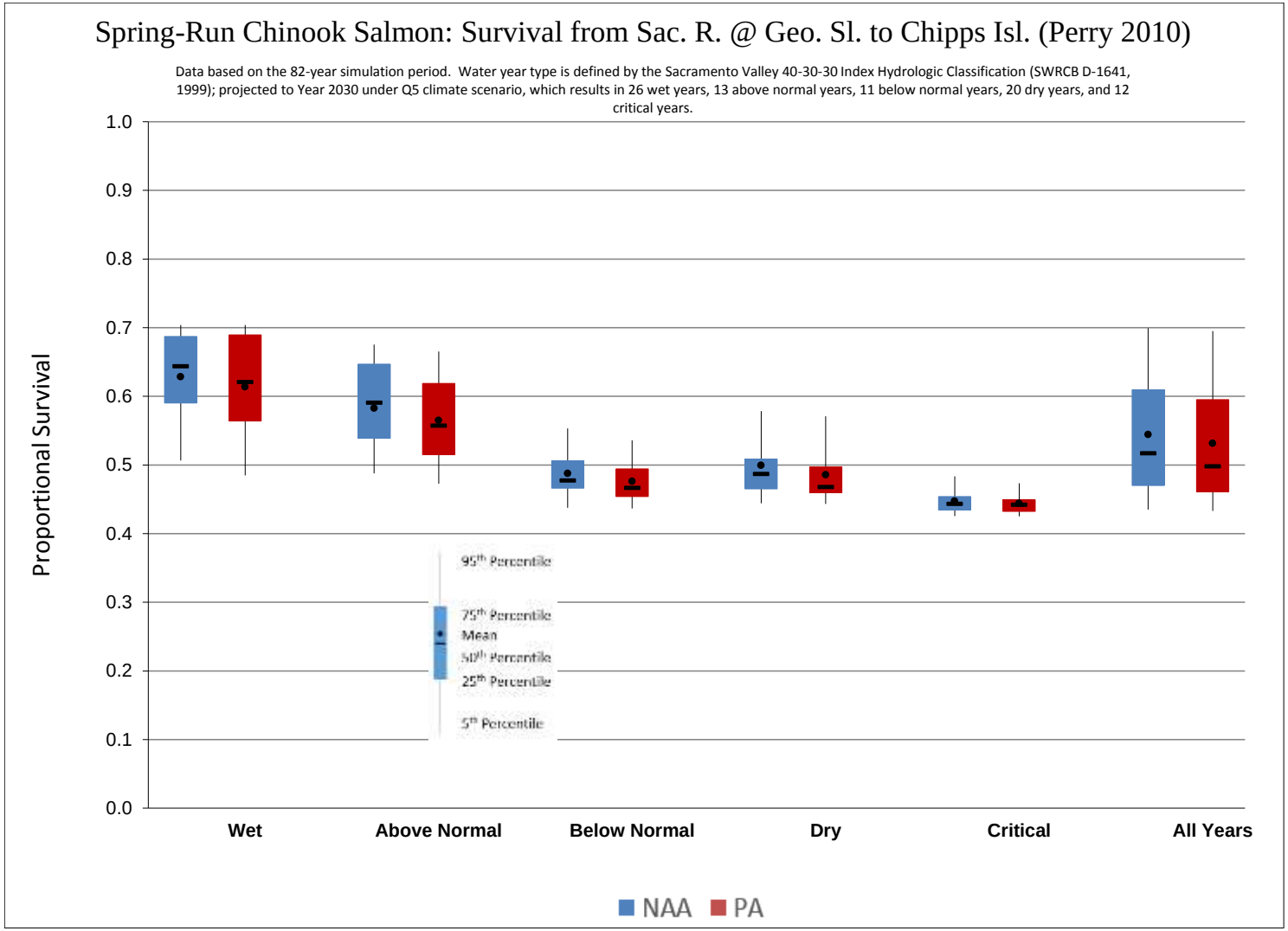


Figure 5.4-19. Box Plots of Juvenile Spring-Run Chinook Salmon Annual Total Survival from the Sacramento River at Georgiana Slough to Chipps Island, Estimated from the Analysis Based on Perry (2010), Grouped by Water Year Type.

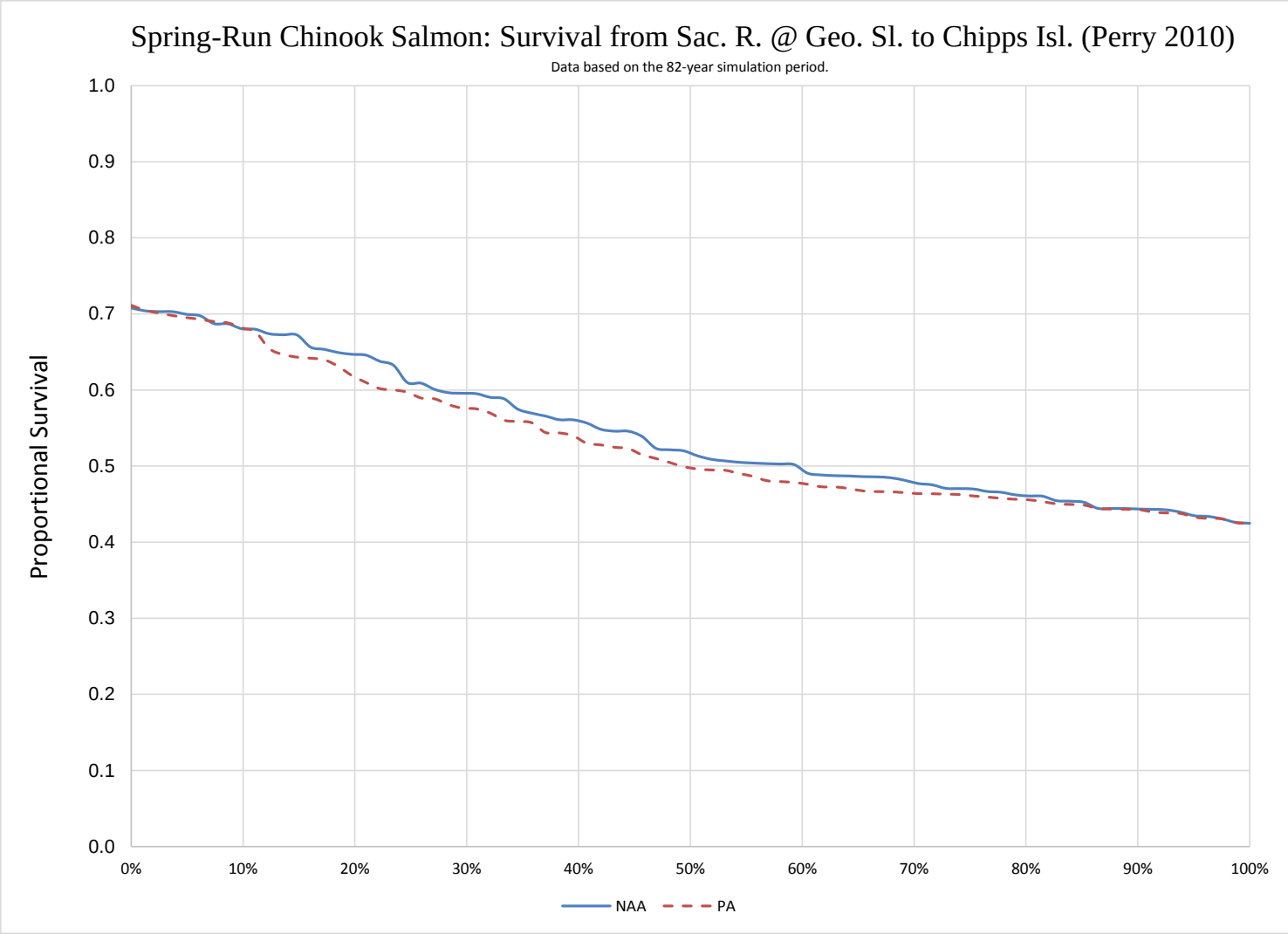


Figure 5.4-20. Exceedance Plot of Juvenile Spring-Run Chinook Salmon Annual Total Survival from the Sacramento River at Georgiana Slough to Chipps Island, Estimated from the Analysis Based on Perry (2010).

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.

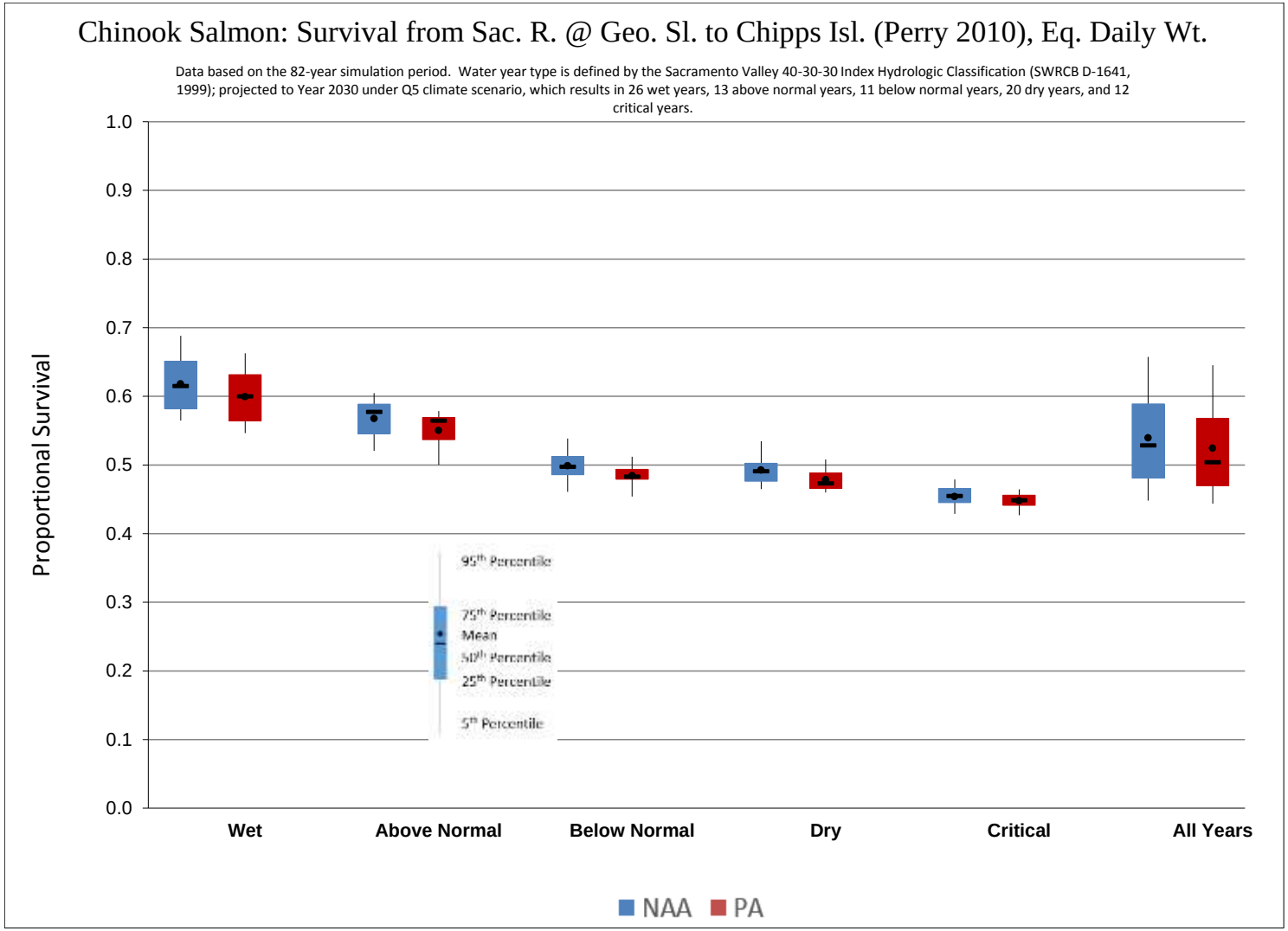


Figure 5.4-21. Box Plots of Juvenile Chinook Salmon Annual Total Survival from the Sacramento River at Georgiana Slough to Chipps Island, Estimated from the Analysis Based on Perry (2010), Grouped by Water Year Type, Assuming Equal Daily Weighting from December to June.

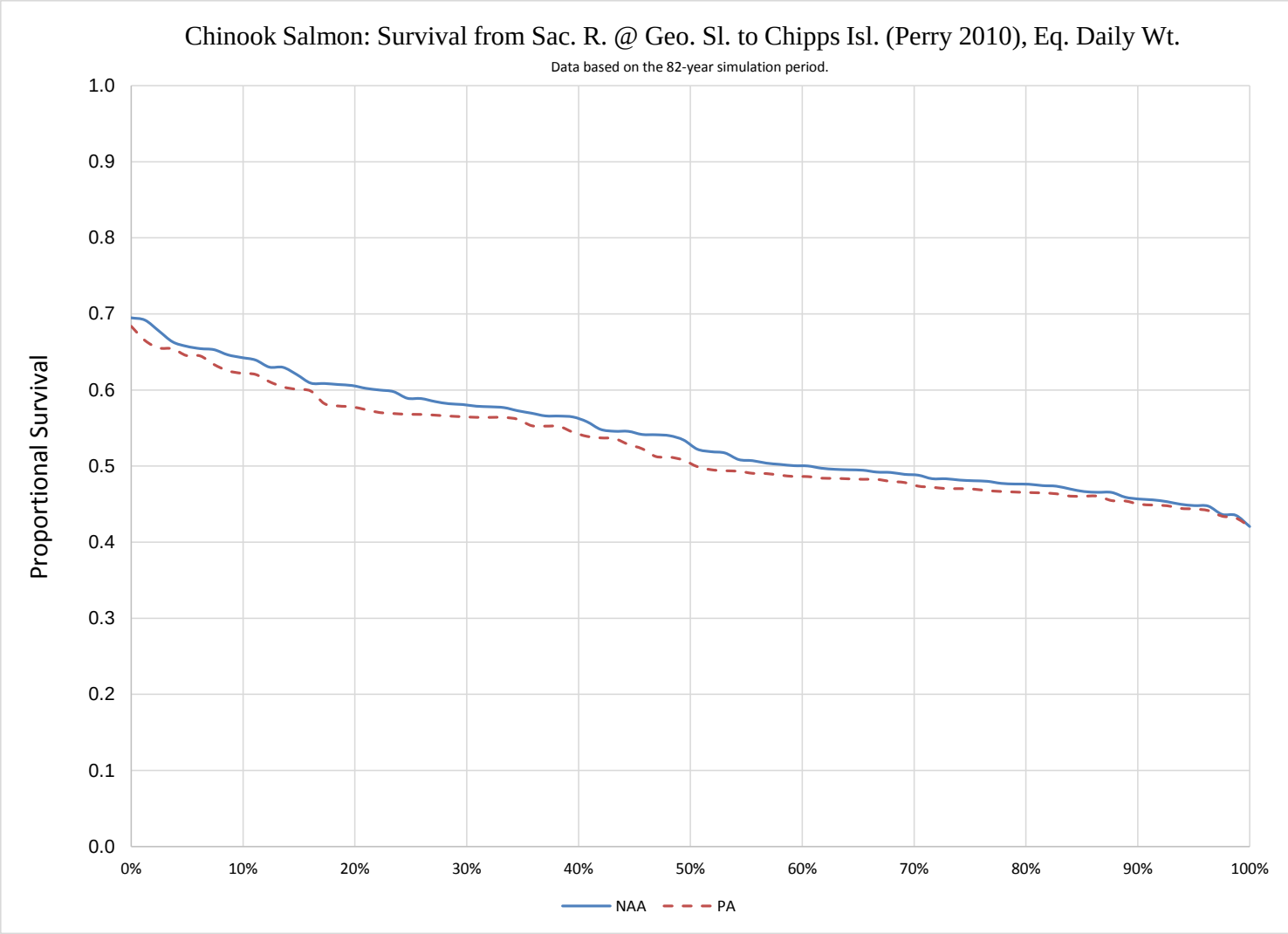


Figure 5.4-22. Exceedance Plot of Juvenile Chinook Salmon Annual Total Survival from the Sacramento River at Georgiana Slough to Chipps Island, Estimated from the Analysis Based on Perry (2010), Assuming Equal Daily Weighting from December to June.

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.