CHAPTER 2. PROBLEM STATEMENT

2.1 Introduction

This chapter summarizes water temperatures and dissolved oxygen concentrations in the Shasta River and its tributaries, and evaluates how these water quality conditions have resulted in the non-attainment of water quality standards. Changes to stream temperature can result from increased solar heating, changes in riparian cover, changes in streamside microclimates, changes in surface flow, changes in spring and groundwater inputs, and changes in channel geometry, including aggradation and pool infilling. Factors contributing to changes in dissolved oxygen concentrations include photosynthesis and respiration of aquatic plants, respiration of aerobic organisms including bacteria that decompose organic material, concentrations of oxygen-consuming constituents, flow, velocity, and water temperature.

Increased water temperatures and low dissolved oxygen levels decrease the area and volume of suitable habitat for salmonids, decrease survival during incubation, rearing, and migration, and can be lethal. In the Shasta River basin, elevated temperatures and low dissolved oxygen contribute to the non-attainment of beneficial uses associated with the cold water fishery, specifically the salmonid fishery.

The analysis presented in this report is based on data gathered by Regional Water Board staff and data contributed by landowners and organizations working in the Shasta River watershed. As additional data become available from sources such as local groups and government agencies, the Regional Water Board can modify the TMDL and numeric targets, if necessary.

2.2 Water Quality Standards

In accordance with the federal Clean Water Act, TMDLs are set at a level necessary to achieve applicable water quality standards. California's water quality standards include designated beneficial uses, narrative or numeric water quality objectives established to protect those uses, and antidegradation policies and prohibitions. This section describes the state water quality standards applicable to the Shasta River basin.

2.2.1 Beneficial Uses

Existing and potential beneficial uses for the Shasta River are identified in the *Water Quality Control Plan for the North Coast Region* (Basin Plan) (North Coast Regional Water Quality Control Board [NCRWQCB] 2005), and are summarized in Table 2.1. The Shasta River Hydrologic Area (HA) is divided into three sections – Shasta River and Tributaries, Lake Shastina, and Lake Shastina Tributaries; each with their own designated beneficial uses.

Table 2.1: Existing and Potential Beneficial Uses in the Shasta River Hydrologic Area

Beneficial Uses	Shasta Valley Hydrologic Area		
	Shasta River and Tributaries	Lake Shastina	Lake Shastina Tributaries
Municipal and Domestic Supply (MUN)*	E	P[1]	E
Agricultural Supply (AGR)	E	E	E
Industrial Service Supply (IND)	E	P	E
Industrial Process Supply (PRO)	P	P	P
Groundwater Recharge (GWR)	E	E	E
Freshwater Replenishment (FRSH)	E	E	E
Navigation (NAV)	E	E	P
Hydropower Generation (POW)[2]	P	-	P
Water Contact Recreation (REC-1)*	E	E	E
Non-Contact Water Recreation (REC-2)	E	E	E
Commercial and Sport Fishing (COMM)*	E	-[3]	E
Warm Freshwater Habitat (WARM)	E	E	E
Cold Freshwater Habitat (COLD)*	E	E	E
Wildlife Habitat (WILD)	E	E	E
Rare, Threatened, or Endangered Species (RARE)*	E	-	-
Migration of Aquatic Organisms (MIGR)*	E	P	E
Spawning, Reproduction, and/or Early Development (SPWN)*	E	-	E
Aquaculture (AQUA)	E	P	P
Native American Cultural (CUL)[4]	-	-	-

E=Existing use, **P**=Potential Use
* Those beneficial uses affected, directly or indirectly, by elevated water temperature and/or low DO.
[1] The Basin Plan identifies MUN as a potential (P) beneficial use in Lake Shastina, however it is currently used as a municipal and domestic water supply for the town of Montague and thus is an existing use (E). This change will be considered in the next Basin Plan update.
[2] The Basin Plan identifies POW as a potential (P) beneficial use in the Shasta River and Tributaries, however hydropower generation is an existing use (E). This change will be considered in the next Basin Plan update.
[3] The Basin Plan does not list COMM as an existing (E) beneficial use in Lake Shastina, however it is currently used for sport fishing. This change will be considered in the next Basin Plan update.
[4]The Basin Plan does not list CUL as an existing (E) or potential (P) beneficial use of the Shasta River HA, however it may be listed in the future should supporting information be submitted.

2.2.2 Water Quality Objectives

The Basin Plan identifies both numeric and narrative water quality objectives for the Shasta River HA. These water quality objectives are developed to ensure protection of all beneficial uses. Table 2.2 summarizes the water quality objectives applicable to the Shasta River temperature and dissolved oxygen TMDLs.

Table 2.2: Narrative and Numeric Water Quality Objectives applicable to the Shasta River basin TMDLs

NARRATIVE OBJECTIVES	
Region-wide Objectives	
Objective	**Description**
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.
Temperature	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 or WARM intrastate water be increased more than 5°F above natural receiving water temperature.

Table 2.2 (Continued): Narrative and Numeric Water Quality Objectives applicable to the Shasta River basin TMDLs

NUMERIC OBJECTIVES				
Shasta Valley Hydrologic Area	**Dissolved Oxygen (mg/l)**		**Hydrogen Ion (pH)**	
	Minimum	**50% lower limit[1]**	**Maximum**	**Minimum**
Shasta River	7.0	9.0	8.5	7.0
Other Streams	7.0	9.0	8.5	7.0
Lake Shastina	6.0	9.0	8.5	7.0

[1] 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 a lower limit.

The biostimulatory substances narrative objective refers to any substance that promotes aquatic plant growth. As demonstrated in Section 4.3.3, photosynthesis and respiration of aquatic plants in the Shasta River affect dissolved oxygen concentrations. Therefore, the biostimulatory substances objective is applicable to the dissolved oxygen TMDL. Similarly, pH is affected by the same processes that affect dissolved oxygen, most notably photosynthesis and respiration of aquatic plants.

The dissolved oxygen objective has two components, a minimum dissolved oxygen concentration and a 50% lower limit. The 50% lower limits represent the 50 percentile values of the monthly means for a calendar year. In other words, 50% or more of the monthly means must be greater than or equal to a lower limit.

In addition to narrative and numeric water quality objectives, the Basin Plan of the North Coast Region contains a provision for “controllable factors.” This provision makes it a violation of the Basin Plan to discharge pollutants from controllable factors into an already impaired waterbody. The controllable factors provision is outlined below:

> Controllable water quality factors shall conform to the water quality objectives contained herein. When other factors result in the degradation of water quality beyond the levels or limits established herein as water quality objectives, then controllable factors shall not cause further degradation of water quality. Controllable water quality factors are those actions, conditions, or circumstances resulting from man's activities that may influence the quality of the waters of the State and that may be reasonably controlled (NCRWQCB 2005).

This provision requires that controllable factors must be used to prevent the further degradation of water quality in areas where the water quality objectives (including the antidegradation policies and beneficial uses) are not being met or supported. In areas where the degradation of water quality beyond the levels or limits established in the Basin Plan have already occurred, no further degradation of water quality from controllable factors is allowed by this provision.

2.2.3 Prohibitions and Policies
The Basin Plan includes prohibitions and policies applicable to the Shasta River basin, as discussed below.

2.2.3.1 Waste Discharge Prohibitions

The Regional Water Board is authorized, by Section 13243 of the Porter-Cologne Water Quality Control Act, to create Waste Discharge Prohibitions and specify conditions or locations where the discharge of all or some waste will not be permitted. The Basin Plan (NCRWQCB 2005, 4-1.00) states that point source waste discharges, except as stipulated by the Thermal Plan, Ocean Plan, and the action plans and policies contained in the Point Source Measures section of the Basin Plan, are prohibited in the Klamath River and its tributaries, including but not limited to the Trinity, Salmon, Scott, and Shasta rivers and their tributaries.

2.2.3.2 Agricultural Wastewater Management Policy

The Basin Plan also includes the Policy for Agricultural Wastewater Management, which is applicable to the Shasta River basin. In 1972 the USEPA was directed, by amendments to Public Law 92-500, to set up a permit system for dischargers that would be administered by the State of California for waters within the State. At the present time, federal regulations require permits for various types of discharges from agricultural operations including irrigation return flow from 3,000 or more acres of land when conveyed to navigable waters from one or more point sources. However, the policy also states "the state may prescribe waste discharge requirements for any point source discharger regardless of size (NCRWQCB 2005, p.4-24.00)."

2.2.3.3 Antidegradation Policies

There are two applicable antidegradation policies pertinent to water quality in the entire 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 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. 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 surface waters 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 will lower the quality of surface water that 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.

2.3 Temperature

Cold freshwater habitat, which includes habitat for salmonids, is the beneficial use most sensitive to elevated stream temperatures. In order to assess whether this beneficial use is fully protected in the Shasta River basin, stream temperatures are compared to temperature thresholds that are protective of salmonids. Temperature requirements of salmonids are summarized below, with an expanded discussion in Electronic Appendix A_e (*The Effects of Temperature on Steelhead Trout, Coho Salmon, and Chinook Salmon Biology and Function by Life Stage: Implications for Klamath Basin TMDLs*).

2.3.1 Temperature Requirements of Salmonids

Temperature is one of the most important factors affecting the success of salmonids and other aquatic life. Most aquatic organisms, including salmon and steelhead, are poikilotherms, meaning their temperature and metabolism are determined by the ambient temperature of water. Temperature therefore influences growth and feeding rates, metabolism, development of embryos and alevins, timing of life history events such as upstream migration, spawning, freshwater rearing, seaward migration, and the availability of food. Temperature changes can also cause stress and mortality (Ligon et al. 1999). Temperatures at sub-lethal levels can also effectively block migration, lead to reduced growth, stress fish, affect reproduction, inhibit smoltification, create disease problems, and alter competitive dominance (Elliott 1981; USEPA 1999). 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).

In considering the effect of temperature on salmonids, it is useful to have a measure of chronic (i.e., sub-lethal) and acute (i.e., lethal) temperature exposures. A common measure of chronic exposure is the maximum weekly average temperature (MWAT). The MWAT is the maximum seasonal or yearly value of the mathematical mean of multiple, equally spaced, daily temperatures over a running seven day consecutive period (Brungs and Jones 1977, p.10). In other words, it is the highest single value of the seven day moving average of temperature for a given time period. A common measure of acute effects is the instantaneous maximum temperature. A third metric, the maximum weekly maximum temperature (MWMT), can be used as a measure of both chronic and acute effects. The MWMT (also known as the seven-day average of the daily maximum temperatures (7-DADM)) is the maximum seasonal or yearly value of the daily maximum temperatures averaged over a running seven day consecutive period. The MWMT is useful because it describes the maximum temperatures in a stream, but is not overly influenced by the maximum temperature of a single day.

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 objectives in the Basin Plan (NCRWQCB 2005). This review included EPA guidance, Oregon and Washington states' standards, reports compiling and summarizing existing scientific information, and laboratory studies. Species-specific requirements were reviewed for the following life stages: migrating adults, spawning and incubation/emergence, and freshwater rearing and growth. Additionally, the effects of temperature on disease and lethality were investigated. Some of the references reviewed covered salmonids as a general class of fish, while others were species specific.

Salmonid stocks do not tend to vary much in their life history thermal needs, regardless of their geographic location. The USEPA (2001a), in their *Summary of Technical Literature Examining the Physiological Effects of Temperature on Salmonid*, makes the case that there is not enough significant genetic variation among stocks or among species of salmonids to warrant geographically-specific water temperature standards. "Many differences that had been attributed in the literature to stock differences are now considered to be statistical problems in analysis, fish behavioral responses under test conditions, or allowing insufficient time for fish to shift from field conditions to test conditions (Konecki et al. 1993; Mathur & Silver 1980, both as cited by USEPA 2001a)." USEPA states that temperature tolerance is likely controlled by multiple genes, and thus would not be easily modified through evolutionary change without a radical shift in associated physiological systems (USEPA 2001a). As a result, literature on the temperature needs of coho and Chinook salmon and steelhead trout stemming from data collected in streams outside Northern California are considered relevant to characterizing the thermal needs of salmonids which use the Shasta River.

As a result of this literature review, Regional Water Board staff selected chronic and acute temperature thresholds for evaluating Shasta River watershed temperatures. 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 2.3. 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. Acute lethal temperature thresholds were selected based upon best professional judgment of the literature, and are presented in Table 2.4. These freshwater temperature thresholds are applicable during the time of year when the life stage of each species is present in the Shasta River basin (see Figure 1.16). Where life history, timing, and/or species needs overlap, the lowest of each temperature metric applies.

Table 2.3: 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.

The University of California Cooperative Extension is conducting a multi-year investigation to document salmonid presence/absence and water quality conditions (including water temperature and dissolved oxygen) at juvenile salmonid rearing locations in the Shasta River. Results of the study have not been reported (Thompson 2005) and thus were not available to use in this assessment, however when the report is available it will provide additional insight regarding temperature and dissolved oxygen conditions affecting the cold freshwater habitat beneficial use.

Table 2.4: 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

[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.

2.3.2 Temperature Conditions of the Mainstem Shasta River

Numerous parties have collected temperature data in the Shasta River basin, including private landowners, the Shasta River Coordinated Resource Management Planning Council, the Shasta Valley Resource Conservation District, the California Department of Fish and Game, the California Department of Water Resources, the US Fish and Wildlife Service, the US EPA, and the Regional Water Board. Shasta River temperature data records date back to the 1930s, but intensive temperature monitoring using continuous recording temperature probes began in the 1990s.

Table 2.5 and Figure 2.1 summarize mainstem Shasta River temperature conditions. Table 2.5 identifies the maximum instantaneous temperature, maximum weekly average temperature (MWAT), and maximum weekly maximum temperature (MWMT) observed at various Shasta River locations from 1994 through 2003. Figure 2.1 presents average weekly maximum temperatures for select Shasta River reaches based on recorded temperatures from the period 1994 through 2003 versus the USEPA (2003) MWMT temperature thresholds. The Highway 263 – USGS gage reach includes temperature data collected at Highway 263, near the end of Old Shasta River Road, and at the USGS flow gage; the Montague-Grenada Road – Anderson Grade Road reach includes temperature data collected at Montague-Grenada Road, Highway 3, Yreka Ager Road, I-5, upstream of Yreka Creek confluence, and at Anderson Grade Road; the Highway A12 – Little Shasta River reach includes temperature data collected at Highway A12, Freeman Road, and upstream of the Little Shasta River confluence; the Hole in the Ground – Willow Creek reach includes temperature data collected at Grenada Irrigation District pumps, East Louie Road, and upstream of the Willow Creek confluence.

The temperature associated with the top of the colored boxes in Figure 2.1 is the threshold temperature for that life stage. The time period that the various life stages occur in the Shasta River basin are depicted by the width of the colored boxes. Where the weekly maximum temperature falls above the colored life stage/threshold box, temperatures are unsuitable for the life stage. The distribution of salmonids in the Shasta River watershed is presented in Chapter 1, Figure 1.16, however locations at which fish presence is not indicated on the map do not necessarily indicate the absence of fish in these areas, as surveys may not have been conducted to determine presence/absence. Figure 2.2 presents surface water temperatures of the Shasta River on the afternoon of July 26, 2003 from thermal infrared imagery (Watershed Sciences, LLC 2004). As an evaluation of lethal temperature conditions, Figure 2.3 shows the maximum and average number of hours that temperatures exceeded lethal salmonid temperature thresholds for juvenile growth and rearing at the mouth of the Shasta River during summer months from 1996 through 2003.

Table 2.5: Mainstem Shasta River Temperature Conditions

Site	River Mile	Sample Year	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	Summary of maximum recorded values 1994-2003	Max	Avg	Min
USGS gage	0.6	Max. Temp.				**29.4**			29.7	30.3	31.5	30.2	Max. Temp.	31.5	30.4	29.7
		MWAT				**24.3**			25.1	24.8	25.6	25.9	MWAT	25.9	25.3	24.8
		MWMT				**28.2**			28.9	29.0	29.8	29.2	MWMT	29.8	29.2	28.9
Highway 263	7.3	Max. Temp.	24.9	26.0	27.6	**24.1**	26.4	26.9	27.9	30.3			Max. Temp.	30.3	27.1	24.9
		MWAT	22.8	22.7	24.2	**22.4**	23.6	22.9	24.6	24.8			MWAT	24.8	23.7	22.7
		MWMT	24.3	24.9	26.5	**23.3**	25.7	25.4	27.0	29.0			MWMT	29.0	26.1	24.3
Yreka Cr	7.6	Max. Temp.								28.4			Max. Temp.		28.4	
		MWAT								24.4			MWAT		24.4	
		MWMT								26.9			MWMT		26.9	
Anderson-Grade Road	8.0	Max. Temp.	29.4	32.5	28.4	**26.6**	27.3	**23.7**	27.2				Max. Temp.	32.5	29.0	27.2
		MWAT	25.3	22.9	24.9	**23.9**	24.7	**21.7**	24.6				MWAT	25.3	24.5	22.9
		MWMT	27.9	29.6	27.2	**25.7**	26.7	**23.7**	26.3				MWMT	29.6	27.5	26.3
Interstate 5	8.6	Max. Temp.								**26.7**			Max. Temp.			
		MWAT								**20.7**			MWAT			
		MWMT								**26.2**			MWMT			
Yreka-Ager Road	10.9	Max. Temp.	31.1	26.1	26.4	**26.7**	25.8	26.8	27.2			27.9	Max. Temp.	31.1	27.3	25.8
		MWAT	24.8	22.1	24.0	**22.1**	23.7	22.7	23.9			24.8	MWAT	24.8	23.7	22.1
		MWMT	29.7	24.4	25.5	**25.7**	25.6	25.7	26.5			26.8	MWMT	29.7	26.3	24.4
Oregon Slough	11.8	Max. Temp.								26.8			Max. Temp.		26.8	
		MWAT								23.3			MWAT		23.3	
		MWMT								26.0			MWMT		26.0	
Highway 3	13.1	Max. Temp.		26.2	27.2	26.0	22.8	26.9	26.4			27.4	Max. Temp.	27.4	26.8	26.2
		MWAT		22.3	23.9	22.4	20.5	21.7	23.8			24.2	MWAT	24.2	23.2	21.7
		MWMT		25.0	26.4	24.6	22.4	26.0	26.1			26.8	MWMT	26.8	26.1	25.0
Montague-Grenada Road	15.5	Max. Temp.	28.3	25.0	26.8		26.2	26.4	26.8		27.5	26.5	Max. Temp.	28.3	26.7	25.0
		MWAT	24.0	21.9	23.3		23.1	22.7	23.6		22.8	23.9	MWAT	24.0	23.1	21.9
		MWMT	27.1	24.5	26.0		25.3	25.1	26.1		25.9	25.9	MWMT	27.1	25.7	24.5
Little Shasta River	16.3	Max. Temp.								26.5			Max. Temp.		26.5	
		MWAT								22.7			MWAT		22.7	
		MWMT								25.2			MWMT		25.2	
Freeman Lane	19.2	Max. Temp.										25.2	Max. Temp.		25.2	
		MWAT										22.4	MWAT		22.4	
		MWMT										24.4	MWMT		24.4	
Highway A-12	21.2	Max. Temp.	26.6	23.2	23.9	**24.2**	23.2	24.2	25.0			24.7	Max. Temp.	26.6	24.4	23.2
		MWAT	22.0	21.0	22.0	**19.3**	21.3	20.9	21.1			21.6	MWAT	22.0	21.4	20.9
		MWMT	25.1	22.0	23.3	**21.3**	22.5	23.4	24.0			24.0	MWMT	25.1	23.5	22.0
Willow Creek	25.1	Max. Temp.								22.5			Max. Temp.		22.5	
		MWAT								20.1			MWAT		20.1	
		MWMT								21.9			MWMT		21.9	
GID	30.6	Max. Temp.	**22.6**	23.6	24.6	22.9	32.5	22.8					Max. Temp.	32.5	25.3	22.8
		MWAT	**19.9**	20.1	20.4	19.0	20.0	19.2					MWAT	20.4	19.8	19.0
		MWMT	**23.2**	23.2	23.7	22.3	26.1	22.2					MWMT	26.1	23.5	22.2
East Louie Road	33.9	Max. Temp.	**23.6**	25.0	25.0		24.4	24.8	24.4				Max. Temp.	25	24.7	24.4
		MWAT	**19.6**	21.7	20.5		20.3	20.4	20.8				MWAT	21.7	20.8	20.3
		MWMT	**23.3**	24.3	23.4		23.1	23.8	23.9				MWMT	24.3	23.7	23.1
Hole in the Ground	34.8	Max. Temp.				**20.9**		20.2	23.6				Max. Temp.	23.6	21.9	20.2
		MWAT				**18.2**		17.4	20.0				MWAT	20.0	18.7	17.4
		MWMT				**19.5**		19.5	22.7				MWMT	22.7	21.1	19.5
Riverside Drive	36.0	Max. Temp.		**24.3**			25.3	26.1	25.3	27.3		23.7	Max. Temp.	27.3	25.5	23.7
		MWAT		**20.2**			20.2	20.9	22.4	22.6		20.9	MWAT	22.6	21.4	20.2
		MWMT		**23.8**			24.8	23.5	24.9	25.6		22.7	MWMT	25.6	24.3	22.7

Note: The temperatures in the grey boxes were calculated from data sets that may not have included the period of hottest summer temperatures. All temperatures are °C.

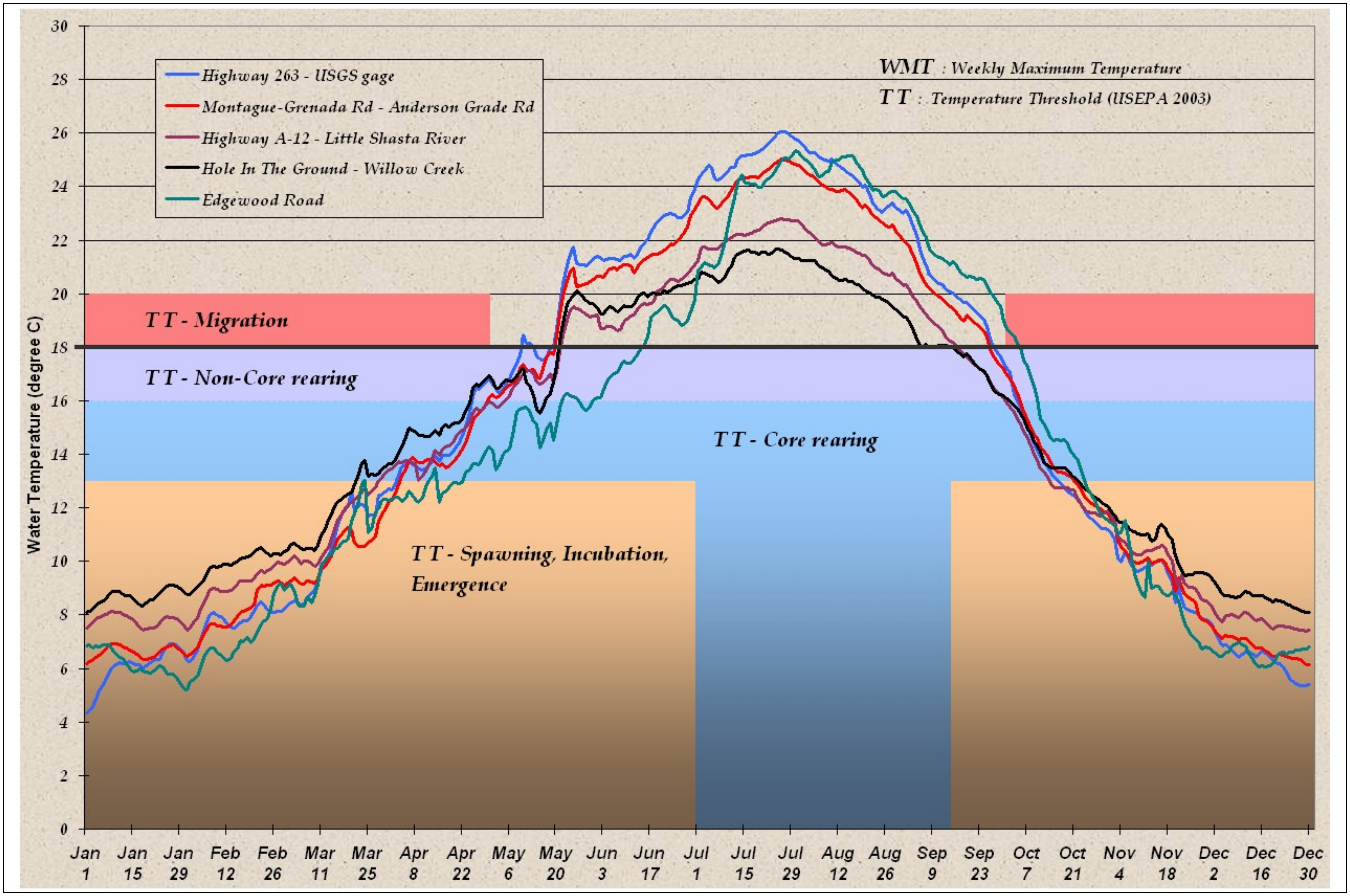

Figure 2.1: Average weekly maximum temperatures, Shasta River, 1994-2003.

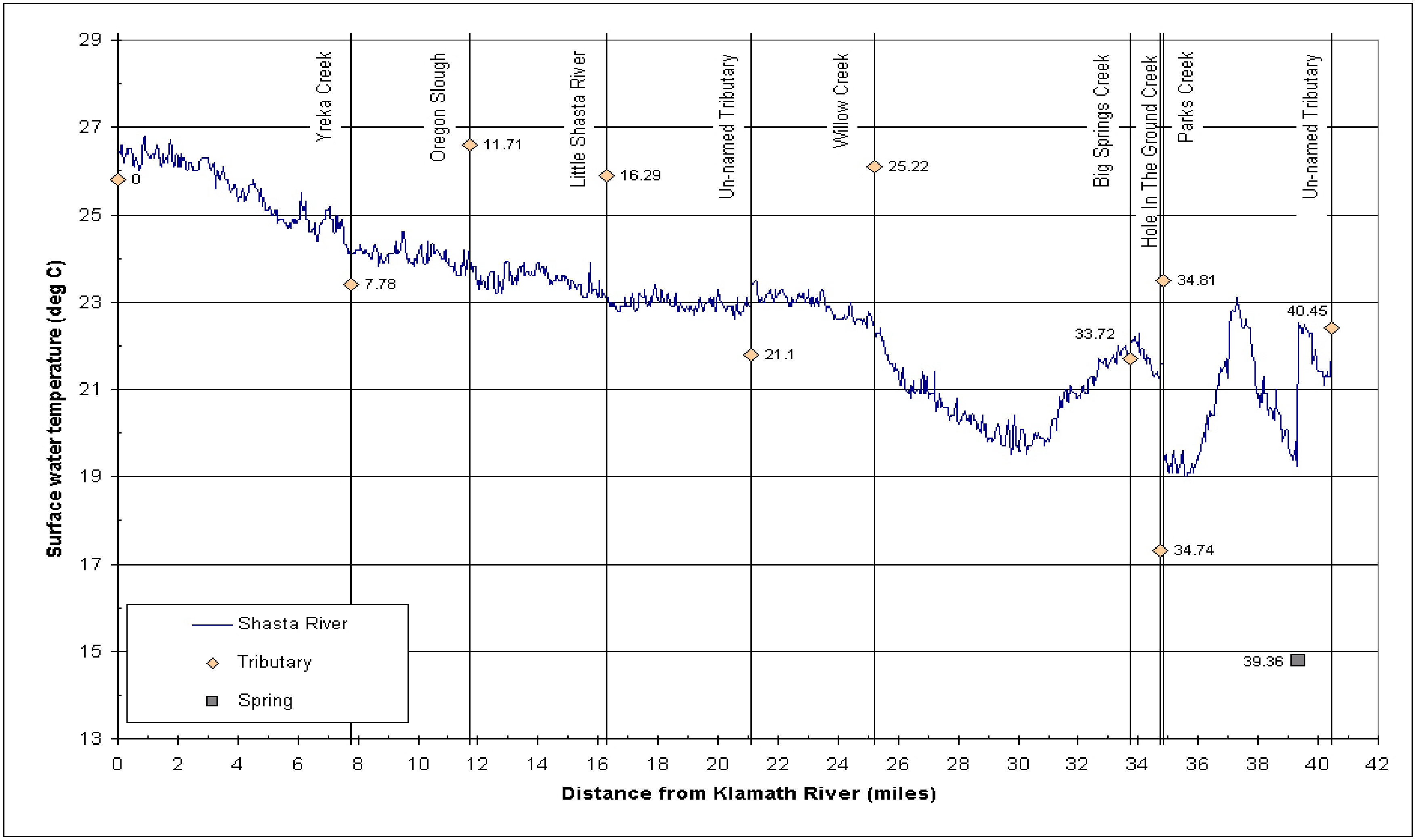

Figure 2.2: Shasta River Surface Water Temperatures - July 26, 2003
From: Watershed Sciences, LLC 2004
Note: The number next to the diamond marker for the tributaries/spring indicates the river mile at which the tributary/spring enters the mainstem Shasta River.

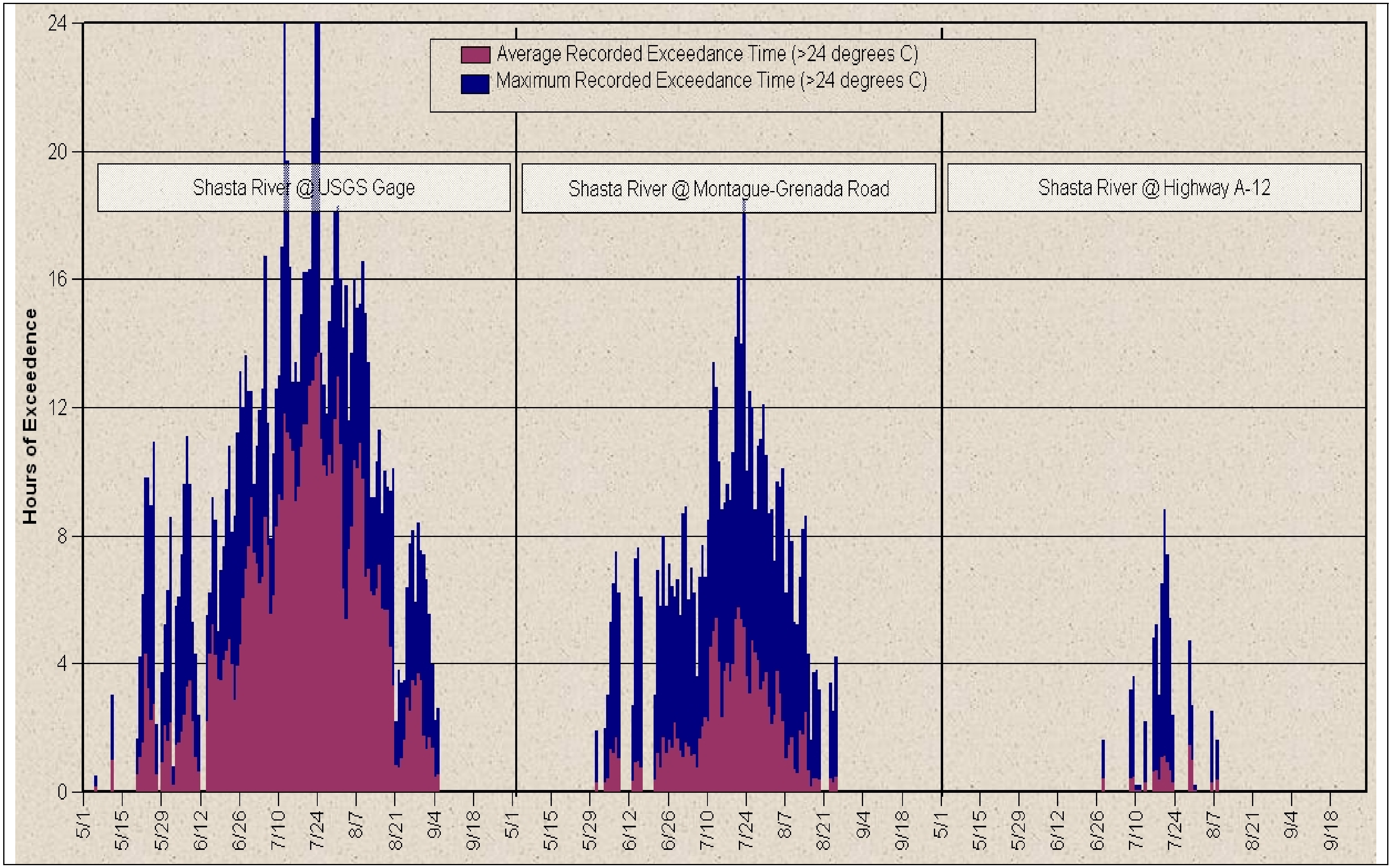

Figure 2.3: Maximum and average number of recorded hours per day Shasta River mainstem temperatures exceeded the lethal temperature threshold for juvenile rearing at the mouth, Montague-Grenada Road, and Highway A-12, 1996-2003

Daily temperature fluctuations vary throughout the Shasta River and tributaries. In the Shasta River, temperatures fluctuate up to 8°C during summer months at some locations including the mouth (i.e. the difference between the daily minimum and daily maximum temperature is 8°C). On average, Shasta River temperatures fluctuate by 4 to 5°C.

Key findings of Shasta River mainstem temperature conditions are:

- Stream temperature conditions vary throughout the Shasta River.
- Shasta River temperatures increase in the downstream direction, most notably downstream of about RM30, near Highway A12.
- On average, the difference between daily maximum and minimum Shasta River temperatures is approximately 4 to 5°C. The difference between daily maximum and minimum temperatures at the mouth approaches 8°C in summer months.
- Weekly maximum temperatures of the Shasta River meet, i.e., are below, the USEPA (2003) salmonid thresholds from approximately November 1 to mid-March.
- Shasta River temperatures are generally suitable for migration during the migration period (i.e., < MWMT of 20°C).
- Weekly maximum temperatures exceed the spawning, incubation, and emergence threshold (i.e. MWMT of 13°C) at all Shasta River reaches from April through June, and in mid-September through October.
- Weekly maximum temperatures of the Shasta River downstream of Dwinnell Dam exceed the core rearing threshold (i.e. MWMT of 16°C) from the end of April through early October, and exceed the non-core rearing threshold (i.e. MWMT of 18°C) from mid-May through September.

Instantaneous temperatures near the mouth of the Shasta River exceed lethal temperatures for juvenile rearing (i.e. >24°C) for some time every day from mid-June through August.

2.3.3 Temperature Conditions of Shasta River Tributaries

Less temperature monitoring has been conducted in the tributaries of the Shasta River. Figures 2.4 and 2.5 summarize average weekly maximum temperatures near the confluence with the Shasta River (Figure 2.4) and at upstream locations (Figure 2.5) for those tributaries with data collected between 2001 and 2003. These average weekly maximum temperatures are compared with the USEPA (2003) MWMT temperature thresholds.

Key findings of Shasta River tributary temperature conditions are:

- Temperatures of Shasta River tributaries are variable.
- Tributary temperatures near the confluence with the Shasta River are higher than temperatures at upper reaches of the tributary.
- Weekly maximum temperatures of measured tributaries near the confluence with the Shasta River tend to be comparable or warmer than Shasta River temperatures near the confluence, with the exception of Yreka Creek, which tends to be cooler than the river.
- Weekly maximum temperatures of measured tributaries near the headwaters are consistently cooler than Shasta River temperatures near the confluence.
- Weekly maximum temperatures of measured tributaries near the confluence with the Shasta River meet, i.e., are below, the USEPA (2003) salmonid thresholds from approximately November 1 to mid-March.

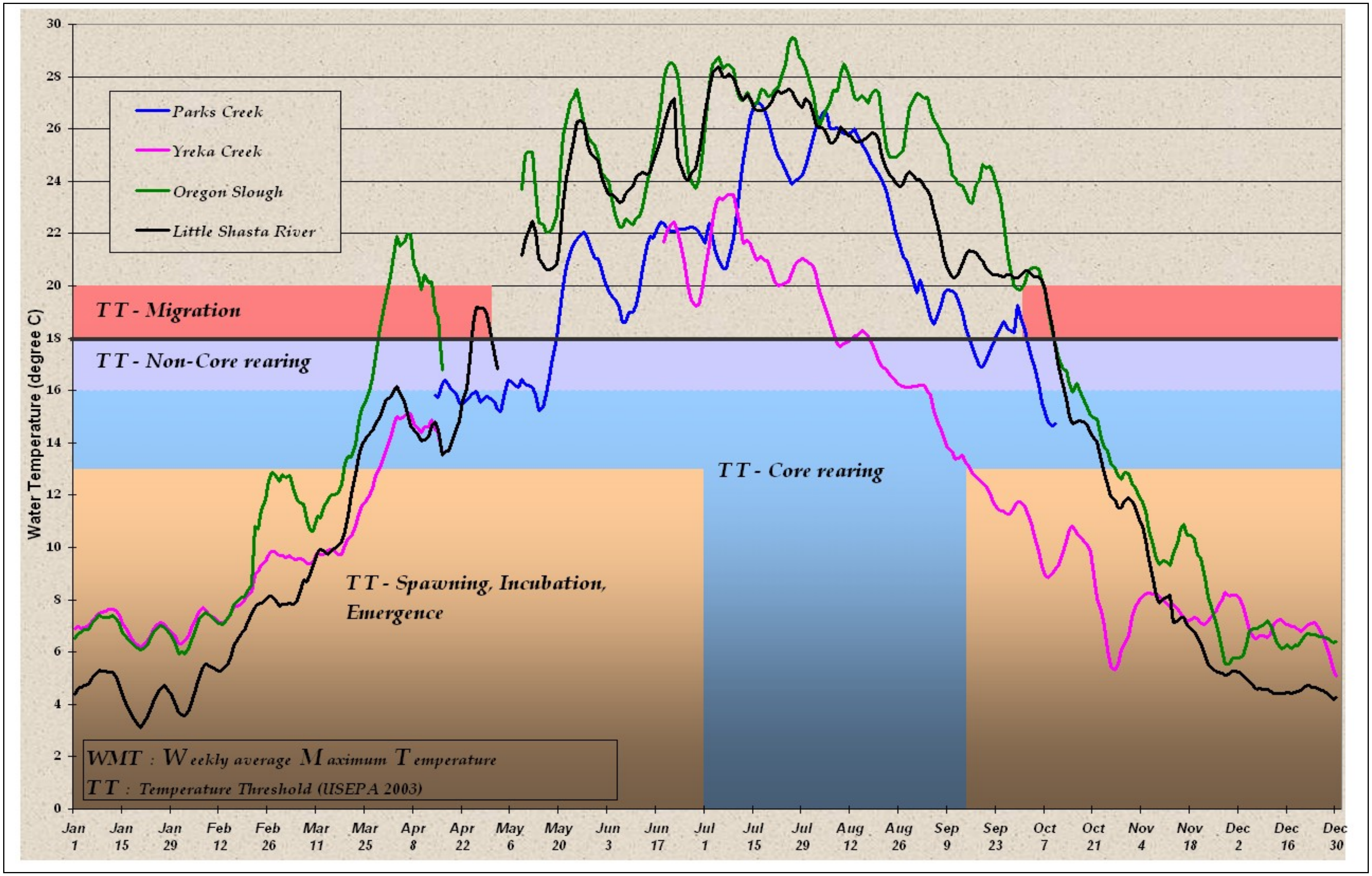

Figure 2.4: Average maximum weekly temperatures, Shasta River tributaries above confluence with Shasta River, 2001-2003
Note: Discontinuity in the data lines is due to data gaps.

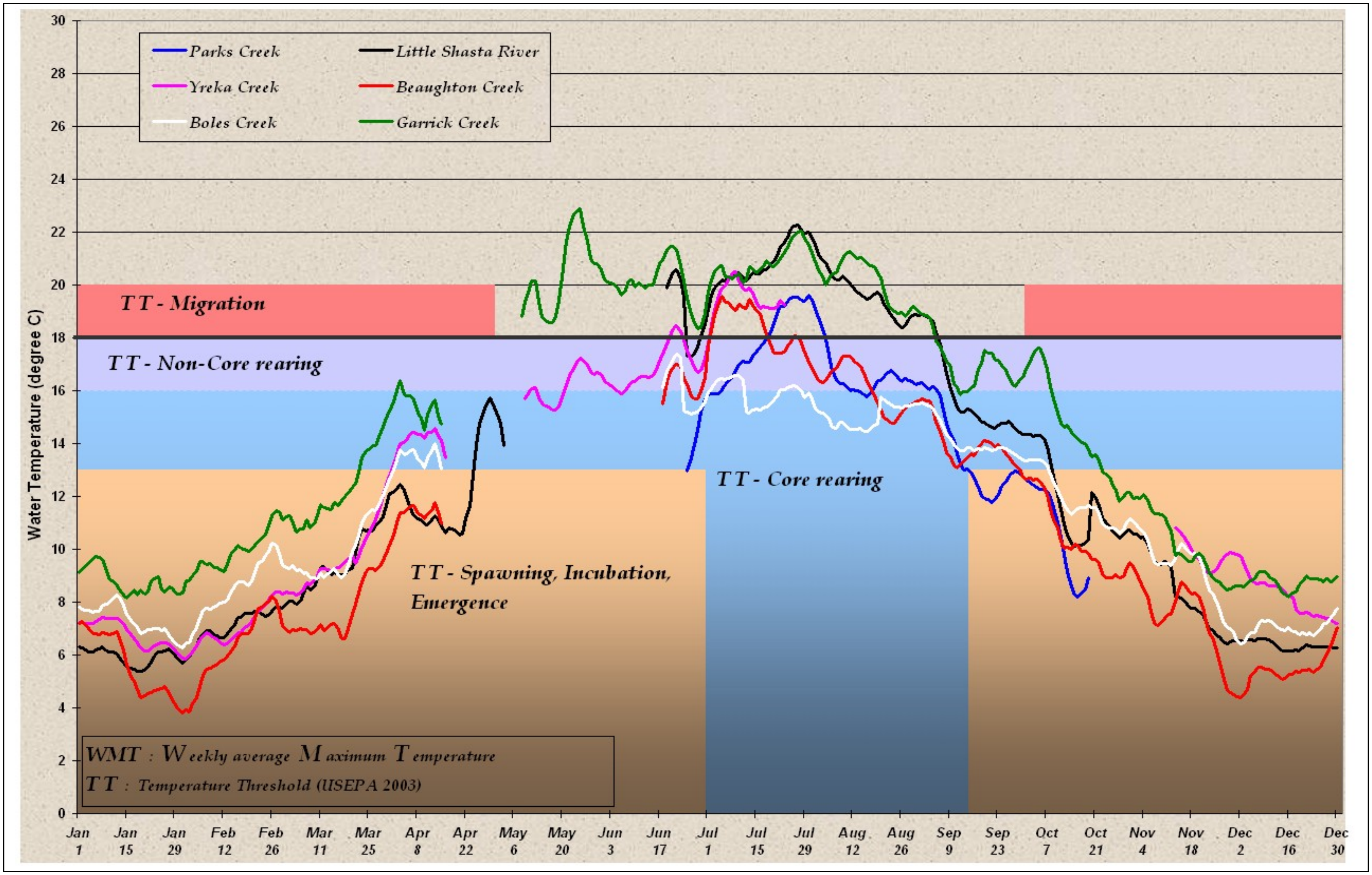

Figure 2.5: Average maximum weekly temperatures, Shasta River tributaries near headwaters, 2001-2003
Note: Discontinuity in the data lines is due to data gaps.

- Weekly maximum temperatures of measured tributaries near the confluence with the Shasta River tend to exceed the spawning, incubation, and emergence threshold (i.e., MWMT of 13°C) from mid-March through June, and mid-September through October.
- Weekly maximum temperatures of measured tributaries near the confluence with the Shasta River tend to exceed the core and non-core rearing threshold (i.e., MWMTs of 16 and 18°C, respectively) from about April through October, with some exceptions.
- Generally, weekly maximum temperatures of measured tributaries near the headwaters are below the core and non-core rearing thresholds during the summer months, except July and parts of August at some locations.

2.3.4 Temperature Conditions of Lake Shastina

Temperature profiles measured near the dam of Lake Shastina are presented in Figure 2.6. Lake Shastina tends to be thermally stratified from June through August, exhibiting warmer surface waters and colder waters at depth of the lake. Surface waters begin to warm in March, and by June stratification has set in. During summer months, surface water temperatures usually exceed 20°C, and bottom temperatures range from about 12 to 16°C. In September, stratification breaks down due to cooler air temperatures and shorter solar days. Isothermal conditions generally occur in late fall and persist through the winter months, with temperatures ranging from about 2 to 9°C. While the exact timing of these conditions varies, the general conditions are consistent. The outlet from Lake Shastina is located near the base of Dwinnell Dam.

Lake Shastina temperatures are not evaluated with respect to the USEPA (2003) thresholds because there are insufficient temperature data from Lake Shastina to calculate weekly maximum temperatures. Further, anadromous salmonids do not currently exist upstream of Dwinnell Dam, which is a barrier to migration. Note, however, that cold freshwater habitat is designated as an existing use in Lake Shastina and Lake Shastina tributaries. For a more complete discussion of temperature conditions in Lake Shastina the reader is referred to Vignola and Deas (2005).

2.4 Dissolved Oxygen

The Basin Plan includes numeric dissolved oxygen objectives for the Shasta River HA (Table 2.2). These dissolved oxygen objectives are currently undergoing revision, however at the time of this report the revisions are not complete and are not incorporated into the Basin Plan. Thus, data for the Shasta River are compared to those numeric dissolved oxygen objectives currently listed in the Basin Plan.

2.4.1 Dissolved Oxygen Requirements of Salmonids

A literature review of dissolved oxygen requirements of salmonids is presented in Electronic Appendix B_e (*The Effects of Dissolved Oxygen on Steelhead Trout, Coho Salmon, and Chinook Salmon Biology and Function by Life Stage*).

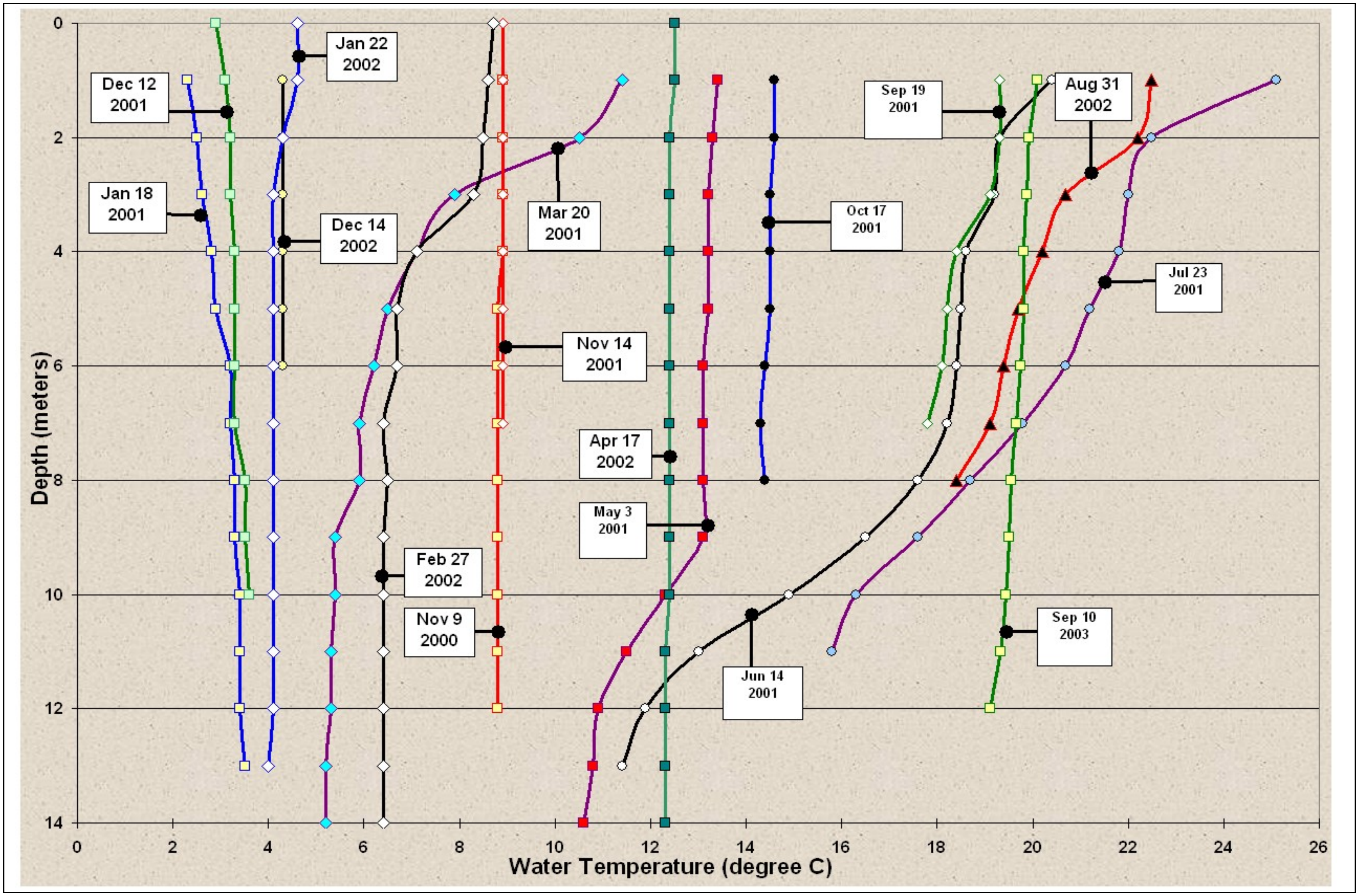

Figure 2.6: Lake Shastina temperature depth profiles, 2001-2003

2.4.1.1 Gas Bubble Disease

Gas bubble disease is not discussed in Appendix B_e, and is summarized here. High levels of total dissolved gas (TDG), including dissolved oxygen, can be harmful to salmonids and other fish and result in "gas bubble disease". This occurs when dissolved gases in their circulatory system come out of solution and form bubbles, which block the flow of blood through the capillary vessels (USEPA 1986, p.145). There are several ways TDG supersaturation can occur, including excessive algal photosynthesis, which can create supersaturated dissolved oxygen conditions (USEPA 1986, p.147). Thus, to protect salmonids and other freshwater fish, the USEPA has set criteria for TDG stating that levels should not exceed 110% of the saturation value.

Numerous studies have been conducted to determine the mortality rate of salmonids exposed to various levels of TDG. Mesa et al. (2000, p.174) conducted laboratory experiments on juvenile Chinook and steelhead. They exposed the fish to different levels of TDG and found no fish died when held at 110% TDG for up to 22 days. When fish were exposed to 120% TDG, 20% of juvenile Chinook died within 40 to 120 hours, while 20% of juvenile steelhead died within 20 to 35 hours. At TDG levels of 130%, Chinook mortality reached 20% after 3 to 6 hours, and steelhead mortality was 20% after 5 to 7 hours. Gale et al. (2001, p.3 and 21) held adult female spring Chinook at mean TDG levels ranging from 114.1% to 125.5% and found the time to first mortality ranged from 10 to 68 hours.

USEPA (1986) discusses various studies on the effects of TDG on salmonids. The following studies are all cited from the USEPA 1986 (p.148-150) water quality criteria document. Bouck et al. (1975) found TDG levels of 115% and above to be acutely lethal to most species of salmonids, and levels of 120% TDG are rapidly lethal to all salmonids. Conclusions drawn from Ebel et al. (1975) and Rulfison and Abel (1971) include the following:

- Adult and juvenile salmonids confined to shallow water (1 m) with TDG levels above 115% experience substantial levels of mortality.
- Juvenile salmonids exposed to sublethal levels of TDG supersaturation are able to recover when returned to normally saturated water, while adults do not recover and generally die.

2.4.2 Dissolved Oxygen Conditions of the Mainstem Shasta River

Measurement of dissolved oxygen concentrations of the Shasta River has been conducted by numerous parties, including private landowners, Shasta River Coordinated Resource Management Planning Council, Shasta Valley Resource Conservation District, City of Yreka, California Department of Fish and Game, California Department of Water Resources, US Fish and Wildlife Service, USEPA, and the Regional Water Board. Dissolved oxygen data records date back to the 1960s, but intensive dissolved oxygen monitoring using continuous recording dissolved oxygen probes began in the 1990s.

Figure 2.7 and Figure 2.8 summarize the available Shasta River mainstem dissolved oxygen conditions from 1994 through 2004. Figure 2.7 is a summary of all dissolved oxygen data measured from mainstem Shasta River locations, compiled into 4-week time periods, and compared to the Basin Plan minimum dissolved oxygen objective. Generally, during the fall/winter seasons (October 1 through March 30), dissolved oxygen concentrations in the Shasta River range from 7 to 19 mg/L. During the spring/summer seasons (April 1 through September 30), dissolved oxygen concentrations range from 2 to 18 mg/L. Figure 2.8 provides a closer look at the summer season data presented in Figure 2.7 by grouping the mainstem Shasta River data into river reaches, and presenting data for 2-week time periods. In addition, Figure 2.8 identifies the percentage of dissolved oxygen measurements that fall below the Basin Plan dissolved oxygen objective. Chapter 4 evaluates these dissolved oxygen data in more detail. The distribution of salmonids in the Shasta River watershed is presented in Chapter 1, Figure 1.16, however, locations at which fish presence is not indicated on the map do not necessarily indicate the absence of fish in these areas, as surveys to determine presence/absence may not have been conducted at all locations in the watershed.

Based on dissolved oxygen concentration and temperature measurements from the summer of 2003 and 2004 in the Shasta River, dissolved oxygen saturation levels were calculated. During these periods, dissolved oxygen saturation levels range from approximately 70% to 150%. The USEPA criteria for total dissolved gases is 110%. While dissolved oxygen is only one of the possible dissolved gases, the USEPA criteria for total dissolved gases is exceeded in the Shasta River at some times. However, there have been no known accounts of fish with gas bubble disease in the Shasta River watershed.

Key findings of Shasta River mainstem dissolved oxygen conditions are:

- Dissolved oxygen concentrations vary seasonally.
- Dissolved oxygen concentrations vary throughout the mainstem Shasta River.
- While Figure 2.7 presents a compilation of Shasta River mainstem dissolved oxygen measurements, the 50% lower limit of 9.0 mg/L appears to be met in at least 7 out of 12 months of the year.
- With few exceptions, mainstem Shasta River dissolved oxygen concentrations are above 7.0 mg/L during fall/winter seasons (October 1 through March 30).
- Dissolved oxygen concentrations fall below 7.0 mg/L for some period of time during the summer season (April 1 through September 30) at all mainstem Shasta River locations monitored.
- In the reach from Montague-Grenada Road to Anderson Grade Road, over 40% of dissolved oxygen measurements fall below 7.0 mg/L.
- In the Shasta River above Lake Shastina (at Edgewood Road), approximately 15% of dissolved oxygen measurements fall below 7.0 mg/L from late June through August.

2.4.3 Dissolved Oxygen Conditions of Shasta River Tributaries

Considerably less dissolved oxygen data have been collected in the tributaries to the Shasta River. Figure 2.9 summarizes dissolved oxygen concentrations in those tributaries monitored between 2001 and 2003, and identifies the percentage of dissolved oxygen measurements that fall below the Basin Plan objective. While the paucity of data limits

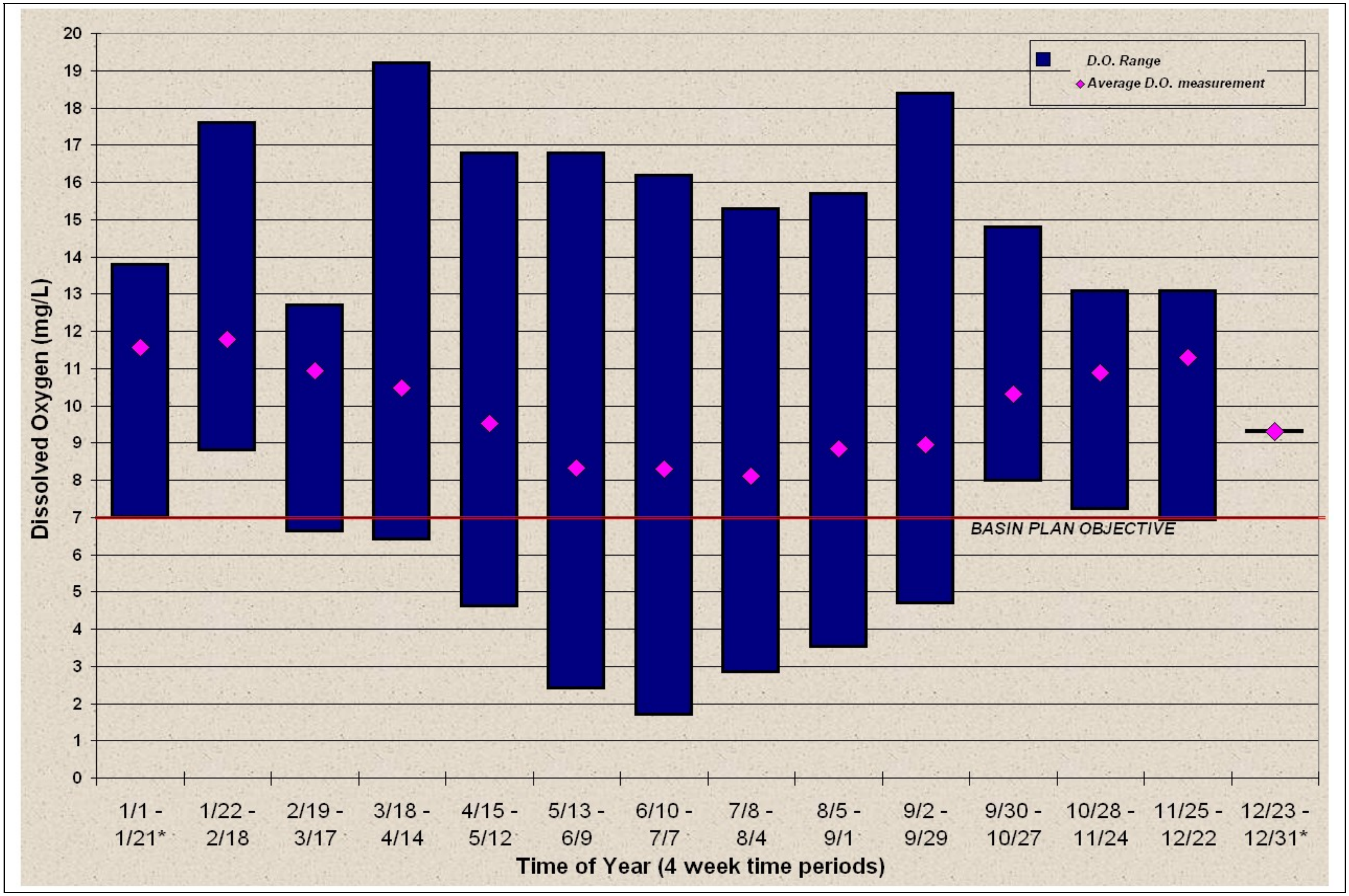

Figure 2.7: Range of recorded dissolved oxygen concentrations, composite of all Shasta River mainstem measurements, 28-day periods, 1994-2004

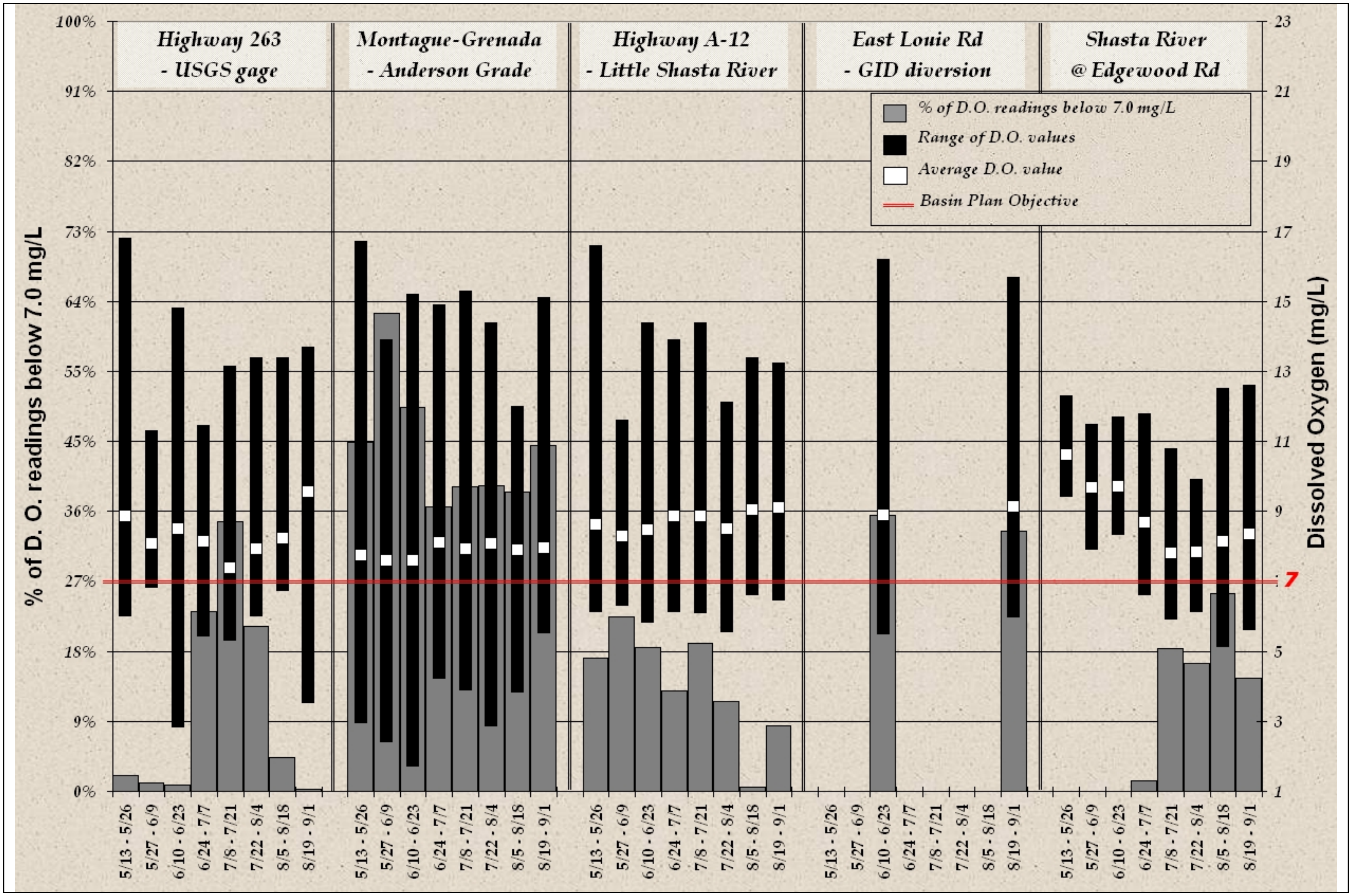

Figure 2.8: Bi-weekly dissolved oxygen concentration range, and percentage of measurements below Basin Plan dissolved oxygen objective, mainstem Shasta River reaches, May through August, 1994-2004

the ability to draw definitive conclusions, the data indicate that during the summer season, dissolved oxygen concentrations in some tributaries, particularly the Little Shasta River and Yreka Creek, fall below 7.0 mg/L for some period of time.

2.4.4 Dissolved Oxygen Conditions of Lake Shastina

Dissolved oxygen profiles measured near the dam of Lake Shastina are presented in Figure 2.10. Lake Shastina exhibits dissolved oxygen characteristics typical of a eutrophic reservoir. During summer months, when the reservoir is thermally stratified, the surface layer (epilimnion) is typically supersaturated with dissolved oxygen, while the bottom layer (hypolimnion) exhibits undersaturated conditions well below the Basin Plan dissolved oxygen objective of 6.0 mg/L. Dissolved oxygen concentrations approached zero in the hypolimnion between June and September 2001. Following fall turnover (mixing), dissolved oxygen concentrations are uniform and near saturation levels (above 6.0 mg/L). The outlet from Lake Shastina is located near the base of Dwinnell Dam. For more information on dissolved oxygen conditions in Lake Shastina, the reader is referred to Vignola and Deas (2005).

2.5 Biostimulatory Substances

The Basin Plan includes a narrative objective for "biostimulatory substances" that is applicable to the entire North Coast region:

> 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 (NCRWQCB 2005).

In this context, biostimulatory substances refer to any substance that promotes aquatic plant growth, but generally is synonymous with the nutrients nitrogen and phosphorus. Nitrogen and phosphorus are the primary macro-nutrients that enrich freshwater aquatic systems. Nuisance is not specifically defined in the Basin Plan. In the context of the Shasta River TMDL, Regional Board staff define nuisance aquatic growth as that which contributes to violation of numeric water quality objectives (particularly dissolved oxygen and pH objectives) or adversely affects beneficial uses. Ammonia (NH_3), nitrate (NO_3^-), and ortho-phosphate (PO_4^{3-}) are the soluble fractions of nitrogen and phosphorus, and are the forms that are directly available to aquatic plants.

2.5.1 Nutrient Criteria and Trophic State Thresholds

Nutrients do not directly affect salmonids, but impact them indirectly by stimulating the growth of algae and aquatic macrophytes to nuisance levels that can adversely impact dissolved oxygen and pH levels in streams. The concentration of nutrients required to cause nuisance levels of aquatic plants varies widely from one stream to another and detailed data analysis is required to determine relationships. US EPA (2000) and Tetra Tech (2005) provide excellent summaries of the literature on these analytical methods and will not be repeated here.

USEPA (1986, p. 267) has "desired goals" for total phosphates as phosphorus for the prevention of nuisance plant growths. The "desired goal" for streams or other flowing waters not discharging directly to lakes or impoundments is 0.1 mg/L; the "desired goal" for streams at the point where they enter a lake or reservoir is 0.05 mg/L; and the "desired goal" for lakes or reservoirs is 0.025 mg/L. These desired goals are guidance levels, not

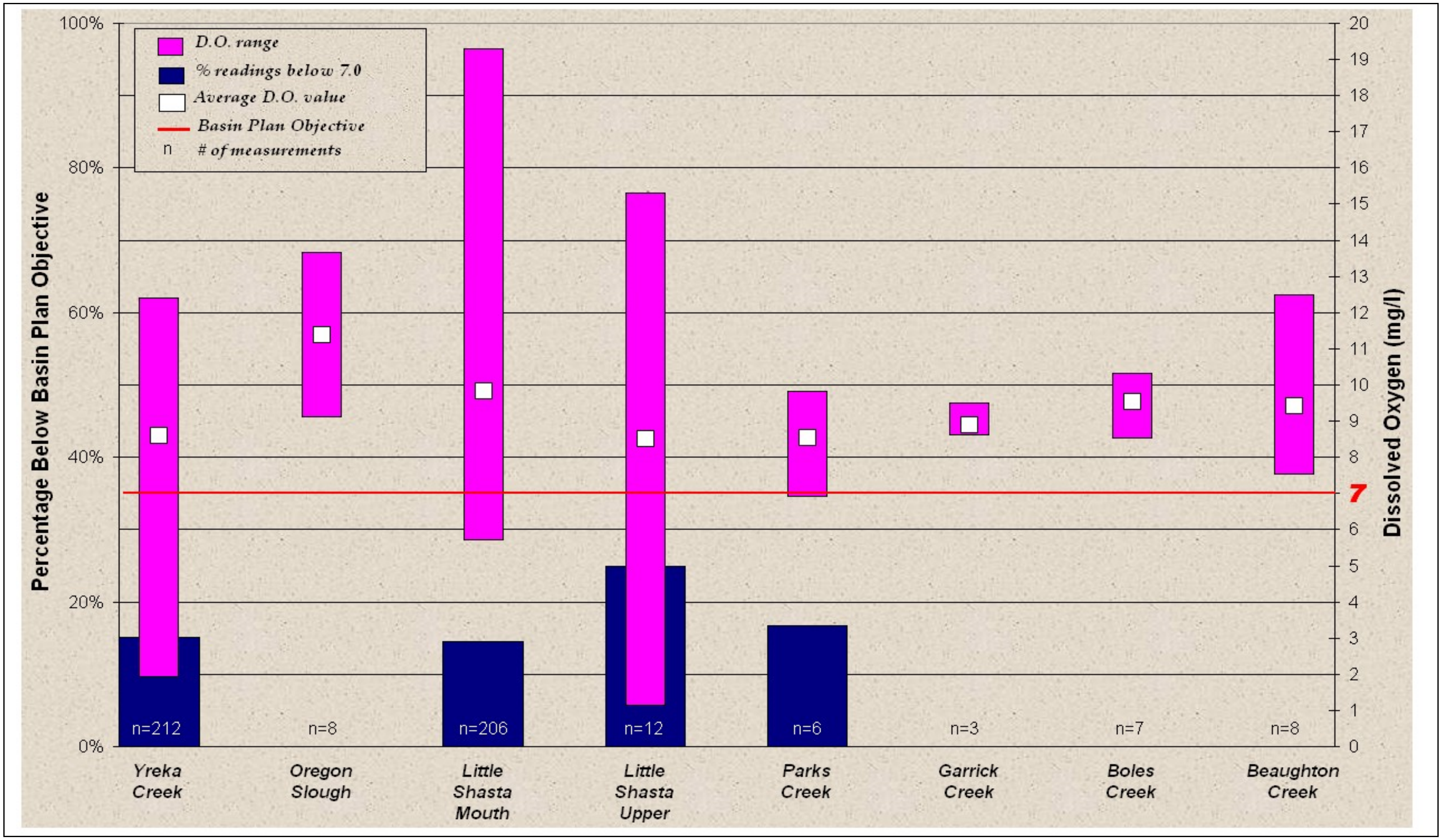

Figure 2.9: Dissolved oxygen concentrations, Shasta River tributaries, May through August, 2001-2003

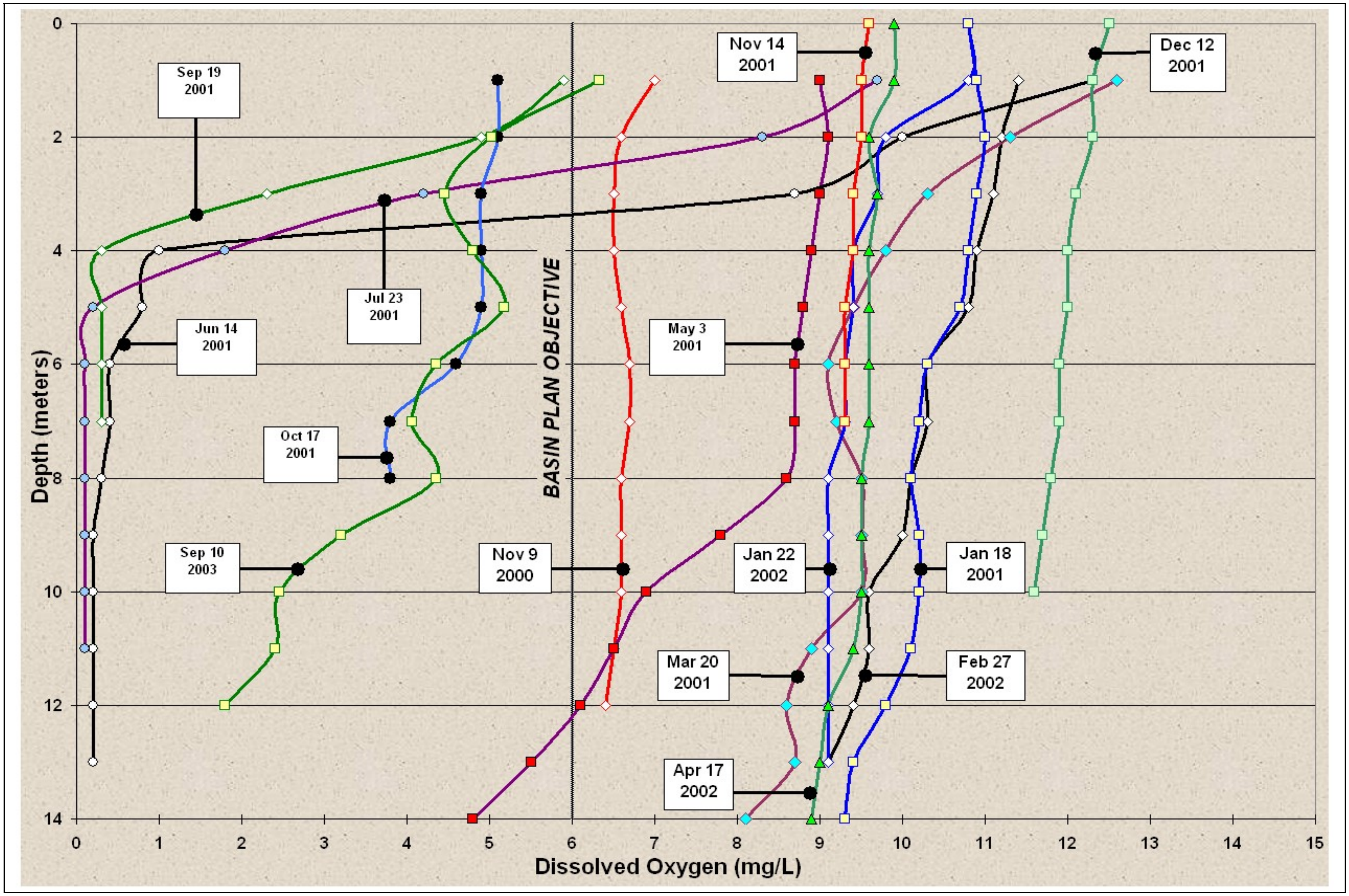

Figure 2.10: Lake Shastina dissolved oxygen depth profiles, 2001-2003

standards or criteria. USEPA (1986, p. 213) does not have a criterion or desired goal for nitrogen for prevention of nuisance plant growth; it does, however, have a criterion for nitrate nitrogen of 10 mg/L for human health protection in domestic water supplies.

In 2001, the USEPA developed recommended nutrient criteria for 13 aggregate ecoregions for rivers and streams of the United States (USEPA 2002). USEPA's recommended ecoregional nutrient criteria represent conditions of surface waters that have minimal impacts caused by human activities. The criteria are suggested baselines. California is in the process of refining these ecoregional criteria. The total phosphorus and total nitrogen criteria for ecoregion II (western forested mountains), which includes the Shasta River, are 0.01 and 0.12 mg/L, respectively.

Dodds et al. (1998) created a classification system for stream trophic state based on frequency distributions of total nitrogen, total phosphorous, and chlorophyll-a data from 200 streams in North America and New Zealand. These data were divided into three trophic state categories based on the lower, middle, and upper thirds of the distribution. USEPA (2000) states: "It should be stressed that this approach proposes trophic state categories based on the current distribution of algal biomass and nutrient concentrations which may be greatly changed from pre-human settlement levels." USEPA (2000) suggests that these distributions be used "to link nutrient concentrations and algal biomass in a very general sense." The trophic classification boundaries are presented below in Table 2.6, although they are not used to evaluate total nitrogen (TN) and total phosphorous (TP) conditions in the Shasta River.

Table 2.6: Boundaries for Trophic Classification of Streams

Parameter	**Oligotrophic-mesotrophic boundary**	**Mesotrophic-eutrophic boundary**	***Sample Size***
TN (mg/L)	0.7	1.5	1070
TP (mg/L)	0.025	0.075	1366

Source: Modified from Dodds et al. 1998

Literature values from various sources associating phosphorus and nitrogen levels in lakes and reservoirs to trophic status are presented in Table 2.7.

Table 2.7: Boundaries for Trophic Classification of Lakes and Reservoirs

Parameter	**Oligotrophic**	**Mesotrophic**	**Eutrophic**	**Hyper-eutrophic**	**Source**
Total P	<0.015	0.015-0.025	0.025-0.1	>0.1	Forsberg and Ryding (1980, as cited by Florida Lake Watch Undated)
Total N	<0.4	0.4-0.6	0.6-1.5	>1.5	Forsberg and Ryding (1980, as cited by Florida Lake Watch Undated)
Total P	<0.01	0.01-0.02	0.02-0.05 0.05-0.1*	>0.1	Environment Waikato Regional Council (Undated)
Total N	<0.2	0.2-0.3	0.3-0.5 0.5-1.5*	>1.5	Environment Waikato Regional Council (Undated)

*Supereutrophic classification
Note: All units are mg/L.

2.5.2 Shasta River Watershed Nutrient Conditions

Tables 2.8, 2.9, 2.10, and 2.11 provide a summary of nitrogen and phosphorus concentrations in the Shasta River, Lake Shastina, springs (including Bassey, Evans, Jim, Hidden Valley, and Big Springs), and key tributaries to the Shasta River, respectively.

2.5.2.1 Total Phosphorus

Total phosphorus levels in the headwaters of the watershed at the North North Fork Shasta River and Shasta River near the headwaters monitoring locations are 0.025 mg/L[1]. These values are below the USEPA 0.1 mg/L "desired goal" value to prevent nuisance growth. It is unknown how these data compare to the 0.01 mg/L USEPA criteria for ecoregion II, as the reporting limit is higher than the criteria value.

Downstream of the headwaters, Beaughton and Boles Creeks enter the Shasta River from the west and flow through the phosphorus rich volcanic soils flanking Mount Shasta. This is reflected in the high total phosphorous values in these creeks with averages of 0.192 and 0.119 mg/L respectively. These total phosphorus values are above the USEPA guidance level of 0.1 mg/L to prevent nuisance growth of aquatic plants. These values are also higher than the 0.01 mg/L USEPA criteria value for ecoregion II. As these creeks enter the Shasta River, they contribute to phosphorus loads in the river, and this is reflected in the high total phosphorous levels in the Shasta River above Dwinnell Dam.

Total phosphorus values in the Shasta River above Dwinnell are relatively high. Data from this portion of the Shasta River reflect water quality conditions entering Lake Shastina, with an average total phosphorus value of 0.09 mg/L. This total phosphorus concentration is above the USEPA "desired goal" of 0.05 mg/L for streams where they enter a lake or reservoir, and above the 0.01 mg/L criteria value for ecoregion II. Garrick Creek (aka Carrick Creek) also discharges directly into Lake Shastina, and total phosphorus values range from 0.1 to 0.29 mg/L. These values are above the USEPA guidance level of 0.05 mg/L and ecoregion II criteria value of 0.01mg/L.

The relatively high total phosphorus concentrations in Garrick Creek and the Shasta River above Dwinnell are reflected in monitoring data from Lake Shastina, where levels of total phosphorus range from 0.025 to 0.59 mg/L near the surface, with an average of 0.138 mg/L. Total phosphorus concentrations near the bottom of the reservoir range from 0.025 to 0.23 mg/L, with an average of 0.085 mg/L. These total phosphorus values

[1] In this TMDL document, all water quality samples with results below the analytical reporting limit were assumed to be half the reporting limit for this analysis. There is no commonly accepted method for statistical analysis of data below detection limits. Conventional methods include assuming the result is equal to the detection limit, half the detection limit, or zero, but these assumptions often have no theoretical basis. There are statistical methods that can be used to infer the distribution of data that are below detection limits. These require that the data be normally or log-normally distributed. The data in this analysis were neither. Since non-parametric statistics are used in this analysis, since the constituents are known to be present in the system, and since the number of data points are limited, the convention of using half the reporting limit is used here although it may lead to unquantified errors, especially when a large percentage of the data points in a set are below the reporting limit.

Table 2.8: Summary of Nitrogen and Phosphorus data for the Shasta River

Location	Metric	Ammonia as N	NO3 as N	NO2+NO3 as N	TKN	Total-N[1]	Ortho-P	Total-P
Shasta River near headwaters	Count	3	1	3	3	-	2	3
	Count (ND)	2	1	3	0	-	2	3
	Max	0.056	0.025	0.025	0.20	0.23	0.025	0.025
	Median	0.041	N/A	0.025	0.20	0.23	N/A	0.025
	Average	0.014	N/A	0.025	0.20	0.23	N/A	0.025
	Min	0.025	0.025	0.025	0.20	0.23	0.025	0.025
Shasta River above Dwinnell	Count	34	5	1	6	-	6	55
	Count (ND)	29	0	0	0	-	1	0
	Max	0.090	0.356	0.081	0.32	0.40	0.111	0.750
	Median	0.025	0.152	N/A	0.20	-	0.029	0.060
	Average	0.030	0.197	N/A	0.22	-	0.048	0.090
	Min	0.020	0.071	0.081	0.16	0.24	0.012	0.005
Shasta River below Dwinnell Dam	Count	485	65	26	165	-	124	273
	Count (ND)	319	34	14	26	-	5	4
	Max	0.700	0.730	0.240	4.00	4.24	0.422	2.010
	Median	0.075	0.122	0.025	0.49	0.52	0.131	0.239
	Average	0.025	0.025	0.087	0.50	0.59	0.140	0.190
	Min	0.005	0.020	0.025	0.10	0.13	0.005	0.020

[1]Total-N was calculated by adding the TKN and NO2+NO3 values listed in the table

Data from 1993-2003

Table 2.9: Summary of Nitrogen and Phosphorus data for Lake Shastina

Location	Metric	Ammonia as N	NO3 as N	NO2+NO3 as N	TKN	Total-N[1]	Ortho-P	Total-P
Lake Shastina (at surface)	Count	14	-	4	4	-	4	20
	Count (ND)	13	-	4	0	-	3	3
	Max	0.093	-	0.025	1.20	1.23	0.170	0.590
	Median	0.025	-	0.025	0.94	0.97	0.025	0.070
	Average	0.030	-	0.025	0.94	0.96	0.061	0.138
	Min	0.025	-	0.025	0.67	0.70	0.025	0.025
Lake Shastina (at depth)	Count	18	-	8	5	-	8	21
	Count (ND)	12	-	8	4	-	6	4
	Max	2.200	-	0.025	2.50	2.53	0.370	0.230
	Median	0.025	-	0.025	0.84	0.87	0.025	0.060
	Average	0.325	-	0.025	1.28	1.30	0.075	0.085
	Min	0.025	-	0.025	0.10	0.13	0.025	0.025

[1]Total-N was calculated by adding the TKN and NO2+NO3 values listed in the table

Data from 1993-2003

Table 2.10: Summary of Nitrogen and Phosphorus data for Springs

Metric	Ammonia as N	NO3 as N	NO2+NO3 as N	TKN	Total-N[1]	Ortho-P	Total-P
Count	8	3	12	8	-	5	8
Count (ND)	7	0	1	7	-	2	2
Max	0.088	0.290	0.260	0.69	0.95	0.160	0.220
Median	0.025	0.260	0.140	0.20	0.34	0.098	0.099
Average	0.033	0.253	0.150	0.26	0.41	0.086	0.107
Min	0.025	0.210	0.025	0.20	0.23	0.025	0.025

[1]Total-N was calculated by adding the TKN and NO2+NO3 values listed in the table

Data from 1993-2003

Note: springs monitored included Bassey, Evans, Jim, Hidden Valley, and Big Springs.

Table 2.11: Summary of Nitrogen and Phosphorus data for Key Tributaries to the Shasta River

Location	Metric	Ammonia as N	NO3 as N	NO2+NO3 as N	TKN	Total-N[1]	Ortho-P	Total-P
N. North Fork	Count	3	-	3	3	-	2	3
	Count (ND)	3	-	2	0	-	0	2
	Max	0.025	-	0.051	1	1.05	0.025	0.025
	Median	0.025	-	0.034	0.20	0.23	N/A	0.025
	Average	0.025	-	0.025	0.47	0.49	N/A	0.025
	Min	0.025	-	0.025	0.20	0.23	0.025	0.025
Beaughton Creek	Count	23	-	3	3	-	3	23
	Count (ND)	20	-	0	0	-	0	0
	Max	0.100	-	0.110	0.20	0.31	0.210	0.400
	Median	0.025	-	0.089	0.20	0.29	0.190	0.170
	Average	0.033	-	0.094	0.20	0.29	0.187	0.192
	Min	0.025	-	0.083	0.20	0.28	0.160	0.070
Boles Creek	Count	16	-	6	6	-	6	17
	Count (ND)	16	-	0	0	-	0	1
	Max	0.025	-	0.560	0.20	0.76	0.120	0.310
	Median	0.025	-	0.525	0.20	0.73	0.100	0.110
	Average	0.025	-	0.493	0.20	0.69	0.101	0.119
	Min	0.025	-	0.360	0.20	0.56	0.082	0.025
Garrick Creek	Count	16	-	-	-	-	-	28
	Count (ND)	16	-	-	-	-	-	0
	Max	0.025	-	-	-	-	-	0.290
	Median	0.025	-	-	-	-	-	0.160
	Average	0.025	-	-	-	-	-	0.169
	Min	0.025	-	-	-	-	-	0.100
Main Canal	Count	4	4	-	3	-	3	4
	Count (ND)	4	3	-	0	-	0	1
	Max	0.025	0.100	-	0.28	-	0.055	0.084
	Median	0.025	0.025	-	0.27	-	0.050	0.080
	Average	0.025	0.044	-	0.26	-	0.048	0.067
	Min	0.025	0.025	-	0.22	-	0.040	0.025
Parks creek	Count	14	1	-	4	-	2	18
	Count (ND)	14	0	-	0	-	2	3
	Max	0.025	0.098	-	0.66	-	0.025	0.260
	Median	0.025	N/A	-	0.20	-	N/A	0.010
	Average	0.025	N/A	-	0.32	-	N/A	0.046
	Min	0.025	0.098	-	0.20	-	0.025	0.005
Little Shasta	Count	24	1	4	8	-	2	36
	Count (ND)	22	1	4	0	-	0	3
	Max	0.100	0.025	0.025	0.95	0.98	0.092	0.400
	Median	0.025	N/A	0.025	0.25	0.28	N/A	0.110
	Average	0.031	N/A	0.025	0.41	0.43	N/A	0.119
	Min	0.025	0.025	0.025	0.20	0.23	0.025	0.025
Oregon Slough	Count	17	-	7	9	-	7	23
	Count (ND)	7	-	0	0	-	0	0
	Max	0.300	-	0.390	1.30	1.69	0.260	14.000
	Median	0.052	-	0.210	0.82	1.03	0.240	0.240
	Average	0.085	-	0.224	0.75	0.98	0.219	0.875
	Min	0.025	-	0.090	0.20	0.29	0.092	0.030
Yreka Creek	Count	8	-	10	72	-	50	143
	Count (ND)	7	-	0	0	-	2	2
	Max	0.076	-	1.600	0.75	2.35	1.220	1.700
	Median	0.025	-	0.860	0.20	1.06	0.050	0.103
	Average	0.031	-	0.763	0.26	1.02	0.119	0.258
	Min	0.025	-	0.098	0.10	0.20	0.010	0.010

[1]Total-N was calculated by adding the TKN and NO2+NO3 values listed in the table

Data from 1993-2003

reflect mesotrophic to hypereutrophic conditions, with the majority of data reflecting conditions which are supereutrophic or hypereutrophic. All total phosphorus data collected in Lake Shastina are above the USEPA "desired goal" for lakes and reservoirs of 0.025 mg/L, indicating levels of phosphorus that can promote nuisance aquatic growth.

Total phosphorus levels in the Shasta River below Dwinnell Dam show spatial variation, and the average total phosphorus level is 0.19 mg/L. Tributaries in this portion of the watershed have total phosphorus values ranging from 0.005 to 1.7 mg/L. The total phosphorus levels in springs are generally high with average values of 0.107 mg/L. Average levels of total phosphorus in the mainstem, tributaries, and springs below Dwinnell Dam are above the USEPA guidance value of 0.1 mg/L, and can promote nuisance aquatic growth. Additionally, average total phosphorous values are well above the recommended USEPA criteria for ecoregion II of 0.01mg/L.

Key findings regarding total phosphorus (TP) conditions are:

- Total phosphorus concentrations of the headwaters of the Shasta River are at levels that do not promote nuisance aquatic growth.
- Average and maximum total phosphorus concentrations of tributaries and the mainstem Shasta River are at levels that can promote nuisance aquatic growth.
- Average and maximum total phosphorus concentrations of Lake Shastina are generally supereutrophic or hypereutrophic, with TP concentrations at levels that can promote nuisance aquatic growth.
- Total phosphorus concentrations of springs are at levels that can promote nuisance aquatic growth.

2.5.2.2 Total Nitrogen

The headwaters of the Shasta River have total nitrogen levels indicative of some level of nutrient enrichment. Data from the Shasta River near the headwaters exceed the USEPA criteria value of 0.12 mg/L for ecoregion II (0.23 mg/L) as do total nitrogen values from the N. North Fork Shasta River (0.23 to 1.05 mg/L).

Total nitrogen levels in Boles Creek range from 0.56 mg/L to 0.76 mg/L and are higher than those in Beaughton Creek, which range from 0.28 to 0.31 mg/L. Data from the Shasta River above Dwinnell Dam reflect total nitrogen levels ranging from 0.24 to 0.40 mg/L. These tributary and mainstem values are at least twice the USEPA criteria for ecoregion II of 0.12 mg/L.

Surface measurements from Lake Shastina reflect conditions that are mesotrophic with values ranging from 0.70 to 1.23 mg/L. The average value of total nitrogen from samples collected at depth is close to the mesotrophic/eutrophic border (1.3 mg/L), and the maximum value is within the eutrophic classification range (2.53 mg/L).

In the Shasta River below Dwinnell Dam, total nitrogen values are all over the 0.12 mg/L USEPA criteria value for ecoregion II. Minimum total nitrogen levels are 0.13 mg/L and average and maximum values are far above the USEPA ecoregion II criteria (0.59 and

4.49mg/L respectively). Measured tributaries below the dam have total nitrogen values that are well above the USEPA criteria value. Average values of total nitrogen in Little Shasta, Oregon Slough and Yreka Creek are 0.43, 0.22, and 1.02 mg/L respectively. Springs in the watershed below the Dwinnell Dam have total nitrogen values ranging from 0.23 to 0.95 mg/L, which are above the 0.12 mg/L USEPA ecoregion II criteria.

Key findings regarding total nitrogen conditions are:

- Total nitrogen levels at measured locations in the Shasta River, tributaries, and springs exceed the USEPA criteria value for ecoregion II, with the exception of the Shasta River below Dwinnell Dam.
- In Lake Shastina, total nitrogen levels are generally mesotrophic to eutrophic, indicating conditions that promote aquatic growth.

2.6 Evidence of Beneficial Use Impairment

The previous three sections characterize temperature, dissolved oxygen, and nutrient conditions of the Shasta River basin. Section 2.3 demonstrates that temperature conditions regularly exceed USEPA temperature thresholds protective of salmonids. Section 2.4 demonstrates that dissolved oxygen concentrations are regularly below the Basin Plan dissolved oxygen objectives. Further, a comparison of the dissolved oxygen data presented in Section 2.4 to the dissolved oxygen requirements of salmonids presented in Electronic Appendix B_e indicates that Shasta River dissolved oxygen concentrations are often not supportive of various life stages of salmonids. Section 2.5 demonstrates that nutrient levels in the Shasta River are biostimulatory. This section summarizes prior documentation of how the temperature and dissolved oxygen conditions of the Shasta River basin are impairing the cold and warm freshwater habitat beneficial uses.

2.6.1 Cold Freshwater Habitat Impairment

As discussed in Section 1.4.10, salmonid populations of the Shasta River basin have declined sharply from historic levels. In 1985, the U.S. Department of Interior linked declining Shasta River salmonid populations to high summer stream temperatures, low summer flows, unscreened water diversions, degraded spawning gravel, and possibly hydroelectric projects (U. S. Department of Interior [USDI] 1985, pp. 5-8 to 5-16). Further, the report identified that rapid in-stream flow reductions at the onset of the spring irrigation season were possibly contributing to juvenile fall Chinook, coho, and steelhead losses, caused by stranding in pools and side channels. In 1987 and 1988, the California Department of Fish and Game (CDFG) sent memos to the Regional Water Board requesting assistance in assessing the link between water quality and the status of the Shasta River fishery. CDFG stated that in late spring during low water years, “depressed dissolved oxygen resulting from high biological oxygen demand and high temperature” in the Shasta Valley contributed to mortality of Chinook and steelhead (CDFG 1987). The 1988 memo cited “critical conditions due to dissolved oxygen concentrations, nutrient concentrations and temperature; especially during poor water years (CDFG 1988).”

A 1990-1991 Shasta River fisheries water quality project, funded by the US Fish and Wildlife Service Klamath River Basin Fisheries Task Force and the Shasta Valley Resource Conservation District, cited that fish kills in the Shasta were attributable to low dissolved oxygen levels (Ouzel Enterprises 1991, p. 2). The National Academy of Science report, "Endangered and Threatened Fishes in the Klamath River Basin: Causes of Decline and Strategies for Recovery," attributes the Shasta basin decline in salmonid production to "substantial reduction of flows by water withdrawal and the associated poor water quality," and states that high water temperature is "a major bottleneck for salmonid production" in the basin (National Research Council of the National Academies [NRC] 2003, p. 133).

In the summer of 2005, the California Department of Fish and Game documented water quality conditions in the Shasta River and a side channel located in the canyon called Salmon Heaven, and observed a number of dead fish (CDFG 2005b). On July 7th, one dead 1+ steelhead was observed in the side channel where the water temperature was 25.2°C, which is well above the juvenile rearing MWMT chronic temperature thresholds in Table 2.3, and over the juvenile lethal threshold in Table 2.4. Salmonids in this side channel were also observed swimming in the pool near the surface. Before dawn (04:42) on July 8th, dissolved oxygen concentrations were 2.17 mg/L in the downstream end of the side channel pool and 2.71 mg/L at the riffle above the pool (Basin Plan dissolved oxygen objective is a minimum of 7.0 mg/L), and stream temperatures ranged from 19.3 to 19.5 °C. On July 14th, 20 dead adult sculpin and 4 dead crayfish were observed in the side channel. No salmonids were observed. In the mid-afternoon (14:15), stream temperature in the side channel was 25°C and dissolved oxygen was 10.5 mg/L. Water temperature and dissolved oxygen levels in a spring that feeds the side channel were respectively 17.9°C and 0.5 mg/L in mid-afternoon (15:50) on the 14th.

These recent and past accounts indicate that stream temperatures and dissolved oxygen concentrations of the Shasta River basin significantly contribute to impairment of the cold freshwater beneficial use of the basin.

2.6.2 Warm Freshwater Habitat Impairment

Fish kills in Lake Shastina have been documented on numerous occasions, beginning in the 1960s. According to California Department of Fish and Game accounts (1975), fish kills were an annual summer-time occurrence in the lake during the 1960s. During that time, fish kills were attributed to low dissolved oxygen levels associated with algal blooms. The algal blooms were noted to occur due to high nutrient levels in the lake. These summer-time fish kills did not occur during the early 1970s, and CDFG (1975) notes that this may be due to improved wastewater treatment and water quality practices resulting in fewer nutrients being discharged into Lake Shastina.

The most recent documented fish kill in Lake Shastina occurred in 2001 when numerous dead Pond smelt and a few dead Tui chub, Golden shiners, and juvenile Largemouth bass were found around the edges of the lake (CDFG 2001). CDFG found no parasites or bacterial pathogens in the live fish tested, although they note that finding symptomatic fish was difficult. Water quality samples for dissolved oxygen, pH, and temperature in the lake were determined to be “okay”, but numeric water quality results were not provided (CDFG 2001).

2.6.3 Potential Municipal and Domestic Water Supply and Contact Recreation Impairment

Lake Shastina is an existing municipal and domestic water supply for the town of Montague. The lake is also used for both contact and non-contact recreation. The outflow from Lake Shastina is located near the bottom of the reservoir at Dwinnell Dam, and water is delivered to the town of Montague drinking water treatment facility via an open ditch periodically treated with a pesticide. Lake Shastina experiences regular summer algal blooms, and the algal assemblage is typical of eutrophic waters (Vignola and Deas 2005). In July 2004, Regional Water Board staff collected algal samples from Lake Shastina at two open water locations (at three depths at each location) in support of TMDL development. All of the algal samples included *Anabaena flos-aquae*, with cell densities ranging from 2 cells/mL at depth up to 994 cells/mL near the surface (NCRWQCB and University of California Davis Aquatic Ecosystems Analysis Laboratory [UCD AEAL] 2005). *Anabaena flos-aquae* is a cyanobacteria (also called blue-green algae) that produces multiple neurotoxins, including anatoxin-a (Kann 2005). The presence of neurotoxins was not analyzed as part of the Regional Water Board’s Lake Shastina study. Anatoxins are neurotoxic agents that have been implicated in numerous animal and wildlife poisonings, and one human fatality (Kann 2005).

Health risks identified by the World Health Organization (Chorus and Bartram 1999, as cited by Vignola and Deas 2005) for managing bathing waters that may contain cyanobacteria cells are:

- Low risk: <20,000 cells/ml
- Moderate risk: 100,000 cells/ml
- High risk: Cyanobacterial scum formation in contact recreation areas

While the cell counts were within the low risk category, the samples were collected at open water locations. Wind can accumulate algal blooms at shoreline locations, and cell densities can readily be increased by 1000 times or more (Brookes et al 2005, as cited by Vignola and Deas 2005).

These results represent a potential impairment to the municipal and domestic supply and contact recreation beneficial uses of Lake Shastina. This condition is not directly related to temperature and dissolved oxygen impairments; however, it is indirectly linked, as the water quality conditions that typically cause algal blooms (i.e. high nutrient concentrations and warm water temperatures) also contribute to low dissolved oxygen levels in reservoirs that are attributed to decomposition of dead algae.