SECTION D
RIPARIAN FUNCTION

INTRODUCTION

Mendocino Redwood Company conducted an assessment of riparian function in the Greenwood Watershed Analysis Unit (WAU) during the summer of 2003. This assessment is divided into two groups: 1) the potential of the riparian stand to recruit large woody debris (LWD) and current demand of LWD in stream channels and 2) a canopy closure and stream temperature assessment. The LWD potential assessment evaluates short-term (the next 2-3 decades) LWD recruitment. It shows the current condition of the riparian stands for generating LWD for stream habitat or stream channel stability. Field observations of current LWD levels in the stream channels and the riparian stand's ability to recruit LWD are presented in relation to channel sensitivity to LWD in order to determine current in-stream needs. The canopy closure and stream temperature assessment presents current canopy closure conditions and results of stream temperature monitoring for the Greenwood WAU. The goal of these evaluations is to provide baseline information on the current riparian stand functions in the Greenwood WAU.

LARGE WOODY DERBIS RECRUITMENT POTENTIAL AND INSTREAM DEMAND METHODS

Short-term LWD recruitment potential (next 20-30 years) was evaluated in designated stream segments within the Greenwood WAU. Stream segments were designated in the stream channel condition assessment and are shown on map E-1 (Stream Channel Condition Module). Generally, stream segments were assessed on any watercourse with less than a 20 percent gradient. In this assessment, vegetation type, size and density is assumed to influence LWD recruitment with the best riparian vegetation being large conifer trees.

To determine the LWD recruitment potential, riparian stands were classified using year 2000 aerial photographs and field observations from the summer of 2000. The riparian stands were evaluated for a distance of approximately one tree height on either side of the watercourse. Riparian stands were evaluated separately for each side of the watercourse. The following vegetation classification scheme for the Mendocino Redwood Company (MRC) timber inventory was used to classify the riparian stands:

Vegetation Classes

RW- greater than 75% of the stand basal area in coast redwood.
RD- combination of Douglas-fir and coast redwood basal area exceeds 75% of the stand, but neither species alone has 75% of the basal area.
MH- mix of hardwood basal area exceeds 75% of the stand, but no one hardwood species has 75% of the basal area.
CH- mix of conifer and hardwood basal area exceeds 75% of the stand, but no one hardwood or conifer species has 75% of the basal area.
Br- Brush

Vegetation Size Classes
1 - <8inches dbh
2 - 8 to 15.9 inches dbh
3 - 16 to 23.9 inches dbh
4 - 24 to 31.9 inches dbh
5 - >32 inches dbh

The size class is determined by looking at the diameters of the trees in the riparian stand. The size class which exceeds 50% of the total basal area is the size class assigned to the stand.

Vegetation Density
O - 5-20% tree canopy cover range
L - 20-40% tree canopy cover range
M - 40-60% tree canopy cover range
D - 60-80% tree canopy cover range
E - >80% tree canopy cover

The codes for vegetation classification of riparian stand condition are based on the three classes listed above. The vegetation code is a string of the classes with the vegetation class first, the size class second, and the vegetation density last. For example, the vegetation code for a redwood stand with greater than 50% of the basal area with 16-23.9 inch dbh or larger and 60-80% canopy cover would be classified RW3D.

In this assessment, vegetation type, size and density is assumed to affect LWD recruitment to the stream channel with the best riparian vegetation being dense areas of large conifer trees. The LWD recruitment potential ratings reflect this. The following table presents the vegetation classification codes for the different LWD recruitment potential ratings (Table D-1).

Table D-1. Description of LWD Recruitment Potential Rating by Riparian Stand Classification for the Greenwood WAU.

Vegetation Type	**Size and Density Classes**					
	Size Classes 1-2 (Young)		**Size Class 3 (Mature)**		**Size classes 4-5 (Old)**	
	Sparse (O, L)	**Dense (M, D, E)**	**Sparse (O, L, M)**	**Dense (D, E)**	**Sparse (O, L, M)**	**Dense (D, E)**
RW	Low	Low	Low	Moderate	Moderate	High
RD	Low	Low	Low	Moderate	Moderate	High
CH	Low	Low	Low	Moderate	Low	High
MH	Low	Low	Low	Low	Low	Moderate

LWD was inventoried in watercourses during the stream channel assessment. All "functional" LWD was tallied within the bankfull channel for each sampled stream segment. Functional LWD was that LWD which is providing some habitat or morphologic function in the stream channel (i.e. pool formation, scour, debris dam, bank stabilization, or gravel storage). The minimum size requirement for functional LWD is 4 inch diameter and 6 foot length; however some exceptions such as stumps with high diameters but short lengths are counted. Length and diameter were recorded for each piece so that volume could be calculated. The diameter is measured at the mid point along the length of the LWD piece. The length was the entire length of the LWD, including those portions outside of the bankfull channel. Specific characteristics of the LWD are identified in the field (Table D-2).

Table D-2. Instream Large Woody Debris Characteristics Identified during Stream Surveys for the Greenwood Watershed Analysis Unit.

Category	LWD Attribute	Description
LWD species	Redwood	coast redwood
	Fir	Douglas fir, hemlock, grand fir, nutmeg, spruce, or pine.
	Alder	red or white alder
	Hardwood	All other hardwoods (oak, bay laurel, maple, etc.)
	Unknown	cannot identify species
LWD Dimensions	Length	Total exposed length including portion outside bankfull channel (portion buried in streambed cannot be measured).
	Diameter	Diameter at center of LWD piece. (the center of a LWD piece is not always in the stream channel.)
Association with other LWD	Debris accumulation	Greater than 3 but less than 10 functional LWD pieces in contact with each other.
	Debris jam	10 or greater functional LWD pieces in contact with each other.
Decay Class (Robison and Beschta, 1990)	Decay class 1	Bark intact, twigs present, texture intact, round shape, original wood color.
	Decay class 2	Bark intact, twigs absent, texture intact, round shape, original wood color.
	Decay class 3	Trace of bark, twigs absent, texture smooth with some surface abrasion, round shape, original wood color or darkening.
	Decay class 4	Bark absent, twigs absent, texture with surface abrasion some holes and openings, round to oval shape, dark wood coloring.
	Decay class 5	Bark absent, twigs absent, texture is vesicular with many holes and openings, round to oval shape, dark wood coloring.
Special characteristics	Buried	If part of LWD is buried in the stream bed or banks.
	Rootwad	LWD has a rootwad attached.
	Alive	LWD is alive.
Location	Station (feet)	The location of the center of each LWD piece within the longitudinal profile (station or distance along the longitudinal profile).
Input process (identify only one process per LWD piece; the dominant input process)	Windthrow	Entire tree uprooted and recruited by wind.
	Wind fragmentation	Portion of tree broken and recruited by wind.
	Bank erosion	Tree or LWD that was delivered from erosion of the bank.
	Mass wasting	LWD delivered from a mass wasting event(s).
	Logging associated	LWD placed or delivered from past harvest activities (i.e. LWD from Humboldt crossing). Only use this designation if harvesting processes (road building, yarding, or tree falling) input the LWD in the channel.
	Restoration	LWD placed as part of a restoration effort.
	Unknown	Cannot identify the input process.

The number of debris accumulations in the stream survey reach was tallied. Debris jams (>10 pieces) were noted and total dimensions and porosity of the debris jam recorded. Porosity of a debris jam was considered to be “air space” and subtracted out of the LWD volume. Total number of pieces and number of key pieces were counted for each debris jam. Species and dimensions were not recorded for individual pieces contained in debris jams. All volume estimates and piece counts were separated in two groups, one not associated with debris jams and one considering all LWD pieces in the segment, debris jams included. The percentage of total volume and total pieces per segment which was contained in debris jams was also calculated.

For the entire stream channel segments surveyed the percentage (0-25%, 25-50%, 50-75% and 75-100%) of the LWD pieces in the stream that were recently recruited (<10 years) were recorded.

Table D-3. Key LWD Piece Size Requirements (adapted from Bilby and Ward, 1989)

Bankfull width (ft.)	Diameter (in.)	Length (ft.)		Minimum volume alternative* (yds^3)
0-10	13	1 or 1.5 times bankfull width**		1
10-20	16	1 or 1.5 times bankfull width**		3
20-30	18	1 or 1.5 times bankfull width**	OR	5
30-40	21	1 or 1.5 times bankfull width**		8
40-60	26	1 or 1.5 times bankfull width**		15
60-80	31	1 or 1.5 times bankfull width**		25
80-100	36	1 or 1.5 times bankfull width**		34

* A piece of LWD counts as a “key piece” if it does not meet the diameter and length criteria but exceeds this minimum volume.
** 1.0 times bankfull width if a rootwad is attached, 1.5 times bankfull width if not.

The LWD is further classified as a key LWD piece if it meets or exceeds size requirements (Table D-3). The quantity of LWD observed was normalized by distance, for comparison through time or to other similar areas, and was presented as a number of LWD pieces per 100 meters (328 feet). This normalized quantity, by distance, was performed for functional and key LWD pieces within the bankfull channel. The key piece quantity (per 100 meters of channel) is compared to the target for what would be an appropriate key piece loading. The target for appropriate key piece loading was derived from Bilby and Ward (1989) and Gregory and Davis (1992) and presented in Table D-4.

Table D-4. Target for Number of Key Large Woody Debris Pieces in Watercourses of the Greenwood WAU.

	# Key Pieces		
Bankfull Width (ft)	**Per 100 meters**	**Per 1000 feet**	**Per Mile**
<15	6.6	20	106
15-35	4.9	15	79
35-45	3.9	12	63
>45	3.3	10	53

An in-stream LWD demand is identified in addition to the riparian stand recruitment potential, discussed previously. The in-stream LWD demand is an indication of what level of concern there is for in-stream LWD for stream channel morphology and fish habitat associations within the Greenwood WAU. The in-stream LWD demand is determined by stream segment considering the overall LWD recruitment, the stream segment LWD sensitivity rating (as determined in the Stream Channel and Fish Habitat Assessment for stream geomorphic units), and the level of LWD currently in the stream segment (on target or off target). Table D-5 shows how these three factors are used to determine the in-stream LWD demand.

Table D-5. In-stream LWD Demand

Recruitment Potential Rating	LWD On Target / LWD Off Target	Channel LWD Sensitivity Rating		
		LOW	**MODERATE**	**HIGH**
LOW	**LWD On Target**	LOW	MODERATE	HIGH
LOW	**LWD Off Target**	MODERATE	HIGH	HIGH
MODERATE	**LWD On Target**	LOW	MODERATE	MODERATE
MODERATE	**LWD Off Target**	MODERATE	HIGH	HIGH
HIGH	**LWD On Target**	LOW	MODERATE	MODERATE
HIGH	**LWD Off Target**	LOW	HIGH	HIGH

Low In-stream LWD Demand - this classification suggests that current riparian LWD recruitment conditions and in-stream LWD are at levels which are sufficient for LWD function in these stream channel types.

Moderate In-stream LWD Demand - this classification suggests that current riparian LWD recruitment conditions and in-stream LWD are at levels which are moderately sufficient for fish habitat and stream channel morphology requirements. Consideration must be given to these areas to improve the LWD recruitment potential of the riparian stand. These areas may also be considered for supplemental LWD or stream structures placed in the stream channel.

High In-stream LWD Demand - this classification suggests that current riparian LWD recruitment conditions and in-stream LWD are at levels which are not sufficient for LWD function in these stream channel types. These areas must consider improvement of the LWD recruitment potential of the riparian stand. These areas should be the highest priority for supplemental LWD or stream structures placed in the stream channel.

Tributaries and Greenwood Creek within each of the two Calwater Planning Watersheds were further evaluated for meeting target conditions. Within each hydrologic watershed of the stream segment analyzed, the percentage of watercourses with low or moderate LWD demand and the percentage of watercourses with an appropriate number of key LWD pieces determine the overall quality rating of watercourse LWD in each stream or stream segment of a Calwater planning watershed. Under this scheme, LWD quality falls into the following categories:

ON TARGET – >80% of watercourses have low or moderate LWD demand, and >80% of stream segments have appropriate number of key LWD pieces.

MARGINAL – 50-80% of watercourses have low or moderate LWD demand, and stream segments have significant functional LWD and are approaching the number of key LWD pieces desired

DEFICIENT – <50% of watercourses have low or moderate LWD demand, and little functional or key LWD.

The percentages that define the break between each of the LWD quality ratings have the intent of realizing that streams and watersheds are dynamic. LWD loadings are naturally found to be variable. Therefore a target of 100% of stream segment meeting LWD quality demand would be inappropriate. However, it seems that if less than half of the watercourses (50%) do not meet LWD demand than a LWD deficiency is assumed.

We consider key LWD for determination of both instream LWD demand and overall LWD quality to help ensure that enough key LWD exists at both small (i.e., stream segment) and large (watershed) spatial scales.

LARGE WOODY DEBRIS RECRUITMENT POTENTIAL AND INSTREAM DEMAND RESULTS

The large woody debris recruitment potential and in-stream LWD demand for the Greenwood WAU is illustrated in Map D-1. The large woody debris recruitment potential and in-stream LWD demand provides baseline information on the structure and composition of the riparian stand and the level of concern about current LWD conditions in the stream. This map provides a tool for prioritizing riparian and stream management for improving LWD recruitment and instream LWD. These areas must be monitored over time to ensure that the recruitment potential is improving and that large woody debris is providing the proper function to the watercourses.

Current instream LWD levels are shown in Table D-6 a, b, c, and d. Approximately 1/3 of the segments surveyed (4 out of 12) in the Greenwood WAU met the target for key LWD. However, many of the streams in the WAU have reasonably good levels of functional LWD. Generally, LWD loading of functional LWD in streams in the Greenwood WAU is good, however the larger stable key piece levels are low.

Debris jams in the Greenwood WAU, were shown to contain a significant portion of the total piece count and volume when they occurred. In the Greenwood WAU, debris jams were observed in five of the segments sampled and contained 43-93% of the total pieces and a considerable amount of the total volume 51-77% (see Table D-6 a and b). In a few stream segments, debris jams affected whether or not the segment met the key LWD target.

LWD species composition was largely conifer dominated (Table D-6b). The majority of segments had redwood and fir LWD, with redwood generally in the highest amounts. A few of the segments, particularly in lower Greenwood Creek (CG4 and CG6) had mainly hardwood LWD. This is due to a high amount of alder and hardwood species adjacent to the stream. The hardwood LWD is less desirable because it breaks down faster and generally is smaller than conifer LWD making for a shorter residence time within the stream.

Generally less than 50% of the amount of LWD in any given segment in the Greenwood WAU was partially buried or had a rootwad attached (Table D-6c). LWD that is partially buried or has a rootwad attached is typically more likely to be stable within a stream during high flows. Only a small portion of live trees within the bankfull channel widths of Greenwood WAU are providing LWD function in the Greenwood WAU; this is expected as live trees are not expected to provide much stream LWD function.

Input process of individual LWD was difficult to determine in the Greenwood WAU. The majority of the LWD was classified as having unknown input process (67%), in other words it could not be determined how the LWD was input to the stream (Table D-6d). Much of the LWD observed had not been recently delivered to the stream so input processes were not identifiable. The main LWD input processes, of the LWD which could be identified, in the Greenwood WAU is wind throw, wind fragmentation and bank erosion. Identifiable mass wasting LWD input was low in the Greenwood WAU. The wind associated inputs (wind throw and wind fragmentation) were generally the highest input processes, with bank erosion next.

Nearly all segments in the Greenwood WAU contained LWD that was not recently contributed to the stream. All but three of the segments observed fell into the 0-25% category for LWD recruited within the last 10 years. This is further observed in the decay class ratings of the individual LWD in the Greenwood WAU. Approximately 1/3 of the LWD is in decay class 5, a high degree of decay. Only 8% of the LWD pieces are in decay class 1 and 2 that would suggest recent recruitment. Though there is not a lot of recent recruitment approximately 2/3 of the LWD in streams of Greenwood WAU is considered sound (has a decay class of 4 or less).

As shown in tables D-6 a and b and Map D-1, there is a need for LWD in many of the channel segments of the Greenwood WAU. Channel segments with low LWD loading will need to be the priority for monitoring future recruitment and potentially LWD restoration work. Even the few segments that met the target need LWD levels to be maintained to ensure LWD is providing fish habitat and morphological function in the stream channels.

Riparian recruitment potential is generally low to moderate in the Greenwood WAU (see map D-1). A greater amount of moderate LWD recruitment potential riparian stands occur in the Lower Greenwood Creek planning watershed than Upper Greenwood Creek. The larger proportion of low LWD recruitment potential stands in Upper Greenwood Creek planning watershed was from a greater amount of hardwood associated with the riparian areas and generally smaller conifer trees.

Due to the low to moderate LWD recruitment potential of riparian stands and few stream segments meeting the key LWD target, the stream segments of the mainstem of Greenwood Creek fall into the high instream LWD demand category. Many of the tributaries are only in moderate need of LWD input; these channels have a higher level of LWD proportional to a low stream width.

Table D-6 a. Large Woody Debris Pieces in Select Stream Segments of the Greenwood Watershed Analysis Unit, 2003.

Stream Segment Name	ID#	Functional LWD Pieces without Debris Jams	Functional LWD Pieces With Debris Jams	Total # of Debris Jams	Total # of Debris Accumulations	Functional LWD (#/328ft.) w/o Debris Jams	Functional LWD (#/328ft.) w/ Debris Jams	Key LWD Pieces without Debris Jams	Key LWD Pieces with Debris Jams	Key LWD Pieces/100m without Debris Jams	Key LWD Pieces/100m with Debris Jams	Percent LWD in Debris Jams
Greenwood Creek	CU2	27	27	-	4	8.7	8.7	0	0	0.0	0.0	0%
Valente Gulch	CU6	19	39	-	1	9.9	20.3	3	8	1.6	4.2	0%
Big Tree	CU12	23	23	-	3	22.9	22.9	13	0	12.9	0.0	0%
Greenwood Creek	CU4	15	15	-	2	4.2	4.2	0	0	0.0	0.0	0%
Big Tree	CU10	29	69	1	3	27.2	64.7	19	34	17.8	31.9	58%
Greenwood Creek	CG4	17	47	1	2	3.8	10.6	3	5	0.7	1.1	60%
Barn Gulch	CG30	22	42	1	2	20.6	39.4	11	13	10.3	12.2	43%
Greenwood Creek	CG6	11	11	-	0	2.8	2.8	0	0	0.0	0.0	0%
Unnamed	CG16	31	66	2	4	20.3	43.3	17	21	11.2	13.8	53%
Corrals tributary	CG25	44	44	-	4	24.9	24.9	0	0	0.0	0.0	0%
Corrals tributary	CG26	19	19	-	-	12.5	12.5	0	0	0.0	0.0	0%
Corrals tributary	CG27	49	49	-	5	40.2	40.2	0	0	0.0	0.0	0%

Table D-6b. Large Woody Debris Volume in Select Stream Segments of the Greenwood Watershed Analysis Unit, 2003.

Stream Segment Name	ID#	Total Volume (yd^3) without Debris Jams	Total Volume (yd^3) with Debris Jams	Total Vol/328ft. (yd^3) without Debris Jams	Total Vol/328ft (yd^3) with Debris Jams	Percent Volume in Debris Jams	Percent Volume Key Pieces without Debris Jams	% of Total Volume By Species w/o Jams					% Current Recruitment (<10 yrs)
								Redwood	Fir	Alder	Hardwood	Unknown	
Greenwood Creek	CU2	41.7	41.7	1.6	0.1	0%	0%	59%	16%	0%	19%	11%	0-25%
Valente Gulch	CU6	22.7	82	4.9	0.3	72%	39%	26%	0%	0%	6%	7%	0-25%
Big Tree	CU12	42.6	42.6	4.9	0.6	0%	94%	58%	13%	0%	0%	29%	0-25%
Greenwood Creek	CU4	8.7	8.7	0.3	0.0	0%	0%	68%	0%	0%	15%	17%	25-50%
Big Tree	CU10	59.9	131	14.2	1.5	54%	96%	87%	5%	0%	0%	8%	0-25%
Greenwood Creek	CG4	50.2	108.6	2.8	0.1	54%	56%	56%	0%	34%	0%	10%	75-100%
Barn Gulch	CG30	103.9	140.9	15.3	1.7	26%	97%	79%	20%	0%	1%	1%	0-25%
Greenwood Creek	CG6	4.9	4.9	0.1	0.0	0%	0%	2%	0%	49%	24%	24%	75-100%
Unnamed	CG16	50.5	92.5	7.0	0.5	45%	87%	73%	0%	0%	11%	15%	0-25%
Corrals tributary	CG25	26	26	1.7	0.1	0%	39%	47%	8%	21%	5%	19%	0-25%
Corrals tributary	CG26	14.9	14.9	1.1	0.1	0%	64%	75%	22%	0%	1%	3%	0-25%
Corrals tributary	CG27	46	46	4.4	0.4	0%	41%	68%	11%	0%	2%	19%	0-25%
Greenwood Creek	CG1	41.7	41.7	1.5	0.1	0%	22%	39%	52%	1%	7%	1%	0-25%

Table D-6c. Percentage of Large Woody Debris Pieces in Select Stream Segments of Greenwood Watershed Analysis that are Root Associated, Buried and Alive, 2003.

Stream Segment Name	ID#	LWD Piece Count					
		Root Associated		Buried		Alive	
		Number	Percent	Number	Percent	Number	Percent
Greenwood Creek	CU2	11	41%	1	4%	2	7%
Valente Gulch	CU6	4	36%	4	36%	2	18%
Big Tree	CU12	3	13%	8	35%	0	0%
Greenwood Creek	CU4	1	7%	2	13%	0	0%
Big Tree	CU10	6	21%	13	45%	0	0%
Greenwood Creek	CG4	12	71%	1	6%	0	0%
Barn Gulch	CG30	1	5%	11	50%	0	0%
Greenwood Creek	CG6	3	27%	0	0%	1	9%
Pond Tributary	CG16	4	13%	6	19%	0	0%
Corrals Tributary	CG25	5	11%	9	20%	1	2%
Corrals Tributary	CG26	5	26%	4	21%	0	0%
Corrals Tributary	CG27	9	100%	1	11%	0	0%
Greenwood Creek	CG1	3	15%	1	5%	2	10%

Table D-6d. Percentage of Large Woody Debris in Select Stream Segments of Greenwood Watershed Analysis Unit by Input Process, 2003.

Stream	Segment	Total LWD Pieces	Windthrow	Wind Fragmentation	Bank Erosion	Mass Wasting	Logging Associated	Restoration	Unknown
Greenwood Creek	CU2	27	7%	4%	4%	11%	0%	0%	67%
Valente Gulch	CU6	39	3%	0%	0%	0%	5%	0%	44%
Big Tree	CU12	23	4%	0%	9%	0%	22%	0%	65%
Greenwood Creek	CU4	15	0%	0%	7%	0%	13%	0%	80%
Big Tree	CU10	29	0%	0%	17%	0%	24%	0%	59%
Greenwood Creek	CG4	19	37%	0%	16%	0%	0%	0%	37%
Barn Gulch	CG30	24	4%	4%	8%	0%	13%	0%	63%
Greenwood Creek	CG6	11	18%	27%	18%	0%	0%	0%	36%
Pond Tributary	CG16	31	13%	3%	6%	0%	3%	0%	74%
Corrals Tributary	CG25	44	5%	7%	16%	0%	2%	0%	66%
Corrals Tributary	CG26	19	5%	16%	0%	0%	5%	0%	74%
Corrals Tributary	CG27	49	0%	2%	2%	0%	0%	0%	96%
Greenwood Creek	CG1	20	10%	5%	0%	0%	0%	0%	80%
Greenwood WAU Total			***7%***	***4%***	***7%***	***1%***	***6%***	***0%***	***67%***

Table D-7 shows the instream LWD quality rating for major streams and sections of Greenwood Creek in each of the two Calwater planning watersheds in the WAU. This quality rating will provide a tool to monitor the quality of the LWD in major streams over time. The entire mainstem of Greenwood Creek is currently classified as deficient. The large size of the channel requires larger LWD which is currently at low levels in Greenwood Creek. Most of the tributaries of Greenwood have marginal or on target ratings. One tributary, Corrals tributary, is deficient primarily due to lack of key LWD.

Table D-7. Instream LWD Quality Ratings for Tributaries and Sections of Greenwood Creek in Calwater Planning Watersheds for the Greenwood WAU.

Stream	**Calwater Planning Watershed**	**Instream LWD Quality Rating**
Greenwood Creek	Lower Greenwood Creek	Deficient
Greenwood Creek	Upper Greenwood Creek	Deficient
Pond Tributary (CG16-22)	Lower Greenwood Creek	On Target
Corrals Tributary (CG25-38)	Lower Greenwood Creek	Deficient
Valente Gulch	Upper Greenwood Creek	Marginal
Big Tree	Upper Greenwood Creek	On Target

CANOPY CLOSURE AND STREAM TEMPERATURE METHODS

Canopy closure, over watercourses, was estimated from aerial photographs (2000) and field observations during the summer of 2003. Field measurements of canopy closure over select stream channels were taken during the stream channel assessments in the Greenwood WAU. The field measurements consisted of estimating canopy closure over a watercourse using a spherical densiometer. The densiometer estimates were taken at approximately 3-5 evenly spaced intervals along a sampled channel segment, typically at a length of 20-30 bankfull widths. The results of the densiometer readings were averaged across the channel to represent the percentage of canopy closure for the channel segment. Based on the field observations and aerial photograph observations five canopy closure classes were determined using aerial photographs (Map D-2). These classes as well as the criteria for an aerial photograph interpretation are shown in Table D-8.

Table D-8. Canopy Closure Classes and Criteria for Interpretation of Classes from Aerial Photographs.

Characteristics Observed on Aerial Photograph	**Canopy Closure Class**
Stream surface not visible	>90%
Stream surface visible in patches	70-90%
Stream surface visible but banks not visible	40-70%
Stream surface visible and banks visible at times	20-40%
Stream surface and banks visible	0-20%

Along each of the sampled stream segments a representative cross section of a riffle of the segment is measured during the stream channel assessment. At this cross section location one reading of the percent of solar radiation the stream is exposed to in August (a high temperature summer month) is measured using a solar pathfinder. In addition to the percent of solar radiation, the percent of topography shading solar radiation and the canopy closure over the stream are observed at the same location.

Stream temperatures have been monitored in Class I (fish bearing) watercourses in the Greenwood Creek WAU, from 1994 until present. In summer 2001 this was expanded to include select Class II watercourses as part of a herpetological study. In 2002 several new temperature monitoring locations were established to research whether stream water temperature is impaired in Greenwood Creek. Greenwood Creek is on a 303(d) "watch list" for temperature impairment by the North Coast Regional Water Quality Control Board. In 2002 three air temperature monitoring locations were also established in the Greenwood WAU; one near the coast, one at the upper end of the Lower Greenwood planning watershed and the other at Maple Basin near the outlet of the Upper Greenwood Creek planning watershed. Map D-2 shows the temperature monitoring locations and Table D-9 describes the temperature monitoring locations.

Table D-9. Stream and Air Temperature Monitoring Locations and Time Periods in the Greenwood Creek WAU (see map D-2).

Temperature Monitoring Station	Stream Channel Segment Number	Years Monitored
84-1	CG1	'92, '93, '95, '97, '99, '00, '02, '03
84-1A (air)	n/a	'02
84-3	CU2	'94, '95, '97, '99, '00, '02, '03
84-3A (air)	n/a	'02
84-20*	-	'01
84-21*	CG41	'01, '03
84-22*	CG42	'01
84-23*	CG40	'01, '03
84-4	CG4	'02, '03
84-4A (air)	n/a	'03
84-5	CG25	'02, '03
84-6	CG6	'02, '03
84-6A (air)	n/a	'02, '03
84-7	CU10	'02, '03
84-8	CU6	'03

* - Class II sites

Stream and air temperature was monitored using electronic temperature recorders (Stowaway, Onset Instruments) that measure the water or air temperature every 2 hours. Stream and air temperatures are monitored during the summer months when the temperatures are highest (typically June-September). The stream temperature recorders were typically placed in shaded locations within shallow pools (<2 ft. in depth) directly downstream of riffles. The air temperature recorder was placed in the shade in close proximity to the corresponded stream temperature recorder number. Maximum and mean daily temperatures were graphed for each temperature monitoring site and presented in Appendix D. Maximum weekly average temperatures (MWATs), maximum weekly maximum temperatures (MWMT) were calculated for the stream and air temperatures by taking a seven day average of the mean and maximum daily water or air temperature. The annual maximum temperature is also calculated.

A stream shade quality rating was derived for tributaries or segments of Greenwood Creek within each Calwater planning watershed. The percentage of perennial watercourses in a stream segment's hydrologic watershed ranked as having "on-target" effective shade determines the overall quality of the stream's shade rating. For Greenwood Creek that flows through 2 Calwater planning watersheds, the percentage of perennial watercourses in stream segments of that planning watershed ranked as having "on-target" effective shade determines the overall quality of the stream or river's shade canopy.

The percentage of effective shade required for an "on-target" rating varies by bankfull width of the watercourse:

- for watercourses with bankfull widths <30 feet, >90% effective shade.
- for watercourses with bankfull widths of 30-100 feet, >70% effective shade.
- for watercourses with bankfull widths of 100-150 feet, >40% effective shade.

We use the following categories of watercourse-shade rating to determine overall shade quality in each major stream or river/stream segment of a planning watershed:

ON TARGET –	>90% of perennial watercourses that contribute to the stream have "on-target" effective shade
MARGINAL –	70-90% of perennial watercourses that contribute to the stream have "on-target" effective shade, or >70% of stream with greater than 70% canopy.
DEFICIENT –	<70% of perennial watercourses that contribute to the stream have "on-target" effective shade or <70% canopy.

CANOPY CLOSURE AND STREAM TEMPERATURE RESULTS AND DISCUSSION

Canopy closure over watercourses in the Greenwood WAU is generally good (Map D-2 and Table D-10). The majority of the tributaries of Greenwood Creek have canopy greater than 80%, Big Tree is the exception at 76%. Greenwood Creek has a few areas with canopies below 70% in the Lower Greenwood planning watershed where the creek is wider.

The percent of solar radiation shaded by streamside trees is high in the Greenwood Creek WAU. The amount of solar radiation shaded by the sun's path on an August day is higher than the canopy over the stream (Table D-11 and Figure 1). This suggests that the riparian areas in Greenwood WAU are providing good protection from adverse water temperature increases. Even in locations along Greenwood Creek where the stream canopy cannot gain as much cover due to the wide stream channel, solar radiation is well shaded. One location (CG1) along Greenwood Creek, in the Lower Greenwood planning watershed, the amount of solar radiation is not as high as other areas of Greenwood Creek (CG4 and CG6) suggesting that increased stream shade from riparian trees is needed in this location.

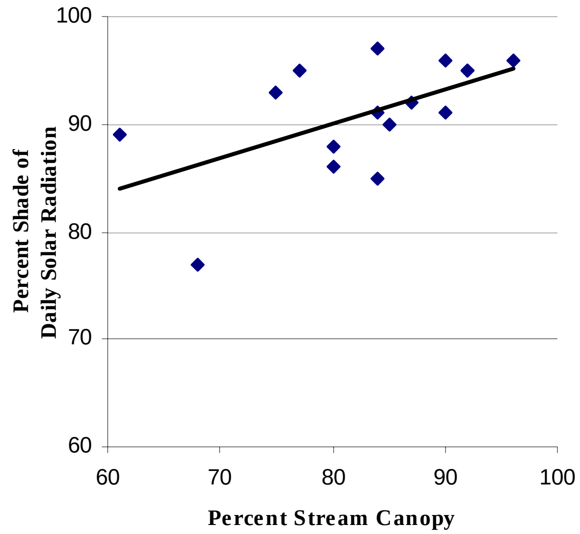
Table D-10. Year 2003 Field Observations of Stream Canopy Closure for Select Stream Channel Segments in the Greenwood WAU.

Stream Segment	ID#	Average Percent Canopy
Greenwood Creek	CU2	70
Valente Gulch	CU6	85
Valente Gulch	CU9	80-90
Trib to Valente Gulch	CU7	>90
Big Tree	CU12	87
Greenwood Creek	CU4	75
Big Tree	CU10	76
Greenwood Creek	CG4	82
Barn Gulch	CG30	78
Greenwood Creek	CG6	56
Unnamed	CG16	94
Unnamed	CG17	84
Corrals Trib.	CG25	80
Corrals Trib.	CG26	80
Corrals Trib.	CG27	92
Greenwood Creek	CG1	56

Table D-11. Solar Radiation Shading Observations for the August Solar Path and Canopy for Select Point Observations in the Greenwood WAU.

Stream	Stream Segment	Percent Solar Radiation Shaded	Percent Solar Radiation Shaded by Topography	Percent Canopy
Greenwood Creek	CU2	86	24	80
Valente Gulch	CU6	95	30	92
Valente Gulch	CU9	93	20	75
Tributary to Valente Gulch	CU7	91	20	90
Big Tree	CU12	91	21	84
Greenwood Creek	CU4	95	45	92
Big Tree	CU10	96	24	90
Greenwood Creek	CG4	90	3	85
Barn Gulch	CG30	95	26	77
Greenwood Creek	CG6	89	20	61
Pond Tributary	CG16	92	9	87
Pond Tributary	CG17	85	10	84
Corrals Tributary	CG25	97	15	84
Corrals Tributary	CG26	88	18	80
Corrals Tributary	CG27	96	11	96
Greenwood Creek	CG1	77	12	68

Figure 1. Percent Solar Radiation Shade versus Percent Stream Canopy for Sites in the Greenwood WAU, 2003.



Stream temperatures in the Greenwood WAU are well within a range preferred by steelhead trout, though above levels that are stressful to coho salmon. Maximum daily temperatures in the Greenwood WAU never exceed the maximum lethal temperatures of coho salmon (23 C^o). However, water temperatures are at or exceed the MWAT threshold maximums for coho salmon (17-18 C^o) (Brett, 1952 and Becker and Genoway, 1979). See Tables D-12, D-13 and D-14. Coho salmon are not present in Greenwood WAU and haven't been for a long time if at all, we would expect that stream temperatures would be in a range within coho salmon's tolerance particularly because of the close proximity of the ocean and the small size of the watershed, not allowing too much water heating.

Air temperatures within the watershed increase as you go east from the ocean (see sites 84-1A, then 84-3A, then 84-6A); similarly water temperature increase as you go east from the ocean corresponding to this increase in air temperature. A possible explanation for higher than expected stream temperatures in Greenwood Creek is from very high air temperatures in the eastern portion of the watershed. This water is heated then travels through a relatively small watershed. The Greenwood Creek watershed is not large (as compared to many of the river basins in the area), so as the warmer water travels west into the cooler air temperature areas of the watershed it is not subjected to cooler air long enough for the water to cool much. The tributaries in the lower portions of Greenwood WAU are subjected to cooler air temperatures, thus have lower water temperatures. But because these cool tributaries are relatively small they do not provide a lot of summer streamflow and are not able to provide much of a cooling influence to the water in Greenwood Creek. Current canopy levels provide good shade to Greenwood Creek but cannot overcome the higher air temperatures in the eastern portion of the watershed.

Table D-12. Maximum Daily Temperatures for the Greenwood WAU.

Station No.	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
84-1	20.0	20.0	**	20.8	**	21.2	**	19.8	17.8	**	20.3	20.8
84-1A (air)	**	**	**	**	**	**	**	**	**	**	22.5	**
84-3	**	**	18.5	20.6	**	19.1	**	20.4	20.3	18.6	20.1	20.3
84-3 A (air)	**	**	**	**	**	**	**	**	**	**	29.8	27.1
84-20*	**	**	**	**	**	**	**	**	**	12.9	**	**
84-21*	**	**	**	**	**	**	**	**	**	14.5	**	15.7
84-22*	**	**	**	**	**	**	**	**	**	14.1	**	**
84-23*	**	**	**	**	**	**	**	**	**	14.1	**	14.8
84-4	**	**	**	**	**	**	**	**	**	**	19.0	19.2
84-4A (air)	**	**	**	**	**	**	**	**	**	**	**	27.9
84-5	**	**	**	**	**	**	**	**	**	**	15.0	17.2
84-6	**	**	**	**	**	**	**	**	**	**	20.4	20.0
84-6A (air)	**	**	**	**	**	**	**	**	**	**	27.8	34.0
84-7	**	**	**	**	**	**	**	**	**	**	15.5	16.5
84-8	**	**	**	**	**	**	**	**	**	**	**	17.3

*Class II watercourse **Data not collected

Table D-13. Maximum Weekly Average Temperature (MWAT) for the Greenwood WAU.

Station No.	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
84-1	17.0	17.0	**	17.1	**	17.7	**	15.7	14.6	**	16.5	17.3
84-1A (air)	**	**	**	**	**	**	**	**	**	**	14.1	**
84-3	**	**	16.4	17.7	**	17.2	**	16.7	17.4	16.2	17.1	17.6
84-3 A (air)	**	**	**	**	**	**	**	**	**	**	16.0	18.0
84-20*	**	**	**	**	**	**	**	**	**	12.6	**	**
84-21*	**	**	**	**	**	**	**	**	**	13.6	**	14.7
84-22*	**	**	**	**	**	**	**	**	**	13.2	**	**
84-23*	**	**	**	**	**	**	**	**	**	13.2	**	14.1
84-4	**	**	**	**	**	**	**	**	**	**	16.6	16.7
84-4A (air)	**	**	**	**	**	**	**	**	**	**	**	16.0
84-5	**	**	**	**	**	**	**	**	**	**	13.8	15.3
84-6	**	**	**	**	**	**	**	**	**	**	16.6	17.2
84-6A (air)	**	**	**	**	**	**	**	**	**	**	16.7	17.5
84-7	**	**	**	**	**	**	**	**	**	**	14.3	15.5
84-8	**	**	**	**	**	**	**	**	**	**	**	15.6

*Class II watercourse **Data not collected

Table D-14. 7-Day Moving Average of the Daily Maximum (MWMT) for the Greenwood WAU.

Station No.	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
84-1	19.1	18.7	**	19.4	**	20.4	**	18.7	16.9	**	18.7	19.9
84-1A (air)	**	**	**	**	**	**	**	**	**	**	18.4	**
84-3	**	**	18.2	19.3	**	18.3	**	19.0	19.7	17.7	18.8	19.6
84-3 A (air)	**	**	**	**	**	**	**	**	**	**	25.3	26.1
84-20*	**	**	**	**	**	**	**	**	**	12.9	**	**
84-21*	**	**	**	**	**	**	**	**	**	14.0	**	15.2
84-22*	**	**	**	**	**	**	**	**	**	13.8	**	**
84-23*	**	**	**	**	**	**	**	**	**	13.6	**	14.4
84-4	**	**	**	**	**	**	**	**	**	**	18.1	18.6
84-4A (air)	**	**	**	**	**	**	**	**	**	**	**	22.3
84-5	**	**	**	**	**	**	**	**	**	**	14.8	16.8
84-6	**	**	**	**	**	**	**	**	**	**	19.3	19.4
84-6A (air)	**	**	**	**	**	**	**	**	**	**	24.2	28.0
84-7	**	**	**	**	**	**	**	**	**	**	15.1	16.2
84-8	**	**	**	**	**	**	**	**	**	**	**	16.9

*Class II watercourse **Data not collected

The Greenwood WAU generally has favorable stream shade conditions as demonstrated by the stream shade ratings (Table D-15). All of the tributaries rated have an "on target" stream shade rating. Greenwood Creek rates as "marginal" in both the upper and lower segments. However, both of these sections of Greenwood Creek are close to being "on target". It is anticipated that over time with policies promoting stream shade these ratings will improve. There are no "deficient" stream shade quality ratings in the Greenwood WAU.

Table D-15. Stream Shade Quality Ratings for Streams in the Greenwood WAU.

Stream	Calwater Planning Watershed	Stream Shade Quality Rating
Greenwood Creek	Lower Greenwood Creek	Marginal
Greenwood Creek	Upper Greenwood Creek	Marginal
Pond Tributary (CG16-22)	Lower Greenwood Creek	On target
Corrals Tributary (CG25-38)	Lower Greenwood Creek	On target
Valente Gulch	Upper Greenwood Creek	On target
Big Tree	Upper Greenwood Creek	On target

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Brett, J.R. 1952. Temperature tolerances in young Pacific salmon, (Oncorhynchus). Journal of Fishery Resources Board Canada 9:268-323.

Gregory, K.J, and R.J. Davis. 1992. Coarse woody debris in stream channels in relation to river channel management in woodland areas. Regulated Rivers: Research and Management 7: pp. 117-136.

Appendix D

Riparian Function

Amount of LWD in Decay Classes in Greenwood Creek

Decay Class	Number of Pieces	Volume (yd^3)
1	14	23.3
2	22	48.7
3	46	51.7
4	127	102.2
5	110	85.7

Figure T84-01. Mean and Maximum Daily Stream Temperatures During Summer 2003 at Greenwood Creek (Site T84-01), Mendocino County, California.

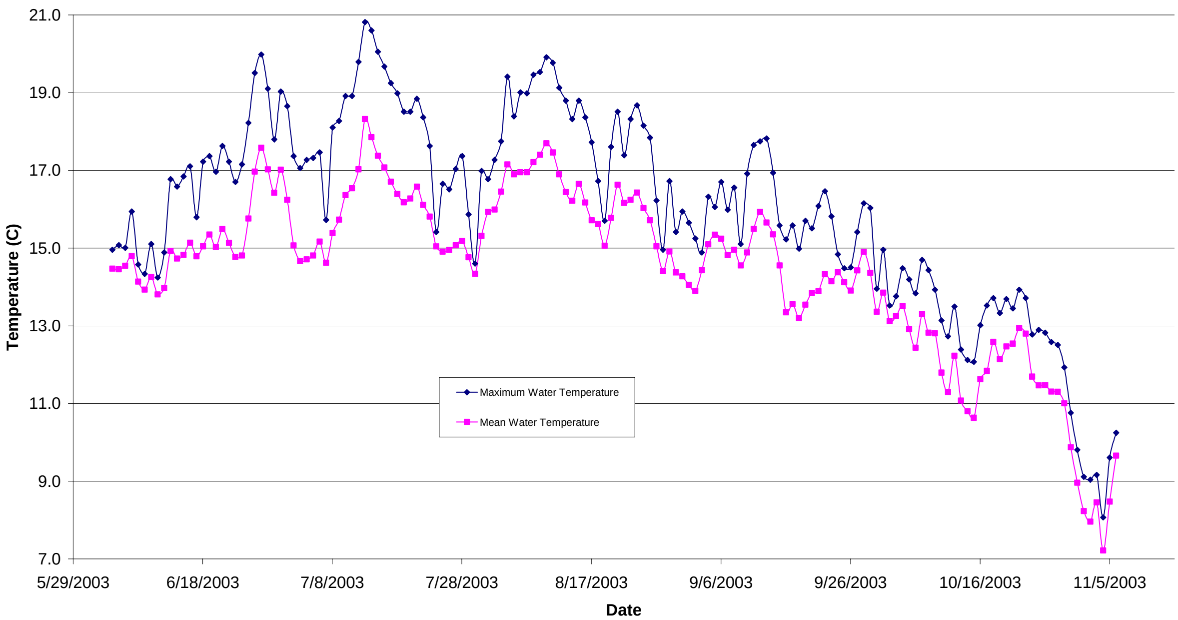

Figure T84-03. Maximum Daily Air Temperature and Mean and Maximum Daily Stream Temperatures During Summer 2003 at Greenwood Creek (Site T84-03 and T84-03a), Mendocino County, California.

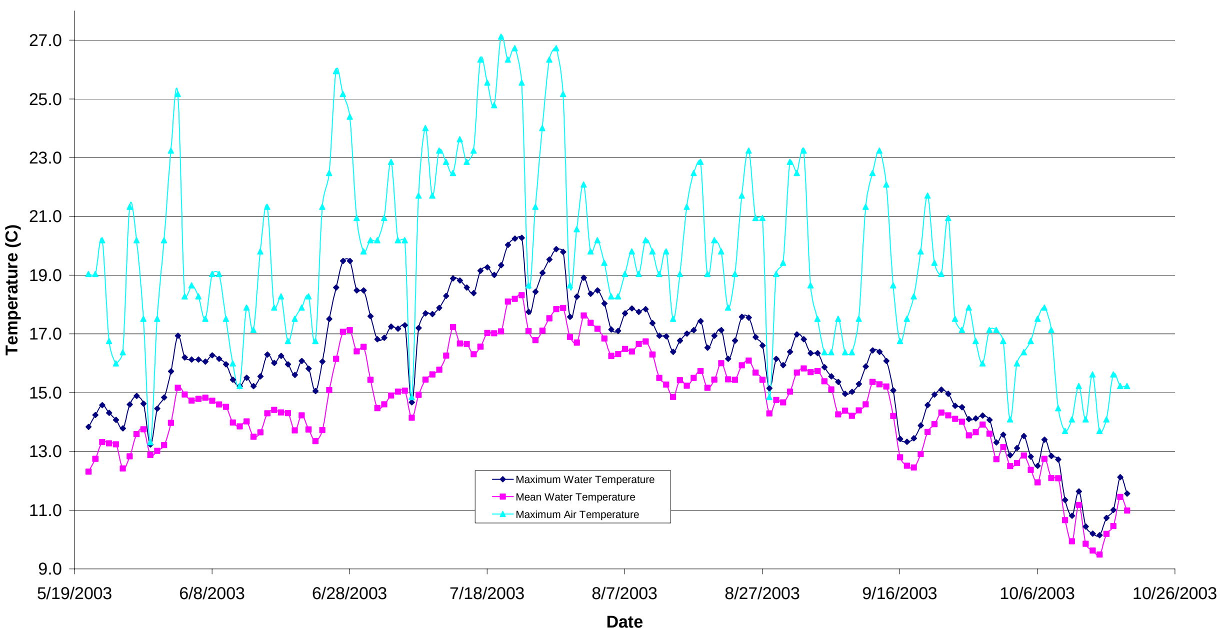

Figure T84-04. Maximum Daily Air Temperature and Mean and Maximum Daily Stream Temperatures During Summer 2003 at Greenwood Creek (Site T84-04 and T84-04a), Mendocino County, California.

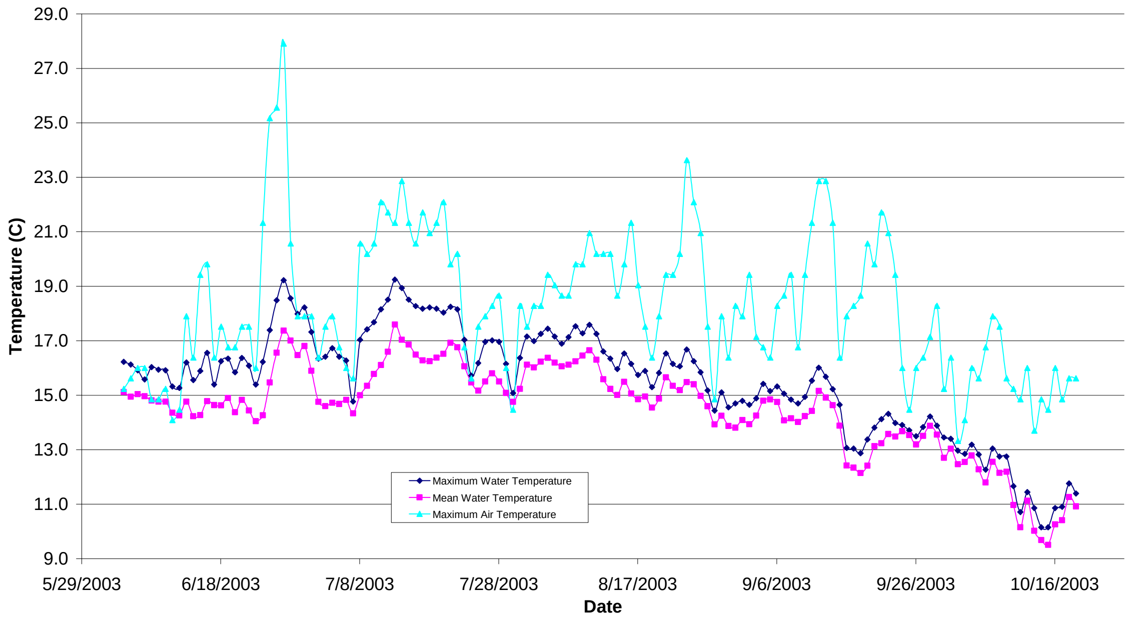

Figure T84-05. Mean and Maximum Daily Stream Temperatures During Summer 2003 at Heather Gulch (Site T84-05), Mendocino County, California.

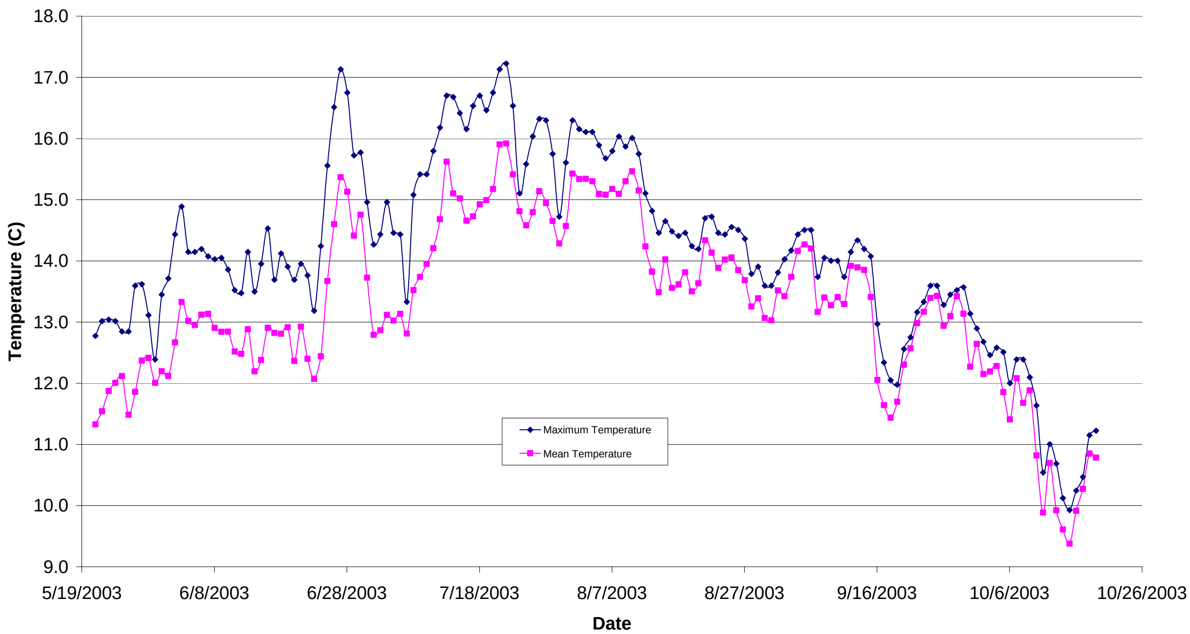

Figure T84-06 Maximum Daily Air Temperature and Mean and Maximum Daily Stream Temperatures During Summer 2003 at Greenwood Creek (Site T84-06 and T84-06a), Mendocino County, California.

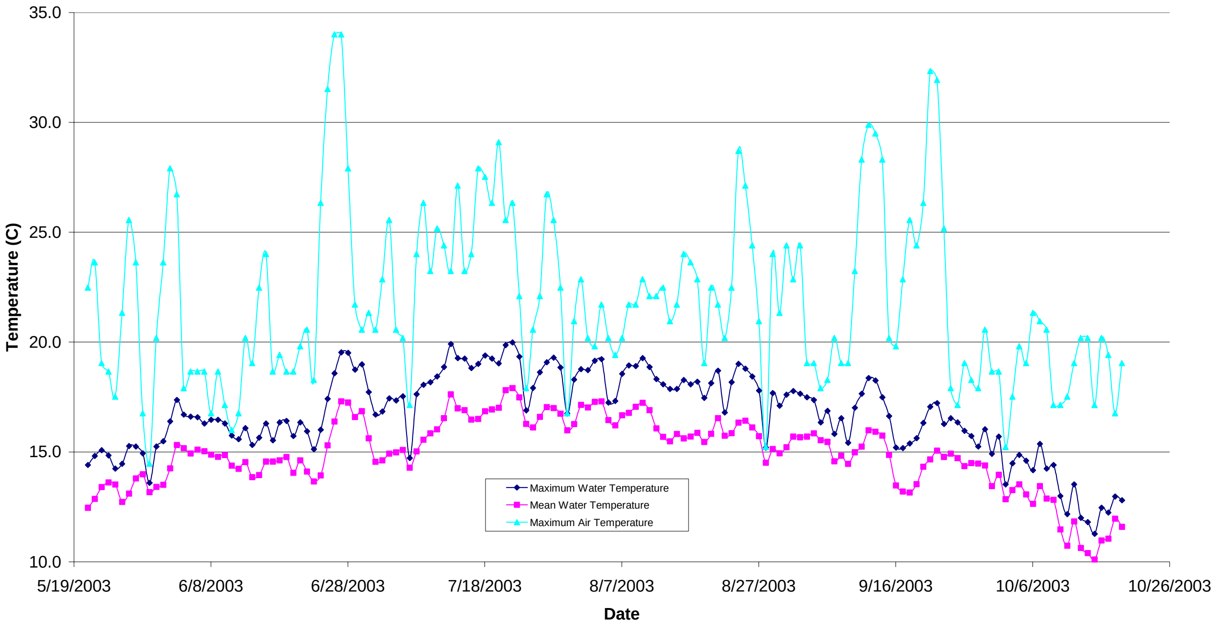

Figure T84-07. Mean and Maximum Daily Stream Temperatures During Summer 2003 at Big Tree Creek (Site T84-07), Mendocino County, California.

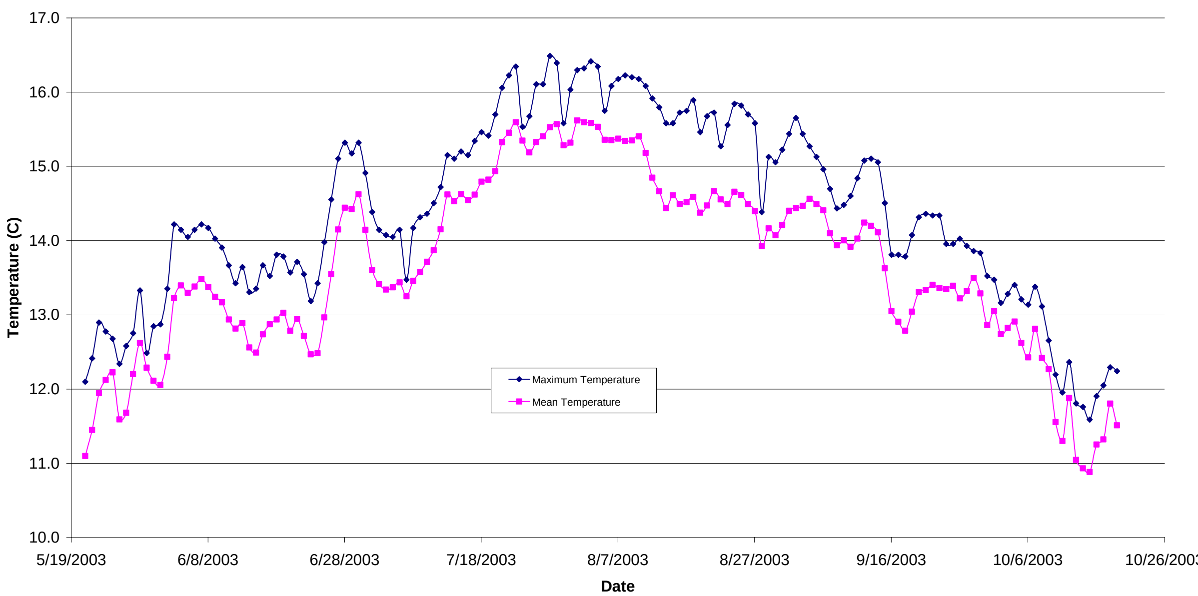

Figure T84-08. Mean and Maximum Daily Stream Temperatures During Summer 2003 at Valenti Gulch (Site T84-08), Mendocino County, California.

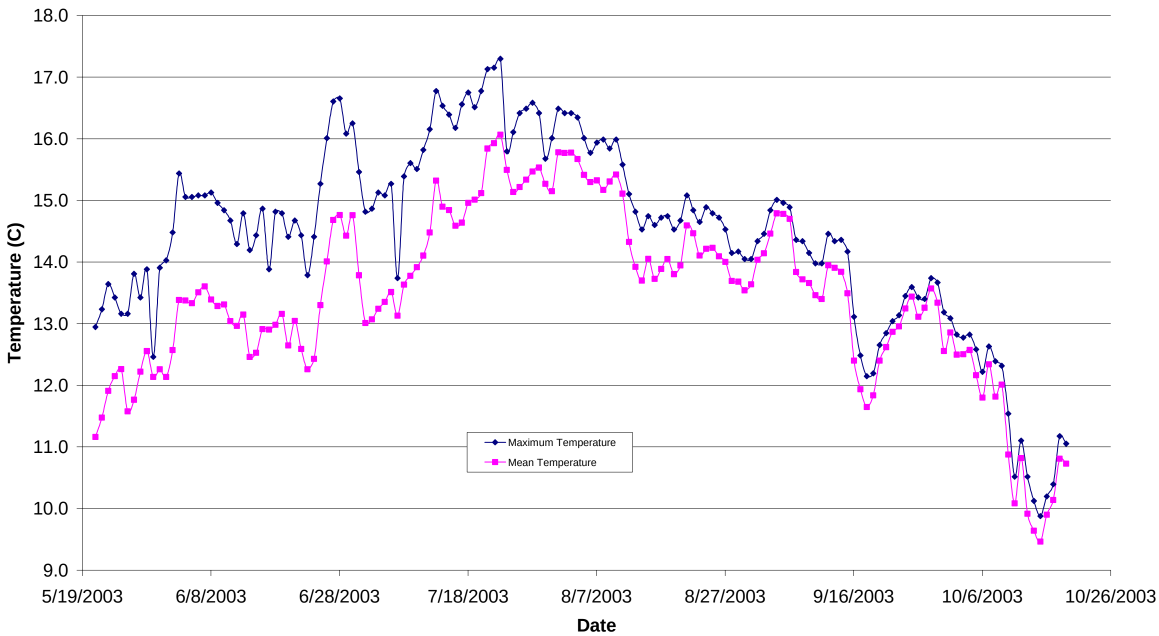

Figure T84-21. Mean and Maximum Daily Stream Temperatures During Summer 2003 at Unnamed Tributary to Greenwood Creek (Site T84-21), Mendocino County, California.

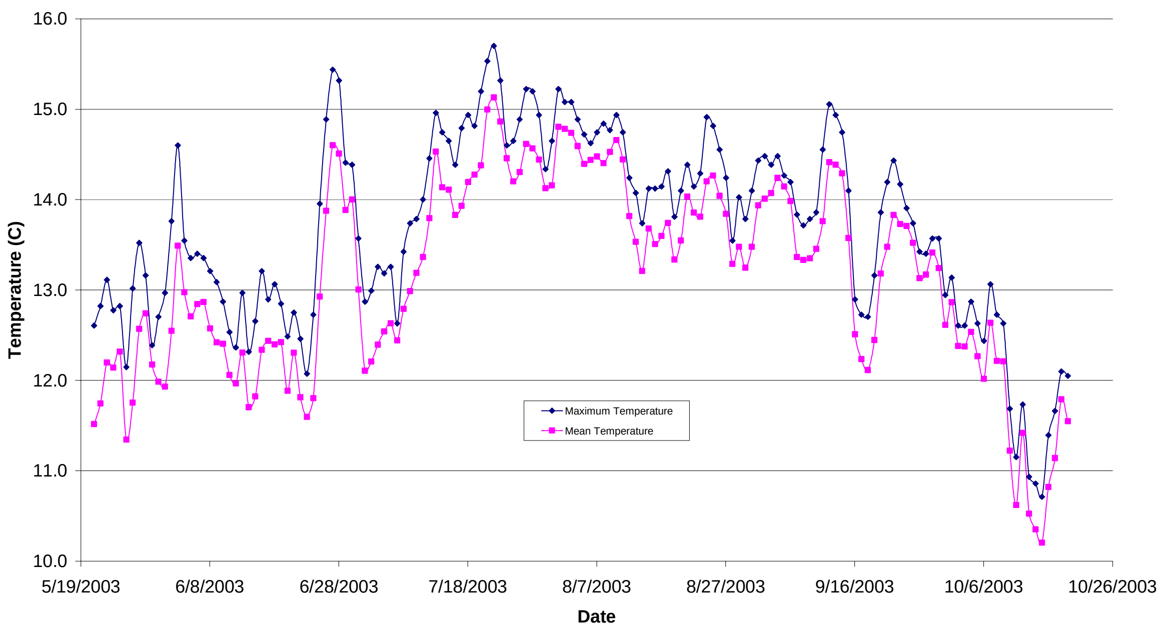

Figure T84-23. Mean and Maximum Daily Stream Temperatures During Summer 2003 at Unnamed Tributary to Greenwood Creek (Site T84-23), Mendocino County, California.

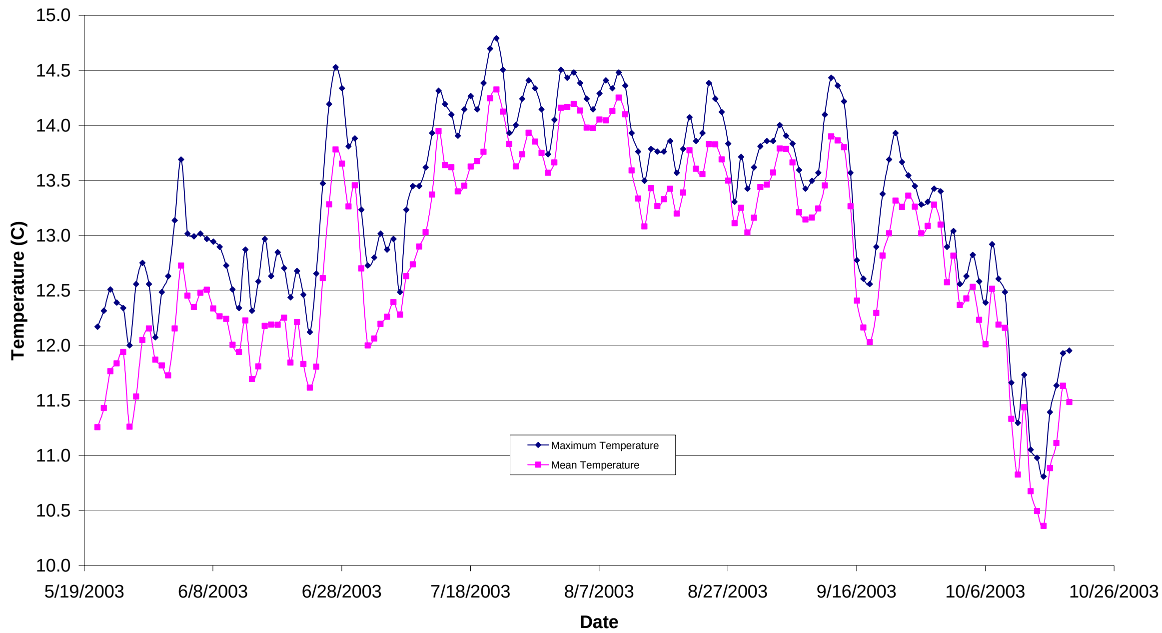

Figure T84-01. Maximum Daily Air Temperature and Mean and Maximum Daily Stream Temperatures During Summer 2002 at Greenwood Creek (Site T84-01), Mendocino County, California.

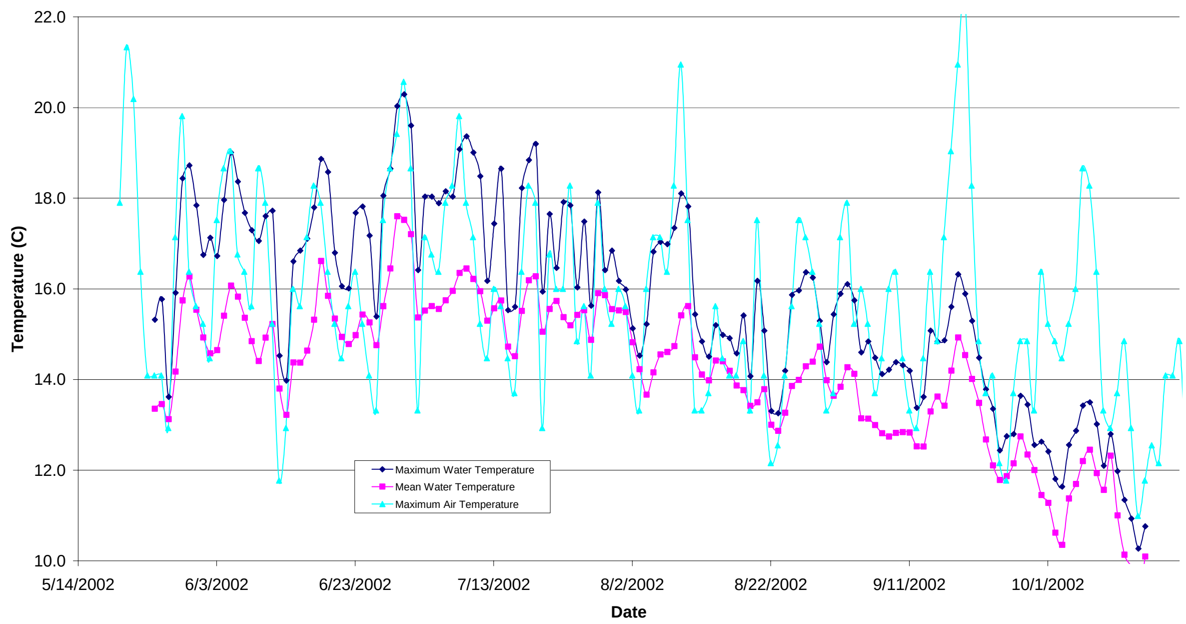

Figure T84-03. Maximum Daily Air Temperature and Mean and Maximum Daily Stream Temperatures During Summer 2002 at Greenwood Creek (Site T84-03), Mendocino County, California.

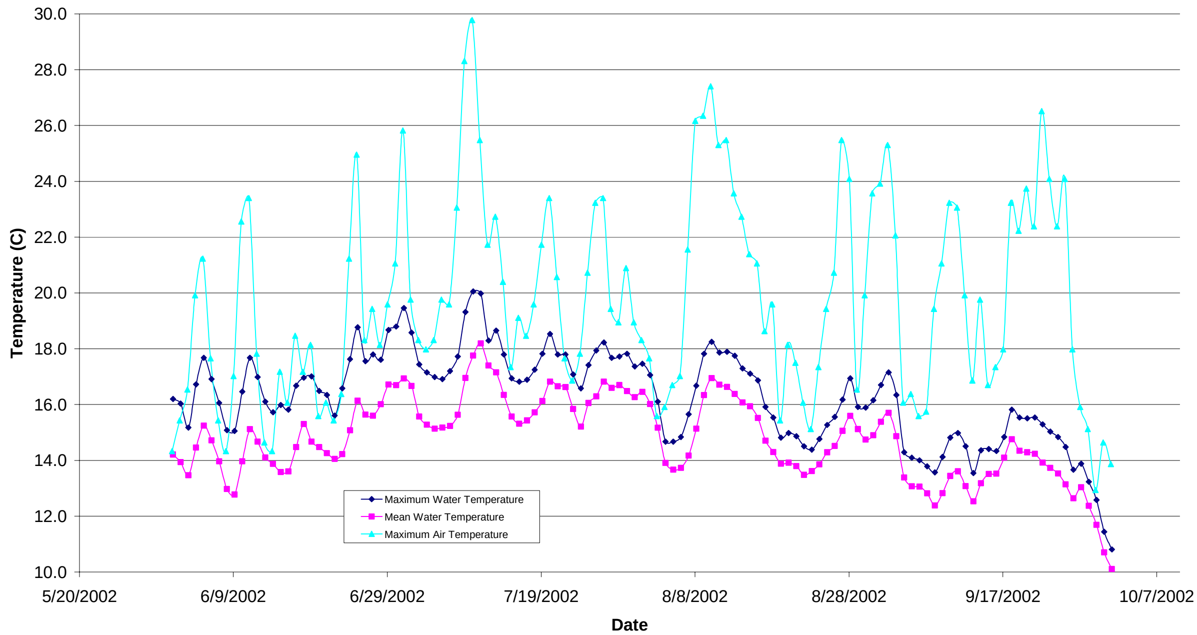

Figure T84-04. Mean and Maximum Daily Stream Temperatures During Summer 2002 at Greenwood Creek (Site T84-04), Mendocino County, California.

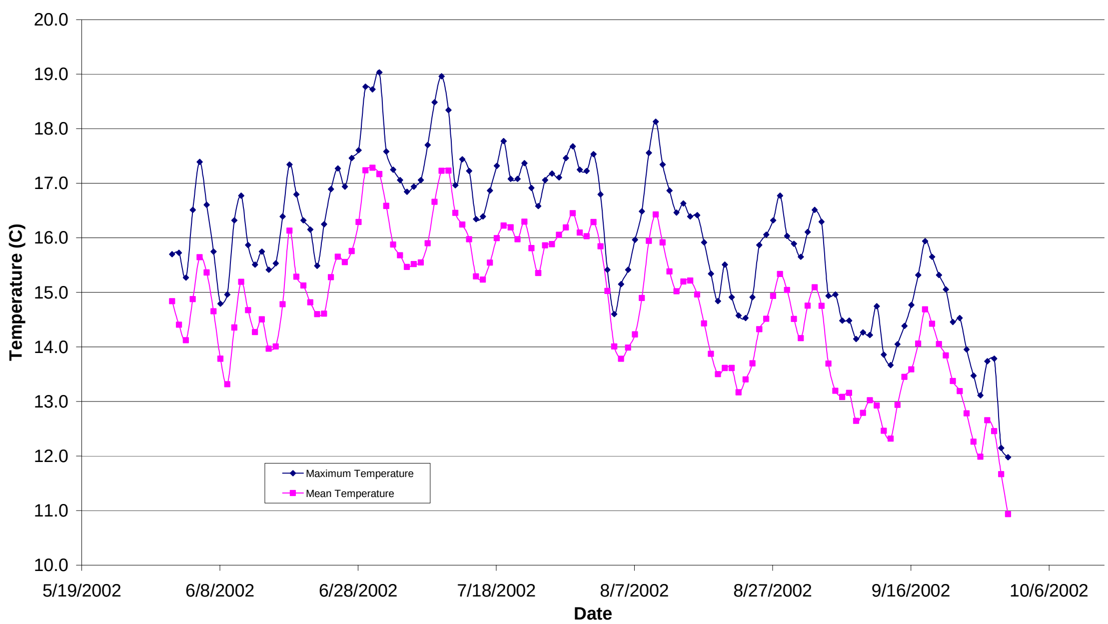

Figure T84-05. Mean and Maximum Daily Stream Temperatures During Summer 2002 at Heather Gulch (Site T84-05), Mendocino County, California.

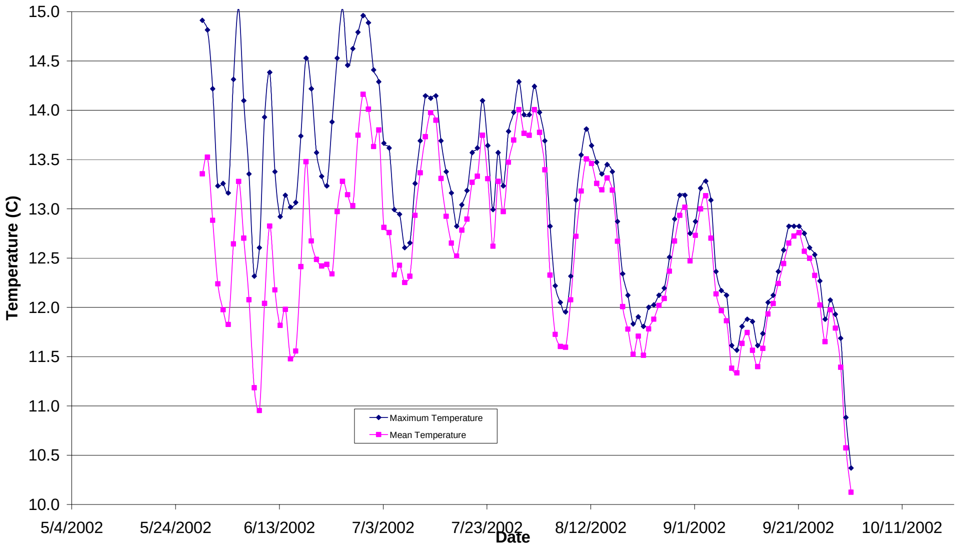

Figure T84-06 Maximum Daily Air Temperature and Mean and Maximum Daily Stream Temperatures During Summer 2002 at Greenwood Creek (Site T84-06), Mendocino County, California.

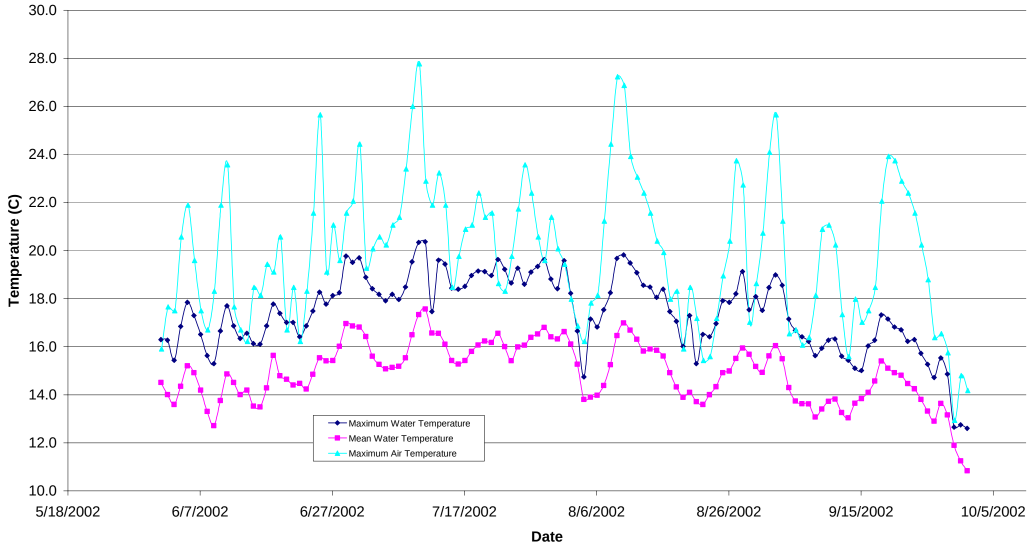

Figure T84-07. Mean and Maximum Daily Stream Temperatures During Summer 2002 at Big Tree Creek (Site T84-07), Mendocino County, California.

Figure 109. Mean and Maximum Daily Stream Temperatures During Summer 2001 at Greenwood Creek (Site 84-3), Mendocino County, California.

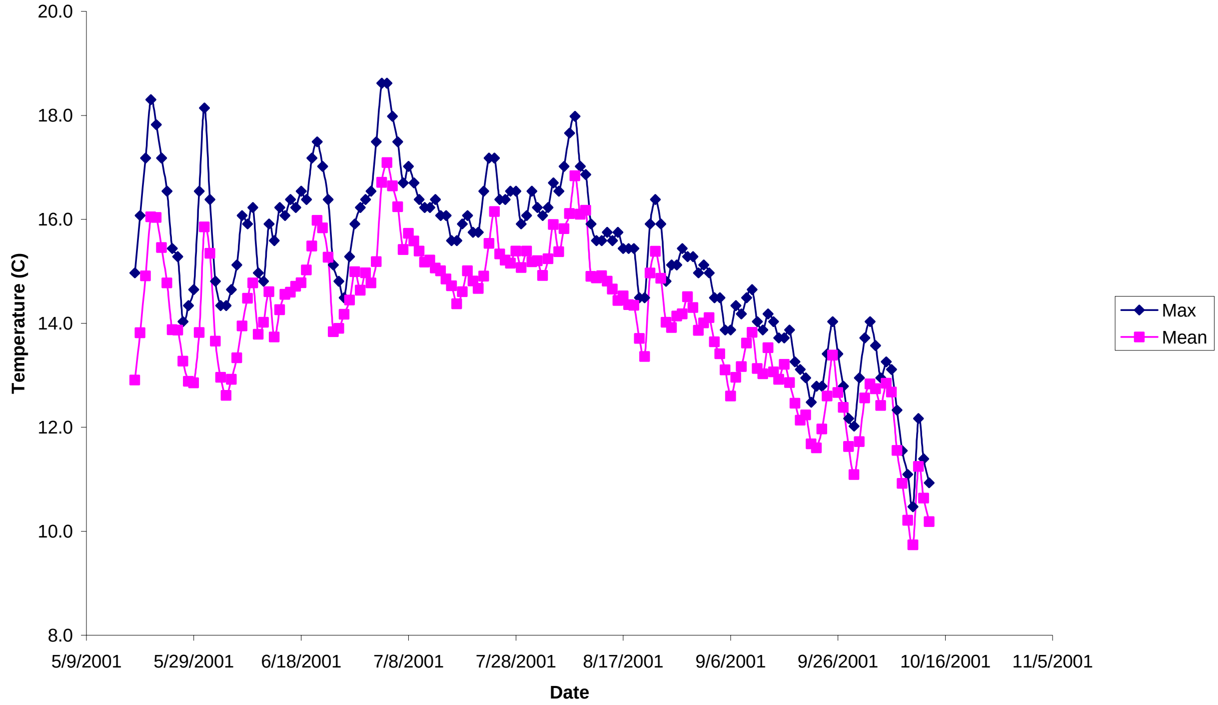

Figure 110. Mean and Maximum Daily Stream Temperatures During Summer 2001 at Tributary to Greenwood Creek (Site 84-20), Mendocino County, California.

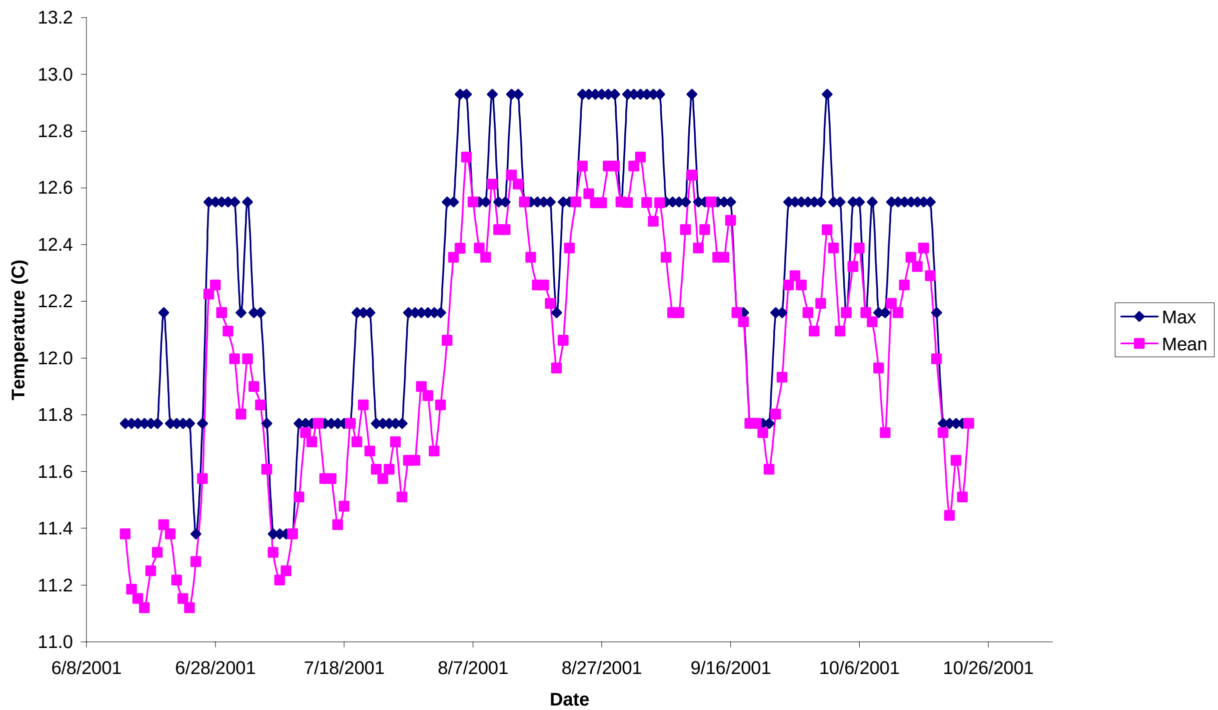

Figure 111. Mean and Maximum Daily Stream Temperatures During Summer 2001 at Tributary to Greenwood Creek (Site 84-21), Mendocino County, California.

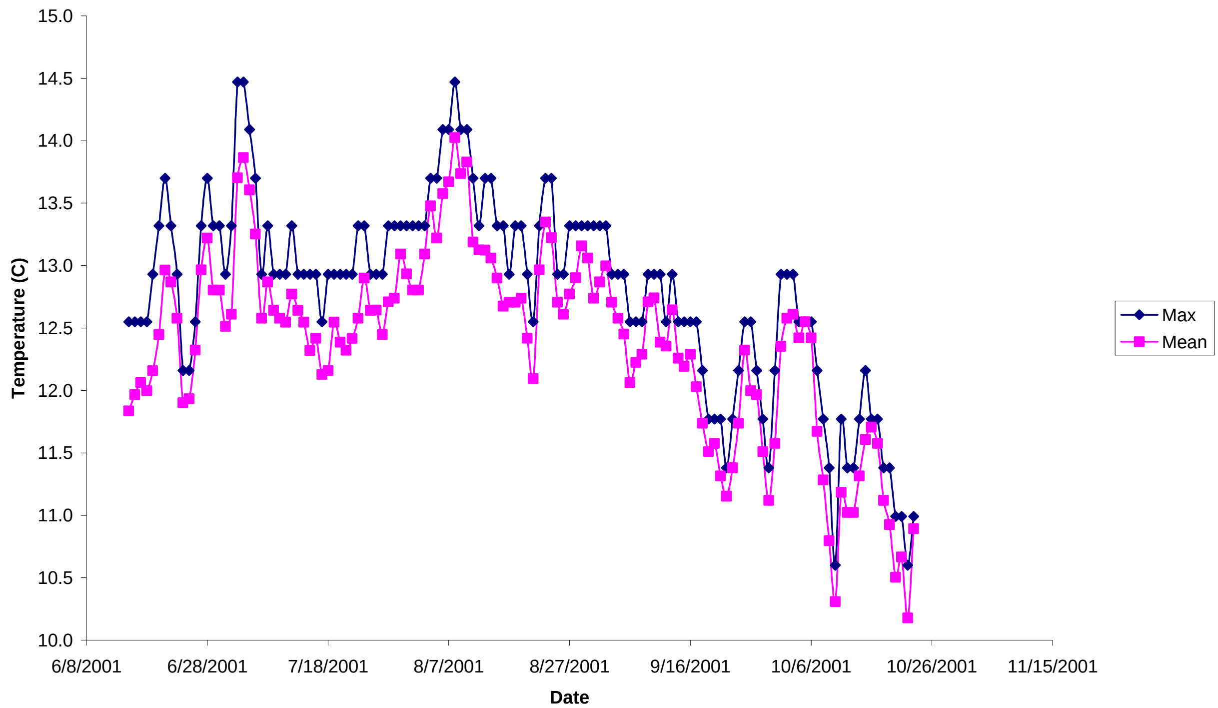

Figure 112. Mean and Maximum Daily Stream Temperatures During Summer 2001 at Tributary to Greenwood Creek (Site 84-22), Mendocino County, California.

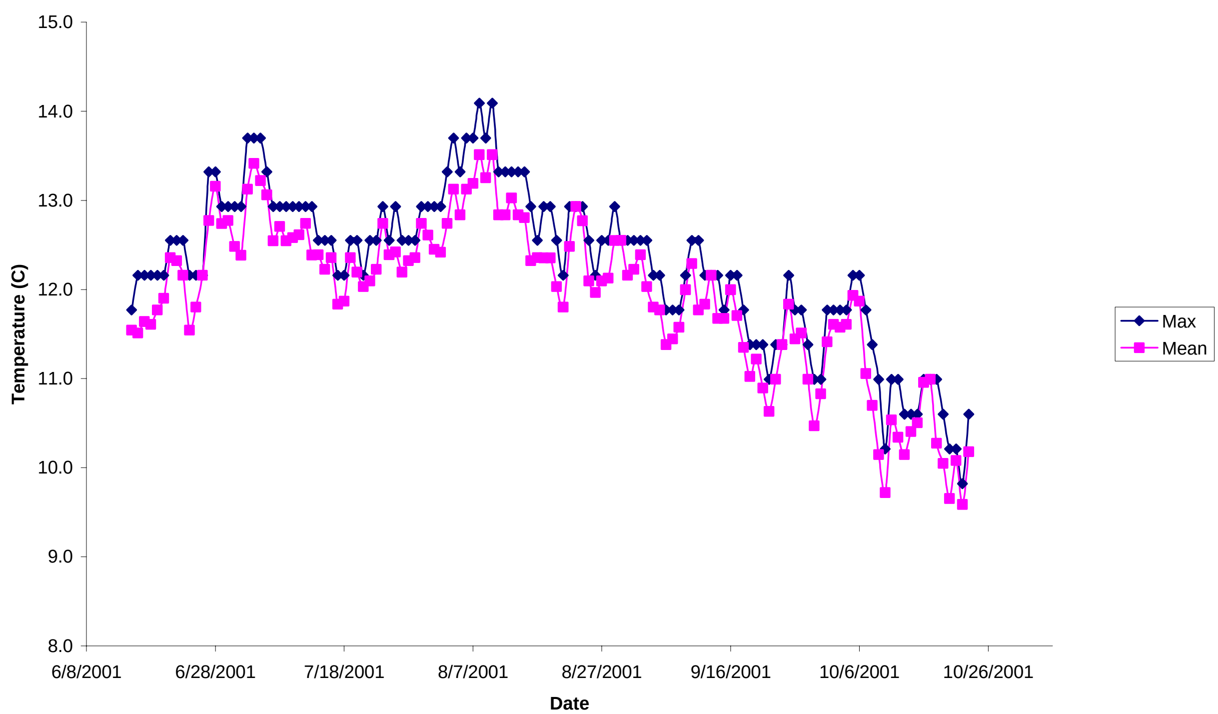

Figure 113. Mean and Maximum Daily Stream Temperatures During Summer 2001 at Tributary to Greenwood Creek (Site 84-23), Mendocino County, California.

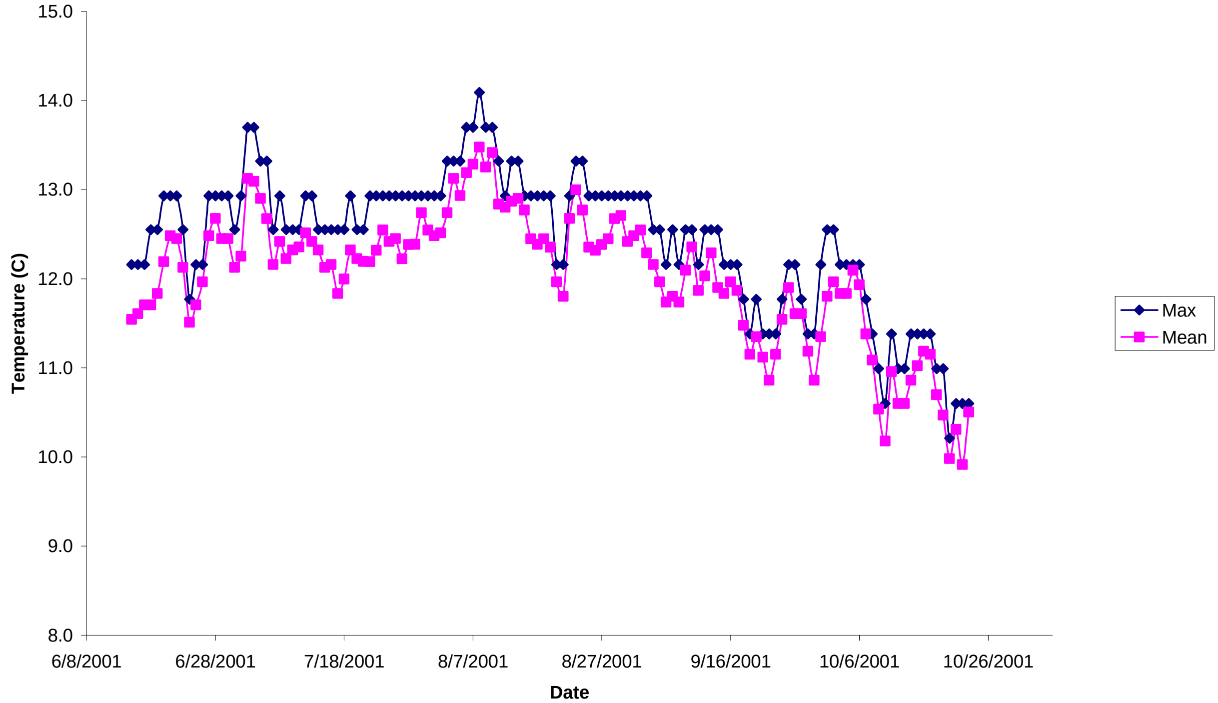

Figure 120a. Maximum and Mean Daily Stream Temperatures During Summer 2000 at Greenwood Creek (Site 84-1), Mendocino County, California.

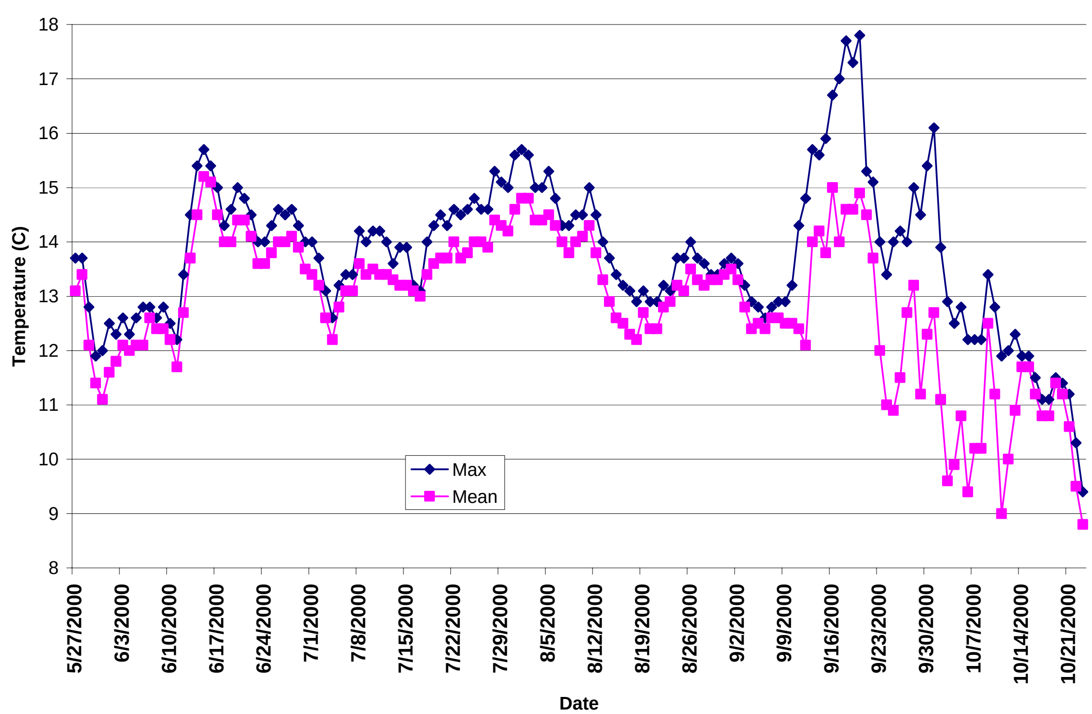

Figure 123. Mean and Maximum Daily Stream Temperatures During Summer 2000 at Greenwood Creek (Site 84-3), Mendocino County, California.

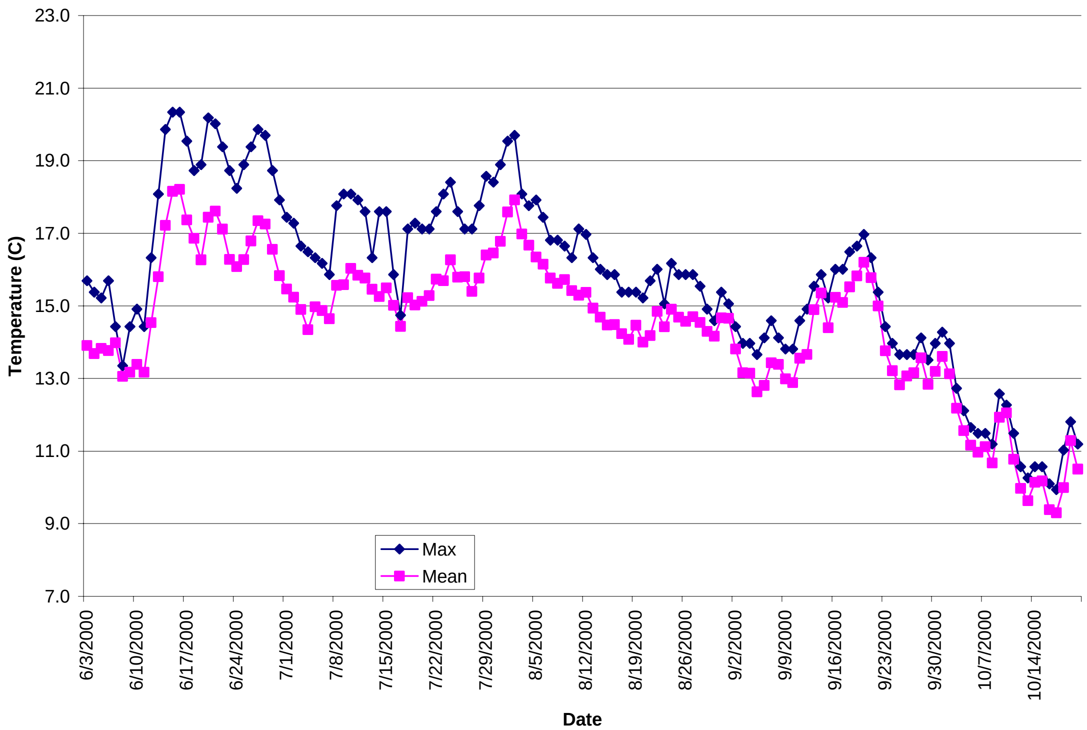

Figure 120. Mean and Maximum Daily Stream Temperatures During Summer 1999 at Greenwood Creek (Site 84-1), Mendocino County, California.

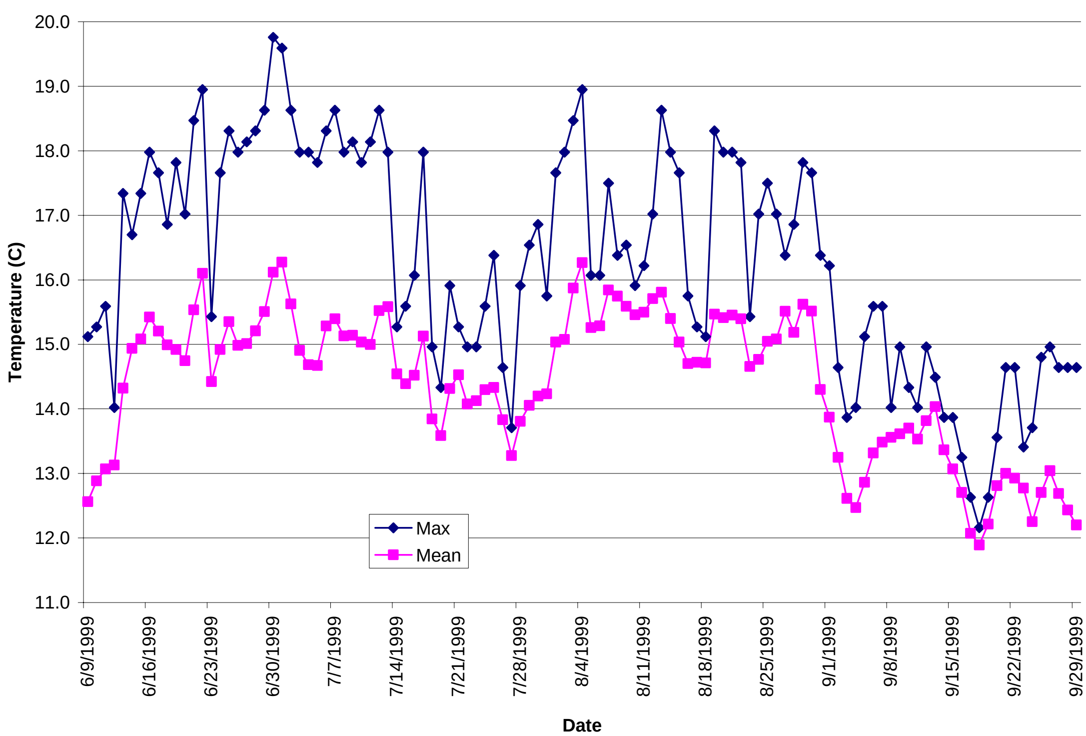

Figure 122. Mean and Maximum Daily Stream Temperatures During Summer 1999 at Greenwood Creek (Site 84-3), Mendocino County, California.

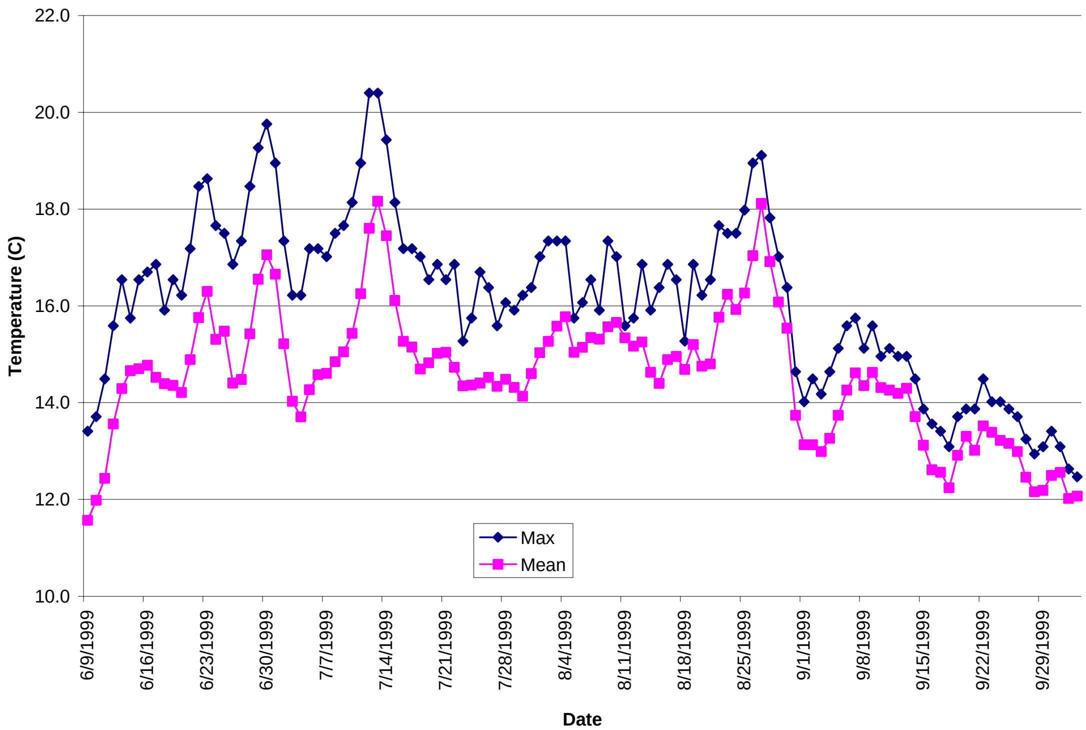

Figure 119. Mean and Maximum Daily Stream Temperatures During Summer 1997 at Greenwood Creek (Site 84-1), Mendocino County, California.

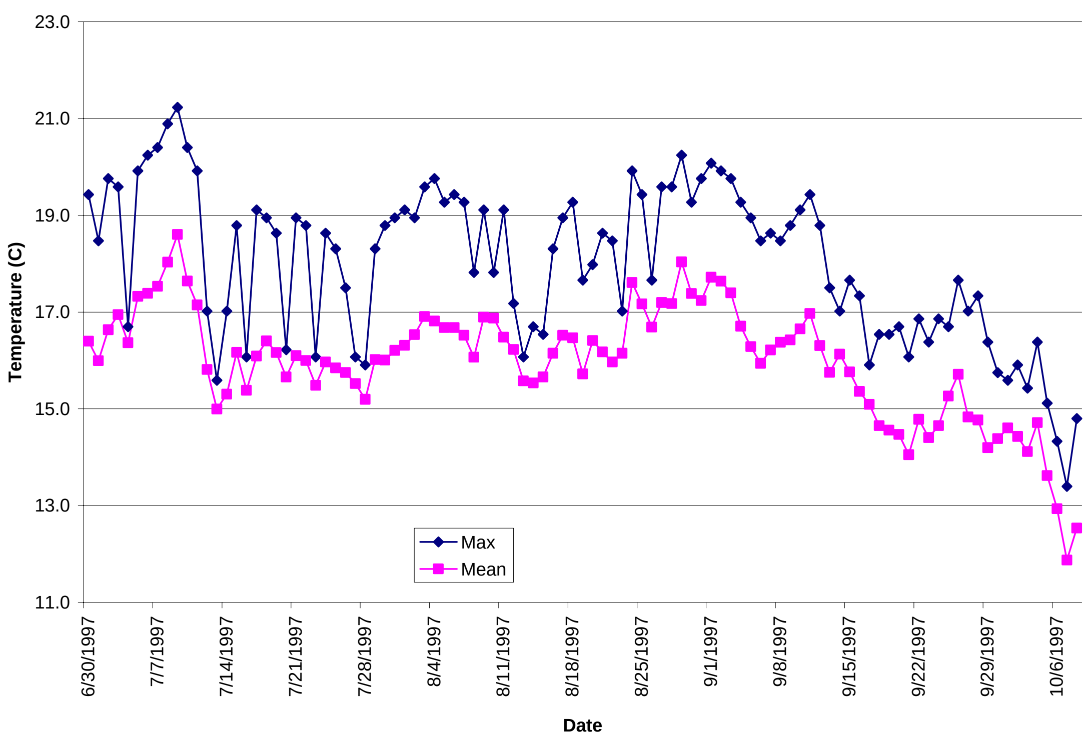

Figure 121. Mean and Maximum Daily Stream Temperatures During Summer 1997 at Greenwood Creek (Site 84-3), Mendocino County, California.

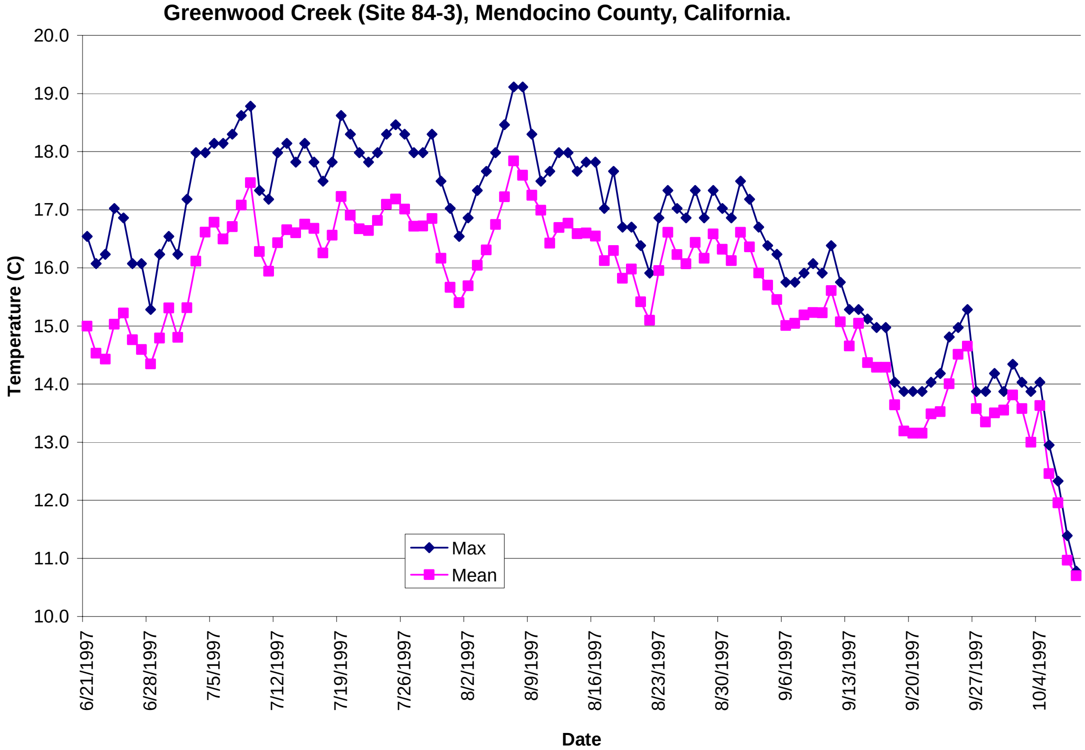

FIGURE 92. MEAN, MAXIMUM, AND MINIMUM DAILY STREAM WATER TEMPERATURES DURING SUMMER (JULY-SEPTEMBER 1995) AT GREENWOOD CREEK (MAP NO. 18; MONITORING SITE NO. 84-1), MENDOCINO CO., CALIFORNIA.

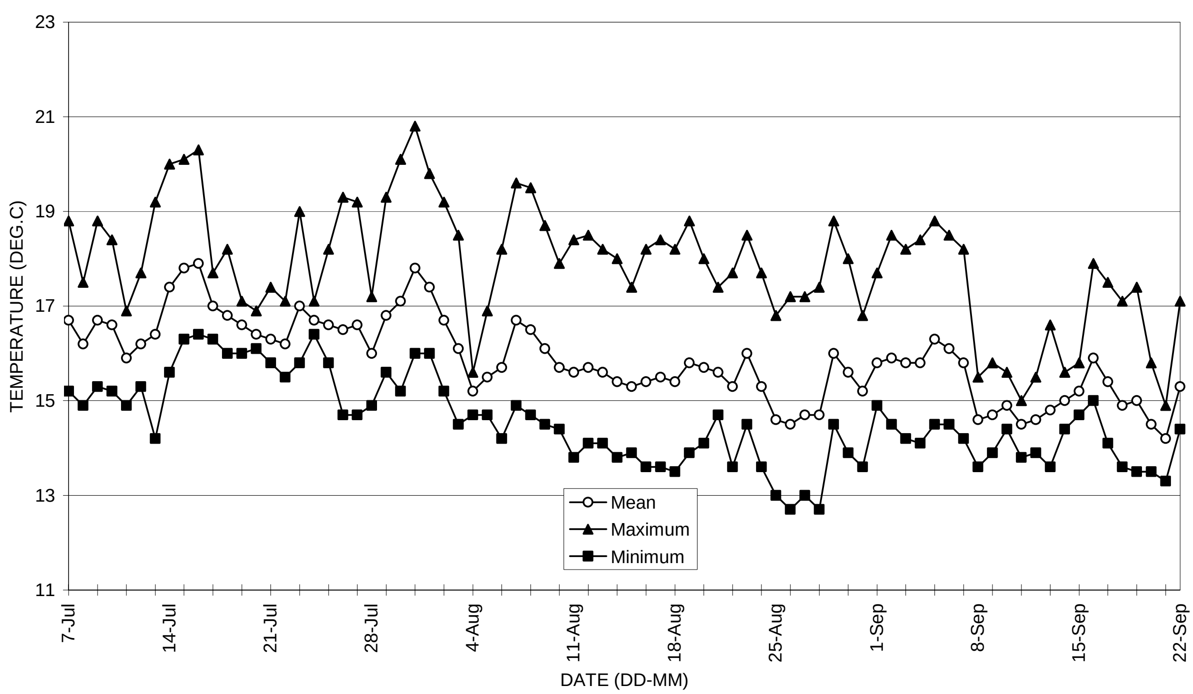

FIGURE 94. MEAN, MAXIMUM, AND MINIMUM DAILY STREAM WATER TEMPERATURES DURING SUMMER (JULY-SEPTEMBER 1995) AT GREENWOOD CREEK (MAP NO. 17; MONITORING SITE NO. 84-3) MENDOCINO CO., CALIFORNIA.

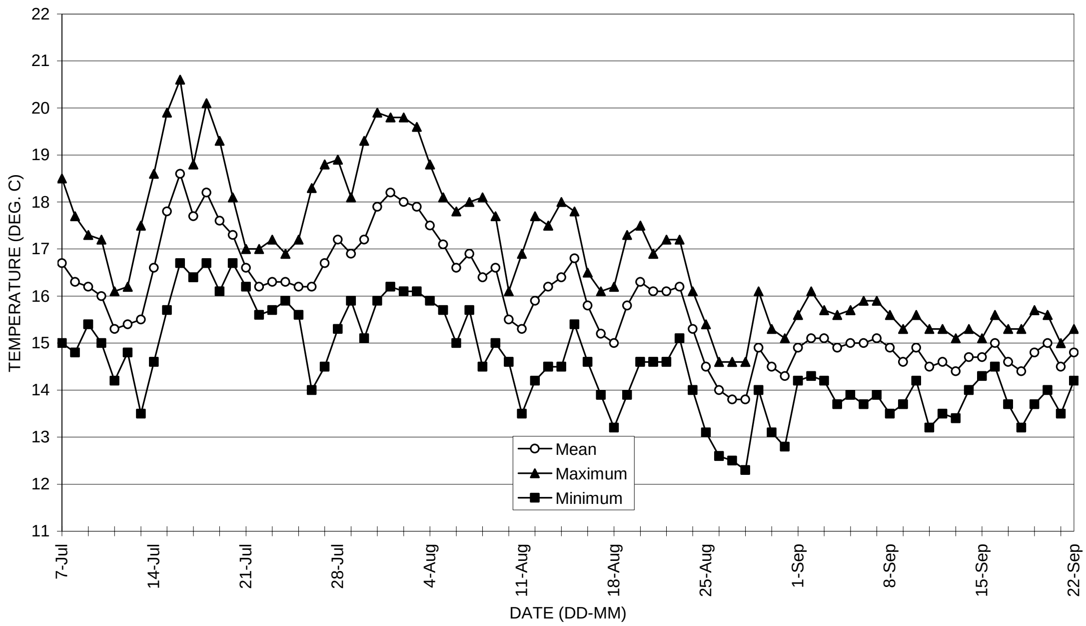

FIGURE 25. MEAN AND MAXIMUM DAILY STREAM WATER TEMPERATURES DURING SUMMER (JUNE-SEPTEMBER 1994) AT GREENWOOD CREEK (FIGURE 1-D; MONITORING SITE NO. 28), MENDOCINO CO., CALIFORNIA.

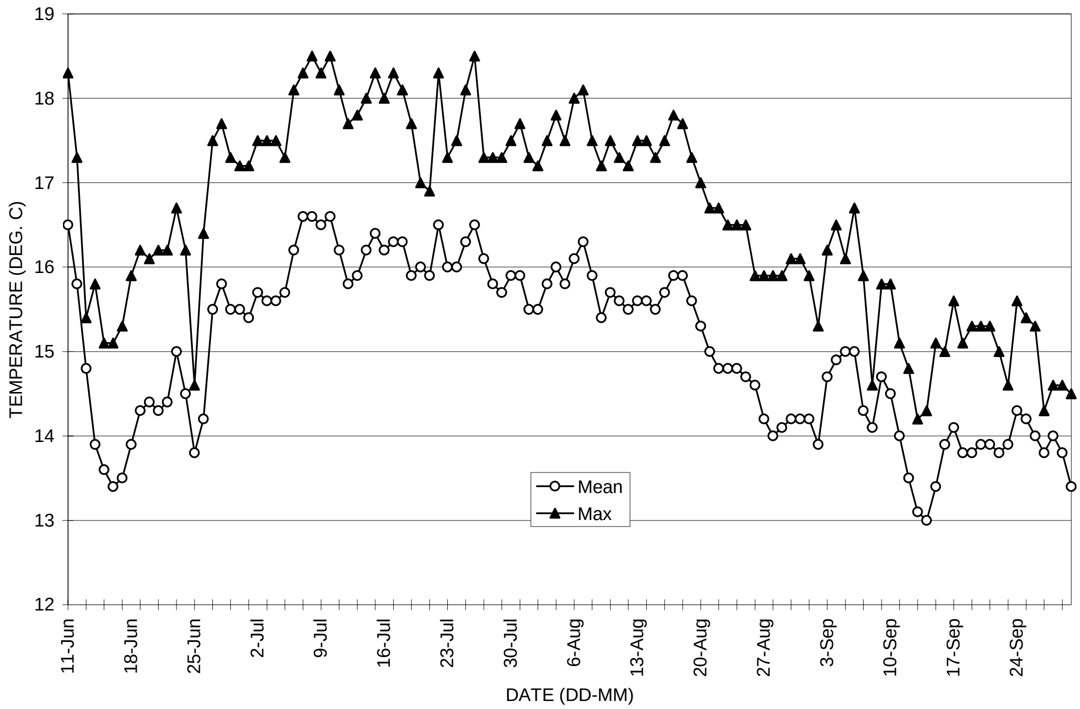

FIGURE 50. MEAN AND MAXIMUM DAILY STREAM WATER TEMPERATURES DURING SUMMER (JUNE-SEPTEMBER 1993) AT GREENWOOD CREEK (MAP NO. 11; MONITORING SITE NO. 27), MENDOCINO CO., CALIFORNIA.

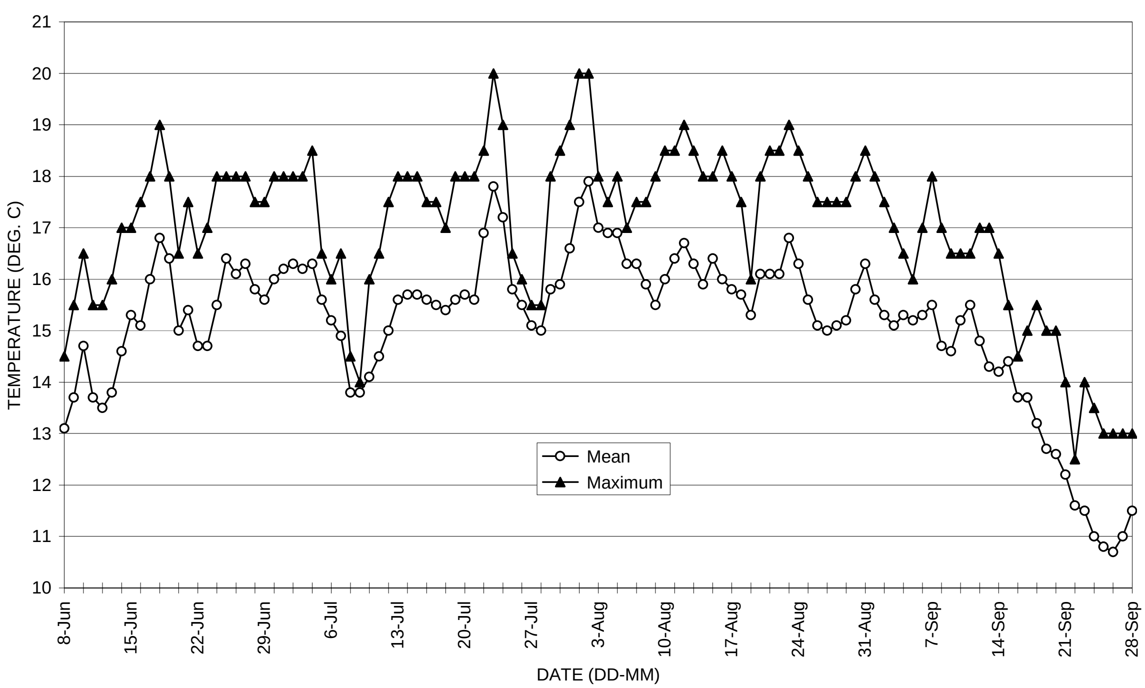

FIGURE 49. MEAN AND MAXIMUM DAILY STREAM WATER TEMPERATURES DURING SUMMER (JULY-SEPTEMBER 1992) AT GREENWOOD CREEK (MAP NO. 11; MONITORING SITE NO. 27), MENDOCINO CO., CALIFORNIA.