Center for Independent Experts (CIE) Independent Peer Review of the

Upper Yuba River Salmonid Habitat Assessment and Population Model

Prepared for NMFS by Stillwater Sciences

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Review of the Upper Yuba River Salmonid Habitat Assessment and Population Model

Executive Summary

The National Marine Fisheries Service (NMFS) desires an assessment of the potential benefits to spring Chinook salmon and steelhead from providing them access to the upper Yuba River, above Englebright Dam. Much of the area in question has been strongly affected by human activity, so historical information on Chinook and steelhead in the basin is of limited utility. NMFS contracted with Stillwater Sciences to modify and parameterize its new habitat assessment model, RIPPLE, to quantify the potential of the habitat for these species in the upper Yuba River under current conditions, and under two alternatives. The resulting report from Stillwater Sciences is the subject of this review.

RIPPLE is a complex, spatially explicit simulation model that simulates habitat, carrying capacity, and equilibrium population, although only the freshwater habitat and carrying capacity were assessed for the upper Yuba River. RIPPLE was designed specifically for data sparse regions, and uses hydraulic geometry relationships and stream gradient to simulate habitat for salmonids, although other information that may be available can be used as well.

Complex simulation models are essentially thought experiments, and as virtual systems can be valuable. However, their utility for assessing real ecological systems is dubious, and leading ecological modelers, including the Recovery Science Review Panel (RSRP), have warned strongly against using them for this purpose. I agree with that advice. Complex simulation models are built of many approximations, each of which adds additional uncertainty to the simulation, and there is no good way to track the uncertainty. Because the system being simulated is non-linear in important respects, the effects of small errors can be large. Moreover, there is a tendency to include factors for which plausible approximations are available, even if they are not that important, and to omit other more important factors for which approximations are not available. RIPPLE, for example, does not simulate the food supply. Moreover, in my opinion, the application of RIPPLE to the upper Yuba River is based on mistaken ideas regarding the biology of spring Chinook. For the upper Yuba River specifically, about which much is already known, other, more appropriate assessment approaches are available. For these reasons, the application of RIPPLE to the upper Yuba River is not a reasonable modeling approach, nor does not represent the best available science.

Organization:

This review is organized following the directions in Annex 1 in the Statement of Work, which is attached as Appendix 2:

1. The CIE independent report shall be prefaced with an Executive Summary providing a concise summary of the findings and recommendations, and specify whether the science reviewed is the best scientific information available.

2. The main body of the reviewer report shall consist of a Background, Description of the Individual Reviewer's Role in the Review Activities, Summary of Findings for each [Term of Reference] in which the weaknesses and strengths are described, and Conclusions and Recommendations in accordance with the [Terms of Reference].

3. The reviewer report shall include the following appendices:

   Appendix 1: Bibliography of materials provided for review
   Appendix 2: A copy of the CIE Statement of Work

Background:

All major rivers flowing into the Central Valley of California are blocked by dams in the foothills that are impassable by anadromous fish, so spring Chinook and steelhead have access to only to remnants of their natural habitats in a few streams such as Mill, Deer, and Butte creeks. Of these rim dams, Englebright on the Yuba River is by far the smallest. It was built in the early 1940s primarily to contain hydraulic mining debris, whereas the other dams were designed primarily for flood control and water conservation. Hydraulic mining never resumed, so the remaining uses of Englebright Dam and lake are recreation and minor generation of hydroelectric power.

Given the limited benefits from Englebright Dam, removing it to open up more habitat for steelhead and Chinook salmon seemed to some an attractive prospect, especially after passage of the Central Valley Project Improvement Act. Others have favored constructing passage facilities, and this seems a more viable alternative politically. Englebright Lake is small enough that juvenile salmonids can be expected to find their way through it on their downstream migration, and the water level is relatively stable, which facilitates operating passage facilities. In either case, any consideration of the costs and benefits will require that the habitat value of the river above the dam be assessed.

The question facing NMFS regarding the upper Yuba River is similar to the question it faced recently regarding the upper Klamath River: what would be the effects of restoring access by anadromous fish? Simple referral to historical data on the range and abundance of salmon and steelhead in the upper Yuba River would be of limited value as an assessment for two reasons. First, human activity has changed the watershed. The upper Yuba River (above Englebright) comprises three forks, and there are other impassable dams on the North Fork and Middle Fork.

Extensive diversions for hydropower have changed the flows in the South and Middle Forks, so that especially the South Fork is warmer than it used to be, and indeed so warm that biologists familiar with the watershed recognize that some modification of the diversions will be necessary if the South Fork is to provide much habitat. Second, anthropogenic climate change is warming the rivers, and will continue to do so. Besides water temperature, warming also changes the annual distribution of flow, because more precipitation will fall as rain instead of snow, and snow will melt earlier in the year.

These complications make modeling essential for the assessment, and NMFS has contracted with Stillwater Sciences to apply the RIPPLE model (hereafter RIPPLE) for the purpose. This required making some modifications to the publically available RIPPLE code to deal with spring Chinook holding habitat, and parameterizing the model for use in the Yuba basin. The assessment simulated current conditions, and also two alternatives that assume different degrees of modification to the diversions, plus additions of spawning gravel to selected reaches.

RIPPLE was produced by a collaboration between the UC Berkeley Department of Earth and Planetary Science and a well-known consulting firm, Stillwater Sciences. The involvement of Bill Dietrich, a prominent geomorphologist at Berkeley who has long been concerned with ecological matters (e.g., Ligon et al. 1995; Power et al. 1996), lends credibility to the model. As described by Dietrich and Ligon (2009), RIPPLE "is a process-based, integrative, adaptive modeling framework incorporating state-of-the-art science and tools for understanding how habitat and ecosystem processes affect salmon populations." RIPPLE comprises three modules (Stillwater Sciences 2012:ES-2, 3):

1. A physical module ("GEO") that stratifies the channel network based on geomorphic and hydrological attributes (e.g., gradient, drainage area, bankfull width and depth, summer low flow width and depth);
2. A habitat carrying capacity module ("HAB") that defines the habitat quantity and quality for each reach, species and life stage; and Technical Report Modeling Spring-Run Chinook Salmon and Steelhead in the Upper Yuba River Watershed;
3. A population dynamics module ("POP") that employs biological parameters and stock-production relationships to estimate equilibrium population sizes at variable spatial scales and locations throughout the watershed.

Additional description of the modules is provided in Dietrich and Ligon (2009); Baker (2009) discusses the structure of the model in mathematical terms.

Description of the Individual Reviewer's Role in the Review Activities:

The Center for Independent Experts (CIE) has contracted with me to provide an independent peer review of a 2012 report prepared by Stillwater Sciences for NMFS: "Upper Yuba River Salmonid Habitat Assessment and Population Model" (hereafter SS12).

The Terms of Reference:

The Terms of Reference (ToRs) specified in the Statement of Work are:

1. Review the RIPPLE model application for the upper Yuba River (Stillwater Sciences 2012) to determine whether the data sets, assumptions, and model parameters represent a reasonable modeling approach to assess the relative potential of upper Yuba River habitats under the three different modeled scenarios.
2. Does the RIPPLE model application for the upper Yuba River produce results that are relevant and appropriate to support the evaluation of anadromous fish reintroduction potential in the upper Yuba River watershed?

The ToRs are closely related, and so are considered together. They are appropriate, as they indicate that NMFS is aware that, as the statistician George Box put it, "… all models are wrong, but some are useful." Accordingly, the threshold question embedded in the ToRs is whether RIPPLE is reasonably useful, both potentially and as applied to the Yuba River by SS12. Other questions to be considered are whether the model advances understanding of the problem, and whether there are practicable alternatives that would be better. Models are tools, and just as driving a nail with a cobble can be reasonable if a hammer is not available, using a model that leaves much to be desired can be reasonable if no good alternative is at hand. A final question whether the model is appropriate for the data that are available. There is little point to using a model requires input data that can only be guessed at, or to use a model to estimate something that is already known. In terms of fish habitat, the three alternatives considered can be ranked without recourse to the model: Alternative 2 is better than Alternative 1 is better than current conditions, and it is reasonable to suppose that the resulting populations would be ordered in the same way. Therefore, to be useful, the model must make usefully good estimates of how much better or worse one option is than another.

Besides the estimated equilibrium population size, RIPPLE also produces estimates of habitat length or area, juvenile rearing capacity, etc., which can also be zero, and were results of interest for SS12. Thus, the estimates should approximate a ratio scale, such that a predicted carrying capacity for over-summering juveniles of X thousand fish or would imply habitat conditions that have roughly twice the carrying capacity for over-summering juveniles as condition that give an estimated carrying capacity of 0.5X thousand, and the magnitude of the carrying capacities should be roughly correct. Even if the estimated carrying capacities were off by some factor, the estimates would still be useful for the assessments if, at the least, the predictions approximate an interval scale, so that the difference between conditions producing estimated carrying capacities 0.4X and 0.5X thousand fish would be roughly the same as between conditions producing estimates of 0.6X and 0.7X. Otherwise, the estimates will not support a meaningful assessment.

Summary of Findings for each ToR:

RIPPLE is a new model for assessing environmental flows for salmonids that is supposed to simulate the equilibrium population size and measures of various habitat and habitat capacity variables, given GIS and other data on the stream basin and information regarding the species of interest. When additional information is available, for example on migration barriers, it can be incorporated. Equilibrium population size seems based more on mathematics than biology, but taken as an index it seems useful, as are the various habitat and habitat capacity indices. SS12 considered only the estimates of habitat and habitat capacity, to avoid the complications arising from anadromous fish spending much of their lives away from the Yuba River.

Fundamental problems with RIPPLE and similar models:

RIPPLE is a complex simulation model. Simulation models are essentially thought experiments (Schnute 2003). As such, they can be extremely useful; for example, Railsback et al. (2003) used a complex individual-based simulation model to show that, given how biologist think drift-feeding salmonids interact with the stream, microhabitat selection should vary with discharge, which challenges a basic assumption of the standard method for environmental flow assessment. Complex simulation models can also be helpful as adjuncts to research programs. However, the utility of such models for predicting outcomes in specific situations or for environmental flow assessments is dubious.

The appeal of RIPPLE and other complex simulation models such as the EDT model seems to be the intuitively appealing notion that more complex and 'realistic' simulations will allow for better assessments, and can provide a framework for organizing information from various sources. However, this notion has been severely criticized by prominent ecological modelers. For example, some years ago NMFS recruited a high level advisory committee, the Recovery Science Review Panel (RSRP), to help with the planning for the recovery of listed salmon on the Pacific Coast. In the report of one of its meetings, the RSRP (2000) wrote that:

> The conclusions to be derived are that large-scale models that attempt to capture the dynamics of many species, or that rely upon the measurement of massive numbers of parameters, are doomed to failure. They substitute sledgehammer simulation for analytical investigation and efforts to identify the few key driving variables. Large models are bedeviled by problems of parameter estimation, the representation of key relationships, and error propagation. When the phenomena are fundamentally non-linear, this leads naturally to path dependence and to sensitivity of results to parameter estimates. As the number of parameters increases, the potential for mischief increases. Thus it is essential to rid models of irrelevant parameters, and to identify key relationships. It also emphasizes the importance of locating what aspects of the model are most likely to lead to the expansion of error, and to focus on representing these as accurately as possible. This can only be done reliably through data-driven methods, with attention to appropriate statistical methodology.
>
> When the data are not available for the needed estimates of parameter values, there is a tendency to insert values based on opinion or expert testimony. This practice is dangerous. The idea that opinion and "expert testimony" might substitute for rigorous scientific methodology is anathema to a serious modeler and clearly represents a dangerous trend. Indeed, there are limitations even to what can be done on the basis of data: the fact that relationships are often nonlinear, and further that interest often rests on understanding the behavior of populations beyond the range of variables that has been observed, creates vexing problems for the modeler. It provides a compelling argument for experimentation in order to elucidate underlying mechanisms, for the recognition of limits to predictability, and for the use of adaptive assessment and management (Ludwig and Hilborn 1983; Holling 1978).

> EDT is a case study of the problems just discussed. The current version which uses 45 habitat variables might be a useful list of things to consider, but the incorporation of so many variables into a formal model renders the predictions of such a model virtually useless. Even more vexing is that EDT depends upon a large number of functional relationships that are simply not known, (and cannot be known adequately) and yet they play key roles in model dynamics. The inclusion of so much detail may create an unjustified sense of accuracy; but actually it introduces sources of inaccuracy, uncertainty and error propagation. Subjective efforts to quantify these models with "expert opinion" compound these ills.

Similarly, the eminent mathematical ecologist Robert May wrote in an article in Science, entitled “Uses and abuses of mathematics in biology,” that “It makes no sense to convey a beguiling sense of ‘reality’ with irrelevant detail, when other equally important factors can only be guessed at” May (2004:793). The criticisms are not new; I heard essentially the same thing in 1977 from Richard Levins, another prominent ecological modeler.

Considering the EDT model is instructive, because in important respects it is similar to the RIPPLE model (Baker 2009). Despite the harsh criticism of EDT by the RSRP, it continues to be used for recovery planning. Apparently, this is because it provides a good framework for describing and ‘trying out’ the opinions of the various stakeholders (Williams 2006, Ch. 14). Advocates of such complex ecosystem simulations seem undeterred by criticisms like those just quoted, and doubtless papers based on such complex simulation models are published every year. However, I have not seen any serious refutation of the criticisms expressed above, and certainly the advocates for such models do not have the academic stature as modelers such as May, Levins, or several members of the RSRP.

Examples of approximations that introduce uncertainty into RIPPLE simulations:

Hydraulic geometry, channel classifications, and habitat area estimates are three examples of ways that approximations introduce uncertainty into RIPPLE.

Hydraulic geometry: The GEO module takes digital terrain data as input, and uses well established hydraulic geometry relationships that predict the width, depth and velocity of stream channels as power law functions of discharge (Q), usually written as:.

$$w = aQ^b, \quad d = cQ^f, \quad v = kQ^m$$

where w, d, v are width, depth and velocity, and a, b, c, f, k and m are parameters determined from data. These relations can be defined both at a point on a stream and along the stream, although the exponents will be different. Hydraulic geometry relations for alluvial channels were described over half a century ago in a classic paper by Leopold and Maddock (1953). More recently, Montgomery and Gran (2001) described hydraulic relations along a stream for bedrock channels. Discharge scales with drainage area, so similar relations can be defined using drainage area for parts of the stream that lack discharge data (e.g., Figure 51 in SS12).

Various workers have claimed that the along-stream hydraulic geometry relations are useful for environmental flow assessments, but the claim is dubious (Williams 2011). Although the relations apply on average, there is considerable scatter even in hydraulic geometry derived from gage data, as noted by Leopold and Maddock (1953). Variation along the stream has recently been emphasized by Fonstad and Marcus (2010; e.g., Figure 1), strongly suggesting that the scatter around the hydraulic geometry relations is greater than indicated by the data from which the relations were paramaterized (e.g., figures 5-1 to 5-6 in SS12), or in other reports on the application of hydraulic geometry to environmental flow assessment. This follows from the kinds of data used to parameterize the relations. Generally, there are data from stream gages (e.g., Leopold and Maddock 1953) or else reach averages (e.g., Montgomery and Gran 2010). For the application of RIPPLE to the Yuba River, Stillwater Sciences (2012) used gage data from Curtis et al. (2006) and (apparently) reach-averaged data from NFMS (Table D-1). Reach averaged data clearly suppress variation, and stream gages are put where the flow pattern in the stream is as smooth and regular as is practicable, which also tends to suppress variation. RIPPLE uses reach averaged data, so this may not seem such a problem, but Fonstad and Marcus's data show that variation from the hydraulic geometry predictions occurs at a length scale comparable to the reaches (arcs) in RIPPLE, and the meaning of habitat averages to fish is questionable.

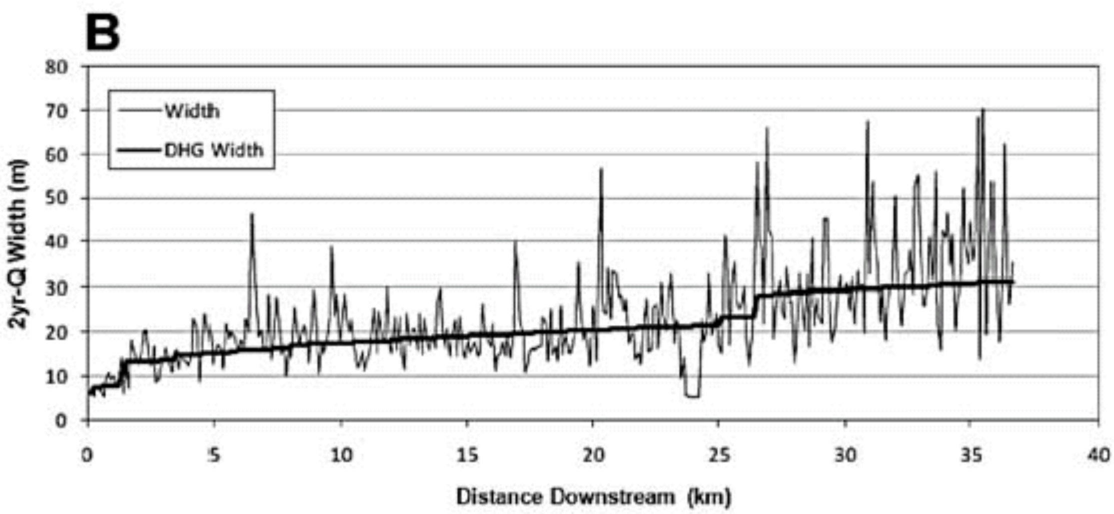

Figure 1. Part of a figure from Fonstad and Marcus (2010), showing variation in width at the two-year flood of Soda Butte Creek, a gravel and cobble bedded stream in the Rocky Mountains.

Channel classification: The use of classification in RIPPLE is described in Dietrich and Ligon (2009:1):

> A landscape-scale stratification or classification is necessary before one can apply RIPPLE. The goal of such classification systems is to identify relatively homogenous regions, or units, for which a single set of characteristics can be developed and then applied without need to verify their accuracy at every site. Ideally, a relatively small number of units in a given region, each of which spans a relatively large area, can be identified and characterized. The physical attributes

> of a geomorphic landscape unit (or "GLU") are what the GEO component uses to provide the physical template for RIPPLE.

It may be that such "relatively homogenous" regions actually exist on the landscape, but since change in nature is normally continuous, the extent to which this is true depends almost entirely on the meaning of "relatively." Rarely can a spatial region such as a GLU be defined such that conditions on either side of a boundary are less similar than are conditions within but at opposite sides of the region, and the fewer such units are, the more rare this will be. Landscape classifications are probably necessary and certainly useful for thinking about many environmental issues, including environmental flow assessment, but it is important to remember that the categories are human inventions, not attributes of nature.

Habitat area: As a final example of an approximation that introduces uncertainty, RIPPLE assumes that the amount of suitable physical habitat available in a reach of a given channel type can be approximated essentially as a fraction of the area of the basin. According to Dietrich and Ligon (2009:16):

> Each channel reach is composed of habitat units that vary in size and suitability. The different types of habitat units defined reflect channel features that vary in their value and use by different salmonid species and life stages. RIPPLE currently uses a classification of four habitat types including pool, riffle, and run habitats where each channel type within a GLU is composed of a similar proportion of these habitat units. Although the proportion of habitat units is similar between reaches of the same channel type, the quantity of habitat within a channel reach is not. Habitat area is calculated based on channel size using a drainage area relationship (from GEO) according to the location of the reach within the drainage basin.

One can ask, why not then just estimate the population from the area of the basin, along with other selected variables, and indeed that is just what Liermann et al. (2010) and Lindley and Davis (2011) did.

As a final example, although many others could be listed, RIPPLE deals only with physical habitat for the species of concern, but the availability of food is also highly important (Wipfli et al. 2010). The temperature tolerance and growth of juvenile salmonids depends strongly on the amount of food available, as shown by classic experiments reported by Brett et al. (1969), as well as by field data (e.g., Jeffries et al. 2008). Growth affects life history choices (Thorpe et al. 1998; Sogard et al. 2012) and the amount of food available also affects territory size and so potential population density (Grant et al., 1998).

Problems with the application of RIPPLE to the Yuba River:

Water temperature thresholds:

Where and whether water temperatures in different reaches of the upper Yuba River are or will be too warm for Chinook and steelhead probably are the most important questions for the assessment of the south and middle forks. The question is also difficult, because the effects of temperature are complex and highly non-linear, especially for holding habitat for spring Chinook.

As SS12 recognizes, the best evidence regarding the temperature tolerance of adult spring Chinook comes from Butte Creek, where a robust and well monitored population exists, but suffered extensive mortality from high temperatures and infections with *columnaris* and *Ich* in 2002 and 2003 (Ward et al. 2006a). According to Ward et al. (2006a), "Previous evaluations suggested that an extended period of mean daily temperatures above 19.4°C during July as measured at the Quartz Bowl Pool preceded the onset of significant pre-spawn mortalities (Ward et al., 2004b; Ward et al., 2006b)."

Based mainly on these reports, SS12 set an upper temperature threshold of 19°C mean weekly average temperature (MWAT) for Chinook holding habitat (p. 17). However, this seems unduly conservative, because the Quartz Bowl is at the upstream end of the holding habitat in Butte Creek, and the water warms downstream, except where returns flows from the Centerville Powerhouse add cooler water to the stream. Almost all of the holding habitat in Butte Creek had average temperatures in excess of 19°C in the second half of July 2005 (Figure 2). According to Ward et al. (2006a) only "likely normal attrition" (~3.5% mortality) occurred in 2005. Williams (2006:123) considered the same temperature data as did Ward et al. (2006b), and remarked that "Assuming that high mortality did not occur in previous years, the data suggest that it results from more than a few days with mean temperature greater than 21°C at a monitoring site (Pool 4) in the central portion of the holding habitat (temperatures are about 1° C cooler at the upstream end of the holding habitat, and about 2°C warmer at the downstream end)." Data presented in Williams (2006; Figure 6.6) show that conditions in 2005 were not unusual, and information from other Central Valley streams also support a higher temperature threshold (Williams 2006).

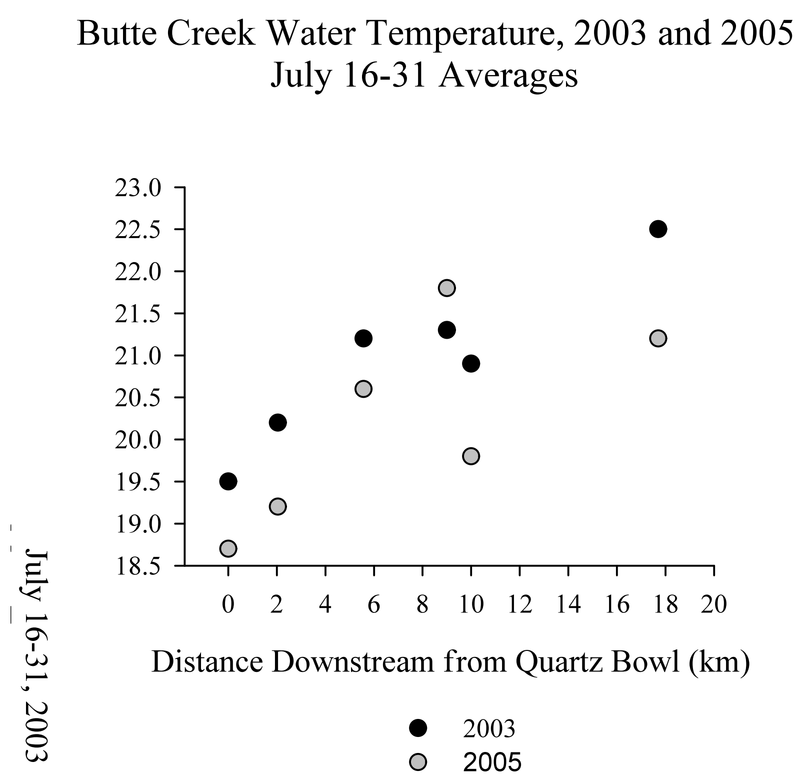

Figure 2: Mean daily water temperature in the Spring Chinook holding reach of Butte Creek for July 16-31, 2003 and 2005. Data from Ward et al. (2006), Table 7. The sudden temperature drop at ~10 miles below the Quartz Bowl reflects the influence of return flows from the Centerville Powerhouse.

The temperature thresholds for rearing juvenile Chinook and steelhead used for SS12 were 19°C and 20°C MWAT, respectively, with alternative higher thresholds for steelhead based on temperatures where resident *O. mykiss* have been observed. The use of alternative thresholds is appropriate. However, the temperature tolerance of juvenile salmonids depends strongly on the amount of food available, and RIPPLE does not model the food supply, as noted above.

Temperature modeling:

SS12 uses results from a temperature model, HFAM, to simulate water temperatures throughout the stream system. HFAM was developed by a consulting firm, Hydrocomp, for the Tuolumne Irrigation District (TID), and adapted to the Yuba for a Federal Emergency Regulatory Commission (FERC) process. HFAM is not described in SS12, which says only that it is a water temperature model, but it is described in Hydrocomp (2012:xi).

> The HFAM hydrologic model of the Tuolumne, developed by Hydrocomp over a twelve year period for the Turlock Irrigation District (TID), was used in this study to simulate the watershed's hydrologic response to precipitation, temperature, evaporation, solar radiation and wind. The model calculates the hydrologic response of more than 900 land segments in the watershed above Don Pedro and routes runoff downstream to reservoirs through 75 channel reaches. Each land segment represents the elevation, soil and rock outcrop, vegetation and aspect associated with a portion of the watershed. The model performs detailed mass and energy budget calculations to simulate the hydrologic cycle on each land segment. By combining and routing the flow from each segment, the model provides detailed information on the effects of basinwide temperature and precipitation changes on runoff, snow, evapotranspiration and soil moistures.

HFAM is a distributed hydrological model, intended to simulate flows, to support operation of the reservoir. Temperature prediction is relevant to the main purpose of the model only as it affects streamflow, and Hydrocomp has had years of data with which to "tune" the model for the Tuolumne River.

The accuracy of HFAM temperature simulations for the Yuba River is questionable. SS12 does not present comparisons of measured temperatures with simulated temperatures, and the reference cited is no doubt available somewhere on the FERC website, but I did not find it. More importantly, however, the modeling was done for other parties for a different purpose, and so results were available only for current conditions. For the alternatives, the effect of temperature thresholds on potential habitat were simply set by professional judgment, as explained obliquely by SS12 at pages 14-15 (Richard Wantuck, NMFS, pers. comm.).

Holding habitat capacity for adult spring Chinook:

Holding habitat capacity for spring Chinook provides another example of expert judgment and approximations are incorporated into the modeling. According to SS12 (16):

> Channels with a summer low-flow width less than 8.5 m (28 ft) were assumed to be too narrow to provide holding pools with suitable depth (≥ 1.2–2.4 m [4–8 ft]; Grimes 1983, Airola and Marcotte 1985, as cited in Vogel 2006) or spawning habitat. This assumption was based on the channel dimensions in the upper portions of the North and South forks of Antelope Creek where holding spring-run Chinook salmon are commonly observed (C. Harvey Arrison, CDFG, Red Bluff, California, pers. comm., 21 June 2011). This channel width also corresponds with the upstream-most spawning location in Butte Creek (Quartz Bowl) (McReynolds et al. 2005, Stillwater Sciences 2007a).

Similarly, at SS12:37-38:

> The amount of usable holding habitat, or usable fraction, was calculated by first determining the proportion of pools considered suitable for holding. This was achieved by comparing the number of suitable holding pools (Vogel 2006) to the total number of pools (Stillwater Sciences 2006b) located in the mainstem Middle Yuba and South Yuba rivers. The portion of each holding pool suitable for holding was then calculated by applying a scaling factor. This fraction likely varies depending on channel shape, hydraulics, water temperature and dissolved oxygen concentration of a given pool (C. Harvey Arrison, CDFG, Red Bluff, California, pers. comm., 21 June 2011). The suitable area of each holding pool was assumed to be, on average, 50% under current conditions and 75% under the two alternative management scenarios (Scenarios 1 and 2) based on professional judgment and observations of spring-run Chinook salmon holding at high densities in bedrock-controlled pools in Butte Creek. While increased flow (as under Scenarios 1 and 2) would likely provide only negligible increases in pool area4 compared with current conditions, it was assumed that increased flow would provide more substantial increases in pool depth, the extent of the bubble curtain and whitewater at the pool head, the length of the pool tail, and the concentration of dissolved oxygen. All of these factors could increase the amount of suitable holding habitat in each pool. Holding pool area was therefore multiplied by 0.5 (for current conditions) or 0.75 (for the two alternative management scenarios) to derive the total amount of holding habitat in the MY and SY sub-basins (Appendix F, Table F-2). No data on the number of holding pools were available for the NY or NBB sub-basins; therefore data from the SY and MY were stratified by gradient category and used to derive usable holding fraction parameters for the NY and NBB sub-basins (Appendix F, Table F-3).

In the model, habitat holding capacity depends on the maximum density in suitable habitat and the amount of suitable habitat. According to SS12:38, the maximum holding capacity was set based on professional judgment, from photographs of spring Chinook holding at high density in Butte Creek, that the fish can hold at densities "ranging from 0.5-1.5 fish/m^2." For the Yuba, the maximum was set at the midpoint, 1 fish/m^2. Then, to get an estimate of the percentage of pools that are suitable for holding on the south and middle forks, the number of pools that were judged suitable in a previous study by Vogel (2006) was divided by the total number of pools estimated in a previous study by Stillwater Sciences. Finally, "(t)he proportion of each holding pool suitable for holding was calculated by applying a scaling factor," which was determined by professional judgment to be 50% under current conditions and 75% under the alternative management scenarios.

Many other examples of parameter values based on expert judgment can be found, for example, the biological parameters for the POP module listed in Table G-1.

Spring Chinook juvenile life history:

The implementation of RIPPLE for the Yuba River assumes that whether juvenile spring Chinook follow a stream- or ocean-type life history depends on temperature during rearing (SS12:7). However, whether juvenile spring Chinook follow a stream-type or ocean-type life history probably depends on the day length when they emerge, based on experimental data reported by Clarke et al. (1992), so fish that emerge when days are still short will follow an ocean-type life history. Both current and historical data for the Central Valley are consistent with this idea, as discussed in Williams (2006). The time from spawning to emergence depends strongly on water temperature during incubation. Low temperatures slow development, so that alevins incubating in cold streams tend to emerge after day length are long enough to induce adaptation of a stream-type life history. Temperatures during incubation may well be correlated with temperatures during the rearing, so that rearing temperatures are correlated with life histories, but basing the model on rearing temperatures will introduce more uncertainty into the results.

SS12 implies that following an ocean-type juvenile life history is a disadvantage for spring Chinook (pp. 7-8). However, stream habitat can be saturated by juveniles, as the report notes, so ocean-type populations of Chinook typically are more productive than stream-type populations; Liermann et al. (2010) and Lindley and Davis (2011) modeled these two types separately on that account. Provided that there is suitable habitat for juveniles to migrate into in winter and early spring, following an ocean-type life history probably is an advantage rather than a disadvantage. Data from Butte Creek, which has the most robust population in the valley, support this. For several years, emigrating juvenile spring Chinook were trapped and tagged close to where the stream enters the valley, near Chico. Recoveries of tags from adults show that the great majority of these moved into low elevation habitat as fry. Recoveries of juveniles in USFWS trawls and Sacramento and Chipps Island shows that the great majority reared somewhere upstream from Sacramento, probably the Sutter By-pass, until they grew to ~ 75-95 mm, and then moved rapidly though the Delta (Figure 3). This suggests that whether suitable valley habitat is available for Yuba River spring Chinook is an important question that SS12 does not address.

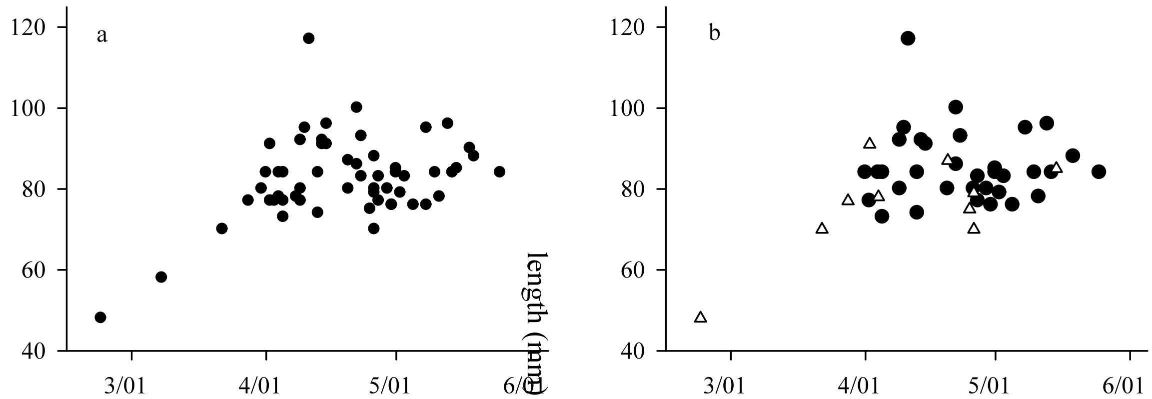

Figure 3. A. Size at date of capture of wild ,coded-wire tagged Butte Creek spring Chinook (n = 57), for all capture locations from Knights Landing to Chipps Island. B. As above, for Chipps Island (circles, n = 34) and Sherwood Island (triangles, n = 10). Data from USFWS, Stockton. Copied from Williams (2009).

Hatchery influence:

The effects of hatchery salmon and steelhead on naturally reproducing fish have received a good deal of attention recently in the literature. For example, Chilcote et al. (2011) reported that the percentage of hatchery fish among natural spawners is the most important predictor of the intrinsic productivity (the rate of population growth in the absence of density-dependent effects, 'α' in the Ricker model) of 89 populations of Chinook, steelhead, or coho in Oregon, Washington, and Idaho; their fitted model estimates that the intrinsic productivity of an all-hatchery population would be only about 13% of that of an all wild population.

SS12 does not discuss which spring Chinook and steelhead might gain access to the upper Yuba River, but presumably they would be the fish currently in the lower Yuba River. Spring and fall Chinook are not distinguished in the Lower Yuba River, but in 2010, the only year for which data are available, the composite population was reported to be 71% hatchery fish (Kormos et al. 2012). From these data, and data on escapements in prior years, it appears that naturally spawning salmon are not reproducing themselves successfully in the lower Yuba River. However, salmon in other streams, such as Butte Creek and Clear Creek, seem to be doing so. I do not know the extent of hatchery influence on steelhead in the Yuba, but I suspect that it is substantial.

Finally, the point of using the RIPPLE for the upper Yuba River is unclear. As pointed out in SS12:11, RIPPLE "was specifically developed for use in conditions where limited data exist, …" However, much information is available for the Middle Yuba and South Yuba, for example in UYRSPST (2007). Why simulate holding or spawning habitat from digital elevation data when they have been measured on the ground?

Alternative modeling approaches:

Modeling essential for the assessing future conditions in the upper Yuba River, but the question remains, what kind of modeling? There is a spectrum of possible approaches for the upper Yuba River, but four will serve as examples for discussion here.

1. Estimation models and model averaging: This is an approach used recently by NMFS for assessing the habitat potential of the upper Klamath basin (Lindley and Davis 2011). A nested set of log-linear regression models were fit to data for Chinook salmon populations in Washington, Oregon, Idaho and California, and the models were ranked and weighted using a model selection method based on information theory. Predictions of future escapement were based on the weighted average of the model results, with confidence intervals developed by bootstrapping. However, the dams and diversions in the upper Yuba River are major obstacles to using this approach.

2. Detailed simulation modeling of the physical and perhaps biological habitat, with implicit or explicit links between habitat and populations. RIPPLE is an example of this type, with explicit population modeling. Unfortunately, such models typically produce only point estimates, and are too complex to allow for tracking the uncertainty in the modeling. As a practical matter, these models tend to function as black boxes, because they are so complex that the effects of changing one or a set of variables can be hard to understand, even for people intimately familiar with the model.

3. Detailed flow and temperature simulation modeling, combined with assessment of the biological consequences using expert judgment. This approach has been common in Australia (Hart and Pollino 2009). Expert judgment can be faulted on various grounds, but is more defensible if the experts are required to spell out the reasoning underlying the judgments carefully enough that the judgments can be tested and updated with new information.

4. Bayesian Networks: Embedding modeling results, expert judgment, and other information in Bayesian Networks allows for explicitly tracking the uncertainty, and also produce approximate interval estimates rather than point estimates. There are many examples of Bayesian Networks applied in environmental assessments (e.g.; Marcot et al. 2001; Steventon et al. 2008; Allan et al. 2012), and the appendix to Hart and Pollino (2009) describes the approach at a useful level of detail. This approach seems appropriate for the upper Yuba River.

Conclusions and Recommendations:

In my opinion, RIPPLE is not a reasonable modeling approach for assessments such as the case at hand. RIPPLE is a complex simulation model that incorporates many approximations, each of which introduces additional uncertainty into the model results, but there is no systematic way to track this uncertainty. Because the system being modeled is highly non-linear as well as complex, even the relative potential of the simulated alternatives is highly uncertain. Because much is already known about the upper Yuba River (e.g., UYRSPST 2007), it is unclear whether the model can help with the assessment. There are also problems with the specific application of RIPPLE to the upper Yuba River.

RIPPLE ranks the alternatives in the same way that a subjective assessment would in this case, but this could be done without using the model. SS12 also uses RIPPLE to make relative assessments, for example, that (p. ES-6): “In the SY sub-basin, redd capacity under Alternative Management Scenarios 1 and 2 is 7 and 16 times higher, respectively, than current conditions. In the MY sub-basin, predicted redd capacity under Alternative Management Scenarios 1 and 2 is 7 and 17 times higher.” In my opinion, RIPPLE results are too uncertain for such statements to have enough meaning to be useful.

Probably the simplest way to make a reasonable assessment of conditions in the upper Yuba, given modifications of the existing system of dams and diversions, would be to combine good temperature modeling with expert assessment of habitat conditions. Temperature is clearly a critical factor, and getting it as right as is practicable is critical. My knowledge of temperature models is too out-of-date for me suggest a specific model, but it is important that the modeler have a good understanding of the model and the basic physics involved, as well as of the basin. The modeling should also allow for simulation of our warmer future. Using professional judgment can be faulted as subjective and subject to bias, but the modeling with RIPPLE already embodies expert assessments, as noted above. It would be more transparent simply to use such assessments directly. Moreover, a great deal of information is available on the Middle Yuba and South Yuba, for example in UYRSPST (2007), and on other relevant streams such as Butte Creek. This would allow the judgments to be well documented and stated in a testable form.

Using Bayesian Networks would also require that expert opinions be put in a testable form, and would facilitate adaptive implementation of any projects that result from the assessment (Williams 2011). The appendix to Hart and Polino (2009) provide a good description of Bayesian Networks.

I regret being so negative, but in my view this project started off in a fundamentally wrong direction. It is unfortunate that many NMFS staff who work on the recovery of listed Pacific salmon, and the consultants who work with them, are not more familiar with the reports of the Recovery Science Review Panel.

Appendix 1
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Appendix 2

Attachment A: Statement of Work for Dr. John Willams

External Independent Peer Review by the Center for Independent Experts

Review of Upper Yuba River Salmonid Habitat Assessment and Population Model

Scope of Work and CIE Process: The National Marine Fisheries Service's (NMFS) Office of Science and Technology coordinates and manages a contract providing external expertise through the Center for Independent Experts (CIE) to conduct independent peer reviews of NMFS scientific projects. The Statement of Work (SoW) described herein was established by the NMFS Project Contact and Contracting Officer's Technical Representative (COTR), and reviewed by CIE for compliance with their policy for providing independent expertise that can provide impartial and independent peer review without conflicts of interest. CIE reviewers are selected by the CIE Steering Committee and CIE Coordination Team to conduct the independent peer review of NMFS science in compliance the predetermined Terms of Reference (ToRs) of the peer review. Each CIE reviewer is contracted to deliver an independent peer review report to be approved by the CIE Steering Committee and the report is to be formatted with content requirements as specified in **Annex 1**. This SoW describes the work tasks and deliverables of the CIE reviewer for conducting an independent peer review of the following NMFS project. Further information on the CIE process can be obtained from www.ciereviews.org.

Project Description: NMFS is interested in assessing the potential for reintroducing anadromous fish upstream of the Narrows hydroelectric complex on the Yuba River as a recovery action for ESA-listed salmon species. In order to gain additional knowledge of the upper Yuba River habitats, NMFS contracted with Stillwater Sciences, Inc. to develop watershed-specific science products to help NMFS assess the potential for reintroduction of anadromous fish to particular areas of the upper Yuba watershed.

The Narrows Hydroelectric Development Complex was constructed approximately 50 years ago on the Yuba River at River Mile 23.4. The complex consists of Englebright Dam and two associated hydropower installations. The combined complex is a complete barrier to the upstream migration of anadromous fish into the South, Middle, and North Yuba Rivers.

The subject matter of this CIE review involves an environmental modeling application known as "RIPPLE," and a related technical report[1] produced for NMFS and other stakeholders by Stillwater Sciences, Inc. The model is built upon extensive research, field investigations, and a comprehensive synthesis of data relating many different physical and biological aspects of the upper Yuba River. The report adds to the base of existing knowledge about the upper Yuba watershed. NMFS is interested in using the information - combined with other relevant and

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[1] **Modeling Habitat Capacity and Population Productivity for Spring-run Chinook Salmon and Steelhead in the Upper Yuba River Watershed,** Technical Report, Prepared for National Marine Fisheries Service Santa Rosa, California 95404. Prepared by Stillwater Sciences, Berkeley, California 94705, February 2012

available science-based information - to perform an assessment and relative comparison of potential anadromous fish habitats existing upstream of the Narrows Hydroelectric Development Complex.

The Terms of Reference (ToRs) of the peer review are attached in **Annex 2**.

Requirements for CIE Reviewers: Three CIE reviewers shall conduct an impartial and independent peer review in accordance with the SoW and ToRs herein. The CIE reviewers shall have the collective expertise, working knowledge and recent experience in the application of

- Knowledge of modeling of geomorphic processes of river systems, hydrology, and aquatic habitat.
- Theoretical mathematical ecology and conservation biology with knowledge in salmon population dynamics, salmonid community ecology, Pacific salmonid life cycle ecology, complex ecological interactions and population ecology of Pacific salmonids including life cycle ecology.

Each CIE reviewer's duties shall not exceed a maximum of 10 days to complete all work tasks of the peer review described herein.

Location of Peer Review: Each CIE reviewer shall conduct an independent peer review as a desk review, therefore no travel is required.

Statement of Tasks: Each CIE reviewers shall complete the following tasks in accordance with the SoW and Schedule of Milestones and Deliverables herein.

<u>Prior to the Peer Review</u>: Upon completion of the CIE reviewer selection by the CIE Steering Committee, the CIE shall provide the CIE reviewer information (full name, title, affiliation, country, address, email) to the COTR, who forwards this information to the NMFS Project Contact no later than the date specified in the Schedule of Milestones and Deliverables. The CIE is responsible for providing the SoW and ToRs to the CIE reviewers. The NMFS Project Contact is responsible for providing the CIE reviewers with the background documents, reports, and other pertinent information. Any changes to the SoW or ToRs must be made through the COTR prior to the commencement of the peer review.

<u>Pre-review Background Documents</u>: Two weeks before the peer review, the NMFS Project Contact will send (by electronic mail or make available at an FTP site) to the CIE reviewers the necessary background information and reports for the peer review. In the case where the documents need to be mailed, the NMFS Project Contact will consult with the CIE Lead Coordinator on where to send documents. CIE reviewers are responsible only for the pre-review documents that are delivered to the reviewer in accordance to the SoW scheduled deadlines specified herein. The CIE reviewers shall read all documents in preparation for the peer review.

<u>Desk Review</u>: Each CIE reviewer shall conduct the independent peer review in accordance with the SoW and ToRs, and shall not serve in any other role unless specified herein. **Modifications to the SoW and ToRs should not be made during the peer review, and any SoW or ToRs**

modifications prior to the peer review shall be approved by the COTR and CIE Lead Coordinator. The CIE Lead Coordinator can contact the Project Contact to confirm any peer review arrangements.

Contract Deliverables - Independent CIE Peer Review Reports: Each CIE reviewer shall complete an independent peer review report in accordance with the SoW. Each CIE reviewer shall complete the independent peer review according to required format and content as described in Annex 1. Each CIE reviewer shall complete the independent peer review addressing each ToR as described in Annex 2.

Specific Tasks for CIE Reviewers: The following chronological list of tasks shall be completed by each CIE reviewer in a timely manner as specified in the **Schedule of Milestones and Deliverables**.

1) Conduct necessary pre-review preparations, including the review of background material and reports provided by the NMFS Project Contact in advance of the peer review.

2) Conduct an independent peer review in accordance with the ToRs (**Annex 2**).

3) No later than September 8, 2012, each CIE reviewer shall submit an independent peer review report addressed to the "Center for Independent Experts," and sent to Manoj Shivlani, CIE Lead Coordinator, via email to shivlanim@bellsouth.net, and CIE Regional Coordinator David Die via email to ddie@rsmas.miami.edu. Each CIE report shall be written using the format and content requirements specified in Annex 1, and address each ToR in **Annex 2**.

Schedule of Milestones and Deliverables: CIE shall complete the tasks and deliverables described in this SoW in accordance with the following schedule.

August 6, 2012	CIE sends reviewer contact information to the COTR, who then sends this to the NMFS Project Contact
August 23, 2012	NMFS Project Contact sends the CIE Reviewers the report and background documents
August 24 – Sept. 6, 2012	Each reviewer conducts an independent peer review as a desk review.
September 8, 2012	CIE reviewers submit draft CIE independent peer review reports to the CIE Lead Coordinator and CIE Regional Coordinator
September 22, 2012	CIE submits the CIE independent peer review reports to the COTR
September 29, 2012	The COTR distributes the final CIE reports to the NMFS Project Contact and regional Center Director

Modifications to the Statement of Work: Requests to modify this SoW must be approved by the Contracting Officer at least 15 working days prior to making any permanent substitutions. The Contracting Officer will notify the COTR within 10 working days after receipt of all required information of the decision on substitutions. The COTR can approve changes to the milestone dates, list of pre-review documents, and ToRs within the SoW as long as the role and ability of the CIE reviewers to complete the deliverable in accordance with the SoW is not adversely impacted. The SoW and ToRs shall not be changed once the peer review has begun.

Acceptance of Deliverables: Upon review and acceptance of the CIE independent peer review reports by the CIE Lead Coordinator, Regional Coordinator, and Steering Committee, these reports shall be sent to the COTR for final approval as contract deliverables based on compliance with the SoW and ToRs. As specified in the Schedule of Milestones and Deliverables, the CIE shall send via e-mail the contract deliverables (CIE independent peer review reports) to the COTR (William Michaels, via William.Michaels@noaa.gov).

Applicable Performance Standards: The contract is successfully completed when the COTR provides final approval of the contract deliverables. The acceptance of the contract deliverables shall be based on three performance standards:
(1) each CIE report shall completed with the format and content in accordance with **Annex 1**,
(2) each CIE report shall address each ToR as specified in **Annex 2**,
(3) the CIE reports shall be delivered in a timely manner as specified in the schedule of milestones and deliverables.

Distribution of Approved Deliverables: Upon acceptance by the COTR, the CIE Lead Coordinator shall send via e-mail the final CIE reports in *.PDF format to the COTR. The COTR will distribute the CIE reports to the NMFS Project Contact and Center Director.

Support Personnel:

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Annex 1: Format and Contents of CIE Independent Peer Review Report

1. The CIE independent report shall be prefaced with an Executive Summary providing a concise summary of the findings and recommendations, and specify whether the science reviewed is the best scientific information available.

2. The main body of the reviewer report shall consist of a Background, Description of the Individual Reviewer's Role in the Review Activities, Summary of Findings for each ToR in which the weaknesses and strengths are described, and Conclusions and Recommendations in accordance with the ToRs.

3. The reviewer report shall include the following appendices:

   Appendix 1: Bibliography of materials provided for review
   Appendix 2: A copy of the CIE Statement of Work

Annex 2: Terms of Reference for the Peer Review

Review of Upper Yuba River Salmonid Habitat Assessment and Population Models[2]

3. Review the RIPPLE model application for the upper Yuba River (Stillwater Sciences 2012) to determine whether the data sets, assumptions, and model parameters represent a reasonable modeling approach to assess the relative potential of upper Yuba River habitats under the three different modeled scenarios.

4. Does the RIPPLE model application for the upper Yuba River produce results that are relevant and appropriate to support the evaluation of anadromous fish reintroduction potential in the upper Yuba River watershed?

Materials provided for review:

1. Primary report:

- *Modeling Habitat Capacity and Population Productivity for Spring-run Chinook Salmon and Steelhead in the Upper Yuba River Watershed*, Technical Report, Prepared for National Marine Fisheries Service, Santa Rosa, California 95404. Prepared by Stillwater Sciences, Berkeley, California 94705, February 2012

2. Background and broad overview of the RIPPLE model structure and rationale:

- *RIPPLE: A Digital Terrain-Based Model for Linking Salmon Population Dynamics to Channel Networks*, University of California, Berkeley Earth and Planetary Science, Berkeley, CA and Stillwater Sciences, Berkeley, CA

[2] The reviewers should be aware that the original project budget was limited to the output and information produced in the report, as a Phase 1 investigation. Following the delivery of this report to NMFS in February 2012, Stillwater Sciences conducted an additional sensitivity analysis of model parameters, but that information is not yet completed and available for this review - which must go forward in order to meet deadlines. Furthermore, NMFS has secured additional funding to enable Stillwater to re-run the models (Phase 2) using updated field information that was gathered by NMFS and other Yuba River stakeholder groups after the model runs for this report were conducted.