Appendix M, Folsom Reservoir Flow and Temperature Management

Attachment M.1 American River Redd Dewatering Analysis

M.1.1 Model Overview

Redd dewatering for salmon and steelhead occurs when the water level (stage) drops below the depth of existing redds or drops low enough to cause lethal conditions for incubating eggs or alevins within the redds. Redd dewatering in a spawning habitat can occur at any time between the start of spawning to the final emergence of alevins from the redds. Fluctuations in flow during this period increase the probability of redd dewatering because higher flows could lead to redd placement in areas that subsequently may be dewatered when flows drop.

The redd dewatering analyses are based on the maximum reduction in flow from the initial flow, or spawning flow, that occurs over the duration of an egg cohort. The duration of a cohort in a redd includes egg incubation and alevin development to emergence from the gravel. The change in river stage is tracked for the duration of each cohort. The minimum flow of the egg cohort period is referred to herein as the dewatering flow. If flows during the incubation period are all greater than the spawning flow, no dewatering is assumed to occur. The analysis uses CALSIM 3 data, which have a monthly time-step, for the redd dewatering analyses. It assumes a new egg cohort begins each month of the spawning period. Results of the analysis are expressed as the percentage of redds dewatered.

M.1.2 Model Development

M.1.2.1 Methods

The redd dewatering analysis for the lower American River used relationships between flow, river stage, and redd depth distribution developed by Bratovich et al. (2017). Composite redd depth frequency distributions were developed for fall-run Chinook salmon and steelhead by combining results from several redd surveys conducted between 1996 and 2016 (Figure M.1-1, Figure M.1-2, and Table M.1-1). The stage versus flow relationship for the river was developed from a combination of field measurements and modeling (Bratovich et al. 2017). For this analysis, CALSIM 3 flow estimates at the Nimbus Dam location were used to estimate stage at the spawning and dewatering flows, and the redd depth frequency distribution was queried to determine the percentage of the redds that occur between those two stages and would therefore be dewatered.

Redd dewatering was estimated for fall-run and steelhead spawning and incubation periods for each year of the CALSIM 3 period of record. Based on ranges provided in Bratovich et al. 2017, fall-run and steelhead were estimated to have 3-month and 2-month incubation periods, respectively. The analysis compared CALSIM 3 flow and the corresponding stage estimates below Nimbus Dam for each spawning month with the minimum flow (and stage) during 2 or 3 months following the spawning month to estimate the percentage of redds dewatered at least once based on the redd depth cumulative frequencies in Table M.1-1. Primary spawning months are January through March for steelhead and October through December for fall-run Chinook. Absolute differences between the alternatives and baseline conditions in the percentage of redds dewatered were used to compare redd dewatering under the alternatives and the baseline.

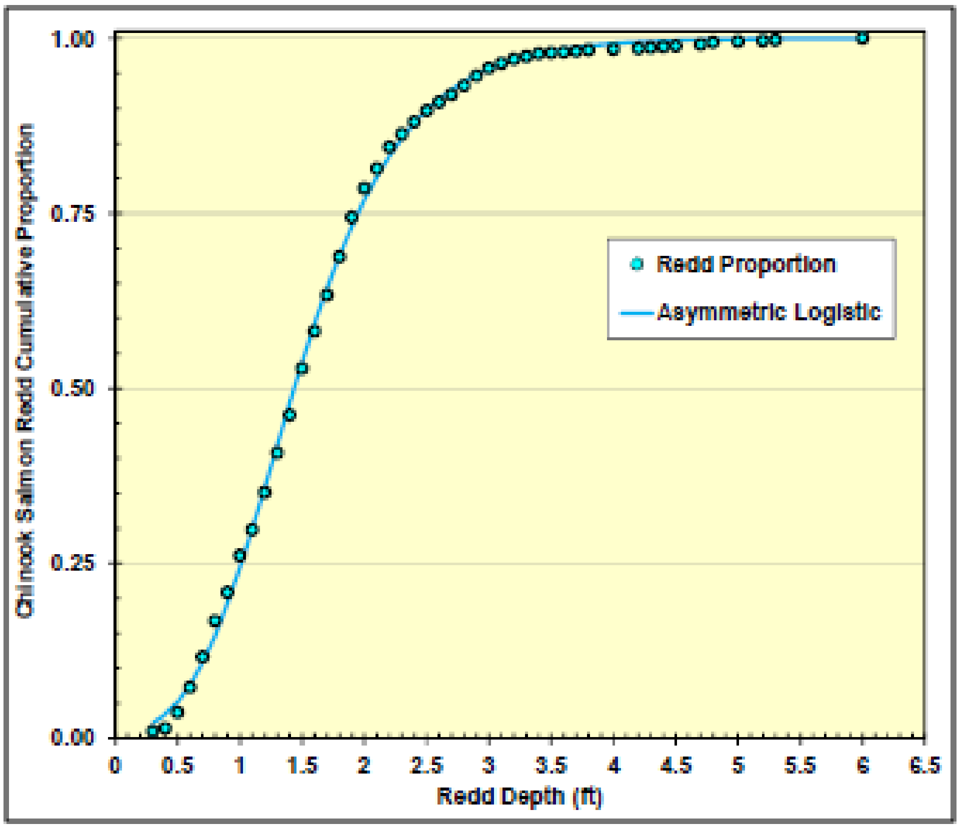

Figure M.1-1. Cumulative Proportions of 920 American River Fall-run Chinook Salmon Redd Depths from Surveys Conducted in 1996, 1998, and 2011 through 2015. Asymmetric Logistic Curve Fitted to the Observed Data.

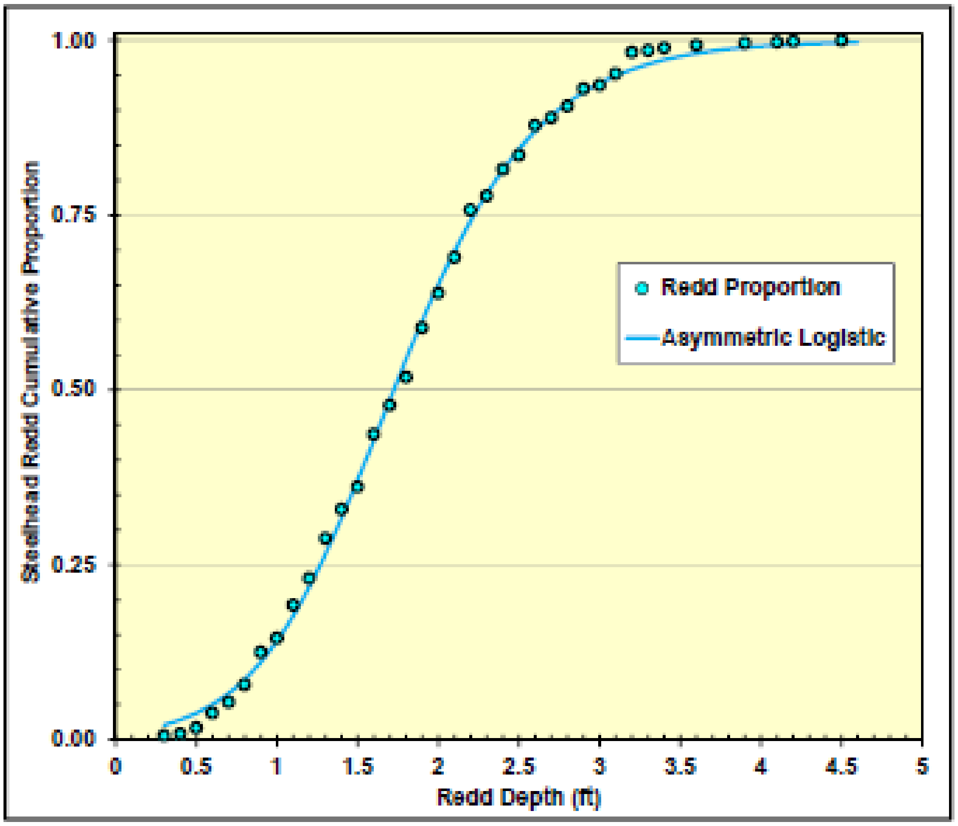

Figure M.1-2. Cumulative Proportions of 841 American River Steelhead Redd Depths from Surveys Conducted in 2002 through 2005, 2007, and 2009 through 2016. Asymmetric Logistic Curve Fitted to the Observed Data.

Table M.1-1. Cumulative Proportions of Fall-run Chinook Salmon and Steelhead Redd Depths Used in the Redd Dewatering Analysis for the Lower American River. Estimated from Logistic Curves in Figure M.1-1 and Figure M.1-2.

Redd Depth (ft)	Fall-run	Steel-head	Redd Depth (ft)	Fall-run	Steel-head	Redd Depth (ft)	Fall-run	Steel-head
0.00	0.0000	0.0000	**2.00**	0.7679	0.6481	**4.00**	0.9928	0.9941
0.01	0.0000	0.0000	**2.01**	0.7714	0.6532	**4.01**	0.9929	0.9943
0.02	0.0000	0.0000	**2.02**	0.7749	0.6582	**4.02**	0.9930	0.9945
0.03	0.0000	0.0000	**2.03**	0.7784	0.6632	**4.03**	0.9932	0.9946
0.04	0.0000	0.0000	**2.04**	0.7818	0.6682	**4.04**	0.9933	0.9948
0.05	0.0000	0.0000	**2.05**	0.7852	0.6731	**4.05**	0.9934	0.9949
0.06	0.0000	0.0000	**2.06**	0.7885	0.6780	**4.06**	0.9935	0.9951
0.07	0.0000	0.0000	**2.07**	0.7918	0.6828	**4.07**	0.9937	0.9952
0.08	0.0000	0.0000	**2.08**	0.7950	0.6876	**4.08**	0.9938	0.9954
0.09	0.0000	0.0000	**2.09**	0.7982	0.6923	**4.09**	0.9939	0.9955
0.10	0.0000	0.0000	**2.10**	0.8014	0.6970	**4.10**	0.9940	0.9957
0.11	0.0000	0.0000	**2.11**	0.8045	0.7016	**4.11**	0.9941	0.9958
0.12	0.0000	0.0000	**2.12**	0.8075	0.7062	**4.12**	0.9942	0.9959
0.13	0.0000	0.0000	**2.13**	0.8106	0.7108	**4.13**	0.9943	0.9961
0.14	0.0000	0.0000	**2.14**	0.8136	0.7153	**4.14**	0.9944	0.9962
0.15	0.0000	0.0000	**2.15**	0.8165	0.7197	**4.15**	0.9945	0.9963
0.16	0.0000	0.0000	**2.16**	0.8194	0.7242	**4.16**	0.9946	0.9965
0.17	0.0000	0.0000	**2.17**	0.8223	0.7285	**4.17**	0.9947	0.9966
0.18	0.0000	0.0000	**2.18**	0.8251	0.7328	**4.18**	0.9948	0.9967
0.19	0.0000	0.0000	**2.19**	0.8279	0.7371	**4.19**	0.9949	0.9968
0.20	0.0000	0.0000	**2.20**	0.8306	0.7413	**4.20**	0.9950	0.9969
0.21	0.0000	0.0000	**2.21**	0.8333	0.7455	**4.21**	0.9951	0.9970
0.22	0.0000	0.0000	**2.22**	0.8360	0.7496	**4.22**	0.9952	0.9972
0.23	0.0000	0.0000	**2.23**	0.8386	0.7536	**4.23**	0.9953	0.9973
0.24	0.0000	0.0000	**2.24**	0.8412	0.7577	**4.24**	0.9954	0.9974
0.25	0.0000	0.0000	**2.25**	0.8438	0.7616	**4.25**	0.9955	0.9975
0.26	0.0000	0.0000	**2.26**	0.8463	0.7656	**4.26**	0.9955	0.9976
0.27	0.0000	0.0000	**2.27**	0.8488	0.7694	**4.27**	0.9956	0.9977
0.28	0.0000	0.0000	**2.28**	0.8513	0.7733	**4.28**	0.9957	0.9978
0.29	0.0000	0.0000	**2.29**	0.8537	0.7770	**4.29**	0.9958	0.9979

Redd Depth (ft)	Fall-run	Steel-head	Redd Depth (ft)	Fall-run	Steel-head	Redd Depth (ft)	Fall-run	Steel-head
0.30	0.0011	0.0000	**2.30**	0.8561	0.7808	**4.30**	0.9959	0.9980
0.31	0.0022	0.0000	**2.31**	0.8584	0.7845	**4.31**	0.9959	0.9981
0.32	0.0034	0.0000	**2.32**	0.8607	0.7881	**4.32**	0.9960	0.9981
0.33	0.0046	0.0000	**2.33**	0.8630	0.7917	**4.33**	0.9961	0.9982
0.34	0.0059	0.0000	**2.34**	0.8652	0.7952	**4.34**	0.9962	0.9983
0.35	0.0072	0.0000	**2.35**	0.8674	0.7987	**4.35**	0.9962	0.9984
0.36	0.0086	0.0008	**2.36**	0.8696	0.8021	**4.36**	0.9963	0.9985
0.37	0.0100	0.0016	**2.37**	0.8718	0.8055	**4.37**	0.9964	0.9986
0.38	0.0114	0.0024	**2.38**	0.8739	0.8089	**4.38**	0.9964	0.9986
0.39	0.0130	0.0033	**2.39**	0.8760	0.8122	**4.39**	0.9965	0.9987
0.40	0.0145	0.0041	**2.40**	0.8780	0.8155	**4.40**	0.9966	0.9988
0.41	0.0162	0.0050	**2.41**	0.8800	0.8187	**4.41**	0.9966	0.9989
0.42	0.0179	0.0059	**2.42**	0.8820	0.8218	**4.42**	0.9967	0.9990
0.43	0.0196	0.0069	**2.43**	0.8840	0.8250	**4.43**	0.9968	0.9990
0.44	0.0214	0.0078	**2.44**	0.8859	0.8280	**4.44**	0.9968	0.9991
0.45	0.0233	0.0088	**2.45**	0.8878	0.8311	**4.45**	0.9969	0.9992
0.46	0.0252	0.0099	**2.46**	0.8897	0.8341	**4.46**	0.9970	0.9992
0.47	0.0272	0.0109	**2.47**	0.8915	0.8370	**4.47**	0.9970	0.9993
0.48	0.0293	0.0120	**2.48**	0.8933	0.8399	**4.48**	0.9971	0.9994
0.49	0.0314	0.0131	**2.49**	0.8951	0.8428	**4.49**	0.9971	0.9994
0.50	0.0336	0.0142	**2.50**	0.8968	0.8456	**4.50**	0.9972	0.9995
0.51	0.0358	0.0154	**2.51**	0.8986	0.8483	**4.51**	0.9972	0.9996
0.52	0.0381	0.0166	**2.52**	0.9003	0.8511	**4.52**	0.9973	0.9996
0.53	0.0405	0.0178	**2.53**	0.9019	0.8538	**4.53**	0.9973	0.9997
0.54	0.0430	0.0191	**2.54**	0.9036	0.8564	**4.54**	0.9974	0.9997
0.55	0.0455	0.0204	**2.55**	0.9052	0.8590	**4.55**	0.9974	0.9998
0.56	0.0481	0.0217	**2.56**	0.9068	0.8616	**4.56**	0.9975	0.9998
0.57	0.0508	0.0231	**2.57**	0.9084	0.8641	**4.57**	0.9975	0.9999
0.58	0.0535	0.0245	**2.58**	0.9099	0.8666	**4.58**	0.9976	0.9999
0.59	0.0563	0.0259	**2.59**	0.9114	0.8690	**4.59**	0.9976	1.0000
0.60	0.0592	0.0274	**2.60**	0.9129	0.8714	**4.60**	0.9977	1.0000
0.61	0.0621	0.0289	**2.61**	0.9144	0.8738	**4.61**	0.9977	1.0000
0.62	0.0652	0.0304	**2.62**	0.9159	0.8761	**4.62**	0.9978	1.0000

Redd Depth (ft)	Fall-run	Steel-head	Redd Depth (ft)	Fall-run	Steel-head	Redd Depth (ft)	Fall-run	Steel-head
0.63	0.0683	0.0320	**2.63**	0.9173	0.8784	**4.63**	0.9978	1.0000
0.64	0.0714	0.0336	**2.64**	0.9187	0.8807	**4.64**	0.9978	1.0000
0.65	0.0747	0.0352	**2.65**	0.9201	0.8829	**4.65**	0.9979	1.0000
0.66	0.0780	0.0369	**2.66**	0.9214	0.8851	**4.66**	0.9979	1.0000
0.67	0.0814	0.0387	**2.67**	0.9228	0.8872	**4.67**	0.9980	--
0.68	0.0849	0.0404	**2.68**	0.9241	0.8894	**4.68**	0.9980	--
0.69	0.0884	0.0423	**2.69**	0.9254	0.8914	**4.69**	0.9981	--
0.70	0.0921	0.0441	**2.70**	0.9267	0.8935	**4.70**	0.9981	--
0.71	0.0958	0.0460	**2.71**	0.9279	0.8955	**4.71**	0.9981	--
0.72	0.0995	0.0480	**2.72**	0.9291	0.8975	**4.72**	0.9982	--
0.73	0.1034	0.0500	**2.73**	0.9304	0.8994	**4.73**	0.9982	--
0.74	0.1073	0.0520	**2.74**	0.9315	0.9013	**4.74**	0.9982	--
0.75	0.1113	0.0541	**2.75**	0.9327	0.9032	**4.75**	0.9983	--
0.76	0.1154	0.0562	**2.76**	0.9339	0.9050	**4.76**	0.9983	--
0.77	0.1195	0.0584	**2.77**	0.9350	0.9069	**4.77**	0.9983	--
0.78	0.1237	0.0606	**2.78**	0.9361	0.9086	**4.78**	0.9984	--
0.79	0.1280	0.0629	**2.79**	0.9372	0.9104	**4.79**	0.9984	--
0.80	0.1324	0.0652	**2.80**	0.9383	0.9121	**4.80**	0.9984	--
0.81	0.1368	0.0676	**2.81**	0.9394	0.9138	**4.81**	0.9985	--
0.82	0.1413	0.0700	**2.82**	0.9404	0.9155	**4.82**	0.9985	--
0.83	0.1458	0.0725	**2.83**	0.9414	0.9171	**4.83**	0.9985	--
0.84	0.1505	0.0750	**2.84**	0.9424	0.9187	**4.84**	0.9986	--
0.85	0.1552	0.0776	**2.85**	0.9434	0.9203	**4.85**	0.9986	--
0.86	0.1599	0.0802	**2.86**	0.9444	0.9218	**4.86**	0.9986	--
0.87	0.1648	0.0829	**2.87**	0.9454	0.9234	**4.87**	0.9986	--
0.88	0.1696	0.0856	**2.88**	0.9463	0.9249	**4.88**	0.9987	--
0.89	0.1746	0.0884	**2.89**	0.9472	0.9263	**4.89**	0.9987	--
0.90	0.1796	0.0913	**2.90**	0.9482	0.9278	**4.90**	0.9987	--
0.91	0.1847	0.0942	**2.91**	0.9491	0.9292	**4.91**	0.9988	--
0.92	0.1898	0.0971	**2.92**	0.9499	0.9306	**4.92**	0.9988	--
0.93	0.1950	0.1001	**2.93**	0.9508	0.9320	**4.93**	0.9988	--
0.94	0.2003	0.1032	**2.94**	0.9517	0.9333	**4.94**	0.9988	--
0.95	0.2056	0.1063	**2.95**	0.9525	0.9346	**4.95**	0.9989	--

Redd Depth (ft)	Fall-run	Steel-head	Redd Depth (ft)	Fall-run	Steel-head	Redd Depth (ft)	Fall-run	Steel-head
0.96	0.2109	0.1095	**2.96**	0.9533	0.9359	**4.96**	0.9989	--
0.97	0.2163	0.1127	**2.97**	0.9541	0.9372	**4.97**	0.9989	--
0.98	0.2218	0.1160	**2.98**	0.9549	0.9384	**4.98**	0.9989	--
0.99	0.2273	0.1194	**2.99**	0.9557	0.9397	**4.99**	0.9989	--
1.00	0.2329	0.1228	**3.00**	0.0000	0.0000	**5.00**	0.9990	--
1.01	0.2385	0.1263	**3.01**	0.0000	0.0000	**5.01**	0.9990	--
1.02	0.2441	0.1298	**3.02**	0.0000	0.0000	**5.02**	0.9990	--
1.03	0.2498	0.1334	**3.03**	0.0000	0.0000	**5.03**	0.9990	--
1.04	0.2555	0.1370	**3.04**	0.0000	0.0000	**5.04**	0.9991	--
1.05	0.2613	0.1407	**3.05**	0.0000	0.0000	**5.05**	0.9991	--
1.06	0.2671	0.1445	**3.06**	0.0000	0.0000	**5.06**	0.9991	--
1.07	0.2729	0.1483	**3.07**	0.0000	0.0000	**5.07**	0.9991	--
1.08	0.2788	0.1522	**3.08**	0.0000	0.0000	**5.08**	0.9991	--
1.09	0.2847	0.1561	**3.09**	0.0000	0.0000	**5.09**	0.9992	--
1.10	0.2906	0.1601	**3.10**	0.0000	0.0000	**5.10**	0.9992	--
1.11	0.2966	0.1642	**3.11**	0.0000	0.0000	**5.11**	0.9992	--
1.12	0.3026	0.1683	**3.12**	0.0000	0.0000	**5.12**	0.9992	--
1.13	0.3086	0.1724	**3.13**	0.0000	0.0000	**5.13**	0.9992	--
1.14	0.3146	0.1767	**3.14**	0.0000	0.0000	**5.14**	0.9992	--
1.15	0.3207	0.1810	**3.15**	0.0000	0.0000	**5.15**	0.9993	--
1.16	0.3267	0.1853	**3.16**	0.0000	0.0000	**5.16**	0.9993	--
1.17	0.3328	0.1897	**3.17**	0.0000	0.0000	**5.17**	0.9993	--
1.18	0.3389	0.1941	**3.18**	0.0000	0.0000	**5.18**	0.9993	--
1.19	0.3451	0.1986	**3.19**	0.0000	0.0000	**5.19**	0.9993	--
1.20	0.3512	0.2032	**3.20**	0.0000	0.0000	**5.20**	0.9993	--
1.21	0.3573	0.2078	**3.21**	0.0000	0.0000	**5.21**	0.9994	--
1.22	0.3635	0.2125	**3.22**	0.0000	0.0000	**5.22**	0.9994	--
1.23	0.3697	0.2172	**3.23**	0.0000	0.0000	**5.23**	0.9994	--
1.24	0.3758	0.2220	**3.24**	0.0000	0.0000	**5.24**	0.9994	--
1.25	0.3820	0.2268	**3.25**	0.0000	0.0000	**5.25**	0.9994	--
1.26	0.3881	0.2317	**3.26**	0.0000	0.0000	**5.26**	0.9994	--
1.27	0.3943	0.2366	**3.27**	0.0000	0.0000	**5.27**	0.9994	--
1.28	0.4005	0.2416	**3.28**	0.0000	0.0000	**5.28**	0.9995	--

Redd Depth (ft)	Fall-run	Steel-head	Redd Depth (ft)	Fall-run	Steel-head	Redd Depth (ft)	Fall-run	Steel-head
1.29	0.4066	0.2466	**3.29**	0.0000	0.0000	**5.29**	0.9995	--
1.30	0.4128	0.2517	**3.30**	0.0011	0.0000	**5.30**	0.9995	--
1.31	0.4190	0.2568	**3.31**	0.0022	0.0000	**5.31**	0.9995	--
1.32	0.4251	0.2620	**3.32**	0.0034	0.0000	**5.32**	0.9995	--
1.33	0.4312	0.2672	**3.33**	0.0046	0.0000	**5.33**	0.9995	--
1.34	0.4373	0.2725	**3.34**	0.0059	0.0000	**5.34**	0.9995	--
1.35	0.4435	0.2778	**3.35**	0.0072	0.0000	**5.35**	0.9995	--
1.36	0.4496	0.2831	**3.36**	0.0086	0.0008	**5.36**	0.9996	--
1.37	0.4556	0.2885	**3.37**	0.0100	0.0016	**5.37**	0.9996	--
1.38	0.4617	0.2939	**3.38**	0.0114	0.0024	**5.38**	0.9996	--
1.39	0.4677	0.2994	**3.39**	0.0130	0.0033	**5.39**	0.9996	--
1.40	0.4738	0.3049	**3.40**	0.0145	0.0041	**5.40**	0.9996	--
1.41	0.4798	0.3104	**3.41**	0.0162	0.0050	**5.41**	0.9996	--
1.42	0.4857	0.3160	**3.42**	0.0179	0.0059	**5.42**	0.9996	--
1.43	0.4917	0.3216	**3.43**	0.0196	0.0069	**5.43**	0.9996	--
1.44	0.4976	0.3272	**3.44**	0.0214	0.0078	**5.44**	0.9996	--
1.45	0.5035	0.3329	**3.45**	0.0233	0.0088	**5.45**	0.9997	--
1.46	0.5094	0.3386	**3.46**	0.0252	0.0099	**5.46**	0.9997	--
1.47	0.5153	0.3443	**3.47**	0.0272	0.0109	**5.47**	0.9997	--
1.48	0.5211	0.3500	**3.48**	0.0293	0.0120	**5.48**	0.9997	--
1.49	0.5269	0.3558	**3.49**	0.0314	0.0131	**5.49**	0.9997	--
1.50	0.5326	0.3616	**3.50**	0.0336	0.0142	**5.50**	0.9997	--
1.51	0.5384	0.3674	**3.51**	0.0358	0.0154	**5.51**	0.9997	--
1.52	0.5441	0.3732	**3.52**	0.0381	0.0166	**5.52**	0.9997	--
1.53	0.5497	0.3791	**3.53**	0.0405	0.0178	**5.53**	0.9997	--
1.54	0.5554	0.3850	**3.54**	0.0430	0.0191	**5.54**	0.9997	--
1.55	0.5609	0.3909	**3.55**	0.0455	0.0204	**5.55**	0.9997	--
1.56	0.5665	0.3968	**3.56**	0.0481	0.0217	**5.56**	0.9998	--
1.57	0.5720	0.4027	**3.57**	0.0508	0.0231	**5.57**	0.9998	--
1.58	0.5775	0.4086	**3.58**	0.0535	0.0245	**5.58**	0.9998	--
1.59	0.5829	0.4145	**3.59**	0.0563	0.0259	**5.59**	0.9998	--
1.60	0.5883	0.4205	**3.60**	0.0592	0.0274	**5.60**	0.9998	--
1.61	0.5937	0.4264	**3.61**	0.0621	0.0289	**5.61**	0.9998	--

Redd Depth (ft)	Fall-run	Steel-head	Redd Depth (ft)	Fall-run	Steel-head	Redd Depth (ft)	Fall-run	Steel-head
1.62	0.5990	0.4324	**3.62**	0.0652	0.0304	**5.62**	0.9998	--
1.63	0.6043	0.4383	**3.63**	0.0683	0.0320	**5.63**	0.9998	-
1.64	0.6095	0.4443	**3.64**	0.0714	0.0336	**5.64**	0.9998	--
1.65	0.6147	0.4502	**3.65**	0.0747	0.0352	**5.65**	0.9998	--
1.66	0.6199	0.4562	**3.66**	0.0780	0.0369	**5.66**	0.9998	--
1.67	0.6250	0.4622	**3.67**	0.0814	0.0387	**5.67**	0.9998	--
1.68	0.6301	0.4681	**3.68**	0.0849	0.0404	**5.68**	0.9998	--
1.69	0.6351	0.4740	**3.69**	0.0884	0.0423	**5.69**	0.9998	--
1.70	0.6401	0.4800	**3.70**	0.0921	0.0441	**5.70**	0.9999	--
1.71	0.6450	0.4859	**3.71**	0.0958	0.0460	**5.71**	0.9999	--
1.72	0.6499	0.4918	**3.72**	0.0995	0.0480	**5.72**	0.9999	--
1.73	0.6547	0.4977	**3.73**	0.1034	0.0500	**5.73**	0.9999	--
1.74	0.6595	0.5036	**3.74**	0.1073	0.0520	**5.74**	0.9999	--
1.75	0.6643	0.5095	**3.75**	0.1113	0.0541	**5.75**	0.9999	--
1.76	0.6690	0.5154	**3.76**	0.1154	0.0562	**5.76**	0.9999	--
1.77	0.6736	0.5212	**3.77**	0.1195	0.0584	**5.77**	0.9999	--
1.78	0.6782	0.5270	**3.78**	0.1237	0.0606	**5.78**	0.9999	--
1.79	0.6828	0.5328	**3.79**	0.1280	0.0629	**5.79**	0.9999	--
1.80	0.6873	0.5386	**3.80**	0.1324	0.0652	**5.80**	0.9999	--
1.81	0.6918	0.5444	**3.81**	0.1368	0.0676	**5.81**	0.9999	--
1.82	0.6962	0.5501	**3.82**	0.1413	0.0700	**5.82**	0.9999	--
1.83	0.7006	0.5558	**3.83**	0.1458	0.0725	**5.83**	0.9999	--
1.84	0.7049	0.5615	**3.84**	0.1505	0.0750	**5.84**	0.9999	--
1.85	0.7092	0.5672	**3.85**	0.1552	0.0776	**5.85**	0.9999	--
1.86	0.7134	0.5728	**3.86**	0.1599	0.0802	**5.86**	0.9999	--
1.87	0.7176	0.5784	**3.87**	0.1648	0.0829	**5.87**	0.9999	--
1.88	0.7218	0.5840	**3.88**	0.1696	0.0856	**5.88**	1.0000	--
1.89	0.7259	0.5895	**3.89**	0.1746	0.0884	**5.89**	1.0000	--
1.90	0.7299	0.5950	**3.90**	0.1796	0.0913	**5.90**	1.0000	--
1.91	0.7339	0.6005	**3.91**	0.1847	0.0942	**5.91**	1.0000	--
1.92	0.7379	0.6059	**3.92**	0.1898	0.0971	**5.92**	1.0000	--
1.93	0.7418	0.6113	**3.93**	0.1950	0.1001	**5.93**	1.0000	--
1.94	0.7457	0.6167	**3.94**	0.2003	0.1032	**5.94**	1.0000	--

Redd Depth (ft)	Fall-run	Steel-head	Redd Depth (ft)	Fall-run	Steel-head	Redd Depth (ft)	Fall-run	Steel-head
1.95	0.7495	0.6220	**3.95**	0.2056	0.1063	**5.95**	1.0000	--
1.96	0.7532	0.6273	**3.96**	0.2109	0.1095	**5.96**	1.0000	--
1.97	0.7570	0.6326	**3.97**	0.2163	0.1127	**5.97**	1.0000	--
1.98	0.7606	0.6378	**3.98**	0.2218	0.1160	**5.98**	1.0000	--
1.99	0.7643	0.6429	**3.99**	0.2273	0.1194	**5.99**	1.0000	--

M.1.2.2 Assumptions / Uncertainty

This section provides a list of some important uncertainties and assumptions of the redd dewatering analyses presented.

1. The use of monthly time-step flow estimates like those obtained from CALSIM 3 modeling likely underestimates redd dewatering rates because they smooth out short-term flow fluctuations. This potential bias is expected to affect the Project and NAA scenarios equally.
2. An assumption of the redd dewatering analysis is that dewatering of the redd results in 100% mortality of the eggs and alevins it contains. This assumption likely overestimates mortality. Several studies have demonstrated that the level of mortality is strongly related to the duration of dewatering, the temperature and humidity in the dewatered redd, and the life stages present when the redd is dewatered (Becker et al. 1982; Reiser and White 1983; McMichael et al. 2005). In general, eggs survive dewatering at a much higher rate than the alevins (Becker et al. 1982). Eggs may survive for weeks in a dewatered redd whereas alevins generally survive only a few hours (Becker et al. 1982; Reiser and White 1983). This observation suggests that dewatering of redds early in the spawning period of a population may have a less negative effect than later dewatering because the egg stage would be more prevalent early in the season than the alevin stage. Although the assumption of 100% mortality resulting from redd dewatering overestimates the effects of redd dewatering on the salmon and steelhead populations under the alternative scenarios, the level of overestimation is uncertain. Regardless, this assumption applies to all alternative scenarios equally.
3. The duration of egg and alevin incubation for fall-run Chinook salmon and steelhead is assumed to be the same regardless of the time of year. This ignores water temperature effects on egg and alevin development times, which increases uncertainty in the analysis. Water temperatures in the lower American River are not expected to differ greatly among the alternative scenarios, so any biases resulting from temperature effects are likely to be similar among scenarios.
4. The redd dewatering analyses assume that channel characteristics of the river, such as proportions of mesohabitat types, during the time of field data collection by U.S. Fish and Wildlife Service (1995–1999) have remained in dynamic equilibrium to the present time and will continue to do so through the life of the Project. If the channel characteristics substantially changed, the stage versus flow relationship might no longer be applicable.

M.1.2.3 Code and Data Repository

This is a spreadsheet model and the relationship is captured above in the tables and figures in Section M.1.2.1, *Methods*. Data used for this analysis are available upon request.

M.1.3 Results

M.1.3.1 Steelhead

The results of the redd dewatering analysis for steelhead indicate that redd dewatering is much greater in wet water years than in dry water years for all BA and EIS modeled scenarios (Table M.1-2 and Table M.1-3, Figure M.1-1 and Figure M.1-2). This difference reflects the greater frequency of larger flow fluctuations in wetter years. Table M.1-3 shows the percent difference between the NAA and the EIS modeled scenarios for the alternatives. Some of the differences, especially for Alt 1, are very large, although the absolute difference in percent redds dewatered between the NAA and Alt 1 are much smaller (e.g., 13.9% for critical water years).

Table M.1-2. Mean Percent Steelhead Redds Dewatered for the American River by Water Year Type for January through March Spawning Period for EXP1, EXP3, the NAA, and Four Phases of Alternative 2. BA Modeled Scenarios

Water Year Type	EXP1	EXP3	NAA	Alt2w TUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA
Wet	39.6	49.7	49.1	49.1	49.1	48.9	48.9
AN	37.6	41.2	38.6	39.5	40.2	39.8	39.8
BN	23.6	26.0	20.6	23.2	22.6	21.1	21.1
Dry	18.6	17.1	8.4	10.6	10.5	10.9	10.9
Critical	15.8	6.1	4.6	5.1	6.7	5.8	5.8
All	27.6	29.4	25.6	26.8	27.0	26.6	26.6

Table M.1-3. Mean Percent Steelhead Redds Dewatered for the American River by Water Year Type for January through March Spawning Period, for the NAA and Alternatives 1-4. The Lower Panel Gives the Percent Differences of the Alternatives and the NAA, EIS Modeled Scenarios

WYT	NAA	Alt 1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt 3	Alt 4
W	49.1	50.5	49.1	49.1	49.1	48.9	46.6	49.0
AN	38.6	46.9	39.7	39.5	40.2	39.8	33.4	40.9
BN	20.6	36.7	23.4	23.2	22.6	21.1	13.6	25.0
D	8.4	29.2	10.7	10.6	10.5	10.9	9.4	13.7
C	4.6	18.5	8.2	5.1	6.7	5.8	3.6	10.8
All	25.6	37.3	27.4	26.8	27.0	26.6	23.0	28.9
WYT	**NAA**	**Alt 1**	**Alt2 wTUCP woVA**	**Alt2 woTUCP woVA**	**Alt2 woTUCP DeltaVA**	**Alt2 woTUCP AllVA**	**Alt 3**	**Alt 4**
Wet	49.1	2.9	0.0	0.0	0.0	-0.3	-5.0	-0.2
AN	38.6	21.3	2.7	1.3	2.0	2.6	-13.5	5.9
BN	20.6	78.4	9.3	8.2	6.8	0.8	-34.1	21.7
Dry	8.4	247.9	21.3	18.7	21.8	15.4	11.7	62.4
Critical	4.6	301.2	18.5	40.0	35.0	-15.3	-21.9	132.7
All	25.6	45.6	4.1	4.1	4.1	1.3	-10.2	13.0

The results for steelhead redd dewatering grouped by months indicate that for both BA and EIS modeled scenarios redd dewatering peaks from February spawning, when flows exhibit the greatest variability (as indicated by flow variance), while dewatering is lower and roughly similar for redds from January and March spawning (Figure M.1-3 and Figure M.1-4).

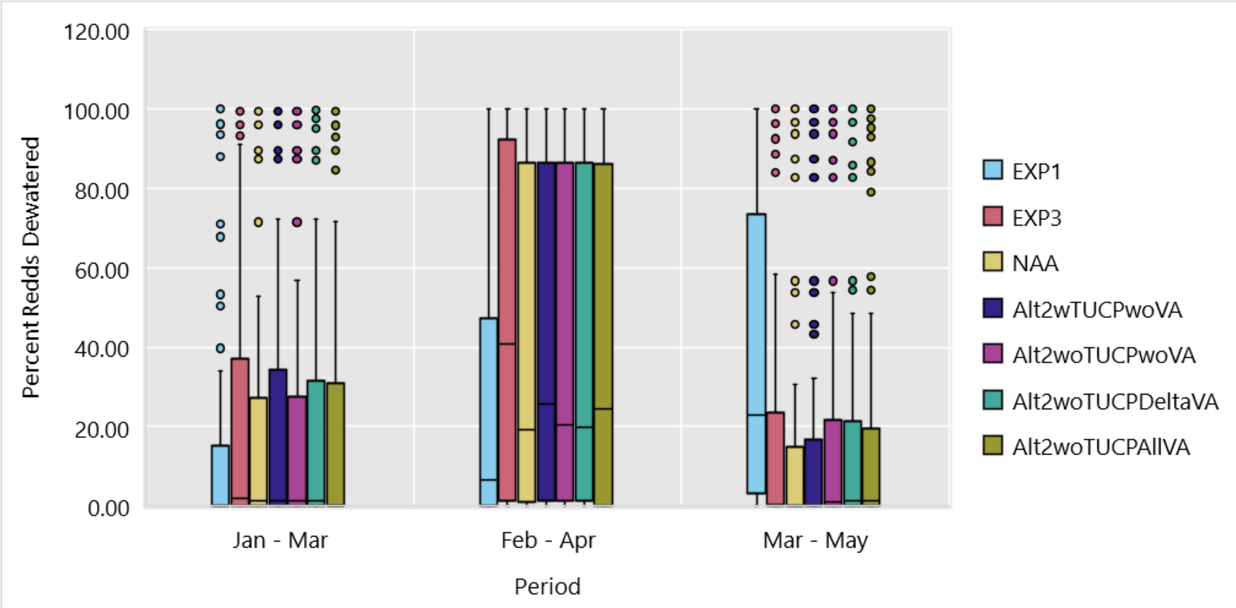

Figure M.1-3. Expected Percent Steelhead Redds Dewatered for the American River for EXP1, EXP3, the NAA, and Four Phases of Alternative 2, by Period, BA Modeled Scenarios.

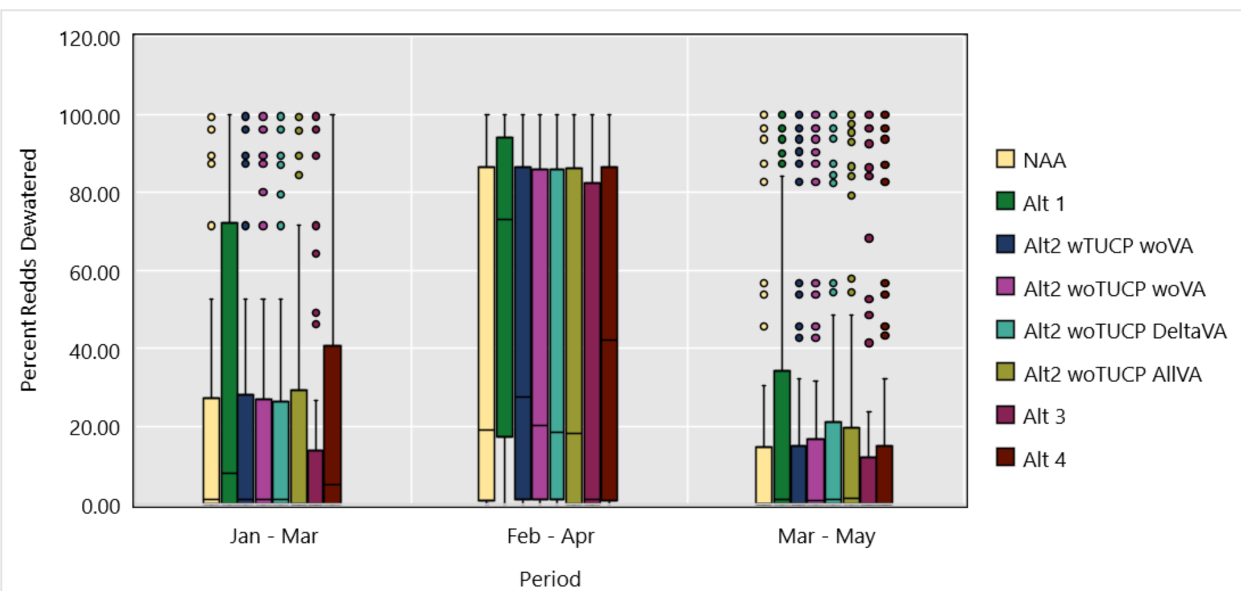

Figure M.1-4. Expected Percent Steelhead Redds Dewatered for the American River for the NAA and Alternatives 1-4, by Period, EIS Modeled Scenarios.

Figure M.1-5 and

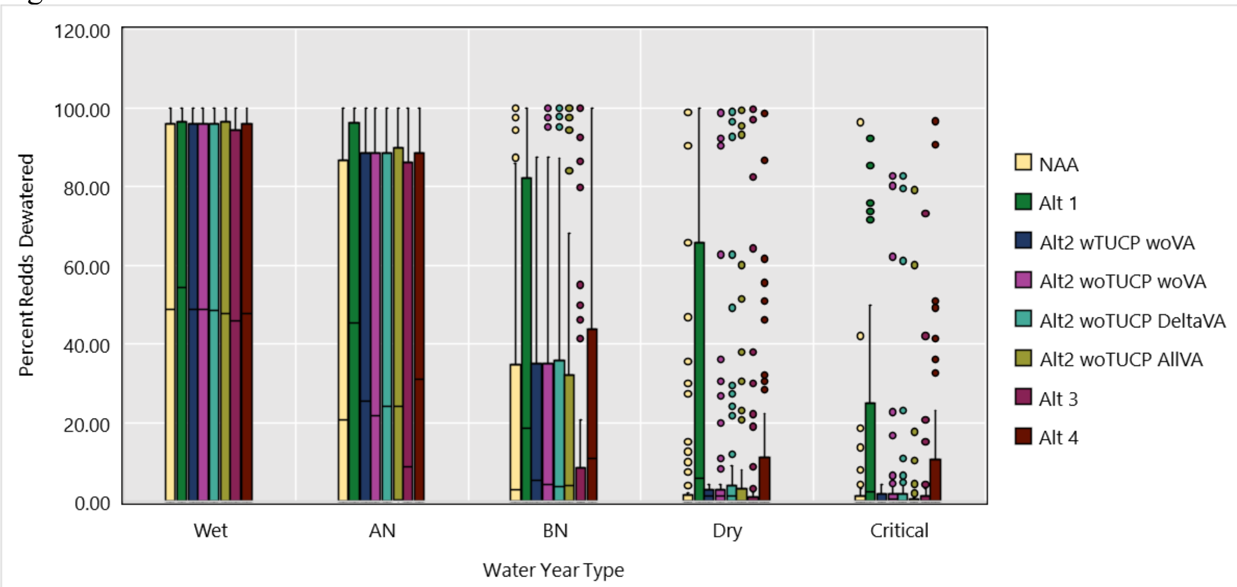

Figure M.1-6 give the results for steelhead redd dewatering grouped by water year types. The results are derived from the same estimates as those provided in Table M.1-2 and Table M.1-3, but additionally show the variations in the redd dewatering results. As described above for Table M.1-2 and Table M.1-3, redd dewatering increases from dry to wet years, reflecting the greater flow fluctuations in the wetter years.

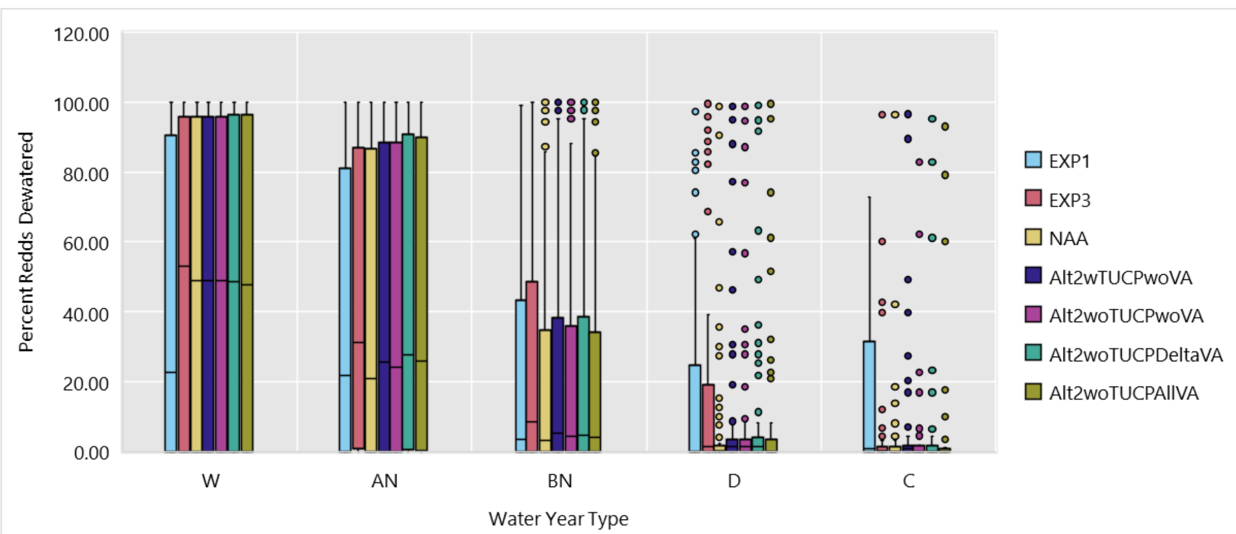

Figure M.1-5. Expected Percent Steelhead Redds Dewatered for the American River by Water Year Type for January through March, BA Modeled Scenarios.

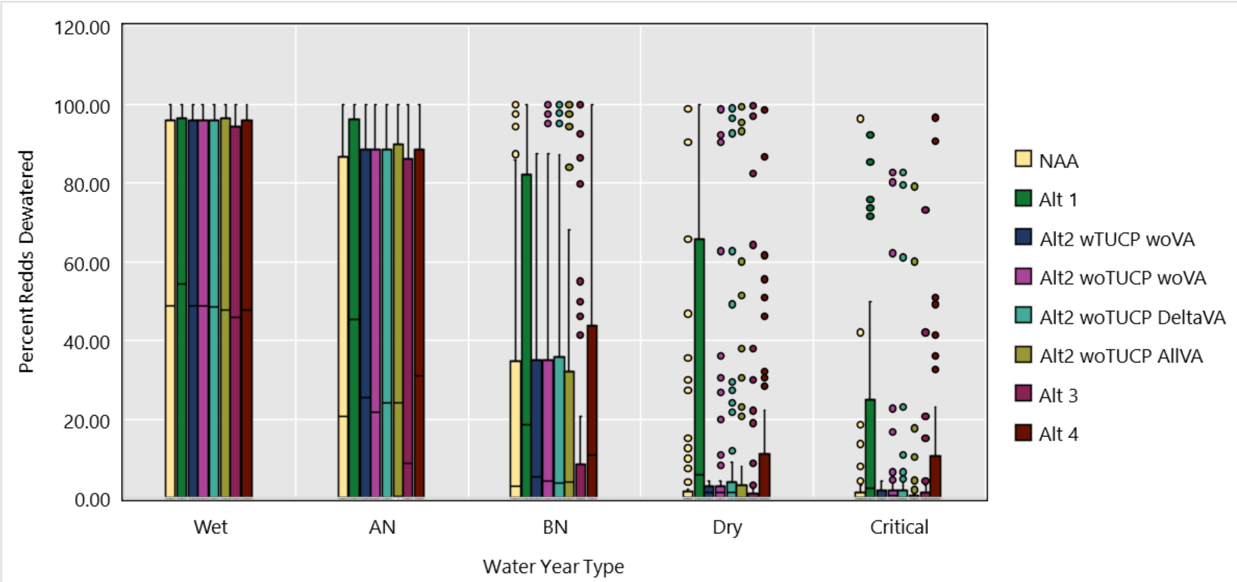

Figure M.1-6. Expected Percent Steelhead Redds Dewatered for the American River by Water Year Type for January through March, EIS Modeled Scenarios.

M.1.3.2 Fall-run Chinook salmon

The results of the redd dewatering analysis for fall-run Chinook indicate that redd dewatering is greater in wet and above normal water years than in the drier water year types for all the EIS modeled scenarios (Table M.1-4 and Figure M.1-5). However, this variation is less pronounced for fall-run than it is for steelhead (Table M.1-2 and Table M.1-3). Table M.1-4 shows the percent difference between the NAA and the EIS modeled scenarios for the alternatives. Some of the differences, especially for Alt 1, are very large, although the absolute difference in percent redds dewatered between the NAA and Alt 1 are much smaller (e.g., 16.1% for above normal water years).

Table M.1-4. Mean Percent Fall-run Chinook Redds Dewatered for the American River by Water Year Type for October through December Spawning Period, for the NAA, and Alternatives Alt 1, Alt 3, Alt 4 and Four Alt 2 Scenarios. The Lower Panel Gives the Percent Differences of the Alternatives and the NAA. EIS Modeled Scenarios

WYT	NAA	Alt 1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt 3	Alt 4
W	18.8	28.0	20.8	20.8	21.1	20.2	16.2	22.9
AN	11.2	27.3	13.5	13.6	13.5	12.7	9.5	15.5
BN	6.4	14.8	6.7	6.8	7.8	8.0	5.9	7.5
D	11.1	19.8	12.0	12.0	11.7	11.6	9.4	11.6
C	7.3	13.4	8.1	8.0	8.0	7.5	3.8	6.7

WYT	NAA	Alt 1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt 3	Alt 4
All	11.9	21.4	13.2	13.2	13.3	12.9	9.9	13.9
WYT	**NAA**	**Alt 1**	**Alt2 wTUCP woVA**	**Alt2 woTUCP woVA**	**Alt2 woTUCP DeltaVA**	**Alt2 woTUCP AllVA**	**Alt 3**	**Alt 4**
Wet	18.8	48.9	10.6	10.6	11.9	7.5	-13.9	21.6
AN	11.2	143.8	20.4	22.0	20.3	13.4	-15.3	38.9
BN	6.4	129.6	5.0	6.4	21.2	24.7	-8.6	16.0
Dry	11.1	79.2	8.7	8.1	6.0	4.7	-14.6	5.2
Critical	7.3	83.2	10.6	9.4	9.4	1.9	-48.4	-8.6
All	11.9	80.2	11.0	11.1	12.4	8.9	-16.9	17.0

The results for fall-run redd dewatering grouped by months indicate that redd dewatering increases from spawning in October to that in December, reflecting the increasingly higher flow levels and fluctuations over this period (Figure M.1-7).

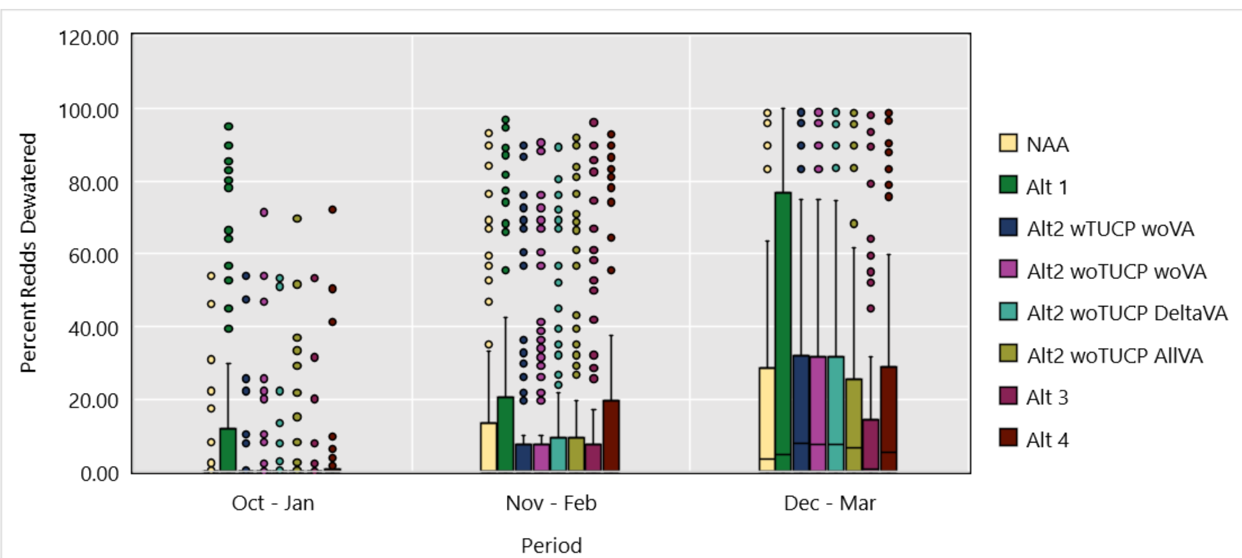

Figure M.1-7. Expected Percent Fall-run Chinook Salmon Redds Dewatered for the American River by Period, EIS Modeled Scenarios.

Grouping the redd dewatering results by water year type rather than month (

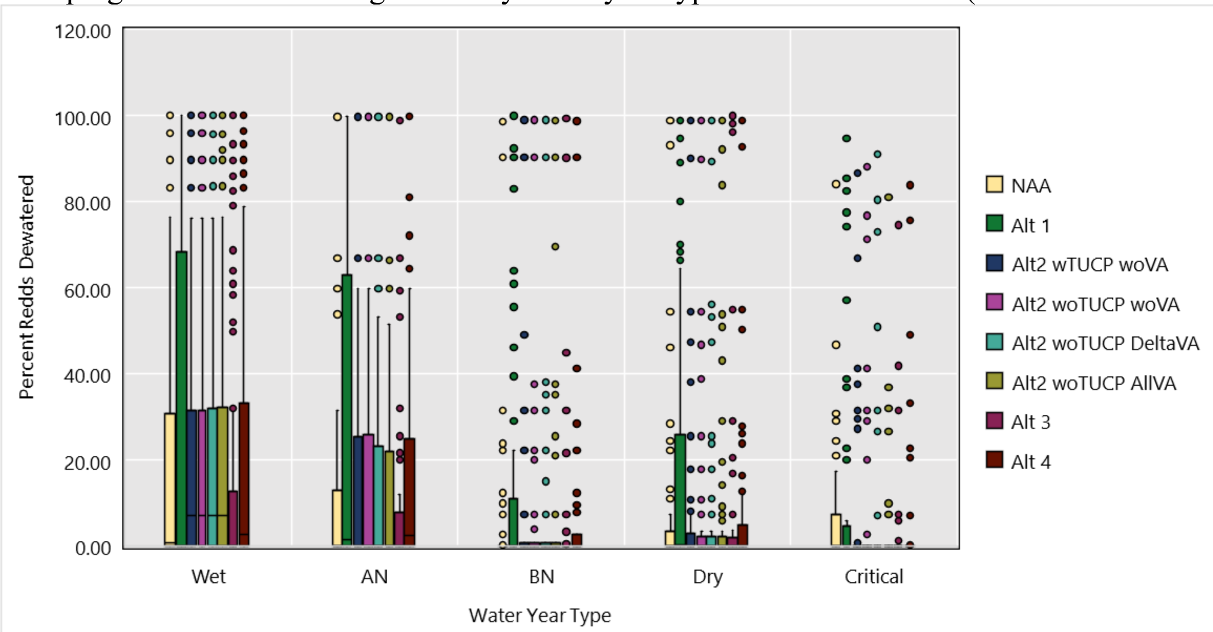

Figure M.1-8) shows greater median values for redd dewatering in wetter years, but the pattern is less pronounced than that found for steelhead (Figure M.1-5 and

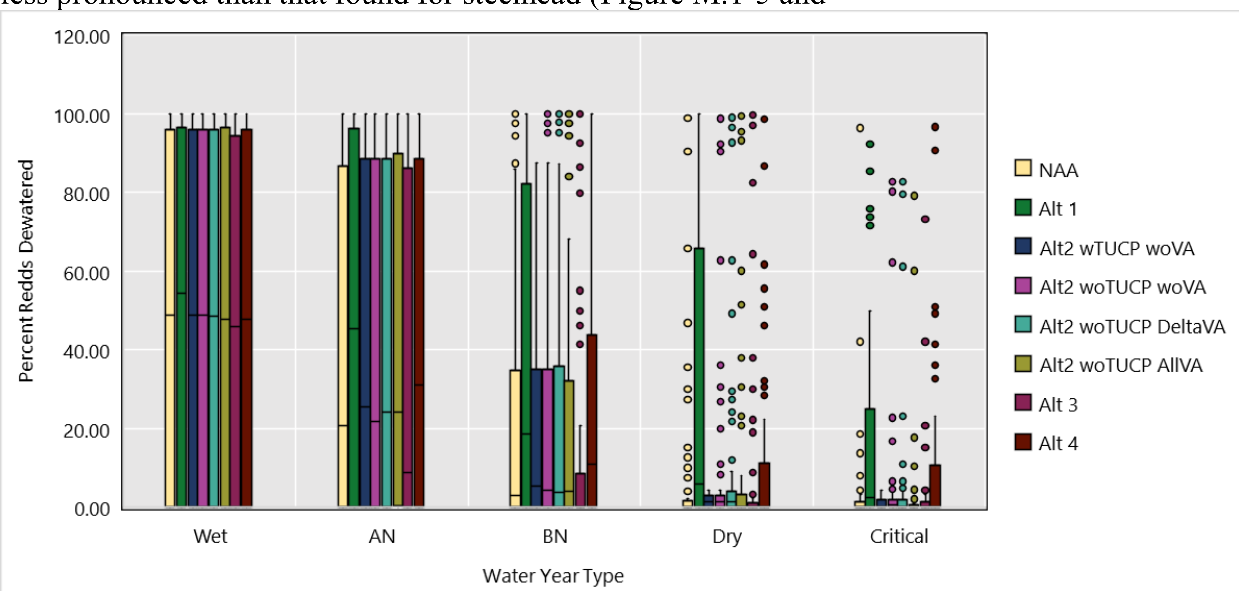

Figure M.1-6)

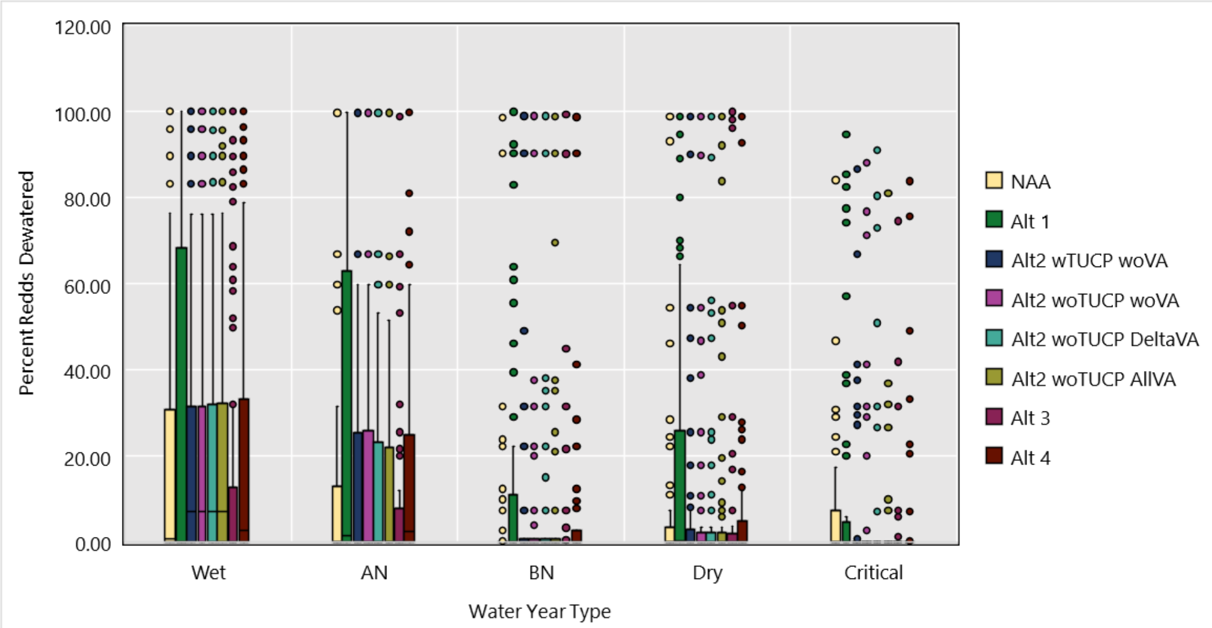

Figure M.1-8. Expected Percent Fall-run Chinook Salmon Redds Dewatered for the American River by Water Year Type, EIS Modeled Scenarios.

M.1.4 References

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