FISH HABITAT ASSESSEMENT: A COMPONENT OF THE WATERSHED MANAGEMENT PLAN FOR THE SULPHUR CREEK WATERSHED, NAPA COUNTY, CALIFORNIA

Prepared For

Stewardship Support and Watershed Assessment in the Napa River Watershed:

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by

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1.0 EXECUTIVE SUMMARY

A fish habitat assessment of Sulphur Creek was performed to examine current conditions within the stream that impact aquatic organisms and fish, specifically steelhead (anadromous rainbow trout, *Oncorhynchus mykiss*). The objective of this study was to identify key elements affecting fish habitat and make recommendations to improve and restore the health of the stream. The assessment included habitat-typing surveys, water temperature monitoring, reviewing and summarizing existing data, and GIS analysis. Other habitat conditions were also examined including migration barriers, and suitability of spawning habitat. The fish habitat component is intended to integrate with other technical tasks on geomorphology, water quality, hydrology, sediment delivery, and historical ecology.

Fish habitat conditions were inventoried using CDFG habitat-typing protocols focusing on life history requirements of steelhead. This study found that perennial fish habitat is limited to the middle and upper reaches of Sulphur Creek and most of Heath Canyon. The portion of Sulphur Creek downstream of the Spring street bridge functions primarily as a migration corridor for steelhead, but does not provide adequate summer rearing habitat due primarily to the absence of stream flow. The far upper reaches of Sulphur Creek are not accessible to migrating steelhead due to several natural barriers. Tributaries to Sulphur Creek were not surveyed due to absence of water. Heath Canyon was inventoried recently by CDFG and was not included in the current survey.

In general, pool habitat is lacking good quality cover such as large woody debris (LWD) for juvenile steelhead rearing throughout Sulphur Creek. Pool cover is especially lacking in reach 2 where pools were relatively shallow and open. Pool frequency in this reach was also greatly deficient. Reach 3 and 4 had abundant pools with suitable cover elements including root masses and aquatic vegetation. These pools had the highest number of observed fish including several age classes of steelhead.

Fish were observed throughout the survey including juvenile steelhead, California roach, and sculpin in the middle reaches and steelhead and sculpin further up the watershed. Heath Canyon also has a significant population of steelhead that were observed during temperature and water quality monitoring visits. Heath Canyon provides high quality spawning and rearing habitat that retains surface flow well into the summer. Several large trout were seen in reach 4, which were likely resident fish. The lower reaches had predominantly roach and stickleback in isolated pools. Only one age class of steelhead (young of year) were observed in reach 2. This suggests that few juvenile steelhead successfully overwintered due to lack of high-flow refugia, seasonal drying, or predation in this reach.

Summer water temperatures in pools appear to be suitable for steelhead rearing in reach 2, 3, 4, and 5. Water temperatures measured in reach 1 were above the physiological stress threshold for steelhead. Filamentous green algae was abundant in the isolated pools of reach 1, which had patchy riparian canopy. Urban development encroaches on the riparian zone and into the channel throughout much of lower Sulphur Creek creating unsuitable habitat conditions. Tolerant fish species were observed frequently in this lower reach.

The best available habitat for steelhead spawning and rearing is presently in reach 3 and 4 of main-stem Sulphur Creek, and all of Heath Canyon Creek. Deep pools with good cover and spawning gravels are much more abundant in reach 3 and 4 than all other surveyed reaches.

Steelhead habitat in reach 3 and 4 currently make the most significant contribution to the population, and it appears to be where the majority of fish are located within the main-stem. It is not clear whether the habitat conditions in these reaches reflect historic conditions for most of Sulphur Creek. Efforts to expand the extent of this high-quality habitat into reach 2 and reach 5 could have a great benefit to the steelhead population within Sulphur Creek.

Several potential migration barriers were identified along Sulphur Creek including the extensive dry lower reach. It is important to maintain the extreme lower extent of the stream as a migration corridor for adults and smolts; however, in a given year, the dry lower part of Sulphur probably presents a complete barrier to outward migration during late spring and early summer. Improvements to the lower part of the stream that create more favorable habitat conditions within the creek would increase the odds of a stranded steelhead smolt surviving the dry season in the lower reach. Other potential partial migration barriers include a dam at the top of reach 2, an abandoned summer dam on Heath Canyon and a double-barreled culvert on Heath Canyon. Both obstacles are being removed by CDFG in the next two years. The dam on Sulphur Creek does not prevent fish passage, and likely does not present a major obstacle during most high to moderate flows. However, it has the potential to limit outmigrating smolts during low flows and possibly adults that are moving upstream at the tail end of a high-flow event. Modifications to this structure would not be difficult to allow for complete fish passage. Natural barriers on both the north fork and main-stem limit the upper extent of the fishery.

Riparian canopy density is generally high throughout Sulphur Creek. The stream has a relatively narrow riparian tree zone in the lower reach, which could be improved by planting riparian trees that would provide shade, forage, and a long term source of wood for the aquatic ecosystem.

Successful steelhead spawning appears to occur in reaches 2, 3, 4, and 5 with the best success in reaches 3 and 4 where suitable spawning gravel is abundant. Analysis of spawning gravels in reach 1 and the areas downstream show levels of fine sediment that are just on the cusp of being unfavorable to salmonids. Fine sediment levels measured at several sites are near the threshold at which impacts to steelhead egg survival and fry emergence begin. Reducing the amount of fine sediment delivery to Sulphur Creek may help to maintain current sediment levels. However, geologic sources of fine sediment inputs may provide high background levels, and reductions in anthropogenic sources may not be significant over time (Sediment Source Assessment, Channel Geomorphology). Reducing the amount of fine sediment would likely improve spawning success and the range of suitable spawning habitat.

2.0 INTRODUCTION AND OBJECTIVES

Stream inventories were conducted during June of 2002 on Sulphur Creek. The inventory was conducted in two parts; habitat typing and a visual biological inventory. The objective of the habitat inventory was to document the amount and condition of available habitat to fish, and other aquatic species with an emphasis on anadromous salmonids in the Sulphur watershed. The biological component documented fish species presence in addition to other pertinent observations on flora and fauna. The objective of this report is to document the current habitat conditions, and recommend options for the potential enhancement of aquatic and riparian habitat focusing on steelhead requirements. Recommendations for habitat improvement activities are based upon target habitat values suitable for salmonids in California's north coast streams.

3.0 STEELHEAD LIFE HISTORY
Steelhead are a good indicator species with relatively narrow habitat requirements, which make them the primary focus of this report. Much work has been done in the Napa River basin to identify key factors limiting steelhead populations including the TMDL study, 2002 and numerous other independent studies by CDFG, USFWS, Stillwater Sciences, and other groups. It is important to have a thorough understanding of steelhead ecology prior to interpreting the findings from such endeavors and making recommendations for habitat improvement or restoration.

Rainbow trout (*Onchorynchus mykiss*) occur both as resident fish and as anadromous steelhead (*O. m. irideus*), which migrate to and from the ocean. These two very different life histories occur within the same populations in the same stream. If access to the ocean is available, the steelhead form tends to dominate due to their larger size and increased egg production. However, if the stream contains barriers to upstream migration, steelhead will not return to reproduce, and the resident form will become predominant in populations above the barrier.

Steelhead spend part of their life in freshwater and part in saltwater, and therefore they face a complex set of environmental and physiological challenges. Over time, steelhead have adapted to cope with changes in the natural processes which have shaped their evolution. In the Napa River basin, adult steelhead spawning runs typically begin in mid November and extend through April, depending on early and late season flows.

Fish that make the upstream migration early have the advantage that their young emerge sooner and grow larger in the first year of life. However, they are more vulnerable to heavy winter storms, which can destroy redds and wash away young fish. Steelhead that migrate later in the season run the risk of being stranded by reduced flows to carry them back to the ocean. Most populations contain a mixture of early and late spawning fish, which improves the overall odds of success from year to year.

Steelhead grow rapidly in the ocean and reach sizes much larger than resident rainbow trout. After spending one to three years in the ocean adult fish, typically between 15 to 30 inches in length, return to their rearing streams to spawn. Unlike many other salmonids, a steelhead can make this spawning migration several times over its lifetime. However, in intermittent streams, such as lower Sulphur Creek, low flows during the peak spawning months (January through April) may prevent anadromous fish from reproducing during a given season.

Steelhead spawn by constructing redds (nests) in gravel substrates typically found in pool riffle crests. The female scoops out a shallow depression with powerful movements of the tail and lays eggs within the redd. Accompanying males then fertilize the eggs, and the female quickly buries the redd with gravel. The egg development rate is highly temperature dependent and takes between one to two months. Eggs hatch in about 31 days at 50° F (Flossi et. al., 1998). Like other salmonids, steelhead hatch as alevins (yolk sac fry) and spend their first two to four weeks in the gravel before emerging into the stream.

Young steelhead spend between one to four years in freshwater with two years being most common in central California streams. Juvenile steelhead feed primarily on aquatic insects and other invertebrates in fast water feeding lanes (riffles) and grow rapidly if food is abundant. When sufficient stream flows are sustained to support large aquatic insect populations throughout the year, juvenile steelhead can reach lengths adequate to out-migrate (smolt) in one year. However, in streams with very low summer flows, steelhead grow very little during mid to late summer, and usually require two years or more to grow large enough to migrate to the ocean. Preliminary work by Stillwater Sciences in Napa County, 2001 has suggested stagnant and often negative growth rates during summer months when riffles run dry. Juvenile steelhead survival is positively correlated with smolt size (Moyle, 02). In reaches of Sulphur Creek that lack perennial surface flow, reduced smolt size would be expected, and hence a reduction in smolt survival once they reach the main stem Napa River.

Sulphur Creek is typical of streams throughout Napa County in terms of seasonal flow reductions and complete cessation during summer months (June – September). Only parts of the middle reaches and all of the upper reaches of Sulphur Creek retain perennial surface flow. Heath Canyon remains flowing to some degree year-round during most years. The lower reaches go completely dry with scattered isolated pools.

3.1 REARING AND OVERWINTERING HABITAT

Juvenile steelhead typically spend at least one to two years in freshwater, and must therefore have adequate year-round habitat. Hiding and escape cover provided by undercut banks, fallen trees, boulders and overhanging vegetation, is an important part of year round rearing habitat for juvenile steelhead, especially for larger yearling fish. Most artificial bank protection including concrete walls, sackrete (stacked bags of concrete), and gabions (wire baskets filled with rocks), provides no protective hiding places for fish. Large riprap boulders (2 foot + diameter) can provide a limited amount of cover when placed in the streambed. However, smaller riprap, with small crevices between rocks, provides little hiding cover and often fills in with fine sediment and sand.

The amount of shade provided by trees and other vegetation along the stream affects rearing habitat in many ways. Shade from a dense riparian canopy benefits steelhead by blocking sunlight and keeping water temperatures cool during hot summer periods. However, too much shade prevents photosynthesis from occurring within the stream, thus reducing primary production at the base of the aquatic food web. Additionally, in streams with very dense canopies, the lack of sunlight may affect juvenile steelhead's ability to locate food. A balance of approximately 75% to 90% canopy cover is desirable in most streams of the central coast region.

Riparian trees provide a valuable source of complex habitat structure as large woody debris. When limbs are lost or whole trees fall into the stream, it creates cover for juvenile steelhead and can promote formation of large pools through scouring. The tree leaves that drop into the stream also provide a significant source of nutrients for aquatic macroinvertebrates.

Juvenile steelhead spend typically one or two winters in the stream, and therefore overwintering habitat that provides refuge from the winter storms is critical. This habitat is often in the form of

deep pools with complexity from undercut banks, large woody debris, backwaters, calm eddies, and other refuges from high storm flows. If juvenile steelhead cannot overwinter safely they may never reach sizes sufficient for migration to the ocean or survive once they do reach the ocean. The abundance of larger, yearling steelhead is a good indicator of the year round habitat quality within a stream.

After spawning in winter most adult steelhead make the return migration to the ocean quickly. However, juvenile steelhead begin the physiological changes for smolting (migrating to the ocean) in late March through May. This late migration allows them to feed longer during the most productive time of the year, growing to sizes which increase the chances for survival. This is also a period of rapidly declining streamflows in California, making the downstream journey over barriers, shallow riffles, and drying stream reaches very risky. For many ephemeral or urbanized central coast streams the outmigration period is a primary limiting factor for steelhead populations. Adult access to good spawning and rearing habitat is unable to compensate for low smolt success during most years. If a stream's lower reaches are completely dry during the outmigration period, steelhead populations are typically limited.

3.2 FINE SEDIMENT
Sediment deposition within pools has a deleterious impact on egg development and fry emergence from spawning gravels. Fine sediments from roads, erosion, and other upland sources smother eggs within the redd by blocking water and oxygen flow through the nest. Silt and sand in the streambed provide unstable habitats and fill crevices in the gravel and cobble, reducing aquatic insect and steelhead abundance.

Fine inorganic sediment can have a significant impact on steelhead rearing habitat. Deposition of fine sediment onto the streambed reduces the amount of aquatic insect habitat, and it smothers algae and aquatic plants which make up the base of the food web. As a consequence, the reductions in macroinvertebrate populations, especially aquatic insects, have direct effects on the availability of food to juvenile steelhead. This is especially critical in the seasonal streams of the central coast region. Since the period of maximum steelhead growth occurs for only a few months of the year, the reduction in food supply during this period can lead to a decrease in average smolt size.

The amount of suitable spawning habitat within a stream can directly determine the ability of that stream to support large populations of steelhead. Adult steelhead need access to spawning gravel in areas free of heavy sedimentation with adequate flow and cool, clear water. Steelhead utilize gravel that is between 0.5 to 6 inches in diameter, dominated by 2 to 3 inch gravel. Typically, steelhead use smaller pockets of spawning gravel than other salmonids, and a lack of available suitable spawning gravel is usually not a major limiting factor (Flossi et. al., 1998).

3.3   MIGRATION BARRIERS
Natural and manmade barriers to upstream migration are important factors in steelhead distribution and abundance. Typically in streams with short or easy migrations many adults return younger and smaller, but may return multiple times to reproduce. In streams with longer more difficult migrations, the larger, stronger adults tend to be most common. The "reproduce

early and often" strategy has a distinct advantage in areas that experience severe seasonal variability with droughts, which cut off flow, or floods that destroy redds. A mixture of adult sizes provides the population with the greatest flexibility, and improves survivability over the long term.

Barriers that prevent steelhead passage can be natural or manmade structures. They may prevent passage during all flow conditions or only during periods of low flow. Waterfalls, dry reaches, log jams, and other natural barriers exist to some degree in all streams. These represent naturally occurring stream features and are not generally considered for removal or improvement unless directly related to poor land use or other anthropogenic cause. However, many structures that have been built by humans within streams have a severe impact on migration and reduce the number of steelhead able to reach suitable upstream habitat. Migration barriers, have been identified on Sulphur Creek, which are impeding upstream and downstream migration of salmonids to varying degrees. A fish ladder was installed in 2002 at the Spring Street Bridge to facilitate fish passage. Plans to remove and modify two barriers on Heath Canyon Creek are being implemented in 2003-2004.

Steelhead, like all anadromous salmonids, migrate both downstream as juvenile smolts and upstream as spawning adults. Unlike other salmonids, however, steelhead are capable of making several spawning migrations throughout their lifetimes. During both migrations, steelhead must be able to remain in good condition if they are to survive the following year. If adult fish must negotiate many difficult obstacles along the way to spawning habitat, they are less likely to survive the trip back to the ocean. Likewise, if out-migrating smolts are stressed heavily, they have far lower odds of surviving the rigors of saltwater life.

Dams built for water extraction and other uses often present a major barrier to fish migration, both upstream and downstream. For smaller dams steelhead passage is affected by the height of the dam and the size of the jump pool below. Large adult steelhead can usually handle a jump if the depth of the pool below is 1.25 times the height of the jump (Flossi et. al. 1998). If the dam is too large for adult steelhead to jump over, the genetic tendency for anadromous rainbow trout is reduced above the barrier.

Culverts frequently have a large drop from downcutting below the outlet side that prevents steelhead from passing upstream. If the culvert has riprap boulders or other material below it to prevent downcutting and erosion, the pool below the culvert is usually impacted and can interfere with jumping. Stream flow within the culvert is spread out into a shallow sheet of water that is difficult for adult steelhead to swim across. When culverts are steeply inclined, the combination of high flow velocity and shallow depth make them extremely difficult for all but the strongest adult steelhead to traverse.

4.0 HABITAT INVENTORY METHODS
The habitat inventory conducted in the Sulphur watershed follows the methodology presented in the <u>California Salmonid Stream Habitat Restoration Manual</u> (Flosi and Reynolds, 1994). The two-person field crew that conducted the inventory was trained in standardized habitat inventory methods by the California Department of Fish and Game (DFG).

4.1 SAMPLING STRATEGY
The inventory uses a method that samples approximately 10% of the habitat units within the survey reach. All habitat units included in the survey are classified according to habitat type and their lengths are measured. Habitat unit types encountered for the first time are further measured for all the parameters and characteristics on the field form. Additionally, from the ten habitat units on each field form page, one is randomly selected for complete measurement. Since quantity and quality of pool habitat has been identified as a critical factor affecting salmonid populations in California streams, all pools encountered during this survey were fully measured.

4.2 HABITAT INVENTORY COMPONENTS
A standardized habitat inventory form has been developed for use in California stream surveys by CDFG. This form was used in the Sulphur watershed to record measurements and observations. There are nine components to the inventory form: flow, channel type, temperatures, habitat type, embeddedness, shelter rating, substrate composition, canopy, and bank composition.
1. Flow:
Streamflow is estimated at the beginning of each day of the survey using categories ranging from low to high. Summer flow estimates in California salmonid streams are most often used to determine presence/absence rather than discrete discharge rates during dry summer months.
2. Channel Type:
Channel typing is conducted according to the classification system developed and revised by David Rosgen (1985 rev. 1994). Channel typing is conducted simultaneously with habitat typing and follows a standard form to record measurements and observations. There are five measured parameters used to determine channel type: 1) water slope gradient, 2) entrenchment, 3) width/depth ratio, 4) substrate composition, and 5) sinuosity.
3. Temperatures:
Water and air temperatures, and time, are measured by crew members with hand held thermometers and recorded at each tenth unit typed. Temperatures are measured at the middle of the habitat unit and within one foot of the water surface. Water temperatures are also measured in most pools.
4. Habitat Type:
Habitat typing uses the 24 habitat classification types defined by McCain and others (1988). Habitat units are numbered sequentially and assigned a type identification number selected from a standard list of 24 habitat types. Dewatered units are labeled "DRY". All habitat typing used standard basin level measurement criteria. These parameters require that the minimum length of a described habitat unit must be equal to or greater than the stream's mean wetted width. All unit lengths were measured, additionally, the first occurrence of each unit type and a randomly selected 10% subset of all units were completely sampled (length, mean width, mean depth, maximum depth and pool tail crest depth). As stated above, all pool habitat units were fully measured.
5. Embeddedness:
The depth of embeddedness of the cobbles in pool tail-out reaches is measured by the percent of the cobble that is surrounded or buried by fine sediment. The values were recorded using the following ranges: 0 - 25% (value 1), 26 - 50% (value 2), 51 - 75% (value 3), 76 - 100% (value

4) based on visual estimates. Additionally, a rating of "not suitable" (5) was assigned to tail-outs deemed unsuited for spawning due to inappropriate substrate particle size, having a bedrock tail-out, or other considerations.

6. Shelter Rating:

Instream shelter is composed of those elements within a stream channel that provide salmonids protection from predation, reduce water velocities so fish can rest and conserve energy, and allow separation of territorial units to reduce density related competition. Using an overhead view, a quantitative estimate of the percentage of the habitat unit covered is made. All shelter is then classified according to a list of nine shelter types. A standard qualitative shelter value of 0 (none), 1 (low), 2 (medium), or 3 (high) is assigned according to the complexity of the shelter. The shelter rating is calculated for each habitat unit by multiplying shelter value and percent covered. Thus, shelter ratings can range from 0-300, and are expressed as mean values by habitat types within a stream.

7. Substrate Composition:

Substrate composition ranges from silt/clay sized particles to boulders and bedrock elements. In all fully measured habitat units, dominant and sub-dominant substrate elements were visually estimated using a list of seven size classes.

8. Canopy:

Stream canopy density was measured using modified handheld spherical densiometers as described in the California Salmonid Stream Habitat Restoration Manual, 1994. Canopy density relates to the amount of stream shaded from the sun. In all surveyed streams, an estimate of the percentage of the habitat unit covered by canopy was made from the center of approximately every third unit in addition to every fully-described unit, giving an approximate 30% sub-sample. In addition, the area of canopy was estimated visually into percentages of evergreen or deciduous trees.

9. Bank Composition:

Bank composition elements range from bedrock to bare soil. However, the stream banks are usually covered with grass, brush, or trees. These factors influence the ability of stream banks to withstand winter flows. In all surveyed streams, the dominant composition type and the dominant vegetation type of both the right and left banks for each fully measured unit were selected from the habitat inventory form. Additionally, the percent of each bank covered by vegetation was estimated and recorded.

4.3 BIOLOGICAL INVENTORY

Biological sampling during a stream inventory is used to determine what fish species are present and their general distribution in the stream. Biological inventory is conducted using one or more of three basic methods: 1) stream bank observation, 2) underwater observation, 3) electrofishing. In this study, all surveyed reaches included stream bank observations to document fish presence within the stream.

4.4 IMPACT INVENTORY & ANALYSIS

Problems such as migration barriers, streambed erosion, poor water quality or temperatures are noted and mapped. In some cases measurements are taken, an analysis of what caused the problem is made and restoration potential and alternatives are recommended.

4.5 LEVEL IV HABITAT TYPE KEY:

The following table can be used to identify habitat types in stream report graphs. The codes in the columns on the right represent CDFG codes for field sheets.

HABITAT TYPE	LETTER	NUMBER
RIFFLE		
Low Gradient Riffle	[LGR]	1.1
High Gradient Riffle	[HGR]	1.2
CASCADE		
Cascade	[CAS]	2.1
Bedrock Sheet	[BRS]	2.2
FLATWATER		
Pocket Water	[POW]	3.1
Glide	[GLD]	3.2
Run	[RUN]	3.3
Step Run	[SRN]	3.4
Edgewater	[EDW]	3.5
MAIN CHANNEL POOLS		
Trench Pool	[TRP]	4.1
Mid-Channel Pool	[MCP]	4.2
Channel Confluence Pool	[CCP]	4.3
Step Pool	[STP]	4.4
SCOUR POOLS		
Corner Pool	[CRP]	5.1
Lateral Scour Pool - Log Enhanced	[LSL]	5.2
Lateral Scour Pool - Root Wad Enhanced	[LSR]	5.3
Lateral Scour Pool - Bedrock Formed	[LSBk]	5.4
Lateral Scour Pool - Boulder Formed	[LSBo]	5.5
Plunge Pool	[PLP]	5.6
BACKWATER POOLS		
Secondary Channel Pool	[SCP]	6.1
Backwater Pool - Boulder Formed	[BPB]	6.2
Backwater Pool - Root Wad Formed	[BPR]	6.3
Backwater Pool - Log Formed	[BPL]	6.4
Dammed Pool	[DPL]	6.5

5.0 HABITAT INVENTORY RESULTS

A habitat inventory of Sulphur Creek, 8/21/2002 - 9/9/2002, was conducted by J. Koehler and M. Champion. The survey began at the confluence with the Napa River and extended up Sulphur Creek in stratified sections to the end of anadromous fish passage at a series of rock falls. Landowner access and presence of flows also limited the extent of the survey. The total length of stream surveyed was 9,988 feet in the main stem and 1,435 feet in the north fork.

Surface flow was highly variable along various reaches of Sulphur Creek during the survey period (see habitat survey reach map). In general, the lower reaches exhibited seasonal drying while middle and upper reaches retained low to moderate flows. This survey was limited to those portions of Sulphur Creek that had water and therefore could be used as year-round rearing habitat for fish and aquatic organisms. The survey did not include Sulphur's largest tributary, Heath Canyon Creek, due to recent habitat surveys completed by CDFG.

The surveyed section of main-fork Sulphur Creek has four reaches with four distinct channel types. From the confluence with the Napa River approximately 982 feet of F4 channel type were surveyed. The survey was restarted at the Spring Street bridge and extended upstream for 5,191 feet, which is C3 channel. The survey restarted at the confluence with the north fork and continued up the main-stem, which included 2,235 feet of F3 channel followed by 1,580 feet of B2 channel. The surveyed reach of the north fork has 1,435 feet of F4 channel. The north fork was dry at the confluence with the main-stem during the survey, and only minimal surface flow was present approximately 1,000 feet upstream where the survey reach began.

• B2 channel types are moderately entrenched, moderate gradient (2-4%), riffle dominated channels, with infrequently spaced pools, a very stable plan and profile, stable banks and have a predominantly boulder substrate.

• C3 channel types are low gradient (<2%), meandering, point-bar, riffle/pool, alluvial channels with a broad, well defined floodplain and a predominantly cobble substrate.

• F3 channel types are entrenched meandering riffle/pool channels on low gradients (<2%) with a high width/depth ratio and a predominantly cobble substrate.

• F4 channel types are entrenched meandering riffle/pool channels on low gradients (<2%) with a high width/depth ratio and a predominantly gravel substrate.

Water temperatures ranged from 13ºC to 20ºC. Air temperatures ranged from 13ºC to 27ºC. Summer temperatures were also measured using remote temperature recorders placed in pools. The results of water temperature monitoring are discussed in Section 6.0 (Water Temperature Monitoring, Sulphur Creek).

Table 1 summarizes the Level II riffle, flatwater, and pool habitat types for main-stem Sulphur Creek. Based on frequency of *occurrence* there were 34% pool units, 33% riffle units, 33% flatwater units and less than 1% dry units (Graph 1). Based on total *length* there were 41% riffle units, 34% flatwater units, 22% pool units and 2% dry units (Graph 2).

A total of 217 habitat units were measured and 37% were completely sampled. Within these 217 units, 18 Level IV habitat types were identified (Table 2).   An additional 27 habitat units were measured in the north fork (reach 5) that are not included in the

following summaries. A brief habitat summary for the north fork is given at the end of this section.

In main-stem Sulphur Creek, 73 pools were identified (Table 3). Mid-channel pools were most often encountered at 16%, and comprised 45% of the total length of pools (Graph 4).
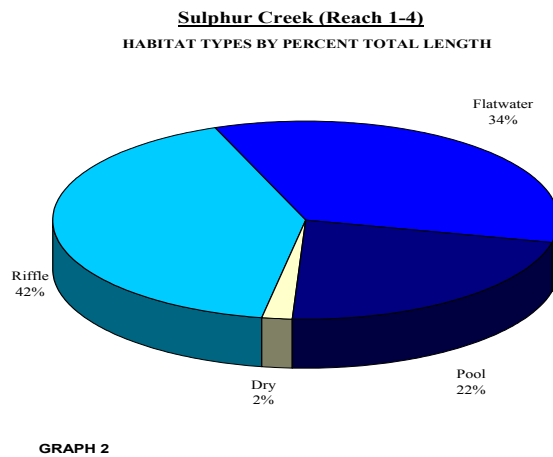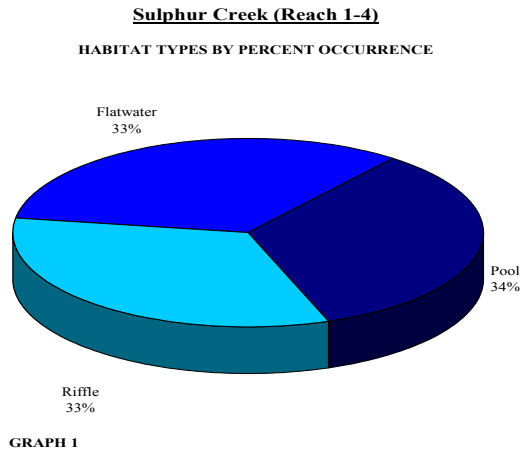
Sulphur Creek (Reach 1-4)

HABITAT TYPES BY PERCENT OCCURRENCE

Flatwater
33%

Pool
34%

Riffle
33%

GRAPH 1

Sulphur Creek (Reach 1-4)
HABITAT TYPES BY PERCENT TOTAL LENGTH

Flatwater
34%

Riffle
42%

Pool
22%

Dry
2%

GRAPH 2

Table 4 is a summary of maximum pool depths by pool habitat types. In general, pool quality for salmonids and other aquatic organisms increases with depth. In Sulphur Creek, 19 of the 73 pools (26%) had a depth of two feet or greater (Graph 5). These deeper pools comprised 7% of the total length of stream habitat. Furthermore, 4 of the 73 pools (5%) had a depth of three feet or greater (Graph 5). These deeper pools comprised approximately 2% of the total length of stream habitat.

Sulphur Creek (Reach 1-4)
HABITAT TYPE BY PERCENT OCCURRENCE
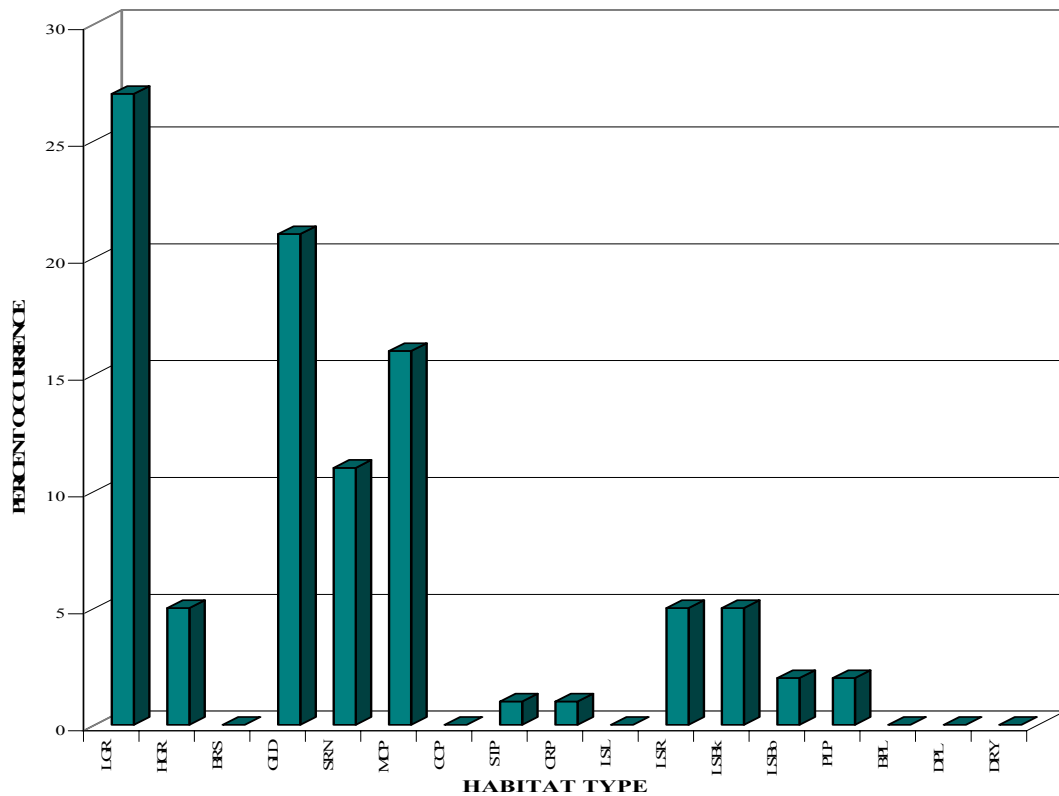
GRAPH 3

A shelter rating was calculated for each habitat unit and expressed as a mean value for each habitat type within the survey using a scale of 0-300. Flatwater units rated 8, riffles rated 5, and pools rated 38 (Table 1). Of the pool types, corner pools rated highest with a mean shelter value of 85 (Table 3).

Table 5 summarizes fish shelter by habitat type. By percent area, the dominant pool shelter types were root masses at 20% and boulders at 19% (Graph 7).

Sulphur Creek (Reach 1-4)

POOL HABITAT TYPES BY PERCENT OCCURRENCE
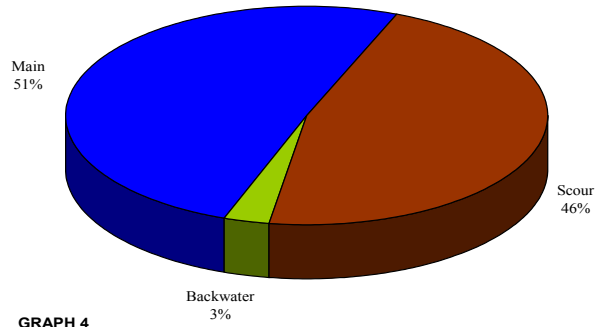
GRAPH 4

Sulphur Creek (Reach 1-4)

MAXIMUM POOL DEPTHS
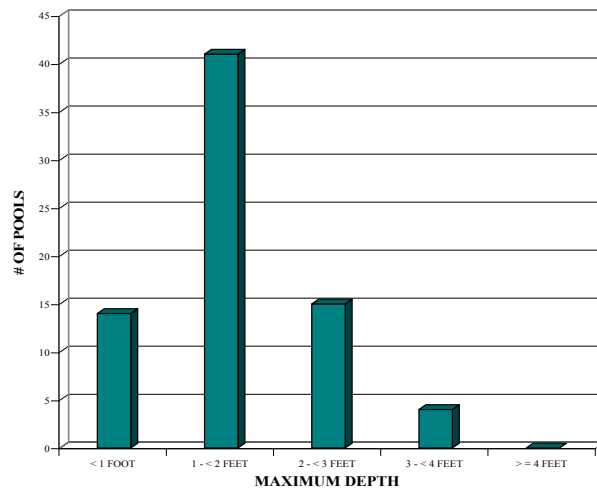
GRAPH 5

Table 6 summarizes the dominant substrate by habitat type. In the 58 low-gradient riffles surveyed, the dominant substrate was gravel (Graph 8).

Sulphur Creek (Reach 1-4)

PERCENT EMBEDDEDNESS

VALUE 2
16%

VALUE 3
3%

VALUE 4
3%

VALUE 5
12%

VALUE 1
66%
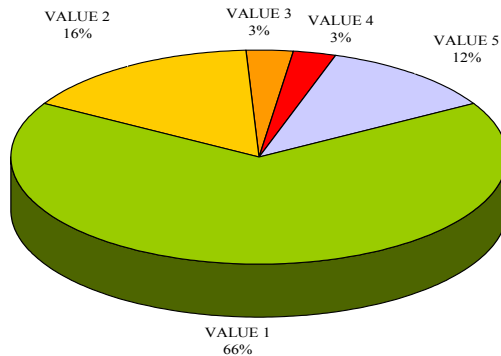
GRAPH 6

McNeil sampling was conducted during the summer of 2002 in the field by Sarah Pearce and Matt O'Connor. Laboratory analysis showed a sample from reach 1 to be 16% fines (<1 mm). Another sample from reach 5 contained 15% fines. Other samples in the lower reaches of Sulphur Creek contained levels of 6% and 13% fines. The combined summary of all four samples averaged 11% fines. Results of sediment samples will be included in the channel geomorphology report by San Francisco Estuary Institute (SFEI).

Sulphur Creek (Reach 1-4)

MEAN PERCENT COVER TYPES IN POOLS

WHITEWATER
2%

AQUATIC VEG
2%

ROOTS
9%

SMALL WOODY
DEBRIS
10%

BOULDERS
24%

TERRESTRIAL
VEG
12%

LARGE WOODY
DEBRIS
15%

UNDERCUT
BANKS
14%

BEDROCK
LEDGES
12%
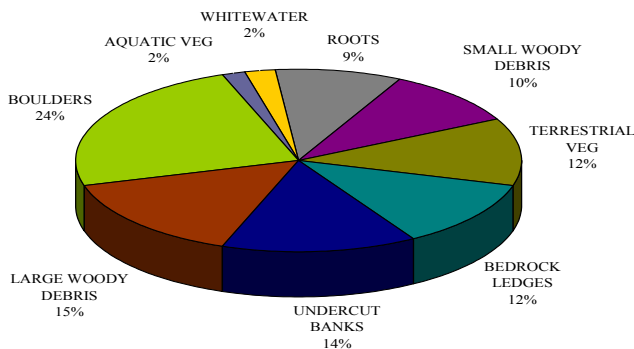
GRAPH 7

Sulphur Creek (Reach 1-4)
SUBSTRATE COMPOSITION IN POOL TAIL-OUTS
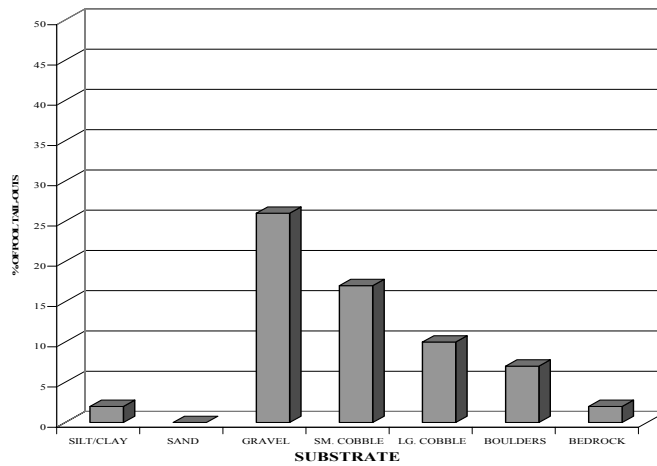
GRAPH 8

The depth of cobble embeddedness was estimated at pool tail-outs. Of the 64 pool tail-outs measured, 41 had a value of 1 (64%), 11 had a value of 2 (17%), 2 had a value of 3 (3%) and 1 had a value of 4 (2%). An additional 9 (14%) riffles rated a 5 which is unsuitable substrate type for spawning (Graph 6). On this scale, a value of one is best for spawning. Gravel was the dominant substrate observed at pool tail-outs (Graph 8).

The mean percent canopy density for the stream reach surveyed was 92%. The mean percentages of deciduous and evergreen trees were 68% and 32%, respectively (Graph 9)

Sulphur Creek (Reach 1-4)
PERCENT CANOPY

DECIDUOUS
TREES
68%

EVERGREEN
TREES
32%

GRAPH 9

16
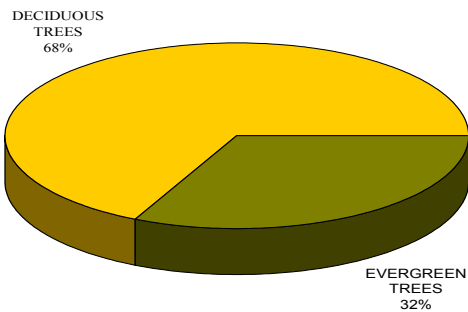
For the entire stream reach surveyed, the mean percent right bank vegetated was 57% and the mean percent left bank vegetated was 66%. The dominant vegetation types for the stream banks were deciduous trees and brush (Graph 11). The dominant substrate for the stream banks were cobble and gravel (Graph 10).

Sulphur Creek (Reach 1-4)

DOMINANT BANK COMPOSITION IN SURVEY REACH

SILT/CLAY
30%

COBBLE/
GRAVEL
14%

BEDROCK
23%

BOULDER
14%

GRAPH 10

Sulphur Creek (Reach 1-4)

DOMINANT BANK VEGETATION IN SURVEY REACH

DECIDUOUS
TREES
41%

BRUSH
35%

EVERGREEN
TREES
17%

GRASS
6%

NO
VEGETATION
1%
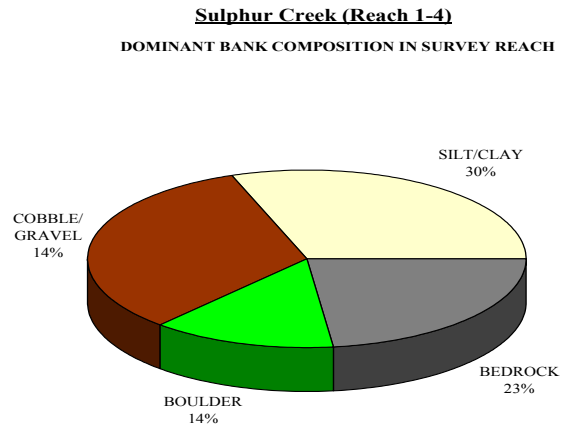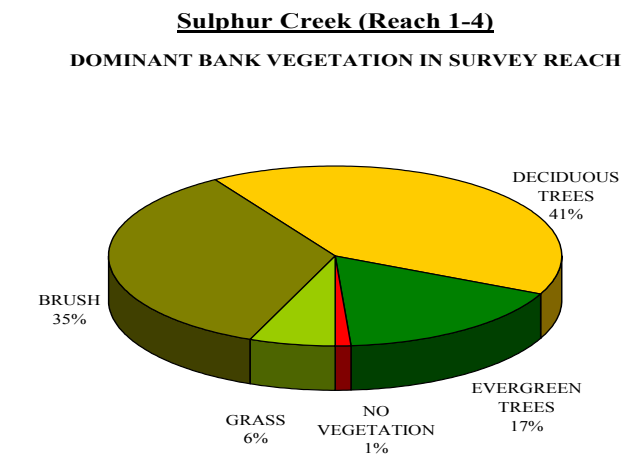
GRAPH 11

5.1 Discussion

Recommendations for habitat enhancement within each channel type are based on physical characteristics. These recommendations offer an initial overview of possible bio-engineering solutions to improve habitat for fish. Projects can be implemented at critical locations within the stream to supplement upslope and land-use changes throughout the watershed. All of the following guidelines have been developed using the CDFG Salmonid Stream Habitat Restoration Manual

There are 982 feet of F4 channel in reach 1, and 1,435 feet of F4 channel in reach 5. In general, F4 channel types are good for bank-placed boulders and fair for low-stage weirs, single and opposing wing-deflectors, channel constrictors and log cover.

There are 5,191 feet of C3 channel in reach 2. In general, C3 channel types are excellent for bank-placed boulders and good for low-stage weirs, boulder clusters, single and opposing wing deflectors and log cover. They are fair for medium-stage weirs.

There are 2,235 feet of F3 channel in reach 3. In general, F3 channel types are good for bank-placed boulders as well as single and opposing wing-deflectors. They are fair for low-stage weirs, boulder clusters, channel constrictors and log cover. Many site specific projects can be designed within this channel type, especially to increase pool frequency, volume and shelter. Any work considered will require careful design, placement, and construction that must include protection for any unstable banks.

There are 1,580 feet of B2 channel in reach 4. In general, B2 channel types are excellent for low and medium-stage plunge weirs, single and opposing wing deflectors and bank cover. These channel types have suitable gradients and the stable stream banks that are necessary for the installation of in-stream structures designed to increase pool habitat, trap spawning gravels, and provide protective shelter for fish.

The water temperatures recorded on the survey days 8/21/2002 - 9/9/2002 ranged from 13ºC to 21ºC. Air temperatures ranged from 13ºC to 27ºC. The warmest water temperatures were recorded in Reach 1. Water temperature was 20°C in Reach 3 where thermal springs enter the stream, but quickly dropped to 17° C within 200 meters downstream. The temperature regime in Sulphur Creek appears to be favorable for steelhead, except in reach 1 which showed elevated water temperatures in several pools. It is unknown if this thermal regime is typical from year to year, but fish were observed more frequently in the upper, cooler sample sites. No trout were seen in reach 1. To make any further conclusions, long term monitoring would be necessary.

In main-stem Sulphur Creek, pools comprised 22% of the total *length* of this survey. In third and fourth order streams a primary pool is defined to have a maximum depth of at least three feet, occupy at least half the width of the low flow channel, and be as long as the low-flow channel's width. In Sulphur Creek, the pools are relatively shallow with only 5% having a maximum depth of at least three feet. These pools comprised just 2% of the total length of stream habitat. In coastal salmon and steelhead streams, it is

generally desirable to have primary pools comprise approximately 50% of total habitat length. In more arid streams such as Sulphur Creek pool habitat targets of 30% total length are generally accepted.

The mean shelter rating for pools was 38. However, a pool shelter rating of 70 or above is desirable. The relatively small amount of pool shelter that now exists is being provided primarily by root masses and boulders. Log and root wad cover in pool and flatwater habitats would improve both summer and winter fish habitat. Log cover provides rearing fry with protection from predation, rest from water velocity, and also divides territorial units to reduce density related competition.

In main-stem Sulphur Creek 5 of the 7 low gradient riffles measured (71%) had either gravel or small cobble as the dominant substrate. This is suitable for spawning salmonids and also favorable substrate for supporting healthy benthic macroinvertebrate populations.

Only 5% of the pool tail-outs measured had embeddedness ratings of either 3 or 4 while 64% had a rating of 1.   Cobble embeddedness measured to be 25% or less (a rating of 1) is considered best for spawning salmon and steelhead. The amount of fine sediment in potential spawning habitat seems to be minimal throughout most of the surveyed reaches.

The mean percent canopy for the survey was 92%, which is very good; 80 percent or greater is generally considered desirable. Canopy was lowest in reach 1 due to urban encroachment into the riparian zone. Elevated water temperatures may be reduced in the lower reach by increasing stream canopy. The large trees required for adequate stream canopy would also eventually provide a long term source of large woody debris needed for in-stream shelter and bank stability.

5.2 CONCLUSIONS AND RESTORATION PRIORITIES

1. The current amount of pool shelter and hiding cover is deficient in reach 2 and 5. Projects that add complexity with larger woody cover (LWD) or other shelter would greatly enhance habitat quality in these reaches, and expand the amount of good summer rearing habitat. Most pools in reach 3 had adequate shelter and can be used as a guide for improving pools in the other sections of the stream. Combination cover/scour structures constructed with boulders and woody debris may be effective in some pool and flatwater locations in reach 2. This must be done where the banks are stable or in conjunction with stream bank armor to prevent excessive erosion.

2. Pool frequency and quality is deficient in reach 2 and 5. If feasible, increase the number of deep pools in these reaches. The suitability of each reach for these types of projects is discussed in the results section above. Since geomorphic and hydrologic limitations exist in these two reaches a broad approach to stream habitat improvement may be more effective in the long term. Rather than focusing on specific restoration sites exclusively, it is important to address upslope and instream processes that are contributing to the general lack of suitable fish habitat. Also, it may be ineffective to increase pool frequency and depth in these reaches without addressing upslope and in-

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stream factors such as high sediment loading and riparian vegetation densities. Restoration and habitat improvement efforts at the watershed scale would be more likely to create a stable aquatic ecosystem that improves fish populations living within it.

3. Sulphur Creek had a low level of embeddedness throughout the middle and upper surveyed reaches, but gravel analysis suggest that current levels of fine sediment are very near values at which negative impacts to steelhead spawning begin. Anthropogenic sources of fine sediment include roads, culverts, agriculture, livestock, and some landslides. Active and potential upslope and in-channel sediment sources have been identified, mapped, and treated according to their potential for sediment yield to the stream and its tributaries (Channel Geomorphology, Sediment Source Assessment).

4. Stream bank erosion along Sulphur Creek is evident in all reaches and general riparian thinning and removal is evident in much of reach 1. Site locations were noted during habitat surveys for future enhancement and restoration. These sites would benefit from native vegetation plantings and simple erosion prevention techniques. If planted in conjunction with trees, these sites would serve a dual purpose to reduce bank erosion and restore canopy function which in turn improves water temperatures and water quality.

5. Migration barriers limit the geographic range of steelhead populations within Sulphur Creek. Several potential partial fish passage barriers were identified along the main-stem as well as natural full migration barriers on both forks that define the upper limit of the fishery. Further investigation is needed during periods of higher streamflow to determine the extent to which these various obstructions limit fish passage. Juvenile steelhead were observed in Sulphur Creek above a concrete dam at the top of reach 2. All potential barriers need to be examined prior to removal or modification to allow for fish passage. Removing barriers to fish passage would allow steelhead to fully utilize available habitat within Sulphur Creek, and may improve outmigration success. Generally, barrier modification or removal should be implemented if fish are unable to pass during at least 90 percent of anticipated flows, but each situation requires careful planning and consideration.

 6. Surface flow is limited in lower Sulphur Creek during summer months. These low flows limit the amount of habitat and food available to rearing steelhead. Additionally, low flows amplify the impacts of reduced riparian cover, which can lead to lethal temperatures and degraded water quality. Flows should be visually assessed regularly to determine what reaches are being affected the most in terms of cumulative impacts to juvenile fish. In reaches 2 and 5, flows were intermittent and did not appear to be adequate to support large numbers of rearing fish.

7. The lower reach of Sulphur Creek that goes completely dry acts mainly as a migration corridor for steelhead and as seasonal stream habitat for other riparian species. Efforts to define the channel and increase riparian canopy would improve the migration routes of adults and may greatly improve outmigrant success during late spring. During the smolt outmigration period, a more distinct channel with cover and adequate depth would increase the odds of successful passage through this long and wide section of the stream.

Channel geomorphology in this reach may limit the feasibility of such an effort due the large amount of sediment deposited during winter storm events. Further exploration of possible habitat improvement alternatives in the dry gravel mining area may be warranted based on the potential benefits to several lifestages of steelhead.

5.3 FISH HABITAT SUMMARY BY STREAM REACH

STREAM REACH 1

Channel Type: f4	Canopy Density: 64%
Channel Length: 982 ft.	Coniferous Component: 22%
Riffle/flatwater Mean Width: 19.5 ft.	Deciduous Component: 68%
Total Pool Mean Depth: 1.1 ft.	Pools by Stream Length: 30%
Base Flow: N/A	Pools >=3 ft.deep: 0%
Water: 17 - 18 °C Air: 16 °C	Mean Pool Shelter Rtn: 31
Dom. Bank Veg.: Deciduous Trees	Dominant Shelter: Root masses
Vegetative Cover: 47%	Occurrence of LWD: 0%
Dom. Bank Substrate: Cobble/Gravel	Dry Channel: 0 ft.

Length of stream sections not surveyed within survey reach: 0 ft.
Embeddness Value: 1. 0%   2. 25%   3. 50%   4. 25%

STREAM REACH 2

Channel Type: c3	Canopy Density: 95%
Channel Length: 5191 ft.	Coniferous Component: 15%
Riffle/flatwater Mean Width: 5.2 ft.	Deciduous Component: 85%
Total Pool Mean Depth: 0.7 ft.	Pools by Stream Length: 17%
Base Flow: N/A	Pools >=3 ft.deep: 3%
Water: 16 - 19 °C Air: 19 - 27 °C	Mean Pool Shelter Rtn: 33
Dom. Bank Veg.: Deciduous Trees	Dominant Shelter: Boulders
Vegetative Cover: 62%	Occurrence of LWD: 7%
Dom. Bank Substrate: Cobble/Gravel	Dry Channel: 249 ft.

Length of stream sections not surveyed within survey reach: 0 ft.
Embeddness Value: 1. 68%   2. 32%   3. 0%   4. 0%

STREAM REACH 3

Channel Type: f3	Canopy Density: 99%
Channel Length: 2286 ft.	Coniferous Component: 53%
Riffle/flatwater Mean Width: 5.9 ft.	Deciduous Component: 46%
Total Pool Mean Depth: 1.2 ft.	Pools by Stream Length: 32%
Base Flow: N/A	Pools >=3 ft.deep: 14%
Water: 13 - 20 °C Air: 13 - 19 °C	Mean Pool Shelter Rtn: 39
Dom. Bank Veg.: Deciduous Trees	Dominant Shelter: Undercut Banks
Vegetative Cover: 67%	Occurrence of LWD: 8%
Dom. Bank Substrate: Cobble/Gravel	Dry Channel: 0 ft.

Length of stream sections not surveyed within survey reach: 0 ft.
Embeddness Value: 1. 88%   2. 12%   3. 0%   4. 0%

STREAM REACH 4
 Channel Type: b2   Canopy Density: 95%
 Channel Length: 1580 ft.   Coniferous Component: 46%
 Riffle/flatwater Mean Width: 5.8 ft.   Deciduous Component: 54%
 Total Pool Mean Depth: 0.8 ft.   Pools by Stream Length: 19%
 Base Flow: N/A   Pools >=3 ft.deep: 0%
 Water: 14 - 15 °C Air: 18 - 25 °C   Mean Pool Shelter Rtn: 50
 Dom. Bank Veg.: Deciduous Trees   Dominant Shelter: Boulders
 Vegetative Cover: 66%   Occurrence of LWD: 5%
 Dom. Bank Substrate: Cobble/Gravel   Dry Channel: 0 ft.
 Length of stream sections not surveyed within survey reach: 0 ft.
 Embeddness Value: 1. 100%   2. 0%   3. 0%   4. 0%

STREAM REACH 5 (North Fork)
 Channel Type: f4   Canopy Density: 84%
 Channel Length: 1435 ft.   Coniferous Component: 37%
 Riffle/flatwater Mean Width: 3.5 ft.   Deciduous Component: 63%
 Total Pool Mean Depth: 0.5 ft.   Pools by Stream Length: 3%
 Base Flow: N/A   Pools >=3 ft.deep: 0%
 Water: 15 °C Air: 19 - 22 °C   Mean Pool Shelter Rtn: 38
 Dom. Bank Veg.: Deciduous Trees   Dominant Shelter: Large Woody Debris
 Vegetative Cover: 55%   Occurrence of LWD: 33%
 Dom. Bank Substrate: Cobble/Gravel   Dry Channel: 118 ft.
 Length of stream sections not surveyed within survey reach: 0 ft.
 Embeddness Value: 1. 0%   2. 50%   3. 50%   4. 0%

SULPHUR CREEK

CALFED III
Fish Habitat Assessment

Survey Reach Map: Reaches are based on channel types measured during habitat surveys. Note the survey did not include areas of Sulphur Creek or its tributaries where surface flow or permanent aquatic habitat was absent.

Legend

REACH
— 1
— 2
— 3
— 4
— 5

～ Heath Canyon
～ Napa River
～ Sulphur Creek
---- Roads
▢ Sulphur Creek Watershed
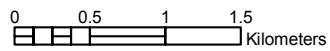
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0   0.25   0.5   1   1.5
                                    Miles

0   0.5   1   1.5
                            Kilometers

Napa County Resource Conservation District

Map by Jonathan Koehler
Napa County RCD
January, 2003
ArcGIS 8.2
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q

North Fork Sulphur

Dry between these two points 8/22/02

Dry 9/9/02

Upper migration limit

Sulphur Creek

Heath Canyon

Highway 29

5

3

4

2

2

1
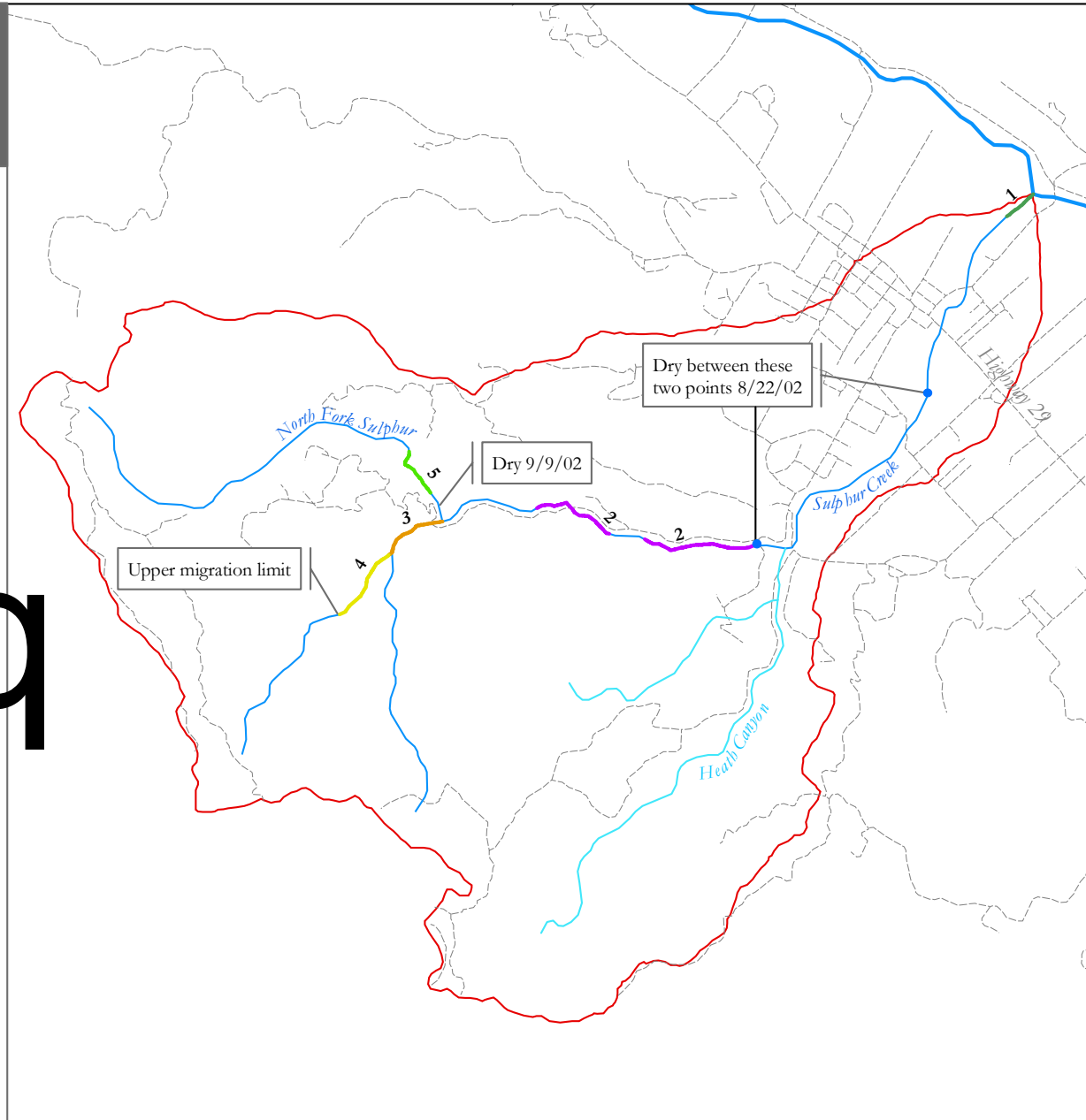
SULPHUR CREEK
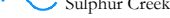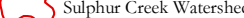
CALFED III
Fish Habitat Assessment

Habitat-Type Map: All habitat units are grouped by function and physical characteristics according to Level III habitat methodologies, which summarize stream features based on fish habitat requirements.

Legend

Habitat Type
- Riffle
- Cascade
- Flatwater
- Main Channel Pool
- Scour Pool
- Backwater Pool
- Dry

- Heath Canyon
- Napa River
- Sulphur Creek
- Roads
- Sulphur Creek Watershed

Scale =1:41,000

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0   0.25   0.5        1          1.5
                                     Miles
```

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0        0.5       1      1.5
                              Kilometers
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Napa County Resource Conservation District

Map by Jonathan Koehler
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January, 2003
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North Fork Sulphur

Sulphur Creek

Highway 29

Heath Canyon

SULPHUR CREEK

CALFED III
Fish Habitat Assessment

**Summer Rearing Habitat Map:
Maximum depths were measured
in all pools. Deep pools (>3 ft)
provide good summer rearing
habitat for juvenile steelhead.
These deeper pools also provide
high-flow refugia during winter**

Legend

Maximum Depth

— < 1 ft.
— 1 - 2 ft.
— 2 - 3 ft.
— > 3 ft.

〜 Heath Canyon
〜 Napa River
〜 Sulphur Creek
- - - Roads
▢ Sulphur Creek Watershed
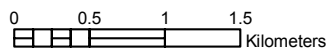
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| 0 | 0.25 | 0.5 | 1 | 1.5 | |
Miles

| 0 | 0.5 | 1 | 1.5 | |
Kilometers

Napa County Resource Conservation District

North Fork Sulphur

Sulphur Creek

Highway 29

Heath Canyon

q

SULPHUR CREEK

CALFED III
Fish Habitat Assessment

Riparian Canopy Map:
Canopy densities were measured
in approximately 30% of surveyed
units using a spherical densiometer.

Legend

Percent Riparian Canopy

— < 25% (Very Low)
— 26 - 50 % (Low)
— 51 - 75 % (Marginal)
— 76 - 100 (High)

∿ Heath Canyon
∿ Napa River
∿ Sulphur Creek
--- Roads
⬭ Sulphur Creek Watershed
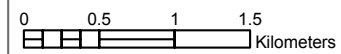
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0 0.25 0.5 1 1.5
Miles

0 0.5 1 1.5
Kilometers

Napa County Resource Conservation District

Map by Jonathan Koehler
Napa County RCD
January, 2003
ArcGIS 8.2
G:\GIS\Projects\sulphur.mxd

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North Fork Sulphur

Sulphur Creek

Heath Canyon

Highway 29

SULPHUR CREEK

CALFED III
Fish Habitat Assessment

Spawning Habitat Map:
Cobble embeddness was visually estimated in pool tail-outs where steelhead typically dig spawning redds. High levels of cobble embeddedness (>50%) indicate potentially excessive amounts of fine sediment within the stream. Pool tail-outs with unsuitable substrate (e.g.- bedrock) were given a value of 5.
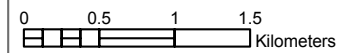
Legend

Cobble Embeddedness

Value 1 (<25%)
Value 2 (25-50%)
Value 3 (50-75%)
Value 4 (75-100%)
Value 5 (Not Suitable)

Heath Canyon
Napa River
Sulphur Creek
Roads
Sulphur Creek Watershed

Scale =1:41,000

0   0.25   0.5   1   1.5
Miles

0   0.5   1   1.5
Kilometers

Napa County Resource Conservation District

Map by Jonathan Koehler
Napa County RCD
January, 2003
ArcGIS 8.2
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North Fork Sulphur

Sulphur Creek

Highway 29

Heath Canyon
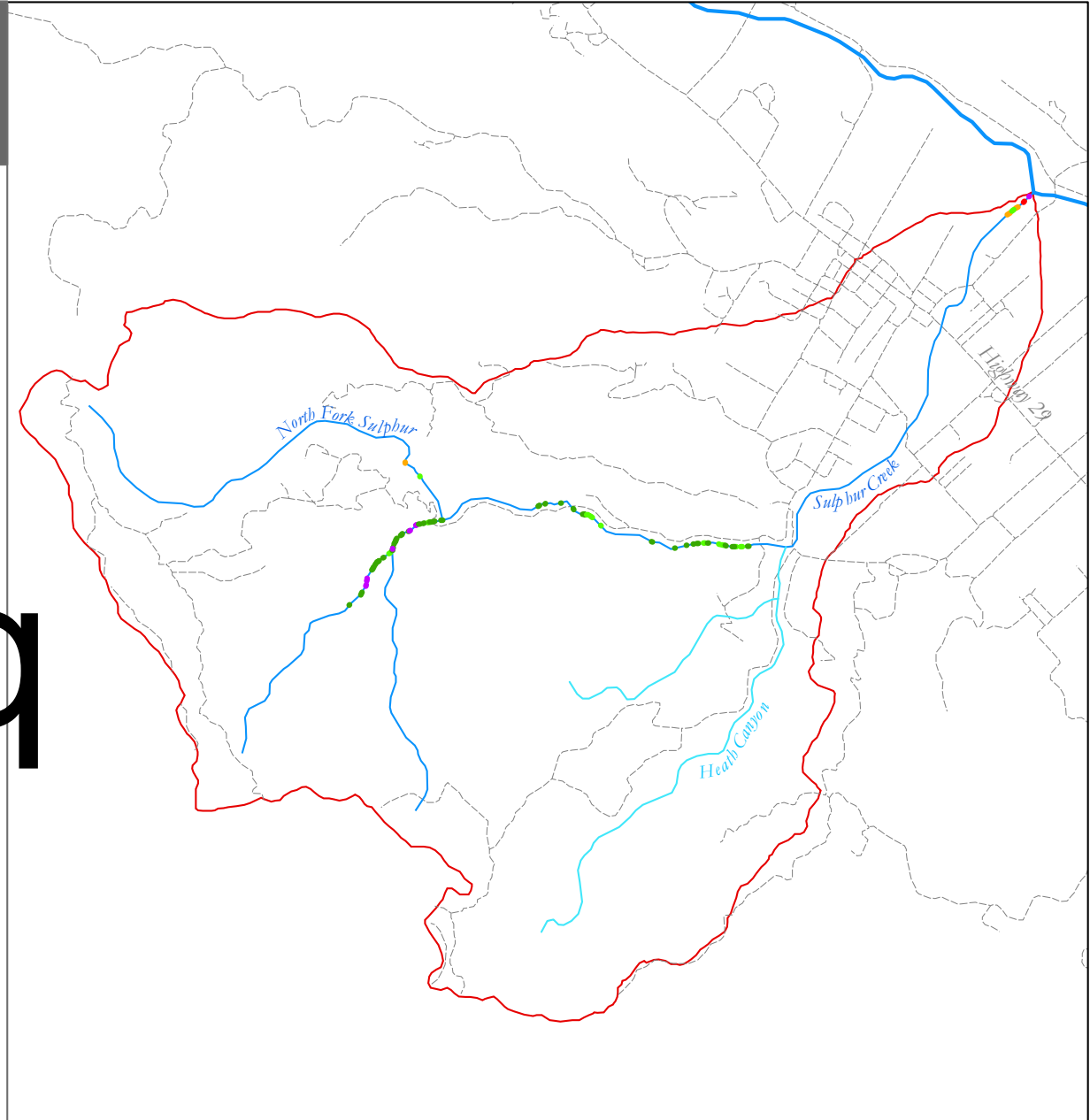
SULPHUR CREEK

CALFED III
Fish Habitat Assessment

Data on steelhead (Oncorhynchus mykiss) distribution and relative abundance were collected via snorkel surveys during spring of 2001. The surveys were conducted by Friendsof the Napa River, Napa County RCD, and volunteers with technical oversight by Ecotrust Environmental Inc.

Legend

Steelhead Survey Results

— Not Surveyed
— Not present
— Low (0 -0.5/sq. m)
— Medium (0.5 - 1/sq. m)
— High (> 1/sq. m)

∼ Heath Canyon
∼ Napa River
∼ Sulphur Creek
- - - Roads
⬭ Sulphur Creek Watershed

Scale =1:40,995
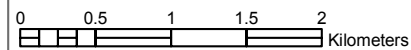
```
0   0.25   0.5        1           1.5
                                    Miles
```

```
0      0.5     1      1.5     2
                              Kilometers
```

q

Napa County Resource Conservation District

North Fork Sulphur

Sulphur Creek

Highway 29

Heath Canyon

6.0 WATER TEMPERATURE MONITORING

Water temperatures within a stream, particularly during spring, summer, and fall, have a major effect on the health and survival of steelhead. Seasonal fluctuations in water temperatures are caused by an array of factors, which include air temperature, instream flow, groundwater influence, riparian shading, and other factors. Like all salmonids, steelhead are characterized as a coldwater species, exhibiting relatively low tolerance for elevated water temperatures. Exposure to elevated water temperatures may lead to reduced health and fitness, reduced growth rates, increased susceptibility to predation and disease, and depending on life-stage and duration of the exposure, may cause direct mortality. The effects of water temperature on steelhead vary greatly with life stage, and from one geographic population to another. Despite these variations, generalized guidelines for water temperatures can be established for use in evaluating the suitability of habitat conditions within the Sulphur Creek watershed.

This study focused on steelhead rearing habitat, which experiences the highest temperatures from June through October in typical intermittent Northern California streams such as Sulphur Creek. Water temperatures during the winter-run period and early spring when alevins emerge are also of great importance to the health of steelhead populations, and would be a valuable set of data to fully document spawning and incubation conditions. However, in Sulphur Creek, the primary impact from elevated temperatures is most likely during summer and early fall, particularly in isolated pools created by intermittent flows. In general, during critical rearing months (July-September), stream temperatures are non-stressful to juvenile steelhead if average daily temperatures are 20° C (68° F) or less, with maximum hourly temperatures of approximately 23° C (73° F) or less. The optimal temperatures for growth of rainbow trout are around 15 – 18°C, a range that corresponds to temperatures selected in the field when possible (Moyle, 2002).

Steelhead are sensitive to elevated water temperature during all phases of life, although adults have a higher thermal tolerance due in large part to their greater mass. Given adequate time to gradually acclimate, adult steelhead, and even larger parrs, are capable of surviving temperatures as high as 26 - 27° C for short periods. It should be noted however, that the increased metabolic demand under such conditions has chronic effects on growth rates and vulnerability to disease. Even when acclimation temperatures are high, temperatures of 24 – 27°C are invariably lethal to trout, except for very short exposures (Moyle,2002). Steelhead and rainbow trout eggs are stenothermal, with highest survival rates between 5 – 10° C, but published data show considerable variation among strains. They can tolerate temperatures as low as 2° C or as high as 15° C but are subject to increased mortality. Time to hatching is inversely related to temperature, but as the temperature increases past the optimal range, there is reduction in alevin size (Myrick et. al, 2001).

Water temperature monitoring within Sulphur Creek was conducted from July – October, 2002 at three sites along the stream. One data logger was not recovered. Water temperature monitoring at all sites was performed using digital temperature loggers

(*Optic Stowaway Temp*) manufactured by Onset Computer Corporation. Temperatures were continuously measured and recorded every thirty minutes for the duration of the study. Results of calibration of the temperature recorders before installation have shown an accuracy of ± 0.2° C (0.4° F).

Water temperature monitoring sites were selected based on habitat quality, presence of water, presence of fish or other aquatic organisms, and access constraints. The three sites achieved a reasonable distribution throughout the watershed, given the extensive lack of perennial surface water along much of Sulphur Creek. The sites consisted of one pool in Heath Canyon (HEA-TL-01), one pool in lower reach 2 (SUL-TL-04), one pool in reach 3. Due to the loss of the uppermost data logger in reach 3, no continuous water temperature data were collected above reach 2. However, temperature measurements were made with a hand-held thermometer in all pools during habitat-typing surveys. Physical characteristics of each site were documented at the time of installation including depth, canopy, substrate, estimated flow, and vegetation (Table 6.1).

Results of water temperature monitoring within Sulphur Creek are shown in Figure 6.1 and Figure 6.2 for the period from late July through mid-October 2002. The results showed a characteristic seasonal trend with generally lower temperatures as summer progressed and days became shorter. Diurnal fluctuations were also typical with high temperatures in the mid day and lowest temperatures at night.

Both sites had thermal ranges that are favorable for summer rearing steelhead. Maximum temperatures slighlty exceeded 20°C in the reach 2 site, however only for a very short period (Figure 6.1). The Heath Canyon site had no temperatures above the 20° C threshold during this study. Both sites also exhibited similar daily fluctuations of approximately 2-3 degrees, which is not a substantial variation through the course of 24 hours. The data suggest a relatively stable thermal regime in both Sulphur and Heath Canyon Creek.

Although no continuous temperature data is available for upper Sulphur Creek, measurements made with hand thermometers were all well below 20° C during habitat surveys. It is also likely that temperatures would be generally lower in reaches 3 and 4 than reach 2 due to the increased pool depth, deeper canyon walls, and higher levels of surface flow present higher in the watershed. Average water temperature for reach 3 was 17° C and 14° C in reach 4 during habitat surveys.

In general, water temperatures do not appear to be a major factor impacting steelhead populations within the Sulphur Creek watershed. Pools in the lower reach showed elevated temperatures (> 20°C) during habitat surveys. This section of the stream has several factors that are likely contributing to elevated water temperature including riparian canopy removal, urban runoff, and bank modification with rock and concrete. The stream provides habitat for a variety of riparian species in reach 1, however juvenile rearing steelhead probably are not able to tolerate the conditions during a typical summer.

	SULPHUR SITE 1	**SULPHUR SITE 2**
Site Code	SUL-TL-04	HEA-TL-O1
Coordinates	38° 29.275' N 122° 29.224' W	38° 29.030' N 122° 28.830' W
Date Launched	7/18/02	7/18/02
Date Retrieved	10/18/02	10/18/02
Sampling Interval	30 minute	30 minute
Site Description	Boulder-formed scour pool	Culvert plunge pool
Hobotemp Depth (ft)	1.5	1.8
Max Depth (ft)	2.1	5.6
Mean Depth (ft)	1.4	2.5
Mean Length (ft)	24	31
Mean Width (ft)	11	24
Canopy (% Total)	95	78
Substrate	Small gravel / Sand	Gravel / Small Cobble
Left Bank Vegetation	Vinca, Alder	Oak / Grass
Right Bank Vegetation	Vinca, Alder, Tree of Heaven	Oak / Alder
Flow (category)	Moderate / Low	Moderate
Fish/Aquatic Organisms Observed	Sculpin, Rainbow trout (YOY), California Roach	Rainbow trout (YOY, 1+, 2+, ~2 8"+) California Roach

Table 6.1: Summarized characteristics of temperature monitoring sites within Sulphur Creek and Heath Canyon Creek.

	SULPHUR SITE 1	SULPHUR SITE 2
Site Code	SUL-TL-04	HEA-TL-01
Number of data points	4404	4404
Mean (°C)	15.57	16.84
Median (°C)	15.64	17.07
Maximum (°C)	21.27	19.80
Minimum (°C)	11.14	11.59
Standard Deviation	1.71	1.62
Number of data pts exceeding threshold	31	0
% of total exceeding threshold	0.70	0

Table 6.2: Summarized results from water temperature monitoring sites within Sulphur Creek and Heath Canyon Creek.

Sulphur Site 1 (SUL-TL-04) facing upstream   7/18/02

Heath Canyon Site 2 (HEA-TL-01) facing upstream   7/18/02
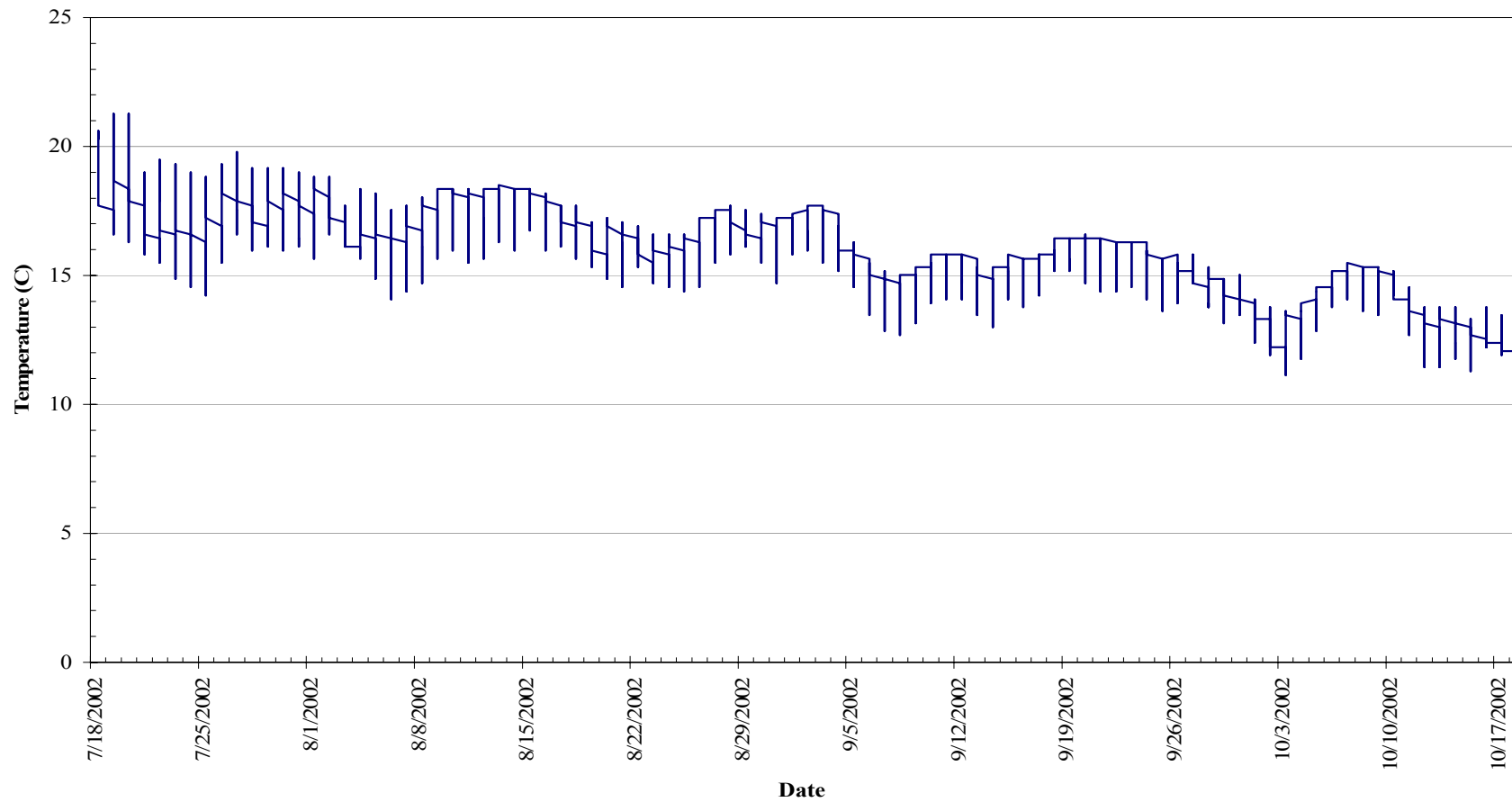
SUL-TL-O4 Water Temperature

FIGURE 6.1

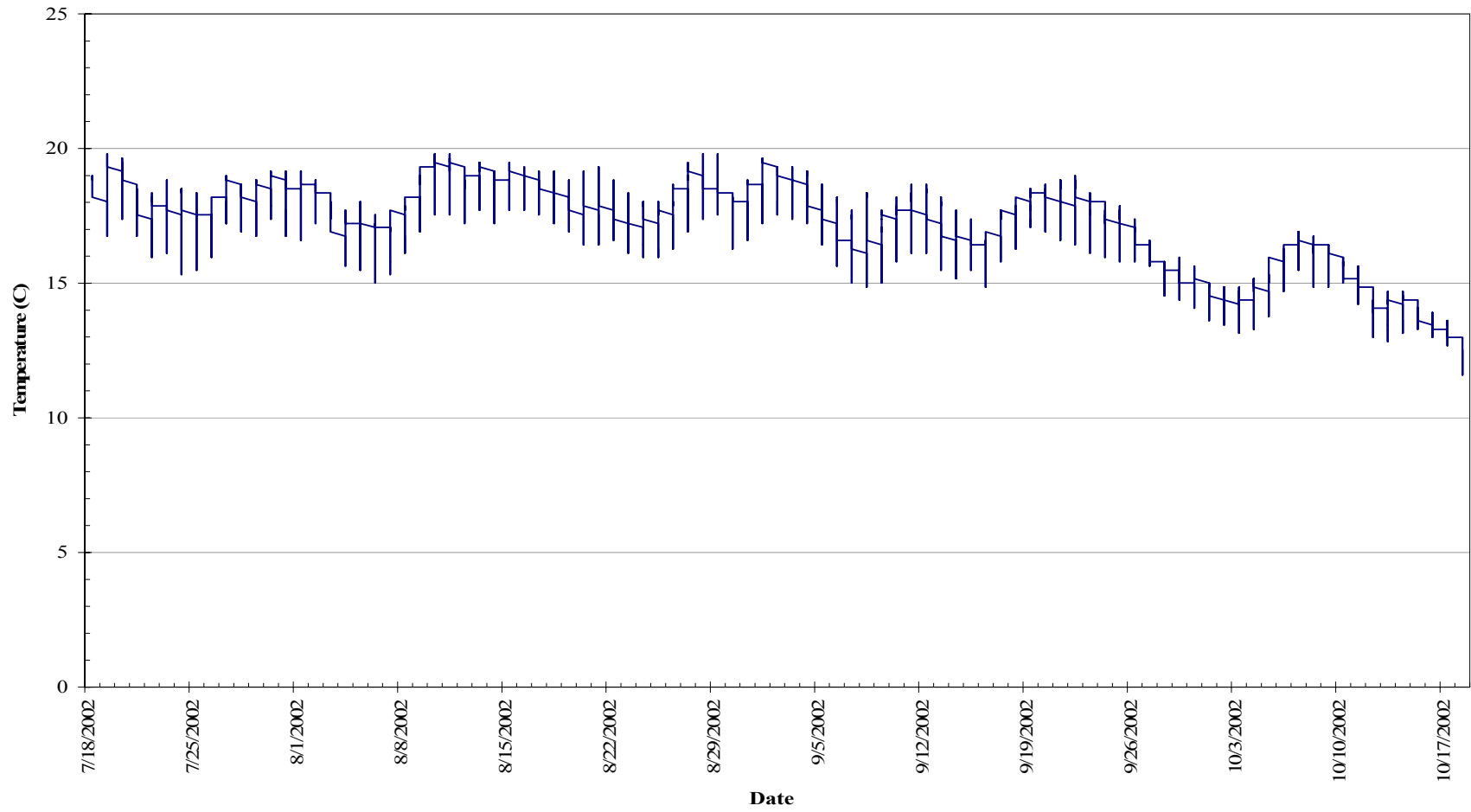# HEA-TL-O1 Water Temperature

FIGURE 6.2

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