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CALIFORNIA DEPARTMENT OF WATER RESOURCES

BEFORE THE

CALIFORNIA STATE WATER RESOURCES CONTROL BOARD

HEARING IN THE MATTER OF CALIFORNIA DEPARTMENT OF WATER RESOURCES AND UNITED STATES BUREAU OF RECLAMATION REQUEST FOR A CHANGE IN POINT OF DIVERSION FOR CALIFORNIA WATER FIX	TESTIMONY OF RICHARD WILDER

I, Richard Wilder, do hereby declare:

I. INTRODUCTION

I am a Senior Fisheries Biologist employed at ICF. I received a Bachelor of Science in Biology from the University of California at Los Angeles (1994) and a Doctor of Philosophy in Biological Sciences from the University of California at Santa Barbara (2003). I have 14 years of professional experience in California fisheries biology. My experience includes conducting impact analyses of several large and complex water resource management projects on sensitive fisheries resources, conducting original research on threatened and endangered fish species, and participating in the development of several habitat conservation planning efforts in California Central Valley waterways and the San Francisco Bay-Delta Estuary.

I have been involved in the development of the California WaterFix (CWF) and its predecessor, the Bay Delta Conservation Plan (BDCP), since 2007. My duties for the CWF/BDCP have included providing biological expertise on alternatives development and analyzing effects of the alternatives on aquatic resources upstream of the Delta for the Environmental Impact Report/Environmental Impact Statement (EIR/EIS) and Biological Assessment (BA).

Attached as Exhibit DWR-1002 is a true and correct copy of my Statement of Qualifications.

II. OVERVIEW OF TESTIMONY

A. EXECUTIVE-LEVEL OVERVIEW OF CONCLUSIONS

The results presented in this testimony indicate that, overall, upstream effects of CWF on winter-run and spring-run Chinook salmon, CCV steelhead, Green Sturgeon, Lamprey, and non-covered species of primary management concern are expected to be small to insignificant. There are a few upstream changes described here that suggest that physical conditions under the CWF would potentially cause degraded conditions relative to the NAA for these species, although the likelihood that a biological effect would result from the changes in the physical conditions is uncertain .

Upstream changes are primarily a result of reductions in the September and November flows under the PA relative to the NAA, as modeled using CALSIM II. The reason for the difference in CALSIM II results is that the increased operational flexibility available through CWF allows additional export of excess run-off in winter and spring, which reduces reliance on reservoir releases to support exports later in the year (i.e., fall) as compared to the NAA. In general, where there are differences in flows when comparing the NAA and CWF, those differences are limited in timing and magnitude. These modeling outcomes do not reflect the totality of the annual, seasonal, and real-time considerations that would be used to determine how to make reservoir releases in the future. For this reason, and because real-time operations processes will continue to improve CWF implementation, I conclude that CWF is reasonably protective of salmonids upstream of the Delta.

My opinion is corroborated by the NMFS biological opinion (BO) determination that the CWF is not likely to jeopardize the continued existence of winter-run and spring-run Chinook Salmon and CCV Steelhead, and is unlikely to destroy or adversely modify designated critical habitat for these species. The FEIR/S further collaborates my results for both listed and unlisted species, finding that potential effects were less-than-significant.

B. DESCRIPTION OF PROPOSED INITIAL OPERATION

In October 2015, California Department of Water Resources (DWR) and U.S. Bureau of Reclamation (Reclamation) (jointly Petitioners) petitioned the State Water Board for the addition of three new points of diversion on Petitioners' water rights permits. In testimony submitted in Part 1 of this hearing, the project was described as Alternative 4A with initial operational criteria that would fall within a range of operations described as H3 to H4. These operational criteria were described in the Recirculated Draft Environmental Impact Report/Supplemental Draft Environmental Impact Statement (RDEIR/SDEIS). (Exhibit SWRCB-3.) For purposes of Part 2 of the hearing, including this testimony, the Cal WaterFix project is described by Alternative 4A under an operational scenario described as H3+ that is set forth in the Final Environmental Impact Report/Environmental Impact Statement and supplemental information adopted by DWR through the issuance of a Notice of Determination in July 2017 (2017 Certified FEIR). (Collectively Exhibits SWRCB-102, SWRCB-108, SWRCB-109, SWRCB-110, SWRCB-111 and SWRCB-112.) The adopted project is referred to as CWF H3+. Additional information is also referenced in this testimony from documents released prior to July 2017, including the Alternative 4A described in the Final Environmental Impact Report/Environmental Impact Statement (2016 FEIR/S, SWRCB 102), Biological Assessment (SWRCB-104), and the NMFS Biological Opinion (SWRCB-106), referred to herein as the 2016 FEIR/S, BA and the BO respectively. Similarly, after July 2017 the California Department of Fish and Wildlife issued a 2081(b) Incidental Take Permit, which is referred to as the ITP. The interrelationship and use of these terms is further described in the testimony of Ms. Bucholz, DWR-1010.

C. ANALYTICAL APPROACH TO TESTIMONY

My testimony provides the basis for my opinion that the CWF is reasonably protective of upstream fishes. In this testimony, I describe the potential effects of the CWF on aquatic resources upstream of the legal Delta ("upstream effects"). My testimony does not include analyzing fish species within the legal Delta; those are included in Dr. Marin Greenwood's written testimony (DWR-1012). The data and opinions that I present are based on effects analyses and other relevant information included in the CWF 2016 FEIR/S, 2017 Certified FEIR, the BA , the CWF California Endangered Species Act (CESA) ITP Application, the CWF Biological Opinion issued by the National Marine Fisheries Service (NMFS BO), the CWF CESA ITP and associated Findings of Fact under the California Environmental Quality Act (CEQA) and CESA issued by the California Department of Fish and Wildlife (CDFW), and other materials as specifically referenced in my testimony. A majority of the analyses evaluate the potential exposure of a species to upstream effects. Certain analyses also include effects modeling.

The only mechanism by which CWF can affect waterways upstream of the Delta is through changes in CVP and SWP reservoir operations caused by the project. The CWF is only expected to potentially change flows or temperatures in the following rivers: Sacramento, Trinity, American, and Feather Rivers and Clear Creek, and those streams are the focus of this testimony.

Changes to reservoir operations influence instream flows and water temperature in the waterway downstream of the reservoir. Different fish species have adapted their life histories to the flows and water temperatures experienced and are affected differently based on the temporal and spatial overlap between the altered environment and life stages. Therefore, my discussion of testimony will be divided by species or groups of similar species as follows:

- Winter-run and spring-run Chinook Salmon, CCV Steelhead, and fall-run and late fall-run Chinook Salmon;
- Green and White Sturgeon;
- Sacramento Splittail;
- Pacific and River Lamprey;
- Non-covered species of primary management concern (Striped Bass, American Shad, Largemouth Bass, Sacramento Tule Perch, and Threadfin Shad;

- Coldwater reservoir species (of the major CVP and SWP reservoirs in the Sacramento River Basin (plus Trinity Lake in the Trinity River Basin).

For each species or species group, I begin my discussion with the background biology of the species and follow with descriptions of the analyses used to evaluate potential upstream effects and of the results of these analyses. My discussions of two of the species groups, non-covered of primary management concern and coldwater reservoir species, do not include background biology because of the large number of species involved and because the analyses used relies only on basic life history information. However, the discussions of these two species groups do include descriptions of the analyses used and their results. In addition to the background biology provided in this testimony, a full background biology of listed species can be found in Section 2.4 of the NMMF BO pp. 66-87, and of all the species can be found in Appendix 11A in the 2016 FEIR/S. My testimony incorporates by these references the biology contained in these documents.

Effects analyses included in the FEIR/S, BA, ITP Application, and BOs reflect extensive collaboration, review, and feedback provided by NMFS and CDFW, as well as by DWR and the US Bureau of Reclamation. Biological modeling methods used outputs from other models described in Mr. Reyes' testimony (Exhibit DWR-1016), such as CalSim II. Detailed descriptions of the biological models are available in the sources referenced in my testimony, and an overview of the analytical methods and models referenced in my testimony is provided in Section IV of my testimony. In some cases more than one model was used to analyze the same effect, in which case conclusions were reached based on the weight of evidence. It should be noted that, in all the modeling results that I discuss in this testimony, there is limited ability to take into account real-time management decisions based on fine-scale temporal and spatial monitoring of fish occurrence in the Delta.

My testimony discusses the results from several different operations modeling scenarios. When describing the results from the 2016 FEIR/S, I reference the results from modeling of H3 and/or H4. When describing the results from the BA, BOs, and ITP Application, the results are generally referring to the BA H3+ scenario, except as specifically noted. Mr.

Reyes' testimony (Exhibit DWR-1016) summarizes the operational criteria for H3, H4, BA H3+, and CWF H3+. A sensitivity analysis comparing the BA H3+ to CWF H3+ is included in the 2017 Certified FEIR (p.129 to p.155) which, as summarized by Mr. Reyes (Exhibit DWR-1016), shows that the two scenarios are generally similar.

D. SUMMARY OF CONCLUSIONS

Based on the CWF project description, the analysis conducted, and the results, I offer the following opinions regarding effects of CWF on listed fish species and their habitats, upstream of the Delta:[1]

- Cal WaterFix will result in minor changes to upstream flows and habitat suitability for early life stages of listed salmonids; avoidance and minimization measures, conservation measures and recommendations, operational criteria, and real-time operational adjustments will reasonably protect listed salmonids;
- Cal WaterFix will result in minor changes to upstream water temperature conditions for spawning and rearing habitat of listed salmonids; avoidance and minimization measures, conservation measures and recommendations, operational criteria, and real-time operational adjustments will reasonably protect listed salmonids.
- Cal WaterFix related changes in flow and water temperatures are unlikely to have a population level effect on salmonids.
- Cal WaterFix will result in minor changes to upstream flows and habitat suitability for early life stages of Green and White Sturgeon; avoidance and minimization measures, conservation measures and recommendations, and operational criteria will reasonably protect sturgeon.
- Cal WaterFix will result in minor changes to upstream water temperature conditions for spawning and rearing habitat of Green and White Sturgeon; avoidance and

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[1] Throughout my testimony I describe various measures that will be included in the CWF for the protection of fisheries. For those species that are protected by the Endangered Species Act (ESA), the level of protection that I have analyzed is that it must be consistent with the requirements of the ESA, pertinent biological opinions and other applicable requirements, including the Fish and Game Code and Water Code. For those species that are not subject to the ESA, etc., my analysis considers the standard of reasonableness regarding impacts on fish and wildlife.

minimization measures, conservation measures and recommendations, and operational criteria will reasonably protect sturgeon.

- Cal WaterFix will maintain reasonably protective flow and water temperature conditions for upstream spawning, rearing, and migration of Sacramento Splittail.
- Cal WaterFix will maintain reasonably protective flow and water temperature conditions for upstream spawning, rearing, and migration of Pacific and River Lamprey.
- The Cal Water Fix is reasonably protective of non-covered species of primary management concern spawning and egg incubation, juvenile rearing, adult occurrence and adult migration.
- Cal WaterFix is reasonably protective of cold water reservoir species in upstream reservoirs.

III. DISCUSSION OF TESTIMONY

A. Salmonids

My opinions concerning the potential upstream-of-Delta effects of the CWF on salmonids are as follows:

- Cal WaterFix will result in minor changes to upstream flows and habitat suitability for all early life stages of listed salmonids; avoidance and minimization measures, conservation measures and recommendations, and operational criteria will reasonably protect listed salmonids;
- Cal WaterFix will result in minor changes to upstream water temperature conditions for spawning and rearing habitat of listed salmonids; avoidance and minimization measures, conservation measures and recommendations, and operational criteria will reasonably protect listed salmonids.
- Cal WaterFix related changes in flow and water temperatures are unlikely to have a population level effect on salmonids.

The results presented in this testimony indicate that, overall, upstream effects of CWF on winter-run and spring-run Chinook Salmon, and CCV steelhead are expected to be predominantly small to insignificant. There are a few upstream changes described here that suggest that physical conditions under CWF may potentially cause degraded conditions relative to the NAA for these species, although there is considerable uncertainty in the likelihood of a biological effect resulting from the changes in the physical conditions.

Upstream changes are primarily a result of reductions in the September and November flows under CWF relative to the NAA, as modeled using CALSIM II. The reason for the difference in CALSIM II results is that the increased operational flexibility available through CWF allows additional export of excess run-off in winter and spring, which reduces reliance on reservoir releases to support exports later in the year (i.e., fall) as compared to the NAA. In general, where there are differences in flows when comparing the NAA and CWF, those differences are limited in timing and magnitude. These modeling outcomes do not reflect the totality of the annual, seasonal, and real-time considerations that would be used to determine how to make reservoir releases in the future. For this reason, and because real-time operations processes will continue to improve CWF implementation, I conclude that CWF is reasonably protective of salmonids upstream of the Delta.

My opinion is corroborated by the NMFS BO determination that the CWF is not likely to jeopardize the continued existence of winter-run and spring-run Chinook salmon and CCV Steelhead, and is unlikely to destroy or adversely modify designated critical habitat for these species. Specific to upstream effects, the BO found that differences between BA H3+ and NAA in redd dewatering risk, redd scour, and juvenile stranding risk would generally be small and often negligible, aside from occasional slight differences that would cause minimal effects (NMFS BO pp. 904-905; pp. 951-952; pp. 1006-1011).

I provide the following overview of salmonid biology and discussion of analyses assessing upstream effects of CWF on salmonids to support these opinions.

1. <u>Overview of Salmonid Biology</u>

Two species of salmonids, Chinook salmon and California Central Valley (CCV) Steelhead, were evaluated. Chinook salmon consist of four unique races: winter-run, spring-run, fall-run, and late fall-run. The National Marine Fisheries Services (NMFS) identifies three evolutionarily significant units (ESU) of Chinook Salmon in the Central Valley: winter-run, spring-run, and a combined fall-run and late fall-run ESU. Therefore, the analyses presented here typically combined fall-run and late fall-run, although differences between the two races are noted. The general timing of upstream presence varies among CCV Steelhead and each race of Chinook Salmon (Table 1).

Table 1. General Timing of Upstream Salmonid Presence by Life-Stage.

Species	**Adult Immigration**	**Adult Holding**	**Spawning, Egg, Incubation, Alevins**	**Upstream Juvenile Rearing**	**Juvenile Emigration**
Winter-Run Chinook Salmon	Dec – Aug	Jan – Aug	Apr – Oct	Jun – Nov	Jul – Mar
Spring-Run Chinook Salmon	Mar – Sep	Apr – Sep	Aug – Dec	Year-round	Oct – May
Fall-Run Chinook Salmon	Jul – Dec	--	Sep – Jan	Dec – Jun	Dec – Jun
Late Fall-Run Chinook Salmon	Nov – Apr	--	Dec – Jun	Mar – Jul	Year-round
Steelhead	Aug – Mar	Sep – Nov	Nov – Apr	Year-round	Nov – Jun

Salmonid adults migrate upstream and either hold for several months before spawning (winter- and spring-run Chinook Salmon and steelhead) or spawn shortly after arriving upstream (fall- and late fall-run Chinook Salmon). All Chinook salmon die within a few days of spawning (DWR-1116, Reynolds et al. 1993), but steelhead are capable of spawning more than once before death (DWR-1127, Busby et al. 1996) and migrate back to the ocean between spawning events (DWR-1128, Burgner et al 1992), during which time they are often called “kelts”. During spawning of both species, the female digs a nest in gravel, called a “redd”, where she deposits her eggs and a male fertilizes the eggs (Healey 1991; DWR -1120, McEwan and Jackson 1996; DWR 1100, Moyle 2002). Egg incubation duration is temperature-dependent, but is typically between 3 weeks to 2 months (DWR-1116, Reynolds et al. 1993; DWR 1100, Moyle 2002). Newly hatched individuals, called “alevins”, remain in the redd for approximately 4 to 6 weeks (DWR-1116, Reynolds et al. 1993; DWR-1120, McEwan and DWR-1122, Jackson 1996). After leaving the redd as “fry”, the juvenile salmonids rear upstream for varying periods of time, depending on the species or Chinook Salmon ESU and environmental factors, finally emigrating to the ocean as “smolts” (Healey 1991; DWR 1100, Moyle 2002; Quinn 2005).

2. Cal WaterFix will result in minor changes to upstream flows and habitat suitability for all early life states of listed salmonids; avoidance and minimization measures, conservation measures and recommendations, and operational criteria will reasonably protect listed salmonids.

Multiple analytical methods and models were used for the impacts analysis. These methods and models are identified in the text. A more complete description of each tool is provided in Section IV of this testimony, including references to the planning documents and literature sources where more information is available.

a. The FEIR/S found no significant environmental effects to upstream flows and habitat suitability for early life stages of upstream salmonids.

The 2016 FEIR/S examined the potential effects of CWF on the three upstream components of the salmonid life cycle: spawning and egg incubation, fry and juvenile rearing, and migration (both emigration as juveniles and immigration upstream as adults, with an additional emigration analysis for CCV Steelhead kelts).

For each species, ESU (for Chinook Salmon), life stage, and river, the analysis evaluated potential impacts by analyzing changes in: (1) modeled reservoir storage volume, (2) flows, and (3) water temperatures during the months of upstream presence (Table 1). The testimony will discuss these potential impacts on each of the salmonid life stages.

i. The FEIR/S concluded that end of year reservoir storage volume is similar between NAA and H3, H4 and CWF H3+ project scenarios suggesting no major change in future reservoir operations during early salmonid life stages.

This analysis compared the month (either EOM or EOS) that either overlapped or was closest to the occurrence of each life stage of salmonid to estimate changes in reservoir releases during the early life stages of salmonids.

Modeled reservoir storage levels at the end of May (EOM) and end of September (EOS) were used to evaluate potential effects to upstream aquatic species, as these are metrics commonly used by the Petitioners and resource agencies to evaluate water supply and the flexibility to provide water to meet demands and regulatory requirements for the several months following May or September. In addition, EOS storage volume is used as a metric for evaluating carryover storage for the following year's cold water pool. Reservoir storage volume was modeled at a monthly time step over an 82-year hydrologic period (1922-1983) using CalSim II (See, DWR-71 for a full description of CalSim II).

Model results indicate that both EOM and EOS storage volumes in the Sacramento, Trinity, Feather, and American Rivers would be similar between the NAA and either H3 or H4 for all life stages of steelhead and all Chinook Salmon ESUs for all reservoirs.[2] Subsequent comparisons conducted as part of a sensitivity analysis indicate that EOM and EOS storage volumes under CWF H3+ NOD are also similar to those under the NAA (2017 Certified FEIR/S, p. 131).

ii. <u>The FEIR/S concluded that CWF would result in no significant flow related effects on early life states of salmonids.</u>

Three tools were used to evaluate flow-related effects of the project on salmonids: 1.) modeled mean flow rate comparisons, 2.) the Sacramento Ecological Flow Tool (SacEFT), and 3.) SALMOD. Modeled mean monthly flow rates from CalSim II for the No Action Alternative (NAA) and the project (Scenarios H3, H4, and BA H3+) were compared for all salmonid life stages present in the Sacramento, Feather, American, and Trinity Rivers and Clear Creek. SacEFT models the effects of changing water operations on the physical habitat components of salmonids and green sturgeon in the Sacramento River (DWR-1125, ESSA Technologies Ltd. 2011). SALMOD evaluates flow- and temperature-related mortality of early life stages (from eggs to juveniles) of Chinook Salmon in the Sacramento River to Red Bluff based on the quality and quantity of physical habitat. See Section IV, Analytical Methods and Models, for descriptions of SacEFT and SALMOD.

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[2] 2016 FEIR/S: p.11-3220, Table 11-4A-11; p. 11-3225; Table 11-4A-18; p. 11-3251, Table 11-4A-25; p. 11-3256, Table 11-4A-31; p. 11-3259, Table 11-4A-34; p. 11-3261, Table 11-4A-37; p. 11-3269, Table 11-4A-40; p. 11-3272, Table 11-4A-43.)

Because the direction of a change in flow rate is not always indicative of the direction of the effect on the species (i.e., flow increases may be beneficial or harmful to a species; DWR-1139, Vogel 2011), the analysis of mean monthly or mean daily modeled flow rate was less preferred than SacEFT and SALMOD. When neither SacEFT nor SALMOD was available, the analysis relied only on the comparison of mean flows. In these cases, it was assumed that increases in flow would benefit a species and decreases in flow would negatively affect the species. It is important to note that this is a conservative assumption; although this assumption is often true, it is not universally true.

(a) Modeled mean monthly flow rates are similar between NAA and H3, H4 and 2016 FEIR/S H3+ project scenarios.

The flow rates comparison found that most changes to flow rates in all rivers would not be of sufficient magnitude or frequency to cause biologically meaningful[3] effects to spawning, rearing, or migration of CCV Steelhead and all races of Chinook Salmon.[4] Reductions in mean flow rates from the NAA to either H3 or H4 were <~5% in the preponderance of months and water year types in which the life stage was present. An evaluation of differences between NAA and 2016 FEIR/S H3+ reveals that there would be smaller and fewer differences between NAA and 2016 FEIR/S H3+ compared to H3 or H4.[5]

In the Sacramento River at Keswick and Red Bluff, about 9% of all 120 combinations of months and water year types at the two locations had a mean flow rate **reductions** between NAA and 2016 FEIR/S H3+ of >5%, and about 11% had mean flow **increases** of >5%.[6] The greatest reduction in mean flows at these locations under 2016 FEIR/S H3+ is up to 26% in November. In the Feather River high flow channel about 18% of all 60 combinations of months and water year types had a mean flow rate **reduction** between NAA and 2016 FEIR/S H3+ of

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[3] "Biologically meaningful" is defined as having a substantial biological effect on a species to the point that it will affect the species at a population level. This determination was made using best professional judgment in lieu of a life cycle model for all species except winter-run Chinook salmon.

[4] 2016 FEIR/S, Appendix 11C, Section 11C.11.1; pp. IIC-772 to 11C-774, Table 2; pp.11C-778 to 11C-780,Table 4. See "H3_REIR Effect", "H4_REIR Effect".

[5] 2016 FEIR/S, Appendix 11C, Section 11C.11.1; pp. IIC-772 to 11C-774, Table 2; pp.11C-778 to 11C-780,Table 4.. See "H3_REIR Effect", "H4_REIR Effect", and "2015 Effect" columns.

[6] 2016 FEIR/S, Appendix 11C, Section 11C.11.1; pp. IIC-772 to 11C-774, Table 2; pp.11C-778 to 11C-780,Table 4. See "2015 Effect" column.

>5%, and about 28% had mean flow **increases** of >5%.[7] The greatest reductions in mean flows in the Feather River under 2016 FEIR/S H3+, up to 35%, were in September In the lower American River at the Sacramento River confluence, about 22% of all 60 combinations of months and water year types had a mean flow rate **reduction** between NAA and 2016 FEIR/S H3+ of >5%, and about 18% had mean flow **increases** of >5%.[8] The greatest reductions in mean flows at this location under 2016 FEIR/S H3+, up to 14%, were in August and November.

Although the reductions in flow overlap with the presence of several salmonid life stages (see Table 1, above), the magnitude and frequency of the differences between NAA and 2016 FEIR/S H3+ was not substantial given the similarity of results. The reductions are generally low magnitude (usually less than ~10%) and occur infrequently (primarily in one month of the year) such that they would affect a small proportion of the population. There are also a number of mean flow rates increases between NAA and 2016 FEIR/S H3+ scenarios indicating improved conditions. Therefore, I conclude that no significant effects of 2016 FEIR/S H3+ were observed in any river for any upstream salmonid life stage based on comparisons of mean monthly flows.

(b) <u>The SALMOD model predicts negligible differences in early life stage mortality between NAA and H3.</u>

SALMOD was conducted for H3 and NAA. The model predicts that there would be negligible differences (1-3%) in flow-related mortality between NAA and H3 for all Chinook salmon races, except winter-run, for which there would be a 7% reduction in flow-related mortality and could represent a very small benefit of H3 (2016 FEIR/S , Chapter 11, p. 11-3231; p. 11-3269; p.11-3325; p. 11-3326). Therefore, SALMOD predicts that CWF scenario H3, which provides lower spring outflows than CWF H3+, would not results in significant flow and temperature related mortality of salmonids.

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[7] 2016 FEIR/S, Appendix 11C, Section 11C.11.1, pp. IIC-806 to 11C-808,Table 16. See “2015 Effect” column.
[8] 2016 FEIR/S, Appendix 11C, Section 11C.11.1. pp. IIC-806 to 11C-808, Table 16. See “2015 Effect” column.

(c) SacEFT shows no flow related effects on juvenile rearing habitat availability, red scour risk, or red dewatering risk for Chinook Salmon between NAA and H3.

SacEFT assessed effects of H3 relative to the NAA. The results indicate that there would be no flow-related effects of H3 on juvenile rearing habitat availability, redd scour risk, or redd dewatering risk for winter-run Chinook Salmon, but there would be modest negative effects of H3 on the percent of years with good conditions for spawning habitat availability (9% reduction relative to NAA) and juvenile stranding risk (20% reduction relative to NAA (2016 FEIR/S, p. 11-3225, Table 11-4A-17). There would be no negative flow-related effects of H3 on spawning or juvenile rearing habitat availability, redd dewatering risk, and juvenile stranding risk for spring- and fall-Run Chinook Salmon, but there would be modest negative effects of H3 on the percent of years with good conditions for redd scour risk (2016 FEIR/FEIS, p. 11-3254, Table 11-4A-28; p. 11-3297, Table 11-4A-52 and 11-4A-53).

These SacEFT results indicate more negative effects of H3, especially for winter-run Chinook Salmon, than indicated by SALMOD results, as well as by the assessments of CalSim II flow and reservoir storage outputs. After an investigation of these modeling results, it was concluded that SacEFT is highly sensitive to relatively small changes in estimated upstream flows (2016 FEIR/FEIS, page 11-3228, Impact AQUA-40). It is also important to note that SacEFT made assumptions that may be refined further in the future. Regardless, when the flow-related effects of H3 on all early life stage effects are rolled up in SALMOD, which SacEFT cannot do, the overall effect of H3 to Chinook Salmon would be negligible.

The results of the FEIR/S indicate that, overall, the CWF effects on flow would not adversely affect any of the life stages of steelhead or any of the Chinook Salmon ESUs in any of the rivers upstream of the Delta. These conclusions are consistent with the NMFS BO.

iii. The NMFS BO concluded that CWF would not jeopardize the species as flow related effects on early life stage salmonids would be minor.[9]

The analyses used in the NMFS BO to evaluate potential effects of CWF on salmonids were different from those in the FEIR/FEIS in two ways:

The BO evaluated potential effects in the Sacramento and American Rivers only. A preliminary multi-agency screening analysis, as described in Section 2.5.1.2 of the NMFS BO, concluded that potential changes to instream flows would be limited to the Sacramento, American, and Feather Rivers; and SacEFT was not used as an analytical tool in the BO. Instead, separate analyses were conducted for each biological parameter that SacEFT evaluates that NMFS, CDFW, DWR and I felt were more indicative of the biology of the species.

Spawning and rearing habitat availability in the Sacramento River for CCV Steelhead and all races of Chinook Salmon were calculated as described in this testimony in Section IV, Analytical Methods and Models, Flow vs. Suitable Habitat Availability Studies.

(a) The flow-habitat analysis shows that BA H3+ will result in minimal changes in spawning habitat availability in most months.

The results of the flow-habitat availability curve analysis for spawning habitat indicate that there were minimal reductions (<~5%) in suitable spawning habitat availability in most months and river reaches for all salmonid species and Chinook Salmon races.[10] There are a

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[9] Potential take of winter-run Chinook salmon by the PP that occurs upstream of the Delta was not evaluated in the ITP Take Analysis because all such take is attributable to the operation of facilities that: 1) are federally owned and operated or 2) in the case of the Oroville Complex, is evaluated in a separate and ongoing NMFS consultation related to FERC licensing. Effects of the operations of Shasta Dam, which is under USBR jurisdiction, on winter-run Chinook Salmon in the Sacramento River are analyzed in the Effects Analysis in Section 4.3.4.2 Upstream Hydrologic Changes. Effects of Folsom Dam, which is also under USBR jurisdiction, are not evaluated in this application because winter-run Chinook salmon do not occur in the American River. All construction related activities of the PP will occur in the Delta.

[10] BA Chapter 5, pp. 5-229 to 5-237, Figure 5.4-34 through Figure 5.4-51; p. 5-202 to 5-203, Table 5.4-31 through Table 5.4-32, spring-run (BA Chapter 5, pp. 5-305 to 314, Figure 5.4-113 through Figure 5.4-130; pp. 5-315 to 5-317, Table 5.4-48 through Table 5.4-50); fall-run Sacramento River (BA Appendix 5.E, p.5.E-117 to 5.E-131, Figure 5.E-48 through Figure 5.E-77; p. 132 to 5.E-136, Table 5.E-28 through Table 5.E-32); American River (BA Appendix 5.E, p. 5.E-273 to 5.E-275, Figure 5.E-241 through Figure 5.E-246; p. 5.E-276, Table 5.E-65); late fall-run (BA Appendix 5.E, p. 5.E-198 to 5.E-207, Figure 5.E-150 through Figure 5.E-167; p. 5.E-208 to 5.E-210, Table 5.E-48 through Table 5.E-50); and steelhead Sacramento River (BA Chapter 5, pp. 5-378 to 5-386, Figure 5.4-184 through Figure 5.4-201; pp. 5-387 to 5-389, Table 5.4-64 through Table 5.4-66); American River (BA Chapter 5, p. 5-468 to 5-470, Figure 5.4-252 through Figure 5.4-25, and p. 5-471, Table 5.4-78.

few limited exceptions where the modeling results suggest a larger change, although these exceptions are infrequent and geographically limited. The analysis predicts that one reach of the Sacramento River (from Keswick Dam to Anderson Colusa Irrigation District Dam) would have up to 12% less suitable spawning habitat availability for winter-run Chinook Salmon during September in drier years (BA Chapter 5, p.5-238, Table 5.4-31), one reach of the Sacramento River (from Cow Creek to Battle Creek) would have up to 13% less suitable spawning habitat availability for spring-run Chinook Salmon (BA Chapter 5, p.5-317, Table 5.4-50) and fall-run Chinook Salmon (BA Chapter 5, p.5.E-76,Table 5.E-30) during October of below normal water years, and two reaches (Anderson Colusa Irrigation District Dam to Cow Creek and Cow Creek to Battle Creek) would have up to 9% less suitable spawning habitat availability for late fall-run Chinook salmon in most water years during June. (BA, p. 5.E-117 to 5.E-118, Table 5.E-49 and Table 5.E-50).

Regardless of some flow-related effects described in this section, the CWF would have minimal effects to flows overall. The CWF has improved operational flexibility to use real-time management to minimize and avoid the effects indicated by model outputs.

(b) The flow-habitat analysis shows that BA H3+ will result in minimal changes in rearing habitat availability in most months.

The results of the flow-habitat availability curve analysis for rearing habitat indicate that there were also minimal reductions (<~5%) in suitable rearing habitat availability in most months and river reaches for all salmonid species and Chinook Salmon runs.[11] There are a few limited exceptions where the modeling results suggest a larger change, although these exceptions are infrequent and geographically limited. The analysis predicts that one reach of the Sacramento River (from Cow Creek to Battle Creek) would have up to 13% less suitable juvenile rearing habitat availability for spring-run Chinook Salmon (BA, Chapter 5, Table 5.4-

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[11] BA, Chapter 5, p. 5-265 to 5-287, Figure 5.4-72 through Figure 5.4-107; p. 5-232 to 5-234, Table 5.4-40 through Table 5.4-45; spring-run Chinook salmon (BA Chapter 5, p. 5-336 to 5-354, Figure 5.4-145 through Figure 5.4-180, p. 5-355 to 361, Table 5.4-56 through Table 5.4-61); fall-run Chinook salmon (BA Appendix 5.E, p. 5.E-161 to 5.E-178, Figure 5.E-107 through Figure 5.E-142, p. 5.E-179 to 5.E-184, Table 5.E-39 through Table 5.E-44); late fall-run Chinook Salmon (BA Appendix 5.E, p. 5.E-236 to 5.E-254, Figure 5.E-198 through Figure 5.E-233, p. 5.E-255 to 5.E-258, Table 5.E-56 through Table 5.E-61); and steelhead (BA Chapter 5, p. 5-406 to 5-423, Figure 5.4-210 through Figure 5.4-245, p. 5-424 to 5-431, Table 5.4-70 through Table 5.4-75).

61), fall-run Chinook Salmon (BA Chapter 5, p. 5-234, Table 5.4-44), and late fall-run Chinook Salmon (BA Chapter 5, p. 5-253, Table 5.4-61) during June in dry and critical water years.

Regardless of some flow-related effects described in this section, the CWF would have minimal effects to flows overall. The CWF has improved operational flexibility to use real-time management to minimize and avoid the effects indicated by model outputs.

(c) __The analysis shows that BA H3+ will result in minimal changes in red dewatering risk in most months.__

The analysis shows that CWF would result in minimal changes to redd dewatering risk. Redd dewatering risk for Chinook Salmon ESUs and CCV Steelhead was evaluated as described in Section IV, Analytical Methods and Models, Redd Dewatering Risk.

The results of the analysis for the Sacramento River indicates that redd dewatering risk would be similar (<5% difference) between NAA and BA H3+ for most months and water year types for all runs of Chinook Salmon and steelhead.[12] However, the analysis also predicts that there would be somewhat larger increases in dewatering risk in below normal, dry, and critical water years during June for winter-run Chinook salmon (5.3% to 6.8% increase in risk under BA H3+), above normal years during August and below normal years during October for spring-run Chinook Salmon (8% and 6% increase in risk under BA H3+), below normal water years during October for fall-run Chinook salmon (6.3% increase in risk under BA H3+ compared to NAA), and above normal water years during August for CCV Steelhead (6.3% increase in risk under BA H3+). In the American River, redd dewatering risk, as estimated using maximum flow reduction, would be similar between NAA and BA H3+ for most months of the fall-run Chinook Salmon and steelhead[13] spawning periods, except for critical water years during October for fall-run Chinook Salmon (5.7% increased risk under H3+), and critical water

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[12] winter-run Chinook salmon (BA Chapter 5, p. 5-244 to 5-246, Figure 5.4-52 through Figure 5.4-57; p. 5-247, Table 5.4-37), spring-run Chinook salmon (BA Chapter 5, p. 5-320 to 5-332, Figure 5.4-131 through 5.4-136, p. 5-398, Table 5.4-33), fall-run Chinook salmon (BA Appendix 5.E, p. 5.E-138 to 5.E-147, Figure 5.E-78 through 5.D-95; p. 5.E-147 to 5.E-149, Table 5.E-34 through 5.E-36), late fall-run Chinook salmon (BA Appendix 5.E, p. 5.E-212 to 5.E-220, Figure 5.4-168 through Figure 5.4-185, p. 5.E-221 to 5.E-223, Table 5.E-51 through Table 5.4-53), and CCV Steelhead (BA Chapter 5, p. 5-395 to 5-397, Figure 5.4-202 through Figure 5.4-207; p. 398, Table 5.4-69).

[13] Fall-run BA Appendix 5.E, p. 5.E-278 to 5.E-280, Figure 5.E-247 through Figure 5.E-252, p. 5.E-281, Table 5.E-66, and steelhead (BA Chapter 5, p. 5-473, Figure 5.4-258 through Figure 5.4-263, p. 5-269, Table 5.4-80)

years during January (5% larger reduction under BA H3+ compared to NAA) and below normal and critical water years during February (6% and 7% larger reductions, respectively) for CCV Steelhead.

All of the >5% increases in dewatering risk exceed 5% by very little and so are unlikely to have a large effect on the salmonids populations. Furthermore, most are a result of the lower Shasta releases in September and November under BA H3+ relative to the NAA, and it is unlikely that the same dewatering risks would occur during future operations because Sacramento River flows in September would likely be sustained at similar levels as the NAA to meet upstream cold water pool requirements (BA, Section 3.4.2.3. Summary of Upstream Effects, pp. 5-493 to 5-495).

(d) The analysis shows that BA H3+ will result in minimal changes in red sour risk in most months.

The analysis shows that CWF would result in minimal changes to red sour risk. Redd scour risk in the Sacramento and American Rivers was evaluated as described in Section IV, Analytical Methods and Models, Redd Scour Risk.

Results of this analysis (BA Chapter 5, p. 5-472, Table 5.4-79; BA Appendix 5.E, p. 5.E-83, Table 5.E-33) indicate that redd scour risk would mostly be similar (<~1% difference between NAA and BA H3+ in frequency of exceedance above all flow thresholds) for all races of Chinook salmon and CCV Steelhead in the Sacramento and American Rivers.

No quantitative juvenile stranding analysis was conducted in the NMFS BO because CALSIM modeling used to evaluate flow in this effects analysis has a monthly time step, which is too long for any meaningful analysis of juvenile stranding. Instead, the NMFS BO explains that current or future ramping rates[14] will be maintained regardless of whether the CWF is implemented. The BO concludes, therefore, that juvenile stranding risk is unlikely to increase under BA H3+ and that there will be minimal stranding effects under BA H3+ (NMFS BO, pp. 568-571).

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[14] Ramping rate is the rate of change (increase or decrease) in water release rate at a reservoir

Regardless of some flow-related effects described in this section, the CWF would have minimal effects to flows overall. The CWF has improved operational flexibility to use real-time management to minimize the effects indicated by model outputs. Real-time decision making will consider the recommendations from many of the decision-making/advisory teams, including a new team, the real time operations coordination team (RTOCT), which will assist DWR and Reclamation in informing the SWP and CVP participants regarding available information and real-time decisions (NMFS BO, p. 15, Section 1.3.1.5, Real-time Operations).

3. Cal WaterFix will result in minor changes to upstream water temperature conditions for spawning and rearing habitat of listed salmonids; avoidance and minimization measures, conservation measures and recommendations, and operational criteria will reasonably protect listed salmonids

Multiple analytical methods and models were used for the impacts analysis. These methods and models are identified in the text. A more complete description of each tool is provided in Section IV of this testimony, including references to the planning documents and literature sources where more information is available.

a. The FEIR/S found no significant temperature related effects.

The FEIR/S analysis of potential water temperature-related effects to Chinook Salmon and CV Steelhead spawning and egg incubation consisted of four different analyses: (1) a “mean monthly water temperature” comparison; (2) a “Level of Concern” analysis in the Sacramento River (not used for CCV Steelhead); (3) a “percentage of months exceeding 56°F threshold” analysis (not used in the Sacramento River); and (4) a “Degree-Day/Degree-Month” analysis in the Sacramento, Feather, and American Rivers.

i. The FEIR/S identified only minor changes in mean monthly water temperatures between NAA and H3 and H4 scenarios.

The mean monthly water temperature analysis compared mean monthly water temperatures between NAA and H3 and H4 during the salmonid spawning periods in the principal spawning reaches within the Sacramento, Feather, and American Rivers. The analysis indicates that there would be no increase >~5% in mean monthly water temperatures under H3 or H4 compared to NAA in any of the rivers, except for a 7% increase in August of critical water years in the Sacramento River at Keswick.[15] The CALSIM modeling used for this analysis assumed a change in Shasta Reservoir release patterns between May and September compared to NAA, which is what drives the Sacramento River increase in temperatures later in the summer. In reality, Shasta reservoir would not be operated differently from NAA and, by using real time operations and adaptive management, temperatures under H3 and H4 are expected to be similar to those under NAA.

ii. **<u>The FEIR/S identified only minor changes in water temperature "level of concern" days between NAA and H3 and H4 scenarios.</u>**

The "Level of Concern" analysis evaluated number of days when temperatures in the Sacramento River exceeded Chinook Salmon temperature thresholds (2016 FEIR/S, p.11-3221, Table 11-45A-12) by >0.5°F to >5°F in 0.5°F increments by month for the 82-year CalSim II period of analysis. The combination of number of days and degrees above the threshold was then summed for each month and further assigned a "level of concern" (decreasing from red to orange to yellow). A more detailed description of this analysis is provided in Section IV, Analytical Methods and Models, Water Temperature Level of Concern Analysis.

The results of this analysis indicate that there was a 4-year increase (5% of 82 years) under H3 compared to the NAA in the red level of concern for the winter-run Chinook Salmon spawning period (2016 FEIR/S, Chapter 11, Table 11-4A-14, p. 11-3222). This differences would not be biologically meaningful to winter-run Chinook salmon spawners and eggs as the 4 years constitute a small proportion of the 82 year period used for this analysis, as long as the years were not consecutive, which they were not in this case. If multiple years of drought occur in the future, DWR and Reclamation would work in close coordination with regulatory agencies to manage reservoir operations to avoid negative impacts to fish, as is currently being done.

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[15] 2016 FEIR/S Appendix 11D, Sections 11.D.10.1 to 11D.10.4, pp. 11D-758 to 11D-773; Section 11.D.10.9 to 11.D.10.11, pp. 11D-790 to 11D-801; Section 11D.10.16, p.11D-818 to 11D-821)

The results for the other comparisons had no more than a 1 year increase for any of the three levels of concern.[16] It is my opinion that these results indicate negligible effects to Chinook Salmon and spawning and egg incubation.

iii. <u>The FEIR/S identified only minor changes in the percent exceedance analysis between NAA and H3 and H4 scenarios.</u>

The "Percent Exceedance" analysis for salmonids evaluated the percent of months in which water temperatures exceeded thresholds provided by NMFS for spawning and egg incubation or rearing by the following increments: >1°F, >2°F, >3°F, >4°F, and >5°F. A more detailed description of this analysis is provided in Section III.G, Analytical Methods and Models, Water Temperature Percent Exceedance Analysis.

The results indicate that the frequency of exceedances would increase above the temperature threshold, with the five increments added, up to 11% (absolute difference) under H3 or H4 in the Feather above the Thermalito Afterbay and the American River at Watt Avenue (2016 FEIR/S, Chapter 11, p. 11-3257, Table 11-4A-32; and p. 11-3386, Table 11-4A-81). The frequency of exceedances would **decrease** up to 20% in the Feather River at Gridley (absolute difference (2016 FEIR/S, Chapter 11, p.11-3311, Table 11-4A-66,). Most of the other frequency of exceedances differed by <5% between the NAA and H3 or H4.[17]

iv. <u>The FEIR/S identified only minor changes in water temperature "degree-day/degree month" between NAA and H3 and H4 scenarios.</u>

The "Degree-Day/Degree-Month" analysis focused on the magnitude and frequency of exceedance above the temperature thresholds provided by NMFS (2016 FEIR/S, Chapter 11, p.11-373, Table 11-1A-13). A more detailed description of this analysis is provided in Section IV, Analytical Methods and Models, Degree-Day/Degree-Month Analysis.

The results for the Sacramento River at Bend Bridge under H3 show a 9% increase for all water years combined during September (2016 FEIR/S, p. 11-3223, Table 11-4A-15).

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[16] 2016 FEIR/S, Chapter 11, Table 11-4A-19, p. 11-3226; Table 11-4A-26, p. 11-3252; Table 11-4A-35, p. 11-3259; Table 11-4A-64, p. 11-3308.

[17] 2016 FEIR/S, p. 11-3262, Table 11-4A-38; p. 11-3270, Table 11-4A-41; p. 11-3273, Table 11-4A-44; p. 11-3301, Table 11-4A-57,; p. 11-3305, Table 11-4A-61, p. 11-3311, Table 11-4A-66; , p. 11-3314, Table 11-4A-68; p. 11-3370, Table 11-4A-76; p. 11-3374, Table 11-4A-78; p. 11-3386Table 11-4A-81.

However, the CALSIM modeling used for this analysis assumed a change in release patterns between May and September compared to NAA that is driving this increase in temperatures later in the summer. In reality, Shasta reservoir would not be operated differently from the NAA, using real time operations and adaptive management, and temperatures are expected to be similar to those under the NAA. The results for the Sacramento River at Red Bluff under H3 show a 19% increase for all water years combined during March (2016 FEIR/S, p. 11-3253, Table 11-4A-27). For this result, and most other results with large percent difference between H3 andH4 and the NAA, the large differences are mathematical artifacts due to small values of degree-days or degree months for NAA. Such differences do not translate into biologically meaningful effects on the salmonids.

The results for the Feather River above Thermalito Afterbay during September through November (2016 FEIR/S, p. 11-3263, Table 11.4A-39,) show larger increases in both the number of degree-months (up to 48 degree-months) and the percentages (up to 47%). However, this increase would have little effect on spring-run Chinook Salmon spawning and egg incubation in the Feather River during these months because an increase of 48 degree-months would not be biologically meaningful, given the 82-year period of analysis (2016 FEIR/S, p. 11-3262). The large percentage increase, as noted above, is an artifact.

Combined, the results from the four analyses conducted consistently indicate that temperature-related effects to the Chinook Salmon ESUs and CCV Steelhead spawning and egg incubation and rearing would be minimal and, therefore, it is my opinion that the CWF is reasonably protective of the egg, larval, and juvenile life stage with respect to water temperature.

b. **The NMFS BO concluded that minor changes in water temperatures would not result in jeopardy or adverse modification of critical habitat.**[18]

The BA and BO analyzed temperature related effects to salmonids principally by comparing the magnitude and frequency of temperature threshold exceedances between BA H3+ and NAA (BA, Chapter 5, Section 5.4.2.1.3.1.1.2, pp. 5-254). A detailed description of threshold criteria used for this analysis is provided in Section IV, Analytical Methods and Models, Water Temperature Threshold Exceedance Analysis,

The results indicate that, for most comparisons of the magnitude and frequency of temperature threshold exceedance between the NAA and BA H3+, the differences are small and not biologically meaningful (BA, Appendix 5D, pp. 5.D-320 to 5.D-419, Table 5.D-63 to Table 5.D-146). However, the results show an increased frequency under BA H3+ relative to the NAA of exceedance of water temperature thresholds for rearing winter- run and spring-run Chinook Salmon during September in the Sacramento River from Keswick to Red Bluff, especially Bend Bridge and Red Bluff in below normal water years, as well as an increased frequency of exceedance of water temperature thresholds for spawning winter-run and spring-run Chinook Salmon during August and September (and into October) in the Sacramento River from Clear Creek to Bend Bridge.[19]

The increases in the modeled frequency of water temperature threshold exceedances noted above would be biologically meaningful if they reflected actual conditions in the Sacramento River. However, the increases likely result primarily from reduced Shasta releases associated with BA H3+ operational modeling. Modeling of the coldwater pool volume, which is more indicative of temperature management, suggests the BA H3+ end-of-September (EOS)

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[18] Potential take of winter-run Chinook Salmon by the PP that occurs upstream of the Delta was not evaluated in the ITP Take Analysis because all such take is attributable to the operation of facilities that: 1) are federally owned and operated or 2) in the case of the Oroville Complex, is evaluated in a separate and ongoing NMFS consultation related to FERC licensing. Effects of the operations of Shasta Dam, which is under USBR jurisdiction, on winter-run Chinook Salmon in the Sacramento River are analyzed in the Effects Analysis in Section 4.3.4.2 Upstream Hydrologic Changes. Effects of Folsom Dam, which is also under USBR jurisdiction, are not evaluated in this application because winter-run Chinook Salmon do not occur in the American River. All construction related activities of the PP will occur in the Delta.

[19] BA, Appendix 5D, Section 5.D.2.5.1, pp. 5.D-325 to 5.D-329, Table 5.D-68 to Table 5.D-72; pp. 5.D-321 to 5.D-323,Table 5.D-64 to Table5.D-66; pp. 5.D-342 to 5.D-351Table 5.D-85 to Table 5.D-89; pp. 5.D-338 to 5.D-340,Table 5.D-81 to Table 5.D-83.

storage similar to that of the NAA (BA Appendix 5.C, Table 5.C.7.21-1, *Shasta Cold Water Pool Volume*). If real-time cold water pool management efforts under BA H3+ use a similar process as currently utilized (i.e. NAA), then releases from Shasta Lake under BA H3+ would actually be sustained at similar levels as the NAA during September. Thus, it is likely that BA H3+ would not experience higher water temperatures relative to the NAA during September, as was modeled in this analysis. None of the water temperature model results presented in the BA Appendix 5D, consider the real-time operational management described in BA Section 3.1.5, Real-Time Operations Upstream of the Delta, and Section 3.3.3, Real-Time Operational Decision-Making Process, that would be used to avoid and minimize any modeled effects (see Aaron Miller's testimony, DWR-1011).

Considering the small differences observed in model outputs, as well as real-time operations and current modifications to the OCAP RPA, it is my opinion that the CWF is reasonably protective of the salmonids' egg, larval, and juvenile life stages with respect to water temperature. (See BA, Section 5.4.2.3, Summary of Upstream Effects, pp. 5-493 to 5.495.)

c. Cal WaterFix related changes in flow and water temperatures are unlikely to have a population level effect on salmonids.

A life cycle model is an effective way to evaluate the combined effects of all potential changes of a project to a species. Descriptions of the life cycle models used in the BA are provided in Section IV, Analytical Methods and Models.

Two winter-run Chinook salmon lifecycle models, Interactive Object-Oriented Simulation Model (IOS; BA: Appendix 5D, Section 5.D.3.1, page 5.D-486) and the Southwest Fisheries Science Centers Winter-run Chinook Life Cycle Model (WRLCM; BO Appendix H), were used to evaluate effects of the BA H3+ scenario on population abundance, cohort replacement rate, habitat use distribution, and juvenile survival.

Both life cycle models indicate that adverse upstream-of-Delta effects to winter-run Chinook salmon eggs and fry would be negligible (IOS: BA Appendix 5-D, Quantitative Methods, p. 5.D-413 to 5.D-418, Figure 5.D-140 through Figure 5.D-145; NMFS BO, p. 803,

Figure 2-180 (WRLCM)). It is my opinion that the CWF is reasonably protective of listed salmonids. The FEIR/S, BA, and BO collaborate my opinion.

B. Green and White Sturgeon

My opinions concerning the potential upstream-of-Delta effects of the CWF on Green and White Sturgeon are as follows:

- Cal WaterFix will result in minor changes to upstream flows and habitat suitability for all early life stages of Green and White Sturgeon; avoidance and minimization measures, conservation measures and recommendations, and operational criteria will reasonably protect sturgeon.
- Cal WaterFix will result in minor changes to upstream water temperature conditions for spawning and rearing habitat of Green and White Sturgeon; avoidance and minimization measures, conservation measures and recommendations, and operational criteria will reasonably protect sturgeon.

Overall, based on the analysis of effects, it is my opinion that the CWF H3+ is reasonably protective of Green and White Sturgeon in upstream waterways. The analysis indicates that there would be minimal effects in the preponderance of months and water year types. The larger effects seen in the results are not frequent or large enough to affect more than a small fraction of the population of either White or Green Sturgeon and, therefore, would not cause biologically meaningful effects on either species.

1. Overview of Biology

The Southern DPS of the North American Green Sturgeon (Green Sturgeon) is listed as threatened under the ESA and listed as a Species of Special Concern under the CESA. The White Sturgeon is not listed under either the ESA or CESA.

Both Green and White Sturgeon are long-lived (up to 60-70 year for Green Sturgeon and over 100 years for White Sturgeon) and late maturing (sexual maturity is reached at 10 to 16 years depending on species and gender (DWR-1114 and DWR-1115, Crossman and Scott 1973; DWR-1100, Moyle 2002; DWR-1103, Van Eenennaam *et al*. 2006). Individuals spend the majority of their adult lives in brackish water or ocean, moving upstream of the Delta only to spawn and rear as juveniles, after which they return to brackish water or the ocean (DWR-1100, Moyle 2002). Green Sturgeon likely spawn every 3 to 4 years (DWR-1117, NFMS 2015), whereas White Sturgeon males spawn every 1 to 2 years and females spawn every 2 to 4 years (NMFS-1100, Moyle 2002). Both species are broadcast spawners over gravel or cobble substrate in deeper pools (DWR-1130, Beamesderfer et al. 2004; DWR-1100, Moyle 2002). For Green Sturgeon, upstream migration occurs from approximately February through June and spawning occurs from approximately March through July (DWR-1100, Moyle 2002). For White Sturgeon, upstream migration occurs from approximately November through May and spawning occurs from approximately February through June (DWR-1100, Moyle 2002). Both Green and White Sturgeon spawn primarily in the Sacramento River, although there is evidence of some spawning in the Feather River (DWR-1112, Shaffter 1997; DWR-1100, Moyle 2002; DWR-1113, Seesholtz et al. 2015; DWR-1122, Jackson et al. 2016). Green Sturgeon larvae and juveniles rear in freshwater for up to 2 years before emigrating to the lower estuary and ocean (DWR-1100, Moyle 2002), but nearly all individuals move downstream of Red Bluff Diversion Dam by October (DWR-1133, Poytress et al. 2014). White Sturgeon actively migrate downstream into the lower river as young of year but are not known to enter brackish water until after 1 year (DWR-1100, Moyle 2002).

A full background biology of Green Sturgeon can be found in Section 2.4 of the NMFS BO, pp. 66-87 and of both Green and White Sturgeon in Appendix 11A in the 2016 FEIR/S. My testimony incorporates by these references the biology contained in these documents.

For Green and White Sturgeon, the 2016 FEIR/S analyzes spawning, rearing and migration habitat upstream of the Delta using several methods similar to those used to evaluate salmonids, including comparisons of flow and water temperatures (Green Sturgeon: 2016 FEIR/S pp. 11-3448 to 11-3469; White Sturgeon: pp. 11-3475 to 11-3491), which are detailed here.

2. Cal WaterFix will result in minor changes to upstream flows and habitat suitability for all early life stages of Green and White Sturgeon; avoidance and minimization measures, conservation measures and recommendations, and operational criteria will reasonably protect sturgeon

Multiple analytical methods and models were used for the impacts analysis. These methods and models are identified in the text. A more complete description of each tool is provided in Section IV of this testimony, including references to the planning documents and literature sources where more information is available.

a. The FEIR/S identified only minor changes in spawning and egg incubation flows between NAA and H3, H4 and 2016 FEIR/S H3+ scenarios.

For spawning and egg incubation effects, mean monthly flows modeled in CalSim II and water temperatures modeled in SRWQM (Sacramento River) and the Reclamation Temperature Model (Feather River) were compared between NAA and both H3 and H4 scenarios during spawning period of each species (February through June for White Sturgeon and March through July for Green Sturgeon) in the Sacramento and Feather Rivers.

The analysis indicates that for Green and White Sturgeon, flows in the Sacramento River from Keswick to Red Bluff during the spawning period would generally be similar between NAA and both H3 and H4 (<~5% difference[20]) (2016 FEIR/S Appendix 11C, Section 11.11C.11, pp. 11C-763 to 11C-774, Table 1 through Table 4). The analysis indicates that flows in the Feather River between Thermalito Afterbay and the confluence with the Sacramento River would generally be either similar between NAA and both H3 and H4 (<~5% difference) or flows would be substantially higher (increased up to 548%) under H3 and H4 compared to NAA (2016 FEIR/S, Appendix 11C, Section 11.11C.1, pp. 11C-803 to 11C-814, Table 15 through Table 18). The one exception is in July, in which there were reductions under H3 and H4 compared to NAA at two locations in the Feather River (up to 50% reductions in flows, but generally in the 10-30% range). However, when 2016 FEIR/S H3+ is compared to NAA, there would be no flow reductions >5% in the Sacramento River in any month of the

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[20] The 5% value was not a strict threshold used to define an effect, but was instead used as a way to characterize changes in flows.

spawning period of both species, and there would be no flow reductions >5% in the Feather River, except during critical years during July of critical years (9% reduction; 2016 FEIR/S Appendix 11C, Section 11.11C.1, pp. 11C-763 to 11C-774, and pp. 11C-803 to 11C-814, Table 1 through Table 4, Table 15 through Table 18, “2015 Effect” column). Given that this was the only instance of a >5% reduction among all months and water year types analyzed, the reduction would not change my opinion that the CWF is reasonably protective of sturgeon spawning.

b. The FEIR/S identified only minor changes in migration flows between NAA and H3, H4 and 2016 FEIR/S H3+ scenarios.

The analysis of potential effects to migration evaluates conditions during larval, juvenile and adult migration periods of Green and White Sturgeon. Because at least one migratory life stage is present year-round, this analysis reviewed year-round mean monthly flows in the Sacramento River between Keswick and Verona and in the Feather River between Thermalito Afterbay and the confluence with the Sacramento River.

The reductions in are generally low magnitude (nearly always less than ~10%) and occur infrequently (only in one or two months of the year) such that they would affect a small proportion of the population. There are limited exceptions. In the Sacramento River at Keswick and Wilkins Slough during November, there were mean flow reductions under H3+ of up to 26%, depending on water year type (2016 FEIR/S, Appendix 11C, Section 11C.11.1, pp. 11C-766 to 11C-768, Table 2; pp. 11C-778 to 11C-780, Table 6, “2015 Effect” column). In the Sacramento River at Verona, during September and November, there were mean flow reductions under H3+ of up to 17%, depending on water year type (2016 FEIR/S, Appendix 11C, Section 11C.11.1, pp. 11C-784 to 11C-785, Table 8. In the Feather River high flow channel during September, there were mean flow reductions under H3+ of up to 35%, depending on water year type (2016 FEIR/S Appendix 11C, Section 11C.11.1, pp. 11C-806 to 11C-808, Table 16; pp. 11C-812 to 11C-814, Table 18).

A comparison of NAA to H3 and H4 reveals that there would be smaller and fewer reported differences in flow. The results indicate that reductions in mean flow rates from the NAA to either H3 or H4 were generally <~5% most months and water year types. There were limited exceptions, particularly July through September and November, when flows were up to 23% lower, but generally <15% lower, (2016 FEIR/S, Appendix 11C, Section 11C.11.1, pp. 11C-766 to 11C-768, Table 2; pp. 11C-784 to 11C-785,Table 8) in the Sacramento River; and during July through September in the Feather River high flow channel, with flows up to 60% lower depending on water year type, but generally <20% lower (2016 FEIR/S Appendix 11C, Section 11C.11.1, pp. 11C-806 to 11C-808, Table 16).

The migration flow analysis also compared exceedance of flow thresholds in the Sacramento River for White Sturgeon between NAA and H3. The analysis is described in Section IV, Analytical Methods and Model. The results of the threshold analyses indicate that there would be negligible increases (<3%) under H3 compared to NAA in exceedance of any threshold (2016 FEIR/S, p. 11-3487, Table 11-4A-107).[21]

As previously explained, these limited observations of reduced flows are primarily the result of upstream changes that are a result of reductions in the September and November flows under the PA relative to the NAA, as modeled using CALSIM II. The reason for the difference in CALSIM II results is that the increased operational flexibility available through CWF allows additional export of excess run-off in winter and spring, which reduces reliance on reservoir releases to support exports later in the year (i.e., fall) as compared to the NAA. In general, where there are differences in flows when comparing the NAA and CWF, those differences are limited in timing and magnitude. These modeling outcomes do not reflect the totality of the annual, seasonal, and real-time considerations that would be used to determine how to make reservoir releases in the future. Further, there is low certainty in the assumed positive linear relationship between flow and migration success. (See BA Appendix 5.D, Quantitative Methods, Section 5.D.2.4, p. 5.D-318, Migration Flow Methods.) Therefore, I

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[21] The NMFS BO did not evaluate changes in flow related to Green Sturgeon. White Sturgeon are unlisted.

conclude that there would be no population-level effects of CWF to migratory life stages of Green and White Sturgeon.

3. Cal WaterFix will result in minor changes to upstream water temperature conditions for spawning and rearing habitat of Green and White Sturgeon; avoidance and minimization measures, conservation measures and recommendations, and operational criteria will reasonably protect sturgeon.

a. The FEIR/S identified only minor changes in spawning and egg water temperatures between NAA and H3 and H4 scenarios.

The analysis of potential water temperature-related effects to Green and White Sturgeon spawning and egg incubation consisted of four different analyses: (1) a “mean monthly water temperature” comparison; (2) a “Level of Concern” analysis in the Sacramento River; (3) a “Percent Exceedance” analysis (Green Sturgeon only) in the Feather River; and (4) a “Degree-Day/Degree-Month” analysis in the Sacramento and Feather Rivers.

The mean monthly water temperature analysis compared mean monthly water temperatures between NAA and H3 and H4 during the Green and White Sturgeon spawning periods in the approximate spawning reaches within the Sacramento and Feather Rivers. The analysis indicates that there would be no increase >~5% in mean monthly water temperatures under H3 or H4 compared to NAA in the Sacramento River at Bend Bridge and Feather River at Gridley (2016 FEIR/S Appendix 11D, Section 11D.10.3, pp. 11D-766 to 11D-769, Table 1 and Table 2; Section 11.D.10.12, pp. 11D-802 to 11D-805, Table 1 and Table 2).

The “Level of Concern" analysis results indicate that there would be no more than a 2 year increase (out of 82 years) under H3 or H4 compared to the NAA in which the level of concern rose to red, orange, or yellow for either species (2016 FEIR/S, Chapter 11, pp. 11-3349, Table 11-4A-93; p. 11-3453, Table 11-4A-97; p. 11-3476, Table 11-4A-101; p. 11-3479, Table 11-4A-104). It is my opinion that these results indicate negligible effects to sturgeon spawning and egg incubation.

The “Percent Exceedance” results indicate that there would be no increased exceedances for Green Sturgeon above the 64°F threshold under H3 or H4 (2016 FEIR/S, Chapter 11, p. 3451, Table 11-4A-95, p. 11-3455, Table 11-4A-99).

The “Degree-Day/Degree-Month” analysis results indicate that there would be no increase in total degree-days or degree-months above thresholds under H3 or H4 relative to NAA in the Sacramento and Feather Rivers.

Combined, the results from the four analyses conducted consistently indicate that temperature-related effects to Green and White Sturgeon spawning and egg incubation would be minimal and, therefore, it is my opinion that the CWF is reasonably protective of this life stage with respect to water temperature.[22]

b. The FEIR/S identified only minor changes in rearing temperatures between NAA and H3 and H4 scenarios

Due to the benthic nature of sturgeon larvae and juveniles, flow was not evaluated as a potential impact mechanism during upstream rearing.[23] Instead, the analysis evaluated changes in water temperature only. To evaluate water temperatures, mean monthly temperatures were compared between NAA and H3 and H4 for both species in the Sacramento River at Bend Bridge and the Feather River at Gridley. The “Percent Exceedance” and the “Degree Day/Degree-Month” analyses were conducted in the Feather River for juvenile Green Sturgeon using the 64°F threshold at Gridley.

The analysis of mean monthly temperatures indicate that there would be no increase >~5% in mean monthly water temperatures under H3 or H4 compared to NAA during the periods of presence of juvenile Green (April through October) and White Sturgeon (year-round).[24]

The “Percent Exceedance” results indicate that the percent of months exceeding the threshold in the Feather River under H3 and H4 would be similar to or up to 28% lower (improved absolute difference) than that under NAA during May through July, and similar or up to 14% greater than that under NAA during August and September (2016 FEIR/S, Chapter 11,

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[22] NMFS found that the risk of redd dewatering and redd scour are low given that preferred spawning habitat is deep pools(NMFS BO p. 506, p. 530, p. 565). Deep pools are less subject to dewatering and, because flow velocity in pools is generally reduced, their substrates are less likely to experience high velocity scouring flows.

[23] The NMFS BO analysis of juvenile stranding indicated that there would be no measurable effect of BA H3+ because stranding is unlikely to occur in the mainstem Sacramento River and effects of BA H3+ on flows in the Yolo Bypass, where stranding could occur, would be negligible (NMFS BiOp p. 570).

[24] (2016 FEIR/S, Appendix 11D, Section 11D.10.3, pp. 11D-766 to 11D-769, Table 1 and Table 2; Section 11.D.10.12, pp. 11D-802 to 11D-805, Table 1 and Table 2.)

p. 3451, Table 11-4A-95; p. 11-3455, Table 11-4A-99). This increase during the latter months could represent a small effect to Green Sturgeon.

The "Degree-Month" analysis results indicate that, combining all water year types for each month, total degree-months of exceedance would be up to 29% lower (improved) under H3 and H4 during May and June, but up to 34% higher during July through September (2016 FEIR/FEIS, Chapter 11, p. 11-3452, Table 11-4A-96; p. 11-3456, Table 11-4A-100). This increase during July through September could cause a small effect to Green Sturgeon rearing conditions during these later months of the rearing period.

The water temperature model outputs presented here, do not consider real-time operational management described in BA Section 3.1.5, Real-Time Operations Upstream of the Delta, and Section 3.3.3, Real-Time Operational Decision-Making Process, that would be used to avoid and minimize any modeled effects (see Aaron Miller's testimony, DWR-1011). Further, the modeling does not consider the current revision process to OCAP RPA Action Suite 1.2 described in Section 3.1.4.5, Annual/Seasonal Temperature Management Upstream of the Delta. Considering the small differences observed in model outputs, as well as real-time operations and current modifications to the OCAP RPA, it is my opinion that the CWF is reasonably protective of Green sturgeon rearing.

c. <u>The BO only identified small changes in rearing temperatures when comparing the NAA to BA H3+ and concluded no jeopardy or adverse modification of critical habitat.</u>

The NMFS BO analysis was limited to Green Sturgeon in the Sacramento River because White Sturgeon is not listed under the ESA. The 2081(b) ITP process did not include either species because neither is listed under the CESA.

The BO concludes that there will be minimal effects of BA H3+ to upstream life stages of Green Sturgeon (NMFS BO, p. 1061) and critical habitat of Green Sturgeon upstream of the Delta will not be degraded by BA H3+ (NMFS BO, p. 882). Using an analysis comparing temperature model outputs and known Green Sturgeon optimal ranges, NMFS found that water temperatures under BA H3+ were generally within the optimal ranges such that any elevated water temperatures seen in modeling results were not of concern (NMFS BO, pp. 422-423).

It is my opinion that the CWF is reasonably protective of Green Sturgeon and White Sturgeon. The FEIR/S, BA, and BO collaborate my opinion.

C. Sacramento Splittail

My opinion concerning the potential upstream-of-Delta effects is as follows:

- Cal WaterFix is reasonably protective of upstream splittail spawning, rearing and migration.

It is my opinion that the CWF is reasonably protective to Sacramento Splittail. Negative effects by CWF are generally lacking. Flows under H3, H4, and BA H3+ would be either similar to or greater than flows under NAA in most of months with a few rare exceptions. Water temperatures under H3and H4 would remain within the optimal splittail range at similar frequency to those under NAA.

1. Overview of Splittail Biology

The Sacramento Splittail is a native minnow that inhabits the Sacramento and San Joaquin rivers, the Delta, and the estuary. In wetter years, spawning occurs on inundated floodplains in the Yolo and Sutter Bypasses, Cosumnes River, and San Joaquin River primarily from February through June (DWR-1111, DWR- 1138, DWR-1137, Sommer et al. 1997, 2001, 2002; DWR-1126, Cain et al. 2004; DWR-1119, Moyle et al. 2004). The population is maintained primarily by strong year classes during wetter years (DWR-1119, Moyle et al. 2004). In all years, splittail spawn and rear in the channel margins farther upstream in the Sacramento River up to Red Bluff, San Joaquin River to Salt Slough, and the lower Petaluma and Napa Rivers (DWR-1119, Moyle et al. 2004; DWR-1123, Feyrer et al. 2005).

2. Cal WaterFix will maintain reasonably protective flow and water temperature conditions for upstream spawning, rearing, and migration of Sacramento Splittail.

Splittail were analyzed as a covered species in the FEIR/S, but were not analyzed in the BOs or the 2081(b) permit application because the species is not listed under either the FESA or CESA. The analysis in the 2016 FEIR/S evaluated effects of H3 and H4 to splittail spawning, rearing, and migration.

The analysis qualitatively assessed differences in inundation of the Yolo Bypass and lower Sutter Bypass, the primary spawning and rearing locations for splittail in wet years, under NAA, H3, and H4 scenarios during their principal period of presence upstream (February through June). A qualitative assessment was warranted because Yolo Bypass improvements would be present in all scenarios (NAA, H3, and H4). As a result, there would be little to no difference in floodplain habitat availability between NAA and either H3 or H4 (2016 FEIR/S, Chapter 11, p. 11-3429, Table 11-4A-86). The analysis also evaluated the risk of dewatering and stranding of splittail eggs and rearing larvae on inundated floodplain habitat and similarly concluded that there would be little to no difference between NAA and H3 and H4 in dewatering or stranding risk because Yolo Bypass improvements would be present in all scenarios (2016 FEIR/S, Chapter 11, p. 11-3429, Table 11-4A-86).

The analysis evaluated channel margin and side-channel habitat availability for spawning, rearing, and migration in the Sacramento River at Wilkins Slough and in the Feather River at the confluence with the Sacramento River by assessing differences in mean monthly flow rates between NAA and H3 and H4 scenarios between February and June. At Wilkins Slough, differences in mean flows would be predominantly small (<~5%) during February through May, with evidence of positive effects during June (up to 12% higher under H3 depending on month and water year type) (2016 FEIR/S Appendix 11C, Section 11C.11.1.3, pp. 11C-778-779, Table 6). Observations of mean flow rates between NAA and 2016 FEIR/S H3+ corroborate these results. In the Feather River at the Sacramento River confluence, mean flow rates under H3 and H4 during February through June would be predominantly similar to or greater than (particularly under H4) mean flow rates under NAA (up to 119% higher depending on month and water year type (2016 FEIR/S, Section 11C.11.1.9, pp. 11C-812 to 11C-814, Table 18, “2015 Effect” column). Small exceptions include critical years in May and June under H4 (7% and 9% flow reduction, respectively). Results from 2016 FEIR/S H3+ corroborate the finding that flow reductions under the project would be infrequent and small. There would be no flow reductions >~5% under 2016 FEIR/S H3+ compared to NAA.[25]

The analysis also compared between NAA and H3 and H4 the frequency at which water temperatures were within a suitable range for splittail spawning, egg incubation, and initial rearing (45°F to 75°F, as assessed in the Oroville FERC relicensing (DWR-1141 [DWR 2004]) during February through June in the Sacramento River at Hamilton City and in the Feather River at the confluence with the Sacramento River, the nearest model output locations to splittail spawning locations. Daily model outputs from SRWQM were used for the Sacramento River and monthly outputs from Reclamation Temperature Model were used for the Feather River. The analysis found there were no increases under H3 or H4 compared to NAA of >~5% in frequency of modeled water temperatures outside the suitable range (2016 FEIR/S pp. 11-3432, 11-3434, Table 11-4A-89 and Table 11-4A-90).

It is my opinion that the CWF is reasonably protective to Sacramento Splittail. The FEIR/S, BA, and BO collaborate my opinion.

D. Pacific and River Lamprey

My opinion concerning the potential upstream-of-Delta effects of the CWF on Pacific and River Lamprey is as follows:

- Cal WaterFix will maintain reasonably protective flow and water temperature conditions for upstream spawning, rearing, and migration of Pacific and River Lamprey.

Overall, based on the analysis of effects, it is my opinion that the CWF H3+ is reasonably protective of Pacific and River Lamprey in upstream waterways. The analysis indicates that there would be minimal effects in the preponderance of months and water year types. The larger effects seen in the results are not frequent or large enough to affect more than a small fraction of the population of either Pacific or River Lamprey and, therefore, would not cause biologically meaningful effects on either species.

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[25] "2015 Effect" column in 2016 FEIR/S Appendix 11C, Section 11C.11.1.3, pp. 11C-778-779; Table 6; Section 11C.11.1.9, pp. 11C-812 to 11C-814, Table 18.

1. **Overview of Lamprey Biology**

Relatively little is known about the biology of Pacific and River Lamprey in California. Much of the life history information presented here and used in the effects analysis is based on other lamprey species or other locations where timing of life history events may differ as a result of differing climates. Therefore, there is high uncertainty in the results and the ability to determine whether the CWF would cause an effect is diminished.

Neither species is listed under the ESA or CESA. In the Central Valley, both lamprey species are thought to be widespread in the Sacramento and San Joaquin Rivers and tributaries (DWR-1100, Moyle 2002). Both species are anadromous but spend most of their lives in freshwater. Adult Pacific Lamprey are likely to spend 5 to 7 years in freshwater and 3 to 4 years or less in the ocean (DWR-1100, Moyle 2002). Adult River Lamprey spend 3 to 5 years in freshwater and only 3 to 4 months in the ocean (DWR-1100, Moyle 2002). Pacific Lamprey adults migrate to upstream spawning locations during January through June and spawn primarily between January and August (DWR-1100, Moyle 2002). River Lamprey adults migrate upstream during September through November and spawn primarily from February through June (DWR-1100, Moyle 2002). Adults dig a redd in gravelly substrate and the female lays eggs just upstream of the nest while the male fertilizes the eggs, after which the eggs float into the nest (DWR-1118, Moyle et al. 2015). Adults die after spawning. Eggs hatch into larvae called “ammocoetes” in 18 to 49 days depending on water temperature (DWR-1129, Brumo 2006). Ammocoetes bury themselves tail-first into silty or sandy backwaters and filter feed on algae detritus and microorganisms for several years. Ammocoetes metamorphose into “macropthalmia” and emigrate through the rivers toward the ocean between December through May (Pacific Lamprey) or September through November (River Lamprey), particularly during peak flow events.

2. **Cal WaterFix will maintain reasonably protective flow and water temperature conditions for upstream spawning, rearing, and migration of Pacific and River Lamprey.**

The 2016 FEIR/S analysis of Pacific and River Lamprey evaluated flow- and water temperature-related effects of CWF on all upstream life stages of both species. Because, there is relatively little known about the biology of either species of lamprey, there were several assumptions made in the analyses, increasing the uncertainty in the results. These assumptions are noted in the description of methods in Section IV, Analytical Methods and Models.

The analysis evaluated flow- and water temperature-related effects to both lamprey species in the Sacramento, Trinity, Feather, and American Rivers.

a. Cal Water Fix is reasonably protective of spawning and egg incubation flows

For spawning and egg incubation, flow-related effects were evaluated using a redd dewatering analysis. For both lamprey species, there would be minimal differences between H3 and NAA in dewatering risk in all rivers, except for a small (10%) increase in the Feather River at Thermalito Afterbay under H3 for Pacific Lamprey (2016 FEIR/S , p. 11-3498, Table 11-4A-110; p. 11-3519, Table 11-4A-121). Closer examination of this increase reveals that the difference between NAA and H3 represents 2% (11 out of 656) of total hypothetical redd cohorts at this single location. This value is considered very small relative to the total population. Therefore, it is my opinion that CWF would not have biologically meaningful effects on Pacific or River Lamprey redd dewatering risk.

b. Cal Water Fix is reasonably protective of spawning and egg incubation water temperature

Water temperature-related effects to spawning and egg incubation of the lamprey species were evaluated by following “egg cohorts”, similarly to how this was done for the redd dewatering risk. For both lamprey species, in the majority of locations, egg cohort temperature exposure under H3 would be within ~10% of exposure under NAA (2016 FEIR/S, Table 11-4A-111, p. 11-3499; Table 11-4A-122, p. 11-3520). However, for Pacific Lamprey, the number of cohorts exposed under H3 would be 92% lower than those under NAA in the Trinity River at Lewiston and 93% greater than those under NAA in the Feather River below Thermalito Afterbay. For River Lamprey, the number of cohorts exposed under H3 would be 54% higher those under NAA in the Feather River below Thermalito Afterbay and the number of cohorts exposed under H3 would be 11% and 19% lower than those under NAA in the American River at Nimbus and the Sacramento River confluence, respectively. Although some of these relative differences appear substantial, the largest difference of 93% represents only 37 egg cohorts, or 5.7% of the 648 total hypothetical cohorts. Therefore, these increases and decreases in egg cohort exposure are small relative to the total population. As a result, it is my opinion that they do not represent a biologically meaningful effect that the CWF is reasonably protective of water temperature conditions needed for successful spawning and egg incubation of the two species.

c. Cal Water Fix is reasonably protective of rearing flows

For rearing ammocoetes, an ammocoete stranding analysis similar to the redd dewatering analysis was conducted that estimates rapid flow reductions in ammocoete rearing reaches. Rapid reductions in flow have the potential to strand ammocoetes, leading to mortality.

The results indicate that there would be no >~5% increase in Pacific Lamprey stranding risk under H3 or H4 for the majority of flow reductions and rivers evaluated, except under H3 for the 75% and 80% flow reductions in the American River at Nimbus Dam (12% and 23% increase, respectively), under H3 for the 85% flow reduction in the American River at the Sacramento River confluence (33% increase), and under H4 for the 85% and 90% flow reductions in the Feather River at Thermalito Afterbay (9% and 53% increase, respectively) (2016 FEIR/S, pp. 11-3502 to 11-3504, Table 11-4A-113 to Table 11-4A-118; p. 3506, Table 11-4A-120). The results also indicate that there would be no >~5% increase in River Lamprey stranding risk under H3 or H4, except under H3 for the 90% flow reduction in the Trinity River at Lewiston (11% increase), under H3 for the 75% and 80% flow reductions in the American River at Nimbus Dam (19% and 22% increase, respectively), under H3 for the 80% and 85% flow reductions in the American River at the Sacramento River confluence (9% and 32% increases, respectively), and under H4 for the 85% and 90% flow reductions in the Feather River at Thermaltio Afterbay (14% and 47% increase) (2016 FEIR/S, pp. 11-3523 to 11-3515, Table 11-4A-124 to Table 11-4A-129; p. 11-3527, Table 11-4A-131).

It is my opinion that the increases in stranding risk listed here would not be biologically meaningful to Pacific or River Lamprey because the increased stranding risk is limited to very small ranges of flow reductions at each location (never more than two adjacent flow reduction levels with >5% increases).

d. Cal Water Fix is reasonably protective of rearing water temperatures

A temperature exceedance analysis for ammocoetes was conducted on H3 using 71.6°F for Pacific lamprey (based on Pacific Lamprey Eggs; DWR-1121,Meeuwig et al. 2005) and 77°F for River Lamprey (based on River Lamprey adults; DWR-1100, Moyle 2002).

The results for Pacific Lamprey, indicate that there would be no >~5% increase in ammocoete cohorts exposed to temperatures >71.6°F in all locations except the Sacramento River at Hamilton City (7% increase under H3) and the Feather River below Thermalito Afterbay (15% increase under H3) (2016 FEIR/S, p. 11-3505, Table 11-4A-119,). For River Lamprey, there would be no >~5% increase in ammocoete cohorts exposed to temperatures >71.6°F in all locations except the Feather River below Thermalito Afterbay (25% increase under H3; p. 11-3526, Table 11-4A-130). In addition, there would be no >~5% increase in River Lamprey ammocoete cohorts exposed to temperatures >77°F except the Feather River below Thermalito Afterbay (100% increase under H3) and the American River at Nimbus (50% increase under H3) (2016 FEIR/S, p. 11-3526, Table 11-4A-130,).

Although the increases under H3 in exceedance of the 77°F threshold noted above appear large, each accounts for differences of 25 of 380 cohorts, or ~7%, of the population evaluated and, therefore, would not constitute a biologically meaningful effect. The 15% and 25% increases under H3 in exceedance of the 71.6°F threshold in the Feather River below Thermalito Afterbay for Pacific and River Lamprey, respectively, are considered moderate temperature effects (2016 FEIR/S, p. 11-3505, Table 11-4A-119; p. 11-3526, Table 11-4A-130). However, because this level of exceedance occurs at only one location in one river, it is my opinion that the CWF is reasonably protective with respect to water temperature effects on lamprey ammocoetes.

e. <u>The Cal Water Fix is reasonably protective of migration flows</u>

For outmigrating macropthalmia and returning adults, mean monthly flow rates were evaluated under the assumption that higher flows meant better migratory conditions for both life stages. The macropthalmia emigration and adult immigration periods for Pacific Lamprey evaluated were December through May and January through June, respectively. Both emigration and immigration for River Lamprey occurs during September through November.

For Pacific Lamprey, flows in the Sacramento River above Red Bluff under H3 and H4 would be similar to or up to 9% higher than flows under NAA in all months examined (2016 FEIS/S, Appendix 11C, Section 11C.11.1.2, pp. 11C-772 to 11C-774, Table 4). Flows in the Feather River at the confluence with the Sacramento River during Pacific Lamprey migration under H3 and H4 would be similar to or up to 119% higher than flows under NAA in most months, except for critical water years during May and June (5% to 11% lower) and wet water years during June (6% lower) (2016 FEIS/S, Appendix 11C, Section 11C.11.1.9, pp. 11C-812 to 11C-814, Table 18). Flows in the American River at the confluence with the Sacramento River during Pacific Lamprey migration under H3 and H4 would be similar to or up to 25% higher than flows under NAA in most months except for below normal years in January (6% to 11% lower), critical water years during May and dry water years in June (17% and 11% lower, respectively) and below normal water years during June (6% lower) (2016 FEIS/S, Appendix 11C, Section 11C.11.1.11, pp. 11C-823 to 11C-825, Table 22,). These flow reductions in the Feather and American Rivers, due to their low magnitude and frequency, would not constitute biologically meaningful effects to Pacific Lamprey migration conditions. Flows at Rio Vista under H3 would generally be lower by up to 21% relative to NAA in drier years (below normal-critical) (2016 FEIR/S, Appendix 11-C, p. 11C-845, Table 30.) Collectively, these modeling results indicate the effect would not be adverse because H3 and H4 would not substantially reduce or degrade migration habitat or substantially reduce the number of fish as a result of mortality. (2016 FEIR/S, p. 11-3511). There would be small to moderate negative effects on H3 on lamprey migration flows in the Sacramento River at Rio Vista, moderately large benefits of H4 in the Feather River, and no effect in the Sacramento River at Red Bluff in the American

River (2016 FEIR/S, p. 11-3511). Combined, these effects would not result in adverse effects on migration conditions for Pacific Lamprey.

Therefore, it is my opinion that CWF is reasonably protective of Pacific Lamprey migration.

For River Lamprey, flows in the Sacramento River above Red Bluff under H3 and H4 would be similar to flows under NAA during October, and up to 18% lower in September and November (2016 FEIR/S, Appendix 11C, Section 11C.11.1.2, pp. 11C-772 to 11C-774 Table 4). Flows in the Feather River at the Sacramento River confluence under H3 and H4 would be similar to up to 17% greater than flows under NAA during October and November and up to 38% lower during September (2016 EIR/S, Appendix 11C, Section 11C.11.1.9, pp. 11C-812 to 11C-814, Table 18). Flows in the American River at the Sacramento River confluence would be similar to or up to 25% greater than flows under NAA during October, but up to 25% lower under H3 and H4 during September and November (2016 FEIR/S, Appendix 11C, Section 11C.11.1.11, pp. 11C-823 to 11C-825, Table 22). These results indicate that there is a mix of small to moderate increases and decreases in flows, and, although they have the potential to have positive and negative effects on River Lamprey migration, the results do not change my opinion that the CWF is protective of River Lamprey. The effect of flow on migration of River Lamprey is highly uncertain, except for known large ammocoete migration events during peak flows caused by large storms. The CWF will have little effect on the magnitude or frequency of peak flow events because they are predominantly caused by large storm events.

It is my opinion that the CWF is reasonably protective of Pacific and River Lamprey which is collaborated by the FEIR/S, BA, and BO.

E. <u>Non-Covered Species of Primary Management Concern</u>

All non-covered species of primary management concern that occur upstream of the Delta (Striped Bass, American Shad, Threadfin Shad, Largemouth Bass, Sacramento Tule Perch, Sacramento-San Joaquin Roach, and Hardhead) are combined here due to the similarities in upstream analyses conducted. My opinion concerning the potential upstream-of-Delta effects of the CWF on non-covered fish species is as follows:

- The Cal Water Fix is reasonably protective of non-covered species of primary management concern spawning and egg incubation, juvenile rearing, adult occurrence and adult migration.

Overall, it is my opinion that the CWF is reasonably protective to the non-covered species. Negative effects by CWF on flow or water temperature are generally lacking. Flow reductions in the Feather River during summer months are of greatest potential concern, but the size of the flow reductions would vary from month to month within a specific water year type, and/or would be offset by increases in flows in the adjoining months. Also, under actual conditions, reservoir releases would be operated in real-time to minimize potential effects to fish species, similarly to how they are currently operated.[26]

1. The Cal Water Fix is reasonably protective of non-covered species of primary management concern spawning and egg incubation, juvenile rearing, adult occurrence and adult migration.

There were two types of analysis in the 2016 FEIR/S for non-covered species of primary management concern, a flow analysis and a water temperature analysis (2016 FEIR/S pp. 11-3539 to 11-3602). Mean monthly flow rates were compared between NAA and either H3 or H4 under the assumption that higher flows were better for fish. Flow analyses were conducted for each species and life stage (spawning and egg incubation, juvenile rearing and adult occurrence, if resident and non-migratory, or adult migration, if migratory, during their upstream occurrence in the Sacramento, Trinity, Feather, American, San Joaquin, and Stanislaus Rivers and in Clear Creek. The water temperature analysis compared number of days (in the Sacramento River) or months (in the Feather, American, Trinity, and Stanislaus Rivers) between NAA and either H3 or H4 for which modeled water temperature was outside the suitable water temperature range for each life stage and species occurring in these rivers. Suitable water temperature ranges were taken from existing scientific literature.

The analysis found no substantial adverse flow effects to any of the life stages of the species examined (2016 FEIR/S, Appendix 11-C, CalSim II Model Results). Reduced modeled

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[26] As previously noted, an overview of biology is not provided for the non-covered species because there are too many species to consider and the analyses methods used for these species require only a general understanding of the species' life histories.

flows, especially in summer (July through September) in the Feather River at the Thermalito Afterbay and the Sacramento River confluence (2016 FEIR/S, Appendix 11-C, Section 11C.11.1.8, p. 11C-806, Table 16; Section 11C.11.1.9, p. 11C-812, Table 18) are potentially of greatest concern. None of the non-covered species spawn or have incubating eggs in the Feather River during the summer, but many of the species have juvenile and/or adult stages in the river during these months (2016 FEIR/S, pp. 11-3568 to 11-3600, Impact AQUA-203; and pp. 11-3600 to 11-3602, Impact AQUA-204). However the summer flow reductions in the Feather River would mostly be small, would vary from month to month within a specific water year type, and/or would be offset by increases in flows in the adjoining months. Therefore, the flow reductions are not expected to have biologically meaningful negative effects on the species. In any case, real-time operations are not adequately represented in CalSim II due to the monthly time step and other model limitations. Under actual conditions, reservoir releases would be operated in real-time to minimize potential effects to fish species, similarly to how they are currently operated.

The results of SRWQM temperature modeling showed no >5% increases in water temperatures between NAA and H3 or H4 at any of the locations on the Sacramento, Trinity, Feather, American, or Stanislaus Rivers and any month or water year type (2016 FEIR/S, Appendix 11-D, Table 2 of Sections 11D.10.1 to 11D.10.21, pp. 11D-760 to 11D-841), except for a 5.4% increase at the Fish Barrier Dam on the Feather River in September of below-normal water years under H4 (2016 FEIR/FEIS, Appendix 11-D, Table 2 of Section 11D.10.9, pp. 11D-792 to 11D-793). Water temperatures in the Sacramento, Trinity, American, and Stanislaus Rivers under H3 andH4 would generally be almost identical to those under NAA. Therefore, the water temperature analysis comparing number of days or months between NAA and H3 and H4 with water temperature outside the suitable water temperature range of the species and life stage was not conducted for these rivers and it was concluded that the rivers would have no temperature related effects. However, the analysis was conducted for the Feather River, and the results showed that, for most of the non-covered species and life stages, there were no >5% differences (absolute values) between the NAA and either H3 or

H4 in the percent of months with water temperatures outside of the suitable range (2016 FEIR/S, pp. 11-3541 to 11-3596, Table 11-4A-132 to Table 11-4A-153). However, there were >5% increases in months with water temperatures outside of the suitable range for spawning and egg incubation habitat of several species. These include Threadfin Shad, 14% increase in below normal years (2016 FEIR/S, p. 11-3550,Table 11-2D-136); Sacramento Tule Perch, 6% increase in wet and dry years and 8% increase in below normal years (2016 FEIR/S pp. 11-702 to 11-703, Table 11-1A-101); Sacramento-San Joaquin Roach, 6% increase in wet years (2016 FEIR/S, p. 3566, Table 11-4A-143); and Hardhead, 6% increase in wet years (2016 FEIR/S, p.3566, Table 11-4A-143). Most of these increases are small and occur for one or a few water year types, so they would not have biologically meaningful effects on the spawning and egg incubation habitats of the species. There were no >5% increases in months with water temperatures outside of the suitable range for rearing juvenile or adult life stages of any of the non-covered species.

Because none of the non-covered species of primary management concern is listed under either the ESA or CESA, these species were not included in the BO or the 2081 (b) Incidental Take Permit process.

F. <u>Coldwater Reservoir Species</u>

My opinion concerning the potential upstream-of-Delta effects of the CWF on coldwater reservoir fish species is as follows:

- Cal WaterFix is reasonably protective of cold water reservoir species in upstream reservoirs

Overall, it is my opinion that the CWF is reasonably protective to coldwater reservoir species. The results of the analysis indicated that, other than Trinity Lake, none of the reservoirs had an increase between the NAA or either H3 or H4 in the number of years with reduced coldwater habitat for any of the reservoirs, and Trinity Lake had a small increase for H3 only.[27]

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[27] As previously noted, an overview of biology is not provided for the coldwater reservoir species because there are too many species to consider and the analyses methods used for these species require only a general understanding of the species' life histories.

1. Cal WaterFix is reasonably protective of cold water reservoir species in upstream reservoirs

The 2016 FEIR/S evaluated effects of CWF on coldwater fish species of CVP and SWP reservoirs upstream of the Delta, such as the important game species, Kokanee Salmon and Rainbow Trout. Preferred habitat for coldwater fish species in the principal Central Valley reservoirs during the summer and fall months is typically restricted to the hypolimnion, where water temperature generally remains below about 60°F. In some lakes and reservoirs, the dissolved oxygen in the hypolimnion can become depleted from oxidation of organic material, but low dissolved oxygen is not a problem in the major CVP and SWP reservoirs. The volume of the hypolimnion in the upstream reservoirs declines each year from spring to fall as coldwater inflows decline, the surface layer is warmed, and the deeper water is released to the river downstream, in part to provide cold water for salmonids in the rivers, especially in the fall. The volume of the hypolimnion, which is directly related to the storage volume of the reservoir (2016 FEIR/S, Chapter 11, p. 11-343, Figure 11-1A-8), typically reaches its minimum each year around the end of September. In dry years with low reservoir storage volume, severe reduction or depletion of the coldwater pool may occur, which is assumed to adversely affect the coldwater reservoir fish species.

The analysis used to evaluate effects of CWF on the volume of coldwater habitat in the reservoirs upstream of the Delta is described in Section IV, Analytical Methods and Models, Coldwater Habitat Threshold Volume Analysis. Results of the analysis indicate that there are no adverse impacts of either H3 or H4 on the coldwater volume of any of the upstream reservoirs. In Lake Shasta, for example, the carryover volume of the NAA dropped below the threshold carryover volume (2,000 TAF) in 18 of the 82 years, while for H3 and H4 the carryover volume fell below the threshold in only 16 years and 14 years, respectively (2016 FEIR/S, pp. 11-764 to 11-765, Impact AQUA-217, Table 11-1A-118). The only exception was for H3 at Trinity Lake. The carryover volume of Trinity Lake dropped below the threshold in 13 years for H3 as opposed to 12 years for the NAA. This increase is minor given the 82-year record evaluated and is therefore not expected to have much effect on the coldwater species in the reservoir. It is my opinion that the CWF is reasonably protective of the coldwater reservoir fish species in all of the upstream reservoirs.

Because none of the reservoir populations of primary management concern are included in the species listings of either the ESA or CESA, the reservoir species' populations were not included in the BO or the 2081 (b) Incidental Take Permit process.

IV. Description of Analytical Methods and Models

This section of my testimony briefly provides an overview of the methods and the physical and biological models referenced in my testimony. Additional detail on these models is provided in the sources referenced in my testimony (see below and footnotes in the preceding testimony). In general, the biological models use as their inputs the outputs from the physical models, especially the CalSim II water operations model. The sections below are organized similarly to my testimony, first by species group and then by the specific life stage analyses used to produce my opinion that CWF is reasonably protective.

A. SALMONIDS

1. Flow Comparisons, CalSim II

CalSim II was used for modeling mean monthly river flows for the 2016 FEIR/S, BA, and BiOps analyses. When flow comparisons were the only available method for evaluating effects of an alternative on fish, it was assumed that increases in flow would benefit the species and decreases in flow would negatively affect the species. It is important to note that this is a conservative assumption; although this assumption is often true, it is not universally true. For instance, flow increases may be harmful to salmon reproduction by reducing the availability of suitable spawning habitat or increasing the risk of redd scour. For more information on CalSim II, see BA, Appendix 5A, CalSim II Modeling and Methods.

2. SRWQM

SRWQM is Reclamation's daily water temperature model for the Sacramento River, used for operations planning, forecasting, and real-time operations. It was developed using the HEC5Q model to simulate mean daily reservoir and river temperatures in Lake Shasta and the Sacramento River, among other water bodies. For more information, see the BA, Appendix 5, *Upstream Water Temperature Methods and Results*, Section 5.C.2, HEC5Q, pp. 5.C-1 to 5.C-3.

3. Reclamation Temperature Model

This is Reclamation’s monthly time-step model for simulating mean monthly water temperature on the Feather River. For more information, see the BA, Appendix 5, *Upstream Water Temperature Methods and Results*, Section 5.C.3, Reclamation Temperature Model, pp. 5.C-6 to 5.C-8.

4. SacEFT

The SacEFT implementation for the 2016 FEIR/S used flow and water temperature model outputs from SRWQM as inputs. Results are reported as the percentage of years of the 82 year simulation with “good” conditions for each biological parameter. “Good” indicates that the CWF effect on the parameter is positive. It is defined differently for each parameter but is not based on biological significance, although a positive change in the number of good years could be seen as beneficial and a reduction in the number of good years could be seen as a negative effect, depending on the number of years in the change. The parameters used to assign a rating of “good” or otherwise include the availability of suitable spawning and rearing habitat, redd dewatering risk, red scour risk, and juvenile stranding risk. The availability of suitable spawning and rearing habitat analysis applied flows modelled by CalSim II to existing field-based relationships from DWR-1104, DWR-1105, DWR-1106 (USFWS (2003a, 2005a,b) between flow rates and the weighted usable area (WUA) of suitable habitat in specific reaches of the Sacramento River, where suitability is modeled as a function of substrate, water depth, and flow velocity.

Redd dewatering occurs when the water level drops below the depth of the redds or drops low enough to produce depth and flow velocity conditions that are inadequate to sustain incubating eggs in the redd. The analysis in SacEFT applied modeled flow outputs to an existing field-based relationship from DWR-1140 (USFWS (2006)) between flow rate reductions and the proportional decrease in redds in spawning regions of the Sacramento River.

Redd scour occurs when flows are high enough to mobilize sediments, destroying redds and their incubating eggs, or entombing the redds when sediments are redeposited. The analysis in SacEFT assesses the frequency at which modeled flow rates would exceed 55,000 cfs, the 80th percentile of 5-year peak flows (note, however, that SacEFT model documentation indicates that there is no biological justification for this threshold (DWR-1125, ESSA 2011).

Juvenile stranding generally results from reductions in flow that occur over short periods of time, leaving juveniles stranded in dewatered or isolated shallow river margin areas. Stranding can lead to direct mortality when these areas drain or dry up, or to indirect mortality from predators or rising water temperatures and deteriorating water quality. The SacEFT analysis applied modeled flow outputs to a field-based existing relationship from USFWS (2006) between flow rate reduction and risk of juvenile stranding in the Sacramento River (DWR-1125, ESSA 2011).

It is important to note that, although SacEFT was used in the FEIR/S analysis, subsequent analyses of upstream effects conducted in the BA and NMFS BO did not use SacEFT, but instead relied upon individual biological analyses to evaluate potential effects reported by SacEFT that NMFS, CDFW, and DWR thought were more indicative of the biology of the species.

5. SALMOD

SALMOD evaluates flow- and temperature-related mortality of early life stages (from eggs to juveniles) of Chinook Salmon in the Sacramento River to Red Bluff based on the quality and quantity of physical habitat. The model uses CalSim II and SRWQM outputs as inputs and provides numerical estimates of mortality of each life stage separately, as well as a juvenile production value for each year evaluated. SALMOD is organized around events occurring during a biological year beginning with spawning and typically concluding with fish that are physiologically “ready” (e.g., pre-smolts) swimming downstream toward the ocean. It operates on a weekly timestep for one or more biological years. Input variables (e.g., streamflow, water temperature, number, and distribution of adult spawners) are represented by their weekly average values.

SALMOD tracks a population of spatially distinct cohorts that originate as eggs and grow from one life stage to another as a function of local water temperature. The biological characteristics of fish within a cohort are the same. Fish cohorts are tracked by life stage and size class within the spatial computational units. Streamflow and habitat type determine available habitat area for a particular life stage for each time-step and computational unit. Habitat area (quantified as weighted usable area or WUA) is computed from flow versus microhabitat area functions developed empirically or by using PHABSIM (Milhous et al. 1989) or similar physical habitat models. Habitat capacity for each life stage is a fixed maximum number of fish (or biomass) per unit of habitat area available estimated from literature or empirical data. Thus, the maximum number of individuals that can reside in each computational unit is calculated for each timestep based on streamflow, habitat type, and available microhabitat. Fish in excess of the habitat's capacity must seek habitat elsewhere. Fish outside the model domain (from stocking, hatchery production, or tributaries) may be added to the modeled stream at any point in their life cycle. See BA, Attachment 5.D.2, SALMOD Model.

6. **<u>Flow vs. Suitable Habitat Availability Studies</u>**

Spawning and rearing habitat availability in the Sacramento River for CCV Steelhead and all ESUs of Chinook Salmon were calculated by applying CalSim II outputs to the same flow-habitat curves from DWR 1104, DWR 1105, DWR 1106(USFWS (2003a, 2005a, b)) that were used in SacEFT. An additional suitable spawning habitat availability analysis was added for fall-run Chinook Salmon and CCV Steelhead in the American River using an existing flow-habitat curve from DWR-1106 (USFWS (2003b)), No flow-habitat availability curves were available for suitable juvenile rearing habitat in the American River. As a result, the analysis relied upon mean monthly flow comparisons, as described above and presented in the FEIR/FEIS See BA. Attachment 5.D, Section 5.D.2.2.4 Weighted Usable Area Analysis, pp. 5_d-288 to 5D-293).

7. Redd Dewatering Risk

Redd dewatering risk in the Sacramento River was evaluated by applying CalSim II outputs to the same flow-redd dewatering relationships from DWR-1140 (USFWS (2006)) used by SacEFT. Based on field evaluations, these curves predict the percent of redds in reaches of the river that would dewater if flows were reduced from one rate to another. No redd dewatering field data were available in the American River. Therefore, the greatest flow reduction over the three-month period following each month of the spawning period for fall-run Chinook Salmon and CCV Steelhead was evaluated during the presence of eggs and alevins in a redd and compared between NAA and H3. See the BA Appendix 5.D, Section 5.D.2.2.5, Redd Dewatering, pp. 5.D-293 to 5.D-307)

8. Redd Scour Risk

Redd scour risk in the Sacramento and American Rivers was evaluated by estimating the probability that flows would exceed estimated bed mobility flow thresholds of 27,300 cfs at Keswick Dam, 21,800 cfs at Bend Bridge, and 19,350 cfs at Hazel Avenue based on DWR-1135, Kondolf (2000); DWR-1126, Cain and Monohan (2008); DWR-1131, Ayres Associates (2001); and DWR-1124, Fairman (2007). It should be noted that there is low certainty that these thresholds represent actual bed mobility thresholds. Further reducing certainty in the analysis was the disparity in time steps between CalSim II (monthly) and the time scale at which redd scour could occur (minutes to hours). For more information see the BA, Appendix 5.D, pp. 5.D-307 to 5.D-309). See the BA Appendix 5.D, Section 5.D.2.2.6, Redd Scour, pp. 5.D-307 to 5.D-309)

9. Water Temperature Level of Concern Analysis

This analysis determined the number of days when temperatures in the Sacramento River exceeded Chinook Salmon temperature thresholds (2016 FEIR/S Table 11-45A-12, p.11-3221) by >0.5°F to >5°F in 0.5°F increments by month for the 82-year CalSim II period of analysis. The combination of number of days and degrees above the threshold was then summed for each month and further assigned a “level of concern” (red, orange, and yellow), as defined in 2016 FEIR/S Table 11-4A-13 (p. 11-3221). The values used to determine levels of concern were not based on specific biological thresholds, but instead were based on convenient numerical breaks (i.e., 0, 5, 10, 15, and 20 days). The highest levels of concern for each year for the CalSim II period were then summed for each scenario and compared between NAA and H3 or H4.

10. Water Temperature Percent Exceedance Analysis

This analysis determined the percent of months in which water temperatures exceeded thresholds provided by NMFS for spawning and egg incubation or rearing by the following increments: >1°F, >2°F, >3°F, >4°F, and >5°F (2016 FEIR/S, Chapter 11, Table 11-1A-13, p.11-373; Table 11-4A-32, p.11-3257). The percent of months in which water temperatures exceeded the threshold by these amounts was compared between NAA and H3 andH4 by month during spawning and egg incubation and rearing periods for the Chinook Salmon ESUs and CCV Steelhead in the Feather and American Rivers.

11. Degree-Day/Degree-Month Analysis

This analysis determined the magnitude and frequency of exceedance above temperature thresholds provided by NMFS (2016 FEIR/S, Chapter 11, Table 11-1A-13, p.11-373). To do this, the number of degrees above a threshold was determined for each day in the Sacramento River or month in the Feather River and then summed for each month and water year type during the spawning period. The cumulative degree-days or degree-months were compared between NAA and H3 and H4.

12. Water Temperature Threshold Exceedance Analysis

The BA and BO analyzed temperature related effects to salmonids principally by comparing the magnitude and frequency of temperature threshold exceedances between BA H3+ and NAA (BA, Chapter 5, Section 5.4.2.1.3.1.1.2, pp. 5-254). A biologically meaningful effect for the water temperature threshold analysis was defined using the months and water year types in which water temperature results met two criteria: (1) the difference between NAA and PA in frequency of exceedance of the threshold was greater than 5%, and (2) the difference between NAA and PA in average daily exceedance was greater than 0.5°F. The 5% criterion was based on best professional judgment of fisheries biologists from NMFS, CDFW, DWR, and Reclamation. The 0.5°F criterion was based on: (1) a review of the water temperature-related mortality rates for steelhead eggs and juveniles and (2) a reasonable water temperature differential that could be resolved through real-time reservoir operations. For spawning and egg/alevin incubation, the threshold used was from the USEPA's 7-day average daily maximum (7DADM) value of 55.4°F, converted by month to function with daily model outputs for each month separately (Appendix 5.D, Section 5.D.2.1, Water Temperature Analysis Methods, Table 5.D-51).

13. IOS & WRLCM

IOS (Interactive Object-Oriented Simulation Model) and WRLCM (Southwest Fisheries Science Centers Winter-run Chinook Life Cycle Model) are both life cycle models. Both models were used in the BiOp to evaluate effects of H3+ scenario on population abundance, cohort replacement rate, habitat use distribution, and juvenile survival. These models provide results for different life stages, allowing an assessment of upstream life stages. For more information on IOS see BA, Appendix 5D, Section 5.D.3.1, page 5.D-486; and for more information on WRLCM see BiOp Appendix H.

B. STURGEON

Flow Comparisons, CalSim II; SRWQM; and the Reclamation Temperature Model are described above.

1. Water Temperature Level of Concern Analysis

This analysis determined the number of days when water temperatures in the Sacramento River exceeded temperature thresholds (Green Sturgeon: 63°F at Bend Bridge, based on DWR, 1102 (Van Eenennaam et al. [2005]); White Sturgeon: 61°F as an optimal temperature threshold and 68°F as a lethal temperature threshold at Hamilton City, based on DWR-1101 (Wang et al. [1985]) by >0.5°F to >5°F in 0.5°F increments by month for the 82-year CalSim II period of analysis. The combination of number of days and degrees above the threshold was then summed for each month and further assigned a "level of concern" (red, orange, and yellow), as defined in 2016 FEIR/S Table 11-4A-13 (p. 11-3221). The values used to determine levels of concern were not based on specific biological thresholds, but instead were based on convenient numerical breaks (i.e., 0, 5, 10, 15, and 20 days). The highest levels of concern for each year for the CalSim II period were then summed for each scenario and compared between NAA and H3 or H4.

2. Water Temperature Percent Exceedance Analysis

This analysis determined the percentage of months in which water temperatures exceeded 64°F in the Feather River at Gridley (this threshold is based on Oroville FERC relicensing analyses [DWR-1134, NMFS 2016]) by specific amounts: >1°F, >2°F, >3°F, >4°F, and >5°F (FEIR/FEIS, Chapter 11, Table 11-1A-13, p.11-373; Table 11-4A-95, p.11-3451). The percent of months in which water temperatures exceeded the threshold by these amounts was compared between NAA and H3/H4 by month during spawning and egg incubation and rearing periods for Green Sturgeon.

3. Degree-Day/Degree-Month Analysis

This analysis focused on the magnitude and frequency of exceedance above the temperature thresholds listed above (Green Sturgeon: 63°F in the Sacramento River at Bend Bridge, 64°F in the Feather River at Gridley; White Sturgeon: 61°F [optimal] and 68°F [lethal] in the Sacramento River at Hamilton City). To do this, the number of degrees above a threshold was calculated for each day in the Sacramento River or month in the Feather River and summed for each month and water year type during the spawning period. The cumulative degree-days or degree-months were compared between NAA and H3/H4.

4. Migration Flow Threshold Analysis

This analysis evaluated potential effects of Sacramento River flow on downstream migration of White Sturgeon larvae. The analysis compared the number of months per year in which flows in the Sacramento River at Wilkins Slough and Verona would exceed 17,700 cfs and 31,000 cfs, respectively, between February and May in wet and above normal water years. These minimum flows, based on correlations between “good recruitment years” and flows at Grimes (CalSim II outputs at Wilkins Slough were used) and Verona, were recommended as restoration actions in the Anadromous Fish Restoration Program’s Working Paper on Restoration Needs (DWR-1107, USFWS 1995) although not adopted in the Final

Restoration Plan. To evaluate potential effects to White Sturgeon adult migration, the analysis compared the number of months per year in which flows at Wilkins Slough and Verona would exceed 5,300 cfs between November and May. The 5,300 cfs flow threshold is the minimum flow below which White Sturgeon tend to cease upstream migration (DWR-1112, Schaffter 1997).

C. LAMPREY

1. Redd Dewatering Risk Analysis

This analysis calculated dewatering risk as the frequency at which each lamprey "egg cohort" (a new cohort was assumed to begin at each month of the spawning period throughout the 82-year CalSim II period) was subjected to month-over-month drops in flow rates of greater than 50%, as modeled in CalSim II. The analysis conservatively assumed that the egg incubation period was 2 months based on DWR, 1129 (Brumo (2006)). The analysis also assumed that a 50% flow reduction would cause substantial lamprey redd dewatering, although there is no information available to determine whether this value is suitable. Spawning and egg incubation periods used were January through June for Pacific Lamprey and September through November for River Lamprey. The analysis assumed that lamprey spawn equally throughout the reach between CalSim II model output locations in each river and that they spawn equally throughout the spawning period. Dewatering risk as calculated was then compared between NAA and H3 for all rivers and between NAA and H4 for the Feather River (other rivers were excluded from the H4 analysis due to similarities in flows between H3 and H4). As discussed for salmonids above, a monthly time step at which to assess changes in flows in the absence of real-time operations provides a very coarse assessment.

2. Spawning and Egg Incubation Water Temperature Effects

Water temperature-related effects to spawning and egg incubation were evaluated by following "egg cohorts" during Pacific and River Lamprey spawning and egg incubation periods over the 82-year CalSim II period, similar to what was done for redd dewatering risk. Because daily water temperature model outputs from SRWQM were available for the Sacramento River, the analysis was conducted on a daily time step in the Sacramento River and assumed the longest (49-day) incubation observed by DWR-1129 (Brumo (2006)). In the Trinity, Feather, and American Rivers, water temperatures from the Reclamation Temperature Model were evaluated over a 2-month incubation period on a monthly time step. For Pacific Lamprey, the analysis compared the number of 49-day periods during which at least one day (for the Sacramento River) or one month (for the Trinity, Feather, and American Rivers) exceeds 71.6°F (22°C) (DWR-1121, Meeuwig et al. 2005) between NAA and H3 over the 82-year CALSIM period. For River Lamprey, a similar analysis was conducted, although no water temperature thresholds have been reported for River Lamprey eggs. Therefore, the analysis was conducted using 71.6°F (based on DWR-1121, Meeuwig et al. [2005] for Pacific lamprey eggs) and 77°F (25°C) (based on DWR-1100, Moyle [2002] for River Lamprey adults). The analysis assumed that lamprey spawn equally throughout the reach of output locations provided by the CalSim II models in each river and that they spawn equally throughout the spawning period.

3. **Ammocoete Stranding Risk Analysis**

Rapid reductions in flow have the potential to strand ammocoetes, leading to mortality. The analysis assessed stranding risk by comparing threshold exceedances by month-over-month flow reductions from CalSim II outputs, using the range of 50%–90% reductions, in 5% increments, as the exceedance thresholds, between NA and H3 and H4. A cohort of ammocoetes was assumed to begin every month during their spawning period (January through August for Pacific Lamprey and September through November for River Lamprey) and spend 7 years rearing upstream. Therefore, a cohort was considered stranded if at least one month-over-month flow reduction was greater than a given flow reduction threshold at any time during the seven-year period. The analysis assumed that ammocoetes could not move in response to reduced flows. The analysis was conducted at a monthly time step in the Sacramento, Trinity, Feather, and American Rivers for H3, and conducted for H4 only in the Feather River due to similarities between H3 and H4 in the other tributaries.

4. Ammocoete Temperature Exceedance Analysis

A temperature exceedance analysis for ammocoetes was conducted on H3 using 71.6°F for Pacific lamprey (based on Pacific Lamprey Eggs; DWR-1121, Meeuwig et al. [2005]) and 77°F for River Lamprey (based on River Lamprey adults; DWR-1100, Moyle 2002). The analysis calculated the number of ammocoete "cohorts" that experience water temperatures greater than 71.6°F for at least one day in the Sacramento River (because daily water temperature data are available) or for at least one month in the Trinity, Feather, and American Rivers over a 7- or 5-year period, the maximum in-river durations of the Pacific and River Lamprey ammocoetes, respectively (DWR-1100, Moyle 2002). Each individual day or month starts a new "cohort" between January and August (Pacific Lamprey) or February through June (River Lamprey).

D. RESERVOIR SPECIES

1. Coldwater Habitat Threshold Volume Analysis

Based on CALSIM simulations of the carryover volume of the reservoirs over the 82-year period-of-record and SRWQM simulations of reservoir temperatures, a relationship was developed between the reservoirs' storage volume and the volume of the hypolimnion (2016 FEIR/S, Chapter 1 – Figures, Figure 11-1A-9). The actual volume of coldwater habitat required to avoid adverse effects on the coldwater species is not known, so a threshold volume was estimated based on the frequency of occurrence of carryover volumes. It was determined that 20% to 25% of the baseline carryover storage values should be less than the selected storage threshold, so that the threshold represents the lowest 20–25% of the years and so that the number of years with these potentially impacted coldwater habitat conditions could be increased if the carryover storage values were reduced substantially by an alternative. On this basis, threshold carryover volumes were estimated for each reservoir (2016 FEIR/S, Impact AQUA-217, Table 11-1A-118, pp. 11-764 to 11-765). An increase from the NAA of greater than 5% in the number of years simulated by CALSIM II that the carryover storage of a reservoir fell below its threshold value was treated as an adverse impact to the coldwater fish in the reservoir.

V. CONCLUSION

Based on the analyses conducted in the 2016 FEIR/S, the BA, and the BO, I conclude that there are no biologically meaningful effects of the CWF to aquatic resources upstream of the Delta. The CWF is, therefore, reasonably protective of these aquatic resources.

The results presented in this testimony indicate that, overall, upstream effects of CWF on winter-run and spring-run Chinook salmon, CCV steelhead, Green Sturgeon, Lamprey, and non-covered species of primary management concern are expected to be small to insignificant. There are a few upstream changes described here that suggest that physical conditions under the CWF would potentially cause degraded conditions relative to the NAA for these species, although the likelihood that a biological effect would result from the changes in the physical conditions is uncertain .

Upstream changes are primarily a result of reductions in the September and November flows under the PA relative to the NAA, as modeled using CALSIM II. The reason for the difference in CALSIM II results is that the increased operational flexibility available through CWF allows additional export of excess run-off in winter and spring, which reduces reliance on reservoir releases to support exports later in the year (i.e., fall) as compared to the NAA. In general, where there are differences in flows when comparing the NAA and CWF, those differences are limited in timing and magnitude. These modeling outcomes do not reflect the totality of the annual, seasonal, and real-time considerations that would be used to determine how to make reservoir releases in the future. For this reason, and because real-time operations process will continue to improve CWF implementation, I conclude that CWF is reasonably protective of salmonids upstream of the Delta.

My opinion is corroborated by the NMFS BO determination that the CWF is not likely to jeopardize the continued existence of winter-run and spring-run Chinook Salmon and CCV Steelhead, and is unlikely to destroy or adversely modify designated critical habitat for these species. The FEIR/S further collaborates my results for both listed and unlisted species, finding that potential effects were less-than-significant.

Executed on this ___ day of _____________, 2017 in Sacramento, California.

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Richard Wilder

VI. REFERENCES

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