FINAL STAFF REPORT
for the
KLAMATH RIVER TOTAL MAXIMUM DAILY LOADS (TMDLs) ADDRESSING TEMPERATURE, DISSOLVED OXYGEN, NUTRIENT, and MICROCYSTIN IMPAIRMENTS IN CALIFORNIA
the
PROPOSED SITE SPECIFIC DISSOLVED OXYGEN OBJECTIVES FOR THE KLAMATH RIVER IN CALIFORNIA,
and the
KLAMATH RIVER and LOST RIVER IMPLEMENTATION PLANS

March 2010

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This TMDL is dedicated in loving memory to Elmer Dudik and Dr. Ranjit Gill who worked tirelessly in their duties to improve water quality in the Klamath River basin and throughout the North Coast to ensure that California's water resources were pollutant free, and beneficial uses were protected for all to enjoy. Their work to protect and restore water quality is a lasting testament to their dedication to the environment and to the people of California. They are sorely missed.

Acknowledgments

Working in collaboration with Oregon Department of Environmental Quality, US Environmental Protection Agency Regions 9 and 10, and Tetra Tech, Inc., the TMDL Development Team of the North Coast Regional Water Quality Control Board was responsible for data collection, data interpretation, modeling, and preparation of the report. This report would not have been possible without the efforts and contributions of many people and organizations including:

- Regional Water Board Staff – Bruce Gwynne and William Hart (GIS)
- US EPA Region 9 – Susan Keydel, Gail Louis, and Maria Rea
- US EPA Region 10 – Ben Cope and Mark Filippini
- Oregon Department of Environmental Quality – Steve Kirk, Eric Nigg, Dan Turner
- Tetra Tech, Inc. – Jon Butcher, Mustafa Faizullabhoy, Andrew Parker, and Rui Zou
- US Geological Survey – Debra Curry, Alan Flint, Laurie Flint
- The multiple agencies, Tribes, companies, and private individuals who collected data in the basin

Our thanks and appreciation to you all.

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CHAPTER 2. PROBLEM STATEMENT

2.1 Introduction

In the Klamath River in California increased water temperatures, elevated nutrient levels, low dissolved oxygen concentrations, elevated pH, potential ammonia toxicity, increased incidence of fish disease, an abundance of aquatic plant growth, high chlorophyll-a levels (both planktonic and periphytic algae), and high concentrations of potentially toxinogenic blue-green algae, particularly in the impounded reaches, decrease the quality and quantity of suitable habitat for fish and aquatic life, and have disrupted traditional cultural uses of the river by resident Tribes. These conditions contribute to the non-attainment of beneficial uses, including the most sensitive beneficial uses: those associated with cold water fish and fisheries (including in particular the salmonid fishery) in California, those related to cultural uses and practices, and those related to recreation.

The purposes of the California Klamath River basin TMDL problem statement are to:

- Provide an overarching assessment framework for the TMDL;
- Present a summary assessment of current water quality conditions; and
- Document beneficial use impairments.

The Klamath River numeric and narrative water quality objectives and beneficial uses that are the comparative benchmarks for the problem statement assessment are described in the Regional Water Board's *Water Quality Control Plan for the North Coast Region* **(**Basin Plan). Section 2.2 of the problem statement, Water Quality Standards, consists of a summary description of the Basin Plan and Tribal water quality standards, objectives, and beneficial uses addressed in the TMDL. The Basin Plan and Tribal water quality standards provide the regulatory context for the assessment that follows. Section 2.3, Numeric Targets, presents the numeric water quality targets that represent attainment of applicable water quality objectives used in this TMDL.

Section 2.4, Water Quality Conceptual Models Overview, describes the technical approach used in the problem statement assessment. To ensure a comprehensive assessment and decision framework, the Regional Water Board has adopted the technical approach from the California Nutrient Numeric Endpoints (CA NNE) framework (Tetra Tech 2006). The CA NNE is used to assess and describe the water quality impacts associated with nutrient and organic enrichment and temperature alteration. The approach involves the development of conceptual models that illustrate how key factors and processes link the primary stressors (nutrients and organic enrichment, and altered temperature regime) with impacts on beneficial uses. In addition, the conceptual models can be used to identify key uncertainties and data gaps, provide lines of evidence for numeric targets and allocations, and are useful tools for adaptive management. The conceptual models for the Klamath River focus on water quality related impacts and provide perspective on other factors that contribute to impairment of beneficial uses within the Klamath River basin.

Section 2.5, Evidence of Water Quality Objective and Numeric Target Exceedances, as the title suggests, presents evidence of exceedances of water quality objectives. The Regional Water Board has compiled water quality monitoring data from several sources to support this analysis (e.g., dissolved oxygen, temperature, pH, nutrient enrichment) and CA NNE indicators (e.g., benthic algal biomass, chlorophyll-a, diurnal dissolved oxygen [DO] and pH patterns). The purpose of the analysis of water quality objectives and CA NNE indicators is to evaluate the risk of impairment to beneficial uses. The Section 2.5 analysis uses data from eleven stations along the length of the Klamath River from the Oregon border to its mouth at the Pacific Ocean. (See Appendix 1 for the Klamath River DO Staff report and a discussion of the recalculation of the SSOs for DO in the mainstem Klamath River as currently contained in the Basin Plan).

As detailed in Section 2.6, Evidence of Beneficial Use Impairment, many designated beneficial uses are not being supported in the Klamath River. The purpose of Section 2.6 is to describe how poor water quality conditions are impairing beneficial uses in the Klamath River. The focus is on the status of the elements that are essential to each beneficial use. For example, to evaluate the Cold Freshwater Habitat (COLD) beneficial use, the historical and current status of cold-water fish populations and the associated fishery is compared to demonstrate a significant degradation of cold water fish and fishery related beneficial uses.

Section 2.7, Problem Statement Synthesis, presents the problem statement conclusions regarding the status of Klamath River beneficial uses and the necessity for fully implementing the TMDL in a timely manner. The problem statement conclusions provide the focus for the TMDL pollutant allocations and implementation.

2.1.1 Non-TMDL Factors and Other Regulatory Processes

It is important to recognize that in the Klamath River basin there are factors that affect the condition of beneficial uses that are not directly addressed through the TMDL process. Klamath River beneficial uses are also impacted by other factors including but not limited to:

- The presence of dams which impede passage of anadromous fish;
- Altered flow conditions that affect habitat conditions;
- The presence of hatchery raised fish with the potential for disease and genetic effects;
- Ocean and in-river fisheries harvest rates; and
- Global climate change.

The problem statement description is a required component of any TMDL, but in this case it takes on added importance because of other ongoing regulatory processes and collaborative settlement discussions (i.e., Klamath Hydroelectric Settlement Agreement and Klamath Basin Restoration Agreement) occurring within the Klamath Basin that must be kept clearly distinct from the TMDL process. The other ongoing regulatory processes include:

- The 50-year Federal Energy Regulatory Commission (FERC) relicense for the four mainstem dams included in the Klamath Hydroelectric Project; and
- Endangered Species Act (ESA) consultation for several native species that have special federal and or state status, including but not limited to Coho salmon, shortnose sucker, Lost River sucker, and Bull trout.
- Tribal Trust responsibilities of the USEPA to Tribes and individual Indians.

The mention of these other non-TMDL factors affecting water quality and other ongoing regulatory processes that will address some of these factors is meant to underscore the need for a comprehensive solution to restore ecosystem integrity to the Klamath River basin. The TMDL process described in this document is only one component of a restoration and management program that must be implemented in the next few years to preserve and restore Klamath River water resource related uses.

2.2 Water Quality Standards

The USEPA describes a water quality standard as consisting of four basic elements: 1) designated uses of the water body, 2) water quality criteria to protect designated uses, 3) an antidegradation policy to maintain and protect existing uses and high quality waters, and 4) general policies addressing implementation issues. More information is available at <http://www.epa.gov/waterscience/standards/about/>.

The Porter Cologne Water Quality Control Act (Porter Cologne)[1] modifies USEPA's language to refer to designated uses as "beneficial uses" and water quality criteria as "water quality objectives", which includes the state anti-degradation policy (Resolution 68-16). Porter Cologne also requires a "program of implementation" (Water Code section 13050(i)) for water quality protection in California. A "program of implementation" includes actions necessary to achieve objectives, a time schedule for the actions to be taken, and surveillance to determine compliance with objectives (see Water Code section 13242).

The Regional Water Board has adopted the Basin Plan in which it establishes the region's water quality standards, including the standards that apply to that portion of the Klamath River basin that falls under the jurisdiction of the state of California. The Basin Plan has been approved by the State Water Board and by USEPA and is in full force and effect. Appendix 1 of this staff report includes the Proposed Site Specific Dissolved Oxygen Objectives for the Klamath River in California, a staff report supporting the recalculation of the existing SSOs for DO in the mainstem Klamath River.

Similarly, the Hoopa Valley Tribe has adopted the *Water Quality Control Plan for the Hoopa Valley Indian Reservation* that has been approved by USEPA and is in full effect.

[1] The Porter-Cologne Water Quality Control Act (Water Code §§ 13000 et seq.) is the act governing the water quality protection activities of the State Water Resources Control Board (State Board) and the nine regional boards within the state of California.

The Hoopa's standards apply to those portions of the Trinity and Klamath Rivers under the jurisdiction of the Hoopa Valley Tribe[2].

The Yurok and Karuk Tribes have also adopted water quality standards, as has the Resighini Rancheria. These water quality plans and standards have not yet been approved by USEPA, however, and the Regional Water Board will consider their content and use for guidance, as appropriate.

The Quartz Valley Tribe, located along the Scott River, is in the process of developing a document on water quality standards for approval by its Tribal government.

2.2.1 Water Quality Control Plan for the North Coast Region

The Basin Plan (Regional Water Board 2007) is divided into 6 chapters. Of concern to this discussion are Chapter 2 (Beneficial Uses), Chapter 3 (Water Quality Objectives), Chapter 4 (Implementation Plans), and Chapter 5 (Plans and Policies).

2.2.1.1 Beneficial Uses

Chapter 2 of the Basin Plan identifies 28 beneficial uses of water within the North Coast region. Within the Klamath River basin, the following beneficial uses are identified as existing uses:

- MUN—Municipal and domestic supply
- AGR—Agricultural supply
- IND—Industrial service supply
- PRO—Industrial process supply
- GWR—Groundwater recharge
- FRSH—Freshwater replenishment
- NAV—Navigation
- POW—Hydropower generation
- REC1—Water contact recreation
- REC2—Non-contact water recreation
- COMM—Commercial and sport fishing
- CUL—Native American Culture
- WARM—Warm freshwater habitat
- COLD—Cold freshwater habitat
- WILD—Wildlife habitat
- RARE—Rare, threatened, or endangered species
- MAR—Marine habitat
- MIGR—Migration of aquatic organisms
- SPWN—Spawning, reproduction, and/or early development
- SHELL—Shellfish harvesting
- EST—Estuarine habitat
- AQUA—Aquaculture

Of particular importance are those uses that are currently not fully supported due in part to degraded water quality. As detailed in Section 2.5, 17 of the 23 designated beneficial uses for the Klamath River are impaired including: Native American Culture; Subsistence Fishing; Cold Freshwater Habitat; Warm Freshwater Habitat; Rare, Threatened, or Endangered Species; Migration of Aquatic Organisms; Spawning, Reproduction, and/or Early Development; Water Contact Recreation; Non-Contact Water Recreation;

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2 The Hoopa Valley Tribe is a sovereign nation with land, 12 miles by 12 miles, primarily in the Trinity River watershed but intersecting with the Klamath River at Saints Rest Bar upstream of the confluence with the Trinity (www.Hoopa-nsn.gov).

Municipal & Domestic Supply; Shellfish Harvesting; Estuary Habitat; Marine Habitat; Aquaculture; Agricultural Supply; Commercial and Sport Fishing; and Wildlife Habitat. Subsistence fishing (FISH) is also listed in the Basin Plan as a beneficial use of the waters in the region. Although the specific areas in which this use exists have not yet been designated in the Basin Plan, this does not alter the need to protect this existing beneficial use.

2.2.1.2 Water Quality Objectives

Chapter 3 of the Basin Plan identifies the water quality objectives deemed necessary to protect beneficial uses. Of concern to this TMDL are the water quality objectives concerning temperature, dissolved oxygen and nutrients. These are the parameters for which instream water quality data indicate exceedances and for which the Klamath River is listed on the 303(d) list as impaired[3]. Additionally, pH is discussed because high pH can be directly stressful to salmonids and it also influences nutrient related parameters such as ammonia toxicity. Toxicity is also discussed as nutrient and temperature impairment contributes to the presence of blue-green algae blooms and associated presence of algal toxins.

Temperature

The Basin Plan contains two separate water quality objectives for temperature. The first objective is the intrastate temperature objective. This objective applies to all waters of the state.

The intrastate temperature objective is a narrative objective with associated numeric criteria and reads:

> The natural receiving water temperature of intrastate waters shall not be altered unless it can be demonstrated to the satisfaction of the Regional Water Board that such alteration in temperature does not adversely affect beneficial uses.
>
> At no time or place shall the temperature of any COLD water be increased by more than 5°F above natural receiving water temperature.
>
> At no time or place shall the temperature of WARM intrastate waters be increased more than 5°F above natural receiving water temperatures.

The second water quality objective for temperature is the interstate temperature objective contained in the state wide *Water Quality Control Plan for Control of Temperature In the Coastal and Interstate Waters and Enclosed Bays and Estuaries of California* (Thermal Plan). The Thermal Plan, as adopted by the State Water Board, is incorporated by reference in the Basin Plan (see Appendix 3 of the Basin Plan). The plan designates the

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[3] The Klamath River downstream of the Trinity River is also on the 303(d) list for Sedimentation/Siltation, and Copco and Iron Gate Reservoirs are on the 303(d) list for the microcystin toxin.

Klamath River as a "Cold Interstate Water". The "Cold Interstate Waters" objective is as follows:

> Elevated temperature waste discharges into cold interstate waters are prohibited.

"Elevated Temperature Waste" is defined as:

> Liquid, solid, or gaseous material including thermal waste discharged at a temperature higher than the natural temperature of receiving water. Irrigation return water is not considered elevated temperature waste for the purpose of this plan.

The interstate objective applies to waters that cross or define the state border. The interstate temperature objective augments, but does not supersede, the intrastate temperature objective.

The federal Clean Water Act (CWA) imposes a criterion for setting loads in addition to the water quality standards defined by the State. For waters impaired by temperature, CWA section 303(d)(1)(D) requires that states estimate "the total maximum daily thermal load required to assure protection and propagation of a balanced, indigenous population of shellfish, fish, and wildlife."

<u>Dissolved Oxygen</u>

The Basin Plan includes two sets of DO objectives. The first set of objectives included on page 3-4.00 are minimum DO levels for various beneficial uses. These DO objectives are based on the life cycle requirements of aquatic species occupying warm water and marine habitat, as well as habitat of inland saline seas, and the life cycle requirements of aquatic species occupying cold water habitat, as well as the spawning and incubation requirements of cold water species. These are given as ambient water quality objectives applicable as instantaneous minimum requirements.

The second set of objectives is included in Basin Plan Table 3-1 of the Basin Plan and describes the background conditions in individual waterbodies as defined by grab sampling studies conducted in the 1950s and 1960s. In the existing Basin Plan (Regional Water Board 2007) the Site Specific Objectives (SSOs) contained in Table 3-1 supersede the life cycle requirements for those waterbodies listed in Table 3-1 with SSOs DO.

For the Klamath River, numeric objectives are assigned in Table 3-1 of the Basin Plan for the following hydrologic areas: 1) upstream of the Iron Gate Dam, 2) downstream of Iron Gate Dam, 3) on tributaries of the Middle Klamath River, and 4) on tributaries of the Lower Klamath River. The Klamath River DO impairment applies only to the mainstem of the Klamath River.

Upstream of the Iron Gate Dam, the instantaneous minimum concentration of DO required is 7.0 mg/L. Half of the monthly mean DO values for the year must be 10.0 mg/L or greater.

Downstream of the Iron Gate Dam, the instantaneous minimum concentration of DO required is 8.0 mg/L. Half of the monthly mean DO values for the year must also be 10.0 mg/L or greater.

Staff has assessed the Basin Plan Table 3-1 DO objectives for the Klamath River, and determines that revised SSOs DO for the Klamath River are warranted and appropriate. Staff proposes the adoption of Basin Plan language in which the Table 3-1 DO objectives for the mainstem Klamath River are eliminated and replaced by percent DO saturation criteria based on natural receiving water temperatures.

Proposed Basin Plan language is as follows:

Table 3.1a[1]

Location[2]	**Percent DO saturation based on natural receiving water temperatures3**	**Time period**
Stateline to the Scott River	90%	October 1 through March 31
	85%	April 1 through September 30
Scott River to Hoopa	90%	Year round
Downstream of Hoopa-California boundary to Turwar	85%	June 1 through August 31
	90%	September 1 through May 31
Upper and Middle Estuary	80%	August 1 through August 31
	85%	September 1 through October 31 and June 1 through July 31
	90%	November 1 through May 31
Lower Estuary	For the protection of estuarine habitat (EST), the dissolved oxygen content of the lower estuary shall not be depressed to levels adversely affecting beneficial uses as a result of controllable water quality factors.	

[1] States may establish site specific objectives equal to natural background (USEPA, 1986. Ambient Water Quality Criteria for Dissolved Oxygen, EPA 440/5-86-033; USEPA Memo from Tudor T. Davies, Director of Office of Science and Technology, USEPA Washington, D.C. dated November 5, 1997). For aquatic life uses, where the natural background condition for a specific parameter is documented, by definition that condition is sufficient to support the level of aquatic life expected to occur naturally at the site absent any interference by humans (Davies, 1997). These DO objectives are derived from the natural conditions baseline scenario (T1BSR) run of the Klamath TMDL model and described in Appendix 7 - *Modeling Scenarios: Klamath River Model for TMDL Development.*

[2] These objectives apply to the maximum extent allowed by law. To the extent that the State lacks jurisdiction, the Site Specific Dissolved Oxygen Objectives for the Mainstem Klamath River are extended as a recommendation to the applicable regulatory authority.

[3] Corresponding DO concentrations are calculated as daily minima, based on site-specific barometric pressure, site-specific salinity, and natural receiving water temperatures as estimated by the natural conditions baseline scenario of the Klamath TMDL model and described in Appendix 7 - Modeling Scenarios: Klamath River Model for TMDL Development. The estimates of natural receiving water temperatures used in these calculations may be updated as new data or method(s) become available. After opportunity for public comment, any update or improvements to the estimate of natural receiving water temperature must be reviewed and approved by Executive Officer before being used for this purpose.

Appendix 1 (*Proposed Site-Specific Dissolved Oxygen Objectives for the Klamath River in California* [Mangelsdorf 2009]) presents Regional Water Board staff's scientific justification for the selection of this proposed site-specific DO objective for the Klamath River in California.

Nutrients

The nutrient objective is a narrative objective for controlling biostimulatory substances. Biostimulatory substances include nitrogen and phosphorus. The objective reads:

> Waters shall not contain biostimulatory substances in concentrations that promote aquatic growths to the extent that such growths cause nuisance or adversely affect beneficial uses.

Nutrient-Related Water Quality Objectives

The cycling of nutrients in an aquatic environment is strongly influenced by several factors. Depending on these factors, there is the potential for impacts to beneficial uses from secondary indicators of biostimulation such as algal biomass, chlorophyll-a, DO, and pH.

The Basin Plan does not contain numeric water quality objectives for algal biomass or chlorophyll-a. The Basin Plan does contain a set of numeric objectives for pH in the

Klamath River. Minimum pH levels shall not drop below 7.0 and maximum pH shall not be raised above 8.5.

Other impacts closely related to excessive nutrient inputs, but qualitatively different are ammonia toxicity and microcystin[4] toxicity. The Basin Plan does not include numeric objectives for ammonia toxicity or microcystin.

The Basin Plan includes a narrative objective for toxicity that reads:

> All waters shall be maintained free of toxic substances in concentrations that are toxic to, or that produce detrimental physiological responses in human, plant, animal, or aquatic life.

2.2.1.3 Antidegradation Policies

There are two applicable antidegradation policies pertinent to water quality in the North Coast Region – a state policy and a federal policy. The state antidegradation policy is titled the *Statement of Policy with Respect to Maintaining High Quality Waters in California* and is commonly known as "Resolution 68-16." The federal antidegradation policy is found at 40 CFR section 131.12. Both policies are incorporated in the Basin Plan for the North Coast Region. Although there are some differences in the state and federal policies, both require that whenever surface waters are of higher quality than

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[4] Microcystin is a toxin produced by a species of blue-green algae.

necessary to protect the designated beneficial uses, such existing quality shall be maintained unless otherwise provided by the policies.

The state antidegradation policy applies to groundwater and surface water whose quality meets or exceeds water quality objectives, which may limit its direct applicability in impaired waterbodies. The state policy establishes a two-step process to determine if discharges that will degrade water quality are allowed. The federal antidegradation policy applies to both surface waters that meet or exceed water quality objectives, and those that do not meet the applicable water quality objectives (i.e., impaired waters). Under the federal policy, an activity or discharge would be prohibited if the activity would lower the quality of surface water including where that surface water currently does not meet water quality standards (i.e., the water quality is not sufficient to support designated beneficial uses) with limited exceptions set forth in federal regulations.

2.2.1.4 Program of Implementation

Chapter 4 of the Basin Plan describes the program of implementation by which the beneficial uses and water quality objectives are applied and enforced. This chapter includes all the prohibitions, schedules of compliance, action plans, policies, and guidelines adopted by the Regional Water Board for that purpose.

Chapter 6 of this TMDL staff report describes the proposed Implementation Plan for the TMDL, and will serve as the basis for the for the Klamath River TMDL Action Plan to be considered by the Regional Water Board as an amendment to Chapter 4 of the Basin Plan.

2.2.2 Tribal Water Quality Standards

The four Tribes in California with land along the mainstem Klamath River are the Hoopa Valley Tribe, the Karuk Tribe, the Resighini Rancheria, and the Yurok Tribe. As stated earlier, only the Hoopa Valley Tribe's water quality standards have been approved by the USEPA at this time. The water quality standards developed by the Yurok and Karuk Tribes and Resighini Rancheria will be used as guidance in developing the TMDL as appropriate.

2.2.2.1 Hoopa Valley Tribe Beneficial Uses

The *Water Quality Control Plan for the Hoopa Valley Indian Reservation* (Hoopa Valley Tribal Environmental Protection Agency [HVTEPA] 2008) identifies nine existing (E), four potential (P), and one historical (H) beneficial uses of water within their jurisdictional reach of the Klamath River. Figure 1.2 identifies the location and boundaries of the Hoopa Valley Indian Reservation, as well as the Yurok Indian Reservation.

- AGR—Agricultural supply(P)
- COLD—Cold freshwater habitat(E)
- CUL—Ceremonial and Cultural Water Use(H)
- GWR—Groundwater recharge(E)
- IND—Industrial service supply(P)
- MGR—Fish Migration(E)
- MUN—Municipal and domestic supply(P)
- PROC—Industrial process supply(P)

- REC1—Water contact recreation(E)
- REC2—Non-contact water recreation(E)
- SPWN—Spawning, reproduction,
- and/or early development(E)
- T&E— Preservation of Threatened and Endangered Species(E)
- W&S—Wild and Scenic(E)
- WILD—Wildlife habitat
- and Endangered Species(E)

2.2.2.2 Hoopa Valley Tribe Water Quality Criteria

The Hoopa Valley Tribe has established DO and nutrients criteria for the Klamath River as described below. The Tribe has not developed temperature criteria for the Klamath River.

Dissolved Oxygen

The existing dissolved oxygen (DO) criterion consists of a 7-day moving average of the daily minimum DO concentrations.

In areas of the Klamath River designated as COLD (year-round), the 7-day moving average of the daily minimum DO concentration required in the water column must be 8.0 mg/L or greater. Areas of the Klamath River designated as SPWN (whenever spawning occurs, has occurred in the past or has potential to occur) must have a 7-day moving average of the daily minimum DO concentration in the water column of the Klamath River of 11.0 mg/L or greater. The intragravel 7-day moving average of the daily minimum DO concentration required in the Klamath River areas designated as SPWN (whenever spawning occurs, has occurred in the past or has potential to occur) must be 8.0 mg/L or greater. In the event that these 7-day moving averages of the daily minimum DO standards "are not achievable due to natural conditions, then the COLD and SPWN standard shall instead be DO concentrations equivalent to 90% saturation under natural receiving water temperatures." This later element is contained in the Hoopa Water Quality Control Plan but has not been approved by USEPA. USEPA requires that a method for determining that the DO objectives are not achievable due to natural conditions be developed and presented. Staff believe the *Klamath TMDL model* as described in this staff report provides the tool necessary to establish natural conditions for comparison to DO objectives.

Nutrients

Nutrient criteria consist of several narrative criteria for controlling biostimulatory substances, nitrate and nitrite levels, and phosphate levels. Additionally, there are numeric objectives for nitrate, total nitrogen, ammonia, and total phosphorus.

The narrative criteria for biostimulatory substances reads:

> Waters shall not contain bio-stimulatory substances in concentrations that promote aquatic growths to the extent that such growths cause nuisance or adversely affect beneficial uses.

The narrative criteria for nitrates applies to all waterbodies except those designated as municipal or domestic supply (which have their own numeric criteria) and reads:

> …levels of nitrate shall not be increased by human related activity above the levels consistent with preservation of the specified beneficial uses.

The narrative criteria for nitrites reads:

> Levels of nitrites shall not be increased, in any body of water, by human related activity above the levels consistent with preservation of the specified beneficial use corresponding to that water body.

The narrative criteria for phosphates reads:

> In order to preserve the existing quality of water within the reservation boundaries from existing and to avoid potential eutrophication of phosphorous in any water body shall not be increased by human related activity above levels consistent with preservation of the specified beneficial uses. <sic>

Numeric nutrient criteria for the Hoopa Valley Tribe reaches of the Klamath River are displayed below in Table 2.1. "If total nitrogen and total phosphorus standards are not achievable due to natural conditions, then the standards shall instead be the natural conditions for total nitrogen and total phosphorus (HVTEPA 2008, p.53)." As stated in a footnote within the Hoopa's Basin Plan, "Through consultation, the ongoing TMDL process for the Klamath River is expected to further define these natural conditions (HVTEPA 2008, p.53)."

Table 2.1: Hoopa Valley Tribe numeric nutrient criteria

	Nitrate (mg/L)	**Total N (mg/L)**[1]	**Ammonia (mgN/L)**	**Total P (mg/L)**[1]
All Streams	-	0.2	-[2]	0.035
Domestic/Municipal supply	10	-	-	-

Source: HVTEPA 2008
[1] 30-day mean of at least two samples per 30-day period.
[2] Maximum one-hour and 30-day average concentrations linked to pH by a formula. Formula can be found in HVTEPA 2008.

Nutrient-Related Water Quality Criteria

In addition to the above narrative and numeric criteria for nutrients, the *Water Quality Control Plan for the Hoopa Valley Indian Reservation* contains narrative criteria for toxicity and Cyanobacterial scums, as well as numeric criteria for parameters which are closely related to excessive nutrient inputs and influence toxicity.

The toxicity narrative reads:

> All waters shall be maintained free of toxic substances in concentrations that produce detrimental physiological responses in human, plant, animal or aquatic life.

The Cyanobacterial scums narrative reads:

> There shall be no presence of cyanobacterial scums.

Table 2.2 displays numeric criteria for algal biomass, pH, blue-green algae, and Microcystin.

Table 2.2: Hoopa Valley Tribe numeric nutrient and toxicity related criteria

	Periphyton	**Hydrogen Ion (pH)**		**Total Potentially Toxinogenic BGA Species**[1]	***Microcystis aeruginosa* and Microcystin**			
	Max annual periphyton mg chl-a per m²	**Max**	**Min**	**Recreation Water**	**Drinking Water**		**Recreation Water**	
				cells/mL	**cells/mL**	**Microcystin (µg/L)**	**cells/mL**	**Microcystin (µg/L)**
All Streams	150	8.5	7.0	<100,000	<5000	<1	<40,000	<8

Source: HVTEPA 2008
[1] Includes: *Anabaena, Microcystis, Planktothrix, Nostoc, Coelosphaerium, Anabaenopsis, Aphanizomenon, Gloeotrichia,* and *Oscillatoria*.

2.2.2.3 Karuk Tribe, Resighini Rancheria, and Yurok Tribe Beneficial Uses

The Karuk Tribe[5], Resighini Rancheria[6], and Yurok Tribe[7], have identified the following existing, potential, and historical beneficial uses within their respective reaches of the Klamath River:

- AGR—Agricultural Supply [6, 7, 8]
- ASQ—Aesthetic Quality [6]
- BIOL—Preservation of Areas of Special Biological Significance[6, 7]
- COL/COLD—Cold Freshwater Habitat [6, 7, 8]
- COMM—Commercial and Sport Fishing [8]
- CUL—Cultural [7,8]
- CUL-1—Cultural Contact Water [6]
- CUL-2—Cultural Non-Contact Water [6]
- EST—Estuarine Habitat [8]
- FC—Fish Consumption [6]
- FRSH—Freshwater Replenishment [6, 8]
- GW—Groundwater Recharge [6, 7, 8]
- IND—Industrial Service Supply[7]
- LIV—Livestock Watering [6]
- MGR/MIGR—Migration of Aquatic Organisms [6, 8]
- MGR—Fish Migration [7]
- MUN—Municipal and Domestic Supply [7, 8]
- NAV—Navigation [6, 8]
- PROC—Industrial Process Supply [7]
- PWR/POW—Hydropower Generation [7, 8]
- RARE/T&E—Rare, Threatened, or Endangered Species [6, 7, 8]
- REC-1—Water Contact Recreation [6, 7, 8]
- REC-2—Non-Contact Water Recreation [6, 7, 8]
- SPAWN—Fish Spawning [7]
- SPN/SPWN—Spawning, Reproduction, and/or Early Development [6, 8]
- WARM—Warm Freshwater Habitat[8]
- WLD/WILD—Wildlife [6, 7, 8]

[5] Beneficial Uses designated by the Karuk Tribe
[6] Beneficial Uses designated by the Resighini Rancheria
[7] Beneficial Uses Designated by the Yurok Tribe

2.2.2.4 Karuk Tribe, Resighini Rancheria, and Yurok Tribe, Water Quality Objectives and Criteria

The Karuk and Yurok Tribes have established narrative water quality objectives for temperature, DO and nutrients. Additionally, the Tribes have created narrative objectives for toxicity and pH. The Resighini Rancheria has established narrative water quality criteria for temperature and nutrients, as well as toxicity. These narrative water quality standards are quoted in Table 2.3.

Table 2.3: Karuk Tribe, Resighini Rancheria, and Yurok Tribe narrative objectives and criteria for the Klamath River in California

KARUK	
Objective	**Description**
Temperature	The natural receiving water temperature of intratribal waters shall not be altered unless it can be demonstrated to the satisfaction of the Department of Natural Resources that such alteration in temperature does not adversely affect beneficial uses. At no time or place shall the temperature of any cold freshwater habitat (COLD) water be increased by more than 5 degrees F above natural receiving water temperature.
Dissolved Oxygen	Dissolved Oxygen Concentrations shall not at any time be depressed more than 10 percent from that which occurs naturally.
Nutrients	Biostimulatory Substances: Waters shall not contain biostimulatory substances in concentrations that promote aquatic growths to the extent that such growths cause nuisance or adversely affect beneficial uses.
Toxicity	All waters shall be maintained free of toxic substances in concentrations that are toxic to, or that produce detrimental physiological responses in human, plant, animal or aquatic life. Where appropriate, additional numerical receiving water standards for specific toxicants will be established as sufficient data become available, and source control of toxic substances will be encouraged.
pH	Changes in normal ambient pH levels shall not exceed 0.5 units within the range specified in fresh waters with designated COLD or WARM beneficial uses.
RESIGHINI RANCHERIA	
Objective	**Description**
Temperature	The natural receiving water temperature of intrastate waters shall not be altered unless it can be demonstrated to the satisfaction of the Business Council that such alteration in temperature does not adversely affect beneficial uses. At no time or place shall the temperature of any water be increased by more than 5 degrees F above natural receiving water temperature.
Nutrients	Biostimulatory Substances: Waters shall not contain biostimulatory substances in concentrations that promote aquatic growths to the extent that such growths cause nuisance or adversely affect beneficial uses.
Toxicity	All waters shall be maintained free of toxic substances in concentrations that are toxic to, or that produce detrimental physiological responses in human, plant, animal or aquatic life.
YUROK	
Objective	**Description**
Temperature	The temperature of waters within the Yurok Indian Reservation shall not be increased by human caused activity by more than 5 degrees Fahrenheit above the background level at any time or place. If a background level has not been determined, the temperature upstream of a project impacting the receiving water will be considered the background level.

Table 2.3 (cont.): Karuk Tribe, Resighini Rancheria, and Yurok Tribe narrative objectives and criteria for the Klamath River in California

YUROK (cont.)	
Objective	**Description**
Dissolved Oxygen	Dissolved oxygen concentrations shall not be altered by human caused activities that could cause a barrier to salmonid fish migration or adversely affect the water to support specified beneficial uses.
Nutrients	Ammonia: Levels of ammonia shall not be increased, in any body of water, by human related activity that could cause a nuisance or adversely affect the water to support specified beneficial uses. Biostimulatory Substances: Waters shall not contain biostimulatory substances in concentrations that promote aquatic growths to the extent that such growths cause nuisance or adversely affect beneficial uses. Nitrites: Levels of nitrites shall not be increased, in any body of water, by human related activity that could cause a nuisance, or adversely affect the water to support specified beneficial uses. Phosphates: Levels of phosphorous in any water body shall not be increased by human related activity above the levels that could cause a nuisance, or adversely affect the water to support specified beneficial uses.
Toxicity	All waters shall be maintained free of toxic substances in concentrations that are toxic to, or that produce detrimental physiological responses in human, plant, animal, or aquatic life.
pH	Changes related to human caused activities in normal pH levels shall not exceed 0.5 pH units.

Sources: Karuk Tribe of California 2002, Resighini Rancheria Environmental Department 2006, and Yurok Tribe Environmental Program (YTEP) 2004

In addition to the narrative criteria, the Karuk Tribe, Resighini Rancheria, and Yurok Tribe have established numeric criteria for water quality parameters including temperature, DO, nutrients, and other criteria related to nutrients and toxicity as displayed in Table 2.4, Table 2.5, and Table 2.6.

Table 2.4 Karuk Tribe numeric water quality objectives

	Temperature (°C)		**Dissolved Oxygen (mg/L)**		**Hydrogen Ion (pH)**	
	MWAT[1]	**Max**	**Min**	**50% lower limit[2]**	**Max**	**Min**
All Streams	15.5	21	-	-	8.5	7.0
Klamath River	-	-	8.0	10.0	-	-
Other Streams	-	-	7.0	9.0	-	-

Sources: Karuk Tribe of California 2002
[1] MWAT is the maximum 7-day average temperature within a given time period.
[2] 50% lower limits represent the 50 percentile values of the monthly means for a calendar year. 50% or more of the monthly means must be greater than or equal to the lower limit.

Table 2.5 Resighini Rancheria numeric water quality criteria

	Dissolved Oxygen (mg/L)	Hydrogen Ion (pH)		*Microcystis aeruginosa* and Microcystin			
				Drinking Water		Recreation Water	
	7-DAMin[1]	Max	Min	cells/mL	Microcystin (µg/L)	cells/mL	Microcystin (µg/L)
COLD water column	8.0	-	-	<5000	<1	<50,000	<10
SPAWN intergravel	8.0	8.5	7.0	-		-	
SPAWN water column	11.0	8.5	6.5	-		-	

Source: Resighini Rancheria Environmental Department 2006
[1] 7-DAMin is the minimum 7-day average dissolved oxygen concentration within a given time period.

Table 2.6: Yurok Tribe numeric water quality objectives

	Temperature (°C)		Dissolved Oxygen (mg/L)		Nutrients		Hydrogen Ion (pH)	
	MWAT[1]	Max	Min	50% lower limit[2]	Nitrate (mg/L)	Ammonia (mgN/L)	Max	Min
All Streams	15.5	21.0	7.0	9.0	-	-[3]	8.5	6.5
Domestic/Municipal supply	-	-	-	-	10	-	-	-

Source: Yurok Tribe Environmental Program (YTEP) 2004
[1] MWAT is the maximum 7-day average temperature within a given time period.
[2]50% lower limits represent the 50 percentile values of the monthly means for a calendar year. 50% or more of the monthly means must be greater than or equal to the lower limit.
[3] Maximum one-hour and 30-day average concentrations linked to pH by a formula. Formula can be found in YTEP 2004.

2.3 Numeric Targets for the Klamath River basin TMDLs

Numeric targets are the numeric water quality conditions that represent attainment of the applicable water quality objectives for a TMDL. In some cases numeric targets can equal a numeric water quality objective. In other cases, numeric targets are a numeric interpretation of the conditions that meet a narrative water quality objective. In all cases numeric targets are used in the calculation of a TMDL. Presented here are the numeric targets applied in the development of these Klamath River TMDLs.

The Regional Water Board considers several factors in selecting the appropriate numeric target values for the selected indicators. The most important factor is to select indicator values that will provide supporting conditions for the most sensitive beneficial uses. Another consideration is ensuring that the target values for the selected indicator(s) are consistent with the desired trophic status of the waterbody, and that the desired trophic status is appropriate for the waterbody. Although trophic classification is a tool to simply characterize the factors that define the productivity of a waterbody, often values defining thresholds between various trophic states (e.g., mesotrophic, eutrophic, or hypereutrophic) are based on ranges. Moreover, systems can be either more or less productive even within a trophic state. Thus, the Regional Water Board considered the following information regarding the trophic status conditions within the Klamath basin in selecting numeric values for selected indicators.

In the case of Upper Klamath Lake (UKL), the transition from a naturally productive condition to its current productivity condition dominated by near-monocultures of *Aphanizomenon* (Eilers et al. 2004) has had profound water quality implications and has resulted in impairment of beneficial uses within the UKL and in downstream waters. As described by Eilers et al. (2004), there have been clear shifts in UKL sediment and nutrient accumulation and species composition in the past 100 years, consistent with large scale land disturbance activities. In addition, this issue has been previously addressed in the technical report from the Upper Klamath Lake TMDL (ODEQ 2002):

> The term eutrophic is often associated with adverse water quality condition (pollution), whereas in reality, a body of water may be both ecologically "healthy" and eutrophic. Historically UKL [Upper Klamath Lake] was a productive (eutrophic) and diverse ecosystem. It is presently a hypereutrophic system that frequently experiences such poor water quality as to be lethal to its native species (Saiki and Monda 1993). Thus statements such as UKL [Upper Klamath Lake] has always been a eutrophic system" should not be used as an excuse for inaction nor construed to mean that the system was polluted or unhealthy. The argument that it is useless to reduce nutrient loading because the lake will still be eutrophic indicates a misunderstanding of trophic level classifications. - Gearheart et al. 1995

Given that UKL is the source water for the Klamath River downstream of UKL, river productivity was also likely to be historically productive with a change to even more productive conditions as UKL began to export massive biomass of blue-green algae. That is, productivity is not fixed and can change based on environmental conditions. Reducing pollutant loading in the upper basin is critical to restoring conditions in the upper Klamath River, currently eutrophic and hypereutrophic, to a range more consistent with pre-disturbance conditions of lower productivity. In addition to the risk co-factor of excessive loading of nutrients and organic matter, another contributing factor (significant risk co-factor – see section 2.4.1) affecting the trophic balance in the Klamath River is the Klamath Hydropower Project (KHP) dams. KHP dams in California have created environmental conditions that have further shifted the trophic status of these portions of the river. The TMDL numeric targets are intended to set restoration goals that are consistent with the formerly supporting trophic status for the reaches now occupied by the reservoirs.

2.3.1 Temperature

The Klamath TMDL water temperature allocations and targets are consistent with water quality standards, which are set to protect all beneficial uses of water. Establishing load allocations and targets based on natural conditions is the best possible means of achieving a balanced indigenous population and fully complies with both state water quality standards and the Clean Water Act's requirement for thermal TMDLs. The protection of all beneficial uses ensures a balanced indigenous population of aquatic life.

The numeric temperature targets are expressed as monthly average temperatures and are calculated from the estimated natural temperature regime of the Klamath River. The approach and assumptions applied in estimating the natural temperatures and calculating the numeric targets at select compliance locations are detailed in Chapter 3. The specific numeric temperature targets for select TMDL compliance locations are presented in Chapter 5.

2.3.2 Dissolved Oxygen and Nutrient-Related

The numeric DO targets are expressed as monthly average and monthly minimum DO concentrations calculated at 85% DO saturation under natural temperatures for most of the river; 90% DO saturation from October through April upstream of the Hoopa-California boundary; and 80% DO saturation during the month of August in the Middle and Upper Estuary. The approach and assumptions applied to estimating the natural temperatures and associated DO concentrations are detailed in Chapter 3. The specific numeric DO targets for select TMDL compliance locations are presented in Chapter 5.

The DO targets are the primary target associated with the nutrient and organic matter TMDLs and associated load allocations. However, additional numeric targets are associated with these TMDLs, and are used to reflect compliance with the narrative biostimulatory substances and toxicity objectives. These additional numeric targets are set for benthic algae biomass, suspended algae chlorophyll-a, *Microcystis aeruginosa* cell density and microsystin concentration. Because the Klamath River alternates between free-flowing reaches and impounded conditions it is necessary to have algal indicators appropriate to both environments: for free-flowing reaches – benthic algal biomass; and for quiescent reaches chlorophyll-a.

2.3.2.1 <u>Benthic Algae Biomass</u>

The benthic algae biomass numeric target is 150 mg chlorophyll-a/m^2. During the summer season, dense mats of attached algae form on the rocky substrate of many reaches of the Klamath River. This vegetative mass is referred to variously in the literature as periphyton, macroalgae, macrophytes, and attached benthic algal biomass. For this assessment we have adopted the term benthic algal biomass. Because of the limited amount of benthic algae data that has been collected in the Klamath River, Regional Water Board staff used various lines of evidence to develop a numeric target for this assessment. The lines of evidence include:

- The California Nutrient Numeric Endpoints (CA NNE) framework (Tetra Tech 2006) sets a benthic algal biomass target for the boundary between Beneficial Use Risk Category II (potentially impaired) and III (presumptively impaired) for streams with a cold-water fishery use (COLD) at 150 mg chlorophyll-a/m^2, interpreted as a maximum biomass in time averaged over a reach (i.e., it does not apply to single point measurements). The CA NNE boundary target is based on a review of both regional and international studies and the recommendation of university and regional experts. The CA NNE also recommends the evaluation of other lines of evidence for each waterbody to ensure the appropriateness of this boundary condition. Because of the natural continuum of conditions from the Klamath headwaters (eutrophic) to its mouth (mesotrophic), the Regional Water Board considered other information for benthic algae biomass target determination. In addition, the analysis of diurnal water chemistry impacts, within reaches of the Klamath River where the benthic algal biomass likely exceeds the proposed target, indicates extreme DO and pH conditions that present stressful conditions to resident fish.

- A recent study sponsored by the U.S. Fish and Wildlife Service -Arcata Office on an assessment of community metabolism and associated kinetic parameters in the Klamath River (Ward and Armstrong 2009 in press) concludes that the Klamath River below Iron Gate dam is mesotrophic. The target of 150 mg chlorophyll-a/m^2, interpreted as a maximum biomass in time averaged over a reach, is consistent with mesotrophic conditions.
- The Regional Water Board and EPA Region IX sponsored a *Nutrient Numeric Endpoint Analysis for the Klamath River, CA* (Appendix 2) in 2008. The study made use of the CA NNE scoping tools (described in Chapter 3) to assess benthic algal biomass targets under both existing conditions and the natural conditions baseline scenarios (described in Chapter 3 and Appendix 7). The scoping tool predicted benthic algal biomass levels very similar to those measured in the field using average current nutrient concentrations and information about other factors (e.g., accrual period). When estimates of natural background nutrient concentrations were applied at four locations along the mainstem Klamath River below Iron Gate Dam, the scoping tool estimated reach-averaged maximum benthic algal biomass densities of 109 to 157 mg chlorophyll-a/m^2, with a mean across the four stations of 141 mg chlorophyll-a/m^2.
- The Hoopa Valley Tribe Basin Plan includes a criterion of 150 mg chlorophyll-a/m^2 for the reach of the Klamath River within the Hoopa Valley Indian Reservation.

Based on these considerations, a benthic algal biomass numeric target of 150 mg chlorophyll-a/m^2 is set for this TMDL. This is a growing season (June – September) reach-average benthic algal biomass target.

The reach average is for the summer growing season and should be measured at a minimum of three points during the growing season (e.g., June, August, September) using the protocols described in: *Standard Operating Procedures for Collecting Stream Algae Samples and Associated Physical Habitat and Chemical Data for Ambient Bioassessments in California* (Fetscher et al. 2009). Sampling locations should be in close proximity to TMDL compliance points.

2.3.2.2 <u>Suspended Algae Chlorophyll-a, *Microcystis aeruginosa*, and Microcystin Toxin</u>

In addition to the benthic algae biomass target, the following nutrient-related numeric targets are set for the Klamath River TMDLs:

- Suspended algae chlorophyll-a = 10 µg/L (as a growing season mean -May to October)
- *Microcystis aeruginosa* cell density = 20,000 cells/mL; and
- Microcystin = 4 µg/L.

Monitoring requirements to assess these targets for each reservoir with recreational uses are: a minimum of one sample per month at each of 3 near shore reservoir entry areas and 1 open water reservoir sample, collected in accordance with *Standard Operating Procedures, Environmental Sampling of Cyanobacteria for Cell Enumeration, Identification and Toxin Analysis* (June 2099) or other protocol as approved by the Regional Water Board. Interpretation of monitoring data for these targets will conform to World Health Organization guidance for low probability of adverse health effects, from the *Guidelines for Safe Recreational Water Environments* (Table 8.3), or superseding guidance. (WHO guidelines are also summarized in *Cyanobacteria in California Recreational Water Bodies*, *Blue-Green Algae Work Group of the State Water Resources Control Board, Department of Public Health, and Office of Environmental Health and Hazard Assessment* (Sept 2008).

The selection of each of these targets is discussed below.

As an indicator for the Klamath River reservoirs, chlorophyll-a is a surrogate measure of suspended algal (phytoplankton) biomass. Chlorophyll-a is a response variable to both water quality stressors (e.g., nutrients) and to impoundment conditions. High levels of suspended algae (chlorophyll-a) indicate an aquatic ecosystem subject to biostimulatory effects due to physical conditions and/or high concentrations of nutrients. Consistently high or episodic chlorophyll-a concentrations indicate the potential occurrence of algal blooms, which can be harmful to aquatic organisms (Welch and Jacoby 2004) and negatively impact several beneficial uses. Prolonged conditions of high levels of chlorophyll-a are typical of eutrophic to hyper-eutrophic water bodies.

Water quality impacts associated with high chlorophyll-a concentrations in the Klamath River reservoirs include:

- Extreme diurnal variation in DO and pH;
- Low DO conditions due to the decay of organic matter resulting from algal blooms;
- Aesthetic impacts, both visual and aroma (olfactory), due to nuisance algal blooms; and
- Increasing likelihood of dominance of toxigenic blue-green algal species at higher concentrations of chlorophyll-a.

The CA NNE framework sets a suspended algae growing season mean chlorophyll-a target of 10 µg/L as the boundary between Beneficial Use Risk Category II (potentially impaired) and Beneficial Use Risk Category III (presumptively impaired) for support of the COLD beneficial use (Tetra Tech 2006). This concentration target was selected in part due to the rapidly increasing likelihood of nuisance algal blooms when chlorophyll-a concentrations are above this concentration (Walker 1985). In addition, as chlorophyll-a levels increase above 10 µg/L, blue-green algal species tend to begin to dominate the algal species assemblage (Downing et al. 2001). That is, the likelihood of blue-green algal biomass dominance rapidly increases as chlorophyll-a concentrations move above the target threshold. With blue-green algal dominance there is an increased probability of algal toxin production under elevated biomass of various toxicogenic blue-green algae, creating a potential public risk hazard for people, livestock, and wildlife.

The chlorophyll-*a* target is primarily for the reservoir environments but also applies to quiescent waters (backwater eddies and the estuary) of the Klamath River. For reasons stated above (increased likelihood of nuisance blooms and associated toxin production), a value of 10 µg/L of chlorophyll-a provides an appropriate target for the quiescent waters of the Klamath River. Under background free-flowing conditions the target value of 10 µg/L of chlorophyll-a would be inappropriately high and unnecessary. However the presence of the reservoirs requires the development of this numeric target due to its effect on increasing suspended algal concentrations. The river upstream rarely exceeds 10 µg/L of chlorophyll- a, despite the currently eutrophic condition of the system. Monitoring data show that mean chlorophyll-a was below 10 µg/L at Shovel Creek above the reservoirs, but above 10 ug/L below the reservoirs at the Hatchery Bridge. This has most recently been illustrated for 2008 in (Table 6 and Figure 6 in Raymond 2009: *Phytoplankton Species and Abundance Observed During 2008 in the vicinity of the Klamath Hydroelectric Project.*) These results are consistent with earlier 2005-2007 data analyzed by Asarian et al (2009); see Figures 2.22, 2.23, and 2.25 below. The reservoirs as controllable factors have created conditions more susceptible to nuisance algal blooms dominated by blue-green algal species.

The CA NNE impairment boundary value of 10 µg/L of chlorophyll-a was developed from studies that included information from a large number of reservoirs from temperate climate locations (Walker 1985). Because a large amount of data has been collected at several stations along the Klamath River including Iron Gate and Copco Reservoirs, it is possible to evaluate the site-specific relationship between high concentrations of chlorophyll-a and blue-green algal dominance (Kann and Corum 2009).

Klamath River monitoring since 2005 has documented elevated levels of the blue-green algae (a.k.a. cyanobacteria) *Microcystis aeruginosa* (MSAE) and the blue-green algae toxin microcystin. Microcystins are a class of toxic chemicals produced by some strains of the blue-green algae *Microcystis aeruginosa.* Microcystins can be found associated with algal cells and are also released into waters when blue-green algal cells die or cell membranes degrade. These chemicals are a human health risk, capable of inducing skin rashes, sore throat, oral blistering, nausea, gastroenteritis, fever, and liver toxicity (World Health Organization [WHO] 2003). Microcystin toxins have also been shown to produce effects on animals including acute livestock poisoning and tumor production in fish guts and liver (de Figueiredo et al. 2004, Lehman et al. 2005, and Xie et al. 2005). Microcystin can thus potentially impair a number of beneficial uses of a waterbody.

The targets for low risk exposure to *Microcystis aeruginosa* and microsystin come from the World Health Organization (WHO) and are 20,000 cells/mL and 4 µg/L respectively (WHO 2003).

When health advisories are issued by agencies concerned that cyanotoxins are present in waterbodies at levels that may pose a health risk, they are often issued based on "guidelines" or "risk levels." These guidelines are derived from analytic thresholds and field observations, and are established by the WHO. The WHO guidelines are largely accepted by nations and territories world-wide (WHO 1999, p. 171-175; WHO 2003, pp. 149-154). The presence of extensive blue-green algal water discolorations and scum accumulations are often used as triggers to assess the relative health risk to humans and other organisms from possible cyanotoxin exposures.

The Regional Water Board has not established numeric water quality objectives for microcystin toxins. However, the Basin Plan narrative objective for toxicity does apply. There are numeric translators for the narrative criteria for both *Microcystis aeruginosa* and microcystin that can be used as the basis for an impairment assessment and to develop numeric targets for the TMDL. The primary source for numeric assessment endpoints comes from the Blue Green Algae Work Group of the State Water Board, Department of Public Health (DPH), and Office of Environmental Health and Hazard Assessment (OEHHA) (Blue Green Algae Work Group), who developed guidance that is described in *Cyanobacteria in California Recreational Water Bodies: Providing Voluntary Guidance about Harmful Algal Blooms, Their Monitoring, and Public Notification* (State Water Board 2008). From this guidance the Regional Water Board has developed the following 303(d) impaired waters listing criteria:

Tissue Listing Criteria:

For the protection of human health from tissue contaminated with microsystin:

- Composite of three or more individual samples with microcystin edible tissue concentration ≥ 26 ng/g wet weight (OEHHA 2008)

Water Column Impairment Listing Criteria:

The following values are not the TMDL target values. TMDL target values are set to protect against beneficial use impacts and were therefore set at the level of low probability of health effects. The values below are used to take action (public health posting or listing) when impairment is occurring and represent a moderate level of health effects. From grab sample or fixed station trend monitoring sites, three or more samples that exceed any of the following numeric listing criteria for the protection of human health and aquatic life:

- Microsystin concentrations ≥ 8 µg/L
- *Microcystis aeruginosa* cell densities ≥ 40,000 cells/mL
- **Or** if a waterbody is posted based on photographic documentation of surface scums containing *Microcystis aeruginosa*. The photographic record must be compiled as part of a monitoring program that has an approved Quality Assurance Program and staff that have been trained in recognizing *Microcystis aeruginosa* scums, as per the posting guidelines established by the Blue Green Algae Work Group (State Water Board 2008).

The data illustrated in Figures 2.1 through 2.6 were collected by the Yurok Environmental Program, Karuk Tribe of California, and PacifiCorp in 2005, 2006, and 2007 (Kann and Corum 2009). The relationships depicted in the figures use chlorophyll-a, which indicates total algal biomass, as a means of assessing potential health effects. Using chlorophyll-a as a public health guidance value for toxic cyanobacteria is common throughout the world and in the literature. For example, the World Health Organization (WHO) uses chlorophyll-a to assess the probability of health effects; and indicates that chlorophyll-a values of 10 µg/L or greater are associated with a moderate probability of acute health effects (Graham et al. 2009). Similarly, Lindon and Heiskary (2009) combined microcystin and chlorophyll-a classes to provide a basis for describing the risk of encountering microcystin as a function of bloom intensity (chlorophyll-a). Bingham et al. (2009) reported on a survey of toxic algal [microcystin] distribution in Florida lakes. This study also provides an analysis of the probability that microcystin concentrations will exceed WHO guidance values as a function of chlorophyll, and conclude that as chlorophyll increases the probability of encountering elevated microcystin concentrations increases. Thus, chlorophyll-a provides a reasonable and robust variable to estimate the potential risk of encountering microcystin or *Microcystis* levels that pose a risk with respect to public health. The relationships depicted in the figures are consistent with these results, and show that when chlorophyll-a is elevated in the Copco/Iron Gate systems during the months presented, the probability for chlorophyll-a to be comprised of *Microcystis* increases.

The relationship illustrated in Figure 2.1 indicates that as chlorophyll-a concentrations reach 10 µg/L and above, there is a sharp increase in *Microcystis aeruginosa* cell density above 20,000 cells/mL. That is, within the Klamath River and Iron Gate and Copco Reservoirs the dominance of toxigenic blue-green algal species rapidly increases above the CA NNE target of 10 µg/L. Figure 2.2, which uses the same data as 2.1, demonstrates that the same relationship exists between chlorophyll-a and microcystin. As chlorophyll-a concentrations exceed 10 µg/L concentrations of microcystin rapidly increase above 4 µg/L. Taken together these relationships provide site-specific support for the use of the CA NNE impairment boundary target of 10 µg/L of chlorophyll-a.

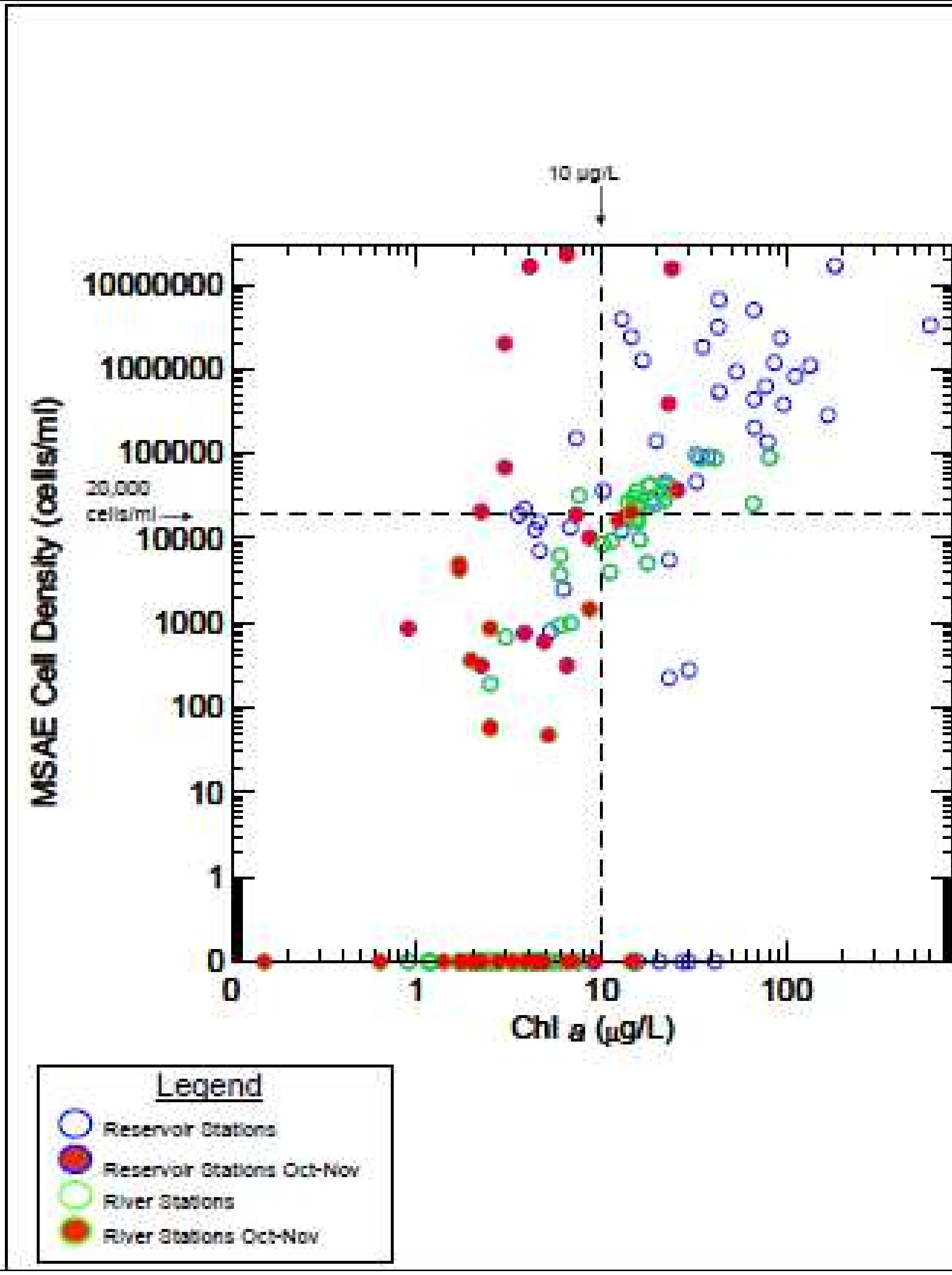

Figure 2.1: Relationship of chlorophyll-a and *Microcystis aeruginosa* (MSAE) cell density at monitoring stations along the Klamath River (2005-2007) from above Copco Reservoir to Orleans.
Source: Kann and Corum 2009

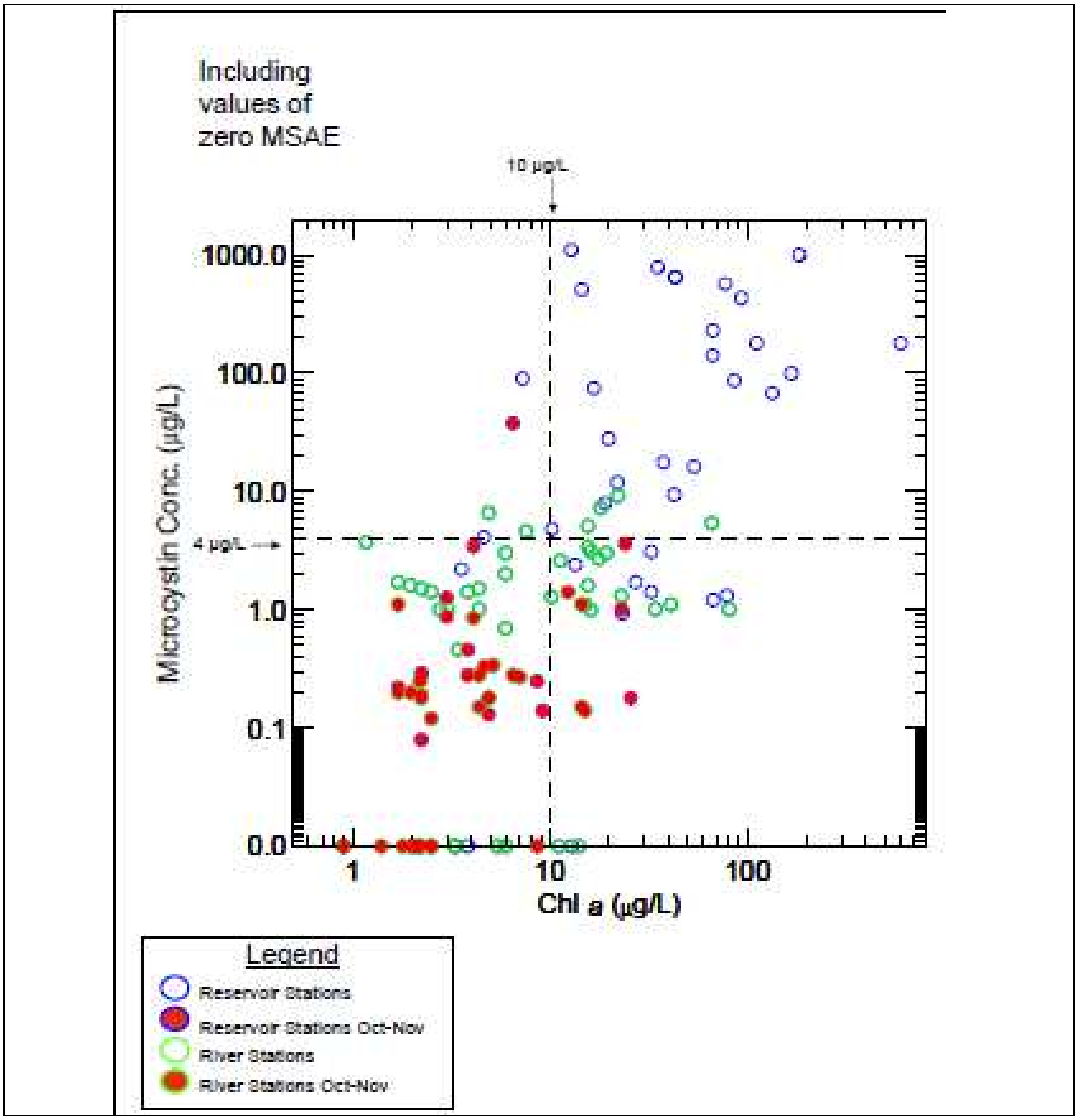

Figure 2.2: Relationship of chlorophyll-a and microcystin at monitoring stations along the Klamath River (2005-2007) from above Copco Reservoir to Orleans.
Source: Kann and Corum 2009

The probability of exceeding three critical *Microcystis aeruginosa* cell density levels at the chlorophyll-a target of 10 µg/L can be computed from nonparametric cross-tabulation probability models developed for Iron Gate and Copco Reservoirs (Kann and Corum 2009 – the computational methodology is explained in Kann and Smith 1999). The probability plots from this analysis are illustrated in Figure 2.3 using *Microcystis aeruginosa* cell density critical values of 20,000 cells/mL (red), 40,000 cells/mL (blue), and 100,000 cells/mL (green). The probability of *Microcystis aeruginosa* cell density exceeding 20,000 cells/mL (red), 40,000 cells/mL (blue), and 100,000 cells/mL (green) at a chlorophyll-a concentration of 10 µg/L (dashed line) are approximately 32%, 13%, and 10% respectively. The exceedance probabilities for the critical values increases rapidly above 10 µg/L. For Iron Gate and Copco Reservoirs the chlorophyll-a target of 10 µg/L is a reasonable threshold to protect against conditions predisposing growth of unacceptable *Microcystis aeruginosa* cell densities.

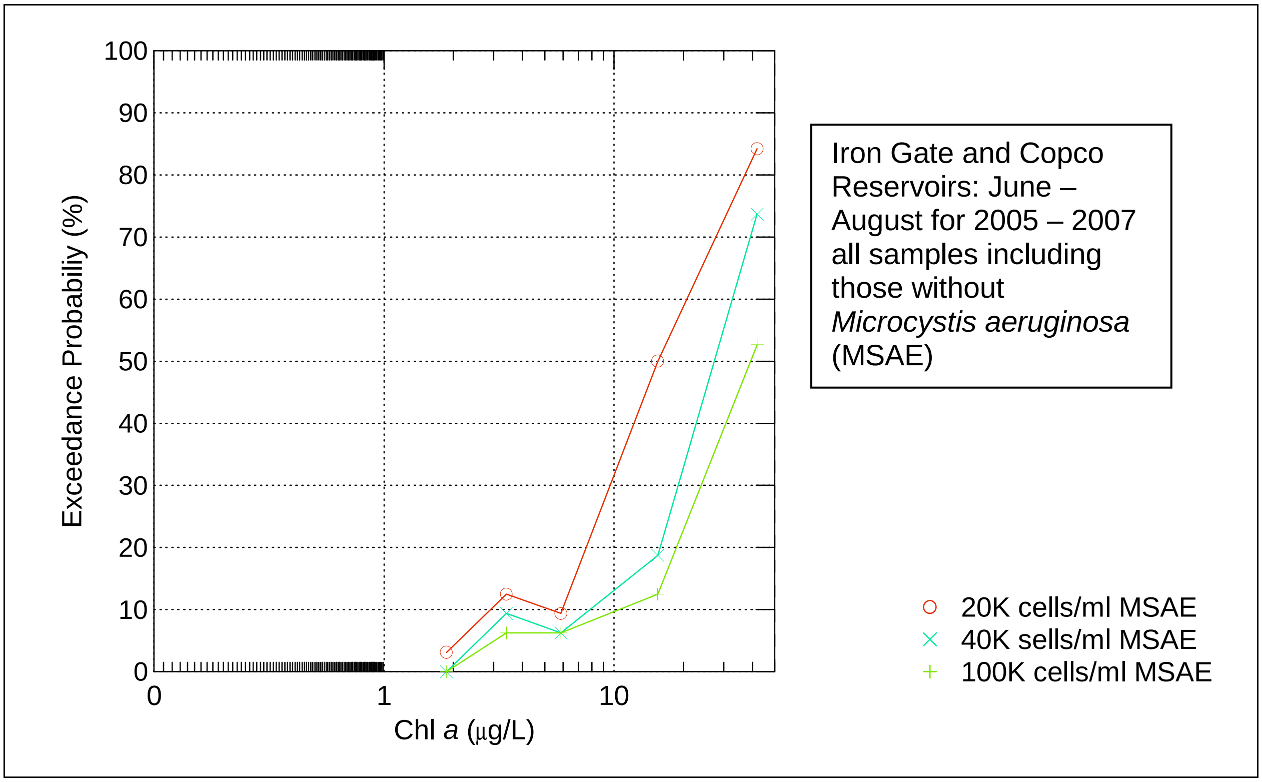

Figure 2.3: *Microcystis aeruginosa* (MSAE) cell density exceedance probability plotted as a function of chlorophyll-a concentration (10 µg/L) for Iron Gate and Copco Reservoirs using data collected by the Karuk Tribe of California for the years 2005, 2006, and 2007 during peak growing season (June – August). The probability plot includes all samples, including those with no *Microcystis aeruginosa* present.
Note: 20K = 20,000, 40K = 40,000, and 100K = 100,000
Source: Kann and Corum 2009

The same plots can be generated for the growing season (June – September) relationship between surface and/or 1 m chlorophyll-a and microcystin for Iron Gate and Copco Reservoirs for the period 2005-2007 with data collected by the Karuk Tribe of California Natural Resources Department. The probability plots from this analysis are illustrated in Figure 2.4 using microcystin concentrations critical values of 4 µg/L (red), 8 µg/L (blue), and 20 µg/L (green). The probabilities of microcystin concentrations exceeding the critical values of 4 µg/L (red), 8 µg/L (blue), and 20 µg/L (green) at a chlorophyll-a concentration of 10 µg/L (dashed line) are approximately 24%, 15%, and 10% respectively. The exceedance probabilities for the critical values increase rapidly above 10 µg/L. For Iron Gate and Copco Reservoirs the chlorophyll-a target of 10 µg/L is a reasonable threshold to protect against conditions with unacceptable microcystin concentrations.

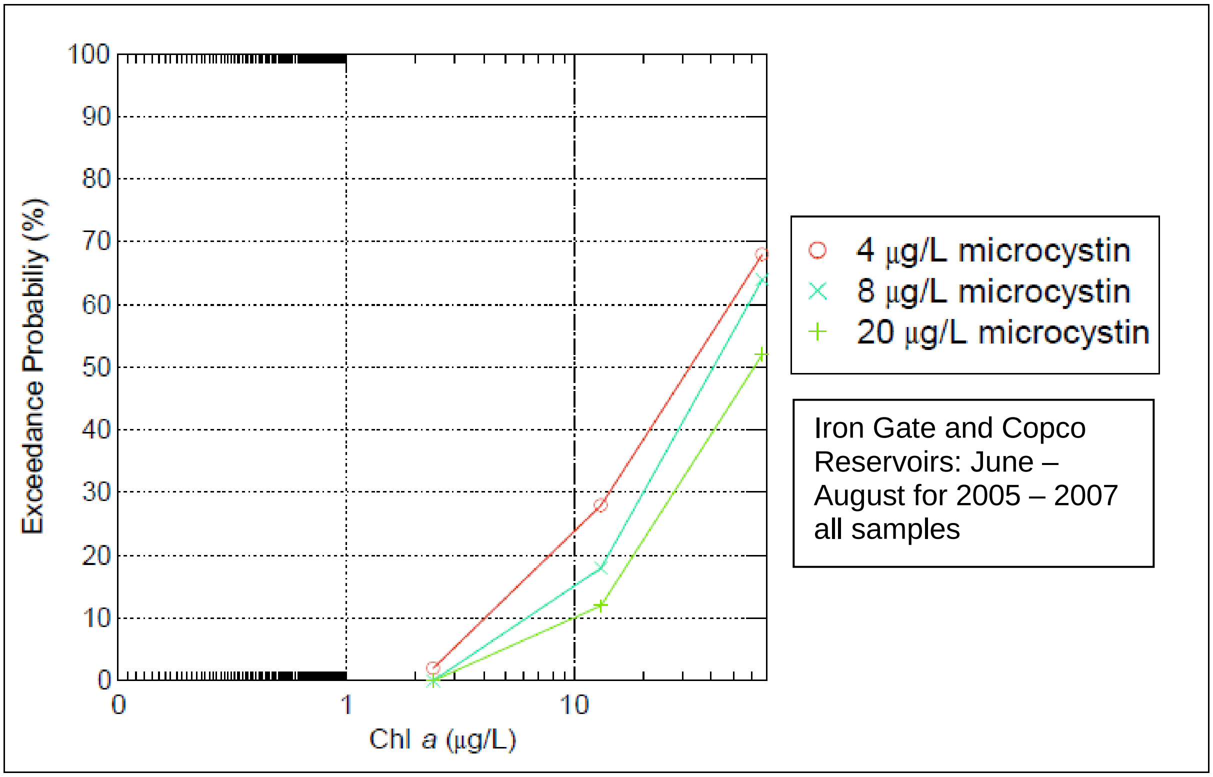

Figure 2.4: Probability of exceeding various WHO public health *Microcystis aeruginosa* (MSAE) cell density levels at varying Chl-a concentration (a), and probability of exceeding various WHO public health microcystin toxin levels at varying Chl-a concentration (b) in Copco and Iron Gate Reservoirs and the Klamath River, 2005-2007. Exceedance probability is computed using nonparametric cross-tabulation method described in Kann and Smith (1999).
Source: Kann and Corum 2009

Figure 2.5 illustrates *Microcystis aeruginosa* cell density during 2006-2007 for all stations from upper Copco through the lower estuary on the X axis with their associated microcystin concentrations on the Y axis. The measurements in the upper right hand quadrant in the chart are those measurements where cell count exceeds 20,000 cells/mL and the microcystin concentration exceeds 4 µg/L of microcystin. In regards to the relationship being evaluated, measurements in this quadrant of the graph are often referred to as true positives. The lower right hand quadrant includes those measurements that would be labeled false positives. For false positives microcystin concentrations are expected to be higher than the threshold criteria of 4 µg/L because they are associated with observed *Microcystis aeruginosa* cell densities above the threshold criteria of 20,000 cells/mL. False positives (samples in the lower right hand quadrant) with concentrations below 4 µg/L **do not** represent a risk to public health.

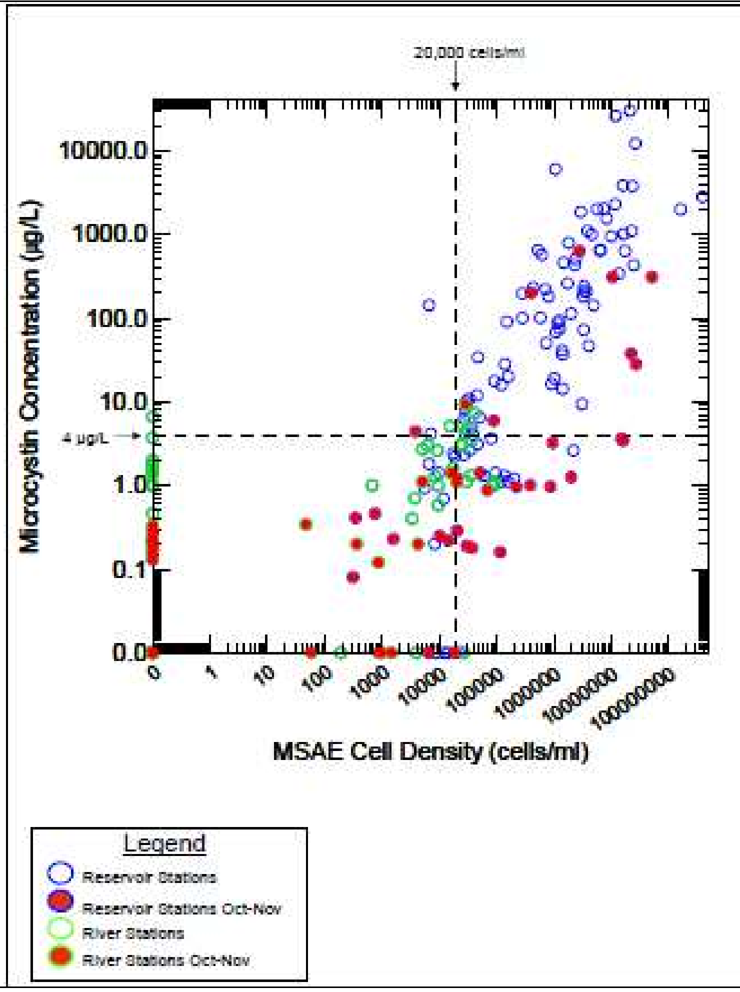

Figure 2.5: Relationship of *Microcystis aeruginosa* (MSAE) cell density and microcystin concentrations for stations along the Klamath River from above Copco Reservoir to the lower Klamath River estuary for the years 2006 and 2007 (Kann and Corum 2009). Data from Yurok Environmental Program, Karuk Natural Resources, and PacifiCorp.
Source: Kann and Corum 2009

The lower left hand quadrant represents the true negative results. That is, the true negative observations in the lower left quadrant have *Microcystis aeruginosa* cell densities less than 20,000 cells/mL and microcystin concentrations less than 4 µg/L. Measurements in the upper left hand quadrant are the false negative measurements. This is the quadrant that would represent the risk to public health with adoption of a numeric target of 4 µg/L of microcystin and a cell density of 20,000 cells/mL of *Microcystis aeruginosa.* False negative observations have concentrations of microcystin that exceed the threshold criteria of 4 µg/L, which is higher than would expected with a *Microcystis aeruginosa* cell density of less than 20,000 cells/mL. Because 4 µg/L of microcystin represents a WHO low effects level and given the few number of measurements in the false negative quadrant, the proposed numeric target represents a reasonable level of protection. The high level of correlation between cell count and microcystin concentration makes it possible to calculate the percent probability that a desired level of microcystin concentration will be exceeded at a particular cell density.

The probability of exceeding three critical level microcystin concentrations at a *Microcystis aeruginosa* cell density level of 20,000 cells/mL can be computed from nonparametric cross-tabulation probability models developed for Iron Gate and Copco Reservoirs (Kann and Corum 2009). The probability plots from this analysis are illustrated in Figure 2.6 using microcystin concentrations of 4, 8, and 20 µg/L as critical values. These concentrations represent WHO health effects levels of low, moderate, and high respectively. The probability of microcystin exceeding the critical values of 4 µg/L (red), 8 µg/L (light blue), and 20 µg/L (green) at a *Microcystis aeruginosa* cell density of 20,000 cells/mL (dashed line) are approximately 47%, 8%, and 0% respectively. Therefore at a cell density target of 20,000 cells/mL there is less than a 50% probability that microcystin concentrations will exceed the low health effects threshold of 4 µg/L.

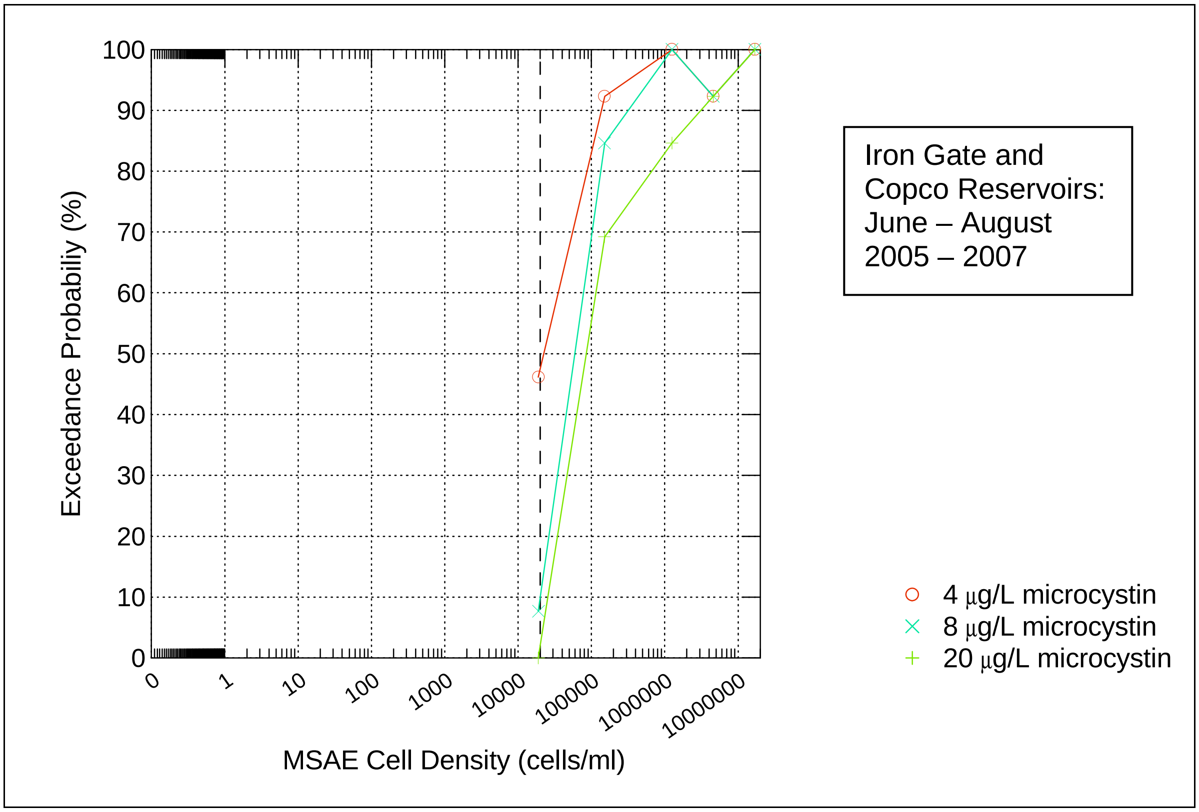

Figure 2.6: Microcystin exceedance probability plotted as a function of *Microcystis aeruginosa* cell density for Iron Gate and Copco Reservoirs using data collected by the Karuk Tribe of California Natural Resources Department and PacifiCorp for the years 2005, 2006, and 2007 during peak growing season (June – August).
Source: Kann and Corum 2009

In addition to these numeric water quality targets, monitoring targets are also identified and included in the Monitoring Plan (Chapter 7) and in Chapter 5.

The probability plots provided in Figures 2.3, 2.4, and 2.6 illustrate an increase in response variable probabilities at the recommended numeric target concentration and cell density for chlorophyll-a concentrations and Microcystis *aeruginosa* respectively. However, the probability models show exceedances of guideline levels below either the

TMDL targets or the State Water Board (2008) guidance on cyanobacteria in public recreational waters for public health. However, as noted by Kann and Corum (2009), this is because the plotted probabilities represent an interval around the median of the independent variable and thus includes values above and below any chosen value.

The probability plots are a good tool for illustrating the relationship between the independent variables (i.e., chlorophyll-a concentrations and Microcystis *aeruginosa* cell densities) and the dependent variable (microcystin concentration). However the plots require an averaging algorithm that limits an evaluation of the probability of exceedance at a specific threshold. It is possible to calculate the exceedance probability at a specific level for the independent variables. The exceedance probability for the microcystin thresholds for several specific values of the independent variables are presented in Table 2.7. The point specific evaluation demonstrates that when chlorophyll-a was less than 10 µg/L that the exceedance frequencies of the public health thresholds for *Microcystis aeruginosa* density or microcystin concentration were less than 10%.

Table 2.7: Percent exceedance for MSAE cell densities and microcystin toxin concentrations at threshold chlorophyll-a of 10 µg/L, and percent exceedance for microcystin toxin concentrations at threshold MSAE cell density of 20,000 cells/ml; Klamath River, California 2005-2007.

	MSAE cell density percent exceedance for Chl<10 µg/L			**MSAE cell density percent exceedance for Chl≥10 µg/L**		
	20,000 cells/ml	**40,000 cells/ml**	**100,000 cells/ml**	**20,000 cells/ml**	**40,000 cells/ml**	**100,000 cells/ml**
all stations all months	8.2	5.2	4.1	69.6	49.3	34.8
reservoirs only; Jun-Aug	7.1	7.1	7.1	66.7	59.3	55.6
	Microcystin conc. percent exceedance for Chl<10 µg/L			**Microcystin conc. percent exceedance for Chl≥10 µg/L**		
	4 µg/L	**8 µg/L**	**20 µg/L**	**4 µg/L**	**8 µg/L**	**20 µg/L**
all stations all months	7.4	2.9	2.9	47.4	40.4	29.8
reservoirs only; Jun-Aug	insufficient sample size			89.5	84.2	68.4
	Microcystin conc. percent exceedance for MSAE<20,000 cells/ml			**Microcystin conc. percent exceedance for MSAE≥20,000 cells/ml**		
	4 µg/L	**8 µg/L**	**20 µg/L**	**4 µg/L**	**8 µg/L**	**20 µg/L**
all stations; Jun-Sep	7.6	1.3	1.3	78.5	70.1	58.9
all stations; Jun-Aug	10.4	0.0	0.0	88.6	75.7	65.7
reservoirs only; Jun-Sep	14.3	7.1	7.1	86.7	81.1	70.0
reservoirs only; Jun-Aug	14.3	0.0	0.0	94.9	86.4	78.0
	Microcystin conc. percent exceedance for MSAE<40,000 cells/ml			**Microcystin conc. percent exceedance for MSAE≥40,000 cells/ml**		
	4 µg/L	**8 µg/L**	**20 µg/L**	**4 µg/L**	**8 µg/L**	**20 µg/L**
reservoirs only; Jun-Sep	37.5	16.7	4.2	88.8	87.5	78.8
reservoirs only; Jun-Aug	46.2	7.7	0.0	96.2	94.3	86.8

Source: Kann and Courm 2009

Likewise, when *Microcystis aeruginosa* cell density was less than 20,000 cells/ml, maximum exceedance frequencies were 14.3% and 7,1% for 4 µg/L and 8 µg/L microcystin. Frequency of exceedance for 8 µg/L microcystin when MSAE cell density was below 40,000 cells per ml was 16.7% (June-September) and 7.7% June-August (Table 2.7). The higher frequency for the computation period that includes September may be due to a tendency towards increased aqueous versus cell-bound toxin during the fall months.

The threshold analysis presented in Table 2.7 supports the numeric targets proposed by the Regional Water Board for chlorophyll-a (10 µg/L), *Microcystis aeruginosa* cell density (20,000 cells / mL), and microcystin (4 µg/L).

2.4 Water Quality Conceptual Models Overview

There are numerous overlapping physical, chemical, and biological factors that are currently contributing to impairment of water quality standards in the Klamath River. The purpose of this section is to describe these factors and discuss how they are contributing to impairment.

The challenge associated with the Klamath River TMDL problem statement is to develop a clear roadmap between the TMDL listing parameters of nutrients, temperature, and DO and their impacts on beneficial uses. There are several issues that must be addressed as part of this challenge. Nutrients and temperature often interact together and with other watershed factors to influence processes within the aquatic ecosystem that then impact ecological elements associated with Klamath River beneficial uses. With multiple factors impacting multiple ecosystem components, impacts on beneficial uses can be cumulative and involve effects from several different pathways. The Klamath River problem statement is based on a process that clearly identifies and evaluates impacts on beneficial uses from multiple concurrent stressors.

This process evaluates the likelihood that adverse ecological impacts may occur in response to one or more stressors by identifying (1) the pathways by which stressors cause ecological effects and (2) informative and representative assessment endpoints. Assessment endpoints are the link between scientifically measurable endpoints and the objectives of stakeholders and resource managers (Suter 1993). Endpoints should be ecologically relevant, related to environmental management objectives, and susceptible to stressors (USEPA 1998). For the Klamath River problem statement evaluation, nutrients and temperature are the primary stressors and separate conceptual models have been developed for each. Assessment endpoints in the conceptual models are comprised of A – Driver/Stressor, B – Environmental Conditions, D – Response/Outcome, and E – Beneficial Use (BU) Impairment. There are a total of thirty-nine assessment endpoints included in the Klamath River nutrient conceptual model, and thirty-five assessment endpoints in the temperature conceptual model. The Klamath River problem statement evaluation includes DO as a secondary indicator in the pathway analysis. The management objective for the Klamath River conceptual models is to assess conditions that are contributing to the impairment of beneficial uses designated to the Klamath River in the Basin Plan.

A conceptual model is a graphical and narrative description of the physical, chemical and biological stressors within a system, their sources, and the pathways by which they are likely to impact multiple ecological resources (Suter 1999) and contribute to beneficial use impairment. The conceptual model is important because it links exposure characteristics such as water quality conditions with the ecological endpoints important for describing the beneficial uses.

Conceptual models consist of two general components (USEPA 1998): (1) a description of the hypothesized pathways between human activities (sources of stressors), stressors, and assessment endpoints; and (2) a diagram that illustrates the relationships between human activities, stressors, and direct and indirect ecological effects on assessment endpoints. The conceptual model consolidates available information on ecological resources, stressors, and effects, and describes, in narrative and graphical form, relationships among human activities, stressors, and the effects on valued ecological resources (Suter 1999). A conceptual model provides a visual representation for the cases where multiple stressors contribute to water quality problems. With the conceptual model, some attribute or related surrogate (termed an "indicator" in both the watershed approach [USEPA 1995] and the TMDL program) provides a measurable quantity that can be used to evaluate the relationship between pollutant sources and their impact on water quality (USEPA 1999a).

2.4.1 Klamath River Nutrient and Temperature Conceptual Models

Figure 2.7 and Figure 2.8 present the nutrient and temperature conceptual models developed for the Klamath River TMDL problem statement. The components of the Klamath River nutrient and temperature conceptual models are described below.

- <u>Driver/Stressor (A)</u> – The primary risk element being evaluated (nutrients and temperature). There is one element, increased nutrient loading, included in this category for the nutrient conceptual model, and five elements in this category for the temperature conceptual model.

- <u>Environmental Conditions (B)</u> – Water quality processes directly impacted by the stressor. These conceptual model “elements” are linked to response/outcome ecosystem elements (e.g., fish populations) that are more directly linked to aspects of the beneficial use. Environmental Condition elements are secondary indicators, providing an intermediate measure (prior to primary impact) of beneficial use condition. There are 12 elements in this category for both the nutrient and the temperature conceptual models respectively.

- <u>Risk Cofactors (C)</u> – In the nutrient conceptual model, these are related conditions or stressors that affect how nutrients are processed in the ecosystem. The nutrient risk cofactors listed in category C can magnify or mitigate the negative impacts linked to nutrients as biostimulatory substances. In the temperature conceptual model, the risk cofactors are processes or factors which are affected by the environmental conditions (category B) caused by an altered

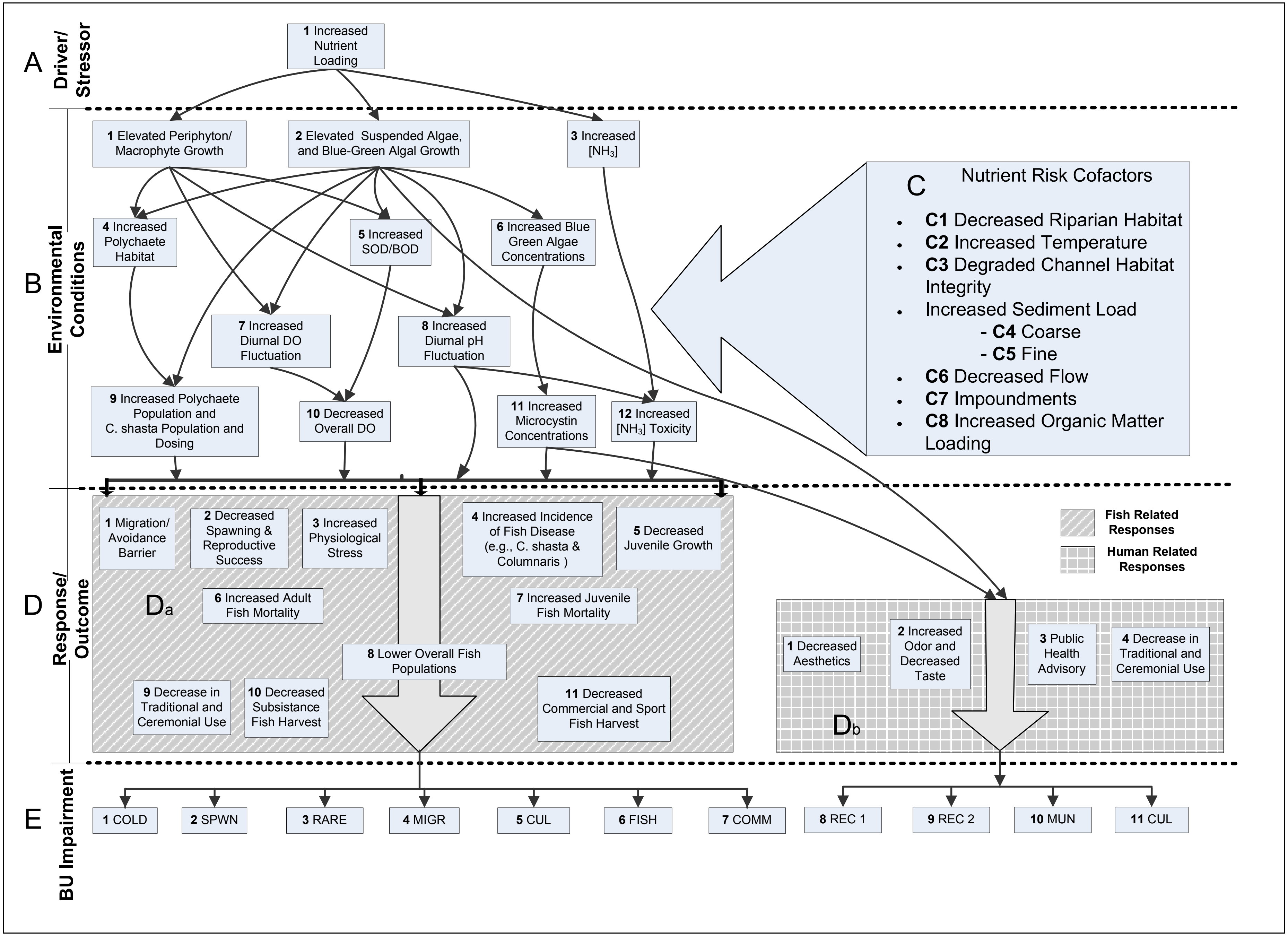

Figure 2.7: Nutrient conceptual model for the Klamath River in California

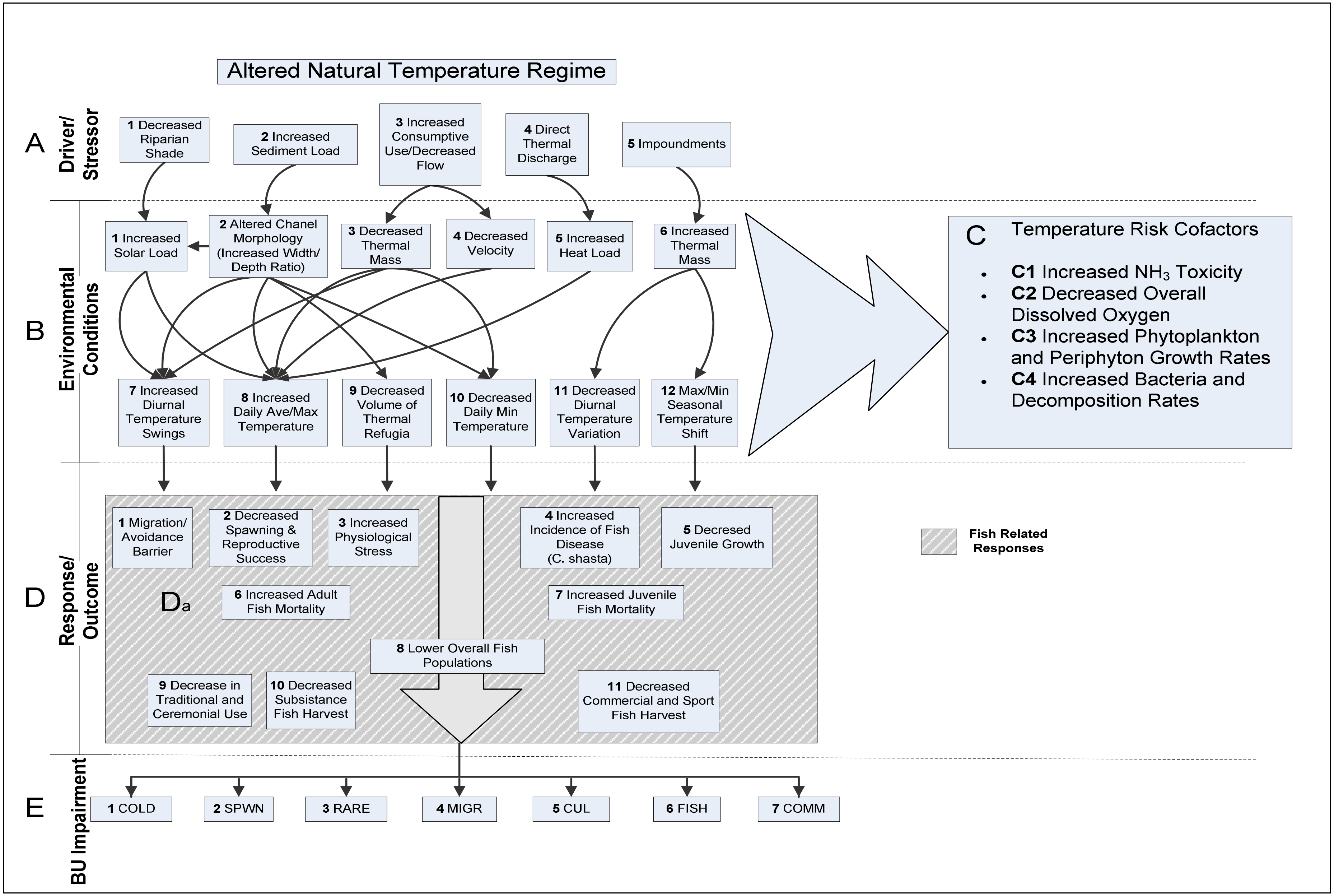

Figure 2.8: Temperature conceptual model for the Klamath River in California

natural temperature regime. There are eight nutrient risk cofactors and four temperature risk cofactors identified.

- Response/Outcome Fish and Aquatic Life (D_a) – The elements included in Category D_a involve some measure of the health of the Klamath River cold water fish populations and associated impacts to Native American culture and commercial and sport fishing. Other forms of aquatic life could be included in this category, but the cold water fish are considered most sensitive to water quality conditions resulting from increased nutrient loading and altered temperature regimes. There are 11 elements in this category for both the nutrient conceptual model and temperature conceptual models.

- Response/Outcome - Human Health and Aesthetics (D_b) – Beneficial uses linked to the human related assessment endpoints are included in category D_b. Risk related to close human contact or conditions that prohibit contact are potentially impacting long standing ceremonial practices of Tribes along the Klamath River and disruption of recreational activities. There are four assessment endpoints for this category.

- Beneficial Use Impairment (E) – Category E includes the beneficial uses that the Regional Water Board has determined to be impacted by water quality conditions in the Klamath River basin, and whose restoration will be the primary focus of the TMDL implementation plan. There are 11 beneficial uses identified as impacted in the nutrient model and seven beneficial uses identified in the temperature conceptual model.

It is not the purpose of the conceptual models developed for the Klamath River TMDL to provide a comprehensive description of all ecosystem elements and pathways. Rather the focus is on identifying assessment endpoints that either should be managed or measured as indicators of water quality condition for attaining and maintaining water quality standards in the Klamath River. The following sections describe the assessment endpoints and the linkages between the assessment endpoints that contribute to impairment of water quality standards in the Klamath River.

In the following sections, components of the nutrient conceptual model will be referenced with the letter “N”, and components of the temperature conceptual model will be referenced with the letter “T”. For example, a discussion related to the environmental condition of increased SOD/BOD from the nutrient conceptual model is referenced as “NB5”, and a discussion of the environmental condition of increased solar loading in the temperature conceptual model is referenced as “TB1”.

2.4.2 Nutrient Conceptual Model Environmental Conditions and Cofactors

The Klamath River prior to anthropogenic impacts was a highly productive ecosystem, in part driven by relatively high background loading of nutrients. More recently, anthropogenic impacts have resulted in increased levels of nutrient and organic loading and altered nutrient dynamics that have amplified the risk associated with **increased nutrient loading (NA1)** throughout the basin.

2.4.2.1 Nutrient Related Effects on Productivity

Increased nutrient loading (NA1) can result in increased primary productivity in waterbodies. Ecologically, an increase in primary production can increase the production of invertebrates and fish in streams (MacDonald et al. 1991). However, **elevated periphyton[8] and suspended algae growth (NB1, NB2)** result in high levels of algal biomass, and through algal respiration and photosynthesis can significantly **increase diurnal DO and pH swings (NB7, NB8)** and result in **decreased overall DO (NB10)** (Welch and Jacoby 2004). In their investigation of water quality conditions on the North Umpqua River, Anderson and Carpenter (1998, p.12) describe the process that occurs in rivers that have significant periphyton communities:

> Photosynthesis, a light driven process (Graham et al., 1982; Wooton and Power, 1993), consumes carbon dioxide (CO_2) and produces oxygen (Equation 1). Respiration by aquatic plants and animals, which occurs at all times, consumes oxygen and produces CO_2. Diel changes in pH are caused by shifts in the carbonate equilibrium (equation 2) as the algae utilize CO_2. (or bicarbonate, HCO3-) during photosynthesis (Wetzel 2001) faster than atmosphere inputs can equilibrate. Streams with significant periphyton communities often have supersaturated DO concentrations and high pH values late in the day and minimum DO and pH values in the early morning (for examples see Kuwabara, 1992 or Tanner and Anderson, 1996). However the solubility of DO is inversely proportional to the water temperature, which rises in response to solar radiation and thereby decreases DO solubility during daylight hours, and is also impacted by physical reaeration. In effect, stream temperature, reaeration, photosynthesis and respiration compete for control of DO and pH in streams.

Equation 1: $$6CO_2 + 6H_2O \underset{\textit{Respiration}}{\overset{\textit{Photosynthesis}}{\rightleftharpoons}} C_6H_{12}O_6 + 6O_2$$

Equation 2: $$CO_2 + H_2O \longleftrightarrow HCO_3^- + H^+ \longleftrightarrow CO_3^{2-} + 2H^+$$

The Klamath River has relatively low alkalinity (<100 mg/L) which means that it is a weakly buffered system that is susceptible to photosynthesis driven changes in pH. DO is incorporated into the Klamath River nutrient conceptual model as an assessment endpoint, and not included as a driver/stressor, because DO is an intermediate parameter that responds to the stressors. The actual concentration of DO in water depends not only

8 For the purposes of the Klamath River TMDL Problem statement the term periphyton refers primarily to plants that are attached to the substrate (mainly benthic algae). However also included are heterotrophic organisms that are also attached to stream substrate such as bacteria and other benthic macroinvertebrates.

on saturation concentration (temperature and barometric pressure dependent) but also on oxygen sinks and sources. Two of the primary oxygen sinks are **sediment oxygen demand (SOD) and biochemical oxygen demand (BOD) ($_N$B5)** of substances in the water. When organic matter, such as periphyton and suspended algae, are broken down by microorganisms in the stream this process consumes oxygen and results in **decreased DO concentrations ($_N$B10)**.

The pathways that have resulted in major documented fish mortalities in the Klamath River in the last several years are illustrated as follows: **increased nutrient loading ($_N$A1) → elevated periphyton/macrophyte growth ($_N$B1)** and **elevated suspended algae and blue-green algal growth ($_N$B2) → increased polychaete habitat ($_N$B4) → increased polychaete population and *Ceratomyxa shasta (C. shasta)* population and dosing ($_N$B9)**. This pathway is not complete without consideration of the combination of increased parasite densities with stressful water quality conditions (e.g., high temperatures, low DO) which results in an increased incidence of disease and mortality.

Ceratomyxa shasta (*C. shasta*) is thought to be indigenous to the Klamath River, and is the primary fish health issue in the Klamath River (Bartholomew et al. 2007). The lifecycle of *C. shasta* is complex because the parasite changes form and the lifecycle involves two hosts, a freshwater polychaete (worm) and a salmonid (Figure 2.9).

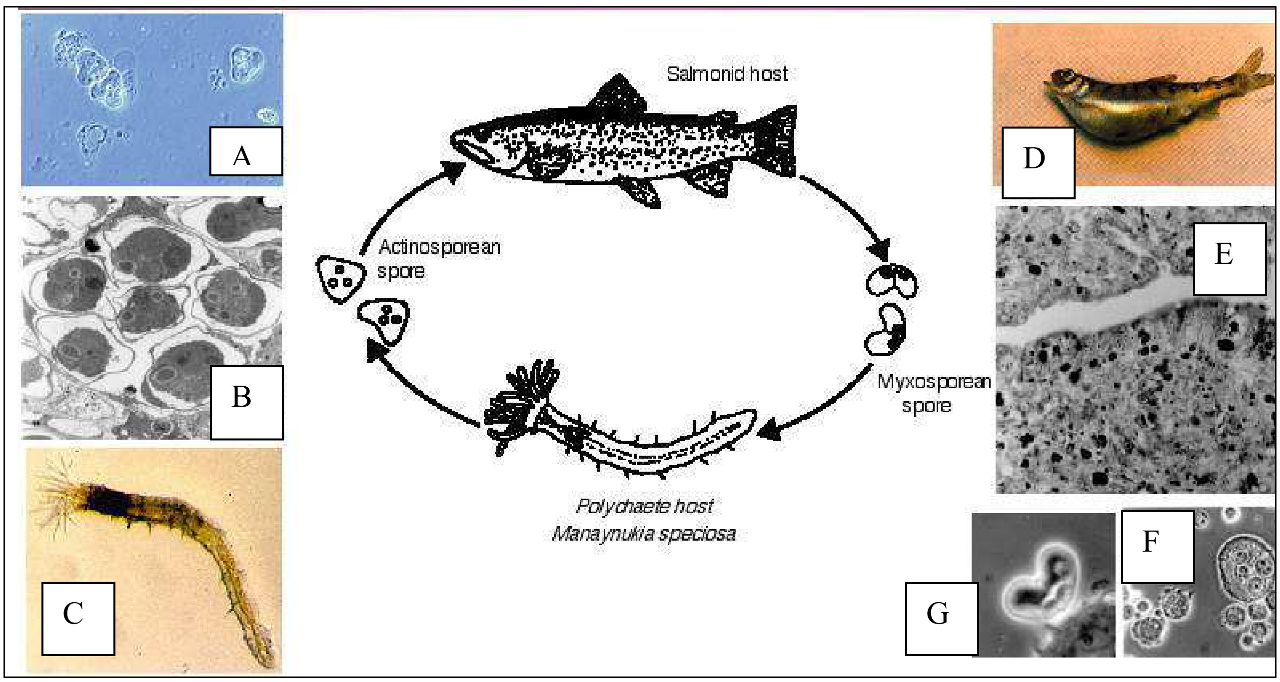

Figure 2.9: Life cycle of *C. shasta* showing release of the myxospore stage from the infected fish, the polychaete alternate host, and release of the alternate actinospore stage from the polychaete. A: released actinospores, B: electron micrograph of actinospores in the polychaete, C: polychaete, D: infected fish, E: histological section of infected intestine, F: trophozoite stages, G: myxospore
Source: Bartholomew et al. 1997 as cited by Stocking and Bartholomew 2004

One of the limiting factors for the presence of *C. shasta* appears to be the presence and abundance of the polychaete in the Klamath River (Bartholomew and Bjork 2007).

In 2003 a study by Stocking and Bartholomew (2004) found the highest densities of the polychaete living in periphyton (commonly made up of *Cladophora*). Study results from 2006 at sites located between Iron Gate Dam and Interstate-5 in California revealed that polychaete populations at habitat locations identified in 2004 and 2005 were not present in 2006, or were present in numbers too low to be considered significant (Stocking and Bartholomew 2007). According to Stocking and Bartholomew (2007), the substrate at these locations was new in 2006 and devoid of periphyton (*Cladophora)*, most likely due to scour caused by winter flushing flows. It appears that the lack of available habitat for the polychaete in 2006 led to their absence from these locations in the Klamath River.

Studies have found that the primary habitat of the polychaete also includes sand and periphyton embedded with fine particulate organic matter (FPOM) (Stocking 2006). FPOM is derived from the breakdown products of particulate organic matter, including periphyton and suspended algae.

Regional Water Board staff have consulted with Dr. Jerri Bartholomew and Mr. Richard Stocking, the principal investigators in the following studies - Bartholomew and Bjork (2007), Stocking and Bartholomew (2004), Stocking and Bartholomew (2007), and Stocking (2006) - to evaluate the presence and abundance of the polychaete that is the intermediate host for *C. Shasta* and the linkage to elevated nutrient concentrations. The conceptual model linkage is initiated with the high levels of FPOM released from the reservoirs (from upstream and within-reservoir sources) during the summer months. The FPOM is retained quite well by *Cladophora*, which grows in high densities in the river reaches below I-5, where the average river gradient decreases along with channel substrate characteristics (PacifiCorp 2004c) which are then more favorable for periphyton colonization. These high levels of FPOM appear to be a critical factor determining distribution and abundance of *M. speciosa*. According to Stocking and Bartholomew the large populations of polychaetes have been identified in the fine sediment rich inflow areas of the reservoirs, but the highest densities occur in their river samples. While the habitat is an important factor it is also likely that the populations are food limited. Published research indicates that FPOM makes up a significant portion of the Fabriciinae diet and personal observations (Stocking and Bartholomew 2007) show that *M. speciosa* (Sabellidae: Fabriciinae) is no exception. Based on discussions with Mr. Stocking the following observations support the following conceptual model linkage:

> Sparse amounts of Cladophora found near Saints Rest Bar (above the confluence with the Trinity River) possessed almost no organic matter and very low polychaete densities. Cladophora found near I-5 was saturated with FPOM and polychaetes (Stocking, 2009). Data results of numerous polychaete populations between these two locations indicate a solid trend. To the extent that project reservoirs have altered the distribution and abundance of organic matter in the Klamath River, there can be no doubt that it has also altered the abundance of C. shasta's polychaete host. (Stocking, 2009)

Based on the above information, there may be a linkage between the proliferation of *C. shasta* in the mainstem Klamath River and elevated nutrient concentrations. **Elevated nutrient concentrations (NA)** result in **increased periphyton (${}_{N}$B1) and increased suspended algae and blue-green algal growth (${}_{N}$B2)** in the river, which have been identified as prime habitat for the polychaete. **Increased habitat (${}_{N}$B4)** leads to an **increased abundance of the polychaete (NB9)**, which in turn leads to a high infectious spore load in the river. This results in a high probability that adult and juvenile salmonids migrating and rearing in the river will be infected by *C. shasta*.

An additional factor that is potentially shifting the balance toward increased parasite concentrations is the **elevated suspended algae and blue-green algal growth (NB2)** in Iron Gate Reservoir, which contributes to **increased polychaete populations (NB9)** in the mainstem Klamath River below the reservoir. The polychaetes are filter feeders and feed on fine organic detritus, as well as various forms of suspended algae. **Elevated nutrient loading (NA)** leads to prolific amounts of phytoplankton growth in the reservoir. The phytoplankton are released into the Klamath River as water flows out of Iron Gate Dam, thus creating an abundant food source for the polychaete, which may contribute to increasing their numbers (USFWS 2006).

Figure 2.10 was presented at the 2008 Klamath River Fish Health Conference to illustrate how the balance between parasite, hosts, and the environment has shifted to favor the increased abundance of parasites. There is an emerging consensus among those conducting research on these relationships in the Klamath River basin that the changes in the environmental conditions identified in the nutrient conceptual model, in association with other risk cofactors, provides a reasonable explanation of the shift to an increasing abundance of parasites (and spores) and higher levels of infection among salmonids in the Klamath River.

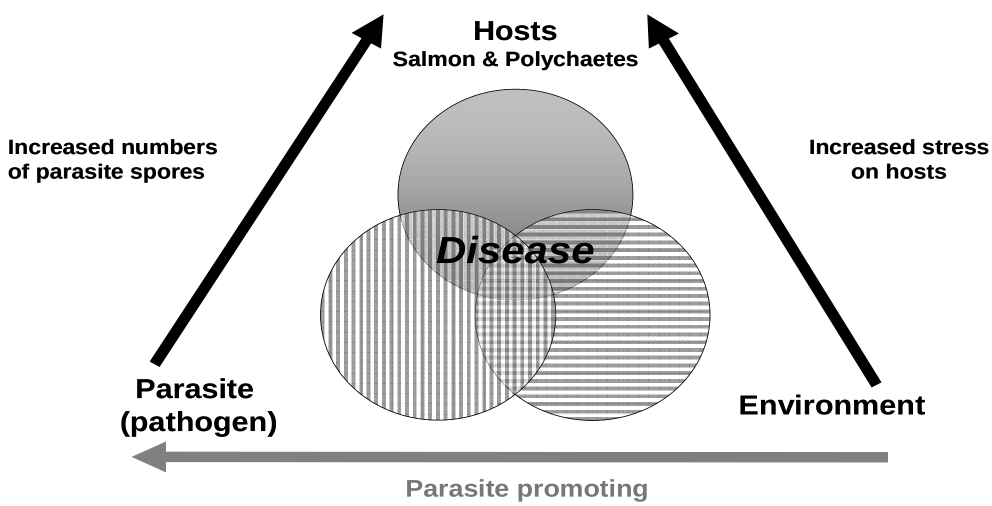

Figure 2.10: Severity of *Ceratomyxosis* in Klamath River suggests a shift in the host/parasite balance towards *C. shasta*
Source: Bartholomew personal communication 2008

The increase in the prevalence of parasite infection and related mortality is a very complex issue and it is likely that other environmental factors are also contributing to the proliferation of *C. shasta*. For example, the existing near-constant summer flow regime has eliminated extreme low flows which could cause the desiccation of the periphyton and resident polychaete populations. In addition, reduced peak flows and the elimination of small gravel from the sediment load has reduced impingement on attached periphyton reducing the amount of scouring that would normally occur, also contributing to increased periphyton densities. An example of the parasite promoting factors included in the conceptual model above is that high densities of salmonids trapped in the reach below Iron Gate lead to increased shedding of the myxosporean spore which then infects the polychaete population in the dense periphyton present downstream of the dam in the reach between Shasta and Scott Rivers. While these potential factors are not addressed explicitly in the conceptual model, they should be included in any comprehensive assessment and mitigation plan to address this issue.

In addition, the prevalence of parasite infection within the lower Klamath River downstream of Iron Gate may be due in part to the presence of the dam, which concentrates the numbers of spawners in this reach. Dense spawning redds and salmon carcasses can be found below Iron Gate Dam (Toz Soto, Karuk Tribal Fisheries Biologist, Personal Communication 2009). This observation is reinforced by U.S. Fish and Wildlife Service data (Grove 2002, as cited in FERC 2007) indicating that ~40% of the fall chinook redds observed within the 82-mile mainstem survey reach (Iron Gate Dam to Indian Creek) in 1993-2002 were located in the first 3.3 miles below Iron Gate Dam (Iron Gate to Cape Horne Creek) and another ~10% in the next 10.2 miles (Cape Horne Creek to Shasta River). There are also dense populations of the polychaete host in this same reach (Stocking and Bartholomew 2007). According to Stocking (Stocking, 2009), it appears that the prevalence of C. *shasta* in the lower Klamath River below Iron Gate may be explained by an emerging understanding of the biology of these animals (both hosts and parasite). As salmon near their spawning grounds, their immune system begins to shut down and all energy is directed towards reproduction. The parasite, *C. shasta*, takes advantage of its hosts weakened immune response and begins to proliferate within the hosts tissues in preparation for the next step in its life-cycle: infecting the polychaete host. The parasite is released from a decomposing salmon carcass, swept up in passing currents, and is deposited within a downstream population of polychaetes.

The Klamath River basin has also been subject to **excessive suspended algae and blue-green algae growth (NB2)**. Blue-green algae grow and thrive in slow-moving to stagnant waterbodies such as ponds, lakes, and low gradient river reaches that usually have high nutrient loads accompanied by adequate sunlight (Hudnell 2009, and Paerl 2008). These conditions are found in Copco and Iron Gate Reservoirs, coupled with elevated nutrient concentrations, which promote nuisance **blooms of blue-green algae (NB6)**; the most common are *Microcystis aeruginosa*, *Anabaena flos-aquae, Anabaena flos-aquae,* and *Gleotricia echinulata*.

All four of these species are capable of producing cyanotoxins; however, the strain of *Aphanizomenon flos-aquae* found in Upper Klamath Lake, and subsequently transported downstream to the Klamath River, has not yet been shown to produce any toxins (Carmichael et al. 2000; Li et al. 2000). Cyanotoxins produced by these blue-green algae include dermatotoxins (cause contact dermatitis and stomach-intestinal disorders), neurotoxins (cause nervous system poisoning), and hepatotoxins (cause liver poisoning) (WHO 1999, p. 57). **Microcystin (NB11)** is a hepatotoxin produced by *Microcystis aeruginosa*, which has been measured in Copco and Iron Gate and detected in slow moving portions of the river downstream of Iron Gate dam, as well as in Klamath River fish tissue (Fetcho 2006, Kann 2006).

2.4.2.2 Nutrient Related Effects on Ammonia Toxicity

Nutrient loading to a waterbody can contribute directly to **increased ammonia concentrations (NB12)** through the addition of nitrogen to the system. The pH of the water column influences the concentration of un-ionized ammonia (NH_3) and ammonium ion (NH_4^+). As pH increases, un-ionized ammonia concentrations increase and ammonium ion concentrations decrease. These speciation relationships are important to ammonia toxicity because un-ionized ammonia is much more toxic to aquatic species than ammonium ions (USEPA 1999b). The **increased diurnal pH (NB8)** swings result in higher pH levels in the water column, and can result in **increased ammonia toxicity (NB12)**. The analysis of the potential for ammonia toxicity in the Klamath River is described below in Section 2.5.7.

2.4.2.3 Nutrient Risk Cofactors

Generally, nutrient concentrations alone do not impair beneficial uses. Rather, in combination with other factors nutrients cause indirect impacts through aquatic plant growth, low DO, high pH, and other related impacts. Nutrients are one factor in the impairment equation that must be present with other risk cofactors to express an impairment. Each of these risk cofactors contributes to the degraded conditions that exist in the Klamath River basin today. Any watershed scale recovery plan must address the potential effect of the following nutrient risk cofactors:

- **Reduced riparian habitat (NC1)** and associated reductions in shading by vegetation increases the amount of sunlight that reaches the stream and that can, in turn, drive photosynthesis of both suspended algae and periphyton. The increased solar radiation also causes **increased temperature (NC2)** of the water column which reduces oxygen saturation potential, and accelerates SOD and BOD processes. Also, reduced riparian habitat can impede riparian functions such as filtering and uptake of pollutants in runoff. These conditions are often associated with **degraded stream bank and stream channel conditions (NC3).**

- **Degraded Channel Habitat Integrity (NC3)** through sediment filling, incidental anthropogenic channel disturbance (e.g. grazing), channelization, or diking repairs can impair natural river processes that retain or remove permanently from the water column nutrients through denitrification, growth of attached algae, and the settling of organic matter. The result of these types of impacts in the upper Klamath River basin is higher downstream nutrient loading than would have occurred historically. Bernot and Dodds (2005) describe several restoration techniques for reversion to historical channel sinuosity, channel complexity, and connectivity to riparian wetlands with the objective of restoring nitrogen retention and removal characteristics.

- **<u>Increased sediment load (NC4, NC5)</u>** includes both the fine and coarse components that can originate from different sources (e.g. roads, mass wasting debris flows), but both have similar impacts on the stream ecosystem. Increased sediment load can result in stream channel aggradation, filling in pools and deeper portions of the stream channel (i.e. thalweg), creating a shallow concave channel cross-section that facilitates accelerated growth rates of periphyton and suspended algae. The transport of sediment into the water column is also a primary mechanism for nutrient loading.

- **<u>Altered flow conditions (NC6)</u>** covers a wide range of potential flow-related impacts, including: reduced flow that is more susceptible to high temperature drivers; persistent flow during normally dry conditions reducing the effect of desiccation and thus promoting excessive macrophyte and algal growth and accrual; and, for the Klamath River below Iron Gate Dam, altered sediment transport leading to reduced impingement (impact from small gravel) on periphyton due to reduced gravel transport downstream, which can increase periphyton accrual time.

- **<u>Impoundments (NC7)</u>** are a significant nutrient risk cofactor. The effect of impoundments on nutrient dynamics in the Klamath River are discussed in Section 4.2.2.2. The Klamath River impoundments are a risk cofactor for nutrients because of multiple factors:

    - Empirical data and model predictions indicate that the Copco 1 and 2 and Iron Gate Reservoirs (impoundments) have a net annual retention of nutrients (PacifiCorp 2006; PacifiCorp 2008; PacifiCorp 2009; Appendix 2 of Staff Report, Asarian et al. 2009).
    - Impoundments spread out event-driven spikes in upstream nutrient loads (PacifiCorp 2006).
    - Iron Gate and Copco Reservoirs are capable of generating their own pulses of nutrients downstream of Iron Gate Dam during intense algae blooms (see for example September 2007 conditions in Figure 14 in Asarian et al. 2009).
    - The effect of reservoir nutrient retention on downstream water quality likely varies by reach.
    - Impoundments create an environment that is more favorable to nuisance blooms of both green and blue-green algae (Kann and Corum 2009, Paerl 2008, Welch and Jacoby 2004, Kann and Asarian 2005, Wetzel 2001).
      As described in more detail in section 2.4.2.1, the Klamath River impoundments alter habitat conditions and increase fine particulate organic matter concentrations downstream of Iron Gate Dam, which may contribute to the high density of the polychaetes below Iron Gate Reservoir (which in turn

supports high densities of the parasite *C. shasta*) (Stocking and Bartholomew 2007).

- Dams typically halt the downstream transport of gravel, resulting in more coarse substrates (Biggs 2000). FERC (2007) concluded that the Klamath Hydroelectric Project reservoirs cause streambed armoring and reduce the frequency of bed-mobilizing flows. below Iron Gate Dam.. Larger substrates like cobble and boulder require higher flows to scour them than smaller substrates like gravel and sand. These coarse substrates are more stable, increasing the amount of periphyton and aquatic macrophytes that can grow (Biggs, 2000; Anderson and Carpenter 1998). In addition, the effect of reduced gravel transport and altered flows reduces the amount of impingement which is an important element contributing to dislodging attached algae (also discussed above in altered flows).

- **Increased Organic Matter Loading (NC8)** is a risk cofactor in a direct manner by contributing additional nutrients to the Klamath system and by exacerbating stressful DO conditions through SOD and BOD. The increased loading of organic matter is also a risk cofactor in a less direct manner due to its contribution to the formation of anoxic conditions that will alter nutrient dynamics increasing the abundance of dissolved inorganic nutrients contributing to increased algal productivity.

2.4.3 Temperature Conceptual Model Environmental Conditions and Cofactors

2.4.3.1 Thermal Processes Related to Solar Loading

Direct solar radiation is the primary factor influencing stream temperatures in summer months. The energy added to a stream from solar radiation far outweighs the energy lost or gained from evaporation or convection (Beschta et al. 1987; Johnson 2004; Sinokrot and Stefan 1993). At a given location, incoming solar radiation is a function of position of the sun, which in turn is determined by latitude, day of the year, and time of day. During the summer months, when solar radiation levels are highest and streamflows are low, shade from streamside forests and vegetation can be a significant control on direct solar radiation reaching streams (Beschta et al. 1987). Because shade limits the amount of direct solar radiation reaching the water, it provides a direct control on the amount of heat energy the water receives. At a workshop convened by the state of Oregon's Independent Multidisciplinary Science Team, 21 scientists reached consensus that solar radiation is the principal energy source that causes stream heating (Independent Multidisciplinary Science Team 2000).

Shade is created by vegetation and topography; however, vegetation typically provides more shade to rivers and streams than topography. The shade provided to a water body by vegetation, especially riparian vegetation, has a dramatic, beneficial effect on stream temperatures. The removal of vegetation **decreases shade (TA1)**, which **increases solar radiation levels (TB1)**, which, in turn, **increases both average and maximum stream temperatures (TB8)**, and leads to **large daily temperature variations (TB7)**. Additionally, the removal of vegetation increases ambient air temperatures, can result in bank erosion, and can result in changes to the channel geometry to a wider and shallower stream channel, all of which also increase water temperatures.

2.4.3.2 Thermal Processes Related to Sediment Load

Increased sediment loads (TA2) and associated changes in channel morphology can affect stream temperature conditions in multiple ways. These effects can manifest at both large (watershed-wide) and small (individual reach) scales. Sediment is defined as any inorganic or organic earthen material, including but not limited to: soil, silt, sand, clay, and rock (Regional Water Board 2007). The sizes of sediment that present a temperature concern are those that may result in pool filling, increased width, decreased depth, and/or a reduction of intergravel flow.

Increases in sediment loads may **alter channel morphology (TB2)**, leading to a wider and shallower wetted channel. In a study of stream channel geometry at twelve gauging stations throughout northwest California, Lisle (1982) described channel widths increasing by as much as one hundred percent, bars becoming smaller, and pools filling in response to increases in sediment supply. Channel widening associated with increased sediment loads can also result in the destruction of riparian canopy and consequent **increases in solar loading (TB1)** by increasing shear forces on channel margins (Lisle 1982). Riparian vegetation may also be removed or buried by sediment, trees, and other debris transported in debris flows. A US Forest Service report documenting the effects of the 1997 flood on Klamath National Forest resources identified the following:

> Riparian vegetation was damaged or removed from some stream segments. Temperature increases in the summer of 1997 were documented at Elk Creek, and may have occurred in the Walker, Indian, Tompkins, Portuguese, and Ukonom Creeks, as well as the South Fork of the Salmon River. Large logs were mobilized in many streams, and re-positioned within the channels. Many of the accumulations are above the bank-full channel. Additionally, channel widening undermined large trees in lower stream reaches, causing them to topple into the channel where many remain at the present time. (De la Fuente and Elder 1998, p.6, Appendix E)

Increased Width-to-Depth Ratios

A wider and shallower channel gains and loses heat more readily than a narrow and deep channel. This principal is true for any stream. A stream's width-to-depth ratio influences stream heating processes by determining the relative proportion of the wetted perimeter in contact with the atmosphere versus the streambed. Water in contact with the streambed exchanges heat via conduction. Conductive heat exchange with the streambed has a moderating influence, reducing daily temperature fluctuations. However, wide and shallow channels have a greater surface area per unit of volume in contact with the atmosphere than a narrower, deeper channel. Water in contact with the atmosphere exchanges heat via evaporation, convection, solar radiation, and long-wave radiation. Heat exchange from solar radiation far outweighs heat exchange from evaporation, convection, and long-wave radiation, unless the stream is significantly shaded. The net effect of changes in width-to-depth ratios is that streams that are wide and shallow heat and cool faster than streams that are narrow and deep (Poole and Berman 2001).

The effects of a wider and shallower channel are similar to the effects of increased solar loading. Both changes lead **to increases in daily average and maximum temperatures (TB8)**, **increased diurnal fluctuations (TB7)**, **and may lead to decreased daily minimum temperatures (TB10).**

Decreased Hyporheic Exchange

Increased sediment loads may also reduce heat exchange associated with hyporheic processes through simplification of the bed topography and reduced permeability due to increases in fine sediment deposition. Hyporheic exchange occurs when surface waters infiltrate into the interstitial spaces of stream beds. As surface water passes through the porous sediment, heat is lost (or gained) through conduction with the sediments. In some settings, streambed conduction can be a significant heat sink that buffers daily maximum temperatures in the summer season (Loheide and Gorelick 2006).

Several published studies describe mechanisms of heat transfer dependent on permeability of bed sediments, effects of sediment on stream channel morphology, and stream channel characteristics related to thermal refugia. Vaux (1968) demonstrated that hyporheic exchange is dependent on the topographic complexity of the bed surface and permeability of the sediments. Lisle (1982) reported a simplification of streambed complexity associated with aggradation at stream gauge sites following the 1964 flood. He observed that gauging sites went from a pool-like form prior to aggradation, to a riffle-like form with flat cross-sectional profiles following aggradation. Wondzell and Swanson (1999) similarly evaluated the effects of large events on channel form. They specifically evaluated changes in the hyporheic zone resulting from large flood events and demonstrated that simplification of stream channel geometry decreases intra-gravel exchange rates. Furthermore, they suggested that loss of pool-step sequences related to channel disturbances could result in decreased intra-gravel exchange.

More recently, researchers have quantified the reduction in surface stream temperatures attributable to hyporheic exchange. In a study of Deer Creek in northern California, Tompkins (2006) found that reduced daily maximum water temperatures in hyporheic seeps on the order of 3.5 ^{o}C (6.3 ^{o}F) created thermal refugia for salmonids. In a study similar to Tomkins', Loheide and Gorelick (2006) documented daily maximum temperature reductions on the order of 2 ^{o}C (3.8 ^{o}F) in study of a 1.7 km (1.1. mi) stream reach of Cottonwood Creek in Plumas County, California.

Morphological changes associated with increased sediment loads can also eliminate or result in a **decreased volume of thermal refugia (TB9)** in a stream or river and impede access to thermal refugia provided by tributaries. Refugial volume can be reduced or eliminated when deep pools fill with sediment, when side channels are buried, or when cold tributary flows percolate into aggraded tributary deltas or gravel bars before entering the river. Similarly, access to refugial tributaries can be reduced or eliminated when sediment loads result in aggradation and cause a tributary to percolate before entering the mainstem and thus become disconnected from the mainstem or become too shallow for fish to swim. Aggradation has impacted the mouths of Hunter, Turwar, Independence, Walker, Oneil, Portuguese and Grider Creeks, as well as 14 of 17 small Lower Klamath tributaries surveyed by the Yurok Tribe (De La Fuente and Elder 1998; Kier Associates 1999). Finally, refugia can be eliminated when tributary temperatures increase beyond salmonid thresholds due to the other effects of increased sediment loads discussed above.

2.4.3.3 Thermal Processes Related to Flow

Surface water diversions (TA3) decrease the volume of water in the stream, and thereby decrease a stream's capacity to assimilate heat. When water is removed from a stream the **thermal mass (TB3)** and **velocity (TB4)** of the water is decreased. Thermal mass refers to the ability of a body to resist changes in temperature. Basically, less water heats or cools faster than more water. Decreases in velocity increase the time required to travel a given distance, and thus increases the time heating and cooling processes can act on the water. These principles are true for any stream, and work in concert with other heat exchange processes to determine the overall temperature of a stream.
The increase in the rate of heating that accompanies a decrease in the volume of flow in a stream can have significant temperature effects. A decrease in thermal mass results in **higher daily high and lower daily low temperatures (TB7, TB8, TB10)**, as well as **higher daily average temperatures (TB8)**. Reduced velocities also result in **higher daily average temperatures (TB8)**.

2.4.3.4 Thermal Processes Related to Direct Thermal Discharges

Direct thermal discharge (TA4) is the discrete addition of heat to a waterbody. Direct thermal discharges occur when water is used in a cooling process, such as in power generation or industrial settings, or when warm materials are placed in a waterbody. In the Klamath basin the main source of direct thermal discharges is related to irrigation tailwater return flows.

Flood irrigation is a common irrigation practice in parts of the Klamath basin, including the Klamath Project area and the Shasta River watershed. When irrigation water is applied to a field in this manner, it generally flows across the field as a thin sheet or in shallow rivulets. As the irrigation water runs across the ground it absorbs heat. When irrigation flows return to a stream, they carry with them the **increased heat load (TB5)** added as they pass through the irrigated lands. Regional Water Board staff deployed temperature monitoring devices at several Shasta Valley locations with irrigation return flows. Upon review of the monitoring results, it was very difficult to determine when the temperature monitoring probes were exposed to irrigation return flow versus when they were exposed to the air, indicating that the temperature of the tailwater return flows was generally at equilibrium with the air temperature. The net effect of direct thermal discharges is an **increase in both daily average and maximum temperatures (TB8)**.

2.4.3.5 Thermal Processes Related to Impoundments

The water stored behind a **dam (TA5)** functions as **thermal mass (TB6)**, storing heat. Because larger volumes of water heat and cool slower than smaller volumes, the large volume of water behind an impoundment acts as a temperature buffer, **reducing daily**

temperature variations downstream (τB11). Similarly, large volumes of water resist **seasonal changes in temperature (τB12)**, and thus delay seasonal temperature changes, resulting in colder temperatures in the spring and warmer temperatures in the fall. In the Klamath River, these effects may extend downstream to the Pacific Ocean under certain conditions (Bartholow et al. 2005). The effects are most pronounced immediately downstream of Iron Gate Dam, diminishing in the downstream direction.

The expected biological implications of the changes in diurnal temperature patterns caused by dams are mixed. The **decreased diurnal temperature variation (τB11)** associated with dams lead to reduced peak temperatures, thereby reducing the most acutely harmful temperatures. Conversely, the increased daily low temperatures associated with dams could reduce the time available for fish to leave thermal refugia to feed. Also, higher daily low temperatures may lead to higher temperatures at the bottom of thermally stratified pools (Nielsen et al. 1994).

The **seasonal temperature changes (τB12)** caused by the dams may also have biological implications. Bartholow et al. (2005) evaluated the thermal effects of the Klamath River dams on downstream reaches and determined that the dams delay the seasonal temperature patterns by approximately 18 days on an annual basis. The physical implication of an 18 day shift in the seasonal temperature pattern is that the river is cooler in the springtime when juvenile salmonids are migrating to the ocean, and warmer in the fall when adults are migrating upstream and spawning, and eggs are incubating in the gravels. Cooler temperatures are known to reduce juvenile salmonid growth rates; however this effect may be mitigated by the benefit gained by reduced incidence of stressfully high temperatures during outmigration. Warmer temperatures in the summer period may reduce the nocturnal feeding opportunities of juvenile salmonids that persist at thermal refugia, thereby reducing their ability to withstand stressfully high daytime temperatures (National Research Council of the National Academies [NRC] 2004). Warmer temperatures in the fall may delay adult migration or lead to stressfully high temperatures when adults are present or eggs are incubating in gravels. More discussion of this topic can be found in Section 2.5.2.1.

2.4.3.6 Temperature Risk Cofactors

Adverse temperature conditions may combine with other factors to further impair beneficial uses beyond the primary effects of high temperatures. Temperature is a physical factor that affects chemical concentrations and biological growth rates of other factors that affect habitat and water quality. These factors are described below. Each of these risk cofactors contribute to the degraded conditions that exist in the Klamath River basin today. Any watershed scale recovery plan must address the potential effect of the following temperature risk cofactors:

- **Increased NH_3 Toxicity (τC1)** – The concentration of un-ionized ammonia (NH_3) in water increases with higher temperature, higher pH, and higher concentration of ionized ammonia (NH_4^+). In waterbodies that have high concentrations of ionized ammonia and frequent excursions of high pH an increase in temperature can result in the formation of un-ionized ammonia, which is toxic to fish and other organisms.

- **<u>Decreased Overall Dissolved Oxygen (TC2)</u>** – The concentration of DO in water is partly a function of the temperature of the water. Colder water can absorb more DO than warm water, if all other factors are equal. Higher temperatures reduce the DO saturation concentration, increasing the risk that other factors that cause a decrease in DO will result in concentrations less than the criteria concentrations needed to support beneficial uses.

- **<u>Increased Suspended Algae and Periphyton Growth Rates (TC3)</u> –** Algal growth rate is partially dependent on the temperature at which they grow. Generally, higher temperatures result in higher rates of growth (up to a limiting temperature), if all other factors are equal.

- **<u>Increased Bacteria and Decomposition Rates (TC4)</u>** – The rate at which bacteria grow and decay is partially dependent on the temperature of the water they are in. Higher temperatures result in higher rates of growth and decay, if all other factors are equal, resulting in greater oxygen demand within the surrounding water column.

2.4.4 Responses/Outcomes

The driver/stressors and environmental conditions discussed in the previous sections have resulted in the response/outcomes identified in Section D of the Nutrient and Temperature Conceptual Models. Many of these have been well documented and are discussed in the following sections, which describes impacts to Klamath River beneficial uses. The current conditions of many of the indicators described in this section will be presented in Section 2.5 to better assess their actual impact on beneficial uses within the Klamath River basin. Additional information on the effects of an altered natural temperature regime and the secondary effects of elevated nutrient levels on salmonids is available in Appendix 4, *Effects of Temperature, Dissolved Oxygen/Total Dissolved Gas, Ammonia, and pH on Salmonids.*

2.4.4.1 <u>Migration/Avoidance Barrier (D_a1)</u>

High water temperatures can inhibit or block upstream migration of adult salmonids. One study specific to the Klamath River was conducted by Strange (2007) and evaluated the association between water temperature in the mainstem Klamath River and adult fall Chinook migration. Utilizing radio telemetry to track the movements and monitor the internal body temperatures of adult fall Chinook salmon during their upriver spawning migration in the Klamath basin, Strange (2007) found that fall Chinook will not migrate upstream when mean daily temperatures are ≥22°C. Strange also noted that adult fall Chinook in the Klamath basin will not migrate upstream if temperatures are 21°C or above and rising, but will migrate at temperatures as high as 23°C if temperatures are rapidly falling.

The upstream migration by adult salmonids is typically a stressful endeavor. Sustained swimming over long distances requires high expenditures of energy and therefore requires adequate levels of DO. Migrating adult Chinook salmon in the San Joaquin River exhibited an avoidance response when DO was below 4.2 mg/L, and most Chinook waited to migrate until DO levels were at 5 mg/L or higher (Hallock et al. 1970). The swimming performance of migrating salmonids is also impacted by reduced concentrations of DO (Bjornn and Reiser 1991).

2.4.4.2 Decreased Spawning and Reproductive Success (D_a2)

There is evidence that fish that over-summer in stressfully high temperatures and low DO concentrations experience reduced reproductive success (Coutant 1987). A study by Coutant (1987) demonstrates that fish experiencing the combination of high temperatures and low DO are subject to physiological harm that persists well after the fish are exposed to these water quality conditions. Persistent effects of high temperature and low DO include a reduction in female spawning success and poor embryo survival.

2.4.4.3 Increased Physiological Stress (D_a3)

Increased temperature and the secondary effects of nutrient loading can result in physiological stress on salmonids. The metabolic processes of salmonids are directly related to temperature. When water temperatures are above the optimal metabolic range for salmonids, the resting metabolic rate increases dramatically. This results in reduced feeding rates, swimming speed, growth, reproduction, and resistance to environmental extremes (USEPA 2001, p.39). Also, if temperatures are high, much of the energy assimilated from food is lost as excessive metabolism (USEPA 2001, p.85). High incubation temperatures may create a metabolic energy deficit for pre-emergent salmon that increases mortality (Heming 1982, as cited by USEPA 2001, p.31). Further, the stressful impacts of water temperatures on salmonids are cumulative and positively correlated to the duration and severity of exposure. The longer the salmonid is exposed to thermal stress, the less chance it has for long-term survival (Ligon et al. 1999).

As the metabolic rates of salmonids increase there is an increased physiologic demand for oxygen. Low DO concentrations (<4-5 mg/L) result in decreased size of newly hatched salmonids (WDOE 2002a, p.14), as well as decreased juvenile salmonid growth and food consumption (Bjornn and Reiser 1999, p.118; Herrmann et al. 1962; and USEPA 1986, p.5-8), and decreased food conversion efficiency (ODEQ 1995, p.A-6). When DO levels are extremely low (2-3 mg/L) weight loss can occur due to decreased food consumption (Herrmann et al. 1962). Low DO concentrations also adversely affect swimming performance in both adult and juvenile salmonids (Bjornn and Reiser 1999, pp.85, 118, 119; WDOE 2002a, p.46).

Concentrations of ammonia acutely toxic to fishes may cause loss of equilibrium, hyperexcitability, increased breathing, cardiac output and oxygen uptake, and, in extreme cases, convulsions, coma, and death. At sub-acute concentrations, ammonia has many effects on fishes, including a reduction in hatching success, reduction in growth rate and morphological development, and pathologic changes in tissues of gills, livers, and kidneys (USEPA 1986, p.17).

The pH of freshwater streams, lakes, and reservoirs is also important for adult and juvenile salmonid development, and is influenced by the respiration of benthic algae and suspended algae. Chronic effects from low pH can occur at levels that are not toxic to adult fish but that impair reproduction including altered spawning behavior, reduced egg viability, decreased hatchability, and reduced survival during early life stages when salmonid development is most vulnerable to low pH (Jordahl and Benson 1987). Chronic high pH levels in freshwater streams can decrease activity levels of salmonids, create stress responses, decrease or cease feeding, and lead to a loss of equilibrium (Murray and Ziebell 1984; Wagner et al. 1997). Additionally, high temperatures can exacerbate the effects of high pH levels on salmonids, and if pH reaches extremely low or high levels, death can occur (Wagner et al. 1997).

2.4.4.4 Increased Incidence of Fish Disease (*Ceratomyxa shasta* and Columnaris) (D_a4)

The USFWS California-Nevada Fish Health Center has identified *C. shasta* as the primary fish health issue in the Klamath River, and Columnaris is the second biggest fish health threat (Foott 2005). Disease has been cited as the ultimate cause of death in most of the adult and juvenile fish kills which have occurred in the Klamath River from Iron Gate Dam to the mouth (CDFG 2000; CDFG 2004; Deas 2000; Engbring 2004; Foott 2000; Foott et al. 2002; Hannum 1997; Hendrickson 1997; KFHAT 2005; Klamt and Carter 2004; USFWS 1997; USFWS 2003a; USFWS 2003b; Williamson and Foott 1998). On more than one occasion the outbreak of disease was termed an "epizootic" (the equivalent of an epidemic in humans), and in all cases the disease outbreaks were exacerbated by a combination of poor water quality conditions including high water temperatures, low DO levels, sediment deposition, and high ammonia concentrations (CDFG 2000; CDFG 2004; Deas 2000; Engbring 2004; Foott 2000; Foott et al. 2002; Foott 2005; Hannum 1997; Hendrickson 1997; KFHAT 2005; Klamt and Carter 2004; USFWS 1997; USFWS 2003a; USFWS 2003b; Williamson and Foott 1998).

The USEPA (2003) and Washington Department of Ecology (WDOE 2002b, p.115) report that as water temperatures increase, the risk and severity of a disease outbreak increases. The infectivity of *C. shasta* and Columnaris increases with increasing temperature, and the lifecycle of these diseases shorten with increasing temperature, making outbreaks more likely. WDOE (2002b) expresses the temperature thresholds that are likely to prevent or exacerbate disease outbreaks as a Maximum Weekly Maximum Temperature (MWMT), which is the maximum seasonal or yearly value of the daily maximum temperatures over a running seven-day consecutive period. The Washington Department of Ecology (WDOE 2002b, p.115) conducted a review of studies on disease outbreak in salmonids and estimated that an MWMT of less than or equal to 14.4°C (midpoint of 12.6-16.2 range) will virtually prevent warm water disease effects. According to WDOE (2002b, p.115), to avoid serious rates of infection and mortality the MWMT should not exceed 17.4°C (midpoint of 15.6-19.2 range), and that severe infections and catastrophic outbreaks become a serious concern when the MWMTs exceed 21.0°C (midpoint of 18.6-23.2 range). In a summary of temperature considerations, USEPA (2003) states that disease risks for juvenile rearing and adult migration are minimized at temperatures from 12°C to13°C, elevated from 14°C to 17°C, and high at temperatures from 18°C to 20°C. Additionally, the crowding of salmonids in thermal refugia increases the likelihood of fish-to-fish transmission of Columnaris.

When the infectious spore load of *C. shasta* in the Klamath River is low, or juvenile salmonids are exposed for less than 24 hours, they can successfully rear at temperatures as high as 21°C (Foott 2006). However, if the infectious spore load in the river is high, or juvenile salmonids are exposed for long periods of time (2-4 days), mortality occurs at temperatures as low as 16°C (Foott 2006).

As discussed in Section 2.4.2.1 there may be a linkage between the proliferation of *C. shasta* in the mainstem Klamath River and elevated nutrient concentrations. Elevated levels of nutrients and organic matter allow for the proliferation of prime polychaete habitat (periphyton and pockets of fine benthic organic matter) and thus large numbers of polychaetes and high infectious spore load in the river. This can lead to an increased probability of *C. shasta* infections.

2.4.4.5 Decreased Juvenile Growth (D_a5)

Low dissolved oxygen levels and elevated temperatures can result in decreased juvenile fish growth, including growth of salmonids.

> Hutchins (1973 [as cited by WDOE 2002a]) reported that at 15°C, growth of juvenile coho salmon fed to repletion and held at velocities between 1.2 and 3.6 l/sec (lengths per second) at an oxygen level of 3 mg/L for 10 to 12 days was reduced by 20 and 65 percent from that of a control salmon held at respective velocities in air-saturated water (9.5 mg/L). At the intermediate oxygen concentration of 5 mg/L, growth rates of salmon were reportedly reduced by 0 and 15 percent over controls, respectively.
>
> Herrmann et al. (1962 [as cited by WDOE 2002a]) found that juvenile coho salmon (age class 0) held at 20°C and fed to repletion twice daily experienced declines in growth with reduction of oxygen from a mean of about 8.3 to 6 and 5 mg/L, and declined more sharply with further reduction of oxygen concentration, suggesting further that concentrations near 4 or 5 mg/L can be exceedingly detrimental. The authors estimated a reduction of both percent weight gain and the rate of food consumption by about 11 percent with reduction of oxygen concentration from 8.3 to 5.0 mg/L, and by at least twice as much with reduction of oxygen concentration to 4 mg/L.

Elevated water temperature has a detrimental effect on juvenile salmonid growth. Banks et al. (1971 as cited by WDOE 2002b) found that growth was similar at 15.6°C and 18.3°C, however temperatures above 19°C were associated with reduced feeding and growth, as well as increased problems with disease. Marine and Cech (2004) found that growth was substantially reduced at 21-24°C when compared to 13-16°C.

2.4.4.6 Increased Fish Mortality and Lower Overall Populations (D_a6, D_a7, D_a8)
The effects of altered temperature, decreased DO, and increased nutrient loading can have a significant impact on salmonids. In the Klamath River basin, the impacts of high water temperature directly, and in combination with other factors, has likely resulted in both adult and juvenile fish mortality and contributed to lower overall fish populations.

Bartholow (1995, p.19) states, "…water temperatures in the Klamath basin are marginal at best for anadromous salmonids, squeezing their thermal resources in both space and time." The National Research Council of the National Academies (NRC) state that various factors including decreased flows and increased water temperatures in the Klamath River basin have contributed to declining salmonid populations during the 20th century (NRC 2004, p.284). Salmonid populations in the Klamath River basin have declined sharply since the early 1900's. In 1931, Snyder (1931, p.9, 121) wrote that the fishery of the Klamath River basin is very important because with proper management it can be maintained, although he also states that depletion of the Klamath salmon is apparent and occurring at an "alarming rate" which artificial propagation alone may not remedy. The NRC (2004, p.284) reports that virtually all Klamath River basin populations of salmonids have declined considerably from their historical abundances, and note the significant link between the decline in coho, spring Chinook, and summer steelhead to the "verge of extinction" and their dependence on cool summer water temperatures. The NRC also notes that the Klamath River has become inhospitable to juvenile coho due to high water temperatures, and although the Klamath River is still important for rearing Chinook and steelhead, further increases in temperatures may make it unsuitable even for those species (NRC 2004, p.284). NRC (2004, p.268) state that in some respects, "…it is remarkable that fall-run Chinook salmon in the Klamath River are doing as well as they seem to be. Both adults migrating upstream and juveniles moving downstream face water temperatures that are bioenergetically unsuitable or even lethal." In 1991, the Klamath River Basin Fisheries Task Force (KRBFTF) identified increased stream temperatures in the lower Klamath River as impeding the recovery and posing threats to coho, winter steelhead, and late run fall Chinook (KRBFTF 1991, p.4-29). A discussion of how temperature and other water quality factors are contributing to fish mortality and salmonid population decline can be found in Section 2.6.1.

2.4.4.7 Impacts to Cultural and Harvest-Related Activities (D_a9, D_a10, D_a11)
The reduction of overall salmonid populations impacts the availability of fish for commercial, sport, and subsistence fish harvesting, as well as traditional and ceremonial uses. All of these activities require robust fish populations for long-term sustainable use of the resource. Thus, water temperatures, DO, pH, and ammonia toxicity outside the range of salmonid suitability can significantly impact these activities. Evidence of temperature and nutrient related impairment to harvest related activities is presented in Sections 2.6.2 and 2.6.4.

2.4.4.8 Impacts to Municipal Supply, Recreation, and Traditional/Cultural Use (D_b1, D_b2, D_b3, D_b4)
Elevated nutrient concentrations in the Klamath River basin have contributed to nuisance blooms of the blue-green algae *Microcystis aeruginosa*, which produces the cyanotoxin

microcystin. Exposure routes of cyanotoxin poisoning can be via direct water contact, ingestion of contaminated water, breathing of aerosolized toxin bearing water, and possibly secondarily through the ingestion of infected fish or other vertebrates, invertebrates, and plant matter. As detailed in Section 2.5.4 this toxin has been detected in Copco and Iron Gate Reservoirs at levels which are considered dangerous for contact or consumption, leading to the posting of public health warnings at the reservoirs and various locations along the river.

The Klamath River Tribes utilize the river for traditional and ceremonial uses including bathing, plant gathering, ingestion, and other activities discussed in Section 2.6.2. The presence of microcystin in the lower river presents a potential human health risk for the Tribes. Further, mats of suspended algae in the reservoirs and river are an aesthetic nuisance impacting the public's ability to enjoy the natural beauty of these waters leading to impacts on the Rec-1 and Rec-2 uses. Additionally, taste and odor problems are associated with high densities of blue-green algae, and these compounds are difficult and costly to remove from water supplies (Welch and Jacoby 2004, p.172).

2.5 Evidence of Water Quality Objective and Numeric Target Exceedances

This section presents observed water quality conditions and evaluates the data with respect to the relevant water quality objectives or surrogate thresholds.

2.5.1 Temperature and Nutrient Data Sources

Stream temperature data used for this analysis were provided by the US Forest Service, Yurok Tribe, Karuk Tribe, Forest Science Project, US Fish and Wildlife Service, Salmon River Restoration Council, and PacifiCorp. In addition, Regional Water Board staff collected temperature data.

For the DO and nutrient analyses, Regional Water Board staff compiled monitoring data from several sources including the US Fish and Wildlife Service, US Geological Survey, PacifiCorp, Karuk Tribe, Yurok Tribe, Regional Water Board, and the US Environmental Protection Agency Environmental Monitoring and Assessment Program.

2.5.2 Temperature

Regional Water Board staff conducted a literature review to evaluate stream temperature requirements for the various life stages of steelhead trout (*Oncorhynchus mykiss*), coho salmon (*Oncorhynchus kisutch*), and Chinook salmon (*Oncorhynchus tschawytscha)* as a means for interpreting the narrative temperature objective in the Basin Plan (Regional Water Board 2007). As a result of this literature review, Regional Water Board staff selected chronic and acute temperature thresholds for evaluating Klamath River basin temperatures. These temperature thresholds are used for assessing the suitability of current Klamath River basin temperatures for fully supporting salmonids. These thresholds are *not* numeric water quality targets used for calculating the Klamath River temperature TMDL. The numeric temperature targets are discussed in Section 2.3.1 and the specific temperature targets are presented in Chapter 5.

Chronic temperature thresholds were selected from the USEPA document *EPA Region 10 Guidance for Pacific Northwest State and Tribal Temperature Water Quality Standards* (2003), and are presented in Table 2.8. The Region 10 guidance is the product of a three-year interagency effort, and has been reviewed by both independent science review panels and the public. Lethal temperature thresholds were selected based upon best professional judgment of the literature, and are presented in Table 2.9. Although some studies of southern California steelhead suggest the possibility of higher temperature tolerances of salmonids occupying the southern end of the species range (Spina 2007), available studies from northern California indicate that the thresholds expressed in USEPA's guidance (2003) are appropriate for the north coast region (Welsh et al. 2001; Hines and Ambrose undated).

Table 2.8: MWMT chronic effects temperature thresholds

Life Stage	**MWMT (°C)**
Adult Migration	20
Adult Migration plus Non-Core Juvenile Rearing [1]	18
Core Juvenile Rearing [2]	16
Spawning, Egg Incubation, and Fry Emergence	13

Source: USEPA 2003

[1] The Adult Migration plus Non-Core Juvenile Rearing designation is recommended by USEPA (2003) for the "protection of migrating adult and juvenile salmonids and moderate to low density salmon and trout juvenile rearing during the period of summer maximum temperatures," usually occurring in the mid to lower part of the basin. The phrase "moderate to low density" is not specifically defined.

[2] The Core Juvenile Rearing designation is recommended by USEPA (2003) for the "protection of moderate to high density summertime salmon and trout juvenile rearing" locations, usually occurring in the mid to upper reaches of the basin. The phrase "moderate to high density" is not specifically defined.

Table 2.9: Lethal temperature thresholds

	Lethal Threshold[1] (°C)		
Life Stage	**Steelhead**	**Chinook**	**Coho**
Adult Migration and Holding	24	25	25
Juvenile Growth and Rearing	24	25	25
Spawning, Egg Incubation, and Fry Emergence	20	20	20

Source: Appendix 4

[1] The lethal thresholds selected in this table are generally for chronic exposure (greater than seven days). Although salmonids may survive brief periods at these temperatures, they are good benchmarks from the literature for lethal conditions. See Appendix 4 for further discussion.

These freshwater temperature thresholds are applicable during the time of year when the life stage of each species is present in the Klamath River basin. Where life history, timing, and/or species needs overlap, the lowest of each temperature metric applies. A discussion of the distribution and periodicity of salmonids in the Klamath River basin is available in Appendix 5, *Fish and Fishery Resources of the Klamath River Basin*. Additional information on the effect of temperature on salmonids and a brief discussion of temperature metrics are available in Appendix 4.

2.5.2.1 Mainstem Klamath River

Temperature data from the Klamath River mainstem indicate that seasonal maximum temperatures are not supportive of beneficial uses. Figure 2.11 shows that MWMT values at all sites from the Oregon-California state line to the estuary are well above the suitable temperature range for full support of salmonids as described by USEPA (2003). These data clearly demonstrate that the river has no capacity to assimilate increased heat loads during the hottest critical periods without adversely affecting the beneficial uses COLD, RARE, and MIGR.

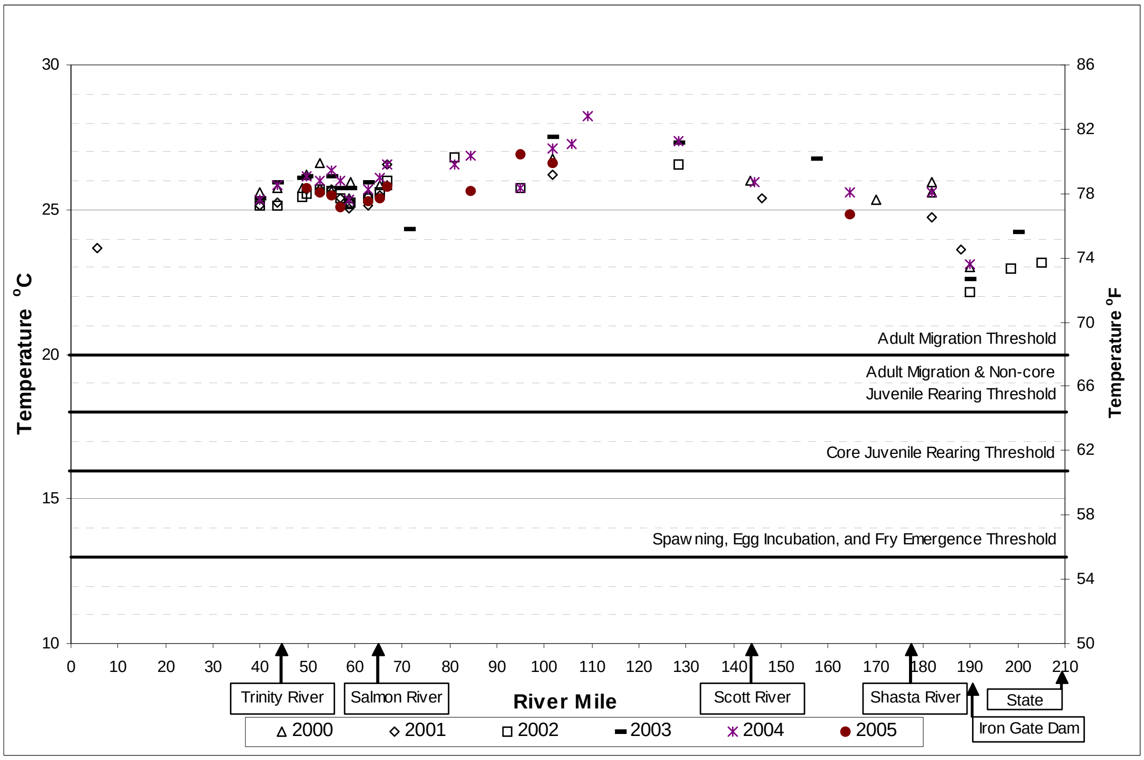

Figure 2.11: Measured Klamath River MWMTs, 2000-2005.
Note: MWMTs typically occur in late July.

The reduced diurnal temperature variation associated with the impoundments seen in Figure 2.12 also results in adverse impacts to coho salmon. The National Research Council report clearly summarizes the effects of elevated daily low mainstem temperatures on coho salmon:

> Overall, it appears that the bioenergetic demands of juvenile coho prevent them from occupying the main stem. Even with abundant food, the thermal refugia (the pools at mouths of tributaries) are inadequate: nighttime temperatures stay too high for them, and the energy costs of interactions with Chinook and steelhead, both of which are much more abundant in the pools, are probably high. Coho juveniles in the pools during June and July may die by late summer. (NRC 2004, p.220).

The results of water quality modeling completed for this TMDL process indicate that human activities have significantly altered the temperature regime of the mainstem Klamath River. The application of the water quality models is described in Chapter 3. These results indicate that the combined effects of human activities in the basin commonly result in temperature alterations in excess of 5 °F, and these alterations can be as much as 18 °F. Figure 2.12 presents simulated natural and current Klamath River temperatures, and the calculated difference, at the site of maximum temperature alteration in California.

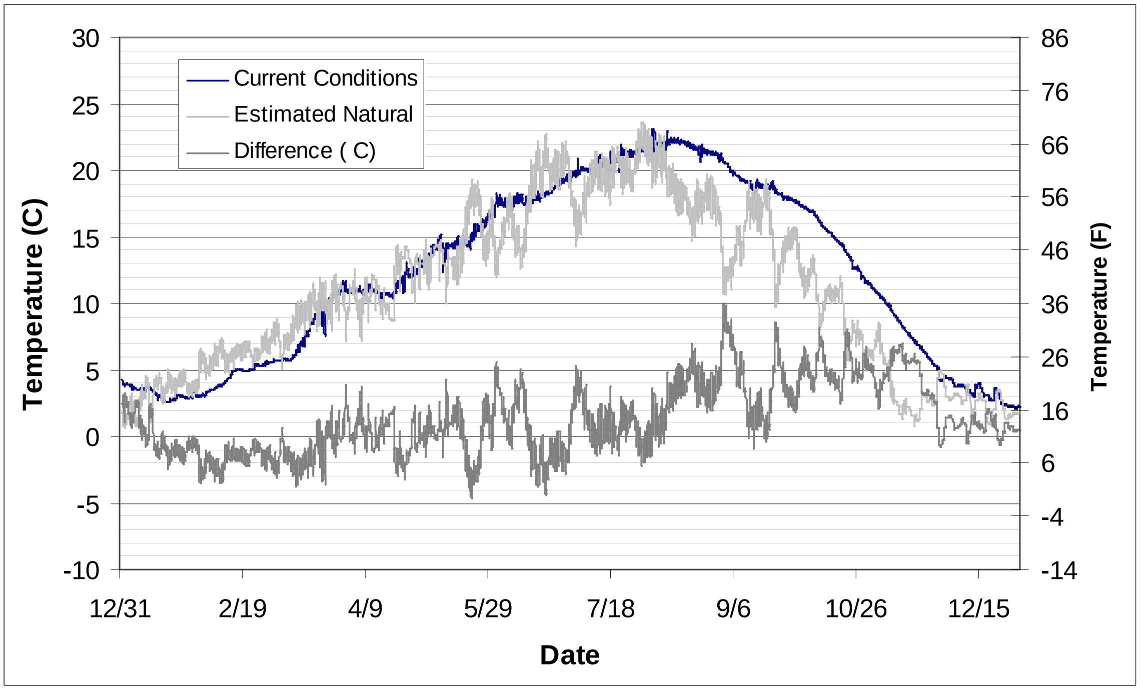

Figure 2.12: Current and estimated natural temperatures downstream of Iron Gate Dam, with difference in temperature, 2000
Note: Model results presented at 1-hour time step.

The results of the water quality modeling completed for this TMDL process are consistent with results of an analysis of temperature effects caused by the Klamath Hydroelectric Project in the 5 years from 2000-2004 (Dunsmoor and Huntington 2006). The results of that analysis are presented in Figure 2.13 and were developed using an earlier version of the modeling system used in this analysis.

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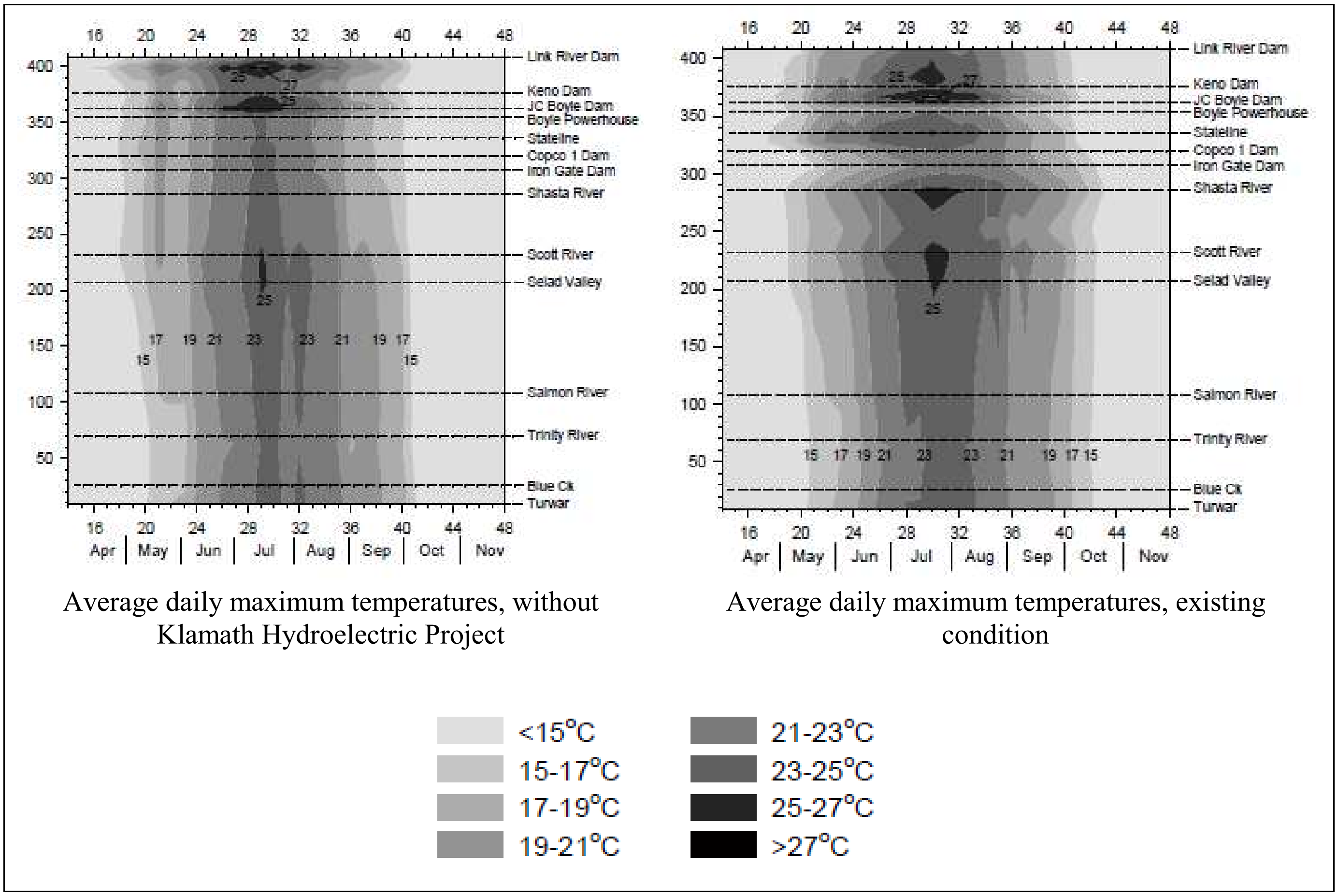

Figure 2.13: Simulated Klamath River temperatures, by week, 2000-2004.
Source: Dunsmoor and Huntington 2006

The temperature modeling indicates human impacts are responsible for the elevated temperatures that are above biological temperature thresholds for rearing juvenile salmonids and reproductive success of adult salmonids. Under current conditions, the seasonal increase in temperatures during the winter and spring months is delayed in comparison to estimated natural temperatures. Similarly, the seasonal decline in temperatures during the fall months is also delayed in comparison to estimated natural temperatures. Dunsmoor and Huntington (2006) evaluated the effects of the delay in the seasonal fall temperature decline on salmonids due to the Klamath Hydropower Project. They evaluated Pacificorp's model output data for the years 2000-2004. Their analysis of temperature alteration during the fall months indicates impaired spawning conditions resulting from the presence of the Klamath Hydropower Project, and is summarized in Table 2.10, below.

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Table 2.10: Summary of fall temperature effects resulting from human alteration at Iron Gate Dam.

	Pacificorp Model, 2000-2004 (Dunsmoor and Huntington, 2006)		**Klamath TMDL Model, 2000**	
Time Period	**Existing Condition**	**Without Project Condition**	**Existing Condition, MWMT (C)**	**Natural Conditions, MWMT (C)**
Sept. 10-23	Stressful or worse 90% of days	Stressful 9% of days	19.2	18.7
Sept. 24 – Oct. 7	Suboptimal or worse 100% of days	Suboptimal 37 % of days	18.1	15.5
Oct. 8 – Oct. 21	Suboptimal 70% of days	Suboptimal 1% of days	16.1	11.4
Oct. 22 – Nov. 4	Optimal 100% of days	Optimal 100% of days	12.9	8.2

Bartholow et al. (2005) concluded that in comparison to the expected temperatures resulting from a natural flow regime, the Klamath River dams create temperature conditions more favorable to migrating juveniles in the spring and less favorable to adults migrating and spawning in the fall. They suggested that the increased temperatures occurring later in the spring may increase growth rates. However, juvenile fish migrating down the Klamath River in the spring suffer high mortality rates due to C. Shasta, which is more virulent at temperatures that typically occur that time of year (see section 2.4.4.4 and Appendix A). Bartholow et al. (2005) further speculated that the changes in seasonal temperature patterns may have affected the timing of the Chinook salmon run since the dams were constructed.

The growth of juvenile salmonids is partially dependent on temperature (USEPA 2003). The optimal temperature range for juvenile salmonids is 10-15 ^{o}C, with a lower limit of 4 ^{o}C (USEPA 2003). The ability of salmonids to survive the ocean phase of their life cycle is partially dependent on their size upon entering the ocean. Thus, the delay in warming that occurs in the late winter may reduce the growth rates of salmonids rearing in the Klamath River, and may ultimately reduce the survival rate of salmonids in the ocean.

USEPA (2001) reviewed multiple literature sources and concluded that optimal protection of salmonids from fertilization through initial fry development requires that temperatures be maintained below 9-10°C, and that daily maximum temperatures should not exceed 13.5-14.5°C. Under current conditions, these temperatures are not reached until late October or November. However, the current Chinook spawning season begins in mid-September and peaks in late October (see Appendix 5 for more details).

In summary, the temperature alterations presented in Figure 2.12 result in adverse effects to salmonids. The comparison of estimated natural and current temperatures for the year 2000 at the location downstream of Iron Gate Dam clearly shows that the water quality objective for temperature is regularly exceeded. This conclusion is based on the observation that current temperatures are regularly more than 5^{o}F above the estimated natural temperatures, and the fact that there is no capacity to assimilate increased heat loads during the hottest critical periods without adversely affecting the beneficial uses.

2.5.2.2 Tributaries to the Klamath River

Tributaries are important habitat for Klamath River salmonids. Tributaries provide the majority of available rearing habitat for juvenile salmonids (NRC, 2004). In addition, many tributary mouth pools provide a refuge from higher mainstem temperatures for chinook salmon and steelhead (*Ibid*). Temperature data from the mouths of Klamath tributaries indicate that the seasonal maximum temperatures of the majority of the tributaries are not supportive of beneficial uses. The MWMT values at most of these sites are well above the non-core (low density rearing habitat) juvenile rearing threshold for salmonids suggested by USEPA (2003), as illustrated in Figure 2.14.

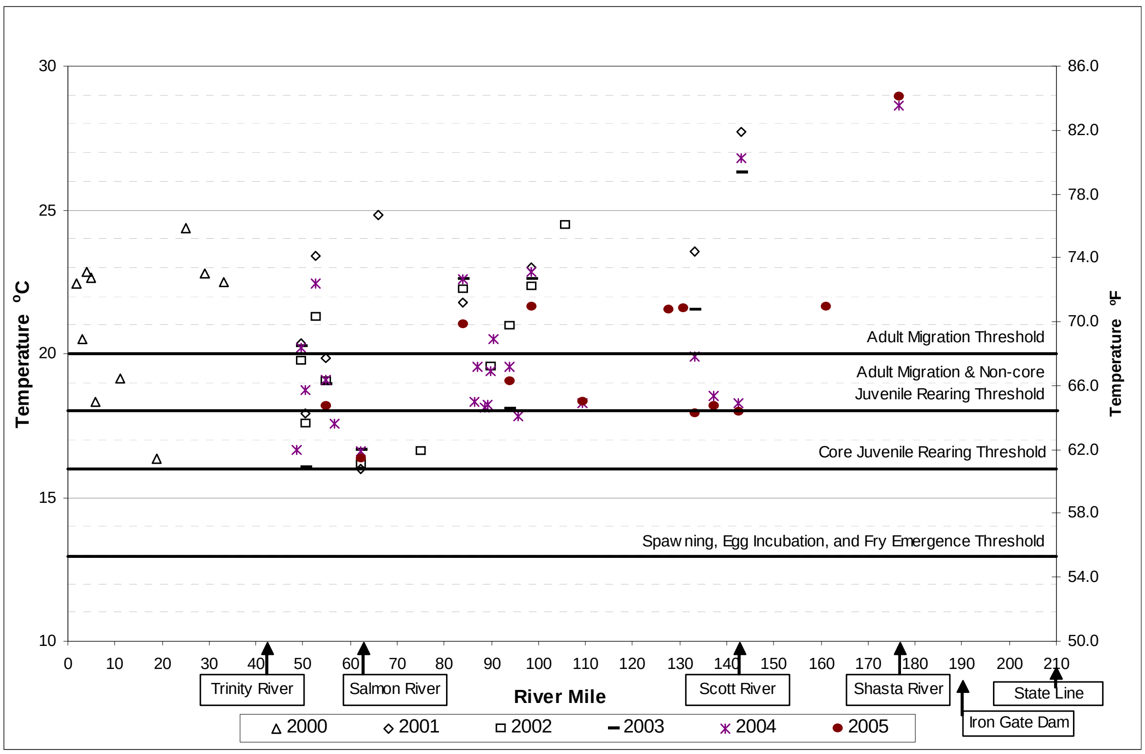

Figure 2.14: Klamath River tributary mouth MWMTs stream temperatures 2000-2005
Note: MWMTs typically occur in late July.

Of the twenty-two tributaries monitored in 2004 (the year with the most tributaries monitored), eighteen had MWMT values in excess of the adult migration and non-core juvenile rearing thresholds for salmonids suggested by USEPA (2003). These data clearly demonstrate that these tributaries have no capacity to assimilate increased heat loads during the hottest critical periods without adversely affecting beneficial uses.

The Shasta, Scott, and Salmon Rivers, three of the largest Klamath River tributaries, have been listed on the 303(d) list for temperature impairment separately. TMDL analyses developed for these tributaries have confirmed the temperature impairments, as well as the human contribution to elevated temperatures in these basins.

Although the temperatures are high relative to the temperature requirements of salmonids (USEPA 2003), the high temperatures do not exceed the water quality objective for temperature unless they are elevated due to human activities, such as riparian vegetation removal and altered channel morphology. However, it is well documented that the erosion associated with the 1997 flood in the Klamath River basin resulted in widespread stream channel alteration, loss of riparian vegetation, and shade reductions (further discussed in Section 2.5.8) and that a significant amount of the erosion was caused or exacerbated by human activities (De La Fuente and Elder 1998). Similarly, it is well known that historic mining, road building, and silvicultural practices have resulted in riparian disturbances and consequent reductions of stream shade in many tributaries (Elder et al. 2002; KNF 1999; KNF 2002). Therefore, Regional Water Board staff conclude that enough information exists to confirm impairment and justify TMDL development and implementation.

2.5.2.3 Reservoirs

The available Iron Gate and Copco Reservoir temperature and DO profile data indicate that during summer stratified conditions, temperatures are only suitable for cold water species, including salmonids, rearing at depths where the DO concentrations are near lethal levels. Redband/rainbow trout are currently present in both Copco and Iron Gate Reservoir (PacifiCorp 2004b, p.4-53 - 4-55, 4-58). A representative example of typical summer conditions is illustrated in the vertical profiles of DO concentration and temperature that are presented in Figure 2.15 for Iron Gate Reservoir.

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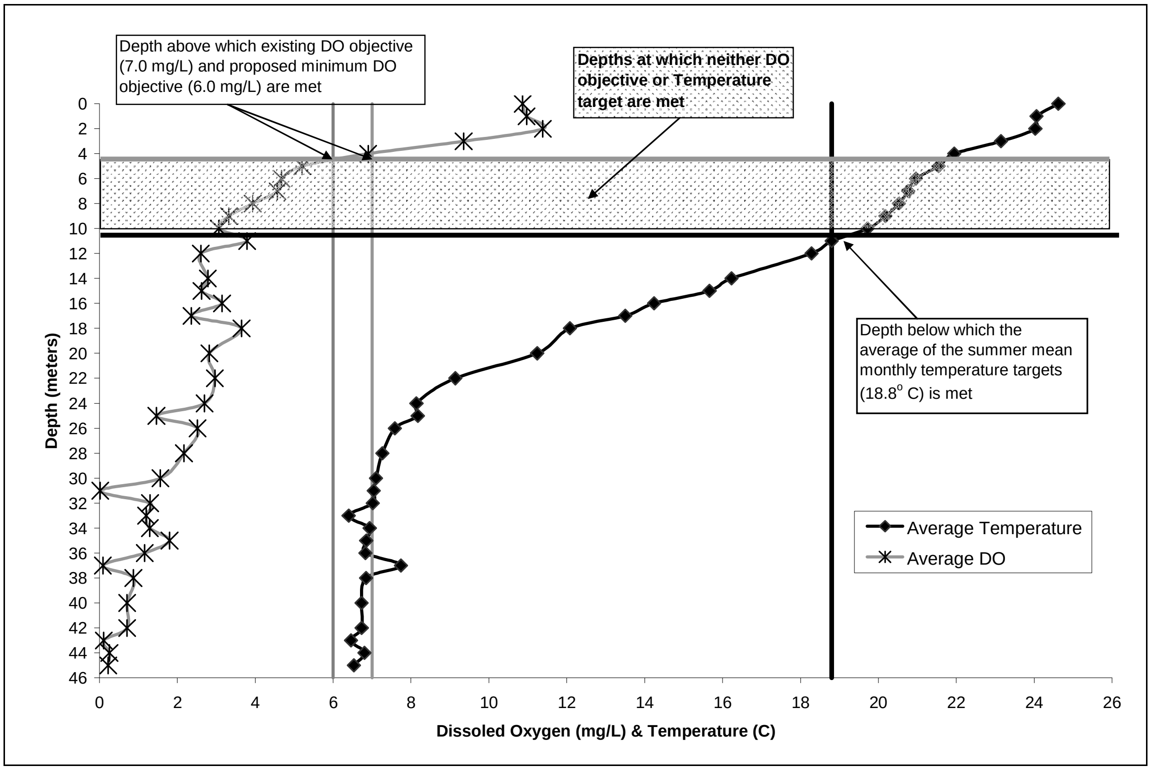


Figure 2.15: Dissolved oxygen and temperature depth profiles in Iron Gate Reservoir – average for July and August 2000 – 2005

The same pattern exists for Copco and for other years. The reservoirs become thermally stratified in the summer months. The stratification of the reservoirs prevents mixing of the low temperature/low DO waters with the high temperature/high DO waters, and thus there are no depths in the reservoirs at which the most sensitive beneficial uses are supported. Given that the stratification and the absence of suitable habitat is due to the presence of the reservoirs, Regional Water Board staff have concluded that the reservoirs contribute to exceedances of the temperature and DO water quality objectives.

2.5.3 Nutrients and Indicators of Nutrient-Related Impairment

Except in extreme cases, nutrients alone do not impair beneficial uses. Rather, they cause indirect impacts through their biostimulatory effect on algal growth, low DO, and extreme pH conditions among others that can impair uses. The water quality objectives with distinct numeric limits include DO and pH. The California Nutrient Numeric Endpoints (CA NNE) framework (Tetra Tech 2006) indentifies indicators for biostimulatory effects that can impair beneficial uses, including benthic algal biomass, planktonic chlorophyll-a concentrations, and diurnal DO and pH fluctuations. Other indicators included here are toxic blue-green algae (*Microcystis*) concentrations, and un-ionized ammonia.

2.5.3.1 Nutrient Concentrations

The primary driver for the nutrient conceptual model is the increased loading of nutrients to the Klamath River ecosystem. High levels of nutrient loading and elevated water column concentrations do not alone result in biostimulatory conditions, but excess nutrients are an essential precondition to this finding. Therefore the first step in evaluating impairment due to biostimulatory conditions is to determine whether existing nutrient loading and water column concentrations exceed natural baseline conditions. If it is determined that nutrient levels above natural baseline concentrations are present in the system, then the CA NNE secondary endpoints are evaluated to determine whether they have exceeded the Beneficial Use Risk Category Level III boundary for impaired waters. It is when both natural baseline nutrient levels and CA NNE Level III indicator boundaries have been exceeded that a finding of impairment due to biostimulatory conditions can be supported.

Several sources within the Klamath and Lost River watersheds contribute nutrient loads. Some of the key sources include irrigated agriculture return flows, internal nutrient cycling from nutrient enriched sediments (especially within UKL), nutrients released as a result of wetland conversion, sediments from external sources derived from land disturbance activities, and to a much lesser extent, point sources. The analysis of Klamath River nutrients involves a comparison of estimated natural baseline water column concentrations of several nutrient species to existing conditions concentrations. Natural baseline conditions are estimated based on TMDL model simulations (described in Chapter 3). These estimates are not interpreted literally but only as approximations of conditions that may have existed under natural conditions. The natural baseline conditions modeling scenario provides an estimate of nutrient loads and concentrations generated from a landscape with minimal anthropogenic disturbance. The existing conditions values come from the mean concentration of composite grab samples taken during the summer (June 1 to September 30) at twelve stations by various organizations from 1996 to 2007. Each station has at least three samples for each summer season over five years. Several stations have a much greater sampling density. The assumption for this analysis is that the annual and daily variability converges to an average over the course of a large number of samples that represent typical conditions during the summer growing season.

The purpose of the comparison is to evaluate whether nutrients have been increased by human related activities above the levels that could cause a nuisance, or adversely affect the ability of water to support specified beneficial uses. This approach does not allow for a complete mass balance comparison for the river since winter flows and concentrations have not been monitored. Rather, the information serves to provide a relative comparison of the mean summer concentrations of total nitrogen and total phosphorus to which aquatic life respond under current and natural baseline conditions (Figures 2.16 and 2.17). The left side of Figures 2.16 and 2.17 present existing conditions from stateline to the estuary, while the right side of the figure presents concentrations under natural baseline conditions. At most stations the existing summer mean concentrations for both total phosphorous and total nitrogen exceed the natural baseline conditions. Frequently the existing summer mean concentrations are more than double the natural background summer mean concentrations and can be up to five times higher than concentrations under the natural conditions baseline scenario. It is important to note that the summer mean for natural baseline conditions is based on two years of model runs versus 12 for existing (current) and that this may underestimate variability in natural conditions. These results suggest that human activities have increased nutrient loads to the Klamath River.

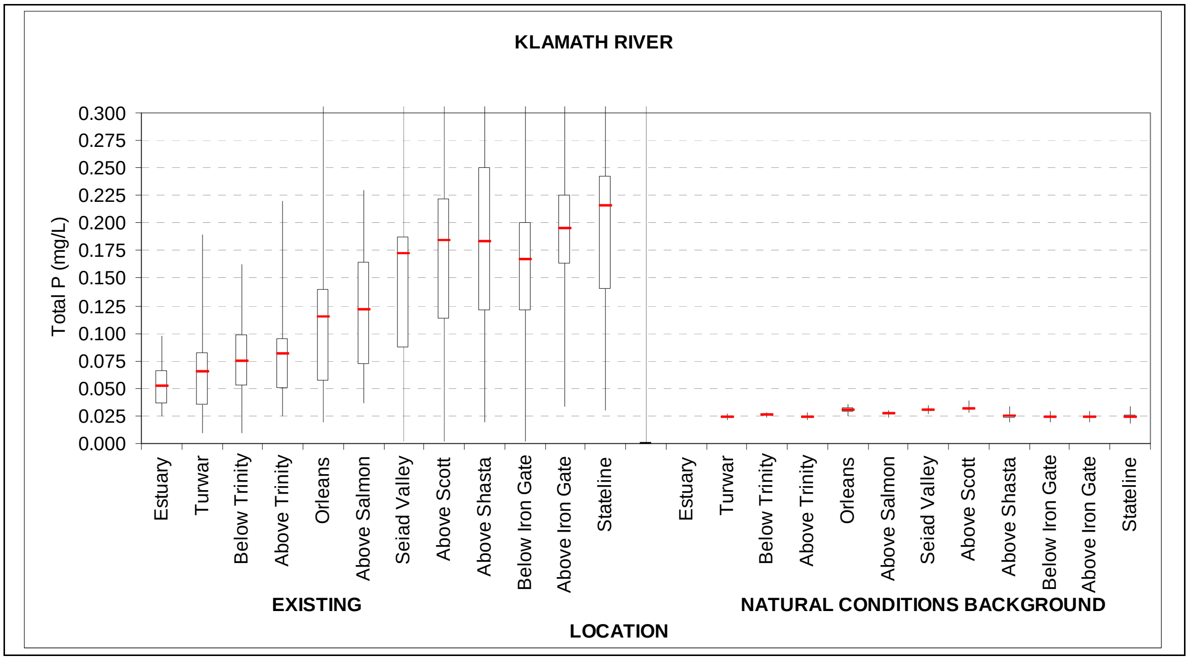


Figure 2.16: Comparison of total phosphorous concentrations for existing conditions (consolidated monitoring data 1996-2007) with estimated (TMDL model) natural baseline conditions at Klamath River monitoring stations in California.

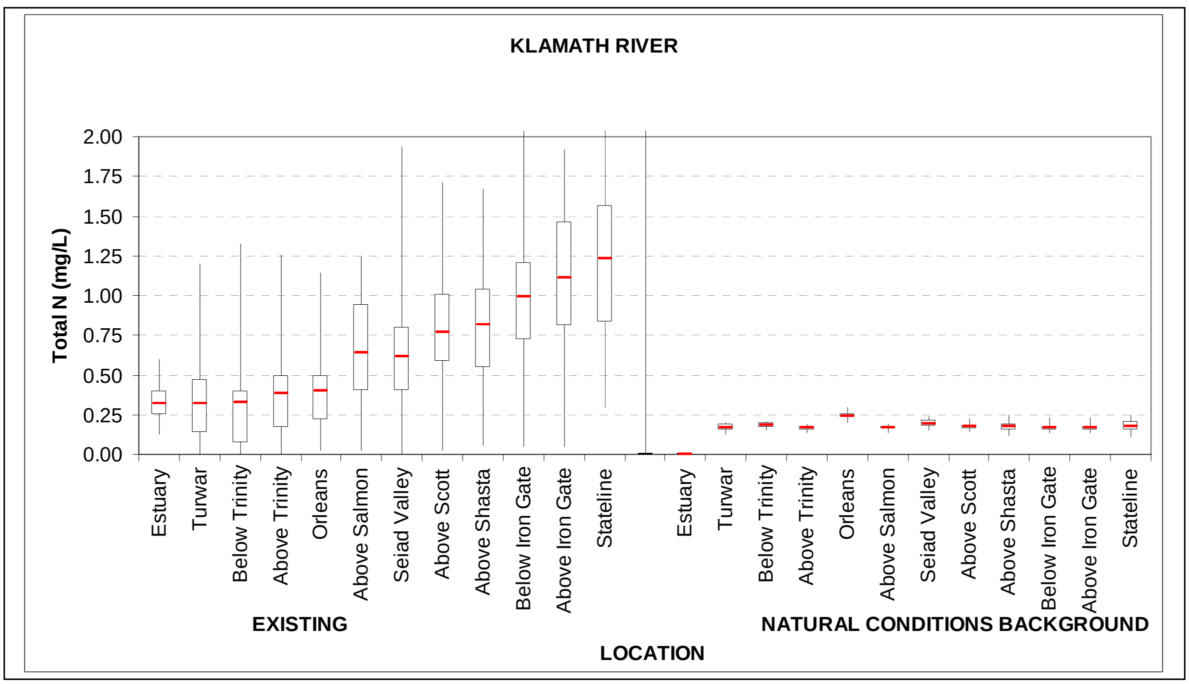


Figure 2.17: Comparison of total nitrogen concentrations for existing conditions (consolidated monitoring data 1996-2007) with estimated (TMDL model) natural baseline conditions at Klamath River monitoring stations in California.

2.5.3.2 Benthic Algal Biomass

Figure 2.18 presents the results of composited benthic algae biomass monitoring samples collected during summer months in 2003, 2004, 2006, and 2007.

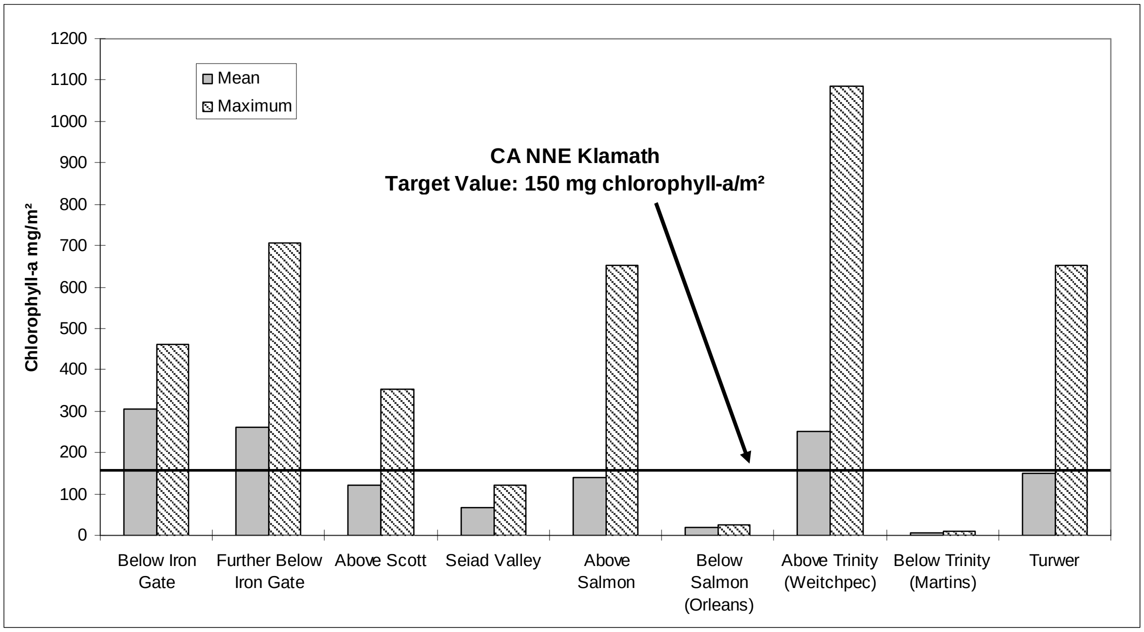


Figure 2.18: Consolidated benthic algal biomass monitoring results (summer mean and maximum) for 2003-2007 with CA NNE/TMDL numeric target.

There are a total of fifty samples for nine stations. The spatial and temporal sampling density is not ideal, but does indicate that during the summer months Klamath River benthic algae biomass in California exceed the CA NNE and TMDL numeric target of 150 mg chl-a/m^2 at several stations.

As demonstrated in the following sections, these benthic algae conditions have a direct impact on water quality via algal photosynthesis and respiration. In addition, the benthic algal biomass densities also provide habitat for polychaetes that serve as a host and source for the fish parasite *C. shasta.* In summary, existing benthic algal biomass conditions strongly suggest impairment.

2.5.3.3 Diurnal DO and pH

For several stations along the Klamath River the diurnal photosynthesis and respiration cycle is strongly influenced by dense colonies of benthic algal biomass which result in extreme diurnal cycles for DO and pH. The water quality conditions of frequent and chronic low DO and high pH illustrated in Figures 2.19 through 2.21 create chronic stressful conditions for fish populations.

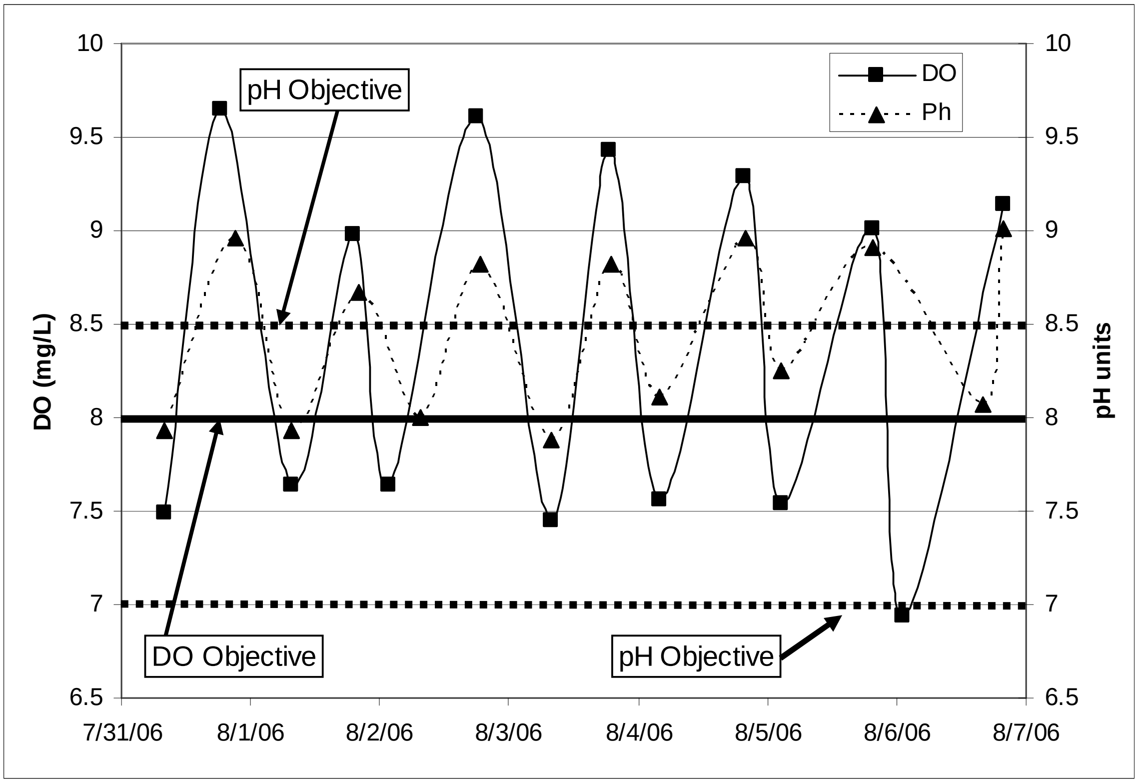


Figure 2.19: Example diurnal DO and pH cycle below Iron Gate Dam, summer 2006

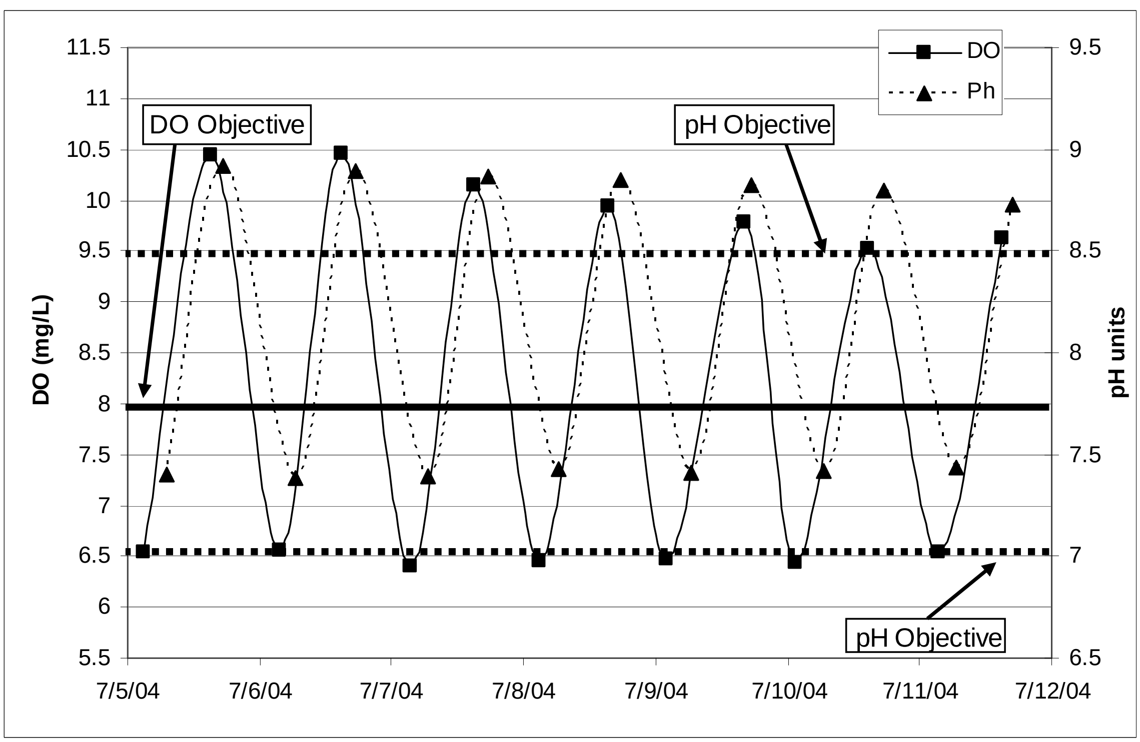


Figure 2.20: Example diurnal DO and pH cycle above the Shasta River, summer 2004

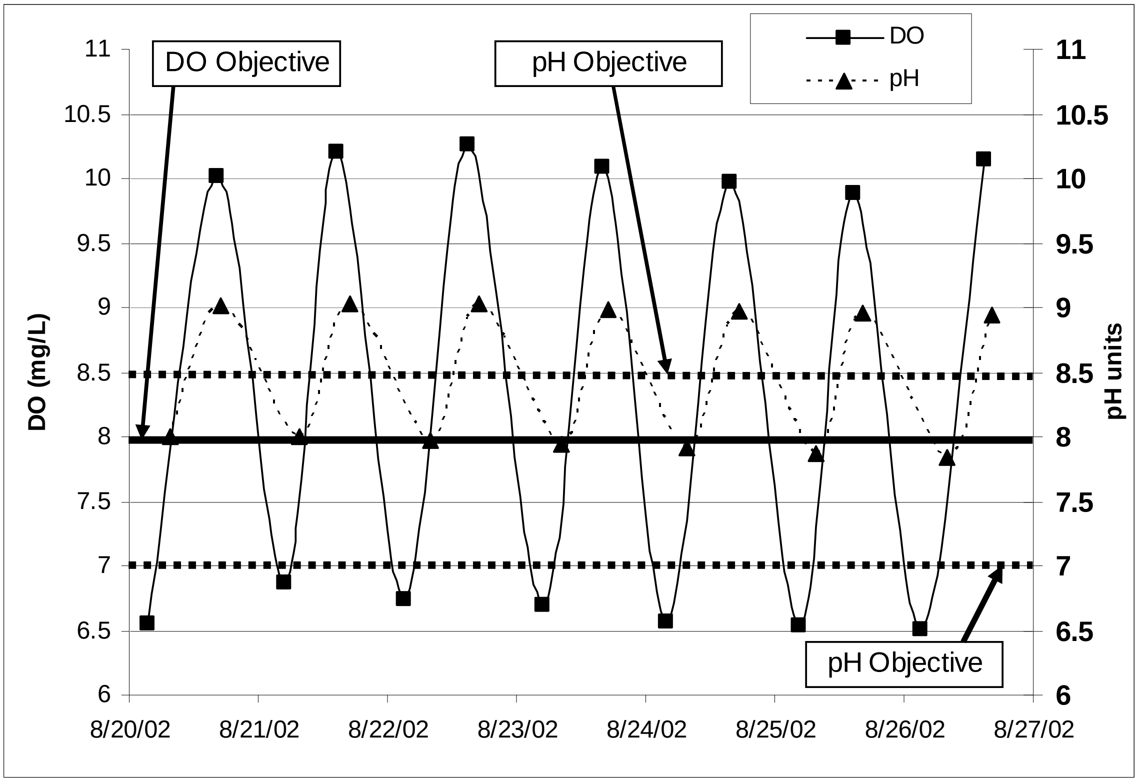
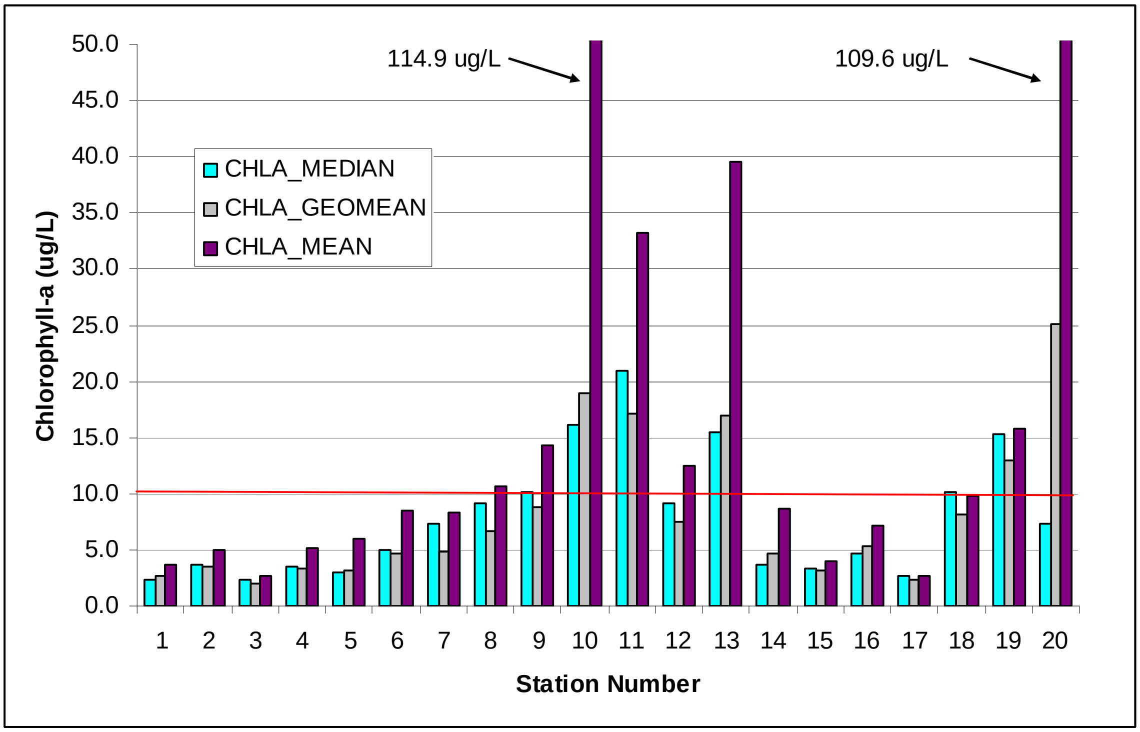


Figure 2.21: Example diurnal DO and pH cycle at Seiad Valley, summer 2002

While the three plots present monitoring data from single stations, the observed pattern is consistent with summer months for other years when diurnal data has been collected and for other stations along the Klamath River. Both the existing DO objective (>8 mg/L) and pH objective (not greater than 8.5 and not less than 7.0) for the Klamath River downstream of Iron Gate Dam are exceeded on a regular basis. The extreme magnitude and regular frequency of these excursions indicate impairment from biostimulatory substances (i.e., nutrients).

2.5.3.4 Chlorophyll-a – Reservoirs

Figure 2.22 compares various measures of central tendency (mean, geometric mean, and median) of the chlorophyll-a data from samples collected during the summer period (May – September) of 2005, 2006, and 2007 by the Yurok Environmental Program, Karuk Tribe of California Natural Resources Department, and PacifiCorp at twenty stations along the Klamath River.



Station List:

1 - Lower Estuary (n=11)
2 - Turwar (n=19)
3 - Below Weitchpec (n=17)
4 - Weitchpec (n=19)
5 - Orleans (n=19)
6 - Seiad Valley (n=26)
7 - Walker Bridge (n=13)
8 - I-5 (n=16)
9 - Below Iron Gate Dam (n=61)
10 - Iron Gate Res. Lower (n=49)
11- Iron Gate Res. Upper (12)
12 - Copco Res. outflow (n=37)
13 - Copco Res. Lower (n=49)
14 - Copco Res. Upper (n=11)
15 - Above Shovel Creek (n=40)
16 - Below JC Boyle Dam (n=9)
17 - JC Boyle Res.(n=3)
18 - Above JC Boyle Res.(n=17
19 - Keno Dam (n=20)
20 - Link Mouth (n=7)

Figure 2.22: Comparison of central tendencies of summer (May – September) chlorophyll-a measurements for 2005, 2006, and 2007 at twenty monitoring stations along the Klamath River. Data from Yurok Tribe Environmental Program, Karuk Tribe of California Natural Resources Department, Regional Water Board, and PacifiCorp.

It is important to note that the data presented are from samples collected by different entities using similar but not identical protocols and the number and timing of samples vary from station to station. Presentation of the mean, geometric mean, and median values of a data set provides a useful way to assess the spread of the data. A close similarity between median and mean values is an indication that the data set is normally distributed. The geometric mean[9] is a useful measure of central tendencies when the data is log normally distributed. All three measures of central tendencies for each station are illustrated in Figure 2.22 allowing a station by station comparison of the three measures. Figure 2.23 presents the same data in box and whisker diagrams. The shoulders of the

[9] To calculate a geometric mean of the distribution values (i.e., chlorophyll-a concentrations) the following steps are taken: 1) log transform the data; 2) calculate the mean of the logged values; and 3) then antilog (raise to 10th power) the mean.

box and whisker diagram represent the 75th and 25th percentile of the distribution of measurements; the median (50th percentile) is the solid line across the box.

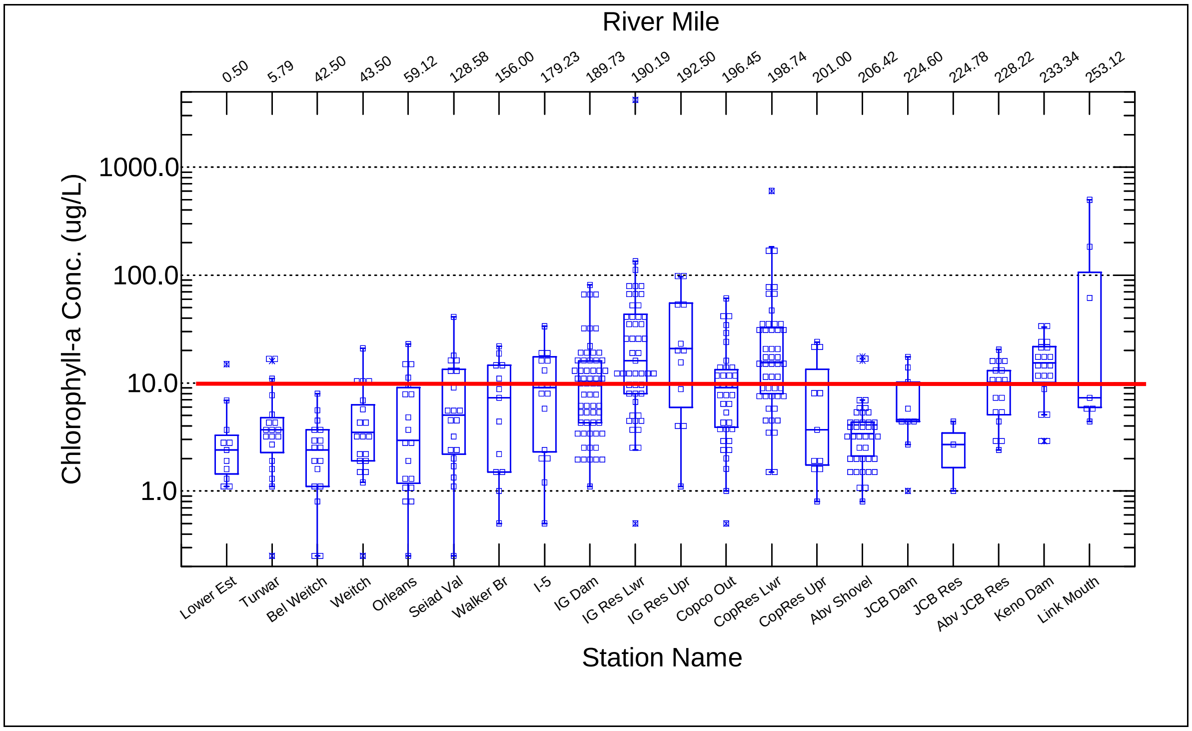


Figure 2.23: Longitudinal analysis of summer (May through September) chlorophyll-a concentrations from 2005 – 2007 along the Klamath River.
Data from Yurok Tribe Environmental Program, Karuk Tribe of California Natural Resources Department, Regional Water Board, and PacifiCorp

Each of the central tendency measures of chlorophyll-a for the Klamath River reservoir stations in California (Copco and Iron Gate) exceed the numeric target of 10 µg/L. There are also high concentrations of chlorophyll-a at Link Mouth, and at Keno Dam and above JC Boyle Reservoir. The high concentrations at these three stations are due in large part to residual algal biomass from Upper Klamath Lake. At most stations the median and the geometric mean are relatively similar, and the mean is higher than both the median and geometric mean. At the California reservoir stations (stations 10-14) however, the mean is significantly higher than either the median or the geometric mean. The very high means can be attributed to the nuisance algae bloom events during the late summer months.

The longitudinal analysis illustrated in Figures 2.22 and 2.23 demonstrates the effect of quiescent waters and the susceptibility of reservoirs on the Klamath River to nuisance algal blooms. Within Upper Klamath Lake and within the reservoirs summer mean and median chlorophyll-a concentrations are substantially higher than at the stations located in the free-flowing sections of the river. Chlorophyll-a concentrations rapidly attenuate downstream of Upper Klamath Lake and the reservoirs.

Nuisance algal blooms within Iron Gate and Copco Reservoirs are well documented in the regular blue-green algae monitoring program reports by the Karuk Tribe of California Natural Resources Department and PacifiCorp. As illustrated in Figure 2.24 the summer (May – September) mean concentrations of chlorophyll-a at all of the reporting stations for the reservoirs are at or above the summer mean numeric target of 10 µg/L. The summer mean concentrations at three of the four stations are more than double the target and the maximum concentrations are generally an order of magnitude higher.

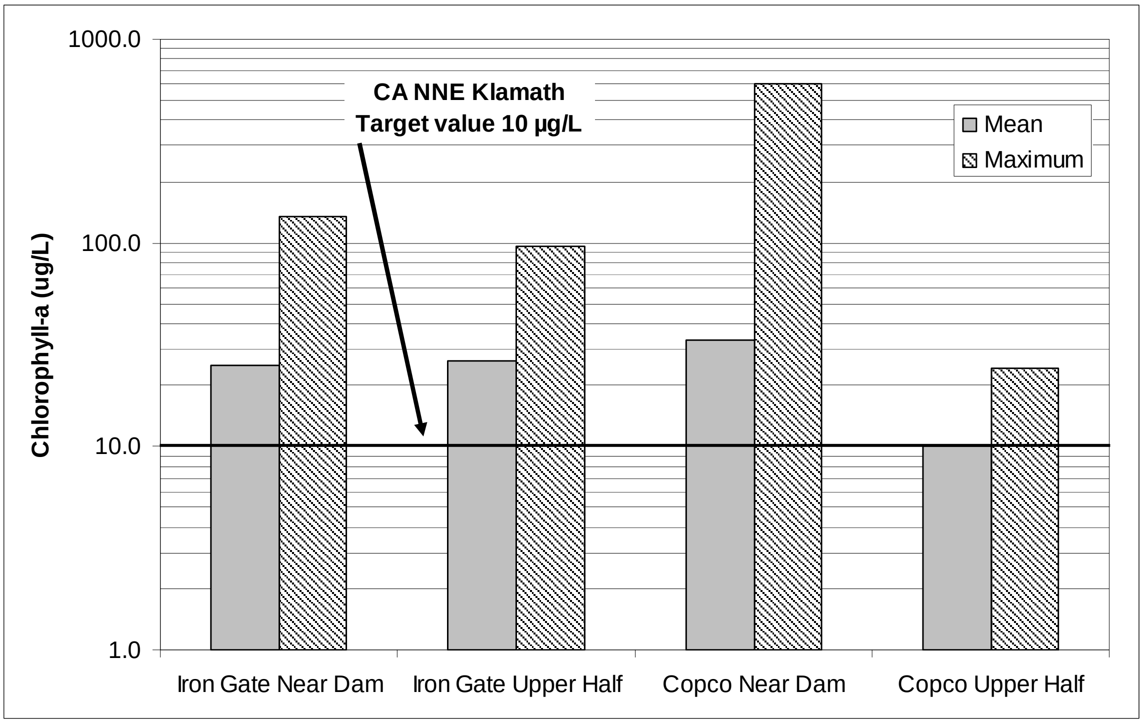


Figure 2.24: Summer (May – September) mean and maximum concentrations of chlorophyll-a (2000 – 2007) at four stations within the Iron Gate and Copco Reservoirs.

Figure 2.25 presents Regional Water Board staffs' seasonal analysis of PacifiCorp 2007 and 2008 data. The data shows an increase in total phytoplankton biovolume below Iron Gate Dam (Station KRBI) compared with above Copco Reservoir (Station KRAC). Normality tests performed on stations above and below the reservoirs showed non-normal distribution. Normality notwithstanding, the Figure 2.25 time series graphs show a distinct seasonal (June -September) increase in total algal biomass (biovolume) below the reservoirs in 2007 and 2008. Two nonparametric tests of the June - September 2007-2008 data show that the distribution of total algal biovolume is significantly greater below the reservoirs than above (Kolmogorov-Smirnov Two-Sample Test [p=0.034] and Kruskal-Wallis Mann-Whitney U Test [p=0.08]).

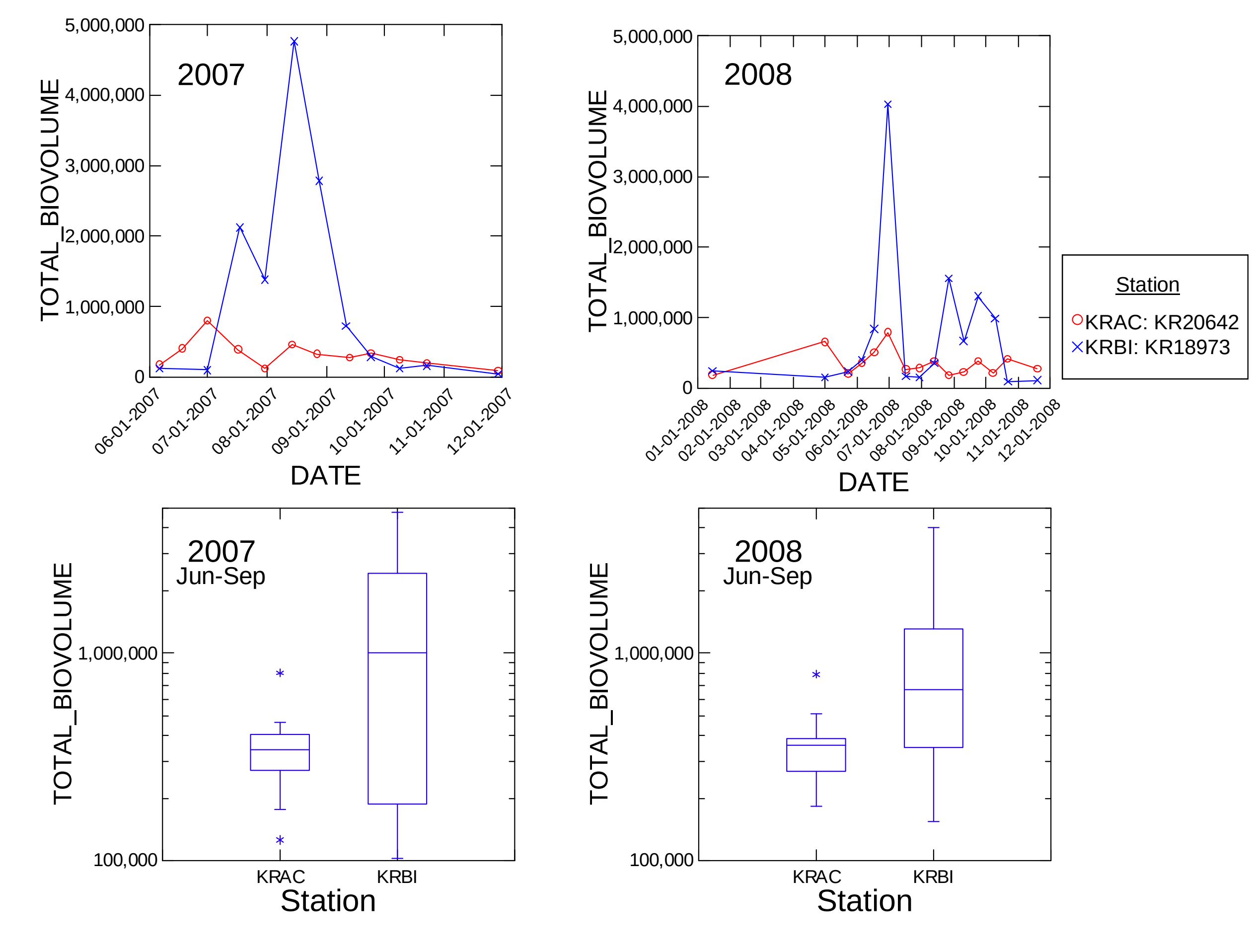


Figure 2.25. Comparison of above Copco Reservoir (Station KRAC; KR20642) and below Iron Gate Dam (Station KRBI; KR18973) biovolume for the summer 2007 and 2008. Data collected by PacifiCorp (http://www.pacificorp.com/es/hydro/hl/kr.html#).

The high concentrations of chlorophyll-a in the reservoirs have water quality impacts downstream. Suspended algae (and their breakdown products) entrained in water released from Iron Gate Reservoir may become available as a food source for polychaetes in the river reaches below the dam. In addition, these algal biomass can be deposited in the river bottom sediments, enhancing habitat conditions for polychaetes which contribute to higher levels of *C. shasta* parasite spores, and therefore contribute to higher rates of infection (Bartholomew et al. 2007; Bartholomew and Bjork 2007). The available data is insufficient to determine how the reservoirs alter the amount and form of particulate organic matter. Therefore, the net effect of fine particulate organic matter exported from the reservoirs on polychaete populations in the river downstream is unclear.

As discussed in more detail in Section 2.5.4, the reservoirs do impact the river below Iron Gate by serving as a source of blue-green algae to downstream water that can continue to grow in backwater and slower sections within the river reaches below the dams (Kann and Corum 2009, Kann and Asarian 2005). The export of algal biomass (including blue-green algae) has been documented by monitoring data showing that both *Microcystis* and microcystin are substantially higher within and below the reservoirs than they are directly upstream. For example, see Raymond (2009; *Phytoplankton Species and Abundance Observed During 2008 in the vicinity of the Klamath Hydroelectric Project* (Report prepared for CH2MHILL and PacifiCorp) which clearly illustrates (Figures 13 and 15) an increase of both *Microcystis* and microcystin toxin within the reservoirs and downstream.

In summary, the available chlorophyll-a and biovolume data suggest that the Iron Gate/Copco Reservoir complex significantly increases the quantity of algal biomass supplied to the river below Iron Gate Dam **and are a net sources of live algae to the river during the algae growing season.** Included in this algal biomass is blue-green algae **that** potentially serves as an in**n**oculant contributing to **nuisance conditions** in downstream backwater habitats. **However, the available data is insufficient to determine the net downstream effect of the reservoirs as a source of dead and decaying particulate organic matter.**

2.5.4 Blue-Green Algae and Microcystin Toxin

An important aspect of the nuisance algae conditions within Copco and Iron Gate Reservoirs is the periodic dominance of toxic blue-green algal species during the summer season. There are many forms of blue-green algae, both toxic and non-toxic. This discussion focuses primarily on *Microcystis aeruginosa* since it has become the dominant species of concern on the Klamath River in California. The frequent documented occurrence of seasonally high concentrations of *Microcystis aeruginosa* and microcystin in reaches of the Klamath River within California in each of the last several years has resulted in the documented impairment of beneficial uses including Native American Culture (CUL), Subsistence Fishing (FISH), Water Contact Recreation (REC-1), Non-Contact Water Recreation (REC-2), Municipal & Domestic Supply (MUN), Shellfish Harvesting (SHELL), Aquaculture (AQUA), Agricultural Supply (AGR), and Commercial and Sport Fishing (COMM), as discussed below. Ongoing research may also demonstrate a direct effect on the health of aquatic organisms from exposure to high levels of microcystin which would lead to the addition of other beneficial uses to this list (de Figueiredo et al. 2004).

Routine public health monitoring of blue-green algae in the Klamath River basin began in 2005. Every year since 2004 *Microcystis aeruginosa* counts and microcystin concentrations on the Klamath River have exceeded the Blue Green Algae Work Group action levels for harmful algal blooms. Table 2.11 summarizes the blue-green algal monitoring data for the years 2006, 2007, and 2008 with respect to the Blue Green Algae Work Group action levels. Data presented in the table is summarized by reach: *Reach 1*) Oregon to Iron Gate Dam; *Reach 2*) Iron Gate Dam to Scott River; *Reach 3*) Scott River to Trinity River; and *Reach 4*) Trinity River to Estuary. The blue-green algae listing criteria are most frequently exceeded in Reach 1, which is primarily composed of sample sites within Copco and Iron Gate Reservoirs. Late summer conditions are typically characterized by dense blue-green algae blooms that form thick viscous scums in parts of the reservoirs. The bloom conditions at times span much of the open water areas within the reservoirs. The reservoirs have been posted with public health advisory signs as a result of these summer blooms in 2006, 2007, and 2008.

Table 2.11: Summary of blue-green algae and microcystin monitoring data for 2006, 2007, and 2008

Reach Name	Reach #	Year	# of monitoring samples that exceed thresholds and targets		
			MSAE Cells ≥ 40,000 ml/L	microcystin ≥ 8 ug/L	Tissue ≥ 26 ng/g
Oregon to Iron Gate Dam	1	2006	27	29	*
Iron Gate Dam to Scott River	2	2006	1	1	*
Scott River to Trinity River	3	2006	2	0	*
Trinity River to Estuary	4	2006	0	0	*
Oregon to Iron Gate Dam	1	2007	47	35	41
Iron Gate Dam to Scott River	2	2007	2	0	1
Scott River to Trinity River	3	2007	4	0	4
Trinity River to Estuary	4	2007	2	0	*
Oregon to Iron Gate Dam **	1	2008	**	14	0 ***
Iron Gate Dam to Scott River	2	2008	4	2	*
Scott River to Trinity River	3	2008	9	4	*
Trinity River to Estuary	4	2008	1	1	*
* Data not collected during this period					
** Not all data from monitoring programs available at time of report publication.					
*** Tissue samples taken prior to bloom to determine baseline conditions, samples were not taken during bloom.					

Data sources: Yurok Environmental Monitoring Program Blue-Green Algae Annual Reports: 2006, 2007, and 2008; Karuk Tribe of California Natural Resources Department Blue Green Algae Monitoring Annual Reports: 2006, 2007, and 2008; and PacifiCorp Blue-Green Algae Monitoring Program annual Reports: 2006, 2007, and 2008.

Table 2.11 also shows high concentrations of *Microcystis aeruginosa* downstream of the Iron Gate Dam in reaches 2, 3, and 4. Some reaches of the Klamath River mainstem were posted with public health advisory signs during the summers of 2008 and 2009. Algae related sampling protocols in the Klamath River have evolved since routine sampling began in 2004. Before 2008 most samples on the Klamath River mainstem were taken from the river at higher velocity areas near the channel mid-point. Until 2008 few samples had been taken in near shore backwater areas where scums have been frequently reported and photographed. Data collected in 2008 showed frequent exceedance of both 8 µg/L microcystin and 40,000 cells/ml *Microcystis aeruginosa* in various river-edge habitats between Iron Gate Dam and Seiad Valley (Figure 6: Kann and Corum 2009). The revised September 2008 Blue Green Algae Work Group report recommends that monitoring for public health should include samples of the Reasonable Maximum Exposure (RME) conditions in areas in which people and animals are most likely to contact water (State Water Board 2008).

2.5.5 *Dissolved Oxygen*

This section evaluates observed DO conditions relative to the existing and proposed Basin Plan water quality objectives for DO.

The US Fish and Wildlife Service (USFWS), in cooperation with the Karuk and Yurok Tribes, monitored DO conditions with datasondes at several stations along the Klamath River from 2001 to 2006. For the purposes of this assessment measured DO concentrations from the three most recent years (2004 – 2006) are evaluated in comparison to the existing and proposed DO objective. USFWS conducted an in-depth quality control review of the DO data (Ward and Armstrong 2006). Final data- sonde results have been summarized by station by evaluating the percent of total measurements during the summer season that fall below the current Basin Plan DO Objective of 8.0 mg/L. The datasondes recorded water quality conditions at 30-minute increments, for a total of forty-eight daily measurements.

In 2005 greater than ten percent of the DO measurements were less than 8.0 mg/L at six of the nine stations along the Klamath River (Table 2.12 and Figure 2.26). For the period 2004, 2005, and 2006 several of the Klamath mainstem stations (below Iron Gate, above Shasta River, above Scott River, and at Seiad Valley) had conditions where more than 40% of the measurements are less than the current Basin Plan objective indicating serious dissolved oxygen impairment for large sections of the river.

Table 2.12: Percent of DO measurements below Basin Plan water quality objective of 8.0 mg/L for 2004 – 2006 at nine stations along the Klamath River

% Measurements below 8 mg/L	2004		2005		2006	
	n	**%**	**n**	**%**	**n**	**%**
At Iron Gate	2706	64	4498	45	5391	61
Above Shasta River	5478	50	5533	49	-	-
Above Scott River	2966	58	4457	47	-	-
At Seiad Valley	3381	57	4713	45	5526	40
At Orleans	4057	37	4533	23	5349	15
Above Trinity	-	-	5535	5	5739	3
At Weitchpec	4142	48	5400	7	5332	6
Below Weitchpec	5500	16	3529	11	5293	4
At/above Turwar	5066	30	5543	6	-	-

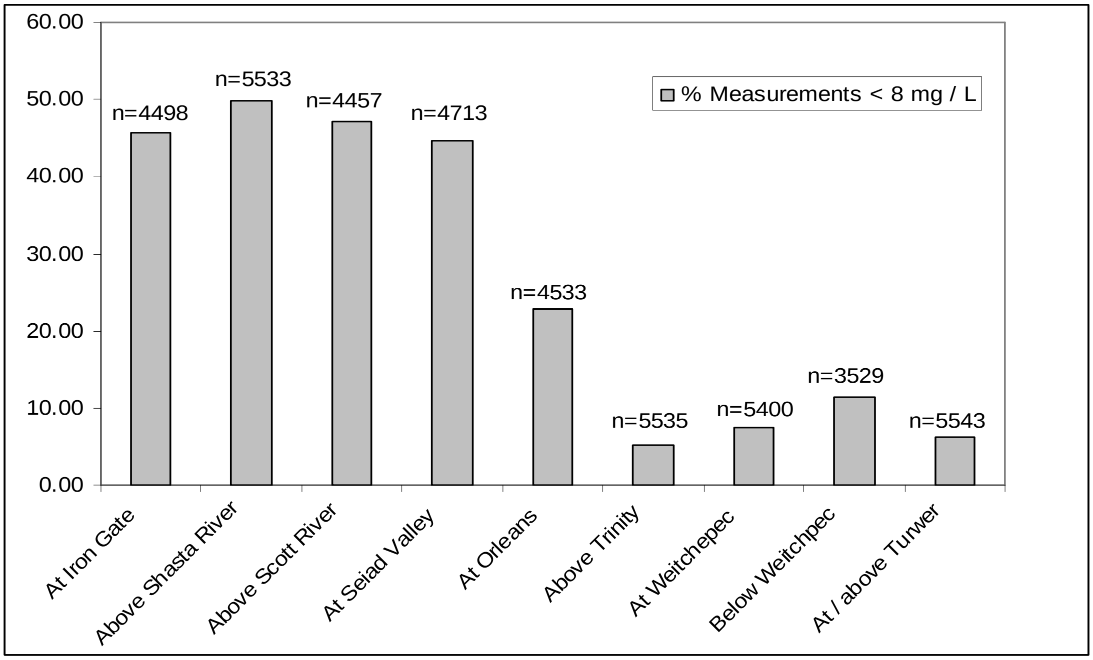


Figure 2.26: Percent of DO measurements below the Basin Plan water quality objective of 8.0 mg/L for 2005 at nine stations along the Klamath River

The analysis presented below addresses the revised DO objective being proposed (see Section 2.2.1.2. and Appendix 1). The revised objective requires that in those waterbodies identified as COLD but unable to meet the salmonid life cycle requirements (instantaneous minimum of 7.0 mg/L upstream of Iron Gate dam and 8.0 mg/L downstream of the dam, with half the monthly mean DO values for the year 10 mg/L or greater) due to natural conditions, a minimum 85% DO saturation limit throughout the mainstem, 90% DO saturation limit from October through April upstream of the Hoopa-California boundary and 80% DO saturation during August in the Middle and Upper Estuary be applied. These percent DO saturation criteria are to be calculated based on natural water temperatures.

In order to compare the USFWS measured DO data to the proposed DO objective assumptions related to temperature and barometric pressure were made. Percent DO saturation was calculated based on measured water temperatures and using a seasonal average barometric pressure. These assumptions make for a very conservative estimate of the percent of measurements below the proposed objective of 85% DO saturation at natural water temperatures. For simplicity, the analysis looks only at the 85% criteria. Estimates of natural water temperatures have not been predicted for the years 2004-2006 using the TMDL model. The results of the analysis are presented in Table 2.13 and Figure 2.27. In 2004, six of the nine stations had more than 10% of the DO measurements below 85% DO saturation.

Table 2.13: Percent of calculated percent DO saturation estimates below the proposed Basin Plan water quality objective of 85% saturation for 2004 – 2006 at nine stations along the Klamath River

% Measurements below 85% saturation at median of pressure range	**2004**		**2005**		**2006**	
	n	**%**	**n**	**%**	**n**	**%**
At Iron Gate	2706	10	4498	6	5391	18
Above Shasta River	5478	25	5533	24	-	-
Above Scott River	2966	35	4457	20	-	-
At Seiad Valley	3381	14	4713	11	5526	0
At Orleans	4057	6	4533	0	5349	0
Above Trinity	-	-	5535	0	5739	0
At Weitchpec	4142	19	5400	0	5332	0
Below Weitchpec	5500	0.1	3529	0	5293	0
At/above Turwar	5066	12	5543	0	-	-

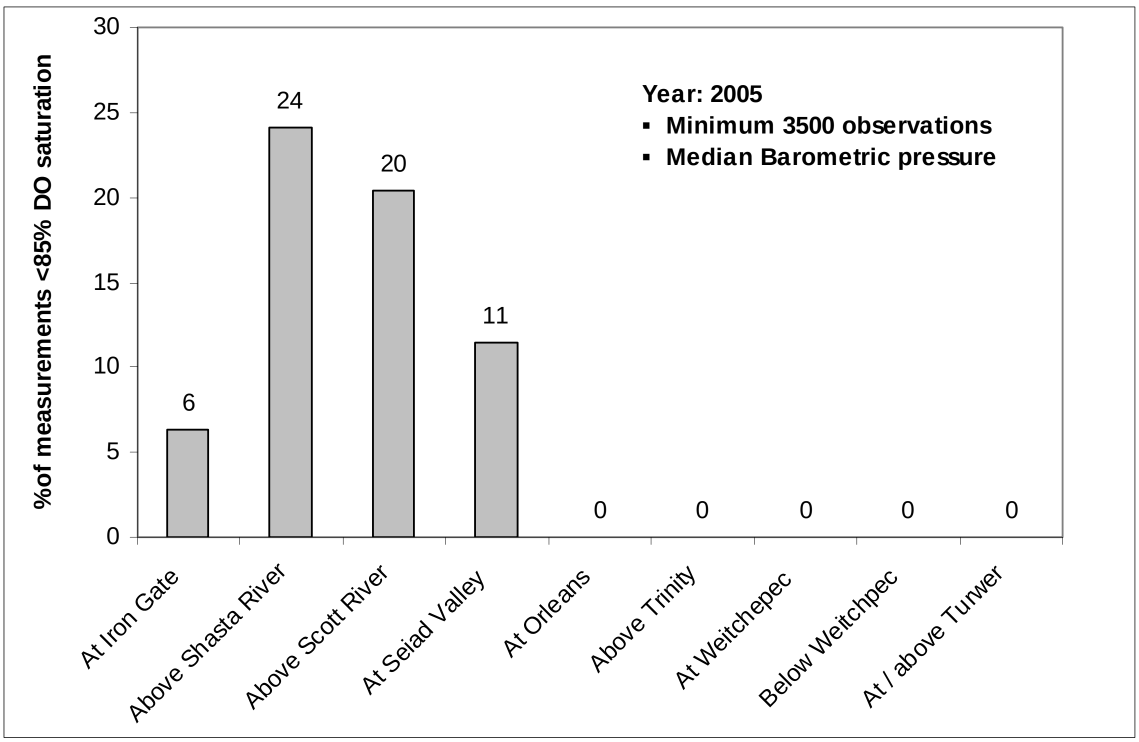


Figure 2.27: Calculated percent DO saturation at nine stations on the Klamath River for 2005 based on data sonde measurements made by U.S. Fish and Wildlife Service, Yurok Tribal Environmental Program, and Karuk Tribe Department of Natural Resources

2.5.6 pH

This assessment includes an evaluation of pH conditions along the Klamath River independent of the diurnal variation driven by photosynthesis that was addressed in Section 2.5.3.3. The data for this analysis also comes from the USFWS, Karuk and Yurok Tribes datasonde measurements. The same years (2004 – 2006) used in the DO analysis were also selected for the pH assessment. The Basin Plan water quality objective for pH is a maximum of 8.5 and a minimum of 7.0.

Five of the stations have more than 20% noncompliant measurements. The highest rate of noncompliant measurements is 48% recorded at Orleans in 2006 (Table 2.14). In the three year sample all nine stations exceeded a noncompliant measurement rate of greater than 10 percent at least once. The rate of noncompliance for the minimum pH of 7.0 is less than 0.05% at all stations. Therefore a sampling station summary table and plot have not been prepared for minimum pH.

Table 2.14: Percent of pH measurements above 8.5 for 2004 – 2006 at nine stations along the Klamath River.

Percent of Measurements above 8.5	**2004**		**2005**		**2006**	
	n	**%**	**n**	**%**	**n**	**%**
At Iron Gate	5192	32	4680	3	5486	30
Above Shasta River	5762	37	5847	40	-	-
Above Scott River	3834	28	3821	19	-	-
At Seiad Valley	3808	1	5838	1	5576	32
At Orleans	4844	0	5608	0	5442	48
Above Trinity	-	-	5826	23	5746	18
At Weitchpec	4449	33	5765	29	5823	27
Below Weitchpec	5823	1	5469	23	5125	42
At/above Turwar	4712	16	5835	23	-	-

For 2005 (Figure 2.28) at six of the nine Klamath River stations the Basin Plan objective of 8.5 is exceeded in more than 15% of the samples taken.

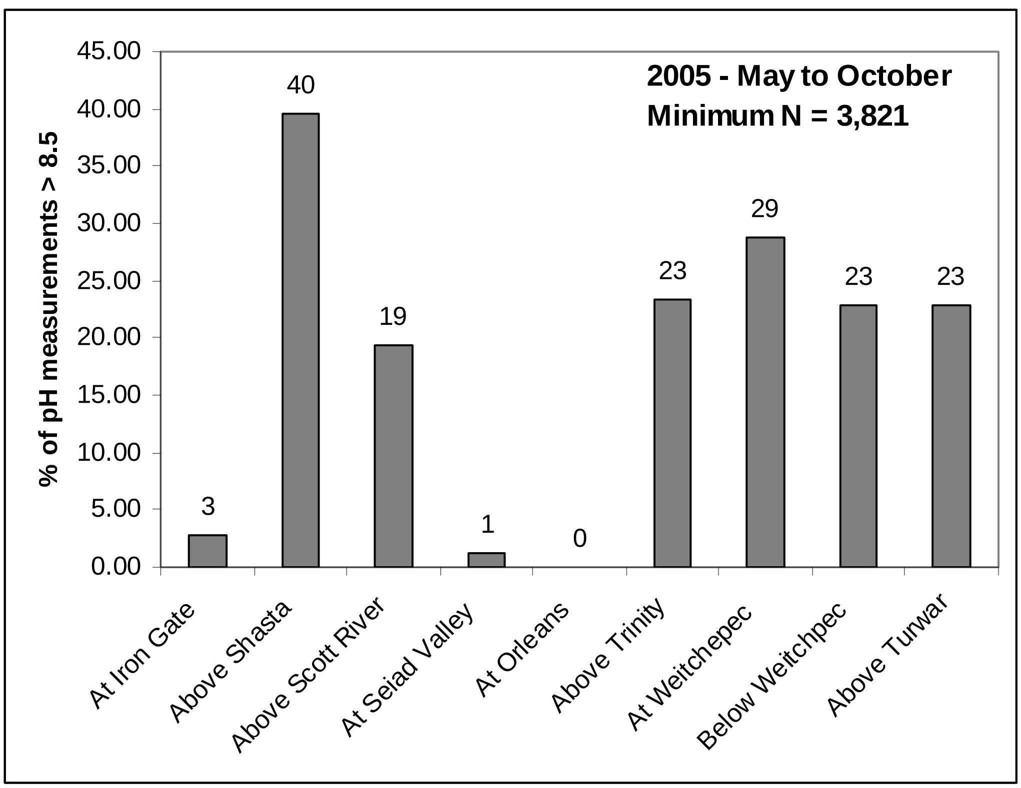


Figure 2.28: Percent of 2005 pH measurements in the Klamath River that exceed 8.5

2.5.7 Ammonia Toxicity

Regional Water Board staff evaluated all the data within our compiled Klamath River datasets in which all 3 parameters (pH, NH3, and temperature) were collected at the same time. Based upon the evaluation, there were no documented times in which acute or chronic aquatic life criteria for ammonia toxicity was exceeded.

To take this one step further, staff evaluated all the available pH and temperature data to determine what the concentration of ammonia would need to be in order for toxicity (acute or chronic) to be present. The results of that effort showed that acute toxicity probably does not occur on the Klamath River in California. However, the results showed that there are probably times when the chronic criteria are exceeded, but only for short durations of perhaps a few hours in a day a few days in a year. EPA guidance suggests that chronic criteria for the protection of aquatic life should be addressed over an averaging period of 4 days. Regional Water Board staff concludes that based on the available data, acute ammonia toxicity has not occurred in the times/years when data is available, and excursions of the chronic ammonia criterion probably only occur for short durations on a few days in a year and, if so, do not constitute an impairment of beneficial uses.

2.5.8 Sediment

The New Years Day flood of 1997 provided an example of some of the ways in which increased sediment loads affect stream temperatures in the Klamath River basin. A report by Klamath National Forest personnel (De La Fuente and Elder 1998) documenting the flood impacts within the Klamath National Forest reported 446 miles (20%) of channels that were significantly altered (i.e. with significant scouring, excessive sediment deposition, or riparian vegetation removal) by the flooding and associated sediment pulses of the 1997 flood. The report stated that "there appeared to be a considerable reduction in size, volume, and depth of pools in Elk, Indian, Beaver, Grider, Tompkins, South Fork Salmon, and Walker Creeks, and there is a larger proportion of fine sediment in the substrate. Alluvial reaches were made shallower and wider due to the sedimentation". The report found that approximately 30% to 60% of riparian vegetation was lost in the alluvial reaches of the most affected tributaries. These effects of increased sediment loads were observed in Elk, Indian, Ukonom, Independence, Grider, Oneil, Portuguese, Beaver, Horse, and Walker Creeks, as well as numerous other streams throughout the Klamath basin after the flood of 1997 (Figure 2.29) (De La Fuente and Elder 1998; Kier Associates 1999). The conclusions of the Klamath National Forest assessment are consistent with Regional Water Board staff observations.

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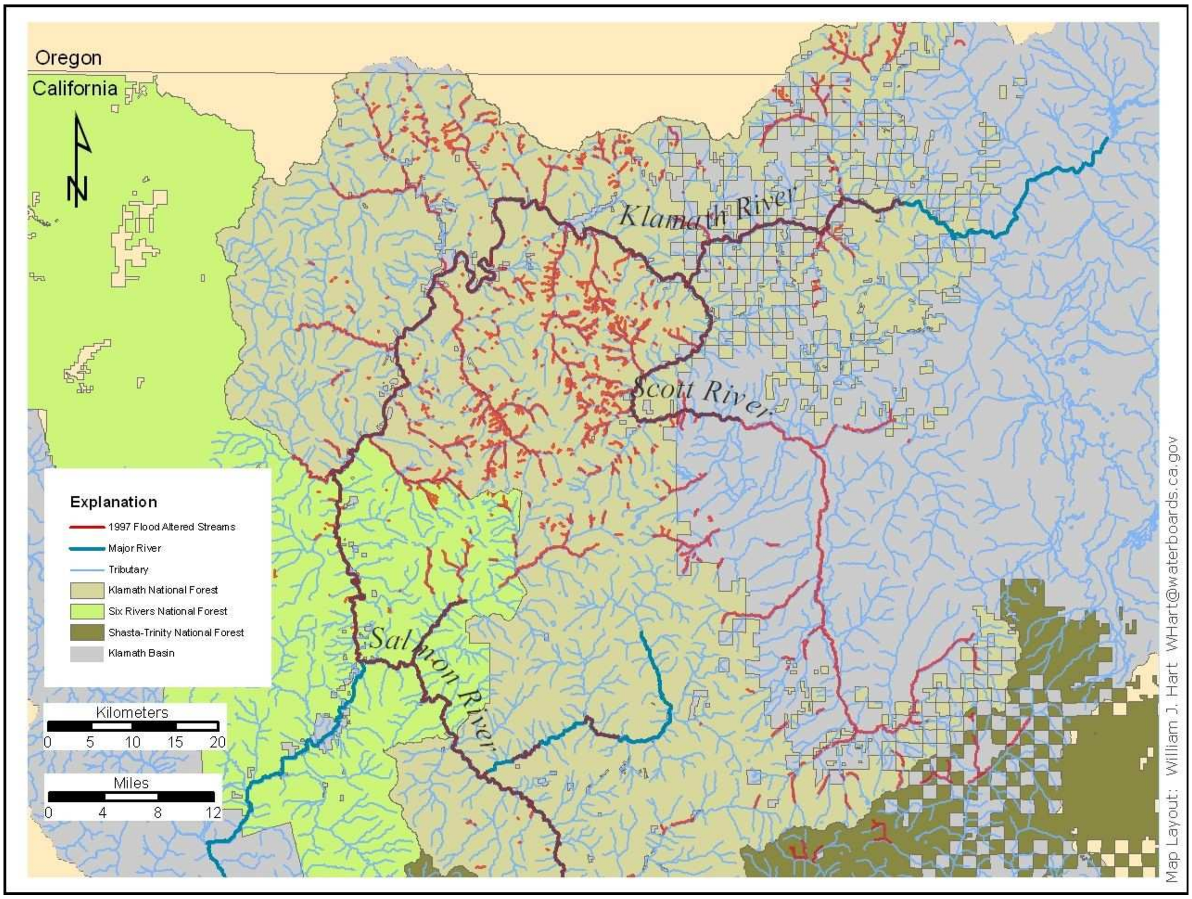

Figure 2.29: Mapped extent of stream channels substantially altered by sediment loads associated with the 1997 flood.
Source: De la Fuente and Elder 1998

The substantial changes in stream shade and channel dimensions that occurred as a result of the 1997 storm are believed to have significantly affected Klamath River tributary temperatures where they occurred. Unfortunately, little pre- and post-flood temperature comparisons are available to evaluate the changes in temperatures that resulted from the flood effects. However, a pre- and post-flood data set exists for one tributary, Elk Creek. De la Fuente and Elder presented a comparison of Elk Creek temperature data before and after the flood. The data showed that in the summer after the flood, the peak temperature was the highest of seven years of record, and was 3.8^{o}F higher than the average from 1990-1995. Likewise, the diurnal variation increased to12.5^{o}F, 4.9^{o}F higher than the 1990-1995 average. Furthermore, comparison of average air temperatures for the seven years show that 1997 was warmer (74.6 ^{o}F) than all years except 1994 (76.0 ^{o}F). The recorded low flow for 1994 was 16.1 cfs, whereas 1997 had the highest low flow of all the years measured (49.3 cfs). Despite higher air temperatures and lower flows in 1994, the instantaneous maximum temperature, 7-day maximum average, 31-day maximum average, and 31-day average diurnal variation were all lower compared to 1997 temperature data, as they were in all other years between 1990 and 1995 (no data are available for 1996). The fact that the season following the major changes in morphology and effective shade associated with the

1997 flood had higher temperatures, expressed in a variety of metrics, than the six years monitored prior to the flood, including a year with higher air temperatures and a fraction of the flow, strongly suggest that the temperature increase was a result of the effects of the flood.

The Final *Staff Report for the 2008 Integrated Report for the Clean Water Act Section 305(b) Surface Water Quality Assessment and the 303(d) List of Impaired Waters* (Regional Water Board 2009) was adopted by the Regional Water Board on June 3, 2009 and includes listings for sediment in 11 tributaries to the Klamath River in the area downstream of Iron Gate Dam to the confluence of the Trinity River. The portion of the Klamath River watershed from the Trinity River to the mouth of the Klamath is currently on the 2006 303(d) List for sedimentation/siltation impairment.

2.6 Evidence of Beneficial Use Impairment

Section 2.5 demonstrates that temperature, DO, biostimulatory substances, and related water quality objectives are not met at many locations at some times of the year in the Klamath River in California. Exceedance of these water quality objectives contributes to the impairment of a number of existing beneficial uses in the Klamath River. Evidence of impairment of the COLD, RARE, MIGR, SPWN, CUL, FISH, REC-1, REC-2, and MUN beneficial uses is presented in this section. This evidence of beneficial use impairment compels the need to develop TMDLs to address the temperature, DO, and nutrient water quality problems in the Klamath River.

2.6.1 Evidence of Impairment to Cold Freshwater Habitat (COLD), Rare, Threatened, or Endangered Species (RARE), Migration of Aquatic Organisms (MIGR), and Spawning, Reproduction, and/or Early Development (SPWN)

The COLD, RARE, MIGR, and SPWN beneficial uses are currently not fully supported in the Klamath River in California, as demonstrated by the decline of salmonid populations, adult and juvenile fish kills caused by disease outbreaks, migration barriers for adult and juvenile salmonids, and degradation of spawning habitat.

2.6.1.1 Salmonid Population Decline

Although historically there were large runs of salmonids in the Klamath River basin, current data indicate that populations have declined sharply since the early 1900's. Utilizing information from Snyder (1931), the NRC estimated that the annual total catch in the Klamath River during the period from 1916-1927 were probably 120,000 to 250,000 fish, and thus the number of potential spawners and total population numbers was considerably higher (NRC 2004, p.267, 268). In 2007, fall and spring Chinook population estimates were 132,167 and 12,628 respectively (CDFG 2008). No current estimate of steelhead and coho populations has been made, however, it is presumed that populations have declined dramatically from historic numbers (Brown and Moyle 1991, p.8; Brown et al. 1994; Busby et al. 1994 as cited by NRC 2004, p.274; CDFG 2002, p.1; NRC 2004, p.273). More detailed information on the decline of salmonid populations in the Klamath River basin can be found in Appendix 5, and brief summaries are presented below.

Fall Chinook Salmon

Fall Chinook numbers in the Klamath River basin have dramatically declined during the past century (Hardy et al. 2006, p.7). The Klamath River fall Chinook run once totaled as many as 500,000 fish annually (Moyle 2002, p.258). Fall Chinook numbers in the Shasta River basin alone historically numbered 20,000-80,000 fish per year (Regional Water Board 2006, p.1-25). Basin-wide fall Chinook population estimates for the period from 1978-2007 ranged from a high of 239,559 fish in 1987 to fewer than 35,000 fish in 1991 (CDFG 2008).

Spring Chinook Salmon

A population of more than 100,000 spring-run Chinook was once present in the basin, although this estimate is probably low because spring-run fish were the main run of Chinook in the Klamath mainstem in the 1800's (Moyle 2002, p.259). Historic run size estimates in each of the Sprague River, Williamson River, Shasta River, and Scott River alone were at least 5,000 fish (CDFG 1990 as cited by Moyle 2002, p.259). Population estimates for spring Chinook during the period from 1980-2006 ranged from a high of 69,004 fish in 1988 to fewer than 1,945 in 1983 (CDFG 2006).

Steelhead Trout

Hardy et al (2006, p.6) report that historical run sizes for steelhead trout in the Klamath River basin were estimated at "400,000 fish in 1960 (USFWS 1960 as cited by Leidy and Leidy 1984), 250,000 in 1967 (Coots 1967), 241,000 in 1972 (Coots 1972) and 135,000 in 1977 (Boydston 1977)." More recent run sizes are summarized below.

Spring/Summer Steelhead Trout

Annual counts of spring/summer steelhead in holding areas throughout the Klamath River basin ranged from 500 to 3,000 fish (Roeloffs 1983, as cited by Hopelain 1998, p.1). In the 1990's it was estimated that there were 1000-1500 spring/summer steelhead adults divided among eight populations in the basin (Barnhart 1994; Moyle et al. 1995; Moyle 2002 as cited by NRC 2004, p.274). NMFS considers spring/summer steelhead stocks depressed and in danger of extinction (Busby et al. 1994 as cited by NRC 2004, p.274).

Fall Steelhead Trout

The fall steelhead represent the largest of the three steelhead runs, and were estimated to include 55,000-75,000 spawning adults and 150,000-225,000 half-pounders during the period from 1980-1982 (D.P. Lee, CDFG, pers. comm. as cited by Hopelain 1998, p.1).

Winter Steelhead Trout

Run size estimates for Klamath River winter steelhead were 170,000 in the 1960s, 129,000 in the 1970s, and 100,000 in the 1980s (Busby et al. 1994 as cited by NRC 2004, p.273). Current population estimates for winter steelhead have not been conducted, although Hopelain (1998, p.1) estimated a run-size of about 5,000 to 25,000 during 1980-1982. It is presumed that winter steelhead abundance is still declining although estimates, both past and present, are not very reliable (NRC 2004, p.273).

Coho Salmon

It is clear from the information available that coho salmon populations statewide have undergone a dramatic decline from historic levels (Brown and Moyle 1991, p.8; Brown et al. 1994; CDFG 2002, p.1). Maximum estimates for coho spawners in California during the 1940's range from 200,000-500,000 fish (Sagar and Glova 1988 as cited by Moyle 2002, p.250). Brown et al. (1994) state that California coho populations are probably less than 6% of what they were in the 1940s, and there has been at least a 70% decline since the 1960s. In 1994, Brown et al. estimated the coho salmon population in California to be 30,000 fish, with natural spawners comprising 43% of the total population or 13,240 fish.

The Southern Oregon/Northern California Coast Evolutionary Significant Unit (SONCC ESU), which encompasses Klamath River stocks, has been listed as threatened by the State of California and the Federal government. Coho salmon occupy only 61% of the SONCC ESU streams previously identified as historical coho salmon streams (CDFG 2002, p.2).

Historical spawning escapement estimates for the Klamath River basin approximate 15,400-20,000 coho, with 8,000 of these fish originating in the Trinity River (USFWS 1979, App. as cited by Brown et al. 1994). In 1965, CDFG estimated 15,400 coho spawners per year in the basin (CDFG 1965, p.369). In 1994, Brown et al. estimated a total abundance of 18,125 coho in the Klamath River, including 1,860 native and naturalized fish. Current population estimates for coho in the Klamath River basin have not been conducted, although adult coho return numbers to the Iron Gate Hatchery, Trinity River Hatchery, and Shasta River Fish Counting Facility during the last 42 years averaged 5949 fish (Hampton 2004, p.1; Hampton 2005a, p.1; Hampton 2005b; KRIS 2006; Marshall 2005; and Rushton 2005).

2.6.1.2 Juvenile and Adult Fish Kills

Poor water quality conditions in the Klamath River have resulted in both adult and juvenile fish kills reflecting an impairment of the COLD and RARE beneficial uses. Figure 2.30 identifies the mainstem Klamath River reaches in California where adult and juvenile fish kills have been documented.

It is believed that juvenile fish kills are very common in the Klamath River from Iron Gate Dam to the mouth of the river but often go undetected. Direct observation of juvenile fish kills is not common due to the small size of the juvenile fish within the large river system and the generally small number of outmigrant traps that operate in the river (Klamath Fish Health Assessment Team [KFHAT] 2005, p.5, 6).

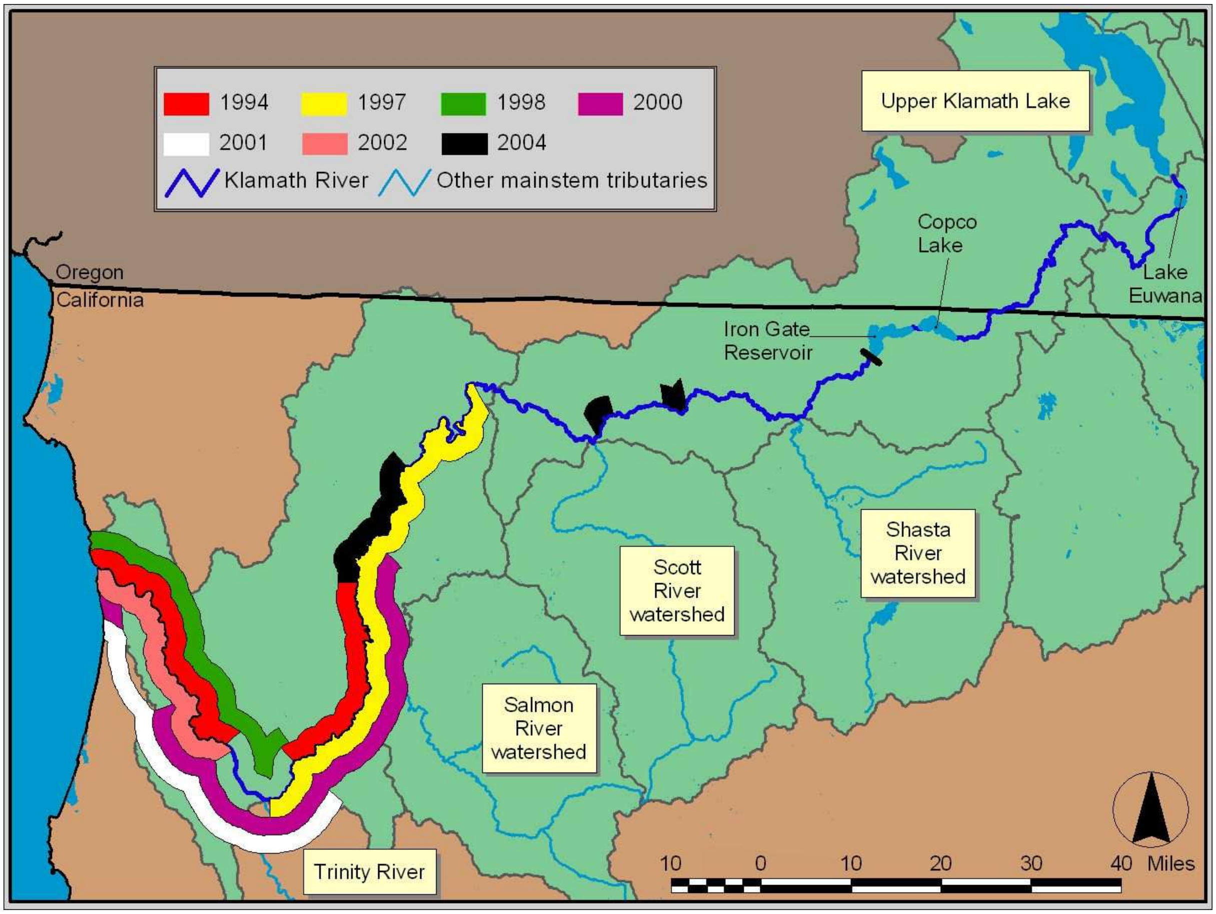

Figure 2.30: Fish kill years and locations in the Klamath River in California

Juvenile fish kills in the Klamath River in California have been documented for the years 1994, 1997, 1998, 2000, 2001, and 2004 (Table 2.15). Estimates of the number of dead fish range from 269-300,000 juvenile salmonids and non-salmonids. Disease was the ultimate cause of death in all juvenile fish kills documented. The effects of disease were exacerbated by poor water quality conditions, including low DO, high water temperature, extreme pH fluctuations, and low flow. Temperatures documented during these fish kills were as high as 25 ^{o}C, well above the lethal threshold for juvenile salmonids. Additionally, DO levels as low as 3.1 mg/L were recorded during these fish kills, which is well below the current Basin Plan objective of 8 mg/L.

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Table 2.15: Juvenile fish kill locations and causes in the Klamath River in California

Year	River Location	Fish	Cause of Death	Exacerbating Factors				Citations
				D.O.	Temp	NH_3	Flow	
1994	middle/ lower	~300 Chinook	None stated		X			Foott (2005) USFWS (1997)
1997	Middle	non-salmonids salmonids	Disease	X	X	X	X	Hannum (1997) Hendrickson (1997) USFWS (1997)
1998	Various	~240,000 Chinook	Disease	X	X		X	Williamson and Foott (1998)
2000	middle/ lower	10,000-300,000 Chinook & steelhead	Disease	X	X			CDFG (2000, p.1, 10, 11), Deas (2000), Foott (2000), USFWS (2003a)
2001		269 Chinook[1]	Disease					Foott et al. (2002)
2004	upper/ middle	>250,000 Chinook	Disease		X			Engbring (2004) KFHAT (2005) Klamt and Carter (2004)

[1] It is likely that the peak of the disease epizootic and associated mortalities of juvenile Chinook likely occurred prior to when KFHAT conducted their reconnaissance surveys, and thus the actual number of dead fish was much higher (KFHAT 2005).

Documentation of adult fish kills in the Klamath River in California is available for 1997 and 2002 (Table 2.16). The 1997 fish kill was determined to be caused by Columnaris and other diseases and was exacerbated by maximum water temperatures around 26°C, low DO levels of 3.1 mg/L, and low flows (Hannum 1997; Hendrickson 1997).

Table 2.16: Adult fish kill locations and Causes in the Klamath River in California

Year	River Location	Fish	Cause of Death	Exacerbating Factors					Citations
				D.O.	Temp	NH_3	Flow	Sediment	
1997	middle	>50/day non-salmonids	Disease	X	X	X	X		Hannum (1997) Hendrickson (1997) USFWS (1997)
2002	lower	>34,000 (including >33,500 salmonids)	Disease		X		X	X	USFWS (2003a) USFWS (2003b) CDFG (2004)

In mid to late September 2002 at least 34,000 fish died in the lower 36 miles of the Klamath River, although actual losses may have been more than double this number (CDFG 2004, p.III). Approximately 98.4% (33,527) of the fish killed were anadromous salmonids, representing 19.2% of the total 169,297 Klamath-Trinity run for 2002 (USFWS 2003b p.ii).

Multiple compounding factors likely contributed to the 2002 fish kill, including an early large run of fall Chinook, low river discharge which did not provide suitable attraction flows to trigger upstream migration, and warm water temperatures which were optimal for disease proliferation (CDFG 2004, p.III, 33, 124; USFWS 2003a, p.ii). Additionally, fish passage through the lower Klamath River may have been impeded by the shallow depth of the water flowing over some riffles, which were created by sediment deposition during high discharge events in the winters of 1997 and 1998 (CDFG 2004, p.III; USFWS 2003a, p.37). The majority of the dead fish examined were infected with the fish diseases *Ichthyophthiriasis* (Ich) and Columnaris, which was identified as the principal cause of death (CDFG 2004, p.III; USFWS 2003a, p.ii). Maximum daily water temperatures recorded at Turwar (RM 7) during September ranged from 18-23°C (CDFG 2004, p.70). Seven-day running averages of the weekly maximum temperature (MWMT) during this period ranged from 19-22.5°C (CDFG 2004, p.70), which exceeds the USEPA (2003) MWMT threshold values of 16°C (adult migration/core juvenile rearing), 18°C (adult migration/non-core juvenile rearing), and 20°C (adult migration). Although these high water temperatures are not unusual for the Klamath River, they are ideal for disease proliferation and thus contributed to a disease epizootic (the equivalent of an epidemic in humans) (CDFG 2004, p.III, 124; USFWS 2003a, p.ii).

2.6.1.3 Adult and Juvenile Salmonid Migration Barriers and Spawning and Rearing Habitat Degradation

Unless otherwise specified, the following information is from CDFG 2004 (p.III, 83), Hardy et al 2006 (p.10, 15, 20), and USFWS 2003a (p.ii, 36).

Poor water quality conditions are contributing to the impairment of migration (MIGR) of aquatic organisms, particularly salmonids. Section 2.4.4.1 summarized findings by Strange (2007) that adult fall Chinook salmon migration is dependent on stream temperature. As shown in Section 2.5.2, Klamath River mainstem and tributary water temperatures during the period of fall Chinook migration are often over the temperatures noted by Strange (2007) that inhibit upstream migration. Thus elevated water temperatures contribute to the impairment of MIGR.

Alterations in flow in the Klamath River basin have contributed to the degradation of salmonid spawning and rearing habitat (SPWN). Principal factors affecting anadromous fish production in the Klamath River from Iron Gate Dam to Weitchpec include impaired flow in some tributaries (particularly the Shasta and Scott Rivers), impaired flows in the mainstem, and alterations to the timing and magnitude of mainstem flows. One of the primary limiting factors for anadromous fish production in the Klamath River from Weitchpec to the mouth is the cumulative effect of impaired flow and alterations in the seasonal hydrograph. These impacts have contributed to the degradation of available spawning gravel from sedimentation (Hardy et al 2006, p.20).

Cumulative impacts resulting in sediment delivery to many tributaries of the Klamath River in California have contributed to the formation and persistence of large delta fans at many tributary confluences, impeding adult and juvenile migration (MIGR). In low flow years, this accumulation of sediment can inhibit or block access to these tributaries, thereby restricting access to habitat and thermal refugia for migrating adult and juvenile salmonids. Salmonids that are unable to enter the tributaries are forced to seek space in the limited areas of thermal refugia in the mainstem Klamath River. Overcrowding of salmonids in mainstem thermal refugia areas, combined with the high water temperatures can exacerbate disease proliferation.

As mentioned in the previous section, there is evidence that conditions inhibiting adult migration may have contributed to the 2002 adult fish kill in the Klamath River. USFWS reported that in 2002 Klamath River flows were too low to trigger upstream migration, causing adults to congregate in the lower river. After the fish kill was underway the U.S. Bureau of Reclamation increased flows, and salmonids responded by migrating out of the lower river. CDFG hypothesized that fish passage may have been impeded by shallow water depth over certain riffles.

> CDFG…reported that in 1997 and 1998 high discharge events occurred in northern California that could have altered the channel of the Klamath River. They suggested that the input of high sediment loads during high discharge events could have resulted in the filling of pools and increased the elevation of riffles in the lower Klamath River. Furthermore, they speculated that discharges that may have been sufficient for fish passage in low discharge years prior to 1997 were inadequate for passage in September 2002 (CDFG 2003b, as cited by USFWS 2003a, p.37).

Additionally,

> USFWS biologists working on the lower Klamath River [in September of 2002] observed low-flow conditions, making it more difficult to traverse shallow riffles in a jet boat than in previous years (Shaw 2002, personal communication). They observed that water depth at Pecwan and Ah Pah riffles appeared shallow enough to be an impediment to adult fish passage. Yurok biologists also observed that fish passage over some riffles was confined to multiple small channels, in which their jet boat with a six-inch draft, would occasionally touch bottom (Belchik 2003, personal communication). A former NMFS fisheries biologist (Gilroy 2003, personal communication) with experience working on the Klamath river suggested when flows are low, fish passage over certain riffles is confined to smaller channels, representing the main thalweg and much of the riffle is too shallow to pass fish. The DFG Fisheries Biologist, who has participated in angler surveys on the Klamath River since 1985, described water levels during September 2002 in the fish-kill area as the lowest she has observed in over 20 years of experience (Borok 2003, personal communication). These anecdotal observations raised concern that shallow water depth over certain riffles might have impaired the ability of salmon and steelhead to migrate upstream (CDFG 2004, p. 87).

Thus, alterations in flow and changes in channel conditions resulting from sedimentation in the mainstem Klamath River in California have contributed to the impairment of MIGR and SPWN.

2.6.2 Impairment of Native American Culture (CUL) and Subsistence Fishing (FISH) Beneficial Uses

The Water Quality Control Plan for the North Coast Region (Basin Plan) includes two Native American Cultural beneficial uses; Native American Culture (CUL) and Subsistence Fishing (FISH). The CUL beneficial use covers "uses of water that support the cultural and/or traditional rights of indigenous people such as subsistence fishing and shellfish gathering, basket weaving and jewelry material collection, navigation to traditional ceremonial locations, and ceremonial uses"; FISH encompasses "uses of water that support subsistence fishing" (Regional Water Board 2007). CUL is designated as an "Existing" use in the Ukonom, Happy Camp, Seiad Valley, Klamath Glen, and Orleans Hydrologic Subareas of the Klamath River. Due to a lack of available information at the time of the last update of the Basin Plan, no waterbodies in the North Coast have been designated as "Existing" or "Potential" use for FISH. Based on the available information, however, Regional Water Board staff consider FISH an existing use within the same Hydrologic Subareas of the Klamath River as those designated CUL.

Given the scope of the CUL and FISH uses within the Klamath River basin in California, support of these uses is closely interrelated with the uses associated with the cold freshwater salmonid fishery (i.e. COMM, COLD, RARE, MIGR, and SPWN), as well as with the water contact and drinking water uses (REC-1 and MUN). The CUL and FISH beneficial uses in the Klamath River in California is currently impaired due to the decline of salmonid populations and degraded water quality resulting in changes to or the elimination of ceremonies and ceremonial practices and risk of exposure to degraded water quality conditions during ceremonial bathing and traditional daily activities. The FISH beneficial use is currently impaired in the Klamath River basin in California due to the decline of salmonid populations and other Tribal Trust fish populations resulting in decreased use, abundance, and value of subsistence fishing locations, altered diet and associated physical and mental health issues, and increased poverty. Additionally, the presence of the toxin microcystin in fish and mussels in the Klamath River has the potential to impair both the CUL and FISH beneficial uses. It is important to note that other beneficial uses, such as COLD and MUN, are linked to the support of the CUL and FISH beneficial uses throughout the year.

2.6.2.1 <u>Decline in Salmonid and Other Fish Populations</u>

The decline of salmon populations, as well as the decline of other Tribal Trust fish species of the Klamath River basin in California including sturgeon, eulachon (candlefish), lamprey (eel) and some species of suckers, has impaired the CUL and FISH beneficial uses. The elimination of the spring Chinook run above the Salmon River has resulted in the elimination of cultural ceremonies associated with the migration of this species through the length of the Klamath River. Declines in fish populations, especially salmonids, has also resulted in decreased use, abundance, and value of subsistence fishing locations, an altered daily diet that has been linked to health issues for Tribal Members, and increased poverty.

An elaborate ceremony, called the First Salmon Ceremony, marks the passing of the first spring Chinook salmon up the Klamath River. This migrating salmon was allowed to pass all the way up the Klamath River to its spawning ground. It was believed that the first spring Chinook migrating upstream would leave its scales at each spawning location for the rest of the salmon run to follow (Roberts 1932 as cited by Sloan 2003, p. 25). This first migrating salmon of the year was considered taboo, and if eaten would cause convulsions and death. Thus, the First Salmon Ceremony allowed this fish to pass safely upstream, thereby lifting the taboo, and allowing the Native People to fish for salmon in the river (Waterman and Kroeber 1938 as cited by Sloan 2003, p.25). The dramatic decline in the spring Chinook run has made it impossible for the Klamath River Tribes to conduct the First Salmon Ceremony. "And how do you perform the Spring Salmon Ceremony, how do you perform the First Salmon Ceremony, when the physical act of going out and harvesting that first fish won't happen?"(Leaf Hillman 2004 as cited by Norgaard 2005, p.35).

The Karuk Tribe historically depended on the abundant populations of fish found in the mainstem Klamath River for subsistence. However, as fish populations have declined the Karuk have shifted their diets to other food sources (Reed 2007a). Ron Reed (2005), traditional dipnet fisherman and cultural biologist for the Karuk Tribe, states that there is only one remaining Tribal fishery location that provides any level of subsistence fishing to the Karuk Tribe, Ishi Pishi Falls. According to Reed (2005), in 2002, about 1,500 fish were caught at Ishi Pishi falls, in 2003 approximately 1,000 fish were caught, and in 2004 only 100 fish were harvested at this location. The limited harvest of fish at Ishi Pishi Falls has meant that even ceremonial salmon consumption is limited (Ron Reed Pers. Comm. as cited by Norgaard 2005, p.4). According to Norgaard (2006), in addition to declining salmonid numbers, the fishery at Ishi Pishi Falls is negatively affected by low flows. When flows are too low the ability to perform dip net fishing is limited and fewer fish are caught (Norgaard 2006).

The importance of fishing to Tribal Members is reflected by the fact that fishing locations are a form of real property (Pierce 2002, p.7-2; Sloan 2003, p.17). They can be owned by individuals, families, or a group of individuals, and can be borrowed, leased, inherited, and bought and sold (Sloan 2003, p.17, 18). The quality, use, and value of these fishing locations has been reduced as changes including increased siltation and decreased salmonid abundance have occurred in the Klamath River and its tributaries (Sloan 2003, p.18, 28).

Historically, the Karuk Tribe had a platform fishery associated with each of their 100 Tribal village sites (Reed 2006). These fisheries were located near the tops of riffles, where eddies were created along the margins of the Klamath River. These areas of low velocity were where the salmon would hold and/or utilize this microhabitat as a migration corridor. According to Reed (2006) these 100 platform fishery locations are no longer as productive as they once were, or are gone. Tribal elders convey that the riffles near these fishing areas have been filled in and flattened out by sediment, contributing to the decline in overall fish populations (Reed 2006), as well as contributing to the loss of a culturally significant way of life.

The decline of salmonids and other Tribal Trust fish populations in the Klamath River basin has altered the diet of each of the Tribes along the river and its tributaries. Historically, traditional consumption of fish by the Karuk Tribe was estimated at 450 pounds per person per year, while in 2003 the Karuk People consumed less than 5 pounds of salmon per person per year, and in 2004 less than ½ pound per person per year was consumed (Norgaard 2005, p.13). In 2005 over 80% of Karuk households surveyed reported that they were unable to harvest adequate amounts of lamprey (eel), salmon or sturgeon to fulfill their family needs (Norgaard 2005, p.4). Furthermore, 40% of Karuk households reported that there are fish species that their family historically caught, which are no longer harvested (Norgaard 2005, p.7).

The decrease in abundance and availability of traditional foods, including salmon, trout, eel, shellfish, sturgeon and riparian plants, is responsible for many diet related illnesses among Native Americans including diabetes, obesity, heart disease, tuberculosis, hypertension, kidney troubles and strokes (Joe and Young 1993 as cited by Norgaard 2005, p.9, 39). These conditions result from the lack of nutrient content in foods consumed in place of the traditional foods such as salmon, as well as from the decrease in exercise associated with fishing and gathering food (Norgaard 2005, p.40). The estimated diabetes rate for the Karuk Tribe is 21%, nearly four times the U.S. average, and the estimated rate of heart disease for the Karuk Tribe is 39.6%, three times the U.S. average (Norgaard 2005, p.40).

In addition to altered diet and increased health issues, declines in fish populations have resulted in a documented increase in poverty rates for some Klamath River Tribes.

> The destruction of the Klamath River fishery has led to both poverty and hunger. Prior to contact with Europeans and the destruction of the fisheries, the Karuk, Hupa and Yurok tribes were the wealthiest people in what is now known as California. Today they are amongst the poorest. This dramatic reversal is directly linked to the destruction of the fisheries resource base.
>
> The devastation of the resource base, especially the fisheries, is also directly linked to the disproportionate unemployment and low socio-economic status of Karuk people today. Before the impacts of dams, mining and over fishing the Karuk people subsisted off salmon year round for tens of thousands of years. Now poverty and hunger rates for the Karuk Tribe are amongst the highest in the State and Nation. The poverty rate of the Karuk Tribe is between 80 and 85% (Norgaard 2005 Exec Summary).

2.6.2.2 Degraded Water Quality

Degraded water quality in the Klamath River basin in California, including the seasonal presence of blue-green algae and algal toxins in the Klamath River and reservoirs (see Section 2.5.4), has impaired the CUL and FISH beneficial use. Known and/or perceived health risks associated with degraded water quality have resulted in the alteration of cultural ceremonies to exclude or limit ingestion of river water. Additionally, known or perceived risk of exposure to degraded water quality conditions during ceremonial bathing and traditional cultural activities such as bathing, gathering and preparing basket materials, and collecting and using plants has resulted in an impairment of CUL.

The presence of blue-green algae and algal toxins in the Klamath River and reservoirs has impaired the cultural practice of subsistence fishing. The Karuk Tribe has only one fishing location available to them and it is flow dependent. Thus, when fish are in the river and the flow is suitable for fishing, Tribal Members must fish even if blue-green algae and algal toxins are present in the river. Susan Corum, Water Resources Coordinator for the Karuk Tribe, states: “It is really not a choice to fish. It is part of their culture which they need to maintain (Corum 2007).”

Microcystin has been identified in the waters of Klamath River, as well as in the liver of salmonids and in mussels from the river. Laboratory analyses detected a trace of microcystin in the liver of an adult steelhead, and 0.54 µg/kg in the liver of a half-pounder steelhead landed in the Klamath River at Weitchpec on October 3, 2005. Although these levels are not above the 250 µg/kg threshold which is advised by Van Buynder et al. (2001) to protect human health, the Yurok Tribe has expressed concern that the mid to late summer blooms of *Microcystis* in the Klamath River generally coincides with increased salmonid upstream migrations and subsequent usage of salmonid meat for recreational, cultural, and sport purposes. Mussels in the Klamath River have also had detectable levels of microcystin found in them. In 2007, a mussel was found in the Klamath River containing >1500 µg/kg microcystin, over the threshold to protect human health advised by Van Buynder et al. (2001). Additionally, upon review of the 2007 data, OEHHA recommended against consuming mussels from the affected sections of the Klamath River and yellow perch from Iron Gate and Copco Reservoirs due to their high concentrations of microcystin (OEHHA 2008). The presence of microcystin in salmonids and mussels of the Klamath River has resulted in an impairment of the cultural practice of subsistence fishing.

The Klamath River Tribes practice their culture through their “World Renewal” ceremonial cycle, such as the “First Salmon Ceremony” and Jump Dance, the Boat Dance, the War Dance, and the White Deerskin Dance (Reed 2007b). Other Tribal ceremonies and rituals include the Brush Dance and the Flower Dance, as wells as other rituals that require a spiritual cleansing process such as for fishing and hunting, funerals, and good luck (Reed 2007b). All of these ceremonies and rituals require Tribal members to be in close proximity to the Klamath River and they are integrally linked to the river and its health (Sloan 2003 p.18).

According to Karuk Cultural Biologist Ron Reed (2006, 2007b), the “World Renewal” ceremonial cycle is held on the Klamath River at Amerikirum (approximately 2 miles below Somes Bar), Clear Creek (Inam), Somes Bar (Katimin), and Orleans (Panamnik) starting in April and continuing through September of each year. The Medicine Man, who leads the ceremony at Clear Creek, walks 14 miles through the ridges and hills along the Klamath River and is joined halfway through his journey by children and adults of the

Tribe who follow him the rest of the way for good luck. Upon reaching the Klamath River at the end of this walk, it was historically tradition to drink water from the river to complete the ceremony. This is no longer done due to health concerns about drinking water directly from the river, though children are still known to jump in and drink the water (Reed 2006).

Ceremonial bathing in the river is an important part of most ceremonies (Curtis 1924 as cited by Sloan 2003, p.28). For example, bathing in the Klamath River and its tributaries is a requirement for participants in the Brush Ceremony (Sloan 2003, P.16). "During the Fish Dam Ceremonies at *Kepel*, young girls were selected by the Medicine Man to participate in the ceremonies. Once selected, they were sent to the river to bathe and then were dressed in full regalia which they would wear during the ceremonies. Then they were sent home to their families, and were required to fast and bathe in the river every day" (Van Stranlen 1942 as cited by Sloan 2003, p. 28). During the World Renewal Ceremonies, the Medicine Man and other participants bathe in the Klamath River for up to 10 days (Reed 2006).

Bathing is also associated with funeral services, subsistence practices, recreational swimming, courtship, and for individual hygiene (Reed 2007a). Bathing associated with funeral rituals occurs year round and includes preparation for burial, and purification after burial (Curtis 1924 as cited by Sloan 2003, p.28). The Karuk Tribe historically bathed freely in the Klamath River, however in more recent years degraded water quality conditions during the summer have forced them to take precautionary steps while bathing in the river (Reed 2007a). The Yurok Tribe has reported that detached algae have been present in the Klamath River in amounts high enough to prevent access and negatively affect the spirituality associated with bathing areas (McKernan 2006).

Willow roots, wild grape, Cottonwood, and Oregon Grape are collected by Tribal Members in the riparian zone of the Klamath River and used to make baskets (Reed 2007a). Traditional collection of these basketry materials often involved wading in the water (Sloan 2007a), and further contact occurs when the material is washed and cleaned in the water (Reed 2007a). Additionally, willow roots are peeled by mouth following cleaning with river water (Reed 2006). In addition, plants are collected for food, medicine, materials, and other cultural functions (Reed 2007a). Gathering plants or plant materials involves wading and contact with the Klamath River (Sloan 2007a; Reed 2007a). Ingestion of water can occur because plants are often cleaned in the river water and water is consumed with medicinal plants (Sloan 2007a). Given degraded water quality conditions, ingestion of water may pose a potential health risk.

Table 2.17 provides a summary of the activities that are encompassed by the CUL and FISH beneficial uses. Table 2.17 also denotes when those activities occur during the year, and the footnotes identify the amount of physical contact with the water associated with each of these activities. This table is not comprehensive, but conveys the magnitude and diversity of activities that are covered under these uses. Based on the information presented, Regional Water Board staff find that the CUL and FISH beneficial uses of the Klamath River in California are not being fully supported.

Table 2.17: Karuk, Yurok, and Quartz Valley Tribes cultural beneficial uses (CUL and FISH) of the Klamath River and tributaries[4]

Resource	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
CUL												
Plants[1,3]	■	■	■	■	■	■	■	■	■	■	■	■
Fish[1]	■	■	■	■	■	■	■	■	■	■	■	■
Fishing[1,2]	■	■	■	■	■	■	■	■	■	■	■	■
Water-drinking, steaming, cooking[1,3]	■	■	■	■	■	■	■	■	■	■	■	■
Rocks[1]	■	■	■	■	■	■	■	■	■	■	■	■
Bathing[2]	■	■	■	■	■	■	■	■	■	■	■	■
Boating[1,2]	■	■	■	■	■	■	■	■	■	■	■	■
Wildlife[1]	■	■	■	■	■	■	■	■	■	■	■	■
Hunting & Trapping[1]	■	■	■	■	■	■	■	■	■	■	■	■
River & Trail Access[1]	■	■	■	■	■	■	■	■	■	■	■	■
Training[2]	■	■	■	■	■	■	■	■	■	■	■	■
Swimming[2]				■	■	■	■	■	■	■		
Prayer & Meditation[1]	■	■	■	■	■	■	■	■	■	■	■	
Fish Dam[1,2]							■	■	■			
Washing[1]	■	■	■	■	■	■	■	■	■	■	■	■
Meditation[1]	■	■	■	■	■	■	■	■	■	■	■	■
Wood Gathering[1]	■	■	■	■	■	■	■	■	■	■	■	■
Tanning Hides[1]	■	■	■	■	■	■	■	■	■	■	■	■
Roots[1,3]	■	■	■	■	■	■	■	■	■	■	■	■
Sticks, Shoots & Bark[1]	■	■	■	■	■	■	■	■	■	■	■	■
Weaving[1]	■	■	■	■	■	■	■	■	■	■	■	■
Shells[1]	■	■	■	■	■	■	■	■	■	■	■	■
World Renewal Ceremonial Cycle[2,3]				■	■	■	■	■	■			
FISH												
Plants[1,3]	■	■	■	■	■	■	■	■	■	■	■	■
Fishing[1,2]	■	■	■	■	■	■	■	■	■	■	■	■
Eeling[1,2]	■	■	■	■	■							
Shellfish[1,2]						■	■	■				
Water-drinking, steaming, cooking[1,3]	■	■	■	■	■	■	■	■	■	■	■	■
Rocks[1]	■	■	■	■	■	■	■	■	■	■	■	■
Bathing[2]	■	■	■	■	■	■	■	■	■	■	■	■
Boating[1,2]	■	■	■	■	■	■	■	■	■	■	■	■
Wildlife[1]	■	■	■	■	■	■	■	■	■	■	■	■
River & Trail Access[1]	■	■	■	■	■	■	■	■	■	■	■	■

Sources: Bowman 2006; Norgaard 2006; Reed 2007a, Reed 2007b; Sloan 2007a, Sloan 2007b

■ Indicates time of use.

1-Wading, 2-Full submersion, 3-Ingestion of water

4-Tributaries utilized by the Tribes of the Klamath River for cultural purposes include many of those from the Scott River down to the mouth of the Klamath river. Additionally, the Quartz Valley Tribe utilized all tributaries which flow into the Scott and Shasta Rivers. Tributaries considered as having cultural beneficial uses include any tributary that provides spawning or rearing, or provides a migration pathway for Tribal Trust species.

Note: This table is not an exhaustive list of all activities covered under the CUL and FISH beneficial uses.

2.6.3 Impairment of Water Contact Recreation (REC-1), Non-Contact Water Recreation (REC-2), and Municipal and Domestic Supply (MUN)

Toxigenic blue-green algae blooms and their associated toxins measured in Copco and Iron Gate Reservoirs and in select reaches of the Klamath River downstream from the reservoirs are periodically impairing the Water Contact Recreation (REC-1) and Non-Contact Water Recreation (REC-2) beneficial uses. Additionally, the toxins have the potential to impair Municipal and Domestic Supply (MUN) beneficial use in the Klamath River.

2.6.3.1 Recreational Impacts

The available data on blue-green algae and toxin concentrations in the Klamath River and reservoirs are presented in Section 2.5.4. Water contact recreation (REC-1) during swimming, diving, and other direct water contact presents a high risk of exposure to inhalation or ingestion of cyanotoxins in waters contaminated with *Microcystis aeruginosa* (or other toxigenic species). Blooms of *Microcystis* and the presence of its cyanotoxin, microcystin, have prompted health advisories by the California Department of Health Services as well as the posting of on-site warnings for the public to avoid contact or use caution during water contact recreational activities in Iron Gate and Copco Reservoirs and some reaches of the river since 2005.

The presence of elevated *Microcystis* and microcystin concentrations in Iron Gate and Copco Reservoirs during August 2005 prompted the Regional Water Board cooperating with the State Water Board, USEPA, and Karuk Tribe to issue a joint press release (State Water Board 2005) warning of the potential adverse health effects to persons recreating in waterbodies of the Klamath River system contaminated with noticeably excessive algal concentrations. The Siskiyou County Health Department also issued a health advisory warning people about elevated toxin levels in Copco Reservoir. Additionally, warning signs were posted at key recreational access facilities around Iron Gate and Copco Reservoirs by the Regional Water Board.

During mid-August 2006, large blooms of *Microcystis aeruginosa* and high concentrations of microcystin led the Regional Water Board, Karuk Tribe, State Water Board, and USEPA to issue another press release, again warning recreational water users and other area residents to use caution when near the reservoirs, or avoid water contact recreation altogether in locations with noticeable blue-green algal blooms in Copco and Iron Gate Reservoirs (State Water Board 2006). The Siskiyou County Health Department also issued a public health advisory for Iron Gate and Copco Reservoirs in 2006 (Siskiyou County Public Health Department 2006). In early September 2006 the Regional Water Board posted warning signs at prominent recreational access points in both reservoirs reiterating the cautionary advisories contained in the earlier press release. In addition to these postings at the reservoirs, the Yurok Tribe posted health advisory signs along the mainstem Klamath River within the reservation borders (Fetcho 2006).

Microcystis scums were present in Iron Gate and Copco Reservoir beginning in mid- to late-June 2007 at concentrations that prompted the Regional Water Board to post precautionary health advisory signs at boat launches, campgrounds, swimming areas, and other high traffic, recreational use access points along the shorelines of the reservoirs. Shortly after the posting of the two reservoirs the USEPA as lead agency, with a number of state agencies, and the Yurok and Karuk Tribes issued a joint press release on July 5, 2007 advising the public to use caution when recreating at the two reservoirs (USEPA 2007). In August 2007, Microcystis cell counts in the mainstem Klamath River exceeded the Blue Green Algae Work Group's guidelines for posting health advisories. Consequently, Regional Water Board staff posted precautionary health advisory signs at 24 locations along the mainstem Klamath River from the sport fishing access point at Iron Gate Hatchery to the Aikens Creek Campground.

2.6.3.2. <u>Health Impacts</u>

Blooms of *Microcystis aeruginosa*, and subsequent releases of its cyanotoxin, microcystin, during the summer and early fall in the mainstem Klamath River have the potential to impair the municipal and domestic supply (MUN) beneficial use. The State Water Board's Department of Water Rights Information Management System (WRIMS 2006) shows numerous existing water rights that utilize in-river water withdrawals for sources of domestic drinking water and other uses. Nearly all of the water rights are located downstream from Iron Gate dam. The location, engineering, and timing of water withdrawals, as well as the magnitude and velocity of streamflow are factors that affect the possibility of entraining blue-green algae and their toxins in water supplies.

There have been no documented human health impacts due to drinking or recreating in Klamath River water during *Microcystis* blooms. However, the presence of the toxin during periods when water withdrawls are occurring and when people are recreating, presents the possibility that human health impacts could occur.

In August of 2007, a dog became very ill a few hours after swimming in Copco Reservoir and drinking the water during a *Microcystis* bloom (Tobler 2007). The sick dog was taken to the vet and tests showed elevated levels of several enzymes indicative of liver disease. Microcystin is a liver toxin, and is capable of producing this type of an enzymatic response.

2.6.3.3. <u>Aesthetic Impacts</u>

Visible scums formed by the presence of *Microcystis aeruginosa* and other blue-green algae in Copco and Iron Gate Reservoirs present an aesthetic nuisance, potentially impacting the aesthetic enjoyment (REC-2) of these reservoirs. A study conducted by CH2M Hill for PacifCorp compiled interviews and survey responses of recreational water users about their experiences at locations along the Klamath River, including Copco and Iron Gate Reservoirs (PacifiCorp 2004a). Interviewees' responses showed that water condition during the summer to early fall seasons has affected the quality and enjoyment of their experiences. The survey did not link responses to a specific time period; however, nearly all of the concerns expressed by respondents pertained to the summer and early fall recreational seasons of 2001 and 2002.

Approximately 70% (n = 89), of the responses to the interview questions stated water quality either detracted a lot or a little from their aesthetic enjoyment of the Klamath River within the geographical boundaries of the survey. By far, the most common complaint related to large amounts of "algae" and odors related to "algae." The survey data show that of the 70% of water uses reporting unfavorable recreational experiences with "algae," approximately 42% (n = 37) of those negative responses directly involved Iron Gate and Copco Reservoirs. Though not stated, presumably the "algae" in question were blue-green algal species that tend to accumulate along shorelines, forming scums and surface films during blooms.

2.6.4 Impairment of Commercial and Sport Fishing (COMM)

The Commercial and Sport Fishing (COMM) beneficial use is currently impaired in the Klamath River in California, as demonstrated by restrictions and closures on the sport and commercial fishing industries in the basin and beyond. Salmonid population decline has resulted in severe reductions in available Chinook salmon for both the in-river and ocean troll commercial fishing communities, and sport fishing community. Additionally, federal regulations have eliminated the right to harvest coho salmon stocks due to their dwindling numbers. Evidence documenting declining numbers of salmonids returning to spawn in the Klamath River basin is discussed in detail in section 2.6.1 and Appendix 5. The apparent disappearance of eulachon (*Thaleicthys pacificus,* also known as candlefish) spawning activity in the Klamath River (Belchik and Larson 1998) has resulted in the cessation of a historically important, commercially valuable non-salmonid fishery that was primarily utilized by Yurok Tribal members.

2.6.4.1 In-River Sport Fishing Impairment

Decreased salmon populations in the Klamath River have resulted in the alteration of fishing regulations further restricting the number of in-river fish harvested recreationally and the length of the recreational salmon in-river fishing season. For the 2006 season, the California Fish and Game Commission (Commission) decreased the number of days that recreational salmon fishing could occur by 11 days in the Klamath River below the Highway 96 bridge at Weitchpec (CFGC 2006). This was done in an attempt to ensure that the quota for in-river recreational harvest would not be met before Labor Day, allowing fishing during the holiday weekend (CFGC 2006).

The documentation of microcystin toxin concentrations in fish tissue of yellow perch from Copco Reservoir above human health thresholds represents an impairment of in-river sport fishing. Table 2.18 presents data from 2005 and 2007 when salmonids were collected in the Klamath River and yellow perch were collected in the reservoirs to test for the presence of microcystin. As the table reflects, microcystin was detected in the liver of a salmonid collected at Iron Gate Hatchery at a level >250 µg/kg, which is over the threshold recommended by Van Buynder et al. (2001) to protect human health. Additionally, four of the yellow perch fish tissue samples and one of the liver samples collected in Copco Reservoir were >250 ug/kg. Yellow perch are commonly harvested from Copco and Iron Gate Reservoirs for consumption.

Table 2.18: Detection of microcystin in fish tissue and liver samples from the Klamath River and reservoirs

Location Fish Collected	Year	# of fish tissue samples where Microcystin Detected	# of fish tissue samples with Microcystin total >250 µg/kg	# of fish liver samples where Microcystin Detected	# of fish liver samples with Microcystin total >250 µg/kg
Klamath River	2005	0 of 2*	0	2 of 4*	0
Iron Gate Hatchery	2005	0 of 2*	0	0 of 2*	0
	2007	0 of 1*	0	1 of 1*	1
Iron Gate Reservoir	2007	15 of 19**	0	2 of 3*	0
Copco Reservoir	2007	18 of 19**	4	3 of 3*	1

*salmonid
** yellow perch

2.6.4.2 Ocean Sport Fishing Impairment

During the period from 1960 through 1965 there was no closed season for ocean salmon sport fishing north of Tomales Point (CDFG 1967). The catch limit during this period remained constant at 3 salmon per day. In 1960 and 1961 the minimum size limit for salmon was 22 inches, and in 1962 one fish of any size was allowed with the remainder to be over 22 inches. From 1963 through 1965 the minimum size limit was one salmon over 20 inches and two over 22 inches.

In contrast, the currently depressed state of the fall Chinook run in the Klamath Management Zone (KMZ), and the listing of coho as threatened on both the federal (1997 listing) and California (2005 listing) Endangered Species lists, has resulted in increased restrictions on the ocean sport fishery. The 2007 ocean sport fishing season in the Klamath Management Zone (KMZ), extending from Humbug Mountain, OR to Point Arena, CA, was open from May 5 to September 4 (Pacific Fishery Management Council [PFMC] 2007). However, the Klamath Control Zone, extending 6 miles north and south of the Klamath River and 12 miles off-shore, was closed in August. The catching of coho was prohibited and the Chinook catch was limited to two fish per day (PFMC 2007). Chinook were required to be a minimum of 24 inches in total length to be legal to keep (PFMC 2007). These greater restrictions have contributed to the impairment of the sport fishery in the Klamath River basin.

2.6.4.3 In-River Commercial Fishery Impairment

Between 1912 and 1934 approximately 957,000 pounds of Chinook salmon, representing close to 55,000 fish, were harvested and preserved during a single fishing season in the Klamath River (Snyder 1931, p. 7, 8, 88, and 89). Daily salmonid catches by the Tribal commercial fishery commonly ranged from 7,000 to 10,000 fish per day, with a one-day high that was reportedly approximately17,000 fish. Catch totals were mostly Chinook, but coho salmon, steelhead trout, lamprey, and green sturgeon were also caught and preserved (Snyder 1931, p. 7, 8, 88, and 89). Due to precipitous declines in salmonid populations attributed to over harvesting by the in-river commercial salmon fishery, the fishery was declared illegal and closed by court order in 1934. It was subsequently reopened by another court order in 1977; however, the Bureau of Indian Affairs closed the Tribal in-river commercial fishery the following year under a “conservation moratorium." It remained closed until 1987, when it was again reopened (Pierce 1998; Yurok Perspectives 2001, p. 7.1-7.13).

In 1993 the Department of Interior modified catch limits for the Klamath River basin Tribes, allotting 50% of the available Klamath River basin salmon harvest to the Hoopa and Yurok Tribes, or an amount sufficient to support a moderate standard of living, which ever is less. Given the depressed condition of the Klamath River basin salmon stocks in 1993, the Department of Interior concluded that 50% of the salmon harvest during that year would be allocated to the Tribes because there weren't enough fish to allow them to catch enough to support a moderate standard of living (50 CFR Part 661, NOAA 1993). Of the 50% allocated to the Tribes, 80% and 20% of that allocation, referred to as Tribal shares, are allotted to the Yurok and Hoopa Tribes, respectively. Currently, the Yurok and Hoopa Tribes are the only Tribes with Federally-recognized commercial fishing rights in the Klamath River (Pierce 1998; Yurok Perspectives 2001, p. 7.1-7.13)

From 1990 through 1998 the in-river Tribal fishery was closed to commercial gillnetting due to depressed salmon runs. In recent years, harvest rates for the Tribal gillnet fishery have varied and are currently so low that it is hard to support an in-river commercial fishery. For the 2006 salmon season the Pacific Fishery Management Council (PFMC), working with the Klamath Fisheries Management Council, determined that the allowable Tribal share of the Klamath-Trinity River basin salmon harvest is 10,000 fish (PFMC 2006a). This would allocate 8,000 salmon to the Yurok Tribe and 2,000 salmon to the Hoopa Tribe from the in-river salmon fishery.

2.6.4.4 Ocean Commercial Fishery Impairment

Salmon sold to fish buyers and processors within the Klamath Management Zone (KMZ) have dwindled significantly since 1976 through 1980 when an average of 143,900 Chinook and 72,100 coho salmon were delivered per season to the port of Crescent City alone (PFMC 2003, 2006b). From 1993 through the present, concerns about the plummeting coho salmon populations have led to the closure of the entire California ocean commercial troll for coho. In order to more rigorously protect all salmonid stocks within the KMZ, regulations on the ocean commercial fishery (consisting mostly of Chinook salmon) has been progressively more restrictive.

The economic impacts to the fishermen and on-shore industries that support the ocean commercial salmon industry have been, and continue to be significant. The maximum dollar values for the ex-vessel price (the price received by fishermen for fish landed at the dock) adjusted to 2005 dollar values are presented in Table 2.19 for the four major ports in the KMZ. The seasons when regulatory closures prohibited commercial ocean salmon fishing are not shown in the table, and correspond to no income for fishermen.

Table 2.19: Estimates of maximum dollars for the ex-vessel price of the commercial ocean salmon fishery for the four major ports within the KMZ from 1976-1990 and 1991-2001.

Port	Year(s)[1] / Maximum Dollars	Year(s)[1] / Maximum Dollars
Brookings, OR	1976-1980 / 7,355,000	1991-1995 / 126,000
Crescent City, CA	1976-1980 / 5,931,000	1991-1995 / 9,000
Eureka, CA	1976-1980 / 8,884,650	1991 / 43,640
Fort Bragg, CA	1986-1990 / 14,902,000	2001 / 663,000

Source: PFMC 2006b
[1]Multiple year's values represent the average income per year

The 2006 ocean commercial troll non-Tribal salmon fishery was severely curtailed along much of the west coast by the PFMC. The potential offspring of the 2002 Chinook stocks, the four year age class, is that cohort of fish that were predicted to have subsequently returned to the Klamath River as spawners in 2006. The loss of over 33,000 salmonids in 2002, mostly fall Chinook (USFWS 2003b p.ii), was a contributing factor to the low return and resulting fishery restrictions in 2006. In particular, within the KMZ, extending from Humbug Mountain north of Brookings, OR to Horse Mountain just south of Shelter Cove, CA, the 2006 season was closed (NOAA 2006). South of Horse Mountain to Point Arena the season was open only from September 1 through September 15, or when a Chinook salmon quota of 4,000 fish was reached. The extreme seasonal and take restrictions were deemed necessary by the PFMC to assure an adequate numbers of spawners returned to the Klamath River.

During 2007 the PFMC (2008) considered Chinook salmon stocks within the KMZ somewhat healthier than 2006 but only opened the ocean commercial Chinook season from September 10 - September 30, imposing a fleet quota of 6,000 fish. Chinook stocks south of the KMZ to Point Arena were deemed depressed to the point that the PFMC only allowed fishing during the periods from April 9-April 27 (fleet quota of 2,000 fish) and August 29-September 30 (no quota set). The ocean coho salmon fishery remained closed along the California coast for the entire fishing season.

2.7 Problem Statement Synthesis

Based on the analysis presented in this chapter, there is little doubt that the Klamath River is an impaired waterbody. The Klamath River TMDL problem statement has identified numerous water quality related factors that must be addressed in the TMDL allocations and the implementation plan. The following is a summary of the water quality conditions and impacts that are addressed in the TMDL.

- Temperature conditions that exceed natural levels exist throughout the Klamath River basin and contribute to: chronic stress and sometimes acute lethal conditions for cold water fish, migration barriers, proliferation of fish diseases such as Columnaris, lower reproductive success, increased juvenile and adult mortality, and lower overall fish populations.
- Nutrient concentrations in much of the Klamath River watershed are well above natural background levels and contribute to excess periphyton and suspended algae growth, which in turn contributes to poor DO and pH conditions, and also

contributes to increased abundance and exposure of fish to parasites (e.g., *C. shasta*).

- High levels of nutrients and the presence of impoundments have contributed to the development of nuisance levels of blue-green algae that have created potential health hazards for people exposed to reservoir and downstream river waters. This health hazard has negatively impacted both recreational and ceremonial use of the reservoirs and the river.
- Conditions of low DO and high pH are persistent in much of the Klamath River and contribute to multiple impacts on cold water fish including: migration barriers, decreased growth and fecundity, decreased reproductive success, increased juvenile fish mortality, increased adult mortality, and lower overall fish populations.
- Excess sediment delivery to the Klamath River and tributary streams has contributed to habitat impairment, increased levels of nutrients, and to the development of water column temperatures that exceed Basin Plan water quality objectives.
- Reduced flows contribute to increased water column temperatures, the accumulation of organic matter, and low DO conditions which have contributed to impacts on aquatic life.
- Water quality objectives for temperature, DO, pH, biostimulatory substances, and toxicity are regularly exceeded in the Klamath River basin in California.
- Seventeen of the twenty-three designated beneficial uses for the Klamath River are not supported due to existing water quality impairments and related factors.

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