TECHNICAL MEMORANDUM REPORT

To: North Coast Regional Water Quality Control Board

From: Quartz Valley Indian Community

Date: August 15th, 2006

Re: Comments Concerning the Klamath River TMDL Approach and Progress to Date

INTRODUCTION

The mainstem Klamath River is listed, as required by the federal Clean Water Act Section 303, as being impaired for temperature, nutrient and dissolved oxygen (NCRWQCB 2001). Total Maximum Daily Load (TMDL) studies are being conducted in an attempt to develop a TMDL plan for remediating the River's pollution and restoring the beneficial uses of its waters.

Although the formal TMDL document is still being developed, several supporting documents and tools are available for review. The Klamath River basin Tribes have been asked to provide comments to North Coast Regional Water Quality Control Board (NCRWQCB) staff and the U.S. Environmental Protection (EPA) agency by August 15, 2006, concerning their view of the Klamath River TMDL development effort. The Quartz Valley Indian Community (QVIC) has reviewed the following documents to provide the appropriate technical comments: Wilder (2006), Flint and Flint (in review), NCRWQCB et al (2006), Leland et al. (2006), a matrix table of TMDL model scenarios, portions of a memo describing the Upper Klamath Lake boundary conditions for the natural conditions model scenario, USBR (2005), and USFWS (2006).

The purpose of the information and conclusions presented here is to assist the agencies in improving their approach to the TMDL in order to facilitate restoration of the River's Pacific salmon population, a key beneficial use recognized by the Clean Water Act, and to help fulfill federal government trust responsibilities to the Tribes.

SUMMARY

The task of developing TMDLs for a river as complex as the Klamath River is difficult, and the importance of the Klamath River to the Klamath Basin Tribes dictates that TMDLs must be of the highest possible quality. In reviewing available documents, we find that we have substantial concerns regarding the approach that is being taken in the development of the Klamath River TMDL, and the progress on its development to date, which concerns we summarize here and discuss in more detail below.

First, our evaluation of the PacifiCorp water quality model, upon on which the Klamath River TMDL model is based, suggests that the model does a poor job of representing the fate and transport of organic matter, a critical component of Klamath River water quality dynamics. The problems with the model are serious enough that, if they cannot be resolved,

that they warrant the abandonment of the modeling effort for other analytical methods to set the Klamath River Nutrient TMDL's nitrogen and phosphorus levels.

Second, the TMDL model has not yet been configured to predict pH in the California reaches of the Klamath River. Given the frequency of exceedance of the Klamath River's pH standards, and the impact of these exceedences on the river's fish resources, it is essential that pH be a cornerstone of the nitrogen and phosphorus TMDLs. This requires some tool, ideally an accurately calibrated and validated computer model, to predict the pH response to varying concentrations of nitrogen and phosphorus.

Third, the TMDL's mainstem-centric model-based approach does not appear to properly characterize the importance of Lower Klamath tributaries as temperature refugia for Pacific salmon nor the need to provide protection to these critical habitats by setting prudent risk thresholds for watershed disturbance. A TMDL that does not ensure protection and restoration of these refugia will not contribute to Klamath River salmon recovery and, therefore, is unacceptable.

APPROACH TO NITROGEN AND PHOSPHORUS TMDLs

The foundation for the nitrogen and phosphorus TMDLs should be to conduct analyses to determine how varying concentrations of nitrogen and phosphorus affect dissolved oxygen (D.O.) and pH conditions. Those analyses should then be used to set nitrogen and phosphorus criteria/targets that would ensure that D.O. and pH criteria would not be exceeded. Finally, analyses of nitrogen and phosphorus loading and transport should be used to determine how far point and non-point sources of nitrogen and phosphorus need to be reduced in order to meet established nitrogen and phosphorus criteria/targets.

Thus far, the approach to the Klamath nitrogen and phosphorus TMDLs has been model-centric in its focus. An alternative approach to developing quantitative relationships between nutrients and D.O./pH conditions is the empirical regression approach used by the Hoopa Valley Tribe to set nutrient criteria for the Klamath River (Kier Associates 2005a).

WATER QUALITY MODELING

Overview of water quality model performance

Flow and temperature are based on the laws of physics, and modeling them is a well-settled practice. Dissolved oxygen, nutrients, and algae are subject not only to the laws of physics, but also to chemistry, biology, and ecology, which are far more complex, unpredictable, and difficult to represent mathematically. To compound this problem, when compared to flow and temperature, far less data is available for these other parameters with which to calibrate and verify the model being used for the Klamath River TMDL studies.

The Klamath River TMDL uses a model developed by PacifiCorp during the re-licensing process for the Klamath Hydroelectric Project. PacifiCorp (2005a and 2005b) has provided the results of water quality and fish passage modeling calibration and verification. Examination of the figures in those documents show that the model predicts flow and temperature quite well (for example, to within about one degree Celsius for temperature), but it does not accurately predict dissolved oxygen, nutrients, or algae. Earlier reviews of the model reached the same conclusion (Wells, 2004). We anticipate that the performance of the TMDL model will be similar to PacifiCorp's and the comments offered here are predicated on that expectation.

Since nutrients are primary drivers of the dynamics of algae and macrophytes, which in turn are primary drivers of the D.O./pH conditions in the river, having a model that accurately represents the spatial and temporal dynamics of nutrients is critical. Under contract to the Yurok Tribe, Asarian and Kann (in progress) have assessed how nutrient concentrations and nutrient loads predicted by the PacifiCorp water quality model fit available field data for the years 2000-2004. The parameters examined included nitrogen, phosphorus, algae, and organic carbon.

Overall, the results presented in Asarian and Kann (in progress) indicate that in its current configuration, the model's performance is inadequate (see particulars below). Given the substantial discrepancies between modeled and measured data, until model performance can be <u>substantially</u> improved it is our recommendation that model results for nutrient-driven parameters (dissolved oxygen, pH, nutrients, phytoplankton, and attached algae) should not be used to make management decisions. <u>If model performance cannot be substantially improved, it should not be used as a foundation for the Klamath TMDL.</u>

The degree to which additional calibration could improve the model's performance is not known at this time. Substantial improvement may require the inclusion of additional processes, such as multiple algal groups and nitrogen fixation. Additionally, the model does not incorporate some of the key factors which regulate the dynamics of attached algae. These include diurnal desiccation, for example in the peaking reach of the Klamath Hydroelectric Project, and scour.

Need to calibrate/validate the model for total nitrogen and total phosphorus

To the best of our knowledge, neither PacifiCorp nor Tetra Tech has properly calibrated and validated the model for all forms of nutrients. PacifiCorp and Tetra Tech comparisons between model prediction and field data have been limited thus far to inorganic forms of nutrients: orthophosphorus (PO4), nitrate/nitrite (NO3+NO2), and ammonia (NH3). This is highly unfortunate, as most of the nitrogen and phosphorus in the Klamath River is in <u>organic</u> form. Without an assessment of how well the model simulates the fate and transport of organic matter, it is not reasonable to be asked to accept the model's products.

Analyses by Asarian and Kann (in progress) found that the PacifiCorp model did a poor job of predicting nutrient dynamics in the Klamath River (Figure 1). <u>Not only were predicted nutrient concentrations and loads typically far different than the observed data, but the modeled data showed strong consistent spatial trends that were completely absent in the field data</u> (Figure 1). In particular:

> 1. The model outputs indicated that nitrogen concentrations were substantially lower below J.C. Boyle and Copco/Iron Gate reservoirs than at sites immediately upstream. In stark contrast, field samples showed that no such decrease occurred. Model outputs for organic matter showed the same pattern (decrease in model data, no decrease in field data) while algae did not, suggesting that it is likely that organic matter is the cause of this discrepancy.

2. The model outputs indicated that nitrogen concentrations remain essentially unchanged from Iron Gate Dam to the Klamath estuary. In contrast, field samples showed that nitrogen concentrations typically decrease substantially between those two sites. It is unclear if this discrepancy is caused by improperly set tributary boundary conditions (discussed below), inadequate calibration, or other model limitations.

When modeled data contradicts field data, the field data should be given more weight and the model data discounted (except when field data are suspect, such as D.O. data showing signs of biofouling). For instance, we strongly caution against using the water quality model (for instance, as proposed in the T4 Dam Allocation model scenario) to determine the effects of Klamath Hydroelectric Project reservoirs on water quality. The model's predictions are clearly contradicted by field data. Instead, we recommend the use of analyses based on field data, such as Kann and Asarian (2005) and Asarian and Kann (2006).

To estimate potential nitrogen retention in the historic (pre-dams) river channel now inundated by Copco and Iron Gate Reservoirs, Asarian and Kann (2006) applied retention rates calculated for the Klamath River reach from Iron Gate to Seiad Valley. Full details are provided in Asarian and Kann (2006), however, the initial comparison of the historic streambed – that which is now inundated -- with current reservoir retention indicates that when retention due to natural river processes is factored into the reservoir retention estimated in Kann and Asarian (2005), reservoir retention is minimal (4.6% of incoming load) or even negative (-3.3% of incoming load) during the periods evaluated (May 21 – October 16 and July 1 – September 30, respectively in the year 2002). Additionally, a comparison of temporal variability of river retention to reservoir retention showed that the river consistently provides moderate positive retention of nutrients, while the combined retention of Iron Gate and Copco reservoirs alternates between positive and negative values.

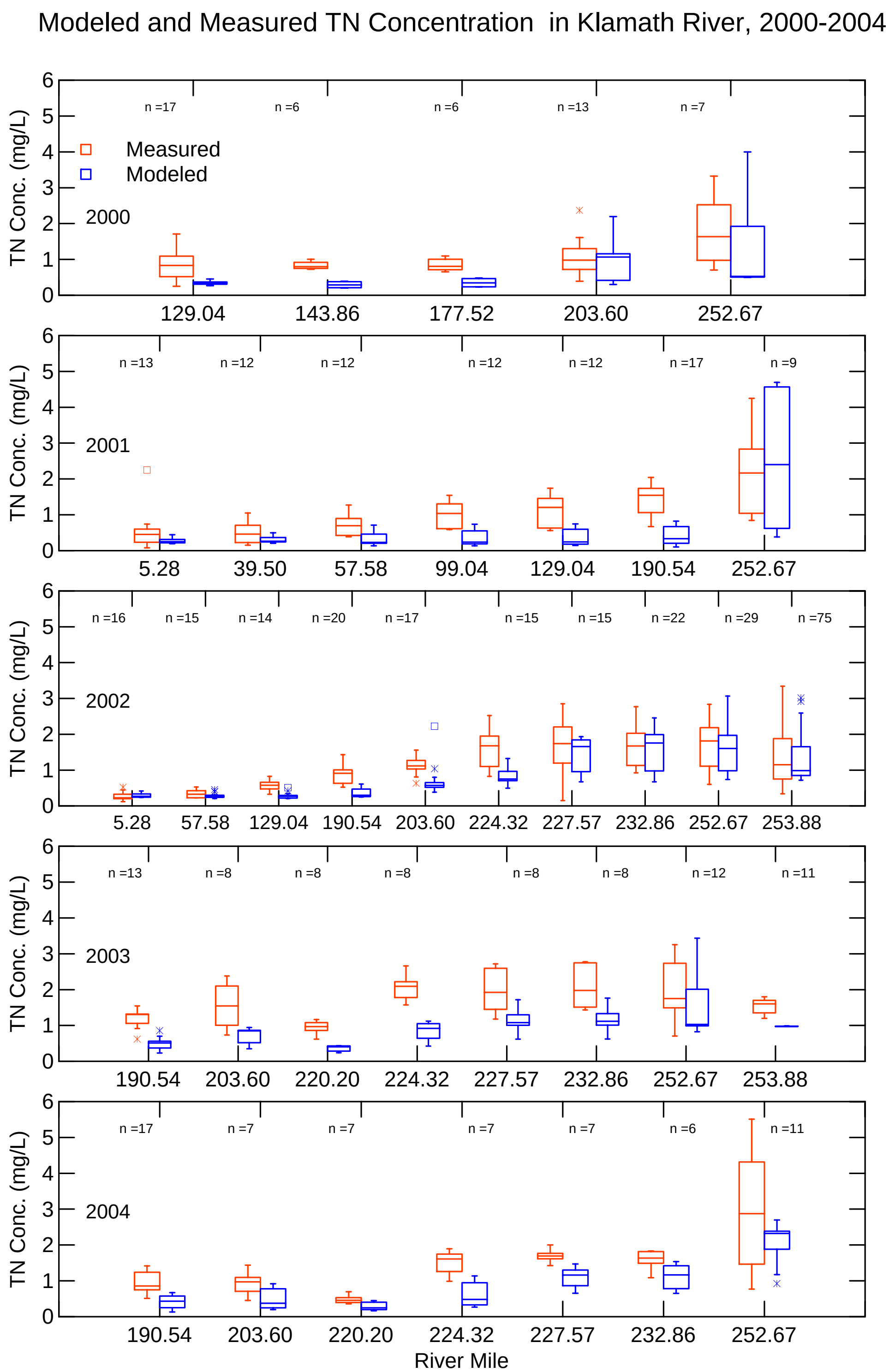

Figure 1. A comparison of total nitrogen concentration calculated from field samples (shown in red) and total nitrogen predicted by the PacifiCorp water quality model (in blue) for the years 2000-2004 at all mainstem sites with available data. Key to river miles: 252.67 = mouth of Link River, 232.86 = Keno Dam, 227.57 = above Boyle Reservoir, 224.32 = below Boyle Reservoir, 220.2 = bypass reach above Boyle powerhouse, 203.6 = above Copco Reservoir, 190.54 = Iron Gate Dam, 57.58 = Orleans, 5.28 = Klamath Glen. Figure from Kann and Asarian (in progress).

The need to model pH

The RMA-11 model which has been used to simulate river reaches in the TMDL model does not explicitly model pH, so pH is, instead, being simulated in an external spreadsheet model. Thus far, that spreadsheet pH model has only been set up for Link River-to-the-Stateline (the Oregon-California border), not for the California portion of the river. This is a serious problem, as pH violates NCRWQCB Basin Plan standards on a daily basis across most of the river in the summer and early fall months (Kier Associates 2005a). In addition to being directly stressful to salmonids (Wilkie and Wood 1995), high pH also increases the toxicity of ammonia (Goldman and Horne 1983).

As discussed above, nitrogen and phosphorus TMDLs should be set by determining how different levels of nutrients affect D.O. and pH conditions. The ability of the model to predict pH is, therefore, a crucial tool for the development of the Klamath TMDLs. We have not yet seen the results of calibration/validation for the pH model to know whether it is accurate enough to warrant its use. Currently, irregular flow regimes between Keno and Copco affect attached algae in ways that have not been taken into account by the model (e.g. scour and diurnal desiccation), so those are not good reaches in which to conduct calibration and validation.

We suggest that the pH model be applied to a pilot reach somewhere below Iron Gate Dam, and that those results be compared with measured field data in order to provide an assessment of the accuracy of the model. If the pH model performs well in that pilot reach, then it should be extended to the entire mainstem Klamath River. If it would be more feasible and less cumbersome, the pH model could instead be applied to a number of shorter, non-contiguous reaches scattered from Iron Gate Dam down to Klamath Glen.

If the pH model does not perform appropriately in the pilot reach, then it should not be applied to the rest of the mainstem and another means of developing a relationship between nutrient concentration and pH must be found. There is no purpose in spending large amounts of resources to apply a non-functional model.

Constant stoichiometric ratios

The TMDL model uses many stoichiometric ratios to convert between various parameters within the model, and to convert field data into model boundary conditions. Some of the most important include:

0.01 = phosphorus: organic matter and phosphorus: algae

0.07 = nitrogen: organic matter and nitrogen: algae

0.45 = carbon: organic matter and carbon: algae

67 = chlorophyll *a* µg/L) to algae (mg/L)

These ratios are problematic because, while they are constant in the model, they can vary substantially in the actual Klamath River system. <u>We recommend that the TMDL modelers explore the possibility of using seasonally dynamic ratios</u>. For instance, instead of using a single constant TN:TP ratio, data from all years combined should be used to derive monthly or seasonal ratios. This may be easier to implement for the conversion of field data to boundary conditions than it would be inside the model itself. Additional details on this subject are provided below in the discussion of the natural conditions model scenario

Specifying Boundary Conditions

Setting Boundary Conditions for Link Dam (Upper Klamath Lake)

Nitrogen and phosphorus are represented in several model parameters. Nitrogen is present in ALGAE, OM, NH3, NO3, and NO2; phosphorus is present in ALGAE, OM, and PO4. It is our understanding that the current ammonia (NH3), nitrate/nitrite (NO3), and orthophosphate (PO4) boundary conditions for Link Dam are set using field data for those same parameters. Organic matter (OM) is calculated from phosphorus data (0.01*(TP-PO4)) and algae are calculated as chlorophyll-a multiplied by a conversion factor of 67.

Deriving OM and algae in this way seems to double-count some OM, as undoubtedly some, if not most, of the OM includes algae, yet this is not accounted for, and algae is calculated in an entirely separate way (i.e., using chlorophyll a).

<u>We suggest that the TMDL modelers test an alternative method for setting boundary conditions</u>, and if that works better, then it should be used for all applicable boundary conditions and scenarios. Total nitrogen (TN) and total phosphorus (TP) should be used as the primary field data for setting boundary conditions, with other measured parameters such as chlorophyll, NO3, NH3, and PO4 used to help determine how the TN and TP should be distributed among the various model parameters.

The sum of the nitrogen and phosphorus contained in the various model parameters assigned to a particular boundary condition should equal, or nearly equal, the total nitrogen and phosphorus reflected in the field data gathered at that same location.

Field data for ammonia (NH3), nitrate/nitrite (NO3), and orthophosphate (PO4) should continue to be applied directly to boundary conditions. The sum of organic matter (OM) and algae should be set using a combination (the mean) of estimates derived from nitrogen and phosphorus data:

OM+algae = ((OM+algae from nitrogen data) + (OM+algae from phosphorus data))/2

OM+algae = (((TP - PO4)/0.01) + ((TN – NO3 - NH3)/0.07))/2

This calculation provides an estimate of the combined concentration of OM+algae, but the model requires that OM and algae be separate parameters. Chlorophyll-a data could, therefore, be used to estimate the concentration that is algae by using a conversion factor (such as 67). This algal concentration could then be subtracted from the combined OM+algae concentration, yielding the OM concentration.

There are some issue that would need to be worked out with this approach, such as what to do when the combined OM+algae concentration (derived from the nitrogen and phosphorus data) is lower than the algae concentration (derived from chlorophyll-a), but at least this approach would feed the correct total amount of nitrogen and phosphorus into the model.

Nutrients, Organic Matter, and Algae Concentrations for Tributaries Below Iron Gate Dam

As discussed above, PacifiCorp's application of the water quality model being used in the Klamath River TMDL predicts that nutrient concentrations remain relatively stable as the river flows from Iron Gate Dam to the Klamath Glen, while field data show a substantial decrease. One factor that contributes to this discrepancy is that the boundary conditions assigned to minor tributaries for nutrients, organic matter (OM), and algae concentrations appear to be set too high.

Only very limited amounts of field data are available for nutrient concentration in these minor tributaries (Tables 2 and 3). Except for Bogus Creek (for reasons discussed below), TN concentrations were 0.24 mg/L on October 30, 2001 and 0.05 mg/L on June 29, 2005. Mean TP concentrations were 0.014 mg/L on October 30, 2001 and 0.006 mg/L on June 29, 2005.

An estimated 12,575 chinook salmon spawned in Bogus Creek in fall 2003 (CDFG 2003, Grove et al. 2001). The timing of the Bogus Creek spawning was not provided in published reports, but spawning in the adjacent mainstem Iron Gate-to-Ash Creek reach peaked during the week of October 29 – November 2, and 31% of the seasons' total redds in the reach had already been observed in the October 15 – 26 period (Grove et al. 2001).

The number of spawners in Bogus Creek is far higher than other small tributaries (CDFG 2003, Grove et al. 2001), likely due to its proximity to Iron Gate hatchery, so nutrient concentrations in Bogus Creek during this time of year are likely not representative of other tributaries. In fact, the TN and TP values at Bogus Creek were 4 and 9.5 times higher, respectively, than those observed in other tributaries in the October 31, 2001 samples (Table 2).

Table 2. Nutrient concentrations from samples collected by the USFWS at minor tributaries on October 30, 2001. Note that values shown in bold were non-detects, and were entered as ½ the detection limit.

Date	Stream Name	NH3 (mg/l)	NO3 (mg/l)	TKN	PO4 (mg/l)	TP (mg/l)	TN (calculated) (mg/l)	TOC (mg/l)
10/30/2001	Beaver Creek	**0.025**	**0.05**	0.21	**0.005**	0.021	0.26	2.5
10/30/2001	Bluff Creek		**0.05**		**0.005**	**0.010**		0.93
10/30/2001	Bogus Creek	0.140	0.23	0.74	0.092	0.130	0.97	2.6
10/30/2001	Clear Creek	0.091	**0.05**	0.18	**0.005**	**0.010**	0.23	1.3
10/30/2001	Dillon Creek	0.077	**0.05**	0.15	**0.005**	**0.010**	0.20	1.8
10/30/2001	Elk Creek	0.140	**0.05**	0.28	0.011	0.021	0.33	2.1
10/30/2001	Red Cap Creek	0.083	**0.05**	0.15	**0.005**	**0.010**	0.20	1.2
	Mean (all)	0.093	0.076	0.285	0.018	0.030	0.39	1.66
	Mean (excl. Bogus)	0.083	0.050	0.194	0.006	0.014	0.24	0.24
	Detection Limit	0.05	0.1	0.1	0.01	0.02		0.50

Table 3. Nutrient concentrations from samples collected by the NCRWQCB at minor tributaries on June 29, 2005. Note that values shown in bold were non-detects, and were entered as ½ the detection limit.

Date	Stream Name	NH3 (mg/l)	N03+N02 (mg/l)	SRP (mg/l)	TP (mg/l)	TN (mg/l)	TOC (mg/l)
6/29/2005	Bluff	**0.005**	**0.005**	0.005	0.007	0.050	0.540
6/29/2005	Red Cap	**0.005**	**0.005**	0.005	0.009	0.050	0.777
6/29/2005	Elk	**0.005**	**0.005**	0.004	0.007	0.050	1.13
6/29/2005	Indian	**0.005**	0.012	0.009	0.006	0.050	0.763
6/29/2005	Clear	**0.005**	**0.005**	0.003	0.004	0.050	0.710
6/29/2005	Dillon	**0.005**	0.016	0.003	0.005	0.050	0.830
	Mean	0.005	0.008	0.005	0.006	0.050	0.792
	Detection Limit	0.010	0.010	0.001	0.002	0.100	0.250

Correspondence from NCRWQCB and Tetra Tech staff indicate that the TMDL water quality model applies the same concentrations for these tributaries as PacifiCorp's application of the model. There are discrepancies regarding the boundary conditions for minor tributaries between the documentation that PacifiCorp (2005b) issued with its most recent model outputs and model input files. For the following calculations, we assume that the model input files are correct, and that the documentation is erroneous.

The formula for calculating total nitrogen (in units of mg/L as N) from the model is:

TN = (0.07)*(ALGAE) + (0.07)*(OM) + (0.07)*(BOD) + NH3 + NO3 + NO2

Filling in the tributary concentrations from the PacifiCorp model outputs yields:

TN = (0.07)*(0.50) + 0.07*(0.00) + (0.07)*(2) + 0.05 + 0.05 + 0 = 0.275 mg/L

The TN concentration of 0.275 mg/L is similar to the TN mean concentration of 0.24 from early fall 2001 USFWS field data, but 5.5 times higher than the 0.05 mg/L from early summer 2005 NCRWQCB field data.

The formula for calculating total nitrogen (in units of mg/L as N) from the model is:

TP = (0.01)*(ALGAE) + (0.01)*(OM) + (0.01)*(BOD) + PO4

Filling in the tributary concentrations from the PacifiCorp model outputs yields:

TP = (0.01)*(0.50) + (0.01)*(0.00) + (0.01)*(2) + 0.05 = 0.075 mg/L

The TP concentration of 0.075 mg/L is 5.4 times higher than the TP mean concentration of 0.014 from early fall 2001 USFWS field data and 12.5 times higher than the 0.006 mg/L from early summer 2005 NCRWQCB field data.

Based on these comparisons of field data to model boundary conditions for the minor tributaries, we recommend that the TMDL model use lower concentrations for algae, OM, BOD, PO4, NH4, NO3 to determine whether that will improve model performance, and, if performance is improved, the change should be made permanent.

The model nutrient, OM and BOD boundary conditions for the Scott, Shasta, Salmon and Trinity Rivers may also be higher than observed field data, but we have not made direct comparisons of field data with the model's concentrations for these larger tributaries. <u>We recommend that the TMDL model calibration report include tables or figures that compare field measurements of TN and TP with the TN and TP in boundary conditions for each of these larger Klamath River tributaries (including showing seasonal variations).</u>

Water Temperature for Minor Tributaries

We reviewed the Flint and Flint (in review) report estimating water temperature in unmeasured tributaries. Overall, for the purposes of serving as an input to the water quality model, the Flint and Flint model seems adequate for filling in data gaps where temperature data does not exist for a particular stream. The following comments are, however, in order.

First, Leland et al. (2006) state that the Flint and Flint dataset will be used for the 2000 and 2002 TMDL water quality model runs, while Flint and Flint (in review) report that they created a temperature record for January 1, 2001 to October 31, 2004, which does not include 2000. We need further clarification on this matter.

Second, substantial amounts of readily available data were not utilized in the development of the model. For instance, although the Karuk Tribe and U.S. Forest Service collected data in 2001 for most tributaries, and, in 2002 for Boise, Camp, Humbug, and Red Cap Creeks (Table 4), none of these data were used by Flint and Flint (in review) despite the fact that the data have all been compiled into a database and are available online at www.krisweb.com and the authors cite KRIS as a data source.

Third, despite the well-understood tendency of streams to warm during the summer season as they flow downstream, the regression model is not explicitly accounting for basin area. Within the regression equation developed for each stream, the basin area is implicitly accounted for by the regression coefficients. However, the regression equations developed for a particular stream are then applied to develop estimates of water temperature in adjacent watersheds, which are sometimes orders of magnitude smaller. For example, the use of the regression equation for the Shasta River (2032 km^2) to predict temperatures in Little Bogus Creek (38 km^2), a watershed with a drainage area 53 times smaller, seems inappropriate. Hence, the accuracy of the estimates for unmeasured tributaries could probably be improved by giving more consideration to basin area when deciding which regression equation to apply.

The extent to which tributary water temperatures affect the temperature of the mainstem Klamath is unknown (the TMDL modeling with help to determine that). Although the tributaries are critical coldwater refugia, due to their spatial distribution, it is not likely that they have a major effect on mainstem temperatures outside refugia. That said, where and when measured temperature data exists, it would be optimal to use it in place of the Flint and Flint (in review) estimates. Given that those data are already compiled into a single database, it would be a relatively simply matter to incorporate them into the water quality model. We recommend that that be done.

Table 4. Locations and dates of available water temperature data in the Klamath National Forest / Karuk Tribe temperature database. Note: database includes data for years 1997-2002 but only

2000-2002 are listed in this table. Database is available online at:
http://krisweb.com/krisklamathtrinity/krisdb/webbuilder/md_cst31.htm

LOC ID	SHORT_NAME	LOCATION	2000 Start	2000 End	2001 Start	2001 End	2002 Start	2002 End
139	Aikens_Lwr	Aikens Creek\RM 0.10	6/26	10/3	5/1	10/24	5/24	11/20
118	Beaver_Lwr	Beaver Creek\just dwn strm rt 96 br	7/19	10/17				
135	Beaver_Mid	Beaver Creek\500 m below forks					6/12	12/4
89	Bluff_Lwr	Bluff Creek\Bluff Creek at mouth under Hwy 96 Bridge	6/27	10/3	5/1	10/23	5/24	11/3
138	Bluff_RM_6.85	Bluff Creek\RM 6.85 at Dragon's Bar	6/28	10/17	5/8	10/24	5/29	11/5
164	Boise_Lwr1	Boise Creek\near mouth (Karuk)	7/31	10/18				
165	Boise_Lwr2	Boise Creek\900 feet upstream of the mouth	6/29	10/5	5/2	10/24	5/25	11/6
133	Buckhorn_Mid	Buckhorn Creek\S. line Sec 34					6/22	12/4
7	Camp_Lwr	Camp Creek\1/2 mile upstream of mouth	6/22	10/3	5/1	10/24	5/23	11/3
137	Camp_Mid	Camp Creek\200 ft downstream of third creek	6/29	10/3	5/3	10/29	5/25	11/5
59	Clear_Lwr	Clear Creek\near mouth, 150 ft upstream of pvt bridge	6/30	10/3	4/27	10/18	4/26	10/4
120	Cow_Mid	Cow Creek\500m dwn strm of Long John Ck					6/12	11/25
10	Dillon_Lwr	Dillon Creek\300 feet upstream from mouth	6/10	10/3	4/27	10/22	4/26	10/4
153	Elk_Lwr	Elk Creek\located near mouth of stream	8/1	10/19				
14	Elk_Mid	Elk Creek\5 mile bridge	7/1	10/3	4/28	10/11	4/26	10/4
57	Grider_Lwr	Grider Creek\50 feet upstream of 46N66 Bridge	7/1	10/12	4/28	10/11	4/26	10/4
125	Horse_Lwr	Horse Creek\at Forest Service Bndy					6/15	12/4
134	Horse_Mid	Horse Creek\100m below forks					6/14	9/25
123	Humbug_Lwr	Humbug Creek\500m downstream of Trail Gl					6/22	8/8
122	Hungry_Lwr	Hungry Creek\100m upstream of mouth	7/19	8/21				
154	Independence_Lwr	Independence Creek\located near mouth/Karuk					6/14	11/4
65	Indian_Lwr	Indian Creek\under second bridge in downtown HC	7/1	9/27				
56	Indian_Mid	Indian Creek\at USGS Gaging station	7/1	9/27	4/28	10/11		
161	Irving_Lwr2	Irving Creek\located near mouth/Karuk					6/23	11/14
136	Middle_Mid	Middle Creek\North West FS Bndy Sec 32					6/22	12/4
141	Pearch_Lwr	Pearch Creek\RM 0.10 at Pearch Cr. campground	6/22	10/3	5/2	10/23	5/23	11/8
140	Red_Cap_Lwr	Red Cap Creek\RM 0.10 near Allen Creek	7/11	10/4	5/3	10/24	5/25	11/4
152	Red_Cap_RM_9.20	Red Cap Creek\RM 9.20 at Schnable Diggings	6/27	10/4	5/2	10/24	5/25	11/5
159	Rock_Lwr	Rock Creek\located near mouth/Karuk					6/22	11/15
53	Seiad_Lwr	Seiad Creek\under HWY 96 bridge			4/28	10/11		
45	Slate_Lwr	Slate Creek\300 feet upstream of mouth	6/26	10/3	5/1	10/23	5/24	11/4
160	Stanshaw_Lwr	Stanshaw Creek\located near the mouth/Karuk					6/17	10/24

Natural Conditions Scenario

It is important to remember that, at their core, TMDLs are about protecting and restoring beneficial uses. The question of what is the "natural condition" for a particular water quality parameter it is actually less important than the question of how much do we need to improve that water quality parameter in order to protect and restore beneficial uses. The development of a robust analysis regarding the linkage between nutrient concentrations and resulting D.O./pH conditions is the foundation for these TMDLs, not a plan to restore to "natural conditions." That said, we have some comments regarding the TMDL's proposed natural conditions scenario.

Temperature for Minor Tributaries

We have reviewed the Wilder (2006) report and agree that 2˚C is a reasonable temperature decrease to assign to the water temperature of minor tributaries in the natural conditions (T1) scenario.

Flow, Temperature, and Water Quality for the Scott and Shasta Rivers

The proposed natural conditions (T1) model scenario uses the unimpaired flows of the Shasta River and the natural flows in the Scott River, and uses the quality of the water coming from those rivers predicted by the TMDL compliance scenarios for the Shasta and Scott River TMDLs (the TMDL compliance scenarios are what the model predicts would occur if the Shasta and Scott TMDLs were to be fully implemented).

This presents an issue since the Scott River TMDL compliance scenario contains <u>no</u> flow increase over present conditions and the Shasta River TMDL contemplates a 48 cubic feet per second increase that is <u>far</u> short of the river's unimpaired flows (though the actual numbers used for Shasta unimpaired flows were not provided in the report).

Full natural flow for the Scott and the unimpaired flow of the Shasta would likely result in very cool temperatures for those rivers as they enter the mainstem Klamath River; hence, the natural conditions scenario uses a combination of flow and temperature for the Scott and Shasta Rivers that has never actually occur. Either those rivers will be low-flow and relatively warm, or high-flow and cool.

<u>We recommend that this discrepancy be remedied by decreasing the temperature of the Scott and Shasta Rivers in the natural conditions scenario</u>.

The calculations used to determine the organic matter (OM) boundary conditions for the Shasta River natural conditions scenario (Leland et al. 2006) are much more complex, and introduce more error, than necessary. The method derived an OM boundary condition by using the equation NBOD = 4.57 (TKN), the ratio of TKN to NH3, the ratio of NH3 to organic nitrogen (ON), and the ratio of organic nitrogen (ON) to organic matter (OM).

A simpler and more accurate way to determine the OM boundary conditions would be to use field data to calculate ON as TKN - NH3, and then calculate the TKN to ON ratio. That ratio could then be used in the NBOD = 4.57 (TKN) equation to determine the ON value, and then ON could be converted to OM. This method is more accurate because in the Shasta River ON typically represents a much larger portion of the TKN than NH3 does, and therefore the ON:TKN ratio should be closer to 1 and much less variable than the ON:NH3 ratio.

Upper Klamath Lake Water Quality Boundary Conditions

We reviewed portions of a memo describing the methods used to determine the natural conditions (T1) scenario water quality boundary condition at Upper Klamath Lake (UKL), based on the UKL TMDL. Because the TMDL included only phosphorus, the nitrogen parameters had to be derived using average ratios between TN:TP, TN:NO3, and TN:NH4. The memo was unclear as to what years of data were included in the averages, and implied that only a single ratio was determined. Additional information should be provided, including which years were used, and what the final ratios were.

We conducted a quick analysis of Klamath Tribes of Oregon data from two monitoring stations near the outlet of Upper Klamath Lake (Pelican Marina and Freemont Bridge) for the years 1990-2005 to see how much the various ratios varied by month. The ratios show substantial variation between months (Figs. 2-5). <u>We recommend, therefore, that a different ratio be used for every month, rather than using a single ratio</u>. The TN:NH4 and TN:NO3 ratios were especially variable (Figs. 3-4)

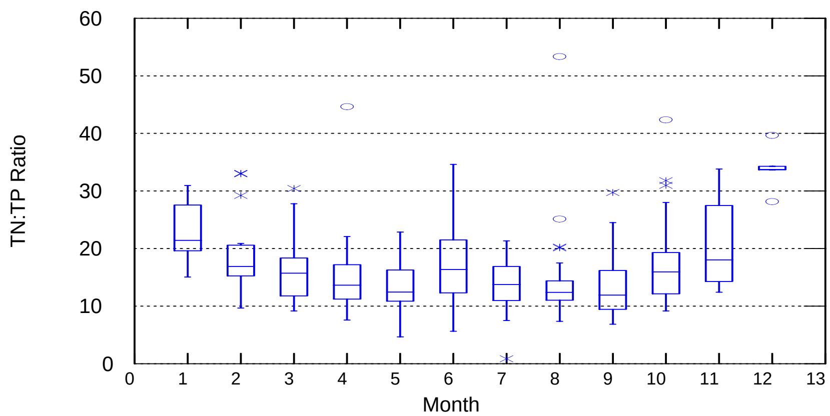

Figure 2. Ratio of total nitrogen (TN) to total phosphorus (TP), by month for the years 1990-2005 near the outlet of UKL at Pelican Marina and Freemont Bridge. Data from the Klamath Tribes.

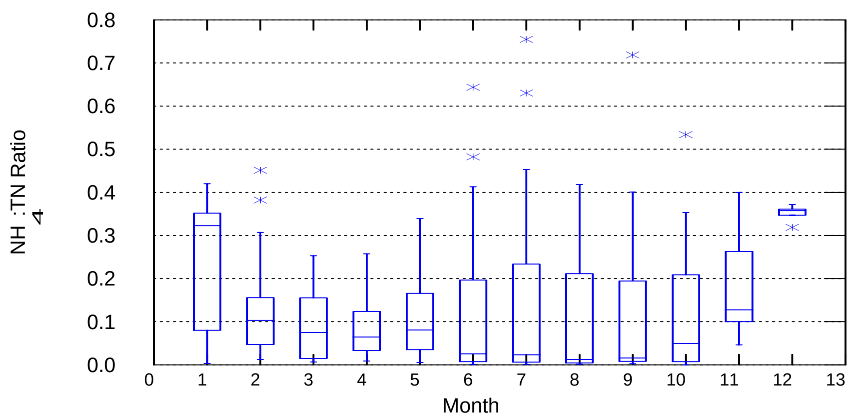

Figure 3. Ratio of ammonia (NH4) to total nitrogen (TN), by month for the years 1990-2005 near the outlet of UKL at Pelican Marina and Freemont Bridge. Data from the Klamath Tribes of Oregon.

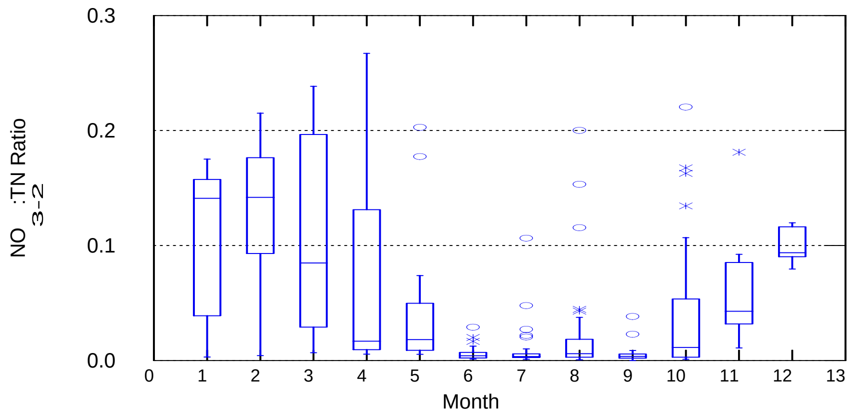

Figure 4. Ratio of nitrate/nitrite (NO3/2) to total nitrogen (TN), by month for the years 1990-2005 near the outlet of UKL at Pelican Marina and Freemont Bridge. Data from the Klamath Tribes.

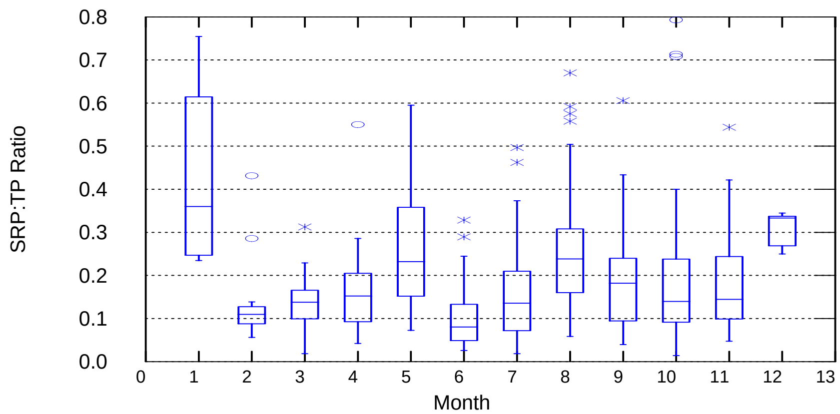

Figure 5. Ratio of soluble reactive phosphorus (SRP) to total phosphorus (TP), by month for the years 1990-2005 near the outlet of UKL at Pelican Marina and Freemont Bridge. Data from the Klamath Tribes.

The memo describing the UKL boundary conditions for the natural conditions scenario states: “Based on Organic P concentrations, the Organic Matter boundary conditions were calculated using a ratio of OM:OP=180.” The rest of the model uses an organic phosphorus to organic matter ratio of 100 (the inverse of the 0.01 ratio described above), so it is unclear why a ratio of 180 is used here. This should be clarified, or corrected if it is erroneous.

The memo describing the UKL boundary conditions for the natural conditions scenario states: “The algae biomass was calculated from the UKL model chlorophyll-a results. Any algae-to-chlorophyll-a ratio of 67 was determined in the model calibration and is used here to derive the algae biomass.” More details should be provided regarding how this conversion factor of 67 was derived. Additionally, consideration should be given to varying the ratio on a seasonal or monthly basis, as field data from the Klamath Tribes shows that the ratio does vary substantially (Figure 6).

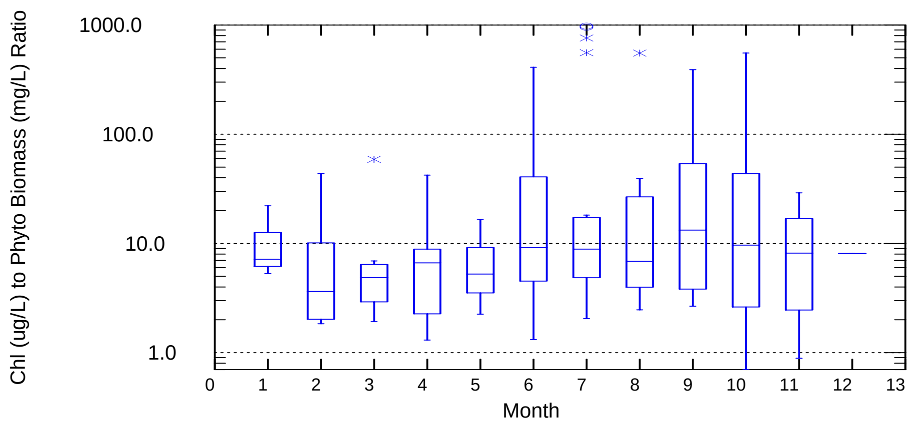

Figure 6. Ratio of chlorophyll (Chl) to phytoplankton biomass, by month for the years 1990-2005 near the outlet of UKL at Pelican Marina and Freemont Bridge. Data from the Klamath Tribes. Phytoplankton biomass derived from biovolume, assuming that wet density phytoplankton is the same as water. Note that the weight here is wet weight, while the TMDL model may be dry weight.

Upper Klamath Lake Flow Boundary Conditions

We briefly reviewed the USBR (2005) Natural Flow of the Upper Klamath River study, as well as the USFWS (2006) review of that study. The study has been improved since the original December 2003 draft, but some problems remain (USFWS 2006). The most significant issue is the USBR's continued refusal to compare their model's prediction with that of real pre-project data from the early 20th century (USFWS 2006). The brief comparison conducted by USFWS (2006) of the model's predictions with the measured pre-project data shows that the model substantially underestimates flow at Link River and Keno. The National Academy of Sciences is currently undertaking a review of the study, but that review may not be completed before the TMDL.

THE ROLE OF TRIBUTARIES IN THE PROTECTION AND RECOVERY OF THE KLAMATH RIVER'S SALMON POPULATIONS MUST BE RECOGNIZED EXPLICITLY IN THE TMDLs

The model-based approach to the Klamath River TMDL uses empirical data and simulated outputs to calculate how tributaries affect mainstem Klamath temperatures. This in no way captures the importance of tributaries as refugia for Pacific salmon juveniles and adults, including their spatial distribution and importance in maintaining and restoring fish populations.

The Klamath River is known to have acute water quality problems that periodically make the mainstem inhospitable for juvenile and adult salmonids (Kier Associates 2006) and require that they seek refuge in small cold water "islands" at the convergence of the river with its tributaries or in the lower reaches of these creeks. Figure 7 shows the maximum floating weekly average water temperature (MWAT) at a dozen Klamath River locations between Happy Camp and Weitchpec from 1997 to 2002. These average values were over 25° C, which is lethal for Pacific salmon (Sullivan et al. 2000), at some locations in some years and over 20° C, a temperature at which all salmonid species are stressed (McCullough, 1999), at all locations in all years.

Mainstem Klamath River temperatures contrast starkly with those of middle Klamath tributaries (Figures 7 and 8), with most of the latter having temperatures suitable or optimal for salmonid rearing. Belchik (1997; 2004) and Sutton (2004) describe how cold pools at convergence points and the lower reaches of cold tributaries serve as refugia for salmonids, when the mainstem Klamath River has highly stressful or lethal conditions for Pacific salmon juveniles and adults. The refugia at the mouth of Pecwan Creek is shown in Figure 9.

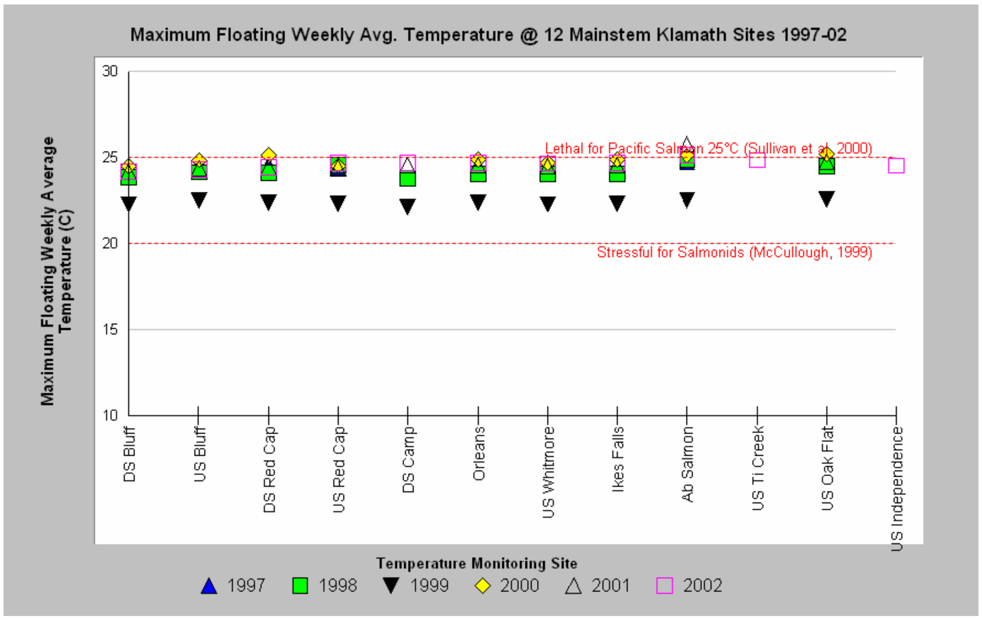

Figure 7. Maximum floating weekly average water temperature at 12 locations on the mainstem Klamath River for the years 1009-2002. Karuk Tribe / Klamath National Forest data from KRIS V 3.0.

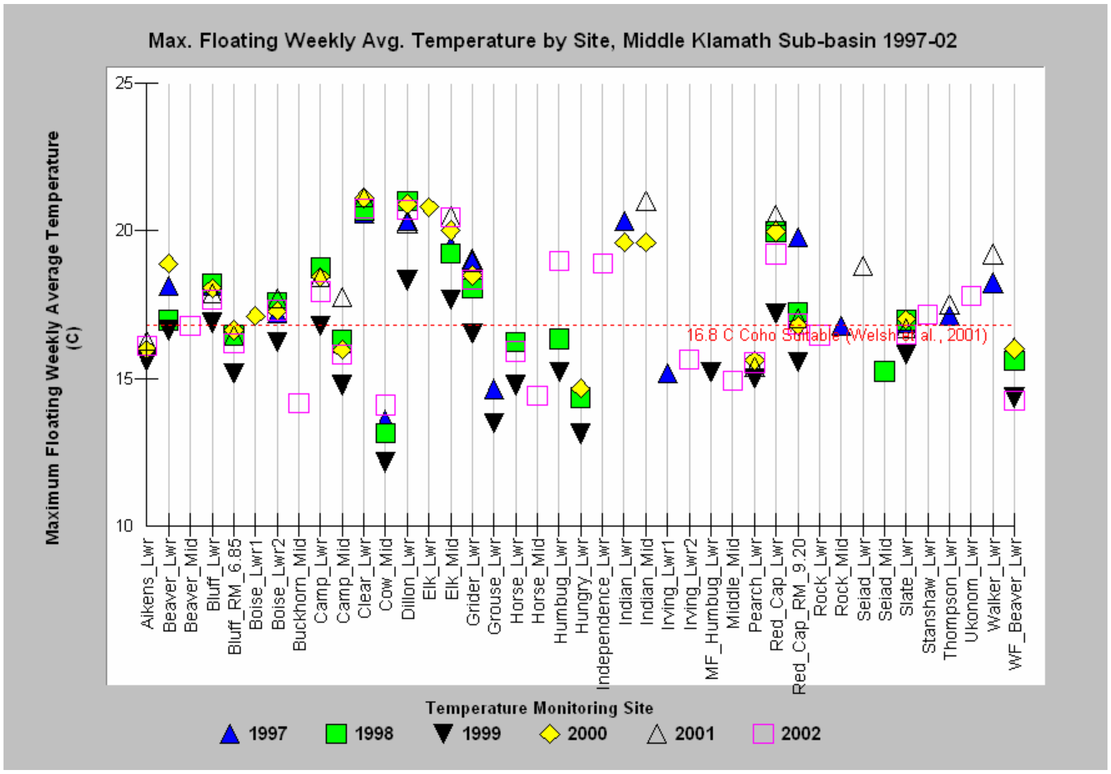

Figure 8. This chart shows the maximum floating weekly average water temperature of Middle Klamath tributaries from Beaver Creek downstream to Weitchpec from 1997-2002. Karuk Tribe / Klamath National Forest data from KRIS V 3.0.

Figure 9. Juvenile salmonids and an adult chinook hold in the cold water lens at the mouth of Pecwan Creek.

The spatial distribution of refugia is shown in Figure 10, including an index of their carrying capacity in 1998 according to Belchik (2004). Figure 11 is a map image showing the MWAT at various Klamath River locations and in tributaries (Figure 8) from the Klamath Resource Information System (KRIS) (TCRCD, 2003).

Fish sampling has been conducted by the Karuk Department of Natural Resources and the Yurok Fisheries Department in several years that indicates that thousands of juvenile steelhead, chinook and coho salmon use the lower reaches of Middle and Lower Klamath tributaries and the cold water areas at the convergence with the Klamath River (Deas et al., In Press).

Samples taken by the Karuk DNR at the mouth of Independence Creek in 2002 show that coho salmon used the stream all summer long, but were not found in the mainstem Klamath River offshore of the mouth (Figure 12). Many tributaries do not provide coho salmon spawning but nevertheless support juvenile rearing in summer. In this way tributary refugia contribute to the survival of the coho populations of major Klamath River tributaries like the Shasta and Scott Rivers by providing places for juvenile salmon to survive, rest and grow on their way to the ocean.

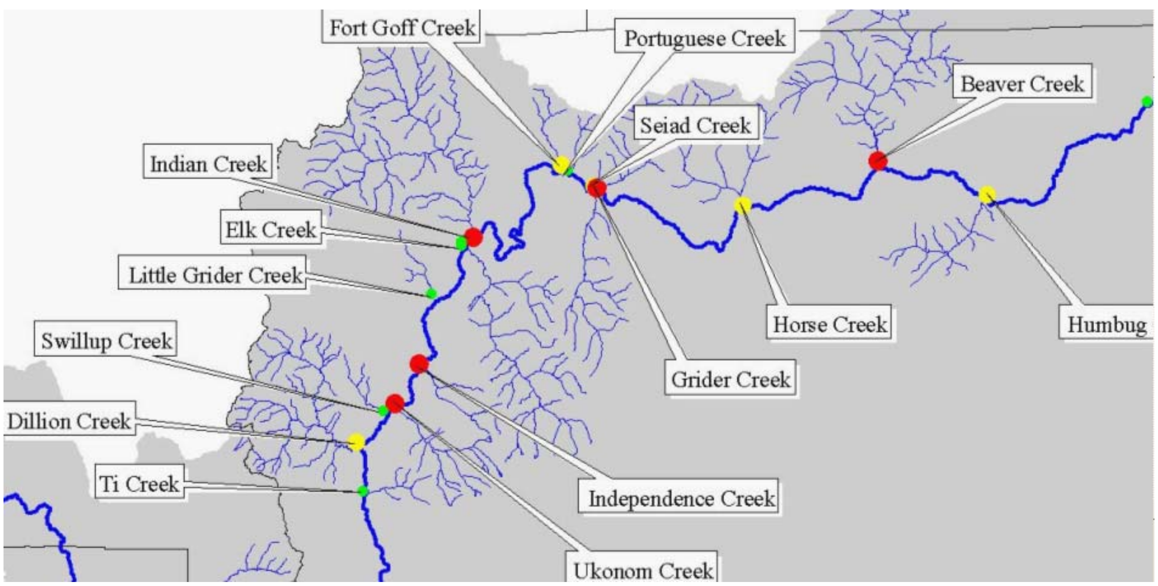

Figure 10. Number of juvenile salmonids counted at the mouths of Middle Klamath tributaries in 1998. Green = <50, yellow = 50-200, red = >200. From Belchik (2004).

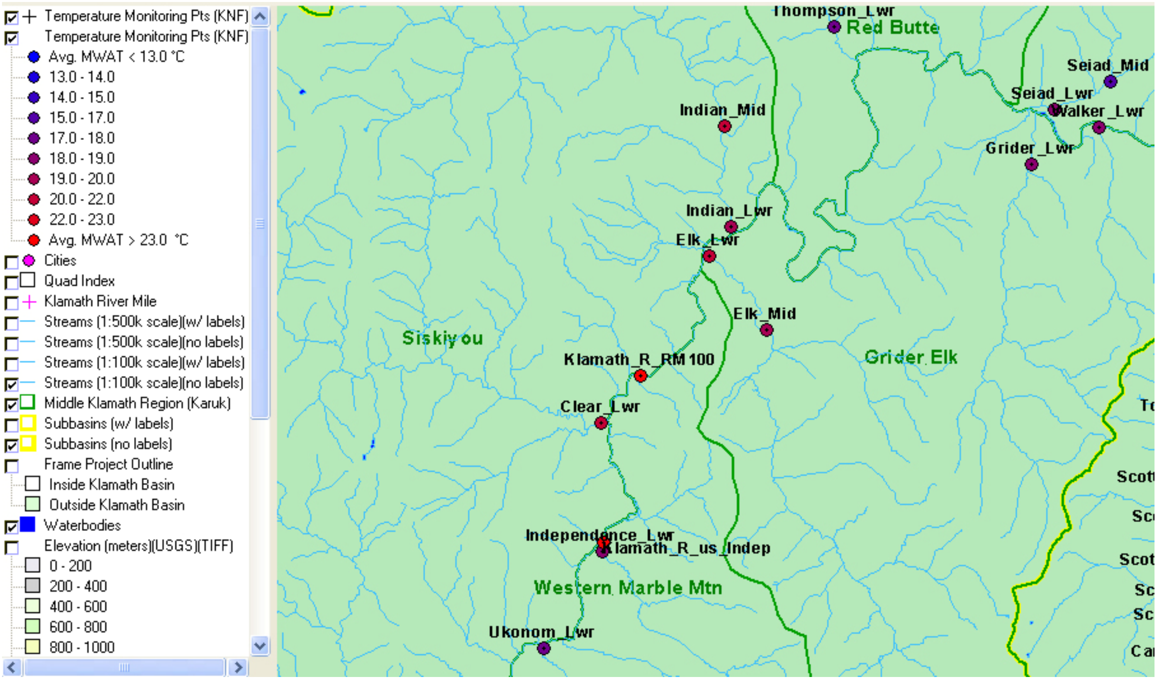

Figure 11. Middle Klamath temperature map showing mainstem Klamath River and tributary temperatures by color code with darker blue colors more suitable for salmonids and red representing those that are less suitable for salmonids. Karuk Tribe / Klamath National Forest data from KRIS V 3.0.

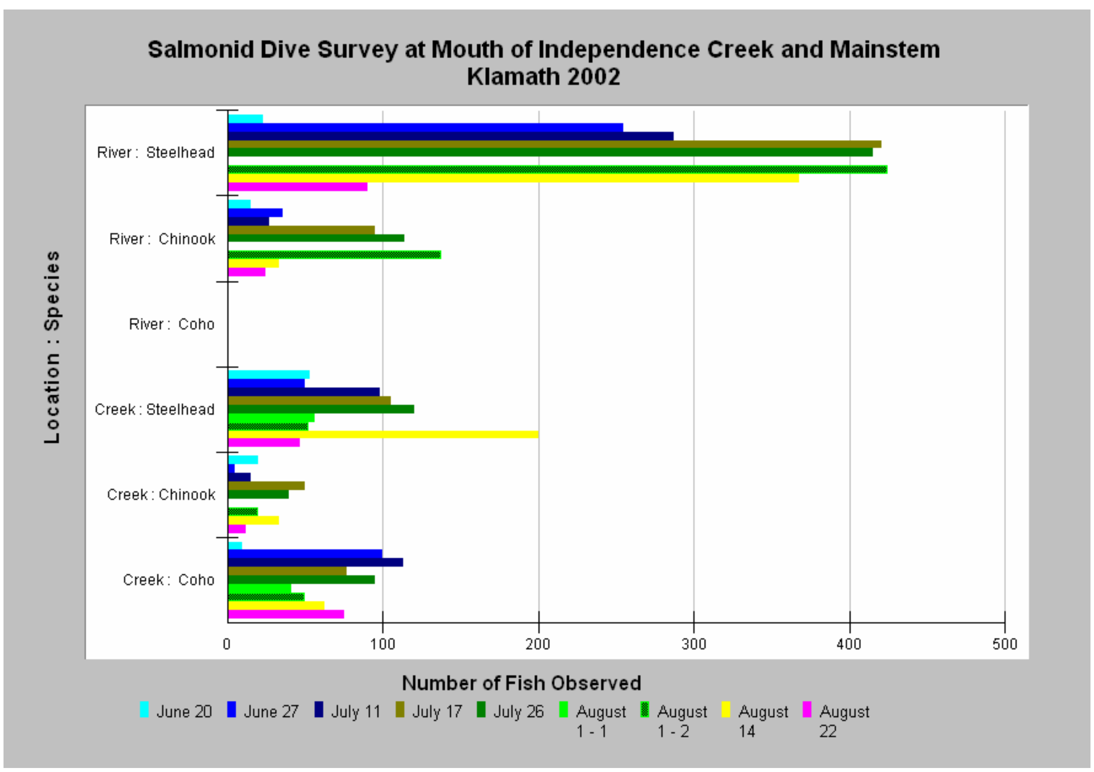

Figure 12. Salmonid data for lower Independence Creek and refugia at the convergence with the Klamath River on nine dates in 2002, with coho in the creek proper but never seen in the mainstem Klamath refugia. Karuk Tribe DNR data from KRIS V 3.0.

The U.S. EPA (2003) *Region 10 Guidance for Pacific Northwest State and Tribal Temperature Water Quality Standards* (U.S. EPA, 2003) provides a good deal of information on the need to protect temperature diversity and refugia, especially in large river systems where temperature problems cannot be fully remedied. According the EPA, water quality targets for tributaries need to be established in the TMDL development process in order to meet the needs of Pacific salmon. Measures for tributary watershed protection must be determined:

> "TMDL allocations should incorporate restoration of the diurnal and seasonal temperature regime and cold water refugia that reflect the natural condition. If it is impracticable to address these impacts quantitatively through allocations, then the TMDL assessment document should qualitatively discuss the human activities that modify these aspects of the natural thermal regime. Plans to implement the TMDL should include measures to restore and protect these unique aspects of the natural condition.
>
> EPA believes it is particularly important for the TMDL itself or the TMDL assessment document to address the above aspects of the natural thermal regime for waterbodies where the natural background maximum 7DADM temperature exceeds 18°C and where the river has significant hydrologic alterations (e.g., dams and reservoirs, water withdrawals, and/or significant river channelization) that have resulted in the loss of temperature diversity in the river or shifted the natural temperature pattern. For example, there may be situations where the natural background maximum temperatures exceed 18°C, but historically the exposure time to maximum temperatures was limited due to the comparatively few number of hours in a day that the water reached these temperatures, the comparatively few number of days that reached these temperatures, and plentiful cold water refugia from cold tributary flows and hyporheic flow in alluvial floodplains where salmonids could avoid the maximum water temperatures."

THE RELATIONSHIP OF CUMULATIVE WATERSHED EFFECTS TO COLDWATER REFUGIA MUST BE RECOGNIZED IN THE TMDLs

Klamath National Forest (de la Fuente and Elder, 1998) found that sediment from the 1997 storm caused channel widening on streams like Elk Creek (Figure 13). Walker Creek, a smaller tributary, went from 50 to 150 feet wide that year as its entire channel was inundated with sediment (Figure 14). The January 1997 storm was judged to be of only a 14-35 year recurrence interval and should <u>not</u> have triggered such widespread damage to streams nor such water temperature degradation.

Tributaries that serve as refugia for salmon are subject to catastrophic damage resulting from human-caused cumulative watershed effects. Elk Creek temperatures increased substantially as a result of aggradation. Its carrying capacity for juvenile salmonids has been reduced substantially, as is apparent from the temperatures shown in Figure 8. The findings of de la Fuente and Elder (1998) were that landslides that damaged streams caused over 435 miles of channel scour on Klamath National Forest resulting from failed road beds, recent timber harvests, recently burned areas, old timber harvests, and undisturbed areas, respectively (Figure 15).

The *Mid-term Evaluation of the Klamath River Basin Fisheries Restoration Program* (Kier Associates 1999) noted that conservative land management and upland restoration programs on Klamath River tributaries within Six Rivers National Forest were successful in preventing stream damage, while Klamath National Forest watersheds had a higher level of disturbance and channel damage from the January 1997 storm. Kier Associates (1999) also pointed out the timber harvest levels and road densities were much higher on private lands within middle Klamath River tributaries, such as within Beaver Creek and Horse Creek, which posed even greater risk of stream damage from cumulative watershed effects. Lower Klamath River tributaries are mostly within private ownership and tributaries are massively aggraded (Payne Associates, 1989). Voight and Gale (1998) noted that 17 of 23 streams below the confluence of the Trinity River lose surface flow at the convergence with the Klamath River because of aggradation.

Figure 13. Shallow, warm Elk Creek with a large delta from January 1997 storm. From KRIS V 3.0.

Figure 14. Flow of Walker Creek is barely visible in this March 1997 photo due to massive sediment deposits stemming from debris torrents and crossing failures on January 1, 1997. Channel widening made the stream much more subject to warming. KRIS V 3.0.

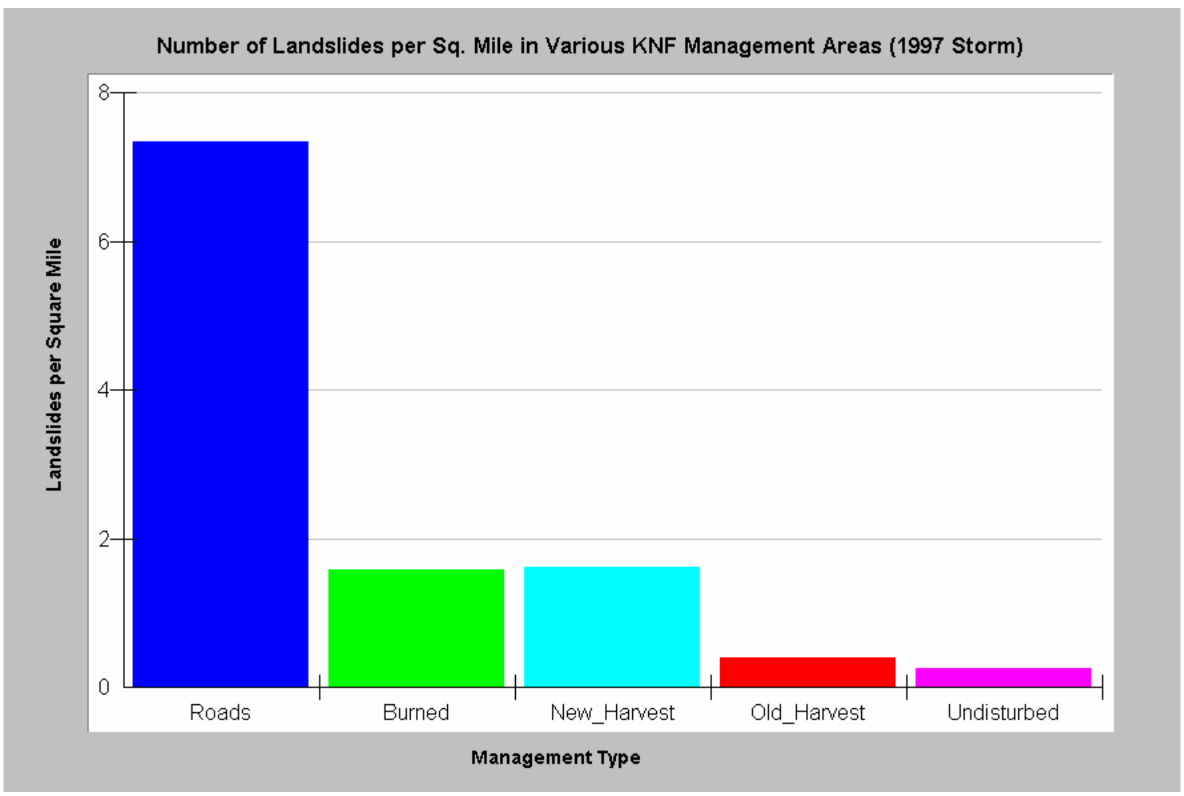

Figure 15. This summary chart is based on data from de la Fuente and Elder (1998) regarding 1997 flood effects and shows few landslides occurred on undisturbed lands of the Klamath National Forest, and slide frequency was associated with human disturbance.

RECOMMENDATION: IMPLEMENTATION ACTIONS NEEDED TO PROTECT COLDWATER REFUGIA

The most important element of establishing water quality standards to protect and restore Pacific salmon according to U.S. EPA (2003) is to "protect existing high quality waters (i.e., waters that currently are colder than the numeric criteria) and prevent any further thermal degradation in these areas."

The damaging water quality effects of increased sediment yield and peak discharge associated with intensive land use management, like timber harvests and roading, is well recognized by recent studies in California (Ligon et al., 1999; Dunne et al., 2001; Collison et al., 2003). The Klamath National Forest study of the January 1997 storm (de la Fuente and Elder, 1998) provides evidence of advanced cumulative effects-related damage to streams in the Middle Klamath Basin.

Given water quality problems in the mainstem Klamath River (Kier Associates 2005a), lower reaches of Klamath River tributaries and cold pools at their mouths need to be protected by reducing further risk of cumulative watersheds effects in these sub-basins.

Table 5 provides a list of land uses that contribute to cumulative watershed effects, including their impacts on stream channels and contributions to thermal pollution. Prudent risk limits on land management are included, based on regional literature. We have notified the NCRWQCB and U.S. EPA in the past of the need to recognize the cumulative watershed effects associated with timber harvest and roads in Klamath River tributaries and the Scott River (Hillman 2004, QVIC 2004). The Klamath River Temperature TMDL needs to explicitly describe cumulative effects risk and the changes in thermal regimes associated with channel changes and to set prudent risk limits to watershed disturbance to prevent recurring stream damage and to allow for the recovery of Pacific salmon stocks.

The U.S. Forest Service has studied Klamath River tributaries extensively (SRNF 2003b, KNF 2000, KNF 2003) and has formulated plans for management of its road networks (SRNF 2003a). Associated documents include characterization of existing conditions and cumulative effects risk (Figure 16) as well as steps needed to protect and improve aquatic habitat through improved upland management and restoration.

The Klamath River TMDL needs to cite these USFS studies and to commend that road decommissioning and the other recommended activities to reduce cumulative effects risk be carried out expeditiously as part of the TMDL's initial implementation.

If the NCRWQCB staff does not feel obliged to set limits to watershed disturbance based on existing regional literature, we request that the Klamath River TMDL recommend focused studies on the relationship between watershed management and changes in channel configuration and water temperatures in tributary refugia. For example, the Klamath River TMDL could recommend use of the RAPID method (Grant, 1988) that would compare historic aerial photos of lower tributary reaches with more recent ones. This would allow changes in channel width and riparian recovery to be measured and compared in basins with various upland management experiences. These data could be combined with cross sections and longitudinal profiles of lower tributary reaches to assess how long it takes to restore pool frequency and depth after aggradation or channel scour. Defining these relationships on a local basis could assist in determining thresholds for prudent risk as part of TMDL implementation so that damage to streams during low frequency interval storms, like that of January, 1997, is prevented.

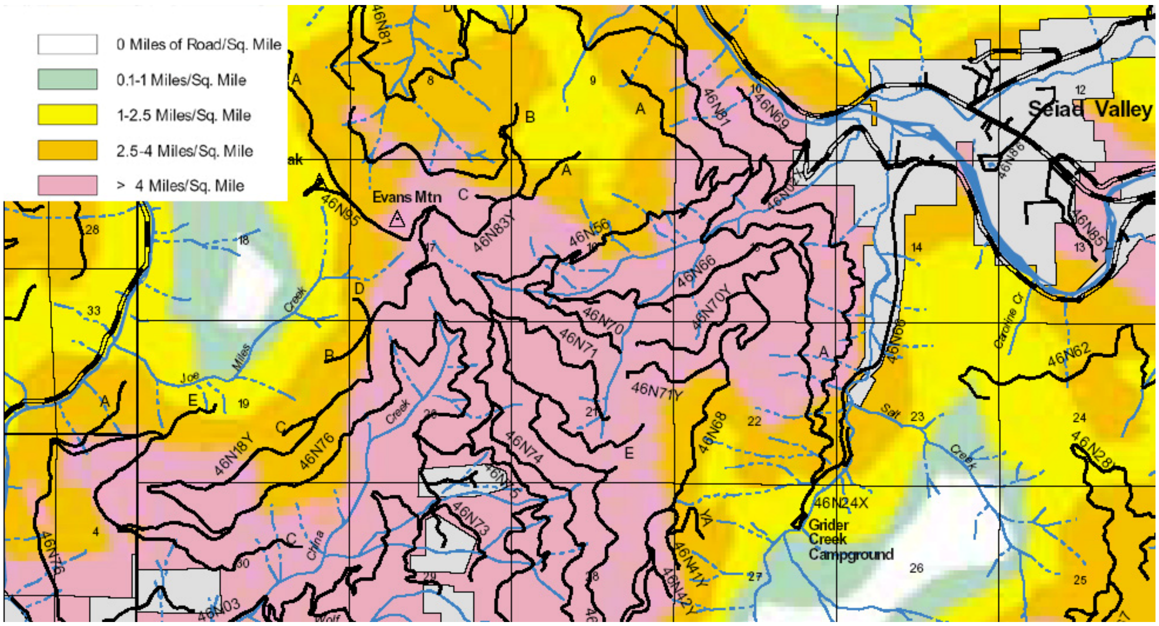

Figure 16 . This map shows the Grider Creek watershed and adjacent areas with color codes indicating the density of roads, with white and green representing lower ranges, yellow intermediate values and orange and pink higher cumulative effects risk. Map from KNF (2000).

Table 5. Management with cumulative watershed effects potential, relationship to streams and suitability for salmonids and recommended steps for management of risk with citations.

Management Issue	**Watershed Effect**	**Channel/Stream Effect**	**Remedy**	**Citation**
Timber Harvest	Increased surface erosion, landslides, and sediment yield; elevated peak discharge, decreased base flows	Widening, decreased depth and pool frequency, increased heat exchange and warming. Reduced summer carrying capacity.	Limit timber harvest to 25% of a watershed over a 25-30 year period (1% of inventory harvested per year)	Reeves et al (1993), Berris and Harr (1987), Heeswijk et al. (1995), LaVen and Lehre (1977), Montgomery and Buffington (1993), Harr (1983)
Road Density	Road failures, increased sediment yield, elevated peak discharge, decreased base flows	Widening, decreased depth and pool frequency, increased heat exchange and warming. Reduced summer carrying capacity.	Limit road density to less than 2.5 mi./sq. mi.	Armantrout et al. (1999), NMFS (1995), NMFS (1996), Jones and Grant (1996), LaVen and Lehre (1977), Harr (1983)
Stream Crossings	Major sediment contributions when culverts plug, multiple crossing failure leads to catastrophic sediment yield	Widening, decreased depth and pool frequency, increased heat exchange and warming. Loss of riparian vegetation.	Limit stream crossings to no more than 1.5 per mile of stream	Armantrout et al. (1999)
Management on Unstable Areas	Increased frequency of landslides with major contributions of sediment with less than natural quantities of large wood	Widening, decreased depth and pool frequency, increased heat exchange and warming. Reduced summer carrying capacity.	Reduce or eliminate timber harvest or road building on unstable areas.	Dietrich et al. (1998)
Riparian Logging	Decreased thermal buffer, reduced large wood contributions, increased landslides and sediment delivery	Reduced pool frequency and cover, increased summer water temperatures and more extreme cold winter temperatures	Reduce or eliminate timber harvest within two site potential tree heights or within the inner gorge.	FEMAT (1993)

THE TMDL SHOULD ADDRESS TOXIC BLUE-GREEN ALGAE IN ITS TECHNICAL REPORT AND IMPLEMENTATION PLAN

Recent studies indicate that a toxic species of blue-green algae, *Microcystis aeruginosa* (MSAE), is flourishing in Iron Gate and Copco reservoirs (Kann and Corum 2006; and Kann 2006). Yurok Tribe Environmental Program samples also detected *Microcystis* as far downstream as the Klamath River estuary and even found small amounts in the liver of steelhead that were bio-assayed (Fetcho 2006).

The results from multiple datasets summarized by Kann (2006) indicate that Iron Gate and Copco Reservoirs were directly responsible for the high levels of MSAE and microcystin toxin detected in the Klamath River below Iron Gate Dam. This conclusion is consistent with literature showing that MSAE and other buoyant cyanobacteria do not dominate in conditions of turbulent mixing (e.g., Huisman et al. 2004) such as that known to occur in the Klamath River above Copco and Iron Gate Reservoirs.

With dam removal and decline in preferred lacustrine habitat for MSAE, the abundance of *Microcystis* can be reduced many fold. Thus, with the inoculant source (Iron Gate and Copco Reservoirs) of MSAE reduced by many orders of magnitude, or even eliminated, even in downstream suitable MSAE habitat such as a quiet backwater, blooms would take longer to develop because they would start from fewer cells, and cells would have less chance of dispersing to suitable habitats.

While the Klamath River TMDL model does not incorporate algal toxins, the TMDL should, at minimum, have a narrative addressing *Microcystis* and algal toxins. Additionally, it should take *Microcystis* and algal toxins into consideration when deciding whether to recommend dam removal as part of TMDL implementation.

Consequently, the role of KHP reservoirs in *Microcystis* production adds weight to arguments that dam removal is needed for restoring Klamath River water quality and should be viewed by staff as a basis for recommending dam removal as part of the Klamath River TMDL implementation.

PACIFIC SALMON STOCK STATUS AND TRENDS REQUIRE URGENT ACTION

Pacific salmon researchers have discovered that there are cycles of approximately 25 years associated with ocean currents and precipitation that alternate between favorable for Washington, Oregon and California salmon and steelhead populations and, then, switch to favor stocks in Alaska and Canada (Hare et al. 1999). Ocean conditions have been favorable for Klamath River stocks and precipitation has been average, or above average, since 1995 (Collison et al. 2003) as this Pacific Decadal Oscillation (PDO) cycle switched to favorable for our region. Instead of rebounding, however, several Klamath River Chinook salmon populations are currently declining precipitously. Salmon River fall Chinook populations have fallen to record lows of around five hundred adults in 2004 and 2005 (Figure 17) and spring Chinook in the same basin have declined to fewer than 100 for the first time on record (Figure 18). Similarly, fall Chinook returns to the Scott River also fell to near, or below 500 for the first time ever in 2004 and 2005 (Figure 19).

The contemporaneous decline of fall and spring Chinook salmon in several Klamath River sub-basins is evidence that mainstem Klamath River water quality problems are likely causing major stress on migrating juveniles and adults. Kier Associates (2006) point out that the Klamath River has not only elevated water temperatures but also highly stressful levels of dissolved ammonia, pH and dissolved oxygen as a result of nutrient pollution. The incidence of disease of juvenile salmonids migrating downstream in the Klamath River has been extremely high in recent years (Nichols and Foott 2005) and juvenile mortality is thought to be a major contributor to low escapement in recent years. The cumulative stress from high temperature, elevated pH, dissolved ammonia and low D.O. are likely combining to compromise the immune system of juvenile salmonids and make them more susceptible to the devastating epidemics that occur almost every year.

<u>The precipitous decline of Scott River fall Chinook and Salmon River fall and spring Chinook stocks should be explicitly addressed in the TMDL</u>, as well as the longer-term cyclical patterns associated with the PDO (Hare et al. 1999). The acute water quality problems in the mainstem Klamath should also underscore the need for expeditious tributary refugia protection and restoration. This information should be used to frame the need for urgent actions ranging from watershed protection and restoration to Klamath Hydroelectric Project decommissioning before less favorable ocean and climatic conditions recur sometime between 2015 and 2025.

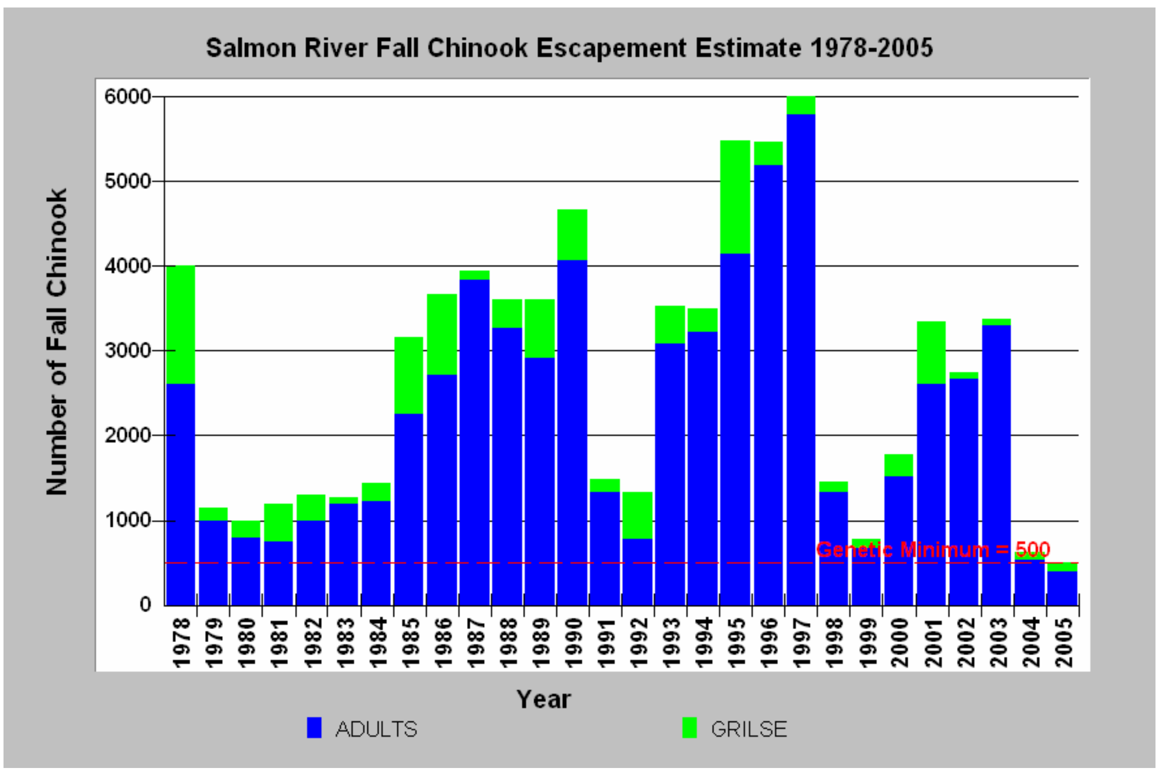

Figure 17. Salmon River fall Chinook escapement plummeted in 2004 and 2005 to the lowest escapement on record since 1978 two years in a row. Data from CDFG (2006).

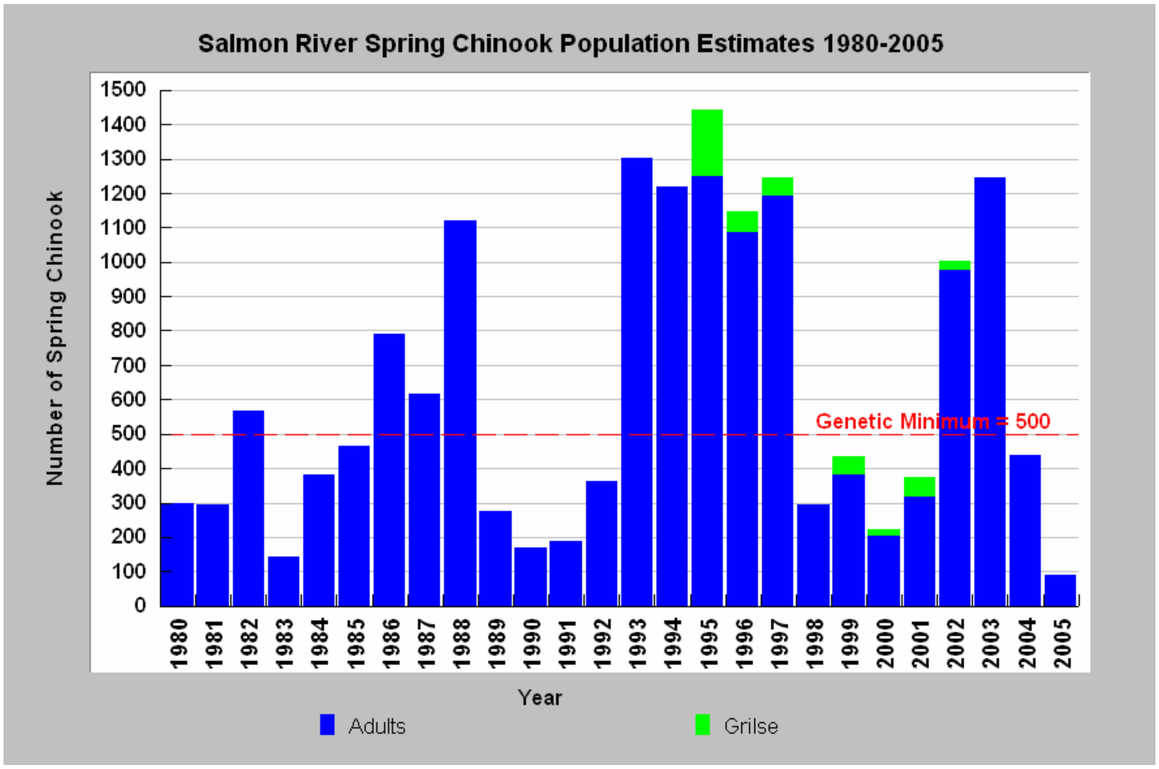

Figure 18. Salmon River spring Chinook fell to an all time low in 2005. Data from Salmon River Restoration Council.

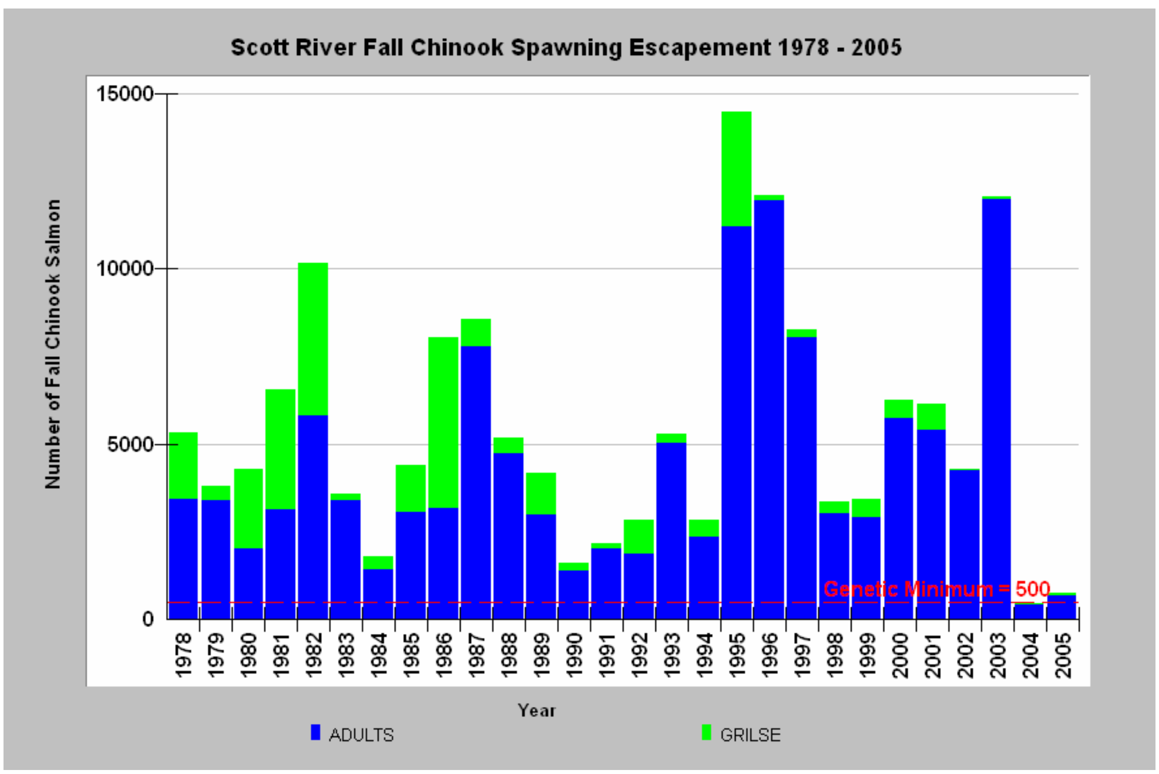

Figure 19. Scott River fall Chinook escapement shows a similar trend to Salmon River populations, with both 2004 and 2005 well below average and the lowest years on record

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