Water Temperatures in the Scott River Watershed in Northern California

PREPARED FOR:

The U. S. Fish and Wildlife Service under a grant partially funding the Siskiyou Resource Conservation District.

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September 20, 2001

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ABSTRACT

Under section 303(d) of the Clean Water Act the Scott River has been listed as impaired for water temperature levels. To provide the EPA with the most extensive information regarding stream temperatures for the watershed, the USFS, Timber Products Company, Fruit Growers Supply Company, and the Siskiyou Resource Conservation District (RCD) have combined data to co-author this report. The objective of this report is to present the distribution of current water temperatures in the Scott River Watershed, and to compile known historical temperature data on the 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.

The Scott River is a free flowing system with no large impoundments, and provides habitat for fall chinook salmon (Oncorhynchus tshawytscha), spring chinook salmon (Oncorhynchus tshawytscha), Coho salmon (Oncorhynchus kisutch), and Steelhead trout (Oncorhynchus mykiss). The Scott River experiences large seasonal variations in water temperatures - cool in the winter and warm during the long Mediterranean summer. 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, as well as local schools. This report focuses on the summer high temperatures occurring between June and September.

Water temperature results described in this report represent the largest number of sites (68) and annual datasets (171) ever described for the Scott River watershed. Review of the Scott River watershed climate, topography, vegetation, channel geomorphology, and hydrology data suggests that six distinct hydrological and geological sub-basins exist including the East and West Headwaters, Valley, Eastside and Westside Mountains, and the Canyon. MWAT water temperatures recorded between 1995 and 2000 in all geomorphic sub-basins fall within the historical range of temperatures recorded in the Scott River watershed since 1951.

Scott River mainstem water temperatures naturally increase as the river flows downstream, which directly relates to elevation decreasing, distance from the hydrographic boundary increasing and the stream channel widening. It was also determined that daily average water and air temperatures are highly correlated in the watershed.

From the temporal and spatial understanding of stream temperatures in the Scott River watershed, the authors make six recommendations for future monitoring. These efforts would serve to reinforce our current understanding of the complex physical relationships that influence water temperatures in the Scott River Watershed. 1.) Study the influence of mainstem sediment deposition on water temperature. 2.) Systematically study the air and water temperature relationships. 3.) Determine the effect of individual tributary flow (surface/subsurface) on mainstem temperatures. 4.) Determine the groundwater/surface water relationship in the Scott River Watershed. 5.) Long-term monitoring of water temperatures in varied riparian areas. 6.) Measure the biological response of anadromous fish to the watersheds historic range of water temperatures.

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 Loads (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 Scott River was one of the river basins included in the agreement and a TMDL is scheduled for completion by the EPA in 2005. Figure 1 shows the Scott River Basin in relation to Northern California.

Under section 303(d) of the Clean Water Act the Scott River has been listed for impaired sediment and temperature 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

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. Public and private landowners and agencies have been collecting water temperature information on the Scott River and its tributaries since 1990. This document represents the efforts of biologists, foresters, managers, and various technical support personnel from the USFS, NRCS, RCD, Timber Products Company, and Fruit Growers Supply Company. Under a grant provided by the U.S. Fish and Wildlife Service and with cooperation of the public and private landowners, this technical report seeks to compile known stream temperature information in the Scott River watershed. An additional objective is to describe and discuss the physical and environmental characteristics of the Scott River watershed and how these characteristics may influence water temperatures. The Scott River basin is a complex area geologically, with a variety of bedrock and several different geomorphic landscapes. The relief map in Figure 2 shows the varied terrain of the Scott River basin.

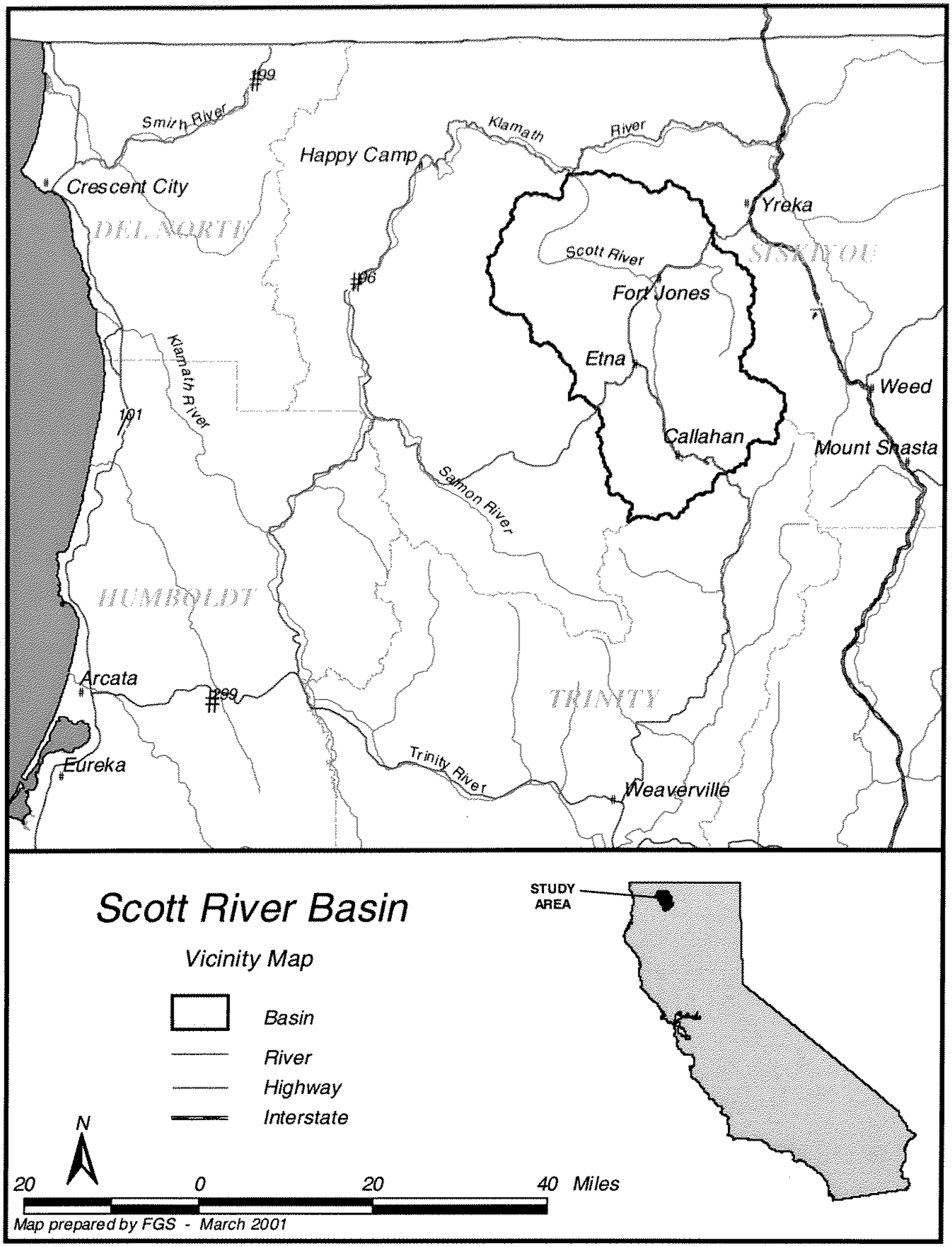


Figure 1. Geographic Location of Study Area.

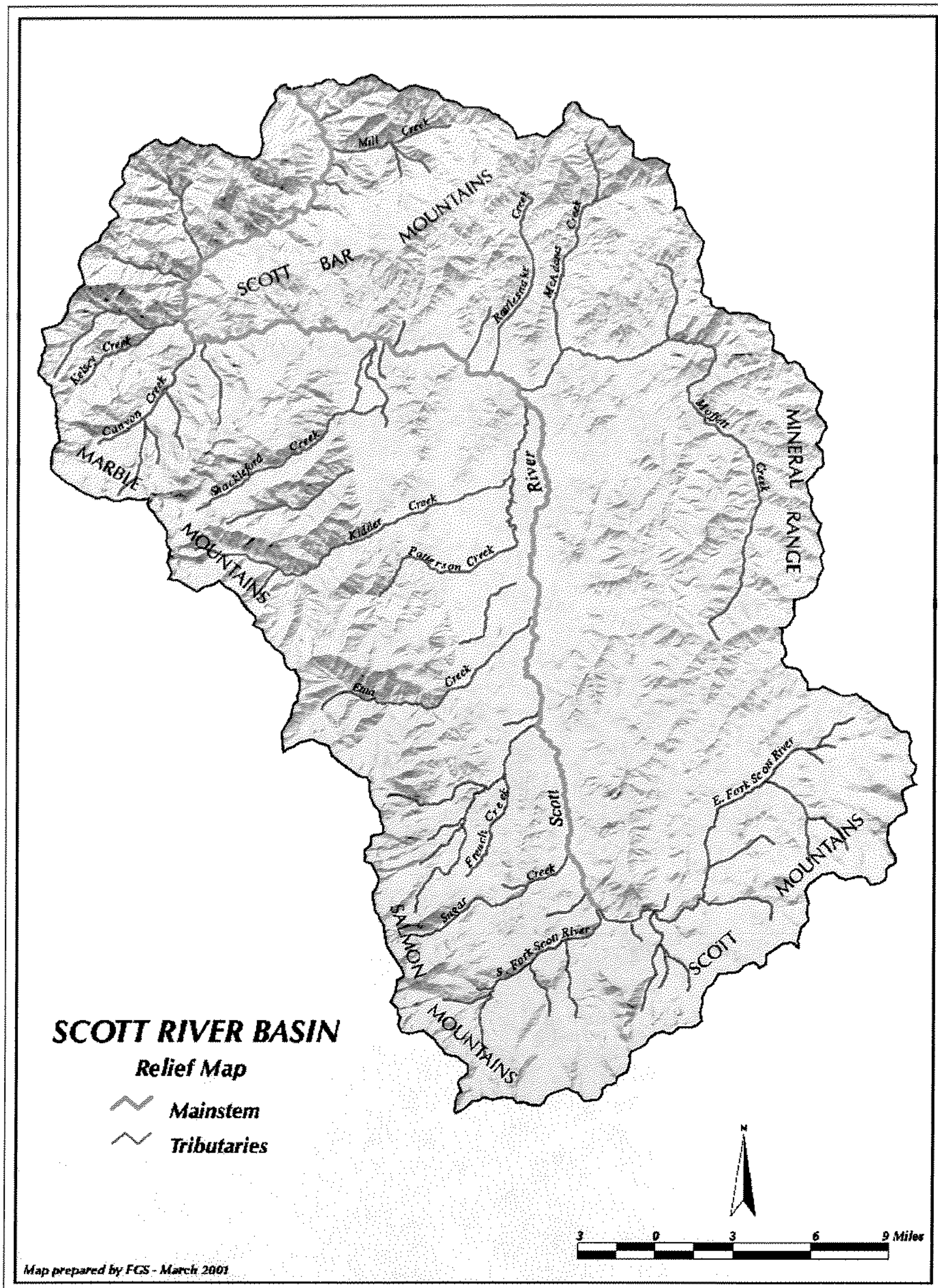


Figure 2. Relief Map of the Scott River Watershed

2.0 ENVIRONMENTAL CONDITIONS

2.1 GEOGRAPHIC RANGE

The Scott River lies in western central Siskiyou County in northern California (Figure 1). The Scott River is part of the Klamath Mountain Province, which encompasses land in both Oregon and California. The Scott River flows northerly to its confluence with the Klamath River near Scott Bar. The Scott River watershed is a large area with substantial variation in geology, geomorphology and climate. The watershed drains a total of 520,612 acres (813 mi^2). The Scott River's headwaters are a horseshoe-shaped range of mountains that surround the Scott Valley to the west, south and east.

The Scott Valley is bordered on the north and northwest by the Scott Bar Mountains. The Scott Mountains border to the south and southeast, and the Salmon and Marble Mountains lie to the west and southwest. In the upper part of the watershed elevations vary from 2,620 -3,100 feet on the valley floor to over 8,000 ft in the high mountain peaks to the south and west. The Scott River enters the Klamath River (RM 143) at an elevation of 1,580 feet.

2.2 TOPOGRAPHY

The Scott River basin is a complex area geologically, with a variety of bedrock and several different geomorphic landscapes. The relief map in Figure 2 shows the varied terrain of the Scott River basin. The basin can be divided into a number of geomorphic landscapes, each with a unique climate, topography, hydrology, and distinctive vegetation.

For the purposes of interpretation this report divides the basin into six geomorphic units based on climate, topography, and hydrology. They are referred to as; East Headwaters, West Headwaters, Valley, Eastside, Westside, and Canyon. Figure 3 shows these units with their respective channel types. The headwaters are divided into East Headwater and West Headwater with the primary difference being the broad alluvial valley characteristic of the East compared to the more rapidly drained narrow alluvial nature of the West. The East Headwater has a large component of irrigated pasture and the West is generally steeper with shorter tributaries and was hydraulically mined in the late 19th century.

The Valley sub-basin is dominated by the alluvial mainstem of the Scott River with historical large-scale dredger tailings and irrigated fields. Large scale mining operations during the 1930's left 6 miles of the upper mainstem as tailing piles. The river channel in the valley is broad and shallow, as wide as 300 feet. To the east of the Valley is the Eastside unit, which receives very little precipitation and is composed primarily of short gulches that produce limited ephemeral flows.

The Westside unit receives the majority of the annual precipitation in this basin,(Figure 4) and produces the greatest yield of flow to the Scott River. This unit yields an estimated 100,000 acre feet of runoff during the summer months(Mack *et al* 1958). This unit is composed of complex watersheds originating in high mountain springs.

In the Canyon the channel is steep and dominated by large boulders. Tributaries in this unit are steep high-energy mountain channels quickly routing water to the mainstem.

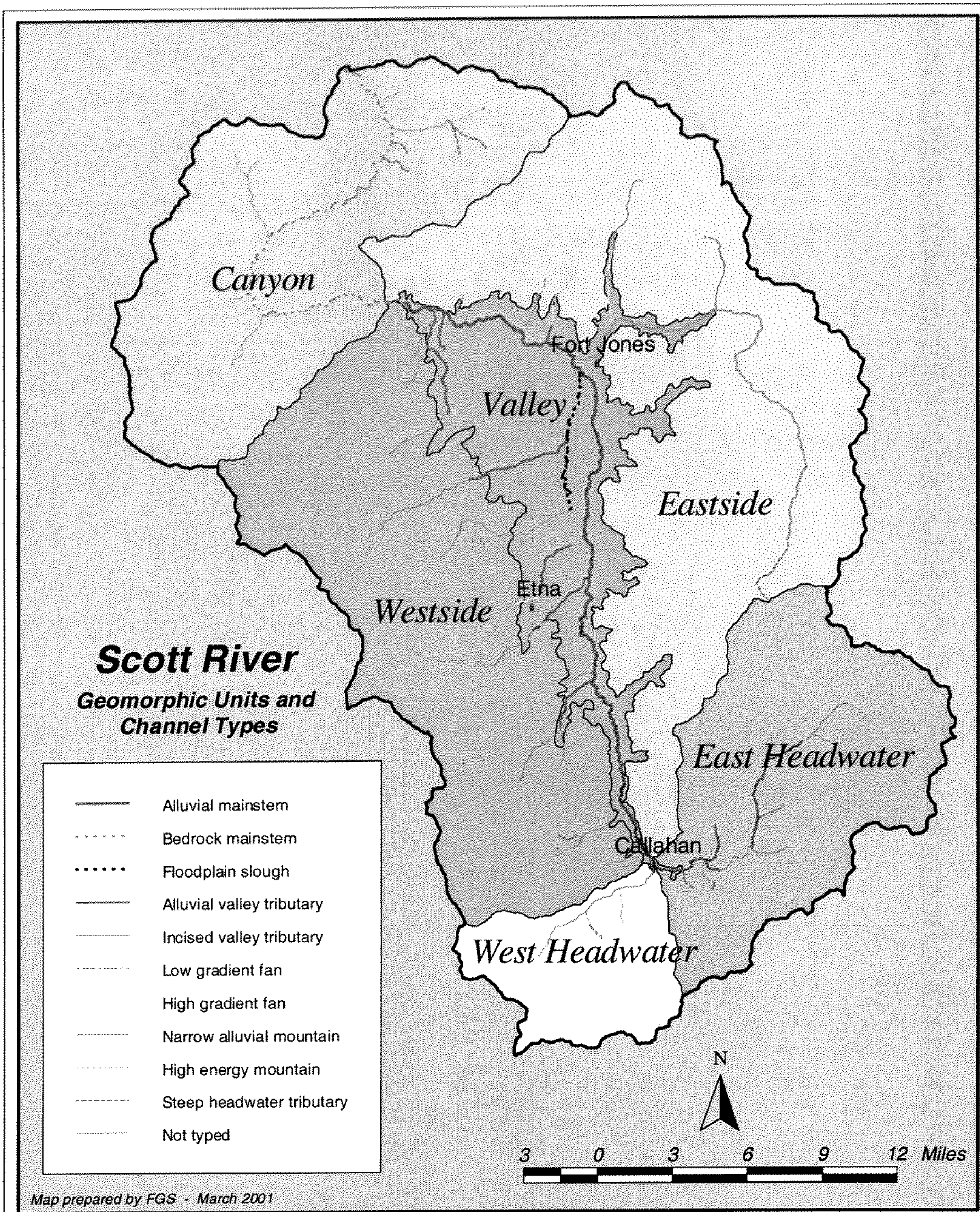


Figure 3. Geomorphic Units and Channel Types

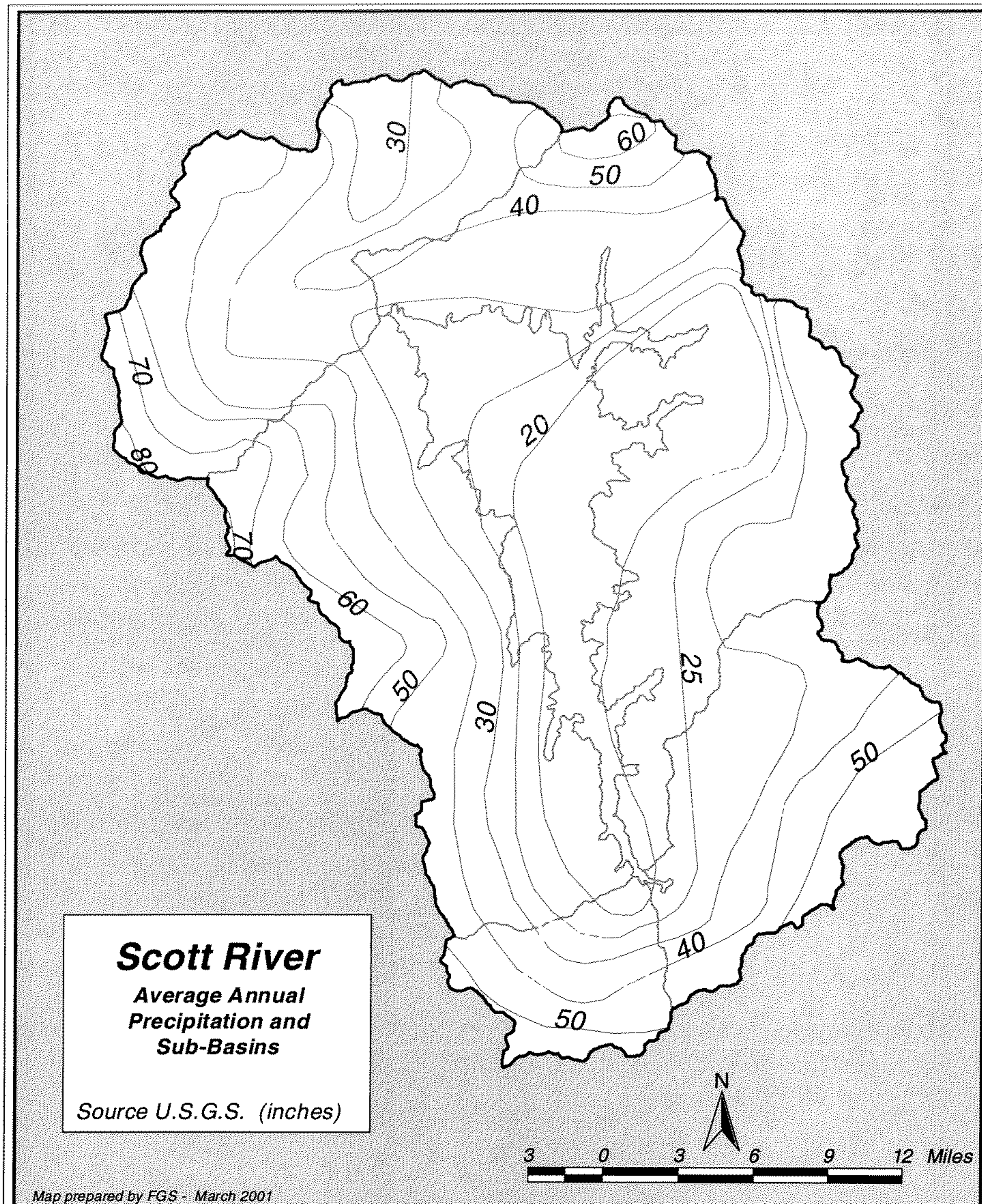


Figure 4. Annual Precipitation Paterns for the Scott Valley

2.3 CLIMATE

Overall, the climate of the Scott River area is a Mediterranean type, with a warm, dry summer season and a cold, wet winter season. Average Daily Air Temperatures in the region around the Scott Valley range from the low 30°'s F in the winter to mid- 90°'s F in the summer. However, there is large variability in local climate due to elevation changes from 8,200' at the high mountain headwaters, to 1, 580' at the confluence with the Klamath. In the rugged mountains to the west and south of the Scott Valley, the climate is colder and dominated by snowfall. At the lower end of the watershed, the climate is warmer with little snow. Figure 5 displays daily air temperature averages and extremes at the National Weather Service Station in Fort Jones. The period of record was from 1948-2000.

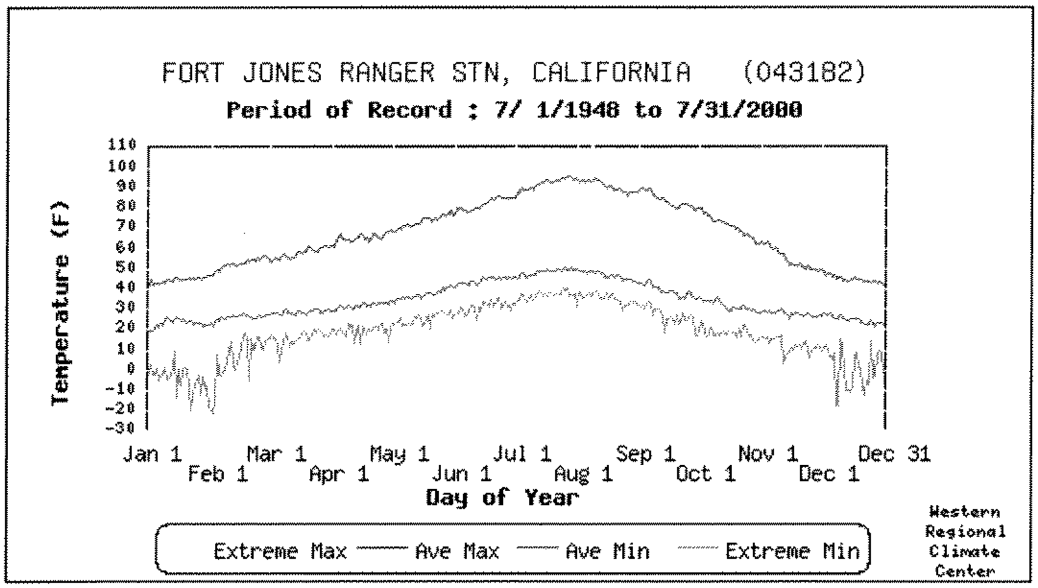


Figure 5. Average Daily Air Temperatures for the period from 1948-2000.
(From Website reference.)

Precipitation in the Scott River Watershed is produced by storms originating from the Pacific Ocean. Most of the precipitation above 4,500' falls as snow. The 7000- 8000' Marble-Salmon-Scott Mountains that lie to the west of Scott Valley exert a strong orographic effect on incoming storms, producing annual precipitation in the range of 60"- 80". Most of this precipitation falls in the West Headwaters, Westside and Canyon sub-basins. It is the heavy snowpack in these sub-basins which contribute to the summer flows in the major tributaries. In the Valley sub-basin, annual precipitation declines to 22"-30" and in the Eastside sub-basin precipitation declines to 12" –15". About 80% of the rainfall occurs between the months of October and March (See Figure 6 - Average Monthly Precipitation).

Due to the proximity to the Pacific Ocean, winter storm systems vary between warm and cold fronts. This tends to produce a zone between 4000' and 5000' where precipitation varies between rain and snow, known as the transient snow zone. A cold storm with snowfall followed by a warm storm with rainfall can produce a "rain-on-snow" event which can produce large amounts of runoff. These events have resulted in the floods of record within the basin (1955, 1964, 1997).

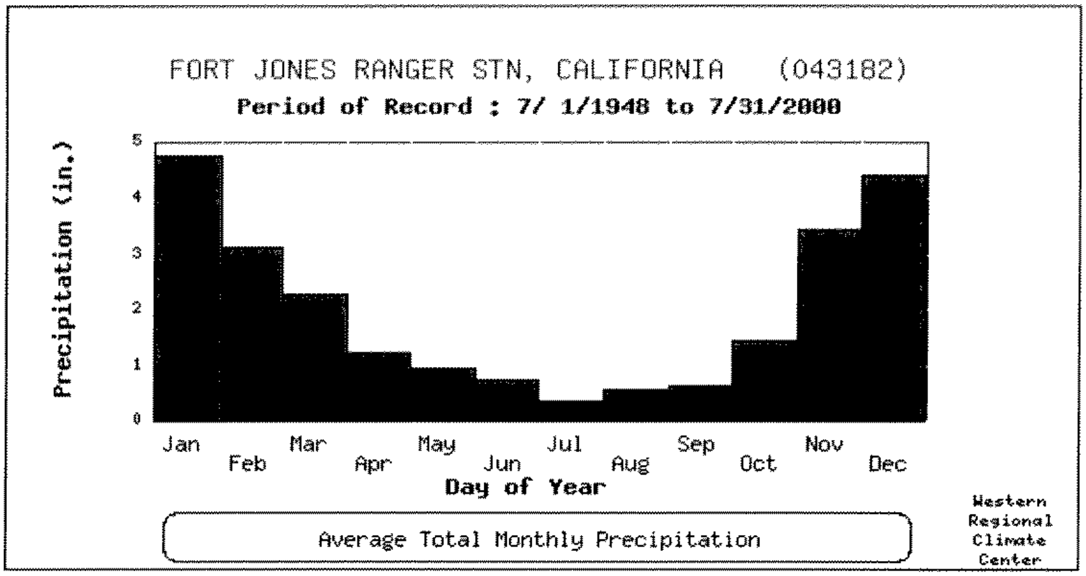


Figure 6. Average Monthly Precipitation for the period from 1948-2000.
(From Website reference).

Thunderstorms sporadically occur during the generally dry summer months. Generally these localized storms do not have any effect on the flow of the Scott River, but occasionally they are widespread and intense and result in increased flow in the Scott River for several days. When this occurs, it quickly decreases water temperature in the Scott River. These thunderstorms are indicated in Figure 7 as the maximum peaks during the summer months.

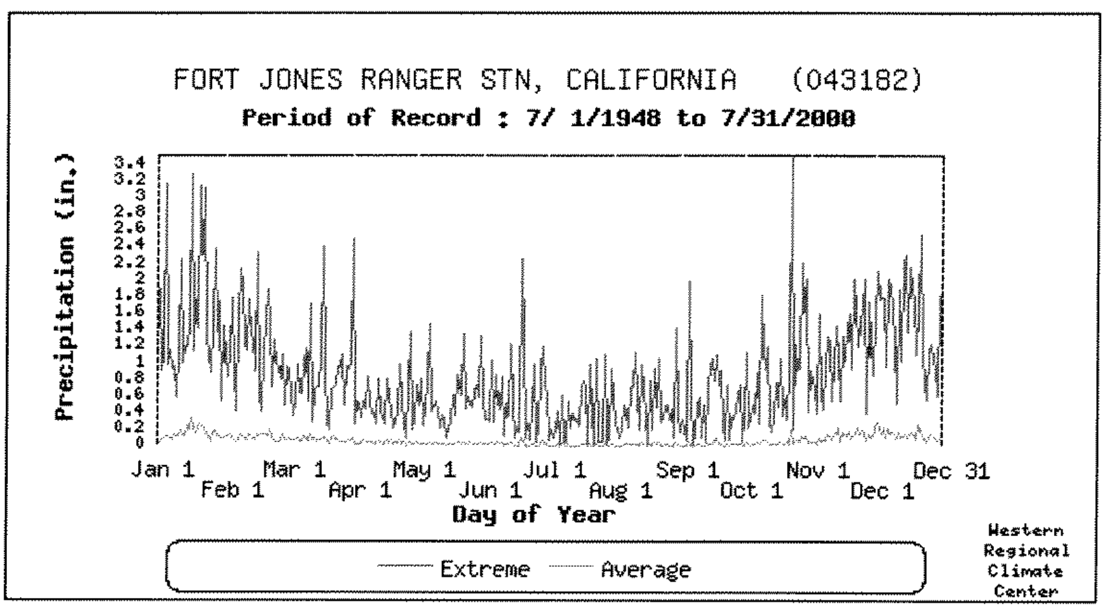


Figure 7. Average and Extreme Daily Precipitation for the period from 1948-2000.
(From Website reference).

2.4 LANDSCAPE VEGETATION

Due to the complex geology and diverse soils of the Klamath Mountains, the Scott 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 coniferous forests (Mayer and Laudenslayer, 1988). The Valley Floor Grasslands occur on flat to gently rolling foothills and in some cases are naturally flooded, or seasonally irrigated. The Foothill Chaparral and Oak Woodland occur at lower elevations and dryer climatic regions on thin, well-drained soils composed primarily of sand, gravel, and rock. The Mountainous Conifer Forests consist of tall, dense to moderately open coniferous forests with patches of broad-leaved evergreen and deciduous trees and shrubs.

2.5 GEOMORPHOLOGY

The Scott River is a unique northern California river in that its upper and lower segments flow through mountainous terrain, similar to the Trinity or Salmon, yet the middle 30 miles of the Scott River flow through a large alluvial valley. There is great diversity in geology, topography, and climate between the different sub-basins.

Identifying and classifying streams channel types based on morphologic characteristics provides a method for rating their resulting stream water temperatures and their relative value to anadromous fish species (Murphy *et al.* 1987). Pertinent morphologic characteristics that were considered include general landform, stream order, channel gradient and channel confinement. The large tributaries in the Canyon – Canyon, Kelsey and Tompkins Creeks have been inventoried by the Forest Service using the Region 5 USFS methodology. Portions of Shackleford, Sugar, Patterson, Crystal, and Moffet have been habitat typed by FGS using CDFG protocols. However, the main Scott River and most of the tributaries that enter Scott Valley have not been channel typed.

Landform reflects the underlying bedrock and the long-term history of events controlling regional landscape evolution, such as glaciation and tectonic uplift. Stream order and gradient are surrogates for stream energy, which regulates the ability of the channel to transport sediment and large woody debris. Channel confinement governs the ability of the channel to migrate laterally, which in this watershed determines the amount of direct exposure to solar radiation. These basic characteristics influence relative fish value by creating the dominant sediment input processes, large woody debris recruitment process and the water temperature heating and cooling processes.

Many of the stream channels in the study area have undergone enormous changes during recent historic time. For the main Scott River, there were several floods in the 1880's that created severe bank erosion in the Scott Valley. The large winter floods of 1955 and 1964 also had a profound effect on the character of the main Scott River channel. In addition, the Army Corps of Engineers channelized the mainstem Scott River and removed much of the riparian vegetation in the 1930's. The net result for the Scott River in the valley is now a wide (up to 300'), shallow channel with almost no vegetation cover. This channel is almost entirely exposed to solar radiation resulting in the potential for a large amount of solar heating.

Many of the tributary channels were also affected by the 1955 and 1964 floods. There is no information on whether the 1880's floods impacted the tributary streams. Some of the channels in the study area, notably Tompkins Creek, were also impacted by the New Year's flood of 1997. The typical result of these floods on tributary channels has been to increase channel width and remove riparian vegetation, which increases the exposure of stream water to solar radiation.

2.6 HYDROLOGY

A typical daily stream discharge for the summer of 1998, at the USGS gage station, is shown in Figure 8. The Mediterranean climate with wet winters and hot dry summers produce yearly discharge pattern that consists of low stream flows in the late summer/early fall and high discharge in the winter. The typical yearly hydrograph can be characterized by 3 phases:

Phase 1 – low summer/fall flows, mid-July to mid-November. Virtually all of the previous winter's snow and rain has moved through the stream system and the Scott is sustained by base flow from groundwater. During dry years, portions of the mainstem Scott River and major tributaries go completely dry.

Phase 2 – Increasing winter discharge in response to rain storms, November – April. Notice the gradual increase in discharge through the winter.

Phase 3 – Spring/Summer snowmelt runoff, followed by a rapid decrease in snowmelt runoff, April to Mid-July.

However, there is also strong variability from year to year based on that year's total precipitation and the timing of precipitation during the winter.

The large variability in elevation, geomorphology and climate between sub-basins results in multiple inputs to the discharge and temperature characteristics of the Scott River. For example, the tributaries on the Westside of Scott Valley contribute a large amount of runoff derived from a mix of rainfall and snowfall. These tributaries provide perennial flows to the mainstem. The tributaries on the eastside of Scott Valley have much less runoff that is derived almost entirely from rainfall, these tributaries only flow ephemerally.

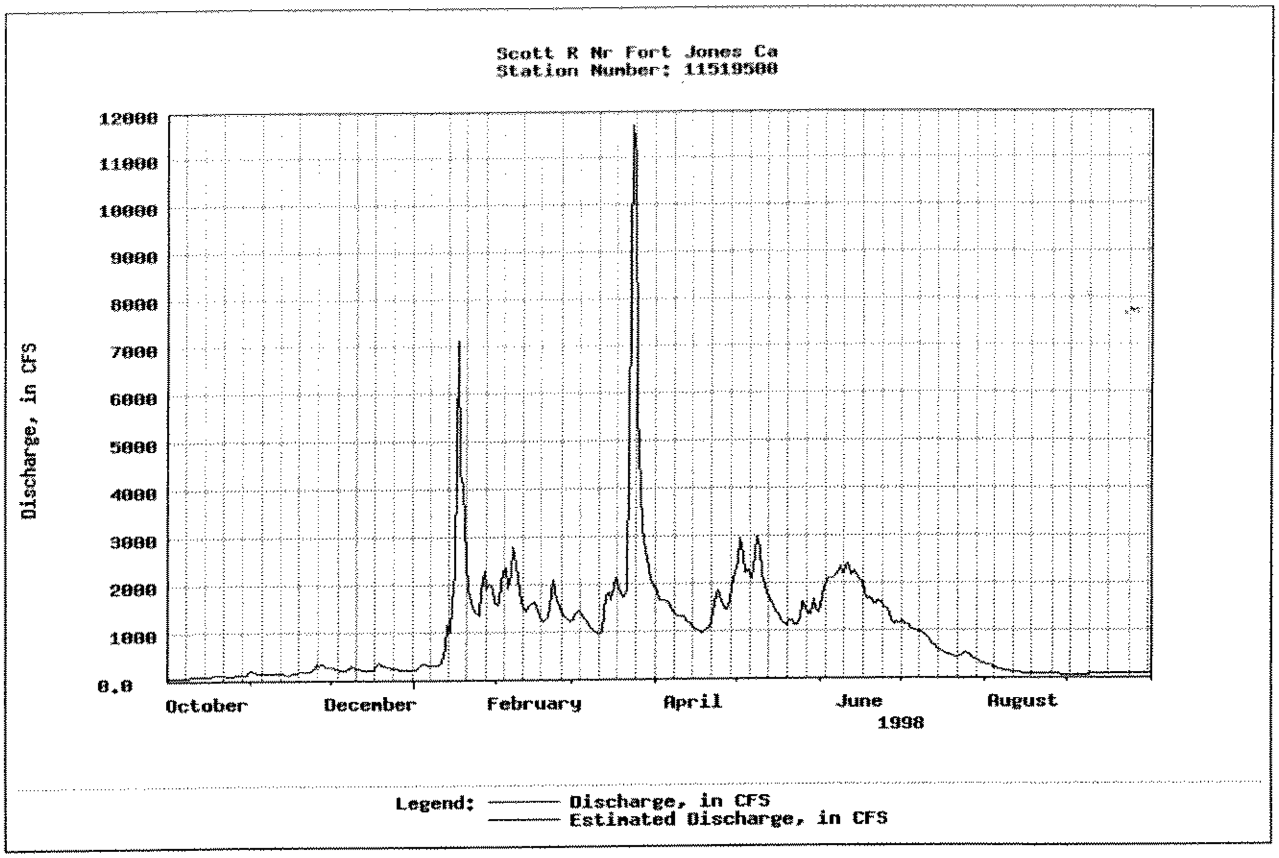


Figure 8. Typical Daily Stream Discharge, Scott River near Fort Jones at USGS Gage.
(From Website reference.)

2.7 GROUNDWATER

The Scott River flows through a large valley, Scott Valley, containing a large groundwater aquifer. The aquifer is comprised of 2 basic geologic components – flood-plain sediments along the bottom of the Valley and alluvial fan deposits along the edges of the Valley. The ground-water storage capacity of sediments lying between 10 and 100 feet below the land surface beneath the entire Valley is estimated to be 400,000 acre feet. Storage capacity in the flood-plain sediments is about 220,000 acre feet (Mack, 1958). The flood-plain deposits have higher permeability than the alluvial fan deposits (Mack, 1958). Thus, the flood-plain deposits may have a very strong influence on the flow and the temperature of the Scott River in the Valley reach due to the large size of the aquifer, the fact that it consists of very permeable alluvium and the fact that it flows through and has the potential to interact with the River for 30 miles.

3.0 BIOLOGICAL CONDITIONS

Since the Scott River is free flowing with no 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 Scott River. The Steelhead trout (Oncorhynchus mykiss) is under review for listing as threatened in the Klamath Mountain Province.

Each species seeks out and utilizes different habitat for spawning and rearing of young. In addition, each species spawns and rears at different times during the year. Fall Chinook utilize the mainstem for spawning and rearing, while Coho and Steelhead spawn and rear primarily in the upper tributaries. Historically, Spring Chinook utilized the Scott River System. However, none have been identified in recent years. Chinook spawn in the late fall, after the river begins to cool. In general, the young of the species rear during the winter months and migrate from the system in early May and June. Coho and Steelhead spawn in late fall and early spring. The young of these species spend a year or more in the system before they out-migrate. Consequentially, summer water temperatures are important for their health. Due to the different locations and timing of their lifecycles, each species has different water temperature needs.

4.0 HYROLOGICAL AND GEOLOGICAL SUB-BASINS

Due to the large variability of climate and geomorphology in the Scott River basin, this investigation has grouped the Scott River into six 'reaches', or sub-basins, with similar geomorphic and hydrologic characteristics. Figure 3 shows the sub-basins and hydrological channel types. The six reaches are: the East Headwaters, West Headwaters, Valley, Eastside, Westside, and Canyon.

EAST HEADWATERS

The headwaters of the Scott River are the East and South Fork which meet at Callahan to form the mainstem of the Scott River. The East Fork drains out of the Scott Mountains, and flows in a southwestern direction to the confluence with the mainstem at Callahan. Elevations in this drainage range from 2,720' at Callahan to 8,540' at China Mt. The East Fork drains a total of 72,650 acres, 14% of the Scott River watershed. Average annual precipitation in the East Fork Watershed is 30"-40". Land use consists of a mix of federal and commercial forestland, rangeland and irrigated agricultural land.

The morphological characteristics of this sub-basin begin with steep headwater tributaries which are generally small, low-order, high gradient streams that transport precipitation in the form of rain. These high gradient streams flow into narrow alluvial mountain channels that are low gradient, moderately confined valley bottoms. These channels are bordered by discontinuous alluvial floodplains.

WEST HEADWATERS

The South Fork drains the Salmon Mountains in the Southwest portion of the Scott Valley, and flows in a northeastern direction towards the confluence with the East Fork. Elevations range from 3,120' at Callahan to 7,400' at the divide. The South Fork drains a total of 25,133 acres, 5% of the Scott River Watershed. Mean annual precipitation ranges from 40''-to 60''. This sub-basin is composed primarily of commercial forestland and wilderness areas with scattered rural residences along the South Fork.

The morphological characteristics of this sub-basin include steep headwater tributaries that are generally small, low-order and high-gradient streams. Snow accumulations and runoff significantly influence stream flows, which transport quickly through steep stream reaches to the lower gradient Scott River.

VALLEY

The valley portion of the Scott River runs south to north for about 30 miles, from the confluence of the two Forks, to the beginning of the canyon. Elevation of the valley ranges from 2,630' to 3,120'. The Valley encompasses 59,877 acres, 12% of the watershed. Precipitation ranges from 20''-30'' annually. Land use in primarily agricultural and the land is heavily irrigated. Much of the river has been stabilized to prevent erosion, and is thus more confined than its historic channel. There is little riparian vegetation along the river. Major tributaries to this reach come from Westside mountain streams.

The morphological characteristics of this sub-basin include alluvial valley tributaries which include the lower sections of larger tributary streams where they enter the mainstem floodplain (ex. lower French Creek) Channels are unconfined with gradients of less than 2 %. This sub-basin also includes the alluvial valley mainstem channel of the Scott River. General landform processes have created a wide, flat floodplain and sinuous channel pattern where bars, islands, side and/or off-channel habitats are common.

The mainstem was dredged from the 1930's to 1950's leaving large-scale tailings from Callahan to French Creek (approximately six miles). These features dominate the hydrologic nature of the river in this reach. The Army Corps of Engineers straightened out the mainstem between Etna and Fort Jones in the 1930's. This drastically altered the hydrologic properties of this river system at both the landscape level as well as locally. The severe flood events of 1955 and 1964 further eroded the stream bank, leaving the river with a wide shallow channel. Today people that live and farm along the river protect their land from erosion by armoring with rip- rap, replanting native vegetation, and putting up livestock exclusion fence.

WESTSIDE MOUNTAINS

The Marble Mountains to the west of the valley are the source of several perennial streams. Etna, French, Kidder/Patterson, and Shackleford are the major drainages on the Westside. Elevations range from 2,700' in Quartz valley to 8,200' at Boulder Mt. The Westside drains 116,342 acres, 22% of the watershed. Mean annual precipitation ranges from 30'' at lower elevations to 80'' in the upper elevations. Most of the precipitation falls as snow in the upper elevations (above 4,000'). This snow accumulation sustains the flow through the early summer months. Land use is primarily wilderness and commercial forestland with rural residences in the lower elevations.

The morphological characteristics of this sub-basin include steep headwater tributaries that are generally small, low-order and high-gradient streams. Snow accumulations and runoff significantly influence stream flows, which transport quickly through steep stream reaches to the lower gradient. These high gradient streams flow into narrow alluvial mountain channels that are low gradient, moderately confined valley bottoms. These channels are bordered by discontinuous alluvial floodplains in the lower reaches.

EASTSIDE FOOTHILLS AND MOFFETT CREEK

The eastside of the valley is dominated by generally dry foothills extending north from the Scott Mountains. Watershed elevation ranges from 2,700' to 6,050'. The largest sub-basin is the Moffett Creek watershed, which drains 145,846 acres, or 28% of the Scott river watershed. Moffett Creek and some of its upper headwater tributaries are the only streams which usually flow year round. Average annual rainfall ranges from 12"-15".

Tributary streams are typically very short and drain rapidly, running intermittently or seasonally. Land use is primarily range land and federal and commercial forestland. Upland soils are well drained with slow permeability. The upland portion of the watershed has localized sheet and gully erosion. Moffett Creek is the principal stream, and flows in a northwest direction before meeting with the main stem Scott River, north of the town of Fort Jones.

CANYON

The Canyon reach is defined as the first 20 miles of the river from the confluence with the Klamath River. The Marble Mountains and Scott Bar Mountains contribute to the flows in this reach. The canyon drains 97,802 acres, 18.8% of the watershed. The mean annual precipitation is 40" - 70", with much of the precipitation falling as snow pack in the upper elevations. The mainstem channel through this reach is confined bedrock.

The morphological characteristics of this sub-basin include steep headwater tributaries that are generally small, low-order and high-gradient streams. These steep high-energy mountain channels route snowmelt and runoff quickly downstream through bedrock falls, boulder cascades and steep chutes to the mainstem Scott River.

The mainstem Scott River reach is a bedrock confined colluvial canyon that transports water through a series of bedrock and boulder pools, side channels, and riffles. Due to steep canyon walls a significant amount of topographic shade is cast over the Scott River. Land use in this sub-basin is primarily federal and commercial forestland with wilderness areas in the higher elevations, and scattered residences along the river. The major drainages are Kelsey Creek, Canyon Creek, Boulder Creek, Tompkins Creek, and Mill Creek.

5.0 PHYSICAL WATERSHED PROCESSES AFFECTING WATER TEMPERATURES

As in most watersheds, water temperatures are influenced by many physical processes: topography, geologic history, soils, climate and disturbance patterns. Major influences of stream temperature such as dams or large urban impacts are not present in the Scott River watershed. Many of the physical watershed and heat transfer processes that determine stream temperature have been extensively researched and are well understood (Edinger and Geyer, 1968; Brown, 1969; Brown, 1971; DeWalle, 1976; Theurer et al, 1984; Adams and Sullivan, 1990).

5.1 HEAT TRANSFER PROCESS

The physics of stream temperature has been widely studied and generally most researchers have utilized the heat transfer process to describe predicted changes in stream temperature (DeWalle, 1976; Brown, 1969; Beschta, 1984; Theurer et al, 1984; Adams and Sullivan, 1990).

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). 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 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). Water temperature is always adjusting to the immediate air temperature surrounding the stream or the environmental conditions present in the reach. 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). 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).

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:

$$Q = Nr +/- E +/- H +/- C$$

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:

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

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:

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

By using a multiplier of .000267 to handle conversion of units the equation above gives the primary components of changes in stream temperature.

Q, heat added, is a function of solar radiation, which varies during the year according to the angle of the sun and latitude. Of the components of Q, net radiation (Nr) varies significantly during the day/night cycle, whereas evaporation and convection vary little (Brown, 1969). Conduction is important in the heat transfer process in small, bedrock channels and much less a factor in larger, gravel bed channels.

The factor for surface area, A, 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 A are the actual stream surface area, 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).

D is the amount of water being heated and has an inverse relationship to changes in water temperature, thus smaller streams will heat up faster than larger streams (Brown, 1969).

5.2 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.

$$T = \frac{(T_1 * Q_1) + (T_2 * Q_2)}{Q_1 + Q_2}$$

T_1 = temperature of inflow Q_1 = stream flow of inflow

T_2 = temperature of receiving stream Q_2 = 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. 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).

5.3 PHYSICAL AND BIOLOGICAL CONDITIONS INFLUENCING WATER TEMPERATURE

Physical factors influencing water temperatures include the actual stream surface area, amount of shading, and orientation of the stream channel as it affects shading. 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 or topography tends to decrease as the streams' wetted width increases. Both of these factors together tend to increase the stream's exposure to solar radiation as the streams get larger. Researchers have documented that elevation (as it effects ambient air temperature), and distance from the watershed divide (as it effects surface area) are the two most important factors influencing water temperature in large river systems (Sullivan et al, 1990; OSU, 1996). It follows that the temperature level of a stream in any given situation is primarily determined by its surface area exposed to solar radiation. Effects of shading from riparian vegetation and topography decrease with the width of streams. Large streams will have a large surface area exposed to solar radiation and thus will be heated to a higher temperature than narrow streams.

The fluvial geomorphology of streams, especially larger streams, has a direct effect on the surface area of streams exposed to solar radiation. Braided channels and wide shallow channels will have more surface area than single, narrow and deep channels. Low gradient channels allow for more time (t) of heating than higher gradient channels. The fluvial geomorphology of streams will also determine water temperatures as they are affected by riparian shade. Streams with confined flood plains do not allow for riparian vegetation growth along the banks of the summer low flow channels, and will therefore have higher summer water temperatures than streams with unconfined flood plains.

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 a variety of vegetation or by topography. 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 (Scott River 1,700-2,900ft) is much lower than headwater tributaries (3,000-8,000ft). The difference in local air temperature at different elevations regulates the heat transfer process for each stream reach, as water temperatures are always reaching equilibrium with the local air temperature. Local air temperature effects increase as topographic or vegetative shading is reduced. The wide or braided river also has much higher direct solar radiation, transferring heat to the water surface.

6.0 METHODS

Even though this report was completed by compiling data across several ownership's, efforts were made to insure that the information was collected in the same manner for each stream. All data contributors followed the same protocol for launching and placement of data recorders. (CDFG 1978, FFFC 1996) An annual meeting was attended to discuss placement, protocol, and to possibly calibrate units. 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.

Salmonid Rearing Temperatures

Existing laboratory studies of water temperature relationships with anadromous salmonids indicates that optimal mean summer temperatures for steelhead and coho rearing are from 10-14°C. (Reiser and Bjornn). As suggested by National Marine Fisheries Service (NMFS) the biological MWAT for anadromous salmonids in northern California is 17.8°C. The standard set by NMFS to determine the effects of proposed projects on water conditions is less than 20.5 °C. The upper lethal temperatures for anadromous salmonids is reported at 24.1-25.2°C. Our results found that tributaries originating in high elevation undisturbed watersheds had MWAT water temperatures between 10.9°C and 17.8°C. Our review of historic instantaneous water temperatures in the mainstem range from 18 to 27°C. The results of this study indicate that current water temperatures of the Westside and Canyon sub-basins fall within the natural and historic range of variability. Existing water temperature within the Valley sub-basin are within the temperatures of those recorded in the 1950's and 1960's, which routinely exceeded 20.5°C.

6.1 EQUIPMENT

Water temperature was measured with continuously recording electronic instruments. Table II outlines the various models of electronic instruments were used.

Table I. Rated Accuracy of various temperature monitoring devices.

Model	Insturment	Temperature 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 75C	+/- 0.2°C
Optic Stowaway	Internal Probe	-5°C to 37°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.

6.2 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, habitat, water depth, water temperature, air temperature, percent canopy closure, 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.

6.3 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 Systems (GIS). GIS coverages of land ownership, land use, streams, roads, precipitation, soils, and watershed boundaries were also utilized for the display and analysis of stream temperatures by sub-watershed.

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

Table II. Unit Conversions.

Metric Units	English Units
1 Meter (m)	3.28 Feet (ft)
1 Kilometers (km)	0.621 Miles (mi.)
1 Sq. Kilometers (km2)	0.386 Sq. Miles (mi2)
1 Cubic Meters per Second (m3/sec)	35.314 Cubic Feet per Second (ft3/sec)
1 Degree Celsius = (F – 32)/0.55	1 Degree Fahrenheit = (C*1.82)+32
1 Hectare	0.4047 Acres

6.4 TECHNICAL DEFINITIONS

Through the scientific literature many terms are used to describe 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 Scott River watershed, and calculations completed for this report. Below is a list of technical definitions that we refer to throughout the report.

Weekly Average Temperature – The average of all temperature readings for any seven day period.

Maximum Weekly Average Temperature (MWAT) – The weekly average temperature of the hottest seven day period

Maximum Weekly Minimum Temperature (MWATmin) – The average of the minimum temperature readings of the hottest seven day period.

Maximum Weekly Maximum Temperature (MWATmax) – The average of the maximum temperature readings of the hottest seven day period.

Maximum Average Daily Fluctuation – The difference between MWATmax & MWATmin for the hottest seven day period.

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

Average MWAT - The arithmetic average of all recorded MWATS.

Natural range of variability – The highest and lowest recorded water temperatures in a watershed or sub-basin with relatively little manmade disturbances.

7.0 RESULTS

Analysis of water temperature data collected in the streams of the Scott River basin reflect the controlling influences of the fundamental physical processes affecting water temperatures as described in Section 5.0. The use of data for this report is not to verify research on the subject, but rather to describe the distribution of water temperatures in the mainstem and tributaries in the Scott River. Only a much more detailed and comprehensive study design could attempt to verify various findings.

7.1 SPATIAL DISTRIBUTION OF WATER TEMPERATURES

This study utilizes data from 68 separate continuous water temperature monitoring sites with a total of 171 datasets. Most of the data was collected from 1997 to 2000, with a few sites dating back to 1995. Data contributors include the Klamath National Forest, Siskiyou County Resource Conservation District, Siskiyou County Schools, Fruit Growers Supply Company, and Timber Products Company. Using a Geographic Information Systems (GIS) we spatially describe the arrangement of monitoring locations throughout the watershed. The geographic location and ownership of each monitoring site is shown in Figure 9. Site identifiers are provided as reference to data provided in Appendix A.

The monitoring sites are well distributed throughout the watershed. Of the 68 sites, 22 are located in the mainstem and 46 are in tributaries. The following table shows the distribution of monitoring sites and datasets by sub-basin:

Table III. Temperature Monitoring by Sub-Basin.

Sub-Basin	Acres	Sites	Datasets
Canyon	97,802	16	30
Valley	59,877	19	52
Westside	116,34	20	61
Eastside	145,846	2	6
West Headwater	25,133	5	9
East Headwater	72,650	6	13
Total		68	171

The relatively low precipitation and low flows in the Eastside sub-basin explain the ratio of sites to acres for this unit. Many of the tributaries in this sub-basin run intermittently, and not at all late in the summer of in dry years. The goal for most of the water temperature monitoring in the Scott River basin was to capture summer high temperature events. Consequently, it did not seem reasonable to commit resources to this area. The gulch nature and the foothill chaparral/oak woodland vegetation of this sub-basin contribute to rapid drainage into the valley bottoms of the major tributaries. As noted previously in this report, this sub-basin contains a relatively large groundwater storage unit.

The mountains located west of the valley receive most of the precipitation and snowpack, thus sustaining most of the surface flow to the mainstem. The volume of water and ownership patterns explain the concentration of monitoring sites in the Canyon and Westside sub-basins.

Maximum weekly average temperatures (MWAT) for each monitoring location are spatially presented in Figure 10. The values displayed represent the average for all data available for the years 1995 to 2000. As data was not available for each site for each year, it was determined that for display purposes, averaging provided the most comprehensive view. It can be seen that the coldest temperatures are located in the upper reaches while the hottest are confined to the mainstem through the lower valley.

An effort was made to bracket a few of the tributaries in order to test their effect on the mainstem. Temperatures in the mainstem showed some localized cooling, but this could not be attributed entirely to the influence of the tributaries. Water temperatures of the mainstem remained relatively unaffected by the addition of cooler waters from the tributaries throughout the lower valley and into the canyon. A good example of this is in the Canyon sub-basin where three very cold tributaries (Kelsey, Canyon, and Boulder Creeks) drain into the mainstem in a relatively short distance with no apparent effect on the temperature of the mainstem.

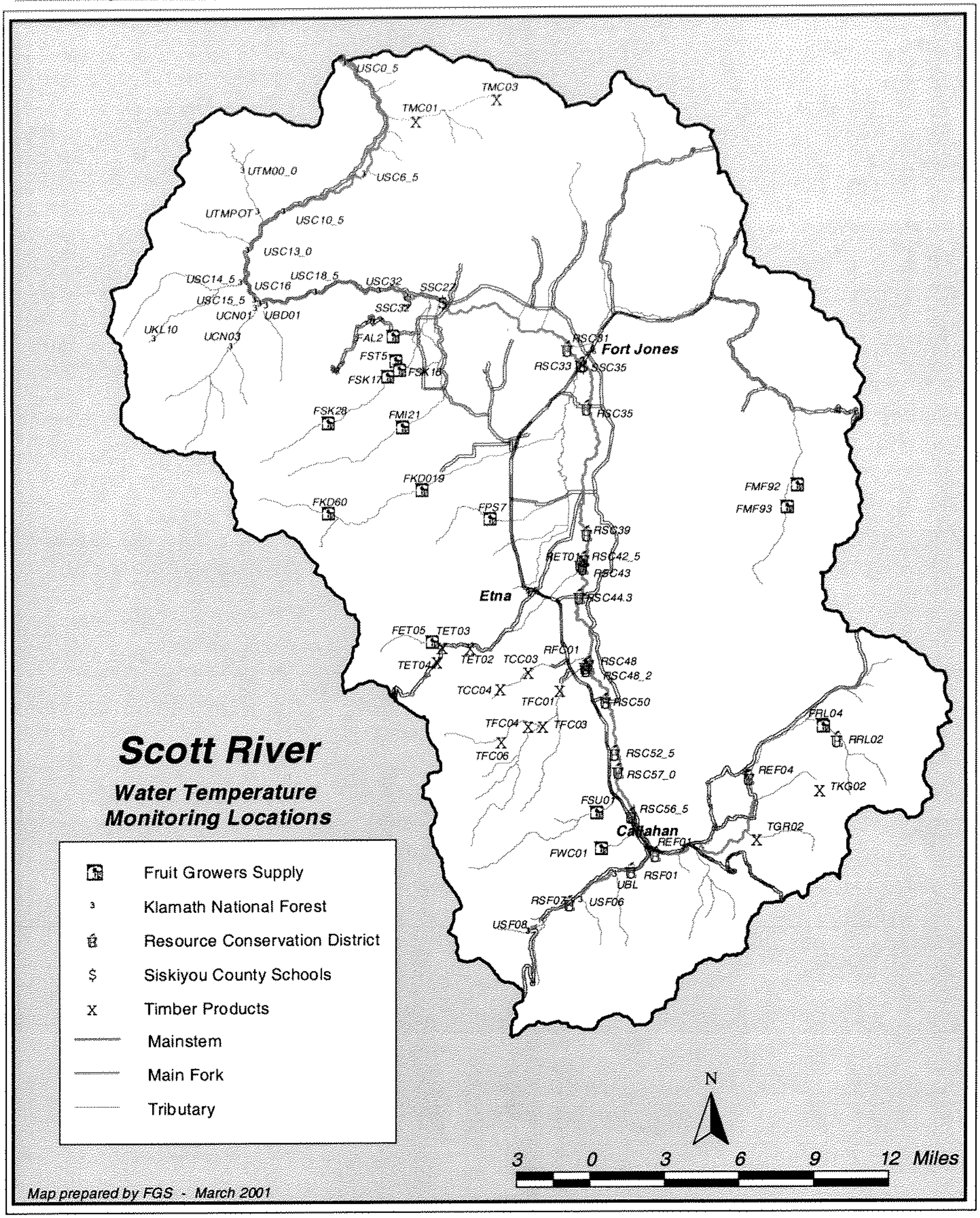


Figure 9. Geographic Location of Stream Temperature Monitoring Devices

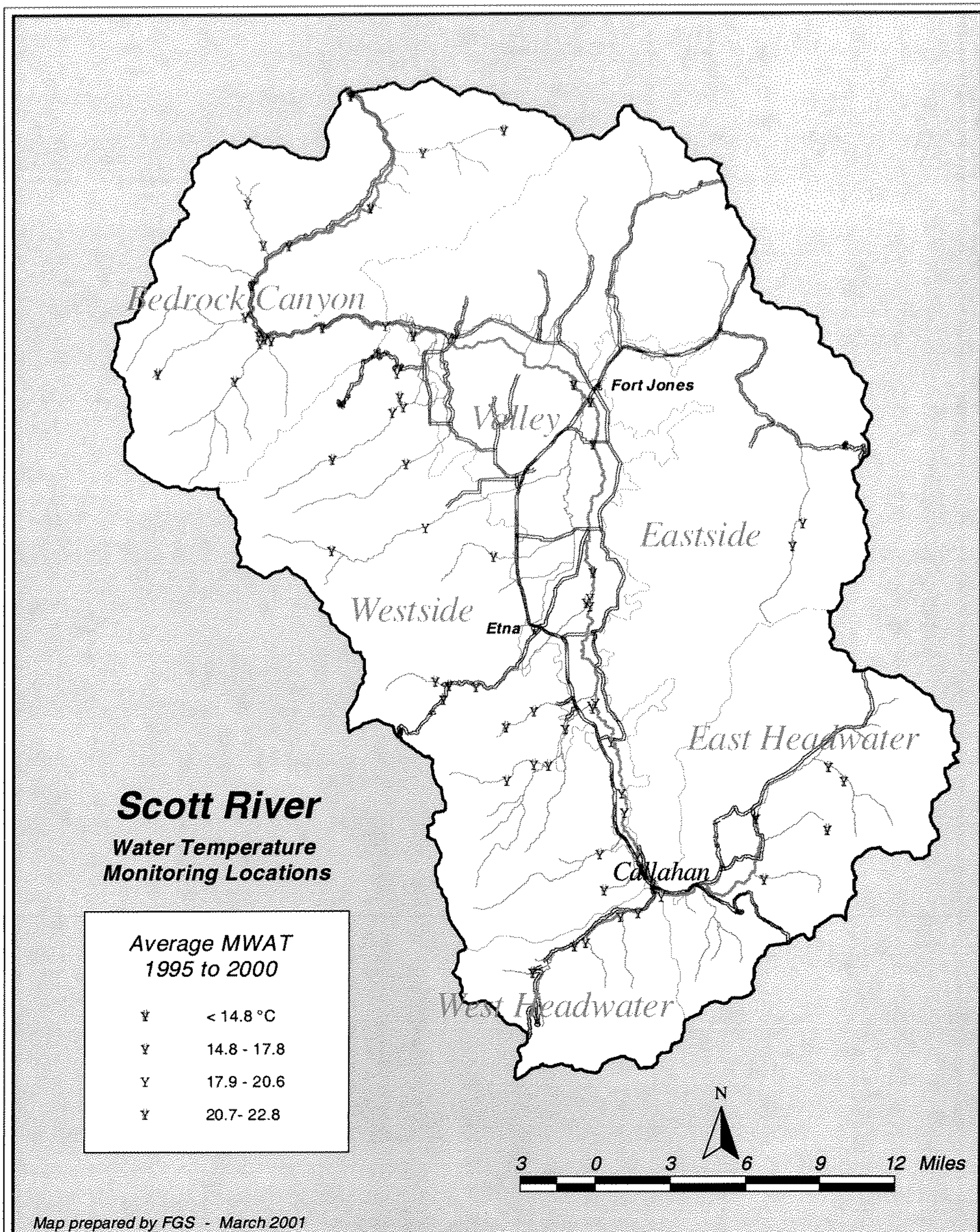


Figure 10. Average Maximum Weekly Average Temperatures (MWAT) - 1995 to 2000

7.2 HISTORICAL RANGE OF WATER TEMPERATURES

Water temperatures have been recorded in Northern California by state and federal agencies and private landowners since the early 1950's. The US Geological Survey (USGS) along with the California Department of Water Resources (DWR) collected water temperatures annually using a variety of field techniques and reported these temperatures by collection station in annual reports (USGS, 1997). The USGS and DWR also summarized the 1951- 1970 annual reports into a reference guide for many of the monitoring stations (Blodgett, 1970).

Historical water temperatures in Northern California watersheds similar to the Scott River watershed indicate that instantaneous water temperatures in the region have exceeded 21°C (70.2°F) since the early 1950's (Table IV) (Blodgett, 1970).

Table IV. Pre-1964 Flood Maximum Instantaneous Water Temperatures - Regional

USGS Station Name	Maximum (°C)	Maximum (°F)	Water Year
South Fork Salmon River near Forks of Salmon	21	70	1961
North Fork Salmon River near Forks of Salmon	22	72	1961
Salmon River near Somes Bar	24	76	1959
Trinity River Above Coffee Creek	24	76	1960
South Fork Trinity River near Hyampom	25	78	1962
South Fork Trinity River near Salyer	28	83	1962
Shasta River near Yreka	31	88	1961
Klamath River near Seiad Valley	26	79	1961

Historical water temperatures have been documented in the Scott River Watershed at eight separate stations (Blodgett, 1970). Due to the various methods, time periods and total number of measurements, limited information and conclusions can be drawn from historical data in the Scott River watershed. In the Scott River watershed the USGS and DWR used the "periodic observation" method for collecting water temperatures. This method entailed using a hand held thermometer and directly reading the thermometer temperature. The stations were located far enough downstream of tributary inflow to ensure that waters were well mixed and usually the stations were associated with water flow gauging stations. Blodgett(1970) reported "...the probable inaccuracies resulting from the sum of instrumental and thermometer placement errors should be less than + or – 1.5° F (+ or – 0.8°C) degrees for periodic data collected with hand-held thermometers." Due to these limitations the authors of this report reviewed the historical information cautiously and used the information only in broad watershed observations.

The instantaneous maximum water temperatures of the eight stations located in Scott River (Table V, from Blodgett, 1970) indicate that these portions of the Scott River watershed have exceeded 20°C (68°F). The historical water temperatures reported in Table V were collected prior to the 1964 flood. The 1964 flood had a strong impact on the channel structure. The present day channel is more open and has less vegetation than prior to 1964.

Table V. Pre-1964 Flood Maximum Instantaneous Water Temperatures in Scott River Watershed.

USGS Station Name	Years Data Collected	Maximum (°C)	Maximum (°F)	Water Year
East Fork Scott River at Callahan	1957 to 1968	27	81	1961
South Fork Scott River near Callahan	1957 to 1960	21	70	1959
Sugar Creek near Callahan	1957 to 1968	20	68	1958
Etna Creek near Etna	1957 to 1962	21	70	1959
Moffett Creek near Fort Jones	1957 to 1968	24	76	1958
Shackleford Creek near Mugginsville	1957 to 1960	21	70	1959
Scott River near Fort Jones	1950 to 1968	26	79	1968*
Canyon Creek near Kelsey Creek	1957 to 1960	18	65	1957

* post-1964 flood

Many of these historical locations are very close to the same locations as the monitoring sites in this study. The Blodgett(1970) report includes periodic observations from the 1950's and 1960's, prior to any significant land management in these tributaries. Table VI compares the maximum recordings from the Blodgett report to the maximum readings from this study as well as to the weekly average of daily maximum temperatures for the hottest seven-day period in the study (MWATmax). It can be seen that temperatures of today are comparable to those of decades ago. This correlation between temperatures 40 years ago, and current temperatures during a time when stream channel and watershed conditions have changed, may indicate that stream heating is primarily a function of local climatic conditions.

Table VI. Historical compared to current stream temperatures in the Scott River Watershed.

Location	Historical Blodgett Max (°C)	Current MWATmax (°C)	Current Daily Max (°C)
Scott River near Fort Jones	26	27.2	27.6
Canyon Creek	18	16.7	17.2
Moffett Ck near Fort Jones	24	23.4	24.3
Shackleford Ck. near Mugginsville	21	19.0	19.4
South Fork Scott at Callahan	21	20.0	20.5
East Fork Scott at Callahan	27	26.4	27.1
Sugar Ck near Callahan	20	18.1	18.5

7.4 GEOGRAPHICAL RANGE OF WATER TEMPERATURES IN THE SCOTT RIVER WATERSHED

Due to the variation in topography, geomorphology, and many other factors discussed in Section 4.0 of this report the Scott River naturally has a wide range of stream temperatures (Figure 14). Water temperature data has been collected throughout the basin, and some trends can be seen.

There is a wide difference between temperatures in the upper tributaries and the lower alluvial reaches of the system. A total of 171 datasets were collected for this study. Within those 171, the range of MWAT is from 10.9°C (51.8°F) in the upper reaches to 23.6°C (74.9°F) in the lower valley. The valley reaches reflect not only natural factors, but the influences of land use and water management. The upper reaches drain primarily high elevation (4000+) wilderness areas with little human influences on water temperature (Some of the larger wilderness lakes have dams built at the outlet, to maintain summer water levels). Temperature data collected from tributaries exiting wilderness showed an MWAT range of 10.9°C to 17.8°C (51.8-64.4°F), with most in the 14.6°C to 16.1°C (58.6-61.3°F) range.

No water temperature data exists for the mainstem Scott River in its pre-settlement state. As described by fur trappers of the early 19th century (Wells, 1880), the valley was a large swamp due to the large population of beaver and beaver dams. This condition would tend to limit the natural range of water temperatures because of the lack of water movement. Presumably water temperatures in this condition would find equilibrium with the ambient air temperature. This is evident in current data for the mainstem as well. The average MWAT of the Scott River mainstem near Fort Jones is 21.3°C (70.7°F), and the maximum average air temperature recorded at Fort Jones since 1948 is 21.7°C (71.5°F). The range of MWAT on the mainstem is 17.1° C to 23.6°C (63.1-74.9°F), with 11 of the 19 sites in the 19.2°C to 22.5°C (66.9-72.9°F) range. The four sites with an average above 21°C are located in the Scott River mainstem near Fort Jones or the alluvial flats of the East Fork Scott River.

7.5 ANNUAL VARIATION OF WATER TEMPERATURE

The variation of water temperatures between calendar years can occur due to many short term and long term watershed processes. Fluctuations in climate from year to year influence water temperatures similarly throughout the basin. The figure below shows the maximum weekly average temperature of the water at various locations for each of the years 1997 to 2000. At all locations water temperatures cooled from 1997 to 1999, then all increased in 2000. The increase in water temperature was presumably in response to relatively higher air temperature during the summer of 2000. These results are supported by research which has found water temperatures of larger river systems to be closely related to ambient air temperatures (Adams 1990, Sullivan 1990).

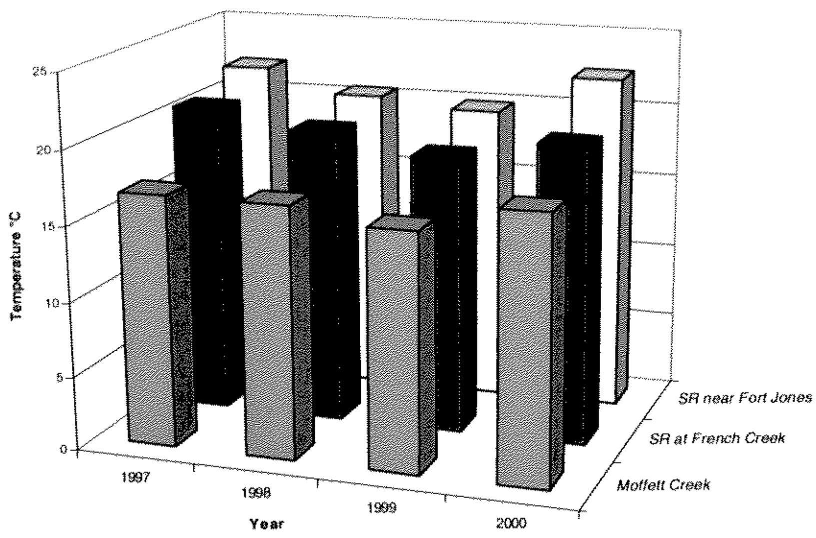


Figure 11. Annual Variation in Water Temperature at various locations in the Scott River Basin.

7.6 INFLUENCES OF AIR TEMPERATURE

Many researchers have found air temperature to be the most significant environmental factor in determining water temperatures, as most of the terms in the heat transfer relationships involve local air temperature. At equilibrium, the daily average water temperature is very near the local daily average air temperature for any given site (Sullivan, 1990). The controlling factors of air temperature are local climate, elevation, aspect, topography, shade, and air movement.

Our results from paired data for air and water temperature collected on Shackleford Creek, support known heat transfer relationships. Shackleford creek is a Rosgen B3 channel type, located in the Westside sub-basin, yielding an average baseflow of approximately 40 cfs. The Figure 12 shows how closely water temperature follows air temperature. Daily and weekly averages are displayed, as averaging masks the localized and short-term fluctuations, thus enhancing interpretation. As air temperatures increase and decrease so do the water temperatures. During periods of high flow and snowmelt, the water temperature stays cool, due to its thermal mass. Late in the summer, as the influence of snowmelt decreases, the thermal mass of the water decreases, and water temperatures become closer to air temperatures. Other physical factors, such as direct solar radiation and stream depth, have more influence on the magnitude of daily and local fluctuations in water temperature. (CH2MHILL, 1999)

The graph also shows the declining effect of air temperature on water temperature as the two temperatures approach each other. The temperature of ground water is typically within 1-3°C of the annual average air temperature for any given area. (Lewis) Once the snow has melted stream flow is sustained by ground water, which would obviously then have a significant influence on stream temperature.

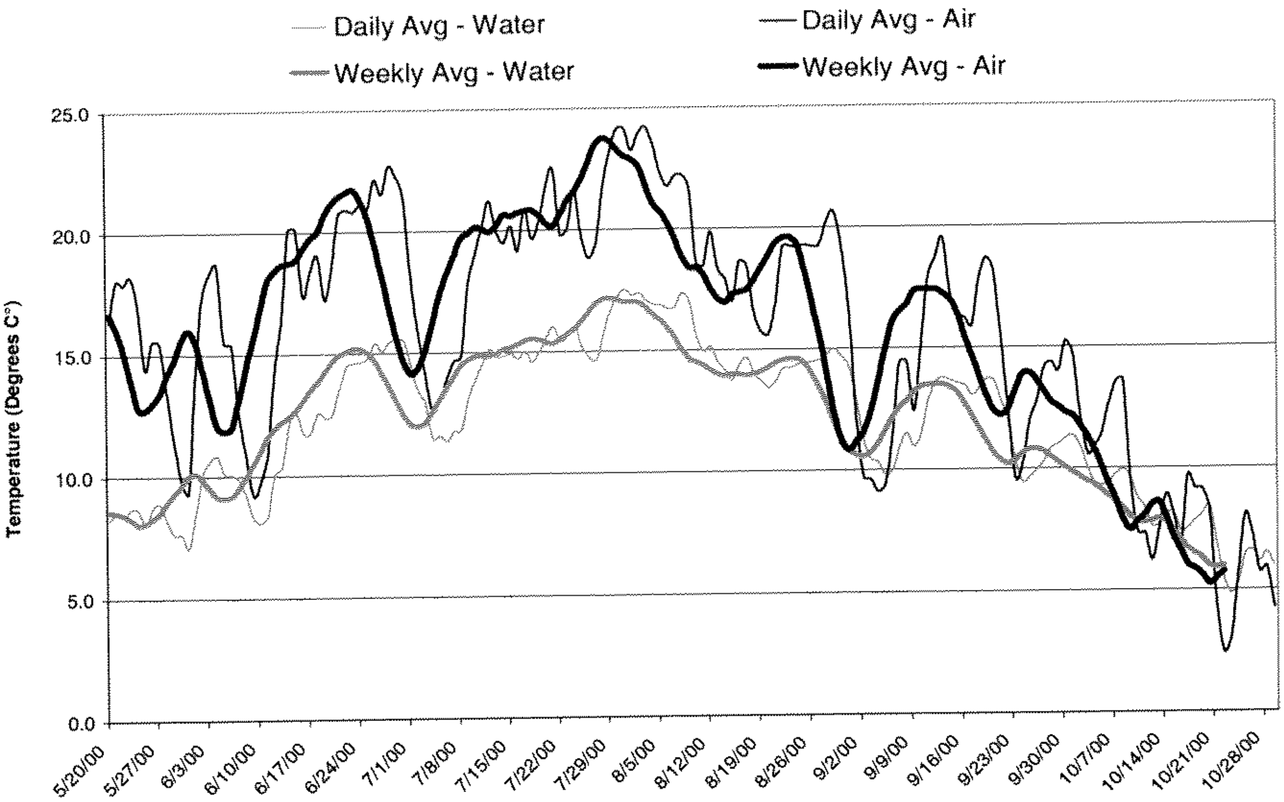


Figure 12. Air vs. Water Temperatures in the Scott River Basin
(Shackleford Creek, summer 2000)

Figure 13 shows the correlation of daily average air and water temperatures for Shackleford Creek during the summer of 2000. Daily average air and water temperatures are highly correlated ($r^2 = 0.800$, n= 163). As the graph shows, this relationship is more prevalent above 14°C (57.5°F). Hourly data is less correlated ($r^2 = 0.733$, n=3,912), which suggests the influence of other localized variables. This may include the variable influx of ground water and/or variations in air movement.

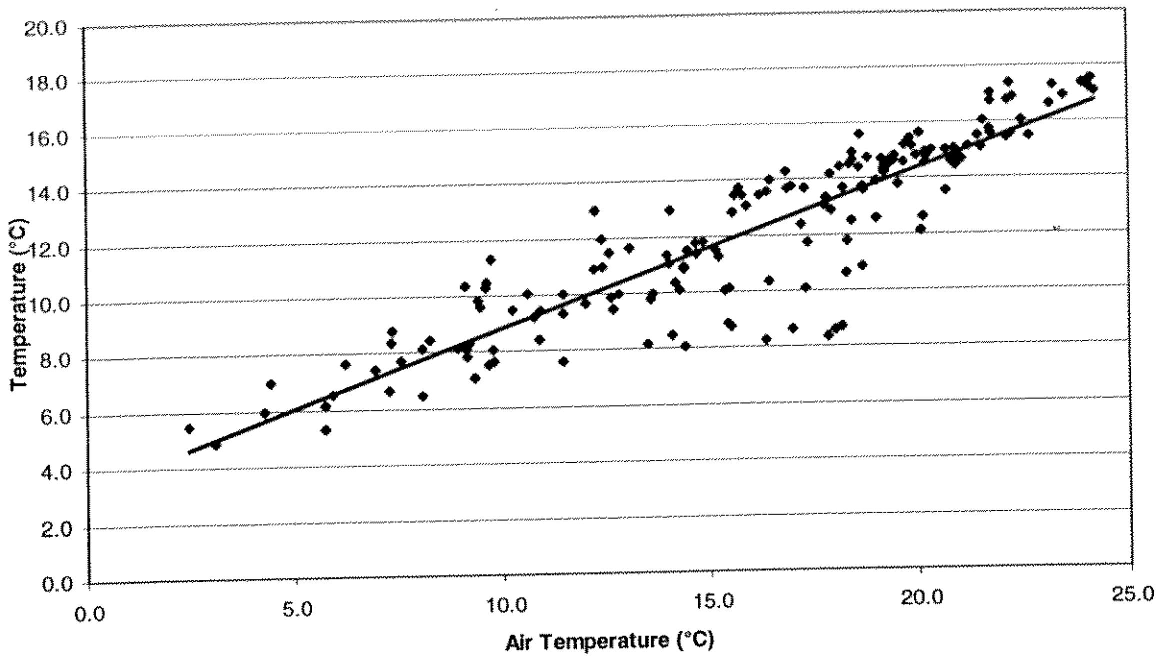


Figure 13. Daily average air vs. water temperatures in the Scott River Basin.
(Shackleford Cr., summer 2000.)

7.7 INFLUENCES OF CHANNEL GEOMORPHOLOGY AND STREAM FLOW

Like any other watershed, flows of the Scott River begin as small headwater streams at high elevations and end at the mouth as a wide, lower elevation river. Stream width naturally increases with accumulated flow and geomorphologic processes. As stream width increases the effectiveness of riparian and topographic shade diminishes to the point where it is no longer a factor. We believe our results (Figure 14) support the trend of increasing water temperatures as the river approaches the confluence with the Klamath River. This is a natural phenomenon common to large alluvial river systems (Sullivan 1990). Stream temperatures naturally increase in the downstream direction from headlands to lowlands, even under closed forest canopy conditions, and create a characteristic temperature profile (Theurer et al 1984; Sullivan and Adams 1990). This can be seen as the trend line in Figure 14. The graphs also shows the linear trend of average MWATs derived as a simple trend in MS Excel. Heat energy can be transported downstream with flowing water, although various heat transfer mechanisms cause the water temperature to change until the net heat transfer is balanced, i.e., energy in equals energy out. This equilibrium temperature varies with changes in environmental conditions over time and space (Adams and Sullivan, 1990).

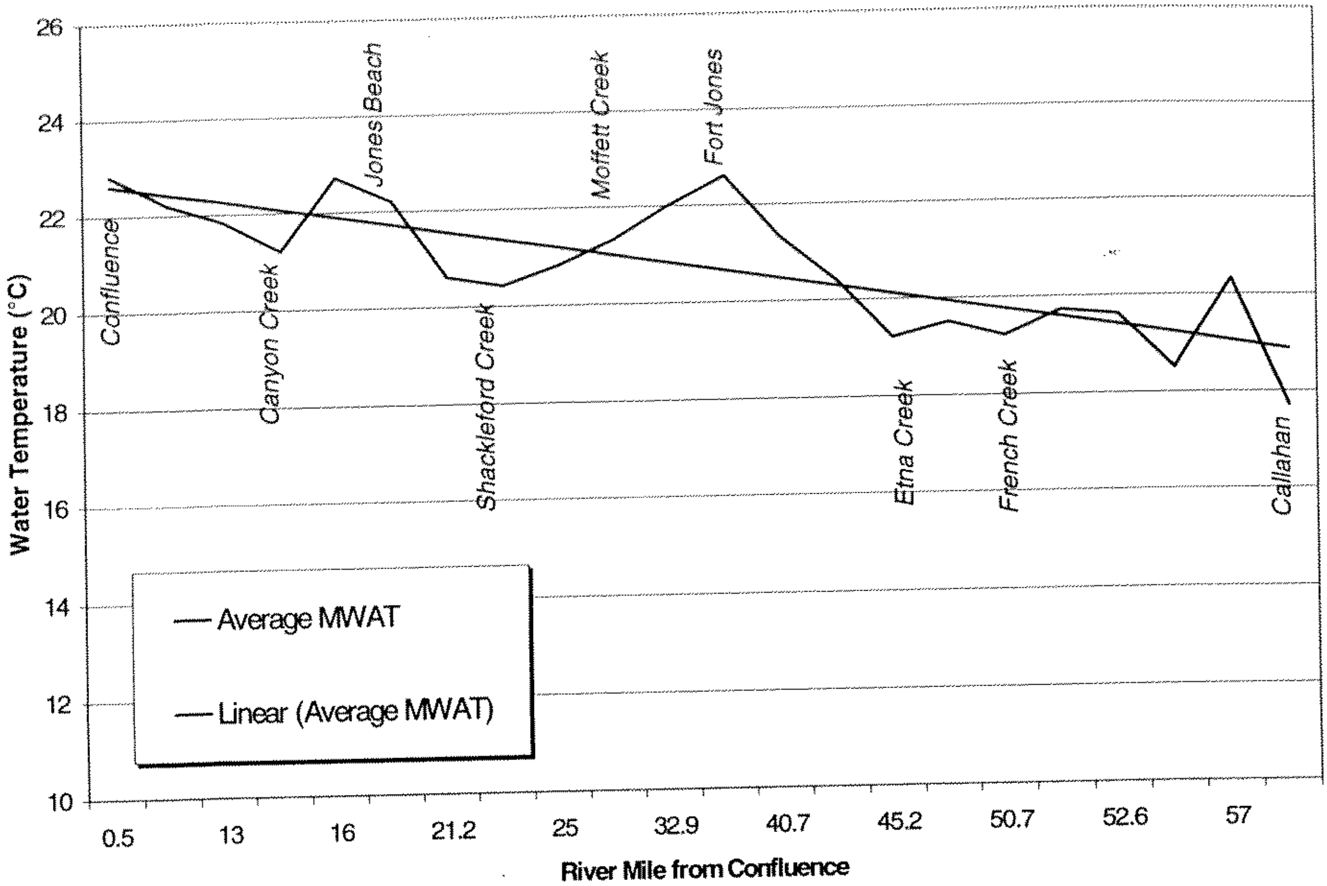
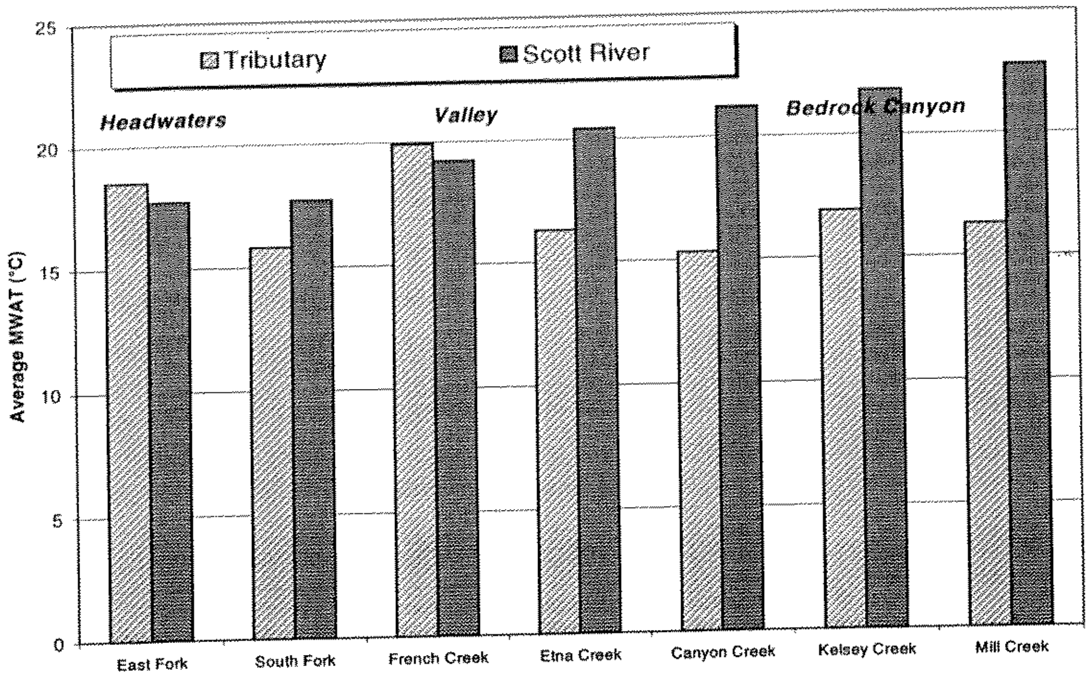


Figure 14. Maximum weekly average stream temperature as a function of river mile.

7.8 INFLUENCES OF TRIBUTARIES ON MAINSTEM WATER TEMPERATURES

Analysis of paired data for water temperatures in tributaries and the mainstem directly below the confluence indicate that little heating or cooling occurs due to tributary flows (Figure 15). This is especially true further downstream as mainstem flows accumulate thus diminishing the proportion of inflowing tributaries and increasing the response time of the mainstem to changes in environmental conditions.

All of the surface waters of the Scott River basin have been adjudicated. Many of the tributaries are diverted into irrigation ditches prior to reaching the valley floor during the summer months. Several larger Westside tributaries (Kidder, Patterson, Mill, and Shackleford) drain into a floodplain slough condition or go underground before reaching the mainstem. This is the result of reduced discharge levels and the low gradient alluvial nature of these reaches. This condition is the controlling environmental factor for water temperatures coming out of these major watersheds.



Average MWATs (1995-2000) of tributaries and Scott River below each tributary.

(* Note: The East Fork and South Fork meet to form the mainstem Scott River. The mainstem temperature shown below the two tributaries is taken at the same location.)

Figure 15. Average temperatures (MWAT) of tributaries and the Scott River below each tributary.

Figure 15 shows the average MWAT temperature in selected tributaries, and the Scott River mainstem just below the mouth of the tributaries. It can be seen that the mixing of waters from the East Fork and South Fork yield a relatively cool temperature. This marks the beginning of the mainstem. The most substantial increase in water temperature is between Etna and Fort Jones (Figure 14). There are no direct tributaries to the mainstem in this reach. Water temperatures overall cool somewhat as the river turns west at Fort Jones (Figure 14), but the accumulated discharge at this point buffers the cooling effects of the very cool tributaries of the Canyon sub-basin. The contribution of cool tributaries and groundwater between Fort Jones and the confluence with the Klamath River appear to have an accumulated cooling effect on the mainstem (Figure 14), but individual tributaries show very little cooling effect (Figure 15).

Other than water diversions for irrigation during the summer, the Scott River is a free flowing system. There are no dams which serve as a barrier to fish passage. Discharge during the summer months is controlled primarily by drought and demands for irrigation. Flow in the mainstem is a determining factor in water temperature. Water volume has a buffering effect on the transfer of heat energy from the air substrate. Higher flows might find the same equilibrium, but if flows were maintained at substantially higher levels, it would take longer to achieve that equilibrium. This larger volume of water would reduce the magnitude of daily and local fluctuations as well as the amount of time which the river experiences these higher temperatures.

7.9 WATER TEMPERATURES BY GEOMORPHIC SUB-BASIN

In general, our results support the original hypothesis that the six geomorphically distinct sub-basins produce different annual water temperatures. The tributaries within the Canyon(16.4°C, 61.8°F) and Westside (15.8°C, 60.8°F) sub-basins produce cooler water temperatures (Table VII). During seasons when water is present in the channel the Eastside sub-basin produces water temperatures that are slightly higher than the Canyon or Westside tributaries. During seasons when water is absent monitoring devices have been left in dry channels and data was discarded. The tributaries and mainstem within the alluvial Valley sub-basin had the highest water temperatures (21.3°C, 70.8°F). Due to small sample size, conclusions interpreted from the data reported for the West and East Headwaters should be done cautiously. However, the general observations are that the West Headwater streams are cooler than the East Headwater streams.

Table VII. MWAT and Diurnal Fluctuation by Geomorphic Sub-unit.

Geomorphic Sub-Basins	1997 MWAT	1997 Diurnal Fluctuation	1998 MWAT	1998 Diurnal Fluctuation
Canyon	16.4	3.9	16.4	4.9
Valley	21.3	7.1	18.4	6.3
Westside	15.8	2.9	15.3	3.0
Eastside	15.3	4.0	17.2	6.5
West Headwaters	14.0	3.1	NA	NA
East Headwaters	NA	NA	17.7	7.7

Table VII represents a two year period in which data was available for most of the sub basins. Table VII. demonstrates the streams diurnal fluctuation as a function of channel geomorphology.

8.0 DISCUSSION

8.1 SUMMARY OF GEOMORPHIC AND ECOLOGICAL CONDITIONS

The results of our examination of historic water temperatures from the 1950's and 1960's in the Scott River watershed indicate that historic water temperatures have routinely exceeded 20°C (68.4°F). Water temperatures measured between 1995 and 2000 appear to be within the range of variability that was observed during the 1950's and early 1960's. Even though climatic conditions have varied, riparian and stream habitats may have varied, we have no information to indicate that water temperatures have varied greatly in the Scott River watershed since the 1950's and 60's. We believe this condition further supports our conclusion that the channel geomorphology and climate of each sub-basin controls the observed water temperatures.

8.2 GEOMORPHIC AND ECOLOGICAL CONDITIONS

East Headwater

The wide alluvial mainstem channel (Figure 3) and low precipitation (Figure 4) of the East Headwater geomorphic sub-basin indicate that water temperatures should be relatively warmer. There were six (6) temperature monitoring locations on the East Fork Scott River. Four were in upper tributaries and two were in the East Fork itself. MWAT temperatures in the tributaries did not exceed 17.8°C (64.4°F) for any of the years studied. This is similar to temperatures observed in the other tributaries of the system, which did not exceed 17.8°C. As was the trend in the watershed, water temperatures reached the warmest recorded in 2000. Both locations on the East Fork mainstem exceeded 20.7°C (69.7°F) in 2000. The wide alluvial mainstem channel appears to create water temperatures at or above the historic range of water temperatures in the entire Scott River watershed.

West Headwater

The narrow alluvial mountain channels (Figure 3) and high precipitation (Figure 4) of the West Headwater geomorphic sub-basin indicate that water temperatures should be relatively cooler. This geomorphic sub-basin is also relatively small (25,000 acres) which also means the distance to the hydrographic boundary is smaller. There were six (6) temperature monitoring locations on the South Fork Scott River. The two in the South Fork itself were monitored for three years, and the average MWAT was 15.8°C (60.4°F), and 14.6°C (58.3°F). Four of these physical geomorphic factors (channel, precipitation, basin size, and distance to hydrographic boundary) create water temperatures that are below the historic range of water temperatures in the entire Scott River watershed.

Valley

It has been shown (Sullivan, 1990) that for large river systems the two most important factors influencing water temperatures are elevation (with respect to air temperature) and distance from the watershed divide, as this leads to an increased width to depth ratio. The elevation in the alluvial mainstem valley reach (Figure 3) varies from 2,700'- 2,900'. The orientation of this reach of the river is northerly, until the river reaches

Fort Jones. At Fort Jones the river turns west. The North/South orientation exposes the river to maximum summer solar radiation for approximately 30 miles. Due to its wide alluvial mainstem geomorphology this reach of the river only has 0-5% riparian cover, exposing the water to solar radiation, as well as heat exchange with the air. As would be expected for a large river system, the water temperatures gradually increase as distance from the headwaters increases (Figure 14).

This sub-basin is best understood as three reaches. From Callahan to Etna Creek (13 miles) is the upper reach, Etna to Fort Jones is the middle reach (15 miles), and Fort Jones to the USGS Gauging Station is the lower reach (10 miles). For various reasons, the lower reach has not been systematically monitored. Only one data recorder has been in place there from 1997 to present. There are 13 monitoring locations in the 28 miles between Fort Jones and Callahan. In the upper reach MWAT temperatures recorded were in the range of 17.1°-20.7°C, (62.8 - 69.26°F) with temperatures increasing with distance from the headwaters. In the reach below Etna Creek the temperatures gradually increase to a high of 23.6°C at Fort Jones (maximum MWAT for all years). This middle reach has no tributaries, and it is believed that groundwater does not enter the river until Fort Jones. Further scientific investigations are warranted to better understand this increased heating in this reach. Scientific investigations should focus on influence of groundwater, tributary streams if flowing, and inter-gravel flow.

Eastside

This incised valley tributary geomorphic sub-basin supports little or no surface water flow from year to year. The combination of the alluvial valley floor geomorphology (Figure 3) with very little precipitation (Figure 4) creates a stream network that supports little to no surface water flow. Most of the eastside system flows only ephemerally during severe storm events. It is not uncommon to have tributary streams be disconnected during the summer or winter for extended reaches and be disconnected from the mainstem Scott River. There are two temperature-monitoring locations within the eastside sub-basin, one on Moffett Creek and one on Sissel Creek. Due to limited sample size, conclusions interpreted from the data reported for this sub-basin should be done cautiously.

Westside and Canyon

The Westside geomorphic sub-basin is the most varied of the six. It is composed of many large sub-watersheds originating in high mountain springs, with a wide range of geology, hydrology, topography, and land management practices. While not the largest sub-basin in this study, it contributes a majority of the water to the Scott River. The Westside has many perennially flowing tributaries, some of which provide habitat for anadromous salmonids. The overall average MWAT for the 61 datasets in this sub-basin is 15.5°C. The range of MWATs for this sub-basin is from 12.0 to 18.6°C, with one location on lower Kidder Creek at 20.1°C in 1997.

The Canyon geomorphic sub-basin contains two channel types, the incised valley mainstem and the high energy mountain transport reaches of the various tributary streams. The incised mainstem of the Scott River enters a bedrock canyon for 19 miles prior to its confluence with the Klamath River. The upper half of this reach is a deep canyon with large mountains on the west and south side. However, in the lower half of this reach the canyon opens up and the canyon walls provide less topographic shading. The mainstem appears to experience a 1°C decrease in MWAT just below Jones Beach (Figure 14). This decrease is due either to topographic shading, cool water from the 2 tributaries in this reach (Boulder and Canyon Creeks) or from inter-gravel flow downstream of Jones Beach. Further scientific investigation of these relationships would be helpful in better understanding this geomorphic sub-basin. However, this decrease in mainstem temperature is temporary as by Scott Bar the River increases in temperature to MWAT levels similar to the average in Scott Valley (Figure 14).

The Canyon geomorphic sub-basin also has several high energy mountain transport tributaries: Boulder, Canyon, Kelsey, Middle, Tompkins and Mill Creeks. Due to these tributaries narrow geomorphology (Figure 3), high precipitation zone (Figure 4) the tributaries range between 14°C and 16° C. These physical and biological conditions combine to create stream temperatures that are below the historic range of water temperatures in the entire Scott River watershed.

The Westside Mountains and Bedrock Canyon geophmorphic sub-basins produce the lowest stream temperatures in the watershed. Tributary reaches within these sub-basins support MWAT stream temperatures that range from 14 to 16°C (57.2-60.8°F). During the peak of the summer air temperature (i.e. more intense solar radiation) these stream reaches also have lower diurnal fluctuation (3 to 5°C) than the other geomorphic sub-basins (3 to 8°C). The channel geomorphology of narrow transport channels (Figure 3) and close proximity to headwater springs and high precipitation (Figure 4) combine to create stream temperatures that are below the historic range of water temperatures in the entire Scott River watershed.

8.3 WATER TEMPERATURES AND SALMONID REARING

Salmonid rearing in the Scott River basin occurs primarily in some of the major tributaries of the Canyon and Westside, in the mainstem Scott River, and the South Fork Scott (West Headwater). Fall Chinook use the mainstem of the river for the majority of their spawning and rearing. They spawn from October to December, and the young of the year outmigrate from the system starting as early as February into late-June. At the end of June 2000, the river reached a daytime high of 22°C at Fort Jones, and a nighttime low of 16°C. Juvenile trapping shows that fish move through the system during the night, and seldom move in the daytime. While mainstem temperatures exceed optimal levels for salmonid rearing, the time period when temperatures are elevated does not overlap with the timing of fish utilization of the habitat.

Coho and Steelhead primarily use the major tributaries for spawning and rearing. Both species spawn in late winter and early spring. Young of the species typically spend 1-2 years in the system before they outmigrate. Mainstem and tributary summer temperatures are of primary concern for these two species. During the course of this study, the year 2000 had the highest recorded temperatures. Temperatures in the major tributaries and the South Fork did not exceed 20°C, and many locations remained below 18°C. In addition, maximum recorded temperatures are usually in the late afternoon, and the river can cool by 2-6 °C during the course of the night. Scott River mainstem temperatures are of concern for Steelhead and Coho because they must outmigrate from the system. Preliminary results from juvenile trapping shows that outmigration occurs from February through June, before river temperatures have reached maximum temperatures.

9.0 CONCLUSIONS

Our stream temperature data supports the following conclusions on stream temperatures in the Scott River Watershed in Northern California:

(1) Water temperature results described in this report represent the largest number of sites (68) and annual datasets (171) ever described for the Scott River watershed.

(2) Review of the Scott River watershed climate, topography, vegetation, channel geomorphology, and hydrology data determined that six distinct hydrological and geological sub-basins exist: East headwaters, West headwaters, Valley, Eastside Mountains, Westside Mountains and Canyon (Figure 3).

(3) Water Temperatures in the headwaters and primary tributaries draining primarily wilderness areas have a temperature range of 10.9 - 17.8 °C, with most in the range of 14.6 -16.1°C. This can be interpreted as the natural range of water temperatures for Scott River tributaries.

(4) Influence of tributaries on mainstem water temperatures within the Valley sub-basin appear undetermined due to floodplain or slough (Kidder, Patterson, Mill, Shackleford) conditions which have little or no surface flow and flows presumably continue underground.

(5) Influence of tributaries on mainstem water temperatures within the Canyon sub-basin appear to temporarily reduce MWAT water temperatures only to see mainstem water temperatures increase back to higher MWAT water temperatures.

(6) Intergravel flow and inflow from ground water aquifers below large gravel depositions in the mainstem Scott River may have a significant affect on surface water temperatures (Figure 16), further investigation is warranted.

(7) Daily average water and air temperatures are highly correlated ($r^2 = 0.800$, n =163)

(8) MWAT water temperatures recorded between 1997 and 2000 in all geomorphic sub-basins (Figure 10) are comparable to the historical range of temperatures recorded in the Scott River watershed since 1951 (Table V, VI).

(9) MWAT water temperatures recorded between 1997 and 2000 in the Westside sub-basin (15.8°C, 60.8°F), Canyon sub-basin (16.4°C, 61.8°F) and Westside headwaters (14.0°C, 57.5°F) fall within the natural range of the water temperatures.

(10) Scott River mainstem temperatures naturally increase as the river flows downstream (Figure 14), corresponding to decreasing elevation (Figure 2), increasing distance from the hydrographic boundary, and widening of the stream channel (Figure 3).

The authors of this report make the following six recommendations for future water temperature monitoring within the Scott River watershed.

(1) Sediment Deposition - Results indicated that Scott River mainstem deposition areas at Jones Beach, Fort Jones and Callahan supported water temperatures that are higher than what might be expected. Additional investigation into the relationship of fine and coarse gravel deposition, inter-gravel flow and ground water influences in these reaches would be insightful.

(2) The observed annual fluctuation in air and water temperatures in the watershed indicate that a more thorough investigation of historic air temperatures is warranted. Analysis of annual air temperature fluctuations might provide insight into the range of water temperature conditions that has occurred historically and is likely to occur in the future.

(3) Tributary effects - An effort should be made to determine the effect of individual tributaries on mainstem temperatures. This includes measurement of flows at each tributary, to determine surface vs. subsurface flows.

(4) Groundwater - Groundwater may be a major contributor to maintaining summer flows. Temperature monitoring stations should be established to bracket known inflows of groundwater. The relationship between surface and groundwater should be researched.

(5) Riparian Monitoring - Temperature monitoring stations should be established along the mainstem at locations of riparian replanting efforts, and on tributaries which are experiencing natural regeneration. Water temperatures should be monitored as well as rate of riparian growth, in relation to stream shade provided.

(6) Temperature monitoring data should be analyzed in relation to the various life stage needs of salmonid species utilizing the stream in question. This report describes water temperatures in comparison to a natural range of variability within the watershed. Future biological monitoring should investigate the response of anadromous fish species to this range of water temperatures.

10.0 ACKNOWLEDGMENTS

We would like to personally thank the fisheries biologists and technicians, foresters, and GIS personnel for their contributions towards this document including:

Bob Hawkins Ann Wagner	Timber Products Company
GIS Staff	Fruit Growers Supply Company
Jeffy Davis-Marx	Resource Conservation District – Siskiyou County
Andrew Eller	Americorps - Watershed Stewards Project
Sue Mauer	Siskiyou County Schools/Siskiyou RCD

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APPENDIX A - MWAT DATA FOR EACH MONITORING STATION

Sub-	Station	CALWATER 2.2		Maximum Weekly Average Tempurature (MWAT)							
Basin	Number	RBUASPW	PWSNAME	1995	1996	1997	1998	1999	2000	Max	Avg
WS	FAL2	1105420904	Snitklaw Creek			15.4	15.2	14	16	16	15.2
WS	FET05	1105420403	Mill Creek			0	15.6	13.9	15.7	15.7	15.1
WS	FKD019	1105420701	Babs and Fork Kidder Creek			20.1	0	17.4	18.5	20.1	18.7
WS	FKD60	1105420707	Upper Kidder Creek			17.2	16.2	14	16.9	17.2	16.1
ES	FMF92	1105420505	Skookum Gulch			0	0	16.3	18.6	18.6	17.5
ES	FMF93	1105420505	Skookum Gulch			16.9	16.8	15.8	17.6	17.6	16.8
WS	FMI21	1105420902	Mill Creek			16.6	14.5	15.8	16.1	16.6	15.8
WS	FPS7	1105420703	Patterson Creek			17.7	17.6	16.4	18.1	18.1	17.5
EH	FRL4	1105420102	Rail Creek			0	0	0	17.4	17.4	17.4
WS	FSK16	1105420901	Lower Shackleford Creek			17	16.6	0	0	17	16.8
WS	FSK17	1105420901	Lower Shackleford Creek			0	0	14.5	17.2	17.2	15.9
WS	FSK28	1105420906	Upper Shackleford Creek			14	14	12	14.3	14.3	13.6
WS	FST5	1105420904	Snitklaw Creek			13.5	14.1	13.1	14.1	14.1	13.7
WS	FSU01	1105420305	Sugar Creek			0	15.5	14	16.7	16.7	15.4
WS	FWC01	1105420304	Wildcat Creek			0	17.2	15.7	17.4	17.4	16.8
WH	REF01	1105420303	Lower Scott River			0	14.4	19.4	21.6	21.6	18.5
EH	REF04	1105420104	Kangaroo Creek			0	21	0	21.4	21.4	21.2
VL	RET01	1105420403	Mill Creek			0	16.3	0	0	16.3	16.3
VL	RFC01	1105420402	Upper French Creek			20.7	19.7	18.1	21.1	21.1	19.9
VL	RRL02	1105420102	Rail Creek			0	16	15.1	17.3	17.3	16.1
VL	RSC31	1105420803	Lower Indian Creek			21.7	21.1	19.9	22.5	22.5	21.3
VL	RSC35	1105420706	Fort Jones			23.1	0	21	23.6	23.6	22.6
VL	RSC39	1105420503	Shell Gulch			22.1	20.5	19.9	22.5	22.5	21.3
VL	RSC42_5	1105420704	Middle Kidder Creek			20.6	20	0	20.6	20.6	20.4
VL	RSC43	1105420408	Clark Creek			20.7	19.7	0	17.2	20.7	19.2
VL	RSC44_3	1105420408	Clark Creek			19.5	0	0	19.4	19.5	19.5
VL	RSC48	1105420408	Clark Creek			20.9	18.2	18.7	19.1	20.9	19.2
VL	RSC48_2	1105420408	Clark Creek			20.8	19.7	18.5	19.8	20.8	19.7
VL	RSC50	1105420405	Lower French Creek			19.6	19.2	0	20	20	19.6
VL	RSC52_5	1105420405	Lower French Creek			0	17	19.9	0	19.9	18.5
VL	RSC56_5	1105420405	Lower French Creek			0	18.3	17.1	0	18.3	17.7
VL	RSC57_0	1105420405	Lower French Creek			0	0	0	20.3	20.3	20.3
VL	RSF01	1105420303	Lower Scott River			0	16.3	13.8	17.3	17.3	15.8
VL	RSF07	1105420301	South Fork Scott River			0	14.8	13.5	15.4	15.4	14.6
VL	SSC27	1105420804	Rattlesnake Creek			21	0	19.8	0	21	20.4
VL	SSC32	1105420905	Meamber Creek			0	0	19.8	21.8	21.8	20.8
VL	SSC35	1105420706	Fort Jones			22.8	0	21.2	0	22.8	22
WS	TCC03	1105420408	Clark Creek			15.3	14.8	13.4	15.6	15.6	14.8
WS	TCC04	1105420408	Clark Creek			14.1	0	0	0	14.1	14.1
WS	TET02	1105420403	Mill Creek			0	15.4	13.5	16.1	16.1	15
WS	TET03	1105420403	Mill Creek			0	0	13.8	0	13.8	13.8
WS	TET04	1105420403	Mill Creek			14.1	13.9	12.1	16.2	16.2	14.1
WS	TFC01	1105420402	Upper French Creek		18.6	0	16.2	17.8	18.6	18.6	17.8

WS	TFC03	1105420401	Meeks Meadow Creek			0	0	14.4	18.4	18.4	16.4
WS	TFC04	1105420401	Meeks Meadow Creek		0	16.5	16.2	0	0	16.5	16.4
WS	TFC06	1105420401	Meeks Meadow Creek			15.5	15.6	13.4	15.9	15.9	15.1
EH	TGR02	1105420105	Big Carmen Creek			0	0	16	18.5	18.5	17.3
EH	TKG02	1105420104	Kangaroo Creek			0	0	11.6	12.3	12.3	12
CN	TMC01	1105410304	West Mill Creek		16.2	16.5	16.3	15.2	17.1	17.1	16.3
CN	TMC03	1105410304	West Mill Creek			0	0	0	14.2	14.2	14.2
CN	UBD01	1105410102	Boulder Creek		14.4	14	0	0	0	14.4	14.2
WH	UBL	1105420303	Lower Scott River		16	0	0	0	0	16	16
CN	UCN01	1105410101	Lower Canyon Creek			15.4	15.2	0	0	15.4	15.3
CN	UCN03	1105410101	Lower Canyon Creek		15.5	15	0	0	0	15.5	15.3
CN	UKL10	1105410204	South Fork Kelsey Creek		10.9	0	0	0	0	10.9	10.9
CN	USC0_5	1105410305	Franklin Gulch		22.8	0	0	0	0	22.8	22.8
CN	USC13_0	1105410202	Middle Creek			21.8	0	0	0	21.8	21.8
CN	USC14_5	1105410201	Kelsey Creek		16.8	17.4	16.6	0	0	17.4	16.9
CN	USC15_5	1105410202	Middle Creek		21.2	0	21.1	0	0	21.2	21.2
CN	USC16	1105410102	Boulder Creek			22.7	0	0	0	22.7	22.7
CN	USC18_5	1105410102	Boulder Creek		22.4	0	22	0	0	22.4	22.2
CN	USC32	1105420905	Meamber Creek	20.2		0	21	0	0	21	20.6
CN	USC6_5	1105410301	Big Ferry Creek		21.9	22.9	21.8	0	0	22.9	22.2
WH	USF06	1105420302	Fox Creek		14.9	0	0	0	0	14.9	14.9
WH	USF08	1105420306	Little Jackson Creek		14.6	0	0	0	0	14.6	14.6
CN	UTM00_0	1105410203	Tompkins Creek			16.9	17.6			17.6	17.3
CN	UTMPOT	1105410203	Tompkins Creek			17.3				17.3	17.3

APPENDIX B - SUPPLEMENTAL GROUNDWATER DATA

Recharge of the Scott Valley ground water body is caused by direct infiltration of winter precipitation and infiltration from tributary streams as they flow over permeable alluvium in the Valley, especially those streams from the western mountains. The regional aquifer in Scott Valley also receives infiltrated water from the numerous irrigation ditches, but the volume of ditch leakage and its contribution to the aquifer is unknown.

Winter precipitation greatly increases the discharge of the Scott River from November to June. There is a marked peak in discharge from snowmelt runoff from mid-April to June each year. During the dry summer, after the snowmelt has been discharged, the flow of the Scott is sustained by base flow from groundwater. There is no information available on the location, volume and water temperature of groundwater inflow. By late summer, the flow of the Scott at the USGS gage at the lower end of the Valley declines to a very low level. In the last decade the August – September flow average around 20-25 CFS. In the 40's and 50's this flow was typically around 50 CFS. The cause of this apparent decline is being debated, but is appears to be due to a mix of climatic and water use factors. (ref drake)

During below average water years, surface flow ceases in several reaches of the Scott River in Scott Valley. Groundwater inflow to the River is cooler than surface flow in the Scott River. This is evidenced by the fact that isolated pools during dry periods have cooler water than the flowing stream.

Table VIII. Capacity of Groundwater Storage Units.

Storage Unit	Location	Area (Acres)	Storage Capacity (Acre-ft)
1	Scott River Flood Plain	16,000	220,000
2	Discharge Zone at edge of Western Mountain	6,500	31,000
3	Western mtn fans and Oro Fino Valley	8,400	50,000
4	Quartz Valley	4,800	61,000
5	Moffet-McAdams Creek	2,600	35,000
6	Hamlin Gulch	1,600	10,000

(From Mack et al 1958)

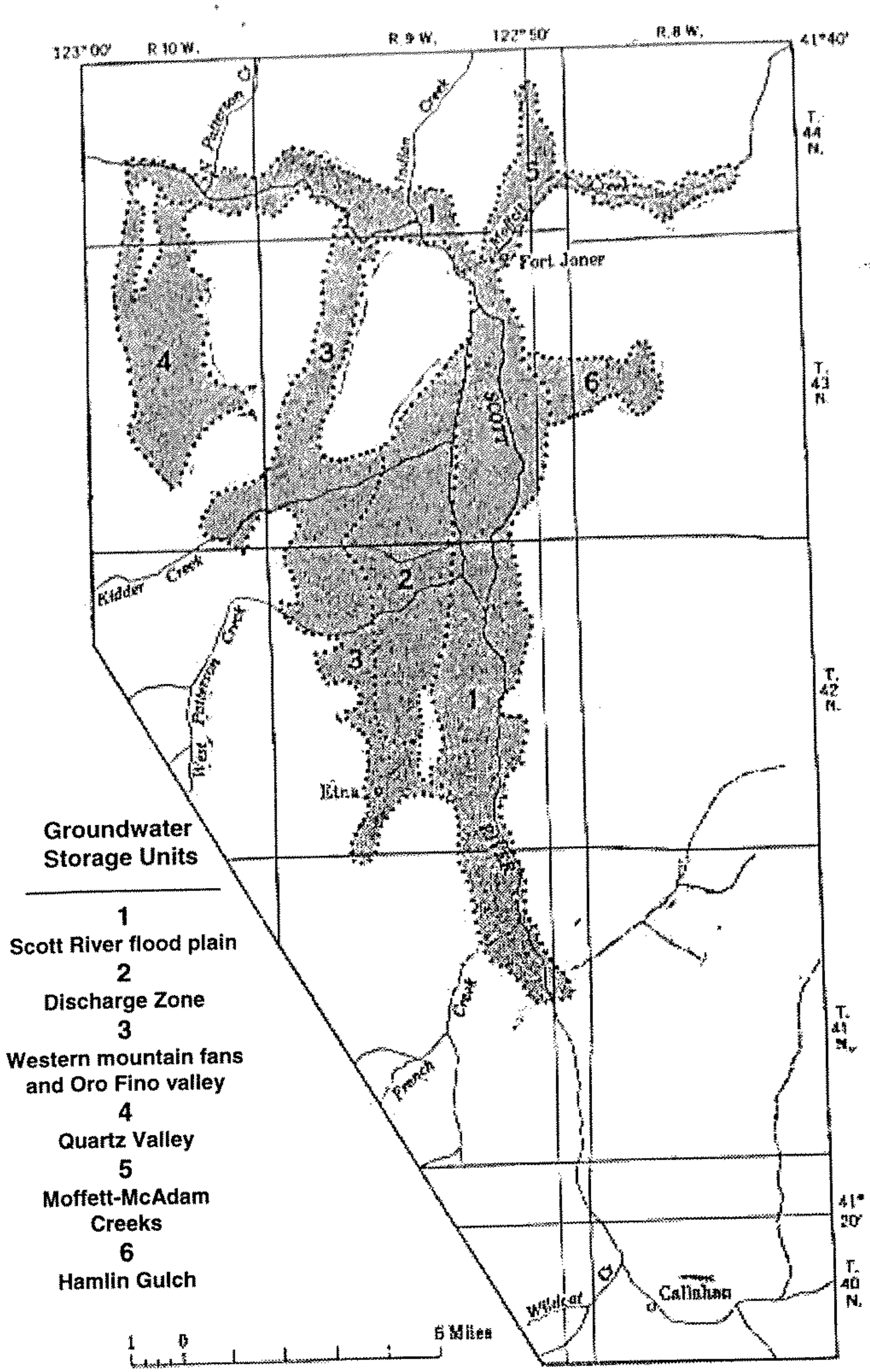


Figure 16. Groundwater Storage Units

Scott River Temperature Monitoring 2000

This report addresses data collected under contract agreement

14-48-11333-99-J022 (97-HP-02)

and

11333-0-J019 (2000-JITW-01)

Report compiled

by

Danielle Quigley

Siskiyou RCD

February 15, 2001

Abstract

This report analyzes water temperature data collected on the Scott River mainstem and various tributaries. Data was collected from May - October, during the summers of 1997-2000. Monitoring locations were designed to give data on spatial trends, climatic effects, and tributary effects. Data at some locations was lost due to theft, vandalism, and dewatering of hobotemps.

Introduction

The Scott River provides spawning and rearing habitat for coho Salmon (Oncorhynchus kisutch), fall chinook salmon (Oncorhynchus tshawytscha) and steelhead trout (Oncorhynchus mykiss). Due to the presence of these anadromous species, water quality is a key issue for the Scott River Watershed Council (SRWC) and Siskiyou RCD. In addition, the Scott River was listed, by the state of California ,as impaired for water temperature in 1994. In the spring of 1995 the RCD implemented a temperature monitoring program on the mainstem of the Scott River. The goal of the program is to identify reaches of the river where restoration projects would be beneficial to water temperature, as well to assess the success of past projects. Temperature stations have been monitored annually since 1997. This report addresses data collected from 1997-2000.

Stream temperatures are of concern because they directly influence the metabolic rates and physiology of aquatic species. Aquatic insects and anadromous fish are especially sensitive to alterations in water temperature. Long term fluctuations in stream temperature can make fisheries habitat unsuitable for native species. A particular concern of fisheries experts is summer rearing temperatures. All salmonid species spend some time in the river during the summer months and have an optimum temperature range of 10 – 15 ^{0}C. Temperatures lethal to juvenile salmonids occur at about 25.5 –26.6 ^{0}C.

Factors affecting water Temperature

Water temperatures in a stream course are affected by complex interactions of a variety of factors; Climatic conditions, groundwater influx, solar radiation, upland vegetation, topographic shade, and tributary flow are major contributors to variations in stream temperatures. The physical characteristics of the stream can buffer or insulate the water from large fluctuations in temperature. The three main physical characteristics of the stream are; the channel, the alluvial aquifer, and the riparian corridor. Human alterations of any of these factors can have a detrimental effect on stream temperatures, either directly or indirectly. Data collected in this contract only allow for analysis of spatial trends, climatic effects, and tributary influence.

The Scott River Basin

Geography and Climate

The Scott River lies in Western Central Siskiyou County, Northern California. The watershed drains a total of 524, 160 acres. Elevations range from 2600-3100 ft on the valley floor, to over 8000 ft at the highest peaks. The river 's headwaters are the Scott and Salmon Mountains at the southern end of the valley. From the headwaters the river flows north to the town of Fort Jones. At Fort Jones the river takes a turn to the north west and flows to its confluence with the Klamath River. *See Appendix A - Map of the Scott River Watershed.* The mainstem of the Scott is 58 miles in length. From the mouth to RM 21 the river runs through USFS land, and is bedrock channel. From RM 21 to the confluence of the East and South Fork (RM 58) the river flows through the alluvial valley floor. Land use is primarily public and private timber land, and agricultural land. The Scott River Watershed has an annual precipitation ranging from 20 inches at the valley floor, 30-40 inches on the east side, to over 70 inches in the western mountain headwaters. Typically 80% of the rainfall occurs between October and March.

Study Area

The area selected for this study was the mainstem valley reach (RM 29 -58) and the two forks; the East Fork and South Fork. The valley stretch can be divided into two reaches; Fay Lane to Fort Jones (RM 52- 29), and the confluence of the forks (RM 58) to Fay Lane. In addition, two tributaries were bracketed to determine their effect on mainstem water temperatures.

The East Fork and South Fork

The headwaters of the Scott River are the East Fork and the South Fork. The East Fork drains out of the Scott Mountains; the South Fork drains the Salmon Mountains. The East and South Forks meet at Callahan to form the main stem of the Scott River. Mean annual precipitation ranges from 40-50 inches.

East Fork

The East Fork flows in a southern direction to its confluence with the main stem. Elevations in this drainage range from 2,720 ft at to 8,540 at China Mtn. The East Fork drains a total of 170,750 acres, 32.6 % of the Scott River watershed. Approximately 12,630 acres of this are considered irrigable valley floor. Annual average precipitation in the East Fork Watershed is 38 inches per year. Land use is primarily rangeland and timberland.

The South Fork

The South Fork has its headwaters in the Salmon Mountains. Most of the land on the South Fork is USFS timber land, with a small amount of private timber land. The channel is small, bedrock confined.

Mainstem

The reach from the confluence to Fay Lane runs through tailings piles created by gold dredging done in the early 1930's. The dredging process turned the stream bed upside down, with the largest rock on top. The course of the river in this area is restricted to flowing between the tailings piles, 200-300 feet wide. The stream bank consists of large tailing piles with no topsoil or vegetation.

Fay Lane to Fort Jones is alluvial mainstem, and flows through agricultural land. Historically, the river had a wide valley floodplain and meandering pattern. Severe flooding in 1955 and again in 1964 caused the loss of much valuable agricultural land. To prevent further erosion much of the stream channel was stabilized. Today much of the river is confined to a channel 150-300 ft wide. This reach contains little riparian vegetation.

During the nineties the Siskiyou RCD has done many projects along the mainstem, installing cattle exclusion fences and planting riparian vegetation. Unfortunately, the plantings are as of yet too young to provide much shading to the stream bed.

There are four major tributaries from the western mountains which feed this portion of the river; Sugar Creek, French Ck., Etna Ck., and Kidder Ck. All except Sugar Creek can go dry during the critical summer months. It is believed that the tributaries go subsurface when they reach the alluvial valley floor. Etna and French Creek were chosen to be bracketed to evaluate their effect on mainstem temperatures.

Material/Methods

A. Equipment

Data collection was done using HoboTemp units (HT) made by Onset Computer Corporation. These units consist of a thermistor, related microelectronics, and a battery enclosed in a $1^{3}/4$" x $1^{1}/4$" x $^{1}/2$" case. This unit is enclosed in a 2" diameter, waterproof PVC case. For this project, the case was then secured in a 7" long, 3" diameter steel pipe. The case was chained to a structure (usually a tree) to prevent transport during high water. Water appeared to flow freely through the case and did not appear to affect the data collected. The stored information can be downloaded to a personal computer through a 9-pin connector. Software to download data and start the recording was also purchase through Onset

B. Calibration

Each HoboTemp (HT) was calibrated at 0^0 C (32^0 F) and then at room temperature. The Hobo Temp were set to record at five-minute intervals in order to establish as many readings within a two-hour frame as possible. The calibration was accomplished by adding equal parts of water and ice to a 30-gallon cooler with a lid. The HT was then placed in the waterproof PVC case. A series of cases were then threaded onto a piece of rebar or steel using the steel ring on the PVC case. The cases threaded onto steel were then immersed in the ice/water bath. An ASTM thermometer was then carefully added to the ice/water bath, ensuring that the mercury-filled bulb was immersed at the same level as the Hobo Temps and that the measuring scale of the thermometer was easily visible. The lid of the cooler was then closed. Participants recorded the ASTM thermometer readings at ten-minute intervals. Ice was added as needed.

Next, the Hobo Temps were then calibrated at room temperature, 19^0 C (66^0 F). Under the Project Quality Assurance Project Plan by California Department of Fish and Game (1995), two water baths, one at 5^0 C and one at 20^0 C are necessary for calibration. Since no laboratory is locally available for completing this type of calibration, and data is used for comparison purposes only, this level of precision was not employed. However, an attempt was made to confirm the results of the ice/water bath calibration. The Hobo Temps were placed in a cardboard box, 6"H x 10"L x 6"W, with no lid. An ASTM thermometer was then taped to the top of the cardboard box with the mercury-filled bulb located in the center of the box, just above the Hobo Temps The thermometer was not horizontal; the mercury-filled bulb was below the top of thermometer. The cardboard box was placed inside a room with normal air circulation (i.e. no fans, no traffic, and no open windows).

Temperature devices that did not meet the +/-0.5^0 C tolerance* were returned to Onset for repairs and not used that data collection season.

C. Site Selection

Sampling sites were those recommended by the Ad Hoc Water Monitoring Committee of the Scott River CRMP at a meeting in April 1997, and monitored during the summer of 1997. Committee members included USDA Forest Service, Siskiyou RCD, Siskiyou County Schools, Timber Products, and Fruit Growers, Inc. Each site was evaluated for its access and physical characteristics. Temperature monitoring stations are located every 3-6 miles along the mainstem, two locations on the forks, and at the mouths of Etna and French Creek. Hobotemps were placed in riffles and runs where possible. As most of the locations are on private land, permission for access was required for most all the proposed sites. All landowner participants were willing to allow monitoring to occur on their property each year. Their consistent participation has been encouraging. Appendix B, *Map of Monitoring Locations*, contains a map of all monitoring locations.

D. Data Collection

Hobo Temps were placed at each location in early May or June, and downloaded after October 15th. Temperature data was recorded every 1.6 hours and downloaded at periodic intervals. All sites were monitored on a regular basis to insure that the Hobo Temps were still under water.. When data sets were downloaded, air and water temperatures were collected using hand-held thermometers. On a few occasions, the HT was moved to insure that it would remain in the thalwag. Data determined to be extraneous (out of water, pre/post placement in water, etc.) was not included in the data analysis. Table 1, *Station Operation Duration*, contains a table summarizing when data was collected from each location.

Weather data consisting of precipitation, and air temperature was retrieved electronically from the California Data Exchange Center (CDEC) maintained by the California Department of Water Resources, Division of Flood Management. Appendix c, *Climate Station Information*, contains a table summarizing the location and type of stations available. Only two stations, Fort Jones and Callahan, were used for comparison in this report as presented in the results section.

E. Data Processing

Data was downloaded using Boxcar 3.5. This data is in raw form and must be transferred to another program for editing and analysis. Both Microsoft Excel v5.0 spreadsheet software and the Klamath River Information System (KRIS, a geographic information system) were used for editing and analyzing data. Data from CDEC was downloaded in Comma Separated Format and imported as text into the spreadsheet program.

Results

Table 1, *Station Operation Duration*, contains a list of the monitoring stations, along with the years in which data was collected. During some years, flows shifted and hobotemps were left exposed to the air. For the purposes of this report, locations exposed to air anytime during the critical months of July and August will not be included in the data analysis.

Table I. Station Operation Duration

Location	RM	1997	1998	1999	2000
S.F @ Baker's	1	ND	6/8-10/20	5/31-11/20	5/12-10/09
S. Fork @ Blue Jay		ND	6/8-10/20	6/1-11/20	5/12-10/09
E.F @ Callahan	1	ND	MD	6/1-11/20	5/12-10/06
E.F @ Masterson Rd		ND	6/8-10/20	LT	5/23-10/06
Etna Cr.	1	LT	DW	LT	LT
French Cr.	1	5/13-10/31	6/10-10/21	5/31-11/05	5/12-10/12
Rail Creek		ND	6/8-10/6	6/1-11/19	5/12/10/06
Eiler Ranch	29.9	5/13-8/9	6/3-10/20	6/1-11/19	5/12-10/12
Serpa Lane	36.8	5/13-8/8	LT	6/1-11/19	5/12-10/12
Eller Lane	40.7	DW	6/3-10/20	6/1-11/19	5/13-10/13
Below Etna Cr.	45.0	5/13-10/30	6/15-10/21	LT	5/26-9/3
Above Etna Cr.	45.2	DW	6/15-10/21	LT	5/26-10/20
Horn Lane	47.4	DW	LT	LT	7/17-10/18
Below French Cr.	50.7	5/13-10/30	6/10-10/21	6/7-11/20	5/12-10/12
Above French Cr.	50.9	5/13-10/30	6/10-10/20	5/31-11/20	5/12-10/12
Fay Lane	52	5/13-10/1	DW	LT	5/23-10/12
Tailings	57	DW	DW	6/1-11/20	5/12-10/12
Red Bridge	58	ND	6/8-10/21	6/1-9/5	LT

DW = Temp was dewatered during crucial months
LT = Temp device was missing
ND = Data not collected

Spatial Trends

One of the goals of this monitoring program was to identify spatial trends in river temperature. Graph 1a shows the variation in Maximum Weekly Ave Temperature by River Mile for 1997-2000. For every year which data was collected, the location at Serpa Lane shows the highest recorded temperature. The river also shows a general warming trend from the confluence to Fort Jones. Graphs 1b-1e show overlays of Ave Daily Temperatures at various locations along the river. Locations shown are approximately 10 miles apart. These graphs show that water temperatures at all the locations on the mainstem rise and fall in similar patterns

Climatic Factors affecting Water Temperatures

A.) Air Temperature and Wind

Heat energy from the air is transferred to the system at the surface of the water. The waters' surface equilibrates with the air temperature, consequentially cooling the air in contact. The heat is then conducted from the surface to the rest of the water. Wide shallow streams will have a greater percentage of surface area and will therefore heat faster. A dense riparian canopy cover can insulate the stream from this process by cooling the air near the surface of the water. Exposure to wind speeds the heating of water by constantly moving the cooled air away from the water and replacing it with warm air.

Solar radiation also transfers heat energy to the waters' surface. Riparian canopy cover shields the stream from solar radiation. Exposure to wind speeds this process in the same way as the transfer of heat energy from the air.

The mainstem of the Scott River has less than 10% canopy cover , and a wide shallow channel. Lack of adequate canopy cover makes the river more susceptible to solar radiation, air temperature and wind. Graphs 2a - 2c compare the average daily air temperature with the average daily water temperature at three locations on the Scott River near Callahan. Not every location had data for all four years.

"Callahan" is the site in the E. Fork behind the USFS guard station, which is also where the air temperature data was collected. " Red Bridge" is approximately 1 mile downstream from Callahan, below the confluence of the two forks. "Above French Creek " is 9 miles downstream from Callahan. The two mainstem sites are located in riffles with no canopy cover. The site on the E. Fork is a shallow riffle with about 20-25% canopy cover.

The data for the 1999 and 2000 seasons show the water temperatures rise and fall in a pattern closely following the air temperature. This is true even for the device located at French Creek, 10 miles downstream from where the weather station. Data for 1998 does not show this pattern, but this could be due to the higher flows during the 1998 season. Higher flows would decrease the percentage of surface area available for transfer of heat energy.

Graph # 3 shows the hydrographs for 1997, 1998, and 1999. During the summer of 1998, flow recorded at the USGS gauge was three times that of 1997. Three locations had good data for both 1997 and 1998. Of these three locations, all were warmer in 1997.

Daily Fluctuation in Air Temperature

Table II shows the maximum daily fluctuation in river temperature for each location, along with canopy cover. The two locations on the South Fork show daily fluctuations of less than 5 C for all years data was collected. Both locations on the East Fork showed daily fluctuations from 6.8 -9.7 C. Rail Creek, the upper tributary of E. Fork, has a daily fluctuation of less than 6 C most years. Somewhere between this tributary and upper Masterson road heating is occurring. All locations on the mainstem have less than 5% canopy cover. During 1998 daily fluctuation ranged from 6-8 C. During 1997 mainstem locations ranged from 6.2 to 10.9 C.

Table II.) Maximum Daily Fluctuation ^{o} C					
Location	**1997**	**1998**	**1999**	**2000**	**% Canopy**
S. Fork @ Blue Jay	ND	3.5	3.5	3.5	40
E.F @ Callahan	ND	6.8	9.5	8.8	15
E.F @ Masterson Rd	ND	8.5	LT	9.7	75
Etna Cr.	ND	7.9	LT	LT	0
French Cr.	6.8	6.0	6.8	8.9	5
Rail Creek		4.9	6.1	5.2	50
Eiler Ranch	8.8	7.4	8.1	8.9	5
Serpa Lane	10.9	LT	7.8	9.3	0
Eller Lane	8.1	8.0	7.9	7.7	0
Below Etna Cr.	7.8	6.9	LT	8.6	0
Above Etna Cr.	10.3	6.7	LT	3.9	4
Horn Lane	6.2	LT	LT	6.8	0
Below French Cr.	8.6	6.5	7.8	7.9	0
Above French Cr.	8.6	6.0	8.6	8.6	0
Fay Lane	7.3	6.6	LT	6.1	0
Alexander	ND	6.9	7.9	8.8	0
Red Bridge	ND	7.2	6.8	LT	0
S.F @ Baker's	ND	4.8	3.8	4.8	40

B.) Precipitation

The Scott Valley receives little precipitation from June - September. Precipitation data is gathered at two locations on the Scott River. Data is collected as accumulated monthly precipitation at Fort Jones. Data collected in Callahan is accumulated daily precipitation. Table II shows monthly precipitation data gathered at the USFS station in Fort Jones.

Table III.) Accumulated Precipitation - Fort Jones

1997	INCHES	1998	INCHES	1999	INCHES	2000	INCHES
6/1/97	1.26	6/1/98	0.41	6/1/99	0.01	6/1/00	0.41
7/1/97	1.31	7/1/98	0.17	7/1/99	0	7/1/00	0.11
8/1/97	1.1	8/1/98	0	8/1/99	0.46	8/1/00	0.22
9/1/97	0.75	9/1/98	0.65	9/1/99	0	9/1/00	0.16
TOTAL	4.42		1.23		0.47		0.9

With the exception of 1997, all years received less than .5 inches of rain in any given month. Graph 4a-4b show average daily water temperatures collected at Callahan overlaid with daily precipitation data collected at the Callahan Guard Station. This locations shows cooling of water temperatures, with a 1-2 day delay after a rain event.

Tributary Effects

Water temperatures were collected from the East Fork, South Fork, Etna and French Creek to try to determine the effect the tributaries have on mainstem temperatures. Temperature devices on the forks were located one mile up from the confluence. The two tributaries were bracketed above, below, and one device at the mouth of each tributary.

The temperature effect of a tributary is closely tied to flow. The volume of water entering a stream determines the magnitude of cooling or heating. The expected change in temperature will follow the following equation:

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

T1 = temperature of the tributary

T2 = temperature of the river.

Q1 = Flow of the Tributary

Q2 = Flow of the river

Flow data for the Scott River is collected at River Mile 21 by USGS. The tributaries studied in this project are Etna Ck (RM 45) , French Creek (RM 50) and the two Forks (RM59). Flow data collected more than 20 miles away is not useful for making any useful correlation.

However, some trends in tributary influence can be observed over the years. To evaluate the effects of tributaries, water temperatures were collected from the mouths of French Creek and Etna Creek, and on the mainstem above and below the confluence's. The data collected for the East Fork and South Fork is shown in graphs 5a-5c. Temperatures collected on the East Fork (Callahan), South Fork (Baker) and below the confluence (Red Bridge) are overlaid on one graph. The data collected at these locations show a straight forward mixing effect. For all years, the East Fork is on average 5 ^{o} C warmer than the South Fork. The temperature recorded at Red Bridge fall in between the temperatures on the two forks. However, 10 miles downstream at French Creek, river temperature have warmed up to close to that of the E. Fork(Graph 2b -2c). Data collected at French Creek from 1997-2000 is shown in Graphs 6a-6d. Some observations cannot be fully explained. For all years except 1999, the mainstem temperature below French Creek is slightly cooler than above. However, the temperature of French Creek itself varies in each year. During 1997 and 1999, French Creek was slightly cooler than the mainstem. Water temperatures recorded below the confluence in 1999, however, was as warm as above. In 1998 and 2000, French Creek was as warm or warmer than the mainstem, yet cooling is seen below the confluence. These effects could be better understood if flow data was collected at each location where temperature data is collected.

Discussion

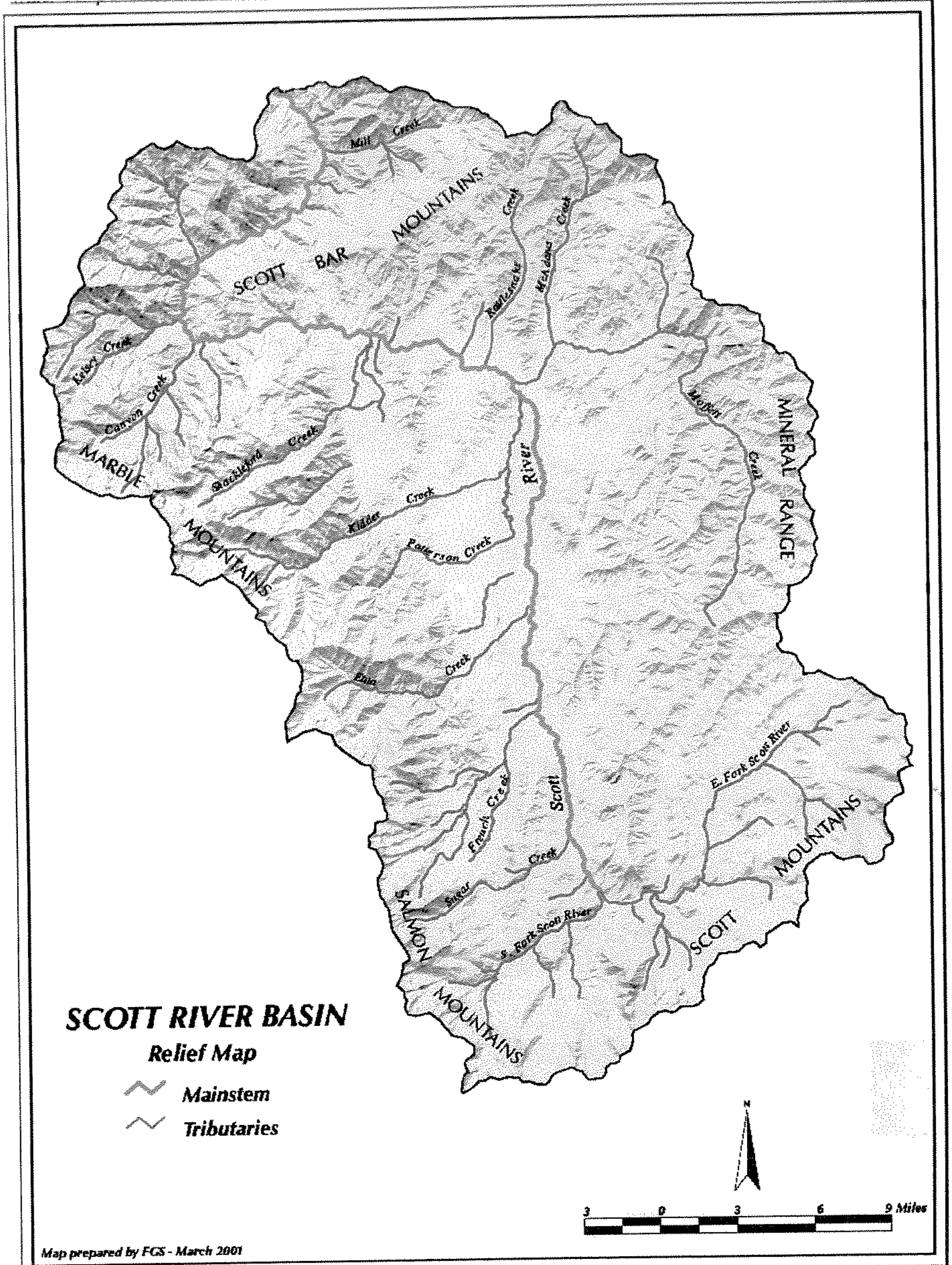
Data collected from 1997-2000 shows that the river temperature is influenced by air temperature. Water temperatures rise and fall in a pattern similar to that of daily air temperature patterns. Mainstem locations showed a daily fluctuation in the range of 6-9 C. The effect of canopy cover on water temperature was not determined. The mainstem locations have less than 5 % canopy cover, and the tributaries varied. Tributary effects were had to determine, due to lack of low data.

Recommendations

Future study should focus more specifically on determining the effects of tributary inflow. Stream flow data should be collected on both forks, at Sugar Creek, Etna Creek, and French Creek. Stream flow measurements above and below the confluence of each tributary would determine which tributaries provide subsurface flows to the mainstem.

Appendix A

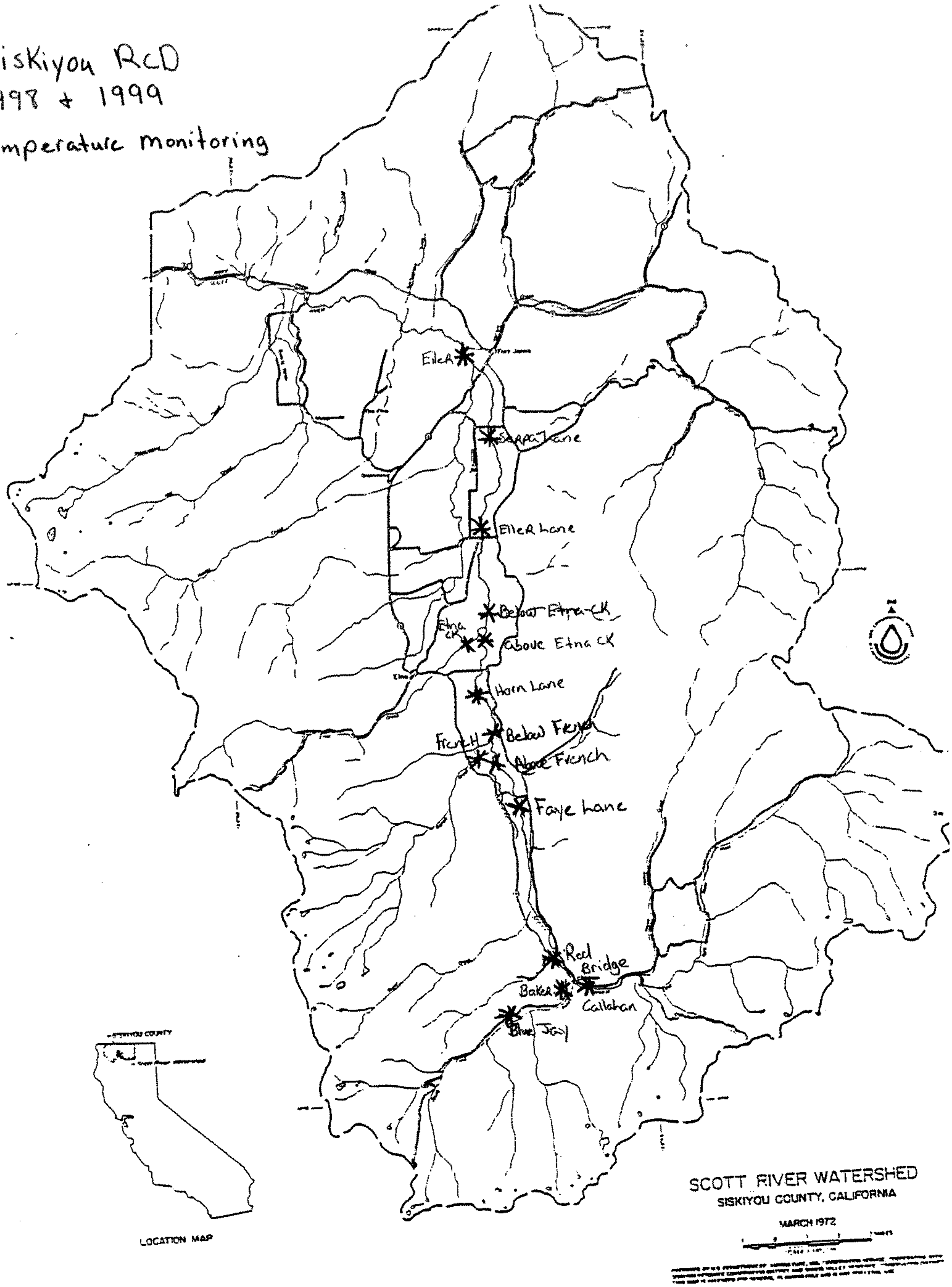
Map of the Scott River Watershed


Mill Creek
SCOTT BAR MOUNTAINS
Rattlesnake Creek
McAdams Creek
Kelsey Creek
Canyon Creek
MARBLE MOUNTAINS
Shackleford Creek
Kidder Creek
Patterson Creek
River
Moffett Creek
MINERAL RANGE
Etna Creek
French Creek
Scott
Sugar Creek
E. Fork Scott River
S. Fork Scott River
SALMON MOUNTAINS
SCOTT MOUNTAINS
SCOTT RIVER BASIN
Relief Map
Mainstem
Tributaries
N
3 0 3 6 9 Miles
Map prepared by FGS - March 2001

Appendix B

Map of Monitoring Locations

Siskiyou RCD
1998 + 1999
Temperature Monitoring



Appendix C

Budget

COOPERATIVE AGREEMENT
11333-0-J019 (2000-JITW-01)
BUDGET

a. Salaries (including benefits)	$6,938.00
b. Travel	200.00
c. Expendable equipment, materials, supplies	894.00
d. Operations and Maintenance	300.00
e. Administrative Costs	833.00
TOTAL PROJECT COST TO USFWS	**$9,165.00**

In-kind Contribution:	$7,036.00
Other Federal Funds	$1,100.00
Total Project Costs:	$17,301.00