Mike Podlech
Aquatic Ecologist
4474 Cortez Drive
Soquel, CA 95073
(831) 239-6750
mpodlech@sbcglobal.net

memorandum

date November 11, 2021

to Montague Water Conservation District

from Mike Podlech, Aquatic Ecologist

subject Review of Best Available Information Regarding Shasta River Salmonid Instream Flow Needs During Extreme Drought

Purpose of Memorandum

On May 10, 2021, California Governor Newsom declared a drought emergency for 41 counties, including Siskiyou County. On August 30, 2021 the State Water Resources Control Board (State Water Board) adopted emergency regulations authorizing curtailments of diversions "where flows are insufficient to protect fish" within certain watersheds in the Klamath River basin, including the Shasta River watershed. The stated purpose of the emergency regulation is to "prevent the diversion of water that would unreasonably interfere with an emergency minimum level of protection for commercially and culturally significant fall-run Chinook salmon and threatened Southern Oregon/Northern California Coast coho salmon" [*emphasis added*]. In September 2021, the State Water Board issued Order WR 2021-0082-DWR imposing curtailments on water right holders in the Shasta River. The order established monthly minimum instream flow targets based on input from the California Department of Fish and Wildlife (CDFW). CDFW set the instream flow targets based on recommendations presented in the 2014 *Shasta River Canyon Instream Flow Needs – Final Report* developed by McBain & Trush, Inc. and Humboldt State University ("M&T" hereafter). The M&T (2014) instream flow needs (IFN) recommendations are based on a Tier 2 "fish in good condition" standard, defined as "extensive habitat available for all life history tactics and all life history stages and their required habitats should have a sufficiently broad distribution to sustain the species indefinitely" that arguably exceeds the State Water Board's "minimum level of protection" standard.

At the request of the Montague Water Conservation District (MWCD), I have conducted a detailed review of the M&T IFN report, State Water Board curtailment orders and regulations, pertinent CDFW

communications, exiting water conservation and salmonid protection and enhancement programs in the Shasta River watersheds, as well as Biological Opinions issued by the National Marine Fisheries Service (NMFS) analyzing the anticipated effects of these programs. Due to the fact that curtailments in the Shasta River watershed are ongoing and target flows recently increased for the November 1, 2021 through December 31, 2021 adult salmon spawning period, my review was focused primarily on this period and life stage. Based on this review, I have concluded that the CDFW-recommended target flows for adult salmon spawning (1) exceed the "emergency minimum level of protection" standard set forth in §875(a) of the drought emergency regulation, and (2) do not consider all of the "best available science". This memorandum summarizes my findings.

Shasta River Canyon Instream Flow Needs Assessment

In 2014, M&T completed an instream flow assessment for the Shasta River Canyon using regional regression models, standard setting methods, riffle-crest measurements, 1- and 2-dimensional hydraulic modeling, direct habitat mapping, and photo documentation to develop Instream Flow Needs (IFN) recommendations measured at USGS gage 115117500 (SRY). M&T considered the results of regional regression equations and combination of 2-dimensional (2-D) modelling with direct habitat (DMH) verification as the primary analytical data set for the following adult salmon spawning IFN recommendations for the period of October 1 – December 31.

Normal/Wet Year:	October 1-15	≥125 cfs
	October 16-30:	≥170 cfs
	October 31 - December 31:	≥195 cfs
Dry Year:	October 1-30:	≥125 cfs
	October 31 - December 31:	≥150 cfs

CDFW used the dry year recommendations to set the Shasta River target curtailment flows. Upon casual review of the M&T recommendation summary provided in Section 7.2 of their report, this may appear as a sound choice to base drought flow restrictions on. However, closer review of the data underlying these recommendations suggests that even the dry year recommendations are on the high end of a range of flows that could reasonably be considered protective of adult salmon migration and spawning appropriate for drought flow management and the "emergency minimum level of protection" standard. The following information provided in the M&T methods (Section 5) and findings (Section 6) should be considered:

M&T Spawning Habitat Rating Curves: The spawning flow recommendations are based on the results of the 2-D model and DMH verification. Habitat-flow relationships were modelled at five study sites: Otolith, Hudson Road Units 1-3, and Salmon Heaven Side Channel. Unfortunately, M&T do not provide the actual numeric model outputs anywhere in the report and the reader must therefore extrapolate results from the salmonid spawning habitat rating curves provided in Figure 44 in Section 6.2.3 of the report (see below), and model polygons overlain on aerial photographs presented in Appendix F of the report.

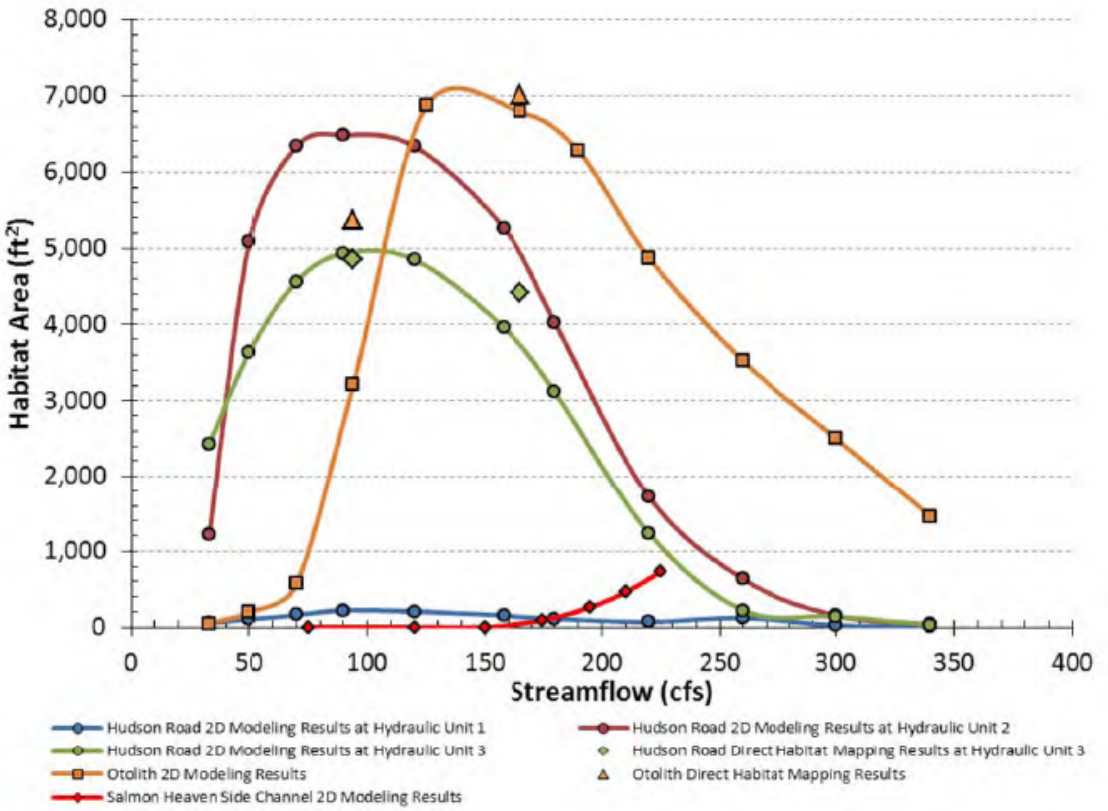

Figure 44. 2-D model predictions of salmonid spawning habitat rating curves and DHM total spawning habitat polygon areas mapped at 94 cfs and 165 cfs for individual hydraulic units in the Otolith Run/Pool Study Site and Hudson Road Study Site.

M&T summarize the habitat-flow relationship modeling results as follows [*emphasis added*]:

- "Spawning habitat in the Canyon is widely available between 50 cfs and 220 cfs based collectively on the four spawning habitat rating curves for individual hydraulic units within the Otolith Run/Pool and Hudson Road study sites (Figure 44)." (p. 68)

- "Habitat rating curves (Figure 44) had peak spawning habitat areas in the Hudson Road and Otolith study sites at 90 cfs and 170 cfs, respectively." (p. 69).

Figure 44 clearly supports the first statement regarding M&T's description of the broad range of flows providing suitable spawning conditions. While Figure 44 also supports the Hudson Road portion of the second statement (i.e., maximum habitat availability at 90 cfs), the curve for the Otolith study site appears to peak at approximately 135 cfs rather than 170 cfs. It is also worth noting that peak habitat availability at the single Otolith site is equivalent to decreased habitat availability at the three Hudson Road sites. At 135 cfs, for example, the three Hudson Road sites experience an approximate 10 percent decline from their peak, and at 170 cfs, the decline from peak spawning habitat availability at the Hudson Road sites is close to 25 percent. In fact, the model's habitat area estimates for the Hudson Road sites at 170 cfs are roughly equivalent to the extent of habitat estimated to be available at approximately 50-60 cfs. Moreover, at the 90 cfs flow modelled to provide maximum spawning habitat

at the Hudson sites, M&T's DHM results depicted in Figure 44 suggest that (1) the 2-D model vastly underestimated habitat availability at the Otolith site by about 70% (i.e., 3,100 ft^2 modelled vs. 5,400 ft^2 mapped) and (2) that spawning habitat availability at Otolith at that flow is comparable to peak Hudson Road Unit 2 and 3 habitat availability. In other words, differences in spawning habitat availability between a flow range of 90-170 cfs are negligible, but a streamflow of 170 cfs favors habitat at the Otolith site at significant expense to the Hudson Road sites, while 90 cfs provides a balanced range of spawning across the three primary study sites. Table 1 summarizes the approximate spawning habitat estimates, extrapolated from Figure 44 in the absence of numeric values, for the study sites at three streamflow levels.

Table 1: Habitat Area (ft^2) Estimated at Three Study Sites Using 2-D Modelling and DHM at 90 cfs, 135 cfs, and 170 cfs. Asterisks denote DHM values.

	90 cfs	135 cfs	170 cfs
Hudson Rd Unit 2	6,500	6,000	4,800
Hudson Rd Unit 3	5,000	4,600	4,400*
Otolith	5,400*	7,000	6,900
Total	**16,900**	**17,600**	**16,100**

In their justification for normal/wet year adult spawning IFNs of up to 195 cfs, M&T (p. 97) note that "spawning habitat is widely available at the Hudson Road Study Site at flows above 70 cfs, and widely available at the Otolith Run/Pool at 120 cfs", but argue that 170 cfs are needed in late October to "laterally distribute spawning reducing the risk of substantial cohort loss if a large scouring flood occurs during egg incubation" and that 195 cfs are need in November and December "to provide spawning habitat in the Salmon Heaven Side Channel". Although I did not include the 195 cfs recommendation in Table 1 above, it is worth noting that based on Figure 44, this flow reduces spawning habitat availability by an approximate combined 5,500 ft^2 (50 percent) from peak availability at Hudson Road Units 2 and 3 in order to activate approximately 500 ft of spawning habitat in the Salmon Heaven side channel.

Using the normal/wet year recommendations as a basis, M&T appear to have relied on professional judgement to develop the dry year recommendations selected by CDFW as the drought curtailment flow targets. The rational M&T provide (p. 98) for the dry year IFN adult spawning recommendations of 125-150 cfs is that promoting side channel spawning "may not be a desirable management strategy because redds are at greater risk of desiccation if flows drop rapidly, and juveniles may face reduced habitat area earlier during the spring season", but that flows should nevertheless rise from 125 cfs in October to 150 cfs in November and December "to provide some lateral distribution of redds and reduce the risk of redd scouring locations". Regarding the 125 cfs October recommendation, Figure 44 suggests this flow would provide only marginally greater spawning habitat availability than at the 90 cfs flow level that provides peak availability at the Hudson Road sites and near-peak availability (based on DHM) at the Ototlith site. Meanwhile, the recommendation for an increase to 150 cfs for November and December to "provide some lateral distribution of redds" is not supported by any of the data presented in the report (e.g., how much lateral distribution is gained by this 25 cfs increase and does it outweigh the

noticeable drop-off in availability at the Hudson Road sites?) and therefore appears to be subjective rather than based on available data.

Adult Salmon Fish Passage Evaluation: An additional data point provided by M&T that is relevant to the question of appropriate emergency minimum levels of protection is that a streamflow of 43 cfs in the canyon was determined to fully meets CDFW's widely-used adult fish passage criteria (p. 65 and Figure 42). As CDFW is aware, the Shasta River watershed contains two primary adult salmon spawning grounds, the Canyon and the Big Springs Complex. Due to the availability of cold spring water, the Big Springs Complex is widely understood to provide juvenile salmonid spring and summer rearing habitat that is far more suitable than the typically warm conditions present in the Canyon during those seasons. In fact, the Shasta River Canyon has been described as an ecological trap for coho salmon (Jeffres and Moyle 2012) due to "the presence of positive environmental cues for spawning during winter in the canyon area which will be unsuitable for rearing of their progeny during the following summer." We recognize that CDFW contends that those unsuitable summer conditions are the result of upstream diversions, but note that some researchers think it "unlikely that even unimpaired streamflows would have provided desirable water temperatures for rearing salmonids" (M&T p. 103) although M&T suggest that summer rearing "may have been" viable due to high primary productivity and thermal variability. I am not qualified to opine on the debate over whether the canyon ever provided suitable summer rearing habitat, but I would note that critical drought conditions that necessitate an emergency minimum level of protection are not the appropriate time to manage for summer rearing habitat in a reach that has not provided that function even in non-drought years under an impeded flow regime or "may have" provided that function under unimpeded conditions. Given the potential for the canyon to continue functioning as an ecological trap in the foreseeable future, especially during extreme drought conditions, it is questionable why CDFW would be promoting maximum spawning habitat conditions in the canyon while also approving late season flow conditions known to result in unsuitable rearing conditions in the canyon during the summer of 2022. I my opinion, during the months of November and December, an emergency minimum drought flow target should be encouraging adult migration to access the Big Springs region where both high-quality spawning and summer rearing habitat is available.

Water Year Designations: Regarding CDFW choice to use M&T's dry year IFN recommendations as emergency minimum drought protection flow targets, it bears noting that M&T only used two water year designations: "Normal/Wet Year" and "Dry Year". M&T explain (p. 94) that while flow management strategies often apply up to five water year classes (wet, above normal, below normal, dry and critically dry), they elected to use a "simple approach" of only two water year classes due to the "generally modest hydrologic variability in the Shasta Basin and the stabilizing effect of spring baseflows". Water year classes are typically defined in terms of percent exceedance (i.e., the probability of a given annual discharge being exceeded). For the Shasta River Canyon IFN assessment, M&T chose to define dry water years as those with an exceedance probability of 61-100 percent. This results in a rather broad range of hydrologic conditions that would fall into the "dry" category. While this approach may be appropriate for M&T's intended objective of long-term flow management, it's use as CDFW's response to the State Water Board's request for flow target recommendations aimed at meeting an "emergency minimum level of protection" during critical drought conditions appears less appropriate. Flow targets based on "very dry" (e.g., 80-100 percent exceedance) or even "critically dry" (e.g., 90-100 percent exceedance) water year types would be better suited for current conditions. For reference, in its "Finding of Emergency", the State Water Board classified the 2020-2021 water year as "one of the severest

droughts on record for the Shasta River watershed" with "flows in the lowest one percent of the historical record" (i.e., 99 percent exceedance probability). While we recognize CDFW did not have "very dry" or "critically dry" water year IFN recommendations readily available, a detailed analysis of M&T could have been used to come up with a more balanced use of severely constrained water flow conditions. In fact, M&T themselves should have been consulted in this decision-making process.

Verification/Effectiveness Monitoring: The M&T Canyon IFN assessment was completed in 2014. We are not aware of any effectiveness studies that have been conducted to validate whether the flow recommendations achieve their goals and objectives. Even now that these recommendations are being used as curtailment target flows, it does not appear that CDFW or other entities are conducting basic monitoring activities such as snorkel surveys to assess rearing habitat utilization (or lack thereof) or spawner surveys to evaluate whether the flow targets are achieving the stated purpose of salmon migration and spawning. We recognize that even if such studies were to be conducted now, the lack of comparative baseline data regarding rearing and spawning success would unfortunately make it difficult to gain a good understanding of whether or not the curtailment target flows are achieving a meaningful improvement to salmon habitat quality and quantity in the canyon.

Conservation and Habitat Enhancement and Restoration Project

MWCD owns and operates Dwinnell Dam in the upper Shasta River watershed. Following a complaint filed by Klamath River Keeper and the Karuk Tribe in 2012, MWCD spent several years developing a water conservation project and instream flow strategy, combined with instream restoration projects, known as the Conservation and Habitat Enhancement and Restoration Project (CHERP). Under CHERP, MWCD committed to implementing instream flow release schedules ("CHERP flows") upon completion of its main canal lining effort, as well as providing "interim flows" for the duration of the 5-year canal lining period. MWCD developed the "interim flows" and "CHERP flows" strategies in close coordination with NMFS for five water year types (very dry, dry, normal, wet, very wet). In September 2017, NMFS issued a Biological Opinion (BiOp) (WCR-2015-2609) that analyzed the anticipated effects of the CHERP project, including the effects of the interim and final CHERP flows. In its analysis, NMFS relied on multiple sources of the best available science, including the results of temperature modeling experimental flow studies (AquaTerra Consulting, 2015) and M&T's 2013 *Shasta River Big Springs Complex Interim Instream Flows Needs Assessment*.

To account for the variability in storage at the onset of irrigation season, and variability in water releases for irrigation and prior rights holders, Watercourse Engineering (2016) developed a water year type classification system for CHERP under which determinations are made on March 1st and then updated on April 1st and again on May 1st. Applying the water year classification criteria to the 30 years of data for which both snow water content and reservoir storage estimates are available, 13 percent of water years would have been categorized as "very dry", roughly equivalent to an 84 percent exceedance probability. For "very dry" water years, the current "interim flows" and pending "CHERP flows" release schedules are identical and consist of a total of 2,250 acre-feet of environmental water releases that include spring pulse flows for smolt emigration and fry/juvenile redistribution, summer releases based on the temperature model and experimental flow study to support juvenile rearing, addition of cold water releases from MWCD's groundwater wells to help maintain suitable summer rearing temperatures, fall releases to support adult migration and spawning, and winter releases to support

juvenile over-wintering. In addition, MWCD bypasses high flows at its Parks Creek diversion in the winter to support salmon migration and spawning in this tributary and the mainstem Shasta River. As shown on Figure 21 of the NMFS Biological Opinion (p. 67), "very dry" year CHERP flows during the November 1-December 31 salmon migration and spawning season actually slightly exceed the 2013 M&T Big Springs Complex IFN recommendation for that period, and NMFS concluded (BiOp p. 71) that "[b]ecause the CHERP flows in the Upper Shasta River and increased bypass flows for Parks Creek are sufficient to provide migration opportunity to adult coho salmon in the fall and winter during the driest of water years, NMFS does not expect the fitness of adult coho salmon to be reduced as a result of changes to the winter hydrograph under the proposed CHERP." Clearly, this NMFS opinion has direct relevance to the State Water Board's emergency minimum level of protection standard and the CHERP "very dry" year flow release schedules should have been considered as part of CDFW's target flow recommendations, especially since NMFS considered a wide range of best available science when it issued its Biological Opinion.

Template Safe Harbor Agreement

Over a period of about six years, NMFS and CDFW negotiated the *Template Safe Harbor Agreement for the Conservation of Coho Salmon the Shasta River* with private landowners and irrigation districts collectively called the Shasta Watershed Conservation Group (SWCG). As a signatory to the Template Safe Harbor Agreement (SHA), CDFW participates both in a regulatory capacity and as permittee for an enrolled property (Big Springs Wildlife Area). The SHA establishes the general requirements for NMFS to issue Enhancement of Survival Permits to non-federal landowners in the Shasta River Basin for the purpose of promoting the conservation, enhancement of survival, and recovery of the Southern Oregon/Northern California Coast coho salmon. The SHA and associated landowner site plans were developed to result in implementation of a wide range of water efficiency projects, riparian planting and fencing, and instream flow dedications for fish and wildlife.

The SHA includes a comprehensive Flow Management Strategy developed by NMFS, CDFW, SWCG and a Technical Advisory Committee (TAC). The Flow Management Strategy objectives are based on the biological requirements of coho salmon at each freshwater life stage but also considered the habitat and flow needs of Chinook salmon (NMFS and Aquaterra 2020). Utilizing relevant scientific information such as the results of a temperature model and experimental flow study (AquaTerra Consulting, 2015) and M&T's IFN assessments for the Big Springs Complex and Shasta Canyon, the TAC developed reach-specific qualitative habitat improvement goals as well as quantitative flow objectives. A comprehensive summary of the various components and commitments of the SHA flow management strategy is beyond the scope of this memorandum but a detailed description is provided by NMFS and Aquaterra (2020). The NMFS Biological Opinion (WCRO-2020-02923) analyzing the effects of the issuance of the Enhancement of Survival Permits and SHA implementation concludes that "NMFS expects the net effects of the proposed action on the Shasta River population of SONCC coho salmon to be an overall improvement to population viability." Flow strategies that are expected to result in improved viability would clearly also provide an emergency minimum level of protection.

While many of the SHA projects that are expected to affect hydrology and water quality have not been completed, the Flow Management Strategy constitutes best available science that should have been considered in setting curtailment flow targets. Interestingly, a July 29, 2021 CDFW letter to the State

Water Board cites a May 2021 event in which "landowners were meeting voluntary obligations identified in their mutually agreed upon Safe Harbor Agreement with NOAA while others were voluntarily reducing their diversion and/or supporting the flow staying in stream" as a "successful example of a temperature and flow relationship." Considering that SHA landowners showed a willingness to contribute flows even prior to full build-out of water efficiency projects, and that CDFW recognized the benefits that can be achieved through a collaborative landowner-based program, it is unclear why the SHA's science-based and NMFS-supported Flow Management Strategy was not incorporated into the curtailment flow target recommendations.

Considering that most agricultural diversions in the Shasta River watershed end by November 1, the current Canyon-based November 1-December 31 curtailment flow target can only be met with Dwinnell providing by-passed releases that exceed the SHA instream flow targets for that period during a "very dry" year. Although storage levels in Dwinnell Reservoir are at historic lows after two years of extreme drought, MWCD has been releasing additional flows since November 1. On November 5, 2021 storage in Dwinnell Reservoir was about 2,800 acre-feet (or 6% of capacity), only slightly above MWCD's total environmental water commitment for a "very dry" year. If MWCD continues to bypass at above-CHERP release levels to meet current curtailment flow targets in the Canyon, MWCD's ability to meet its 2022 flow release commitments, especially spring pulse flow releases that have been shown by CDFW to greatly increase smolt survival, will be jeopardized.

Prior to 2014, survival of coho salmon smolts migrating out of the Upper Shasta had been documented to be relatively low (77%) (Adams, 2013). Qualitative observations made by CDFW staff suggested that exceedingly shallow water depths, particularly downstream of beaver dams, may be partially responsible for low outmigration survival. In 2014, MWCD implemented spring pulse flow releases. Pulse flow monitoring conducted by CDFW (2015) reported improved outmigration conditions, and subsequent PIT tag data analysis revealed increased survival (90%) of smolts migrating out of the Upper Shasta River reach in spring 2014 (CDFW, 2016). Unfortunately, there is a distinct possibility that water year 2022 could be another drought year and the ability of MWCD to provide spring pulse flow releases would be an important aspect of achieving the emergency minimum level of protection sought by the State Water Board.

It is also important to note that an irrigation efficiency study (Davids Engineering 2011) prepared for CDFW and Emmerson Investment suggests that several cold-water springs located downstream of Dwinnell Dam and in the Parks Creek watershed may be directly influenced by Dwinnell Reservoir storage volumes. Anecdotal evidence of spring discharges decreasing or ceasing during years of low Dwinnell storage volumes appear to confirm this. Cold water discharges in the upper Shasta River watershed have been documented to create the high-quality juvenile salmon summer rearing habitat the Big Springs Complex is known for and will be even more important in the event of another drought year in 2022. Every acre-foot of water discharged by MWCD in excess of its "very dry" year commitments in November and December 2021 to meet current Canyon-based flow targets will be unavailable for supporting salmon protection in spring and summer 2022. To put this into perspective, the 25 cfs increase from the CDFW October target to the November/December target alone amounts to a total of approximately 3,000 acre-feet of water over a two-month period to achieve a very subjective management goal of "some lateral distribution of redds" in the canyon.

Conclusion and Recommendation

CDFW relied on the dry water year instream flow recommendations developed for the Shasta Canyon reach by M&T to set drought curtailment flow targets. Although the M&T flow recommendations were never evaluated for effectiveness after their 2014 publication, I agree with CDFW that the M&T report constitutes one of a number of sources for the best available science regarding Shasta River flow needs for Chinook and coho salmon and that it was therefore reasonable to consider the results of the M&T assessment in the development of flow targets. However, CDFW chose to simply adopt the M&T recommendations intended to provide a long-term flow management strategy rather than evaluating the assessment results to better define flows that would meet the minimum level of protection standard defined in the drought emergency regulations. For the November 1-December 31 adult migration and spawning season, the M&T assessment results clearly show that (1) CDFW's current fish passage criteria for adult salmon migration in the canyon are met at a flow of 43 cfs; (2) spawning habitat in the canyon is "widely available" at flows as low as 50 cfs; and (3) peak spawning habitat availability at three of the four study sites is achieved at 90 cfs. As such, the data set referenced by CDFW as the best available science provides strong scientific justification for selecting winter flow targets in the range of 43-90 cfs for temporary emergency minimum protection during extreme drought conditions.

Moreover, extensive effort and resources have been expended by NMFS, CDFW, and landowners in the Upper Shasta River watershed to develop flow management strategies for the protection, enhancement, and recovery of salmon based on the best and most recent science available. Not only should those efforts and strategies have been considered in the development of the curtailment flow targets, but the potential adverse effects of the current 150 cfs flow target on spring and summer 2022 salmon protection efforts could be detrimental. Given that the Upper Shasta River watershed is widely recognized to provide far more critically important rearing habitat than the canyon reach that has been described as an ecological trap for salmon, ensuring that emergency minimum protection levels can be provided in the upper watershed during another potential drought year is critically important.

Based on my review of the M&T IFN assessment results and other pertinent information, my professional opinion is that a 90 cfs flow target for October through December 2021 would have offered a more than adequate emergency minimum level of protection for Chinook salmon migration and spawning. However, considering that October 2021 curtailment flow targets had already been set at 125 cfs and some level of lateral distribution of redd construction may have occurred, it may be more prudent to retain that 125 cfs target through the end of 2021.

I also recommend CDFW and State Water Board work with MWCD and other the SHA participants to consider M&T IFN recommendations for the Big Springs Complex (including Parks Creek) and implement existing flow strategies and schedules for those reaches over meeting a canyon flow objective. While the canyon reach is one of two critical reaches for fall Chinook salmon spawning and rearing, it should not be the focus reach for winter. The objective should be providing dependable flows in the Big Springs Complex, including storing for releases later in the season to ensure that subsequent life stages are protected.

If hydrologic conditions during the remainder of 2021 result in continued emergency drought conditions into 2022, a thorough review of M&T's IFN assessment results for the winter rearing, smolt

outmigration, and summer rearing life stages should be conducted and flow targets adjusted as appropriate.

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