Water Temperatures in the South Fork Trinity River Watershed in Northern California

PREPARED FOR:

The U. S. Environmental Protection Agency and the North Coast Regional Water Quality Control Board for their consideration during the development of the South Fork Trinity River TMDL.

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ABSTRACT

Under section 303(d) of the Clean Water Act the South Fork Trinity River has been listed for impaired water temperature levels. To provide the EPA with the most extensive and intensive information regarding stream temperatures reported for the watershed the USFS, NRCS, and Timber Products Company have combined data to co-author this report. The objective of this technical report was to assimilate known stream temperature information within the South Fork Trinity River watershed. An additional objective is to describe and discuss the physical and environmental characteristics of the watershed and how those characteristics are influencing water temperatures.

Since the South Fork Trinity River is free flowing with few impoundments the distribution of anadromous salmonid species is very extensive. Fall chinook salmon, Spring chinook salmon, Steelhead trout, and Coho salmon migrate into the basin, spawn, rear, and out migrate from the watershed.

As in many other watersheds physical topography, geomorphic history, and climate have dominated the water temperatures for previous 50 years. Historical pre-1964 flood data indicates that the South Fork Trinity River mainstem maximum water temperatures exceeded 22C (72.0 F) and Hayfork Creek exceeded 20°C (68.4°F). Historic pre-1964 flood water temperatures recorded throughout Northern California shows that water temperatures in the range of 20-30°C (68.4°F -86.6°F were prevalent.

A total of 71 separate water temperature monitoring sites have been collected data between 1989 and 1997. Few tributaries to the South Fork Trinity River have water temperatures outside the natural range of variability found within the South Fork Trinity River watershed. Many mainstem water temperatures exceed 20°C (68.4°F) yet fall within the historic and natural range of variability found within South Fork Trinity River watershed. The natural range of variability is defined by the water temperatures found in the Yolla Bolla Wilderness of 16.6°C (62.2°F) and the North Fork Trinity River watershed of 22.2°C (72.4°F).

It appears that the South Fork Trinity River water temperatures are primarily being controlled by topographic (elevation) and geomorphic characteristics (channel width). Water temperatures in the South Fork Trinity River appear to be not influenced by tributary streams as no heating or cooling occurs immediately downstream of tributaries. Also paired air and water temperature and stream flow data collected in Hayfork Creek indicate that higher summer base flows do not reduce water temperatures.

Setting and achievement of water quality goals for the South Fork Trinity River should consider the unique set of physical and environmental characteristics that determine water temperatures in the watershed. The water quality goals should recognize that the physical and environmental characteristics of the watershed could severely limit the effectiveness of any proposed mitigation to improve water quality. Effective mitigation to improve water quality should focus on sub-watersheds that currently have water temperatures outside the natural range of variability found within the South Fork Trinity River watershed.

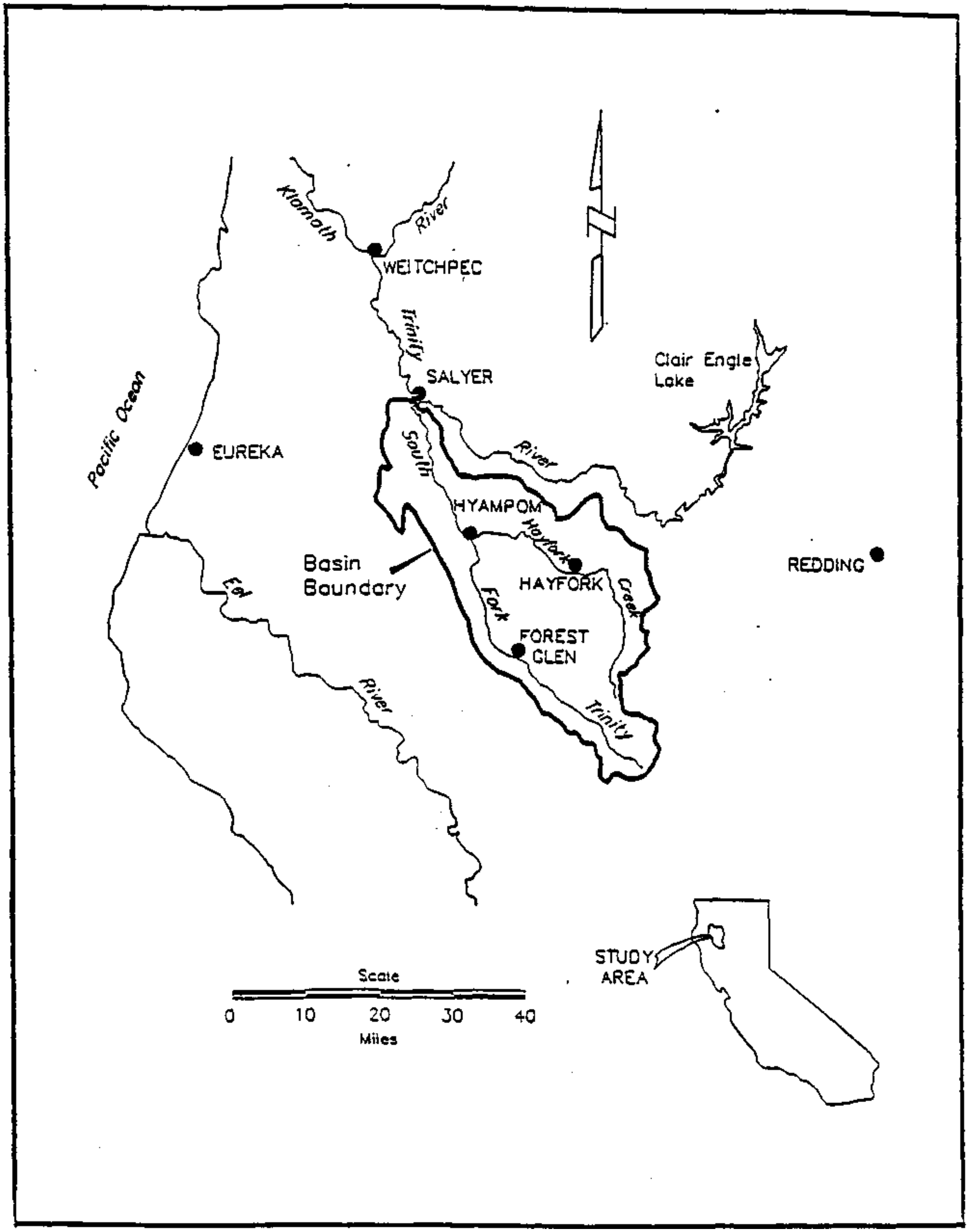
1.0 INTRODUCTION

On March 7th 1997, the U.S. Environmental Protection Agency (EPA), the U.S. Department of Justice, and the U.S. Attorney for the Northern District of California filed an agreement in federal district court to settle a lawsuit with 14 environmental and fishing industry groups concerning development of Total Maximum Daily Load's (TMDL) for 17 river basins in Northern California. Under the federal Clean Water Act a TMDL provides the method for assessing the environmental problems in a watershed and developing a strategy to reach acceptable water quality standards within a set time frame. The South Fork Trinity River was one of the river basins included in the agreement and a TMDL is scheduled for completion by the EPA on December 31, 1998.

Under section 303(d) of the Clean Water Act the South Fork Trinity River has been listed for impaired sediment levels in excess of water quality standards described in the Clean Water Act or in the North Coast Regional Water Quality Control Board (NCRWQB) basin plan. Subsequently a bi-annual review of water quality conditions within each watershed in the State of California by the North Coast Water Quality Control Board listed the South Fork Trinity River as an impaired waterbody due to elevated water temperature.

As part of the ongoing development of the South Fork Trinity River TMDL the EPA has requested any additional data, or information concerning water quality in the watershed. To provide the EPA with the most extensive and intensive information regarding stream temperatures reported for the watershed the USFS, NRCS, and Timber Products Company have combined data to co-author this report. The objective of this technical report was to assimilate known stream temperature information with the South Fork Trinity River. An additional objective is to describe and discuss the physical and environmental characteristics of the watershed and how those characteristics are influencing water temperatures.

Figure 1 Geographic location of Report Area
(Pacific Watershed Associates, 1994)



2.0 ENVIRONMENTAL CONDITIONS

2.1 GEOGRAPHIC RANGE

The South Fork Trinity River lies within Trinity County and Humboldt County in Northern California (Figure 1). From the headwaters in the Yolla Bolla Wilderness area the South Fork Trinity River flows north into the Trinity River. The South Fork Trinity River watershed is over 900,000 acres in size and is the largest undammed river in California.

2.2 TOPOGRAPHY

The South Fork watershed varies from the very rugged South Fork Mountain to the foothills and valley floor of the Hayfork valley. The highest watershed divides exceed 6,000 feet in elevation while the valley floors are below 1,500 in elevation.

2.3 CLIMATE

The South Fork Trinity River lies within the Klamath Mountains range. The general climatic conditions within the Klamath Mountains are characterized normally by cool, moist winters and warm, dry summers. . Climatic differences are primarily influenced by latitude, longitude, elevation, and other factors. Annual precipitation totals decrease from west to east and with elevation. The range is from 20 inches/year in the upper East Fork of Hayfork Creek to over 70 inches/year along South Fork Mountain. Precipitation typically occurs between September and May, with 80% falling from November through March. Generally, precipitation falls as rain below 4,000 feet, but it can rain during warm winter storms to as high as 6,000 feet. Snow can occur down to 1,000 feet, but generally accumulates above 4,000 feet. Air temperature during the spring, summer, and fall can vary widely, but daily maximum temperatures over 80 degrees are common, over 90 degrees are frequent, and over 100 degrees occurs during the peak of summer in July and August.

2.4 LANDSCAPE VEGETATION

Due to the complex geology of the Klamath Mountains and diverse soils the South Fork Trinity River watershed has a rich diversity of landscape vegetation. The watershed has three dominant landscape vegetation types: valley floor grasslands, foothill chaparral and oak woodland, and mountainous mixed coniferous forests (Mayer and Laudenslayer, 1988).

Valley Floor Grasslands Annual grasslands and pastures occur throughout the watershed but primarily within the Hayfork valley. These grasslands occur on flat to gently rolling foothills and in some cases are naturally flooded, or seasonally irrigated. The vegetation generally consists of a mix of annual and some perennial grasses or legumes. Density and height of vegetation can depend on the growing season, soil type, drainage, plant species mix, and grazing management and many other factors. Annual grasslands and pastures often occur adjacent or in association with cropland. Wet meadows and emergent wetlands can occur within the grasslands. These types occur in many varieties of basins, and depressions that are saturated or temporarily flooded.

Foothill Chaparral and Oak Woodland The Montane Chaparral and Mixed Chaparral vegetation types occur at all elevations and climatic regions throughout the watershed. Generally, chaparral types occur on thin, well-drained soils composed primarily of sand, gravel, and rock. Species composition changes with elevation, soil type, aspect, and geographical setting. Dominant species groups or series in the montane chaparral vegetation type can include: huckleberry oak/pinemat manzanita, bush chinquapin, greenleaf manzanita, tobacco bush, and mountain whitethorn series. Dominant species in the mixed chaparral vegetation type can include: scrub oak, chaparral oak, and many species of Ceanothus, and manzanita.

Mountainous Mixed Conifer Forests The Klamath Mixed Conifer vegetation type is the most dominant vegetation type throughout mountainous forests. In general, the type consists of tall, dense to moderately open coniferous forests with patches of broad-leaved evergreen and deciduous trees and shrubs. The overstory is composed of a mixture of Douglas-fir, white fir, ponderosa pine, incense cedar, Shasta red fir, and sugar pine within no one species occupying more than 40% of the type. Broadleaf trees include Oregon white oak, California black oak, Canyon live oak, maple, chinkapin, madrone. These mixed types include a dense understory which can include laurel, dwarf rose, western thimbleberry, chinkapin, manzanita, Snowberry, and dwarf Oregon grape.

3.0 BIOLOGICAL CONDITIONS

Since the South Fork Trinity River is free flowing with few impoundments the distribution of anadromous salmonid species is very extensive. Fall chinook salmon, Spring chinook salmon, Steelhead trout, and Coho salmon migrate into the basin, spawn, rear, and out migrate from the watershed. All of these species are being considered or have been reviewed under the Endangered Species Act (ESA). Both the fall chinook salmon (Oncorhynchus tshawytscha) and the spring chinook salmon (Oncorhynchus tshawytscha) have been petitioned for listing under the federal ESA. The Coho salmon (Oncorhynchus kisutch) has been listed as threatened in the South Fork Trinity River. The Steelhead trout (Oncorhynchus mykiss) was petitioned for listing and the National Marine Fisheries Service (NMFS) declined to list the species citing "abundant populations within the Klamath Mountains province".

Due to the presence of anadromous salmonid species within the watershed and water quality standards requiring cool stream temperatures, monitoring of water temperatures within the watershed has been conducted for many years and continues today by both public and private landowners and agencies.

4.0 PHYSICAL WATERSHED PROCESSES AFFECTING WATER TEMPERATURES

The South Fork Trinity River is generally unregulated by dams and reservoirs and is free flowing from the Yolla Bolla Wilderness area to the confluence with the Trinity River. Major influences of stream temperature such as dams, major agriculture diversions, or large urban impacts are not present in the watershed. In free-flowing, unregulated stream environments water temperatures are governed by the laws of thermal physics. The controlling physical factors in the forested watersheds have been extensively researched and are well understood (Edinger and Geyer, 1968; Brown, 1969, 1971, 1974; DeWalle, 1976; Theurer et al, 1984; Adams and Sullivan, 1990).

4.1 HEAT TRANSFER PROCESS

Most researchers have utilized the heat transfer (exchange) process to describe thermal heating and cooling of forest streams (DeWalle, 1976; Brown, 1969, 1974; Beschta, 1984; Theurer et al, 1984; and Adams and Sullivan, 1990). The physics that affects stream temperature are best understood and supported by research when applied on reaches within a watershed (Brown, 1969; Adams and Sullivan, 1990; Sullivan et al, 1990). When compared in field testing the reach based understanding of stream heating is more accurate at predicting daily mean and daily maximum temperatures (Brown, 1969; Sullivan et al, 1990). However, heated water can move downstream through a watershed (Brown, 1971), and overall heating of stream temperatures due to many factors has been reported for very large river systems (Beschta and Taylor, 1988). Of the many possible variables that could influence stream temperature, Adams and Sullivan (1990) found that the five environmental variables of riparian canopy, stream depth, stream width, ambient air temperature, and groundwater inflow regulate heating and cooling of streams.

The transfer of heat energy from the environment into the stream occurs through solar radiation, convection with the air, evaporation, conduction with the soil, and advection from incoming water sources (Brown, 1969; Adams and Sullivan, 1990). Brown (1974) states: "The principal source of heat for small forest streams is solar energy striking the stream surface directly." Convection, conduction and evaporation have minor influences in comparison, depending on local circumstances (Brown, 1976). Brown (1974) offered the following equation to understand and predict heat gains in streams: "The net rate of heat (Q) per unit area added to the stream... is the algebraic sum of net radiation (Nr) , evaporation (E), convection (H), and conduction (C)." This is written as:

$$Q = Nr \pm E \pm H \pm C$$

To estimate change in water temperature it is necessary to estimate total heat added to the stream and know the total volume of water being heated:

$$\text{Change in temperature} = \frac{\text{Total heat added}}{\text{Total Volume}}$$

Total heat added is the product of the rate per unit area (Q) at which heat is received, the area over which it is received (A), and the time extent of heating (t):

$$\text{Total Heat} = Q \times A \times t$$

Total volume heated is determined by multiplying stream's discharge (D) and time:

$$\text{Total Volume} = D \times t$$

The change in temperature equation now becomes:

$$\text{Change in temperature} = \frac{Q \times A}{D}$$

Heat Added (Q) Researchers have found that the major component of heat added (Q) to a stream is solar radiation which varies during the year according angle of the sun and latitude. Also the net radiation (Nr) varies significantly during the day/night cycle, whereas evaporation and convection vary little (Brown, 1969). Conduction(C) can be important in the heat transfer process in small, bedrock channels and is much less a factor in larger, gravel bed channels.

Surface Area of Stream (A) The surface area of a stream (A) are part of the equation also has a direct relationship to the change in water temperature. The surface area is not the actual surface area of the stream, rather it is the surface area of the stream that is exposed to direct solar radiation. Factors influencing the actual stream surface area can be the amount of shading either from vegetation or topography, and orientation as it affects shading streams flowing north/south are more exposed to solar radiation than those flowing east/west.

Volume of Water (D) The amount of water being heated and has been found to have an inverse relationship to changes in water temperature, thus smaller streams will heat up faster than larger streams (Brown, 1969; Caldwell et al, 1991).

4.2 WATER MASS PROCESS

Mixing of water from smaller tributaries into larger streams and rivers has been described (Brown, 1969) and extensively used in watershed monitoring efforts (Caldwell et al, 1991). In general, the proportion (flow) of heated or cooled water entering the stream from a tributary determines the rate of increase or decrease in mainstem stream temperature.

Water temperature balance equation from Brown, 1969.

$$\frac{(T1*Q1) + (T2*Q2)}{Q1 + Q2}$$

T1 = temperature of inflow Ql = stream flow of inflow
T2 = temperature of receiving stream Q2 = stream flow of receiving stream

Streams with lower flows cannot store as much heat energy for downstream transport as streams with large flows. The temperature of a large stream will not be influenced substantially by inflows of smaller tributaries. As an example, using the Brown's equation, Big Creek a tributary to the South Fork Trinity River below Hyampom had a maximum weekly average temperature of 16.8°C (62.6°F) in 1997. Big Creek has less than 10% of the flow of the South Fork Trinity River which is 22.5°C (73.0°F) at the confluence with Big Creek. The resulting temperature when the two streams mix is 21.9°C (71.9°F) in the area immediately surrounding the confluence.

Research in Washington State found that the effect of major tributaries on mainstem streams or rivers extends 150 meters or less (Caldwell et al, 1991). "The response of larger streams or rivers never exceeded 0.5°C change in temperature attributable to an incoming smaller tributary" (Caldwell et al, 1991). "A lack of response was seen in both cases where warm and cool tributaries flowed into large streams or rivers" (Caldwell et al, 1991).

4.3 INFLUENCE OF AIR TEMPERATURES AND ELEVATION

While not studied extensively in forested watersheds it is understood that "the air temperature in the vicinity of the stream regulates many of the processes of heat loss from the stream" (Sullivan et al, 1990). As a major part of the energy balance equation, air temperatures have been found to be highly correlated with water temperatures (Adams and Sullivan, 1990). The combination of solar radiation and air temperatures have been found to be highly correlated with the diurnal fluctuation of water temperatures. Due to these strong relationships many models that predict water temperatures (SSTEMP) utilize regional air temperature regimes to predict water temperatures.

It is well understood that generally at low elevations air temperatures are warmer than air temperatures at higher elevations. Except for coastal marine climate zones that are influenced by coastal fog this understanding appears to apply to northern California. Some have suggested that due to effects of adiabatic cooling, air temperatures decrease approximately 2°C (3.6°F) for every 300 meters (984 ft) decrease in elevation (Sullivan et al, 1990). From these understandings researchers have found that water temperatures can be highly correlated with elevation (Caldwell et al, 1991).

4.4 INFLUENCE OF STREAM DEPTH, WIDTH, AND FLOW

The fluvial geomorphology of streams has a direct effect on the surface area of a streams width, depth, and subsequent exposure to solar radiation. In large river systems braided channels and wide shallow channels will have more surface area than single, narrow and deep channels. The physical surface area of the stream, as represented by wetted width increases as the distance from the watershed divide increases (Sullivan, et al, 1990). Shading from riparian vegetation and topography tends to decrease as the streams' wetted width increases. Large streams will have a large surface area exposed to solar radiation and thus will be heated to a higher temperature than narrow streams. Both of these factors together tend to increase the stream's exposure to solar radiation as the streams get larger and directly increase water temperatures.

4.5 INFLUENCES OF RIPARIAN HABITAT

One of the functions of riparian habitats is to provide for shade to provide for water temperature control. Narrow smaller streams can be easily shaded by many different vegetation including shrubs, trees or topography. The wetted width of small streams increase as the distance from the watershed divide increases (Sullivan et al, 1990). Many studies on small streams have documented the effects of riparian vegetation and its removal on summer stream temperatures (Beschta et al, 1987). Removal of riparian vegetation within small stream riparian areas can significantly increase daily mean and maximum temperatures during the summer months (Brown and Krygier, 1970). Studies of small streams conclude that water temperatures are best predicted by the influences of elevation, riparian canopy closure, water depth, and ground water inflow (Sullivan et al, 1990).

However, within large river systems the main channel can be quite wide or braided and the influences on water temperature are complicated. Generally, the elevation of the large river or in this case the South Fork Trinity River elevations (1,000-2,000ft) are much lower than headwater tributaries (l,500-5,000ft). The difference in local air temperature at much different elevations regulates the heat transfer process for each reach as water temperatures are always reaching equilibrium with the local air temperature. The wide or braided river has much higher direct solar radiation heating water temperatures, and local air temperatures increase as topographic or vegetative shading is minimal. Researchers have documented that elevation (air temperature) and distance from the watershed divide (wetted width) are the single most important factors influencing water temperature in large river systems (Sullivan et al, 1990).

5.0 METHODS

Because this report was completed by compiling data across several ownerships, not all of the information was collected in the same manner for each stream. Different owners and agencies have different objectives with respect to fisheries and watershed monitoring. Nonetheless, we were very cognizant of the fact that all analyses needed to be performed on data that was comparable in nature. As such, the individual data collection methods were compared and if methodologies prevented the use of information the data was excluded from analyses.

5.1 EQUIPMENT

Water temperature was measured with continuously recording electronic instruments. Various models of electronic instruments were used (Table 1).

Table 1

MODEL	INSTRUMENT	TEMP. RANGE	ACCURACY +/-
Hobo Temp	Internal Probe	-20°C to 70°C (-4°F to 158°F)	+/- 0.5°C
StowAway XTI	Internal Probe	-40°C to 75°C	+/- 0.2°C
Optic Stowaway	Internal Probe	-5°C to 37°C	+/- 0.2°C
Ryan Tempmentor	Internal Probe	-58°C to 73°C	+/- 0.2°C

Each instrument was calibrated before each field season following calibration protocols described by the FFFC (1996). All the instruments used in this study maintained accuracy standards described in the calibration protocols and described in USGS (1978). Using an EPA certified ASTM thermometer during calibration indicated that accuracy of instruments was +/- 0.2 at 0°C.

5.2 FIELD PROTOCOLS

To be consistent with other research, our data has been collected using techniques similar to those described in FFFC (1996) and USGS (1978). Field data recorded included date, time, individual, serial number, activity, location, water temperature, air temperature, and downloaded computer file name. The field measurements are maintained to verify stream data recordings and allow exchange of stream data between various landowners and agencies.

5.3 DATABASE AND GIS COVERAGES

All stream temperature thermographs were transferred from individual databases to a central database. Due to the large geographic scale of the watershed the distribution of water temperature recording stations were entered into a Geographic Information System (GIS). GIS coverages of land ownership, land use, streams, roads, and watershed boundaries for the display and analysis of stream temperatures by sub-watershed.

To better understand stream temperature data over this broad watershed the results are expressed in both metric and English units. Below is a summary of the conversions between metric and English units.

Metric Units	English Units
1 Meter (m)	3.28 Feet (ft)
1 Kilometers (km)	0.621 Miles (mi)
1 Sq. Kilometers (km^2)	0.386 Sq. Miles (mi^2)
1 Cubic Meters per Second (m^3/sec)	35.314 Cubic Feet per Second (ft^3/sec)
1 Degree Celsius = (°F - 32) * 0.55	1 Degree Fahrenheit = (°C * 1.82) + 32

5.4 TECHNICAL DEFINITIONS

Through the scientific literature many terms are used to define the metrics used to describe water temperatures. We found that a list of the definitions was quite helpful in fully understanding data from other research, historical data found within the South Fork Trinity River watershed, and calculations completed for this report. Below is a list of technical definitions that we refer to throughout the report.

7-day maximum weekly average temperature: The average of a 7-day period of the highest consecutive maximum water temperatures recorded for the year. (Recommended by the NCRWQCB)

7-day maximum weekly maximum temperature: The average of the 7 highest consecutive maximum water temperatures recorded for the year.

Maximum instantaneous temperature: This is the highest single recorded temperature for a year. This usually represents the temperature of water for anywhere from 1 minute to 2 hours. Much of the historical data was recorded using this metric.

6.0 RESULTS

Analysis of water temperature data collected in the streams of the South Fork Trinity River watershed reflect the controlling influences of the fundamental physical processes affecting water temperatures as described in Section 4.0. The use of the data for this report is not to verify research on the subject, but rather to describe how these processes are the controlling factors in the South Fork Trinity River and tributaries the watershed. Only a much more detailed and well thought out study design could attempt to verify various findings. To the extent that other research appears to support our findings we have noted where applicable.

6.1 SPATIAL DISTRIBUTION OF WATER TEMPERATURES

We were able to locate and identify 71 separate continues recording water temperature monitoring sites within the South Fork Trinity River watershed. The 71 monitoring sites have been collected between 1989 and 1997 by the Shasta-Trinity National Forest, Trinity County R.C.D., Natural Resource Conservation Service, Timber Products Company, Sierra Pacific Industries, and the Six Rivers National Forest (Figure 2). We contacted all the major landowners in the watershed and we feel this assimilation of water temperature data is very extensive. We also recognize that a few other monitoring sites exist (1998 data) within the watershed, but due to time constraints we were unable to include the data in this report.

Even though the 71 separate monitoring sites were collected for various research objectives the monitoring sites are spatially well distributed within the watershed (Figure 2). While a large portion of the watershed has been monitored, due to the non-systematic approach of the sites some sub-watersheds cannot be described. The temporal distribution of monitoring sites is not complete. None of the monitoring sites collected data for the entire period between 1989 and 1997. Many monitoring sites have data for extended periods within this 8 year period of record. We were very cognizant of ensuring that when analyzing water temperature data we compared and contrasted data from the same year.

To simply spatially display water temperatures a specific metric and system of grouping was used. Throughout water temperature research a wide variety of metrics and grouping systems have been proposed. To simply display data for this report we choose a metric and grouping system that has been used in northern California and is supported by historical data and unmanaged watershed data discussed in Section 6.4 of this report. This metric and grouping system falls within the natural range of variability that has historically existed and currently exists in the South Fork Trinity River watershed. We determined that 7-day maximum average water temperatures have historically been in excess of 20°C (68.4°F) in the mainstem of the South Fork Trinity River (See Section 6.4 of this report). From data collected between 1989 and 1997 we reviewed individual year data and multiple year data collected for individual sub-watersheds and identified sub-watersheds as either having water temperatures above or below 20 °C (68.4°F) (Figure 3). We also reviewed data for monitoring sites along the South Fork Trinity River mainstem and along Hayfork Creek and identified reaches that have water temperatures either above or below 20°C (68.4°F) (Figure 4).

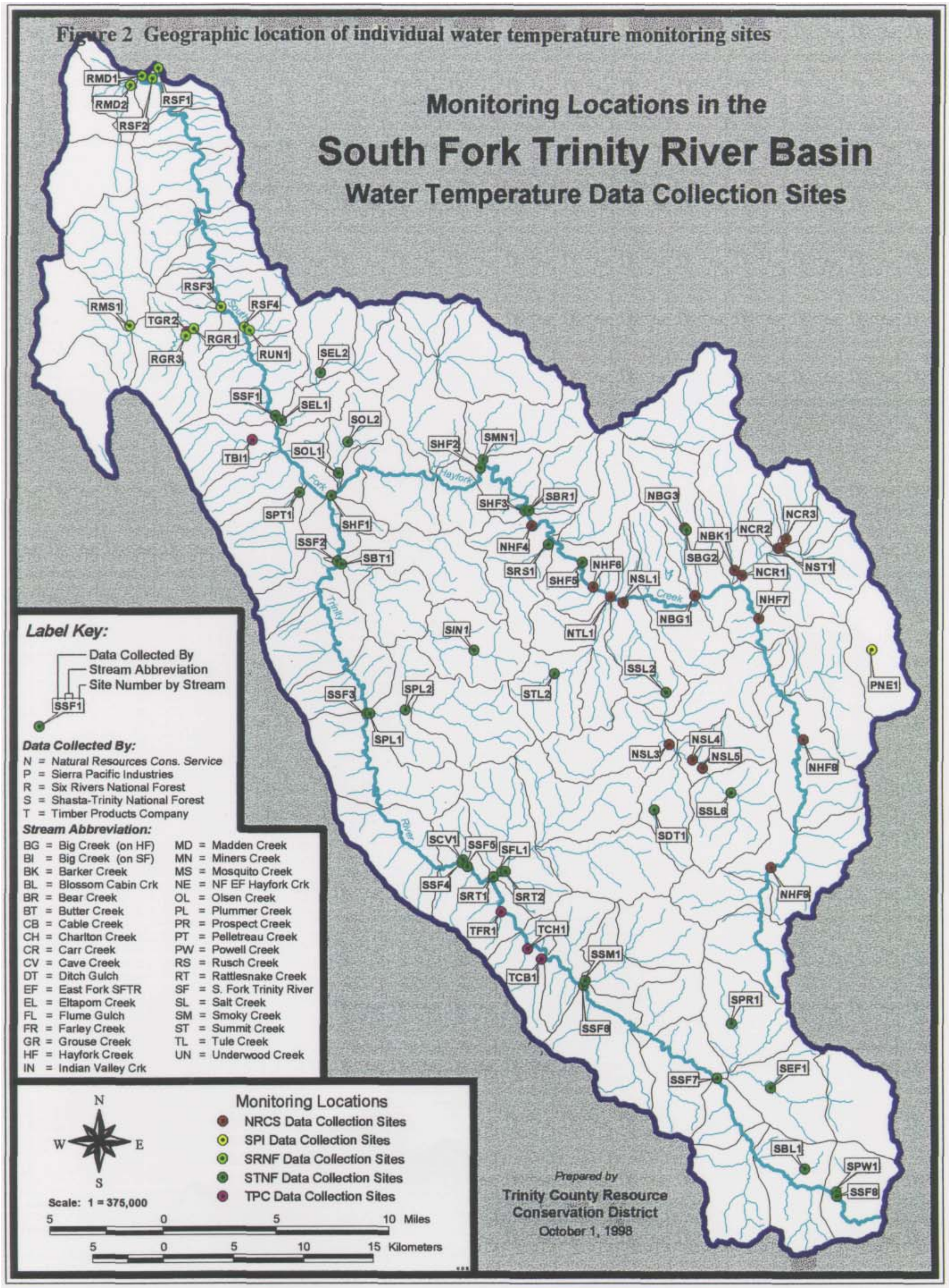
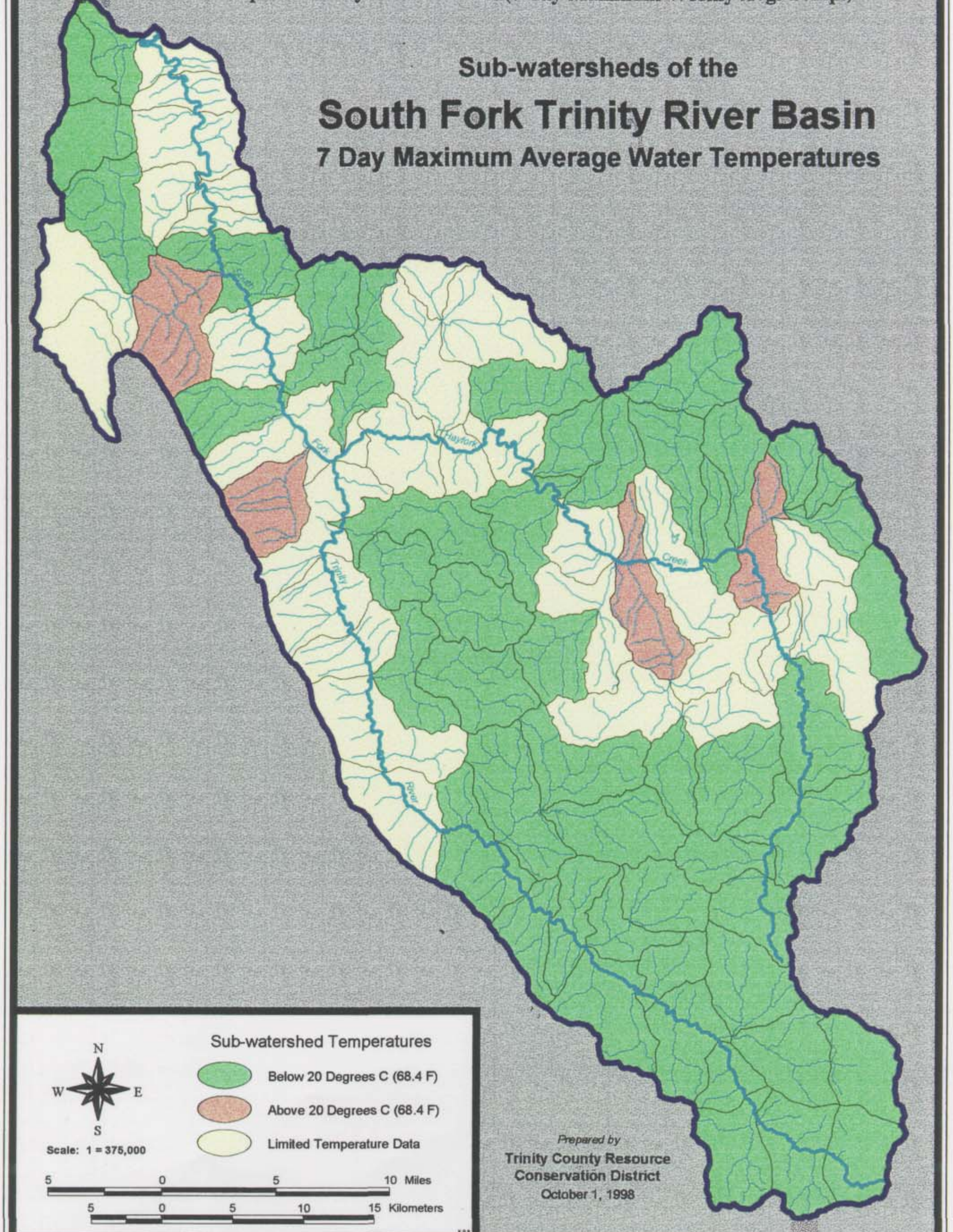


Figure 2 Geographic location of individual water temperature monitoring sites

Figure 3 Water Temperatures by Sub-watershed(7-day Maximum Weekly Avg. Temp.)



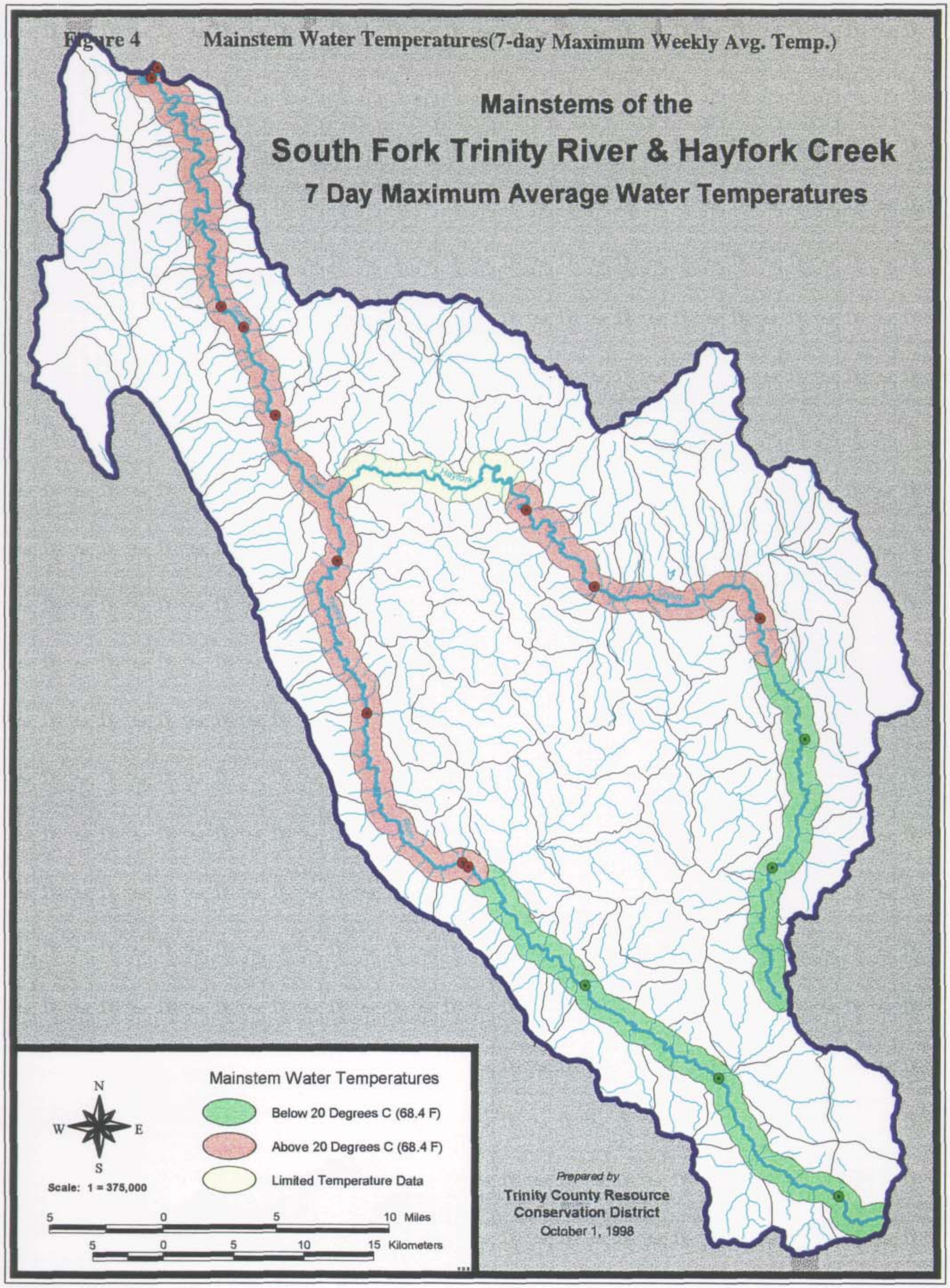
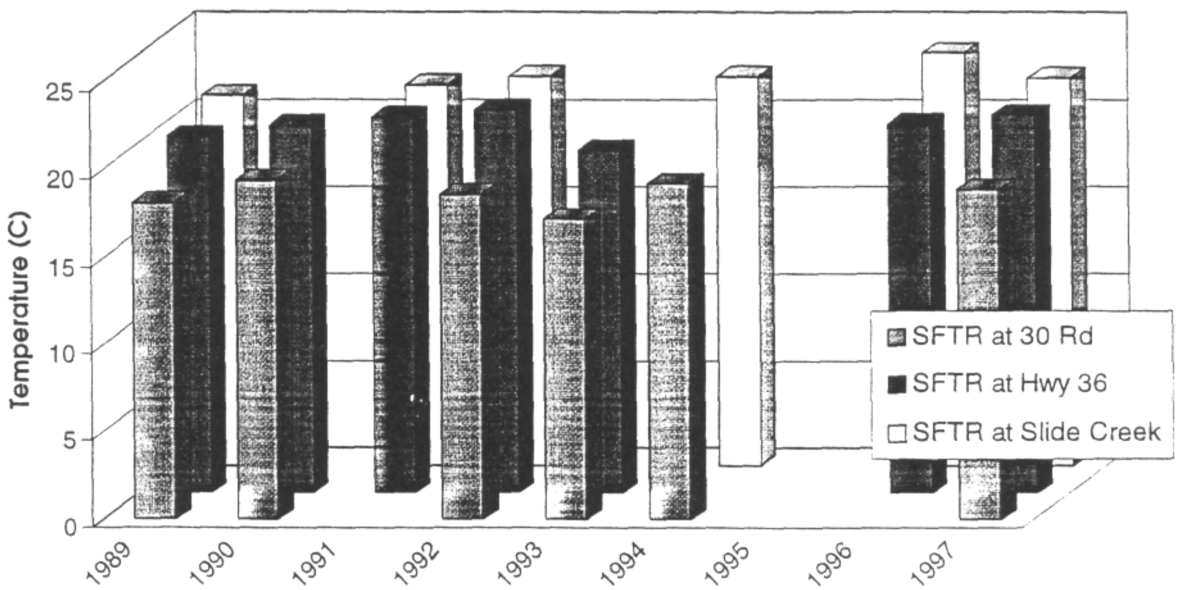


Figure 4 Mainstem Water Temperatures(7-day Maximum Weekly Avg. Temp.)
Mainstems of the
South Fork Trinity River & Hayfork Creek
7 Day Maximum Average Water Temperatures
Mainstem Water Temperatures
Below 20 Degrees C (68.4 F)
Above 20 Degrees C (68.4 F)
Limited Temperature Data
N
W
E
S
Scale: 1 = 375,000
5 0 5 10 Miles
5 0 5 10 15 Kilometers
Prepared by
Trinity County Resource Conservation District
October 1, 1998

6.2 ANNUAL VARIATION OF WATER TEMPERATURES

The variation of water temperatures between calendar years can occur due to many short term and long term watershed processes. Air temperature can be one of the single most significant influences on water temperatures. Fluctuations in climate from year to year can influence water temperatures in the South Fork Trinity River. Figure 5 shows water temperature data for three locations along the main stem of the South Fork Trinity River from 1989 to 1997. These results are supported by many researchers who have found larger river systems due primarily to larger water flows remain relatively stable reaching equilibrium with the natural topographic factors controlling water temperatures.

Figure 5 Annual Variation in Water Temperatures for Three Locations on the South Fork Trinity River (7-day Maximum Weekly Average Temp.)



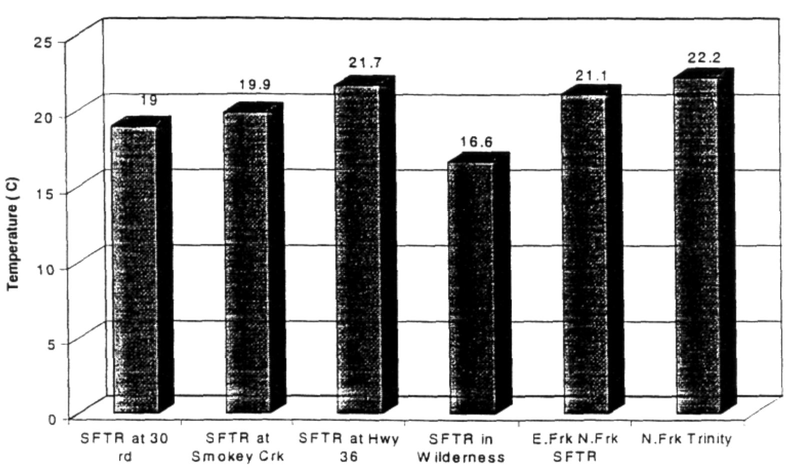
6.3 NATURAL RANGE OF WATER TEMPERATURES IN THE SOUTH FORK TRINITY RIVER WATERSHEDS

Due to the natural topography, geomorphology and many other factors discussed in Section 4.0 of this report the South Fork Trinity River has always had a natural range of stream temperatures. While the fundamental understanding of theoretical watershed processes can describe this variation, there are two unmanaged large sub-basins that have had water temperature data collected that can represent the possible natural range of water temperatures. The Yolla Bolla Wilderness area at the headwaters of the East Fork of the South Fork and the North Fork Trinity River which is highly representative of many sub-basins in the South Fork watershed.

The North Fork Trinity River and the East Fork North Fork Trinity River flow from watersheds with their headwaters in Wilderness. Over 90 percent of these watersheds are in Wilderness and have never been under timber management. The lower portion of the North Fork Trinity River is physically similar to the South Fork Trinity River in that it has relatively low elevation channels, are confined in steep canyons oriented north/south, and are thus exposed to similar levels of solar radiation. The drainage areas for the North Fork Trinity and East Fork North Fork Trinity are 68,000 acres and 30,000 acres, respectively. Acreage for the South Fork sites are as follows: South Fork at 30 Road, 27,000 acres; South Fork at Smoky Creek, 88,000 acres; and South Fork at Hwy 36, 108,000 acres.

Figure 6 compares water temperatures from the three Wilderness monitoring sites with three locations on the main stem of the South Fork Trinity River. The natural range of maximum weekly average temperatures for the Wilderness sites is between 16.6°C (62.2°F) and 22.2°C (72.4°F). Historical records of water temperatures in the New River (also predominately in Wilderness) show high water temperatures of 22°C (72.0°F). The 22°C reading for the New River at Denny was recorded on July 30, 1962 (Blodgett, 1970). Additional historical data presented in Section 6.4 of this report indicate that the main stems of large rivers with similar physical attributes will show high summer water temperatures in the range of 20-26°C (68.4 - 79.3°F). The current water temperature data and historical data indicate that water temperatures in the South Fork Trinity River, North Fork Trinity River, East Fork North Fork Trinity River and the New River describe a natural range of variability between 16.6°C (62.2°F) and 22.2°C (72.4°F).

Figure 6 7-Day Maximum Weekly Average Temperature for 1997

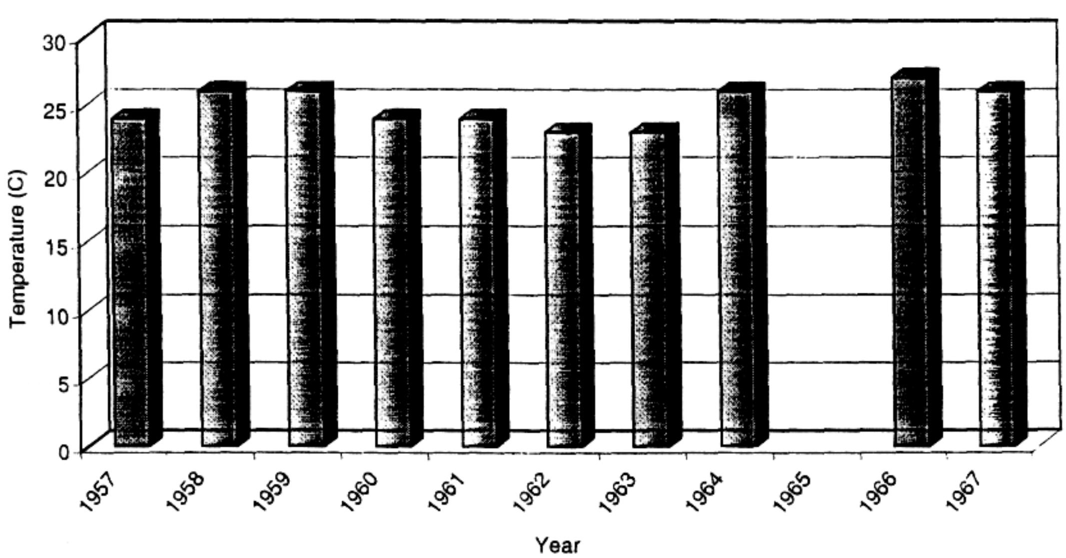


6.4 HISTORIC RANGE OF WATER TEMPERATURES IN THE SOUTH FORK TRINITY RIVER WATERSHEDS

A point of contention in the South Fork Trinity River regarding stream temperature is what is "natural" and what is within the "natural" range of variability of water temperature. The dominant physical factors discussed in Section 4.0 of this document have not changed in the past several decades. Several unpublished reports have made reference to the effects of the 1964 flood and how the main stem of the South Fork became wider and shallower due to the influx of sediment (Pacific Watershed Associates, 1994, Haskins and Irizarry, 1988). The implication drawn for water temperatures was an increase in water temperature above what was natural before the effects of the flood. One report states the belief that the river has not "recovered" from the influx of 1964 sediment and also implies that main stem water temperatures have also not "recovered" to pre-1964 flood levels (Pacific Watershed Associates, 1994).

An examination of recorded stream temperatures following the flood did show an increase in summer water temperatures (Blodgett, 1970) in the years immediately following the flood. However, Figure 7 displays the historic nature of water temperature variation from year to year, and the relatively warm temperatures existing in the pre-1964 channel of the South Fork Trinity River. This data from Blodgett (1970) was used because it provides the longest period or record of water temperatures in the South Fork Trinity River system. The historic data displayed are the instantaneous maximum temperatures. In the three years prior to the flood event water temperatures in the South Fork upstream from Hyampom ranged from 20-25°C (68.4-77.5°F). Following the flood event a new station was put in the river downstream of Hyampom. For the years 1966 to 1968 high water temperatures there reached 28-29°C (82.9-84.8°F) (Blodgett, 1970). In recent years the high water temperatures in the South Fork Trinity River downstream

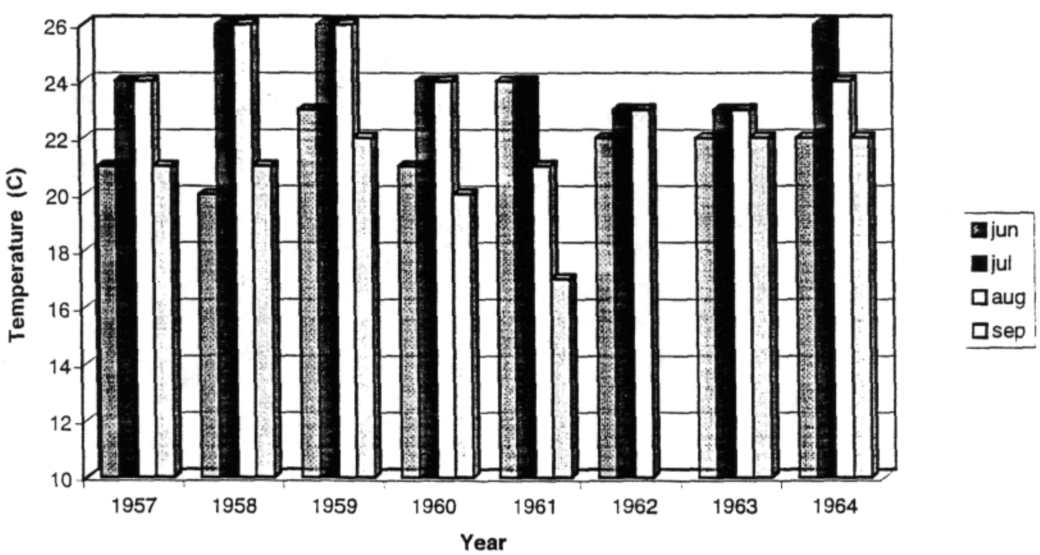
Figure 7 Annual Variation of Historic Water Temperatures for the South Fork River Near Salyer (Instantaneous Maximum Temperatures)



of Hyampom have ranged from 23.2°C (74.2°F)(1990) to 26.7°C (80.6°F) (1996). The South Fork Trinity River in the vicinity of Hyampom has been and continues to be a system with water temperatures that exceed 20°C (68.4°F) level on an annual basis. Water temperatures at this site suggest that large events such as the 1964 flood event will have immediate effects on the highest water temperature attained, but will not drastically alter the range of water temperatures in this reach.

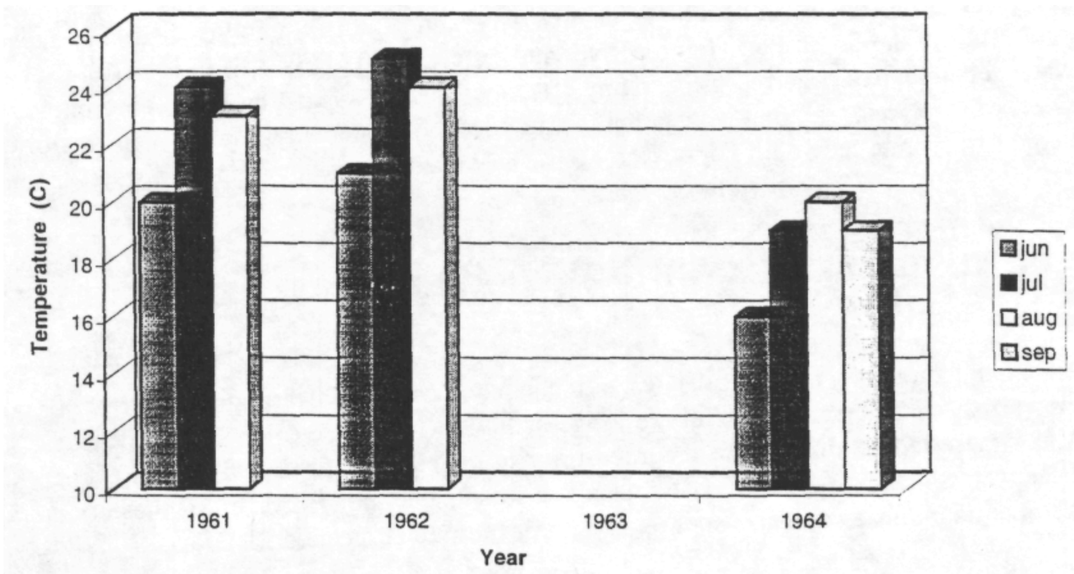
Additional historical data is available from "Water Temperatures of California Streams. North Coastal Subregion by J.C. Blodgett, 1970. The following is a review of historic water temperatures in the South Fork Trinity River that is pertinent to this subject. Figures 8, 9 and 10 show the instantaneous maximum water temperatures data by month for Hayfork Creek, and two locations along the South Fork Trinity River. All three locations had water temperatures collected prior to the 1964 flood event. Water temperatures collected at the confluence with the Trinity River indicate that water temperatures in exceeded 22°C (72.0°F) during the months of July and August every year from 1957 to 1964 (Figure 8).

Figure 8 Pre-1964 Flood Water Temperatures South Fork Trinity River near Salyer



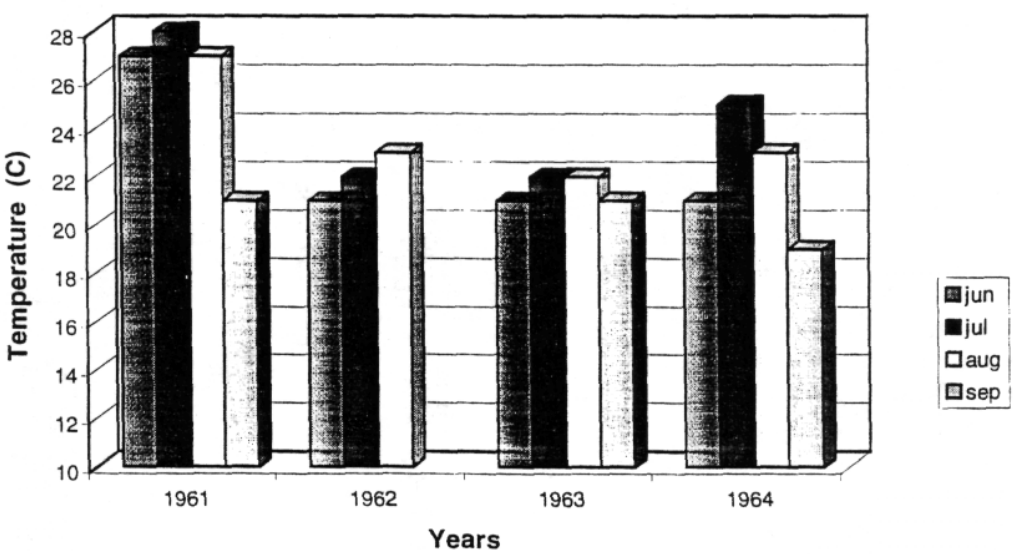
Farther upstream at a location one half mile upstream from the confluence of Hayfork Creek water temperatures exceed 20°C (68.4°F) plus range for 1961 and 1962 and only slightly below in 1964 (Figure 9). From data collected periodically at this location from 1956 to 1966 indicate the highest temperatures recorded for all years: 21°C (70.2°F) for June, 21°C (70.2°F) for July, 22°C (72.0°F) for August, and 20°C (68.4°F) for September.

Figure 9 Pre-Flood Water Temperatures in South Fork Trinity River near Hyampom



In Hayfork Creek near the confluence with the South Fork Trinity River near Hyampom water temperature data for the years 1961 to 1964 exceed 20°C (68.4°F)(Figure 10). From data collected periodically at this location from 1953 to 1960 indicate the highest temperatures recorded for all years: 19°C (66.6 F) for June, 25°C (77.5°F) for July, 22°C (72.0°F) for August, and 21°C (70.2°F) for September. The highest water temperature of 25°C (77.5°F) was recorded on July 14, 1955.

Figure 10 Pre-1964 Flood Water Temperatures in Hayfork Creek near Hyampom



Summary of this historical data indicates that water temperatures pre-1964 regularly exceeded 22°C (72.0°F) in the South Fork Trinity River and exceeded 20°C (68.4°F) in Hayfork Creek. These water temperatures occurred prior to any effects of the 1964 flood on the geomorphology of the river channel and riparian vegetation along these mainstem systems. This historical data demonstrates that the South Fork Trinity River mainstem has never supported water temperatures below 20°C (68.4°F) in previous 50 years.

6.4.1 HISTORICAL RANGE OF WATER TEMPERATURES IN NORTHERN CALIFORNIA

An examination of instantaneous water temperatures recorded throughout northern California shows that water temperatures in the range of 20-30°C (68.4-86.6°F) were prevalent (Table 2). All of these temperatures were recorded prior to the effects of the 1964 flood event. Some of these watersheds have been heavily managed, some have not. However all these rivers indicate that maximum instantaneous water temperatures routinely exceeded 21°C (70.2°F).

Table 2 Pre-1964-Flood Water Temperatures for North Coastal Streams Maximum Instantaneous Temperature Recorded(Blodgett, 1970)

USGS Gauging Station Name	Basin Area (Sq. Miles)	Maximum Temp. (C)	Maximum Temp. (F)	Year
Garcia River near Point Arena	98.5	22	72	1964*
Navarro River near Navarro	303	25	78	1959
Eel River blw Scott Dam	290	22	72	1951
Eel River abv Dos Rios	705	28	83	1952
Middle Fk Eel River near Dos Rios	745	30	87	1958
Eel River blw Dos Rios	1484	28	83	1951
N Fk Eel River near Mina	248	28	83	1961
S Fk Eel River near Branscomb	43.9	24	76	1959
S Fk Eel River near Miranda	537	26	79	1955*
Eel River at Scotia	3113	28	83	1955
Van Duzen River near Dinsmores	85.1	24	76	1956
Van Duzen River at Bridgeville	202	24	76	1951
Mad River near Forest Glen	143	26	79	1961*
N Fk Mad River near Korbel	40.5	22	72	1959
Mad River near Arcata	485	23	74	1960
Redwood Creek near Blue Lake	67.5	22	72	1953*
Shasta River near Weed	26.6	22	72	1959
S Fk Scott River near Callahan	41.4	21	70	1959*
S Fk Salmon River near Forks of Salmon	252	21	70	1961*
N Fk Salmon River near Forks of Salmon	205	22	72	1961
Salmon River at Somes Bar	751	24	76	1959*
Trinity River abv Coffee Creek	149	24	76	1960

* Temperature was recorded on other dates as well as the one listed.

6.5 CHANNEL GEOMORPHOLOGY AND STREAM FLOWS - SOUTH FORK TRINITY RIVER

Like many large watersheds the South Fork Trinity River flows begin as small headwater streams at high elevations and ends at the confluence with the Trinity River as a wide lower elevation river. The South Fork Trinity River like many rivers increases in width due to river flow and due to historic geomorphology processes. As river width increases the ability of topography and riparian canopy closure to shade the surface of the water diminishes to the point where it is no longer a factor. The general flow of the South Fork Trinity River is from the south to the north. This is significant because this maximizes the amount of direct solar radiation that strikes the exposed water surface. As a large river system flows from high elevation where air temperatures are cooler to lower elevation where air temperatures are warmer the water temperature is constantly reaching equilibrium with the air temperature. Many researchers have found increase water temperatures as a function of lower elevations and subsequent high air temperatures (Sullivan et al, 1990). The result is a steady increase in water temperature as the South Fork Trinity River flows from its headwaters in the Yolla Bolly Wilderness to the confluence with the Trinity River (Figure 11).

Figure 11 Mainstem Maximum Weekly Average Temperatures from Headwaters to Confluence with the Trinity River

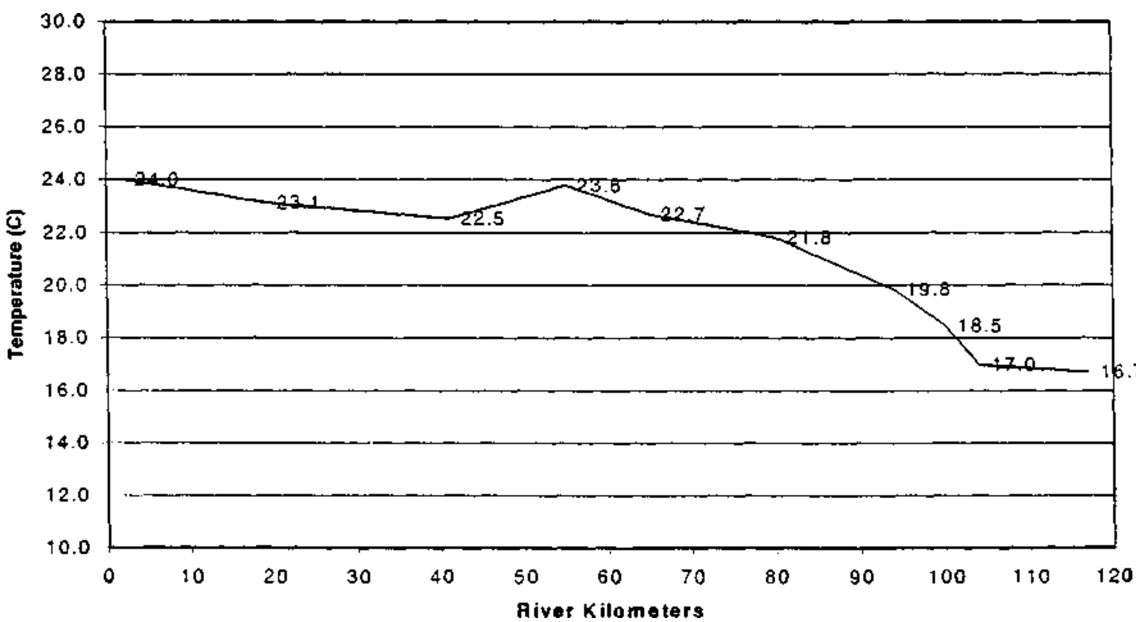


Figure 11 (Continued)

River Kilometer	Recorder Site Name
2	Above Confluence with Trinity River
19	Below Grouse Creek
41	At Slide Creek (below Hyampom)
55	Below Butter Creek
67	At Plummer Creek
81	Below Hwy 36 (Forest Glen)
95	Above Smoky Creek
104	At 30 Road Bridge
117	Above Powell Creek (in Yolla Bolly Wilderness)

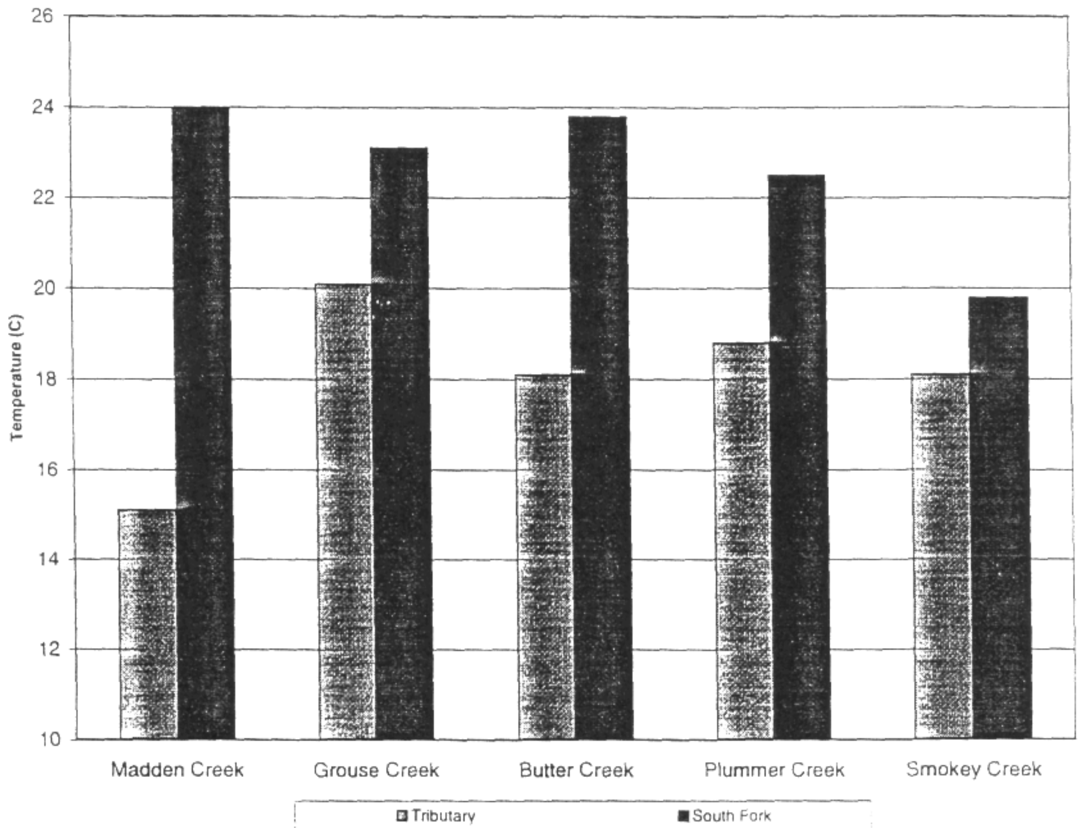
The South Fork Trinity River slowly warms with no abrupt heating or cooling of the river as tributary flows enter into the river (Figure 11). Water temperatures of the main stem of the South Fork Trinity River appear to be not influenced by tributary water temperatures. It appears that the South Fork Trinity River water temperatures are then primarily being controlled by topographic (elevation) and geomorphic characteristics (channel width) of the watershed.

Analysis of water temperatures and the distance from the hydrographic boundary found a strong correlation on the South Fork Trinity River (R^2 = 0.77) which also indicates geomorphic characteristics of the watershed are determining water temperatures.

A determination of the effects of tributary water temperatures on the main stem of the South Fork Trinity River was done in 1990 (USFS, 1990). Using Brown's equation as discussed in Section 4.2 the effect of Rattlesnake Creek to cool the main stern water temperature by only 0.4°C, while the effect of a cooler but smaller tributary (Cave Creek) was only 0.1°C. These small temperature influences quickly diminished downstream in the South Fork Trinity River.

Analysis of paired data for water temperatures in tributaries and main stem water temperatures directly below confluences indicate that little heating or cooling occurs due to tributary flows (Figure 12). These small increases or decreases are within the accuracy of the instruments used to measure temperature. These are also within the natural variation of topography, river width, and elevation measured between tributaries. From both mainstem and tributary data it appears that the South Fork Trinity River water temperatures are then primarily being controlled by topographic (elevation and orientation) and geomorphic (channel width) characteristics of the watershed.

Figure 12 7-day Maximum Average Water Temperatures for the Mainstem vs. Tributary (1997)



6.6 CHANNEL GEOMORPHOLOGY AND STREAM FLOWS - HAYFORK CREEK

It is well documented that heat transfer from air to water increases as the depth of the stream decreases (Adams and Sullivan. 1990; Sullivan. 1990). Changes in the depth of the stream can occur from low flows occurring due to drought, water diversions, or fluctuations in water releases from dams. However, water temperature and stream flow data collected during high flow year of 1995 and the lower flow year of 1997 on Hayfork Creek indicates that water temperatures remain relatively the same during high flow and low flow years (Figure 12). This relationship also occurs in the upper reaches of Hayfork Creek above Deep Gulch (Figure 13).

Figure 12 Flow vs. Water Temperature on Hayfork Creek

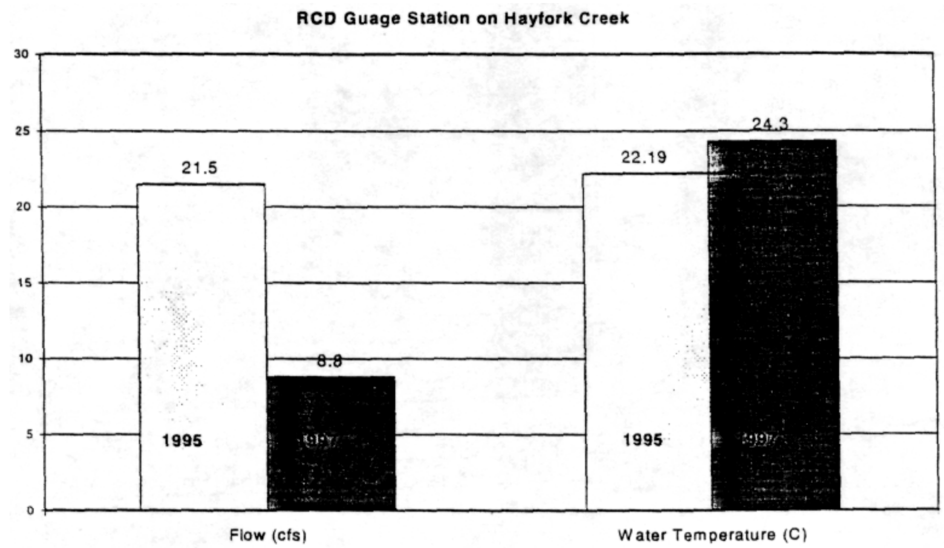
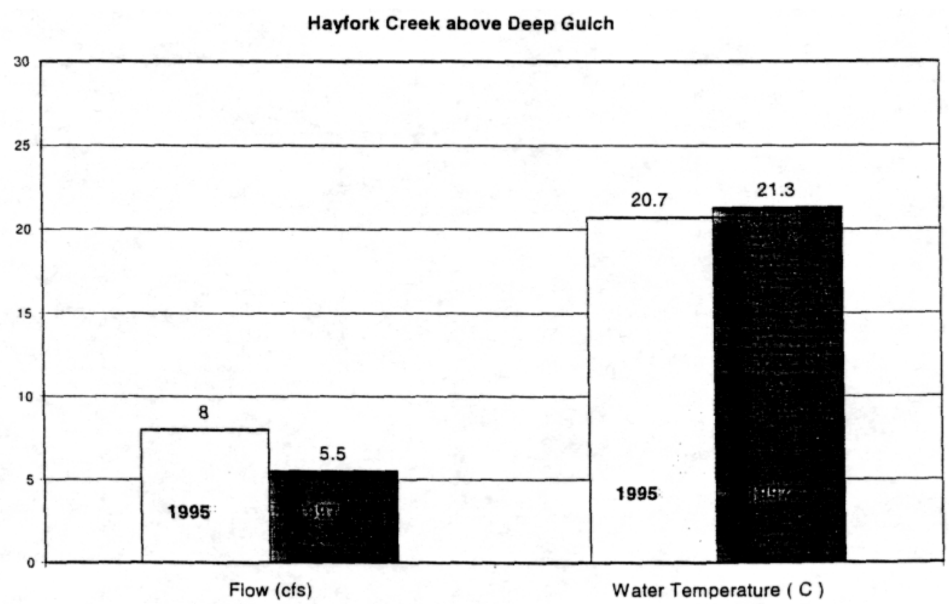
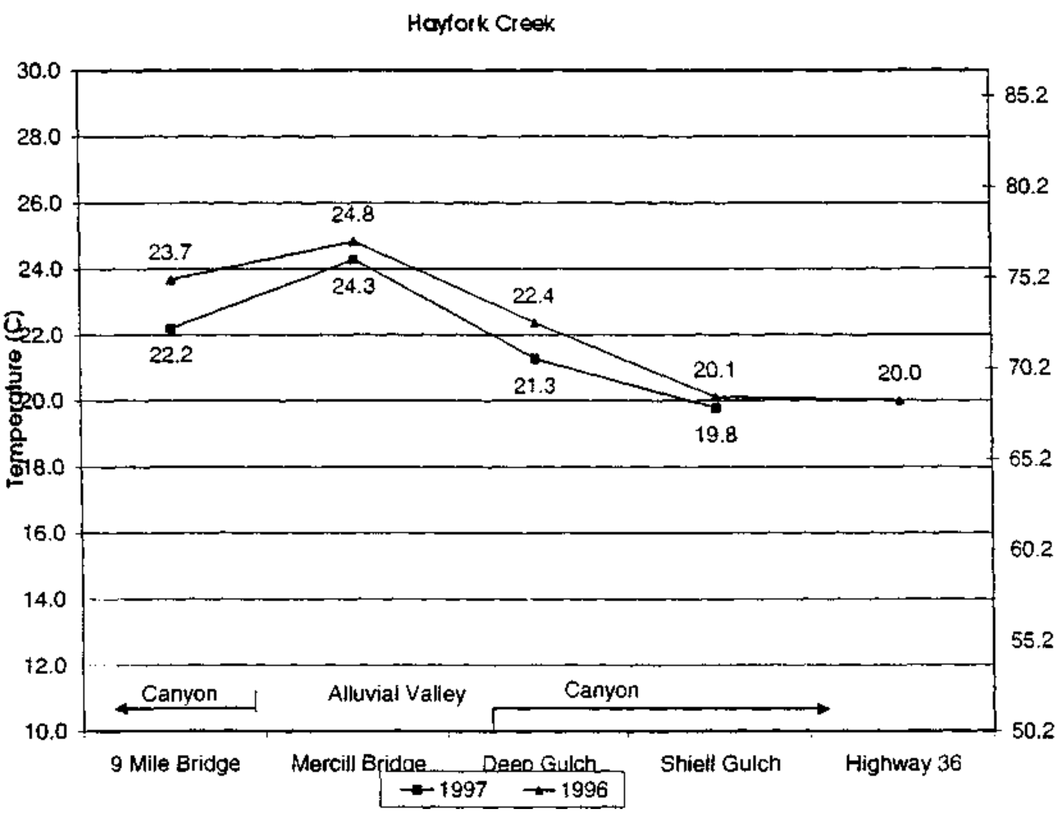


Figure 13 Flow vs. Water Temperature on Hayfork Creek Above Deep Gulch



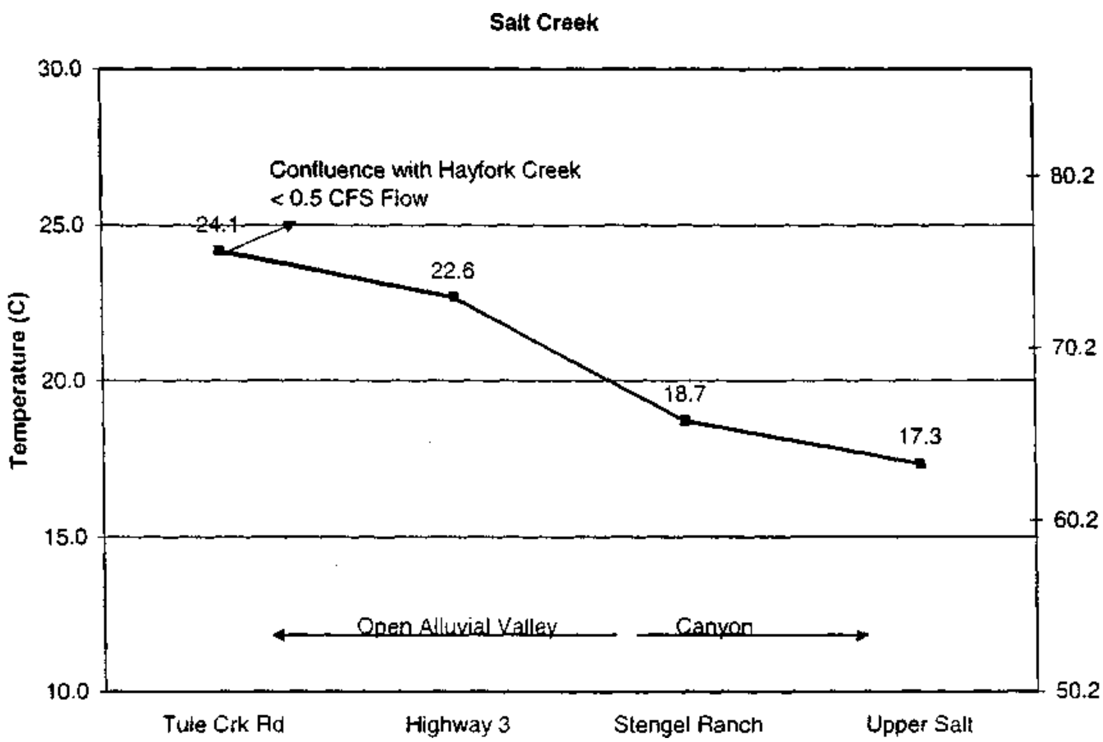
Water temperatures during the summer months in the mainstem of Hayfork Creek follow a warming pattern from the headwaters downstream to the alluvial Hayfork valley(Figure 14). The headwaters of the watershed are generally forested with topographically confined narrow channels. As the creek flows through the alluvial Hayfork valley the channel widens. As the creek enters the Hayfork canyon the channel again narrows and flows to the South Fork Trinity River. The headwaters of Hayfork Creek are relatively cool but as the creek flows through the wide alluvial flood plain water temperatures increase (Figure 14). Summer water temperatures peak through the alluvial Hayfork valley and begin a slight cooling as the creek enters the Hayfork canyon. The limited temperature data for the lower Hayfork Creek indicates that a cooling of Hayfork Creek occurs until the creek reaches the alluvial reach of the Hyampom valley.

Figure 14 1996 and 1997 Maximum Weekly Average Temperatures for Hayfork Creek



The effect of geomorphology which has determined stream width and stream exposure to direct solar radiation is also found in Salt Creek (a major tributary to Hayfork Creek). Salt Creek headwaters is also located in a forested topographically confined narrow channel that flows into a alluvial flood plain that is wide and open and has little topographic or vegetative shade (Figure 15). Water temperatures are relatively cool in the upper reaches of Salt Creek and temperatures are warmer in the alluvial flood plain.

Figure 15 1996 Maximum Weekly Average Temperatures for Salt Creek



6.7 AIR TEMPERATURES

As discussed previously many researchers have found that air temperatures can be a controlling environmental factor in determining water temperatures. Air temperatures can be influenced by the local climate, elevation, aspect, topography, and vegetative shade. The South Fork Trinity River watershed is located in the interior Klamath Mountains range that experiences cool winters and hot dry summers. A continuous RCD stream gauge is operated along Hayfork Creek downstream of the town of Hayfork. The gauge collects air and water temperature and stream flow. Analysis of data from this gauge indicates that average daily air temperatures can exceed 25°C (77.5°F)(Figure 16). The air and water temperatures are highly correlated (R^2 = 0.93) and this result is similar to results found by other researchers (Adam and Sullivan, 1991; Sullivan et al. 1990).

The daily instantaneous maximum air temperatures can exceed 37.4°C (100.0°F)(Figure 17). The extremely hot daytime air temperatures in combination with direct solar radiation can heat the water temperatures in excess of 24°C (75.7°F).

Figure 16 Average Daily Water Temperatures and Air Temperatures along Hayfork Creek

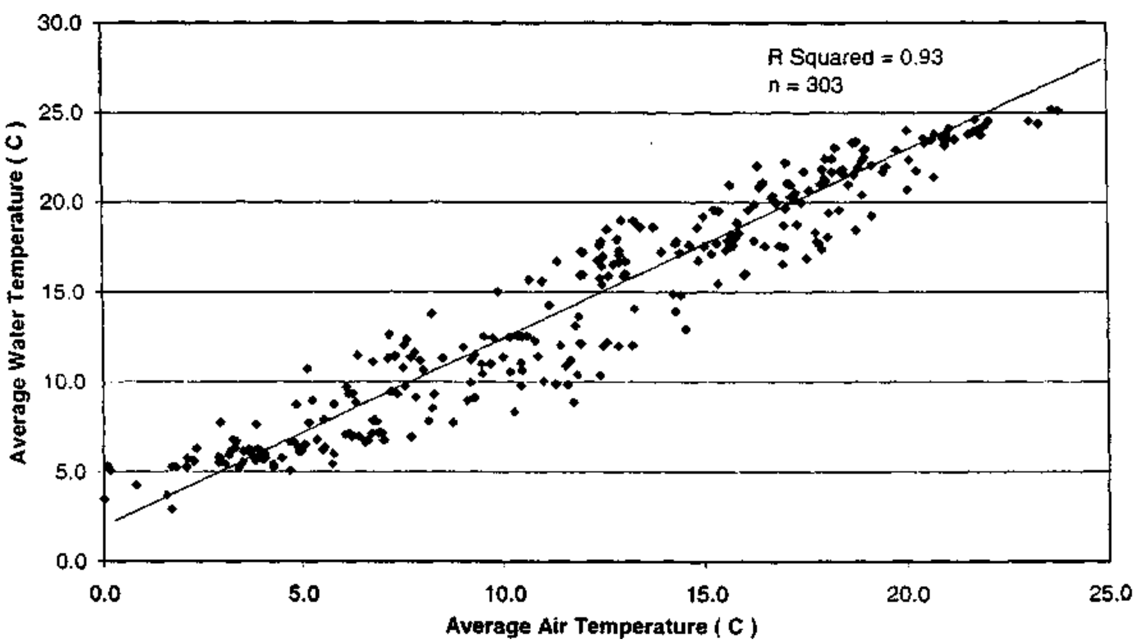
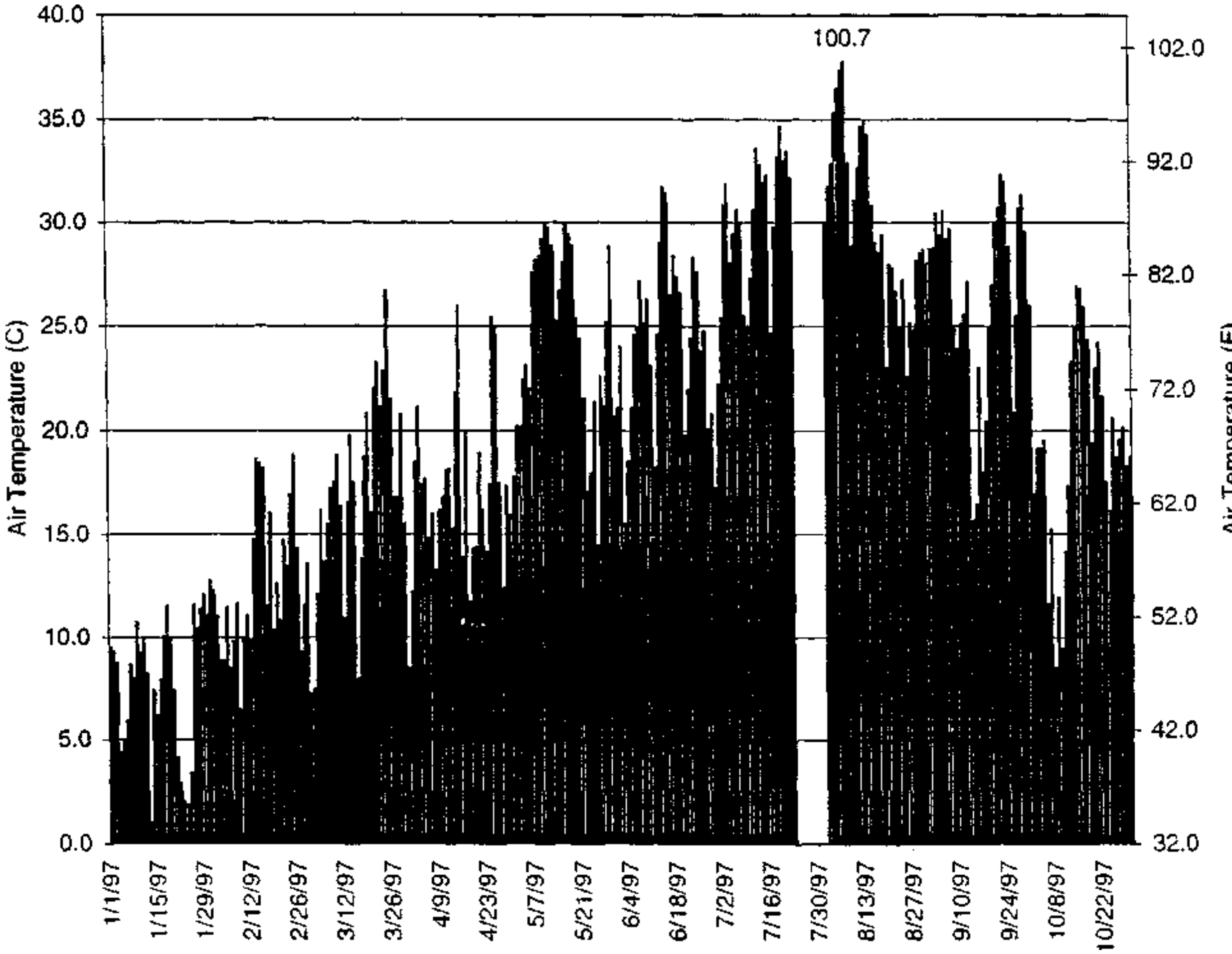
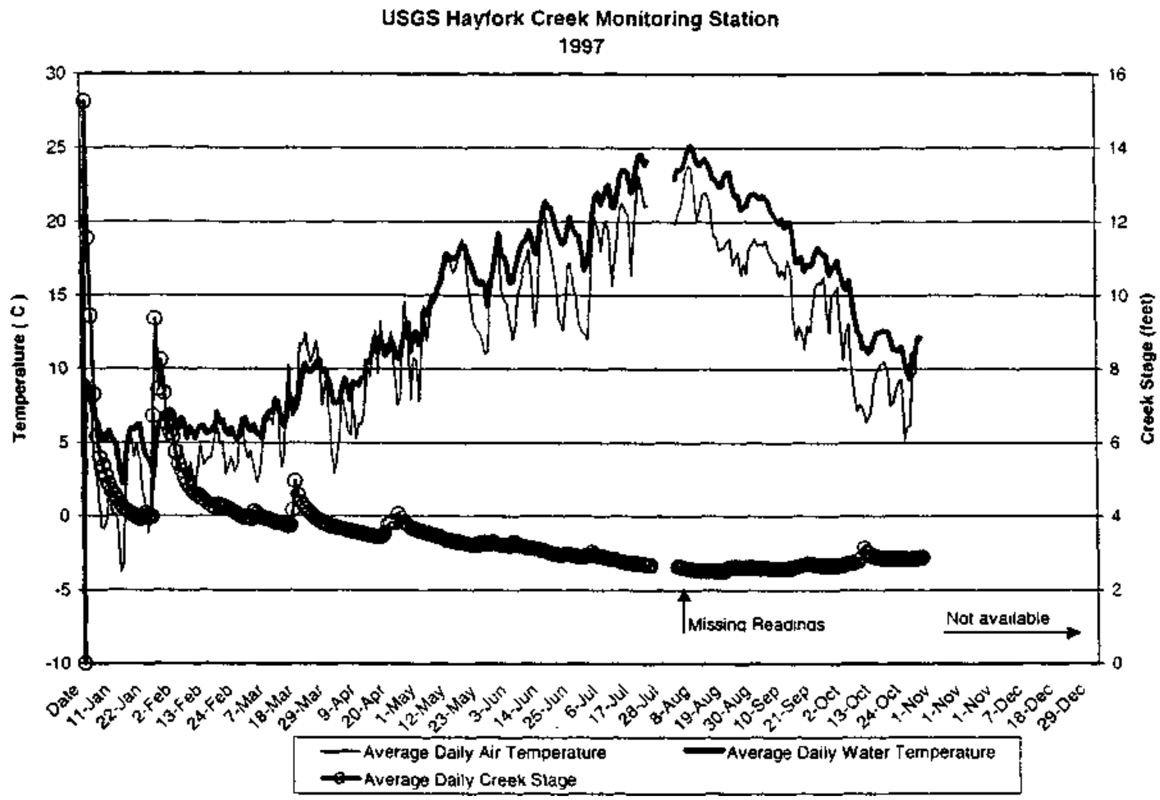


Figure 17 1996 Daily Air Temperatures along Hayfork Creek



From the same RCD stream gauge along Hayfork Creek direct comparison of daily average recordings of air and water temperatures indicate that air temperatures and solar radiation are major watershed processes controlling water temperatures (Figure 18). As the average daily air temperature increases or decreases throughout the year the average daily water temperature decreases (Correlated $R^2 = 0.93$) Yet water temperatures increase and decrease independent of creek stage. As the creek stage continues to drop to base flow conditions at the end of August, the water temperature has decreased from peaks in late July (Figure 18). This independence of creek stage is due to the peak in air temperatures occurs in late July or early August. Also this independence of creek stage is due to the peak in solar radiation which occurs during the middle of June.

Figure 18 Daily Average Water and Air Temperatures Compared with Creek Stage



6.8 PHYSICAL LANDSCAPE CONDITIONS - A PHOTOGRAPHIC HISTORICAL PERSPECTIVE

A historical example of the main stem channel conditions of the South Fork Trinity River that influence water temperatures refer to Figures 19 and 20. Both these pictures were taken from the same location on the South Fork Trinity River approximately 2 kilometers down stream from the Hyampom Valley. Both pictures are looking downstream with the confluence of Eltapom Creek in the distance, coming in from the right. Figure 19 was taken in the summer of 1912 by Rudolph W. Van Norden and published in: Report On an Hydro-Electric Power Project, South Fork of Trinity River, California (Van Norden, 1912).

Both photos are representative of a large portion of the lower river channel showing a meandering river confined by steep mountains on both sides. The river gradient is low with a gravel substrate covering the entire width of the confined floodplain. Riparian vegetation along the banks of the summer low flow channel is sparse or non-existent. The summer low flow channel is thus nearly completely exposed to solar radiation. The flow of the channel at this point is from south to north which ensures a long exposure time during the peak of solar radiation in the summer months. It is inevitable that the water temperature of the river at this location will be high, as both pre and post 1964 flood records have shown it to be. From the physical attributes displayed in Figures 19 and 20, the historic temperature records (Blodgett, 1970), and current water temperature data indicate that as in 1912 the South Fork Trinity River has always had water temperatures exceeding 20°C (68.4°F).

Figure 19 South Fork Trinity River Below Hyampom as it Appeared in 1912

Figure 20 South Fork Trinity River as it Appeared on July 9, 1997

7.0 DISCUSSION

7.1 NATURAL AND HISTORIC WATERSHED CONDITIONS

The South Fork Trinity River was listed as having impaired water temperatures due to information provided to the North Coast Regional Water Quality Control Board by the E.P.A. Water temperature data collected by California Department of Fish and Game and the Shasta-Trinity National Forest was reviewed by E.P.A. against the NCRWQCB "reference value" of 16.8°C (62.5°F)(Stumph, 1997). The "reference value" or MWAT is a numeric calculation based on the physiological water temperature optimums to support various life stages of coho salmon throughout the range of the species. We believe that maintaining water temperatures that support the life stages of anadromous salmonids is fundamental goal. However, it is well recognized that anadromous salmonids can be acclimated to the specific watersheds and the climates of those watersheds. To our knowledge no studies have been conducted on anadromous salmonids response to various water temperature regimes within the South Fork Trinity River watershed. However, abundant salmonid populations existing in the 1950's through the 1970's must have adapted to water temperatures in excess of 20°C (68.4°F).

Understanding the fundamental watershed processes and analysis of historical and current water temperatures indicates that a natural range of water temperature variability occurs in the South Fork Trinity River watershed. This natural range is defined by the water temperatures found in the Yolla Bolla Wilderness of 16.6°C (62.2°F) and the North Fork Trinity River of 22°C (72.0°F). The pre-1964 flood historical data along Hayfork Creek and the South Fork Trinity River support this range of water temperatures. Historical data presented in Figure 8, 9 and 10 (Blodgett, 1970) indicates that the South Fork Trinity River mainstem maximum water temperatures exceeded 22°C (72.0°F) and Hayfork Creek exceeded 20°C (68.4°F). These historical data also fall within the boundaries of the natural range of variability found in naturally occurring watersheds. We believe that use of local natural and historic conditions within the watershed is scientifically supported and grounded in well understood watershed processes.

7.2 SUB-WATERSHEDS WITHIN NATURAL RANGE OF VARIABILITY

Use of the natural range of variability in water temperatures can help describe the temperature conditions within sub-watersheds and mainstem reaches. Our results indicate that a significant number of the sub-watersheds in the South Fork Trinity River watershed are within the natural range of variability in the basin (Figure 3). A few sub-watersheds are at or above the natural range of variability of the South Fork Trinity River watershed (Figure 3). Due to a lack of information regarding local fish stock responses to the use of thermal refuge, and use of cooler tributaries for rearing it is undetermined whether sub-watersheds and mainstem reaches are in fact above the natural range of variability. As we have discussed, there are many physical and environmental influences on water temperatures in the watershed. It is unclear the significant watershed processes that may be elevating water temperatures in some of these sub-basins or mainstem reaches. Further analysis of existing data and possible collection of additional channel data is necessary to quantitatively identify the controlling watershed processes. We recommend that E.P.A and the N.C.R.W.Q.C.B. work with local landowners and regulatory agencies to develop a monitoring plan for these sub-basins and mainstem reaches that are outside the natural range of variability to better understand the controlling watershed processes.

7.3 SETTING WATER QUALITY GOALS

The water quality of a specific watershed is controlled by many factors including topography, geomorphic history, climate, vegetation, and land use patterns. It appears that the Clean Water Act through the TMDL process recognizes that each watershed is unique and subsequent water quality goals should be unique to a watershed. We attempted in this report to identify the local watershed factors influencing and controlling water temperatures in South Fork Trinity River watershed. These factors were identified, measured, and water temperatures reviewed in the context of the local watershed processes. This scientific basis and understanding of the watershed processes should be used to set water quality goals for the South Fork Trinity River watershed.

From our extensive review of literature and our own collection and analysis of water quality data within the South Fork Trinity River watershed we recommend that five fundamental principles that should be followed when setting water quality goals.

(1) A unique set of physical and environmental characteristics of any watershed including the South Fork Trinity River determines the watersheds water quality.

(2) Aquatic species that inhabit any watershed including the South Fork Trinity River have adapted to local watershed conditions.

(3) A natural range of water quality conditions has existed within many watersheds for decades including the South Fork Trinity River watershed.

(4) Water quality goals should maintain stream conditions within the natural range of variability within a specific watershed including the range of natural variability present in the South Fork Trinity River.

(5) Extensive historical data exists regarding water temperatures in Northern California. Significant effort should be expended to research and review the quantity, quality, and applicability of historical data as this data has provided keen insights into "natural" or historic conditions in the South Fork Trinity River watershed.

7.4 ACHIEVING WATER QUALITY GOALS

Voluntary and regulatory mechanisms have been in place for many years that attempt to achieve water quality goals (CFPR, 1998; FEMAT, 1993) Achievement of water quality goals will occur in part due to the on-going effort to maintain water quality through these existing mechanisms. Achieving water quality goals through the Clean Water Act and implementation of a TMDL in the basin plan will only add to the on-going mechanisms in place if the goals recognize the following:

(1) The controlling physical and environmental characteristics of any watershed including the South Fork Trinity River including air temperature, solar radiation, topography, and geomorphology may severely limit the effectiveness of any proposed mitigation to improve water quality.

(2) Effective mitigation should focus on sub-watersheds that have water temperatures above the natural range of variability of similar sub-watersheds in the South Fork Trinity River watershed.

(3) Physical and environmental influences of water temperature in watersheds that are above the natural range of variability of similar sub-watersheds in the South Fork Trinity River watershed remain undetermined. A commitment by the E.P.A. and the NCRWQCB to cooperatively support further study of these undetermined influences could accelerate understanding of water temperature relationships.

8.0 CONCLUSIONS

We feel our temporal and spatial understanding of stream temperatures in the South Fork Trinity River watershed in northern California support these conclusions:

1) A total of 71 separate water temperature monitoring sites have collected data between 1989 and 1997.

2) Historical pre-1964 flood data indicates that the South Fork Trinity River mainstem maximum water temperatures exceeded 22°C (72.0°F) and Hayfork Creek exceeded 20°C (68.4°F).

3) Historic pre-1964 flood water temperatures recorded throughout Northern California shows that water temperatures in the range of 20-30°C (68.4-86.6°F) were prevalent.

4) Historical pre-1964 flood water temperatures demonstrate that the South Fork Trinity River mainstem has never supported maximum water temperatures below 20°C (68.4°F) in previous 50 years.

5) A range of natural variability is defined by the water temperatures found in the Yolla Bolla Wilderness of 16.6°C (62.2°F) and the North Fork Trinity River of 22.2°C (72.4°F).

6) Average daily air and water temperatures are highly correlated (R^2 = 0.93).

7) Few tributaries to the South Fork Trinity River have water temperatures outside the natural range of variability found within the South Fork Trinity River watershed.

8) Many mainstem water temperatures exceed 20°C (68.4°F) yet fall within the historic and natural range of variability found within South Fork Trinity River watershed.

9) It appears that the South Fork Trinity River water temperatures are primarily being controlled by topographic (elevation) and geomorphic characteristics (channel width).

10) Water temperatures in the South Fork Trinity River appear to be not influenced by tributary streams as no heating or cooling occurs immediately downstream of tributaries.

11) Paired air and water temperature and stream flow data collected in Hayfork Creek indicate that higher summer base flows may not reduce water temperatures.

12) To achieve water quality goals regulatory agencies must recognize that the controlling physical and environmental characteristics of the South Fork Trinity River watershed may severely limit the effectiveness any proposed mitigation to improve water quality. Effective mitigation should focus on monitoring sub-watersheds that appear to not currently support water quality within the natural range of variability within the South Fork Trinity River watershed.

9.0 ACKNOWLEDGMENTS

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Tim Lewis	Forest Science Project
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10.0 REFERENCES

Adams, T.A. and K. Sullivan, 1990. The physics of forest stream heating: a simple model. Timber/Fish/Wildlife Report TFW-WQ3-90-007, Washington Dept. of Natural Resources, Olympia, WA

Beschta, R.L. 1984. A computer model for predicting stream temperatures resulting from the management of streamside vegetation. USDA. Watershed Systems Development Group, Ft. Collins, CO.

Beschta, R.L. and R.L. Taylor. 1988. Stream temperature increases and land use in a forested Oregon watershed. Water Resources Bulletin 24(1): 19-25.

Blodgett, J.C., 1970. Water temperatures of California streams, north coastal subregion. Open File Report. US Department of the Interior, Geological Survey, Water Resources Division. Menlo Park, Ca.

Brown, G.W. 1969. Predicting temperatures of small streams. Water Resources 5(l):68-75.

Brown, G.W. 1971. An improved temperature prediction model for small streams. Water Resources Research Institute Paper No. WRRI-16, Oregon State Univ. Corvallis, OR

Brown, George, 1974. Forestry and water quality. O.S.U. Book Stores, Inc. Corvallis, Oregon. P25-34.

Brown, G.W. and J.T. Krygier, 1970. Effects of clearcutting on stream temperature. Water Resources Res. 6(4): 1133-1139.

Caldwell, J.E., K. Doughty, and K. Sullivan, 1991. Evaluation of downstream temperature effects of Type 4/5 waters. Timber/Fish/Wildlife Report TFW-WQ5-91-004, Washington Dept. of Natural Resources, Olympia, WA.

CFPR, 1998. California Forest Practice Rules. Title 14, California Code of Regulations. Z'berg Nejedley Forest Practice Act and the Professional Foresters Law

DeWalle, D.R. 1976. Effect of atmospheric stability on water temperature predictions for a thermally loaded stream. Water Resources Research 12(2):239-244.

Edinger, J.E. and J.C. Geyer, 1968. Analying stream electric power plant discharges. J. Sanit. Eng. Proc. Amer. Soc. Civil Eng. 94(SA4):611-623.

Fish, Forest and Farms Community 1996. Aquatic Field Protocols adopted by the F.F.F.C. Technical Committee.

Haskins, D.M. and Richard Irizarry, 1988. A holistic appraisal of cumulative watershed effects on watershed condition and fisheries, South fork Trinity River, Northwestern California. USDA Forest Service, Shasta-Trinity National Forests, Redding, CA, 40 p.

Mayer, K.E. and W.F. Laudenslayer, eds. 1988. A Guide to Wildlife Habitats of California. California Department of Forestry and Fire Protection. Sacramento, California. 166 pp.

Pacific Watershed Associates, 1994. Action plan for restoration of the South Fork Trinity River watershed and its fisheries. Prepared for US Bureau of Reclamation and The Trinity River Task Force.

Sullivan, K.J. Tooley, K. Doughty, J.E. Caldwell and P. Knudsen, 1990. Evaluation of prediction of models and characterization of stream temperature regimes in Washington. Timber/Fish/Wildlife Report TFW-WQ3-90-006, Washington Dept. of Natural Resources, Olympia, WA.

Stumph, T. 1997. Letter to the NCRWQCB regarding "analysis of water temperature data conducted by EPA for the South Fork of the Trinity River". August 20, 1997

Theurer, F.D., K.A. Voos and W.J. Miller, 1984. Instream water temperature model, Instream Flow Information Paper #16 U.S. Fish and Wildlife Service FWS/OBS-84/15.

U.S. Department of Agriculture (U.S. Forest Service), U.S. Department of Interior, U.S. Department of Commerce, and the Environmental Protection Agency. 1993. Forest Ecosystem Management: An Ecological, Economic, and Social Assessment. Report of the Forest Ecosystem Management Assessment Team. USDA, Forest Service, USDI, Fish and Wildlife Service, National Marine Fisheries Service, National Park Service, USDI, Bureau of Land Management, and Environmental Protection Agency. Interagency SEIS Team, Portland, Oregon. 1004 pp.

USFS, 1990. South Fork Trinity River watershed and fisheries monitoring program, 1990 Progress Report. USDA Forest Service, Shasta-Trinity National Forests, Redding, CA

USFS 1991. Annual progress report for South Fork Trinity River watershed and fisheries monitoring program. June 28, 1991.

U.S. Geological Service. Techniques of Water-Resource investigations of the U.S.G.S. Chapter Dl

Van Norden, R. 1912. Report on an Hydro-Electric Power Project, South Fork of the Trinity River, California.