FISH HABITAT ASSESSMENT: A COMPONENT OF THE WATERSHED MANAGEMENT PLAN FOR THE CARNEROS 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 Carneros 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 reaches of Carneros Creek, which begin near Old Sonoma Bridge and extend upstream approximately 4.2 miles until the channel goes dry. The portion of Carneros Creek between the Napa River and Old Sonoma Bridge functions as a migration corridor for steelhead, but does not provide adequate summer rearing habitat due primarily to the absence of stream flow. Some deep isolated pools in this lower portion may support small numbers of fish, but overall they do not contribute a significant amount of favorable habitat. The upper reaches of Carneros Creek were completely dry during the survey, which is the typical pattern during summer months according to local landowners. The upper dry reach does not provide rearing habitat, but spawning may occur in suitable sites during winter when flow is present. Young fry could then migrate downstream to suitable rearing pools in the middle reaches. Adult spawning surveys and redd counts in the upper reach would offer a more distinct upstream limit to steelhead.

Tributaries to Carneros Creek were not surveyed due to absence of water. Several spot visits confirmed the overall lack of summer rearing habitat within tributaries. Two intermittent streams are tributary to the middle reaches of Carneros Creek, and they may provide suitable spawning habitat that functions similarly to the upper dry reach of the main stem. After emerging, young fish would be forced to migrate quickly downstream into perennial main stem pools to survive the summer.

In general, pool habitat is lacking good quality cover such as large woody debris (LWD) for juvenile steelhead rearing throughout Carneros Creek. Pool cover is especially lacking in Reaches 1 and 2, where many young-of-year were observed in open water without hiding refugia from predators such as birds. Reach 3 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, threespine stickleback, California roach, and sculpin. Several large trout were seen in reach 3, 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 1. 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 and 3. Water temperatures measured in reach 1 reached levels above the physiological "comfortable" range for steelhead; however the pools in this lower reach do not appear to provide suitable rearing habitat due to a combination of no flow and poor water quality. The duration of slightly elevated water temperatures in lower Carneros Creek was not extensive, and these conditions probably do not have chronic impacts on growth rates or fitness. In reach 2, water temperature monitoring showed a very favorable and narrow range of daily temperatures within a representative bedrock pool. Peak values in the middle reach were well below steelhead stress levels.

The best available habitat for steelhead spawning and rearing is presently in reach 3 and parts of reach 2, which span about 2 miles. Deep pools with good cover and spawning gravels are more frequent in these two reaches than lower in the stream. Steelhead habitat in reach 2 and 3 currently makes the most significant contribution to the population, and appears to be where the majority of fish are located. It is not clear whether the habitat conditions in these reaches reflect historic conditions for most of Carneros Creek. Efforts to expand the extent of this high-quality habitat could have a great benefit to the population within Carneros Creek.

Several potential migration barriers were identified along Carneros 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 Carneros 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 two concrete summer dams in reach 2 and 3, and a bedrock cascade with a small concrete dam in reach 2. These dams do not prevent fish passage, and likely do not present a major obstacle under most high and moderate flows. However, they have 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. Modifying these structures to allow for complete fish passage would not be difficult.

Riparian canopy density is generally high throughout Carneros Creek. Throughout the survey, much of the immediate stream canopy is provided by mature oaks and bays with large exposed root masses along the bank. The stream has a relatively narrow riparian tree zone, and the loss of these trees may have a deleterious effect on water temperature and water quality. Improving the long term viability of the riparian canopy by stabilizing stream banks and planting second-growth trees would allow for natural succession without compromising the aquatic habitat.

Successful steelhead spawning appears to occur primarily in reach 2 and 3 where good spawning gravel is abundant. Analysis of spawning gravels in reach 1 and the areas downstream show levels of fine sediment that are not favorable to salmonids. Values for several sites indicate amounts of fine sediment that are near levels that begin to significantly impact spawning success. The amounts of fine sediment in these reaches are not as important directly to steelhead spawning however since this part of the stream does not provide suitable year-round habitat.

2.0 Introduction and Objectives

Stream inventories were conducted during June of 2002 on Carneros 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 Carneros 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 represent Carneros Creek's only special-status fish species, and is 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 portions of Carneros Creek and its tributaries, 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 Carneros 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 and lower estuary.

Carneros Creek is typical of streams throughout Napa County in terms of seasonal flow reductions and complete cessation during summer months (June – September). Only the middle reaches of Carneros Creek retain perennial surface flow. The upper and 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. Escape or hiding 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 salmonid 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, primarily seasonal dams, have been identified on Carneros Creek, which are impeding upstream and downstream migration of salmonids to varying degrees.

Steelhead migrate both downstream as juvenile smolts and upstream as spawning adults. Unlike most other salmonids, 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 METHODS

The habitat inventory conducted in the Carneros watershed follows the methodology presented in the California Salmonid Stream Habitat Restoration Manual (Flosi and Reynolds, 1994). The two-person field crew that conducted the inventory was trained in standardized habitat inventory methods by the CDFG.

4.1 SAMPLING STRATEGY

The inventory uses a method that samples approximately 10% of the habitat units within the survey reach (Hopelain, 1994). 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 Carneros 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 <u>California Salmonid Stream Habitat Restoration Manual</u>, 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 located 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

The habitat inventory of Carneros Creek, 9/11/2002 - 9/24/2002, was conducted by J.Koehler and M.Champion beginning at Old Sonoma Bridge and extending up the creek to the point where suface flows diminished. Several spot checks were made above and below the survey reach to confirm the absence of water or suitable rearing pools. The total length of stream surveyed was 22,208 feet, with an additional 31 feet of side channel. Surface flows were generally low or totally absent in Carneros Creek during the survey period. All tables are located at the end of this report.

This section of Carneros Creek has 3 reaches defined by 3 distinct channel types: from Old Sonoma Bridge to 7,522 feet it is a C3 type, followed by 5,771 feet of F3 type channel, and finally 8,915 feet of F1 type channel (see habitat survey reach map).

• 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.

• F1 channel types are entrenched meandering riffle/pool channels on low gradients (<2%) with a high width/depth ratio and a predominantly bedrock

Water temperatures ranged from 12ºC to 15ºC. Air temperatures ranged from 14ºC to 24ºC. 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)

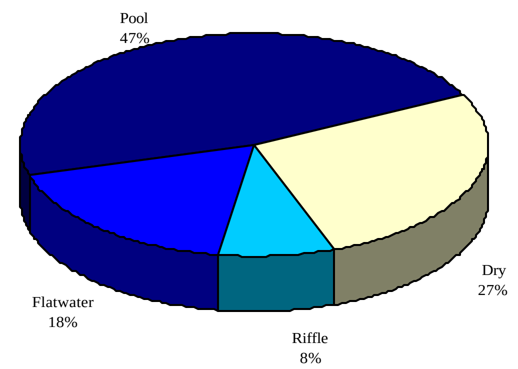
Table 1 summarizes the Level II riffle, flatwater, and pool habitat types. Based on frequency of *occurrence* there were 47% pool units, 26% dry units, 18 % flatwater units and 8% riffle units (Graph 1). Based on total *length* there were 47% dry units, 35% pool units, 14% flatwater units and 4% riffle units (Graph 2).

A total of 348 habitat units were measured and 44% were completely sampled. Within these 348 units, 16 Level IV habitat types were identified. The data are summarized in Table 2. The most frequent habitat types by percent *occurrence* were mid-channel pools at 28% and glide at 16%. (Graph 3). By percent total *length*, mid-channel pools comprised 24% and glides comprised 11% of the surveyed reaches.

In the surveyed reaches of Carneros Creek, 163 pools were identified (Table 3). Mid-channel pools were most often encountered at 28%, and comprised 66% of the total length of pools (Graph 4).

Carneros Creek

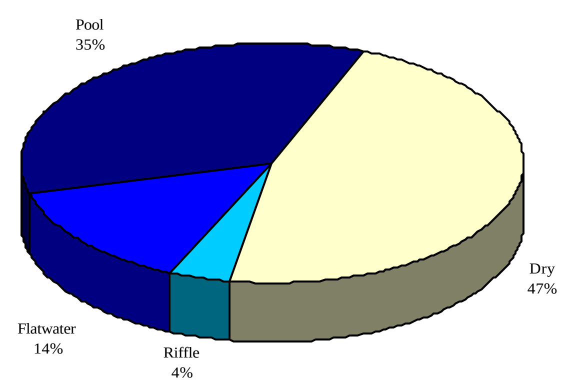
HABITAT TYPES BY PERCENT OCCURRENCE



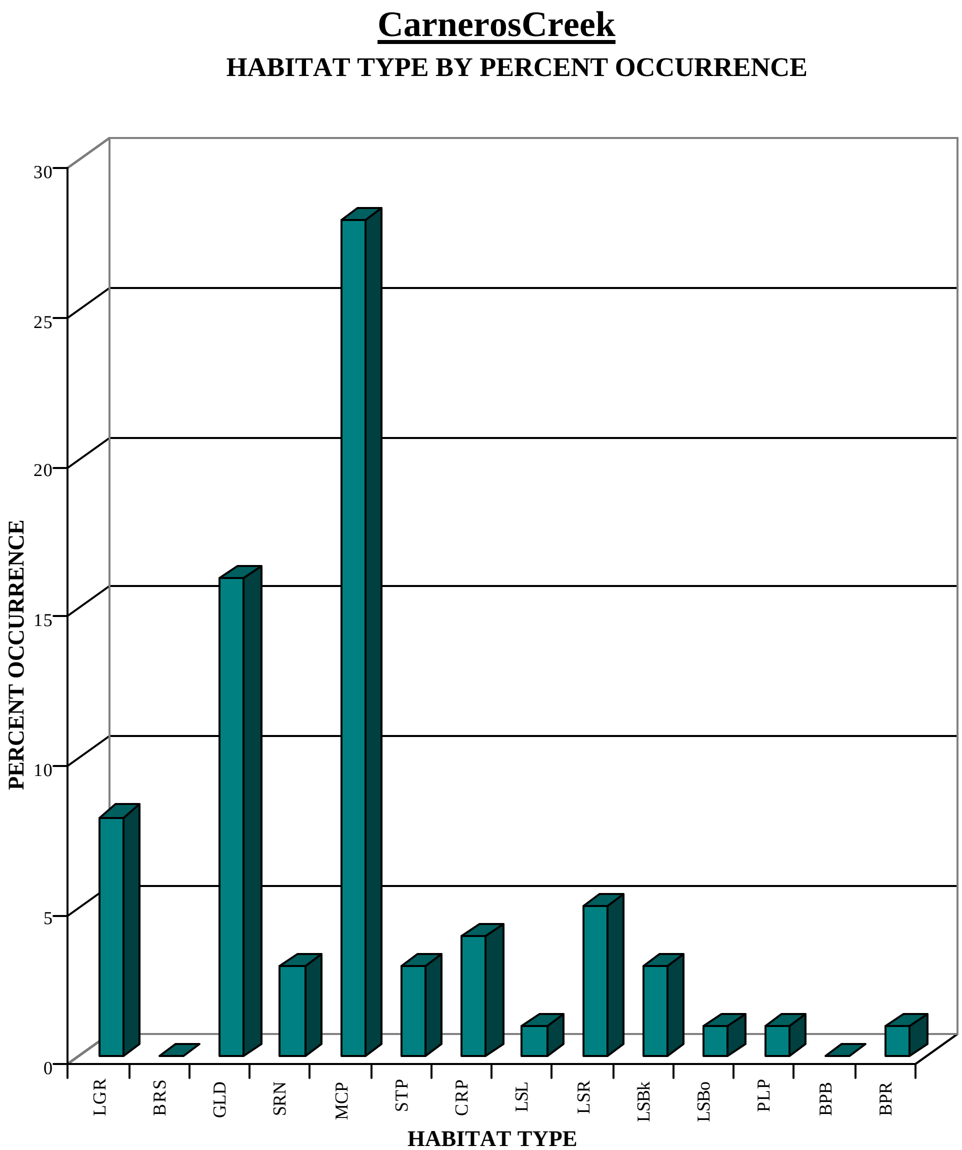
GRAPH 1

Carneros Creek

HABITAT TYPES BY PERCENT TOTAL LENGTH



GRAPH 2

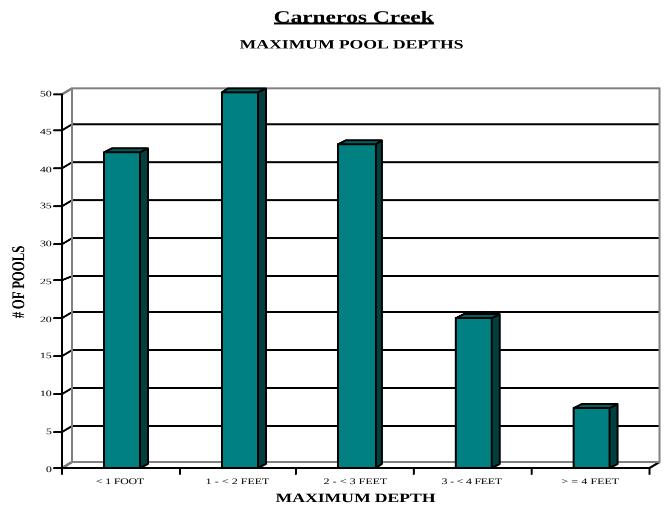


GRAPH 3

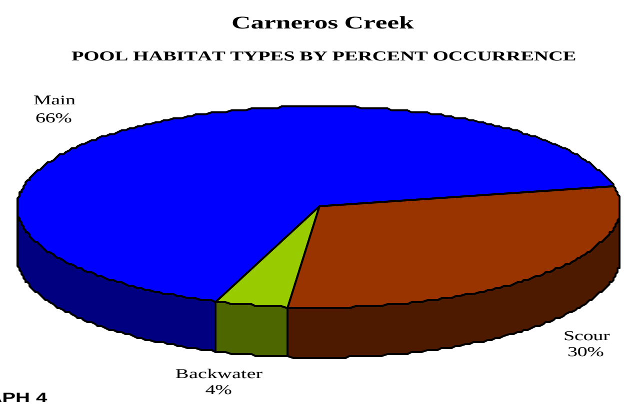
Table 4 is a summary of maximum pool depths by pool habitat types. In general, pool quality for aquatic organisms and fish, especially salmonids, increases with depth. Within Carneros Creek, 71 of the 163 pools (44%) had a depth of two feet or greater (Graph 5). These deeper pools comprised 18% of the total length of stream habitat. Additionally, 28 of the 163 pools (17%)

had a depth of three feet or greater (Graph 5). These deeper pools comprised 8% of the total length of stream habitat.

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 28, Pools rated 51 and Riffles rated 4 (Table 1). Of the pool types, step pools rated highest with a mean shelter value of 90 followed by lateral scour pool - log enhanced which rated 80 (Table 3).

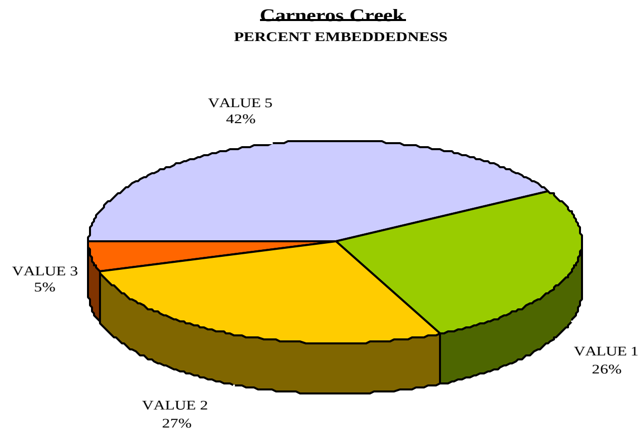


GRAPH 5

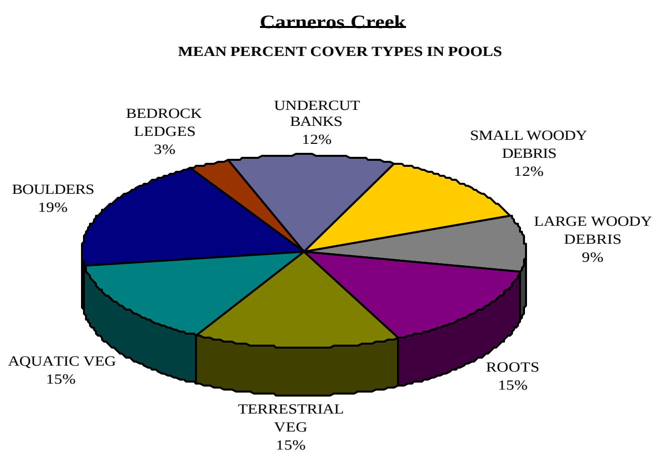


GRAPH 4

Table 5 summarizes fish shelter by habitat type. By percent area, the dominant pool shelter types were aquatic vegetation at 29% and terrestrial vegetation at 16% (Graph 7).



GRAPH 6

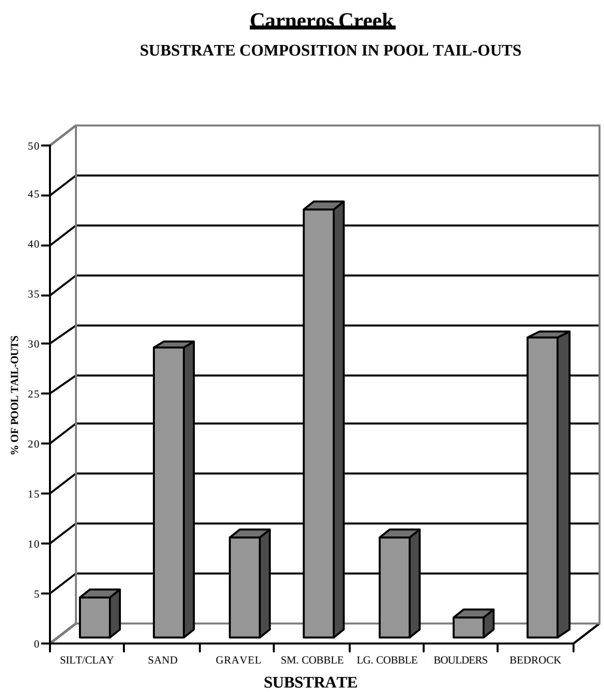


GRAPH 7

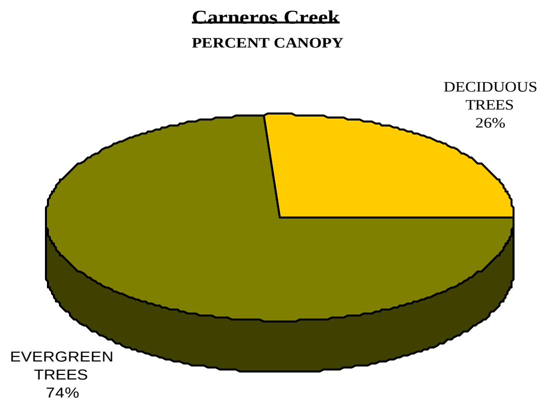
Table 6 summarizes the dominant substrate by habitat type. In the 28 low-gradient riffles surveyed, the dominant substrate was small cobble (Graph 8).

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). Other samples in the lower portion of Carneros Creek contained levels of 9% and 11% fines. The combined summary of all three samples averaged 13% fines. Results of sediment sampling will be included in the channel geomorphology report by San Francisco Estuary Institute (SFEI).

The depth of cobble/gravel embeddedness was visually estimated at pool tail-outs. Of the 121 pool tail-outs measured, 33 had a value of 1 (27%), 33 had a value of 2 (27%) and 6 had a value of 3 (5%). An additional 49 (40%) riffles rated a 5, which is unsuitable substrate type for spawning (Graph 6). On this scale, a value of one is best for fish spawning habitat. Small cobble was the dominant substrate observed at pool tail-outs (Graph 7).

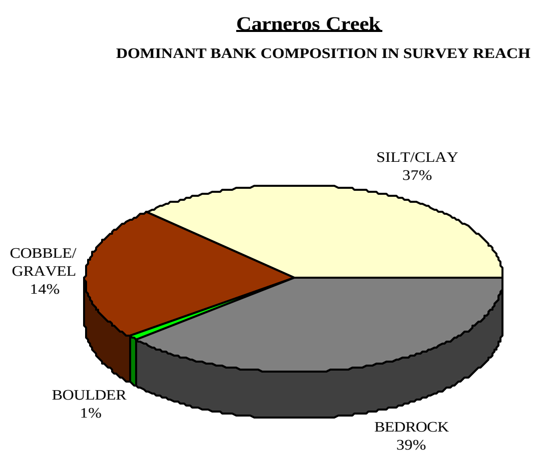


GRAPH 8



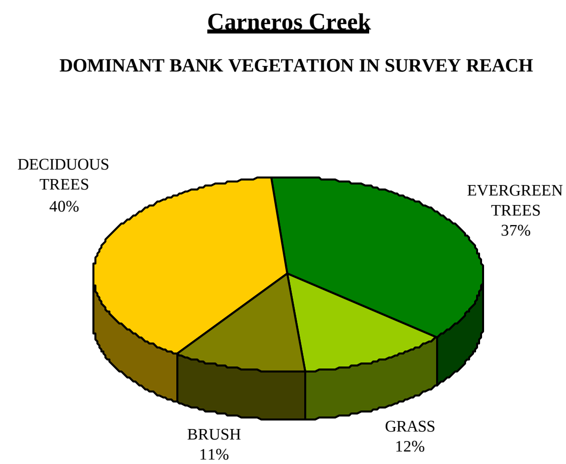
GRAPH 9

The mean percent canopy density for the entire survey was 91%. The mean percentages of deciduous and evergreen trees were 26% and 74%, respectively (Graph 9).



GRAPH 10

For the entire stream reach surveyed, the mean percent right bank vegetated was 62% and the mean percent left bank vegetated was 57%. The dominant vegetation types for the stream banks were deciduous and evergreen trees (Graph 10).



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. These 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 7,522 feet of C3 channel type in Reach 1. 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. Any work considered will require careful design, placement, and construction that must include protection for any unstable banks.

There are 5,771 feet of F3 channel type in Reach 2. 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. As in reach 1, any work considered will require careful design, placement, and construction that must include protection for any unstable banks.

There are 8,915 feet of F1 channel type in Reach 3. In general F1 channel types are good for bank-placed boulders and fair for single wing-deflectors and log cover. The bedrock substrate in this channel type limits the options for increasing pool frequency and depth.

The water temperatures recorded on the survey days 9/11/2002 - 9/24/2002 ranged from 12º C to 15º C. Air temperatures ranged from 14º C to 24º C. The warmest water temperatures were recorded in Reach 1. This temperature regime is generally favorable to salmonids, and is below the stress threshold of 20° C. This is discussed further in section 6.0. It is unknown if this thermal regime is typical from year to year, but but fish were observed more frequently in the upper, cooler sample sites. To make any further conclusions, long term monitoring would be necessary.

Pools comprised 35% 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 width. In Carneros Creek, the pools are relatively deep with 17% having a maximum depth of at least three feet. These pools comprised 8% 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. However, in more arid streams such as Carneros Creek pool habitat targets of 30% total length are typical.

The mean shelter rating for pools was 55. However, a pool shelter rating of approximately 70 or above is desirable. The relatively small amount of pool shelter that now exists is being provided primarily by aquatic vegetation (29%), terrestrial vegetation (16%), and root mass (15%). Large woody debris accounted for only 6% of all pool cover. Additional log and root wad cover in pool and flatwater habitats would improve both summer and winter aquatic habitat. Log cover provides rearing steelhead fry with protection from predation, rest from water velocity, and also divides territorial units to reduce density related competition.

In the survey reaches of Carneros Creek, 4 of the 5 low gradient riffles measured (80%) had either gravel or small cobble as the dominant substrate. This is generally considered good for spawning salmonids. This is also favorable substrate for supporting diverse benthic macroinvertebrate populations.

Only 5% of the pool tail-outs measured had embeddedness ratings of either 3 or 4. On the other end of the spectrum, 27% had a rating of 1. Cobble embeddedness measured to be 25% or less (a rating of 1) is considered best for the needs of salmon and steelhead spawning. The amount of fine sediment in potential spawning habitat seems to be minimal. Although substrate is generally finer in reach 1 and below, these areas are not suitable for summer rearing and are do not contribute much to the steelhead rearing habitat available within Carneros Creek.

The mean percent canopy for the survey was 91%, which is very good; 80 percent and above is generally considered desirable. However, the riparian buffer is thin or patchy in areas with livestock or agriculture. Riparian removal, intensive grazing, and vineyard development within the riparian corridor could all lead to less stream canopy and channel incision causing bank erosion and higher water temperatures. Much of the riparian canopy is also in danger of falling into the stream due to heavy bank erosion. Efforts to preserve these trees, especially in Reaches 1 and 2, would benefit the long-term health of the riparian and aquatic ecosystems.

5.2 CONCLUSIONS AND RESTORATION PRIORITIES

1. Pool frequency and quality is deficient in Reach 1, and to a lesser extent in Reach 2. Where feasible, increase the number of pools and amount of pool shelter in these reaches. The suitability of each reach for these types of projects is discussed in the results section above. A watershed approach to stream habitat improvement would 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. Making improvements to the watershed as a whole will create a more stable aquatic ecosystem and ultimately benefit fish populations living within it.

2. Carneros Creek has a moderate level of embeddedness throughout the surveyed reaches, and treatments to reduce the delivery of fines into the stream should be considered. Gravel analysis suggest that current levels of fine sediment are near the threshold at which negative impacts on fry emergence begin. 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 as part of this watershed assessment (Sediment Source Assessment, Channel Geomorphology). Sources of fine sediment include roads, culverts, agriculture, livestock, and landslides.

3. The existing cover is deficient throughout Reach 1 and 2, and adding complexity with larger woody cover (LWD) or other shelter would greatly enhance habitat quality. Most pools in Reach 3 had adequate shelter and can be used as a guide for improving pools in the lower section of the stream. Combination cover/scour structures constructed with boulders and woody debris would be effective in many pool and flatwater locations in all reaches. This must be done where the banks are stable or in conjunction with stream bank armor to prevent excessive erosion.

4. Stream bank erosion along Carneros Creek is evident in all reaches, and general riparian thinning and removal is evident in much of Reaches 1 and 2. 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 may reduce peak water temperatures and improve water quality.

5. Migration barriers may limit the geographic range of steelhead populations within Carneros Creek. Several potential fish passage barriers were identified including 3 dams and a small bedrock cascade. Further investigation is needed during periods of higher streamflow to determine the extent to which these various obstructions limit fish passage. Steelhead were observed in Carneros Creek above a concrete dam in the middle of Reach 2. All potential barriers must be examined for their potential impacts on fish passage before removing or modifying them. 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 very limited in much of Carneros Creek during summer months. These low flows severely limit the amount of habitat and food available to rearing salmonids. 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.

5.3 FISH HABITAT SUMMARY BY STREAM REACH

STREAM REACH 1

Channel Type: c3
Channel Length: 7522 ft.
Riffle/flatwater Mean Width: 7.2 ft.
Total Pool Mean Depth: 1.1 ft.
Base Flow: none
Water: 13 - 15 °C Air: 14 - 27 °C
Dom. Bank Veg.: Deciduous Trees
Vegetative Cover: 60%
Dom. Bank Substrate: Bedrock

Canopy Density: 93%
Coniferous Component: 83%
Deciduous Component: 18%
Pools by Stream Length: 18%
Pools >=3 ft.deep: 20%
Mean Pool Shelter Rtn: 39
Dominant Shelter: Boulders
Occurrence of LWD: 6%
Dry Channel: 5980 ft.

Length of stream sections not surveyed within survey reach: 0 ft.
Embeddness Value: 1. 33% 2. 57% 3. 10% 4. 0%

STREAM REACH 2

Channel Type: f3
Channel Length: 5771 ft.
Riffle/flatwater Mean Width: 4.0 ft.
Total Pool Mean Depth: 0.8 ft.
Base Flow: low/intermittent
Water: 12 - 14 °C Air: 15 - 24 °C
Dom. Bank Veg.: Deciduous Trees
Vegetative Cover: 65%
Dom. Bank Substrate: Bedrock

Canopy Density: 93%
Coniferous Component: 67%
Deciduous Component: 33%
Pools by Stream Length: 29%
Pools >=3 ft.deep: 10%
Mean Pool Shelter Rtn: 39
Dominant Shelter: Root masses
Occurrence of LWD: 8%
Dry Channel: 3327 ft.

Length of stream sections not surveyed within survey reach: 0 ft.
Embeddness Value: 1. 36% 2. 57% 3. 7% 4. 0%

STREAM REACH 3

Channel Type: f1
Channel Length: 8915 ft.
Riffle/flatwater Mean Width: 6.9 ft.
Total Pool Mean Depth: 1.2 ft.
Base Flow: low
Water: 13 - 14 °C Air: 17 - 31 °C
Dom. Bank Veg.: Deciduous Trees
Vegetative Cover: 56%
Dom. Bank Substrate: Bedrock

Canopy Density: 89%
Coniferous Component: 73%
Deciduous Component: 27%
Pools by Stream Length: 54%
Pools >=3 ft.deep: 20%
Mean Pool Shelter Rtn: 67
Dominant Shelter: Aquatic Vegetation
Occurrence of LWD: 6%
Dry Channel: 1155 ft.

Length of stream sections not surveyed within survey reach: 0 ft.
Embeddness Value: 1. 57% 2. 35% 3. 8% 4. 0%

CARNEROS 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 Carneros Creek or its tributaries where surface flow or permanent aquatic habitat was absent.

Legend

Napa River
Carneros Creek
Intermittent Tributaries
Roads
Carneros Creek Watershed
Reach 1
Reach 2
Reach 3

Map Scale = 1:58,000

0 0.5 1 1.5 2 Miles

0 0.5 1 1.5 2 2.5 3 Kilometers

Napa County Resource Conservation District

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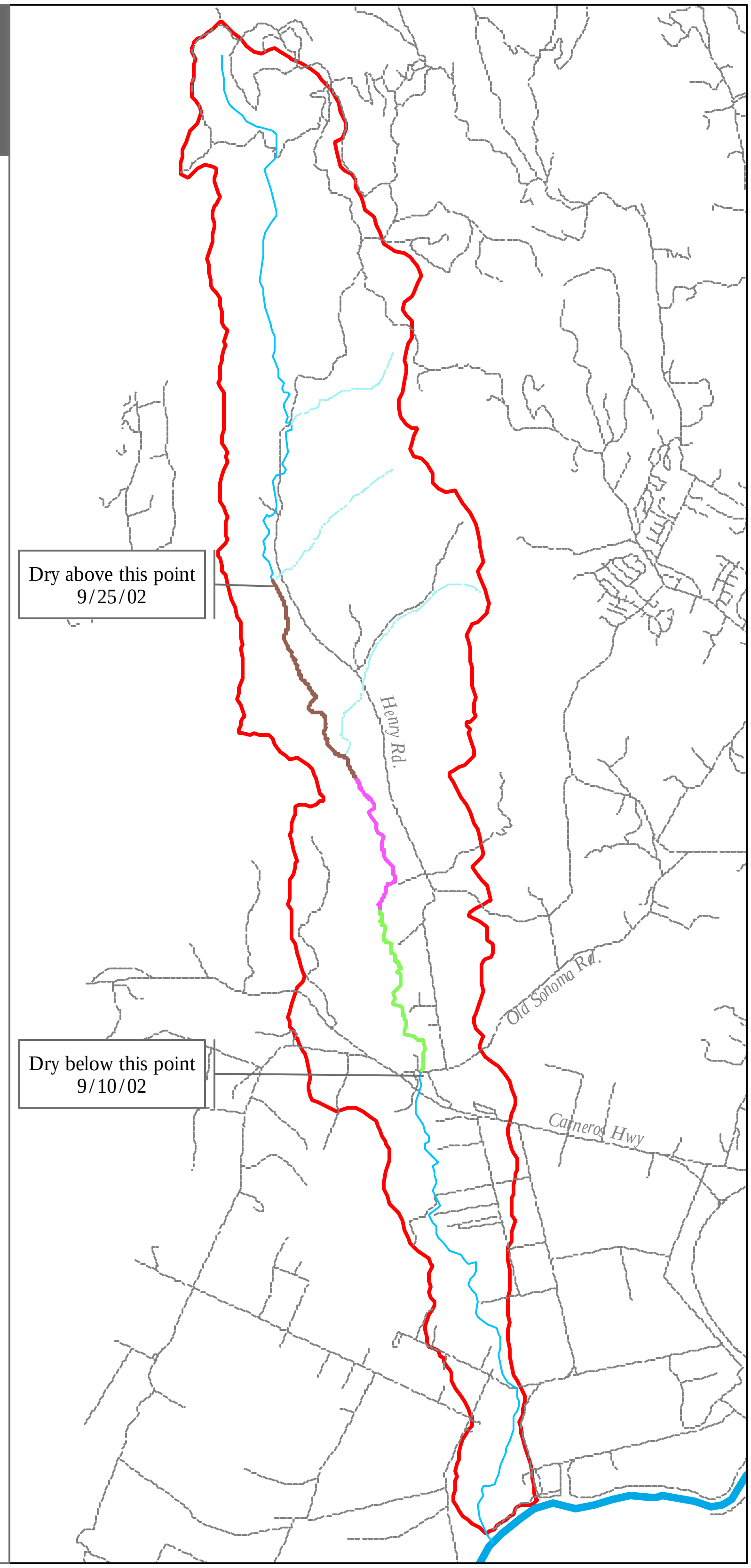

CARNEROS CREEK

CALFED III
Fish Habitat Assessment

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

Legend

Napa River
Carneros Creek
Intermittent Tributaries
Roads

Carneros Creek Watershed

Riparian Canopy

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

Map Scale = 1:58,000

0 0.5 1 1.5 2 Miles

0 0.5 1 1.5 2 2.5 3 Kilometers

Napa County Resource Conservation District

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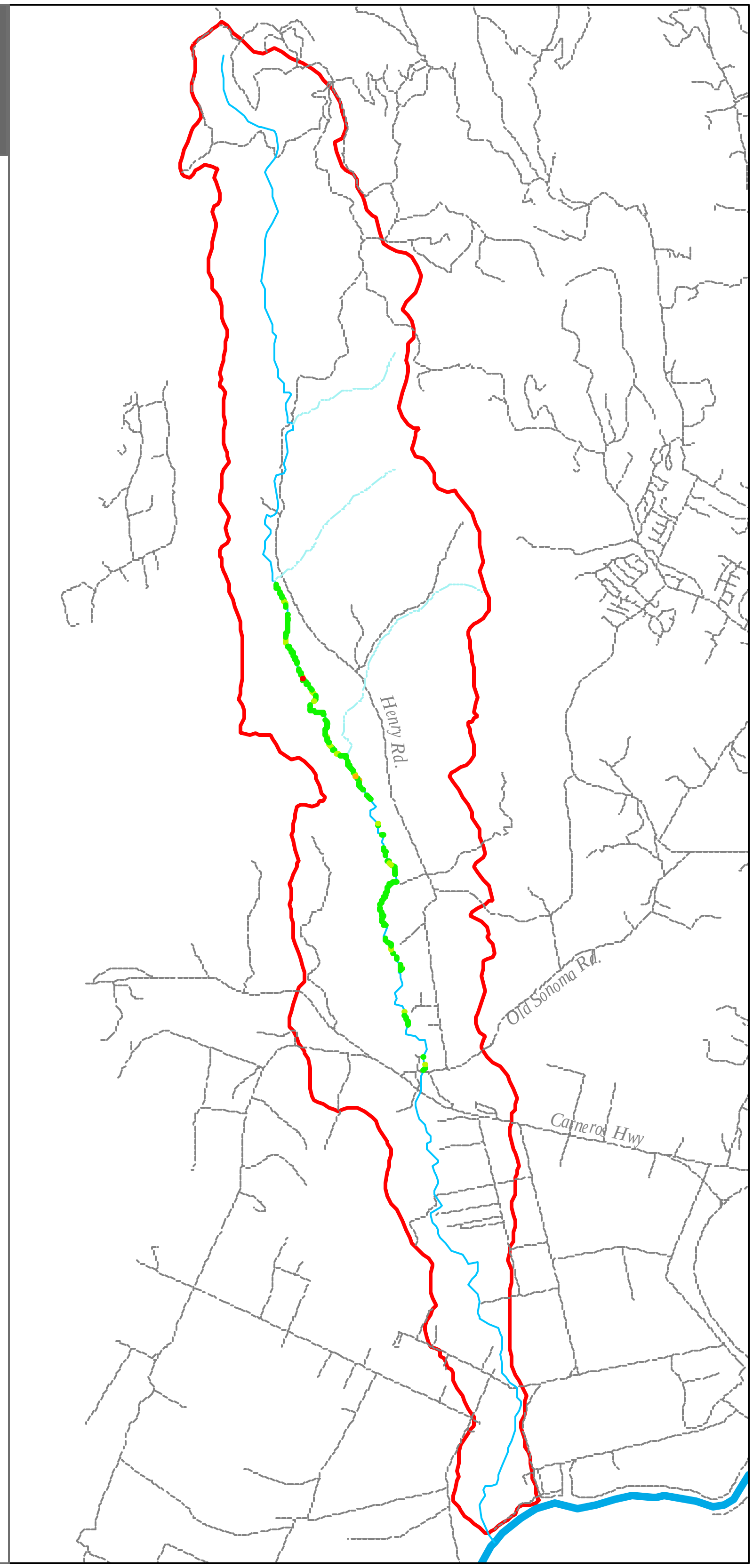

CARNEROS CREEK

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

Napa River
Carneros Creek
Intermittent Tributaries
Roads

Carneros Creek Watershed

Cobble Embeddedness

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

Map Scale = 1:57,999

0 0.5 1 1.5 2 Miles

0 0.5 1 1.5 2 2.5 3 Kilometers

Napa County Resource Conservation District

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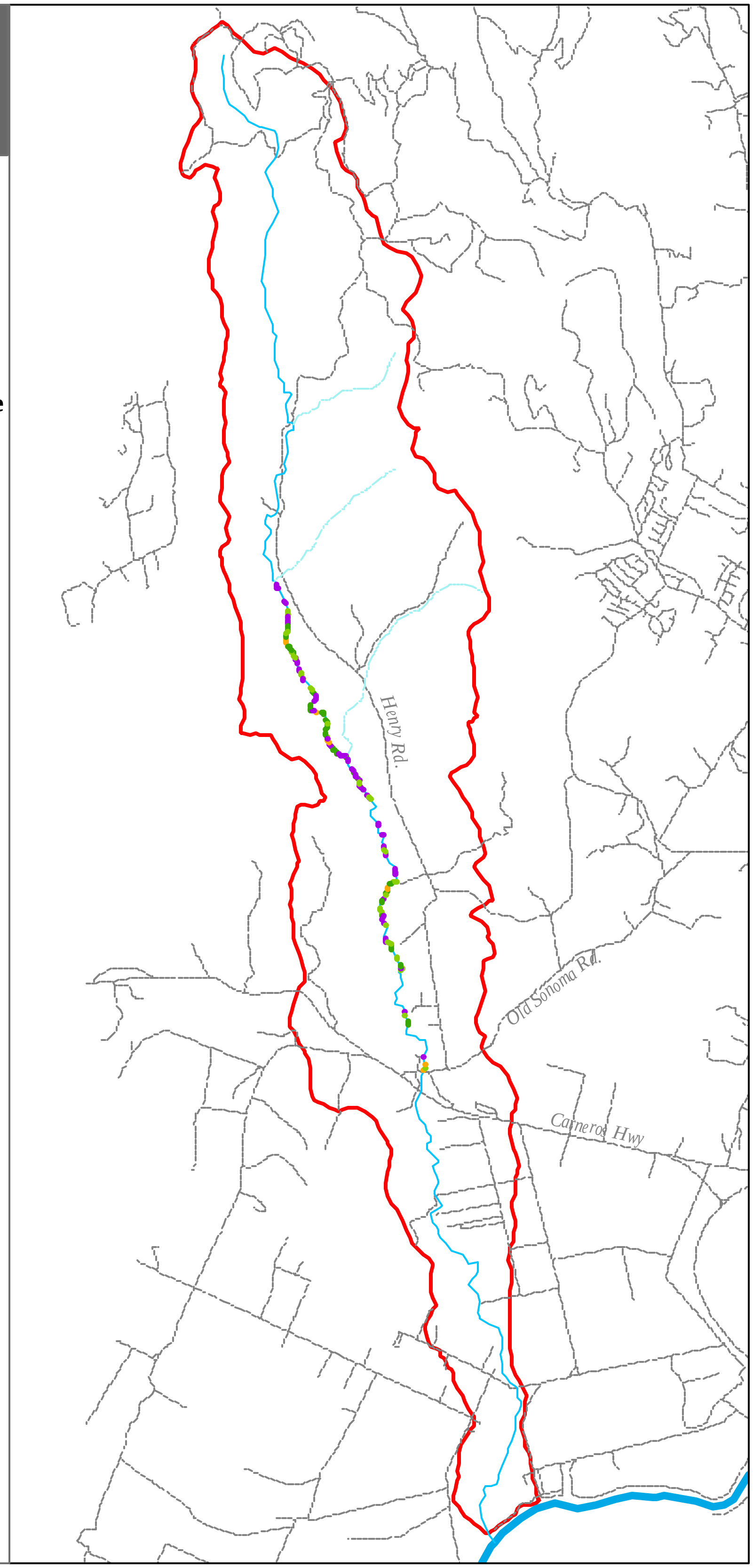

CARNEROS CREEK

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

- Napa River
- Carneros Creek
- Intermittent Tributaries
- Roads
- Carneros Creek Watershed

Habitat Type

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

Map Scale = 1:58,000

0 0.5 1 1.5 2 Miles

0 0.5 1 1.5 2 2.5 Kilometers

Napa County Resource Conservation District

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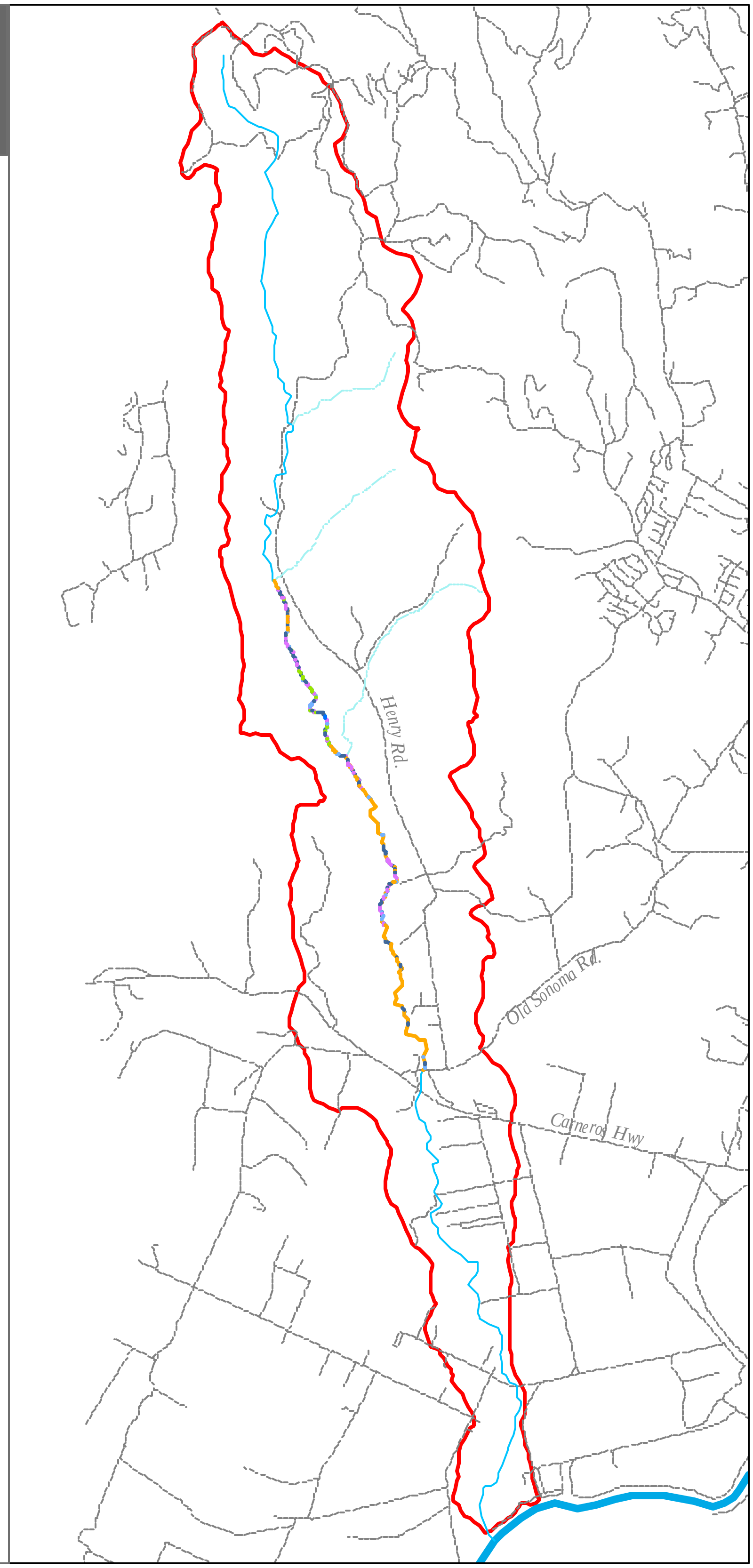

CARNEROS CREEK

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 storms.

Legend

Napa River
Carneros Creek
Intermittent Tributaries
Roads

Carneros Creek Watershed

Maximum Depth

< 2 ft
2 -3 ft
3-4 ft
> 4 ft.

Map Scale = 1:58,000

0 0.5 1 1.5 2 Miles

0 0.5 1 1.5 2 2.5 3 Kilometers

Napa County Resource Conservation District

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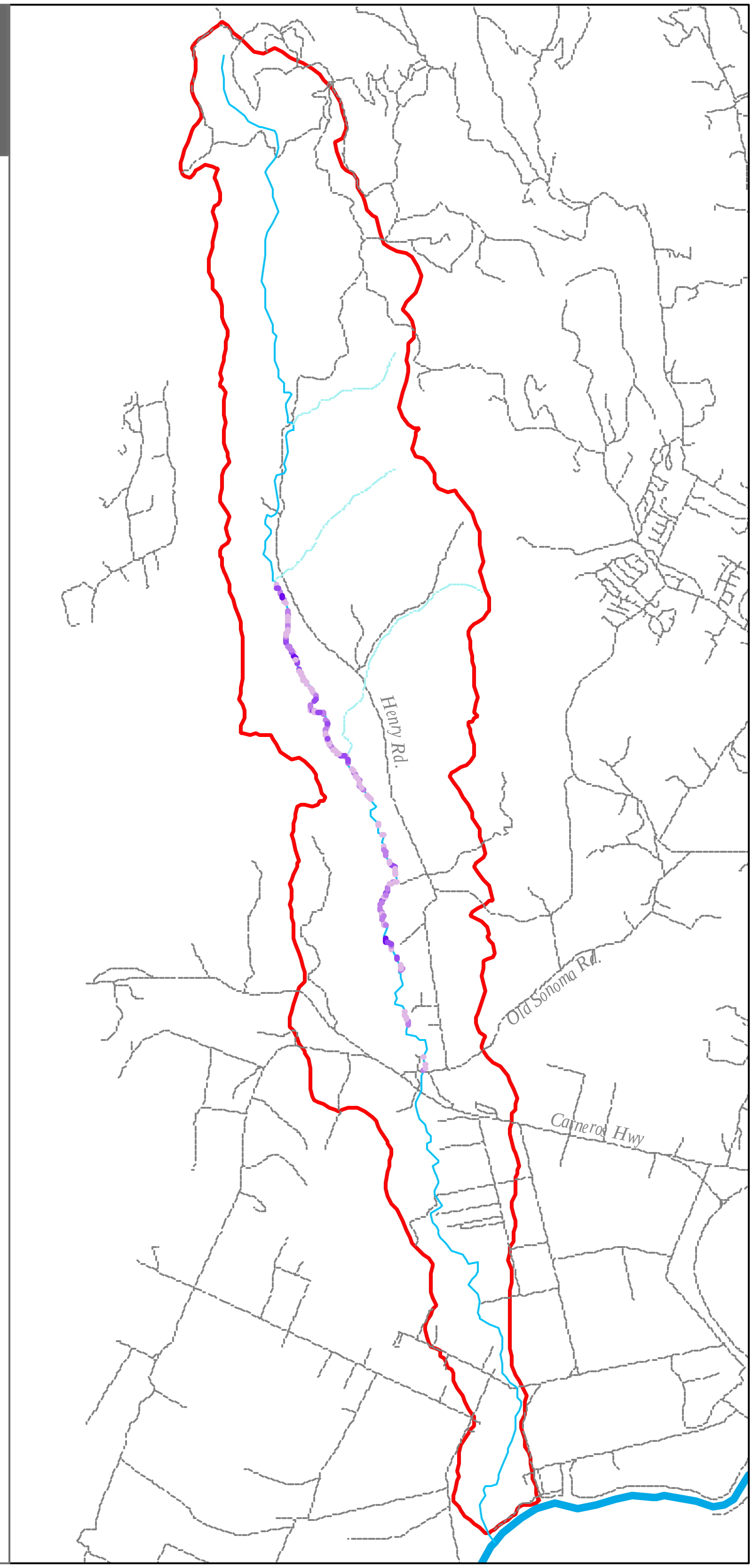


6.0 WATER TEMPERATURE MONITORING

Water temperatures within a stream, particularly during spring, summer, and fall, have a major effect on the health and survival of steelhead (anadromous rainbow trout, *Oncorhynchus mykiss*). 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 Carneros Creek watershed.

This study focused on steelhead rearing habitat, which experiences the highest water temperatures from June through October in typical intermittent Northern California streams such as Carneros 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 Carneros 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 steno thermal, 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 Carneros Creek was conducted from July – October, 2002 at three sites along the stream. One of the three sites (CAR-TL-O2) was not included in this report due to a malfunction in the temperature logger. 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 and/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 Carneros Creek. A programming error eliminated data from the third and uppermost site (CAR-TL-02). Physical characteristics of each site were documented at the time of installation including depth, canopy, substrate, estimated flow, and vegetation, which are summarized in Table 6.1. Temperature loggers were attached to rods which were pounded into the substrate within the upper third of the pool habitat unit. In pools with bedrock substrate, temperature loggers were attached to large stones.

Results of water temperature monitoring within Carneros Creek are shown for both station locations in Figures 6.1 and 6.2 for the period from late July through mid-October 2002. In addition, air temperature measurements were collected at the Carneros Creek telemetric streamgage at Old Sonoma Road. These data are shown in Figure 6.3 for the period from July through October for comparison. The results showed a characteristic seasonal trend with generally lower temperatures as summer progressed. Diurnal fluctuations were also typical with high temperatures in the mid day and lowest temperatures at night.

The lower site in reach 1 had temperatures generally higher than in the upper reaches. Maximum temperatures exceeded 20°C, however only for a fairly short period (Figure 6.1). It is also likely that these pools experience thermal stratification with cold temperatures near the bottom and warmer temperatures near the surface. The highest temperatures at this site were recorded while the datalogger was near the surface at the end of the summer. As the pool dried out, water levels dropped significantly (>2 ft) and eventually exposed the datalogger.

The upper site showed a very narrow range of daily temperatures well below 20°C for the duration of summer (Figure 6.2). Water temperatures in the pools of reach 2 and 3 are likely being buffered by the bedrock substrate and heavy canopy cover. These favorable low temperatures were consistent with hand measurements made in all pools during habitat surveys.

In general, water temperatures do not appear to be a major factor impacting juvenile steelhead and other cold-water organisms within Carneros Creek. Although pools in the lower reach showed slightly elevated temperatures and daily ranges above the optimal levels for steelhead, this section of the stream has other environmental stressors, such as lack of flow, that may outweigh water temperature in terms of impacts to fish and aquatic organisms.

	CARNEROS SITE 1	CARNEROS SITE 3
Site Code	CAR-TL-01	CAR-TL-03
Number of data points	3326	2481
Mean (°C)	17.41	13.69
Median (°C)	17.83	13.66
Maximum (°C)	21.57	16.01
Minimum (°C)	8.63	10.89
Standard Deviation	1.88	1.14
Number of data pts exceeding threshold	72	0
% of total exceeding threshold	2.2	0

Table 6.1: Summarized results from water temperature monitoring sites within Carneros Creek. A stress-threshold temperature of 20° C was selected based on literature values for steelhead and other salmonids.

	CARNEROS SITE 1	CARNEROS SITE 3
Site Code	CAR-TL-01	CAR-TL-03
Coordinates	38° 15.443’ N 122° 20.445’ W	38° 16.340’ N 122° 21.269’
Date Launched	7/24/02	8/27/02
Date Retrieved	10/4/02	10/18/02
Sampling Interval	30 minute	30 minute
Site Description	Mid-channel pool	Mid-channel pool
Hobotemp Depth (ft)	2.2	2.0
Max Depth (ft)	3.1	2.2
Mean Depth (ft)	2.0	1.6
Mean Length (ft)	58	20
Mean Width (ft)	12	15
Canopy (% Total)	28	100
Substrate	Silt/Sand	Bedrock
Left Bank Vegetation	Wild Grape, Eucalyptus	Oak, Bay
Right Bank Vegetation	Wild Grape, Him. Blackberry	Oak, Bay
Flow (category)	No flow – isolated	Low
Fish/Aquatic Organisms Observed	Small fish – no ID/ water stained brown	steelhead (YOY and 1+), rough-skinned newts. Water stained by tannins.

TABLE 6.2: Summarized characteristics of temperature monitoring sites within Carneros Creek.

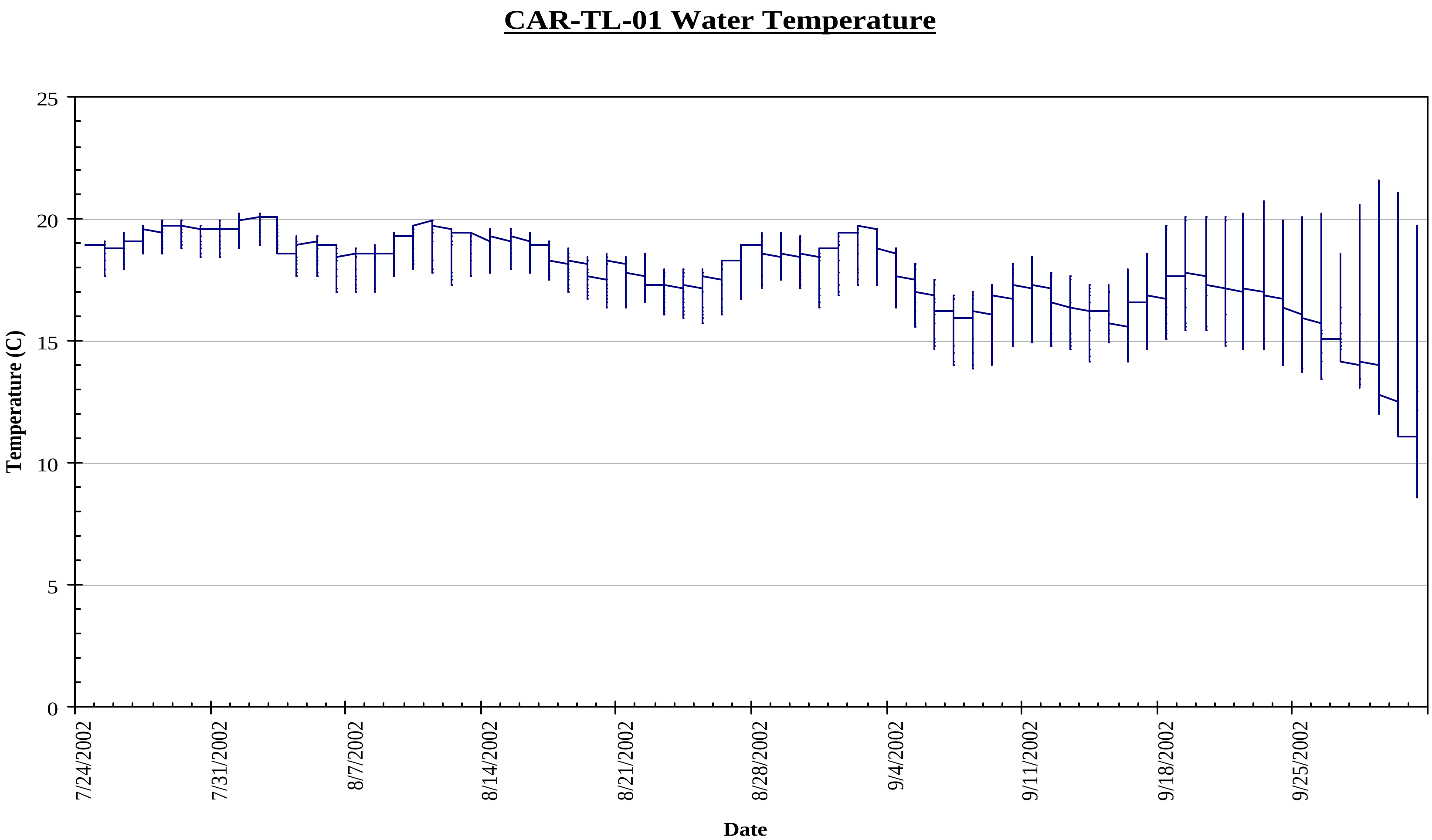


FIGURE 6.1: Water temperature results for Carneros Site 01 in the lower reach of Carneros Creek. Data near the end of the record show higher variability due to reduced water levels and ultimately exposure to the air during late September.

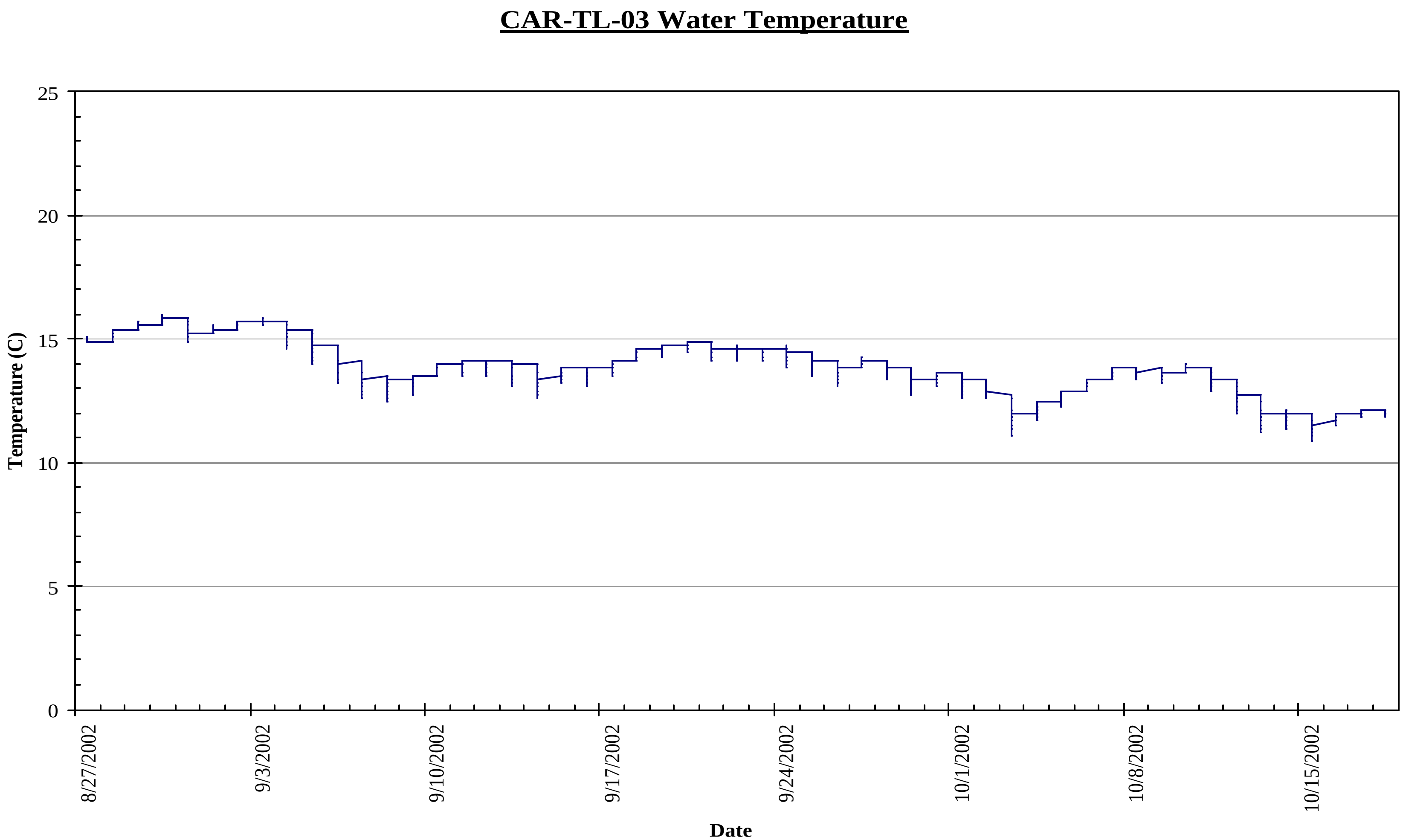
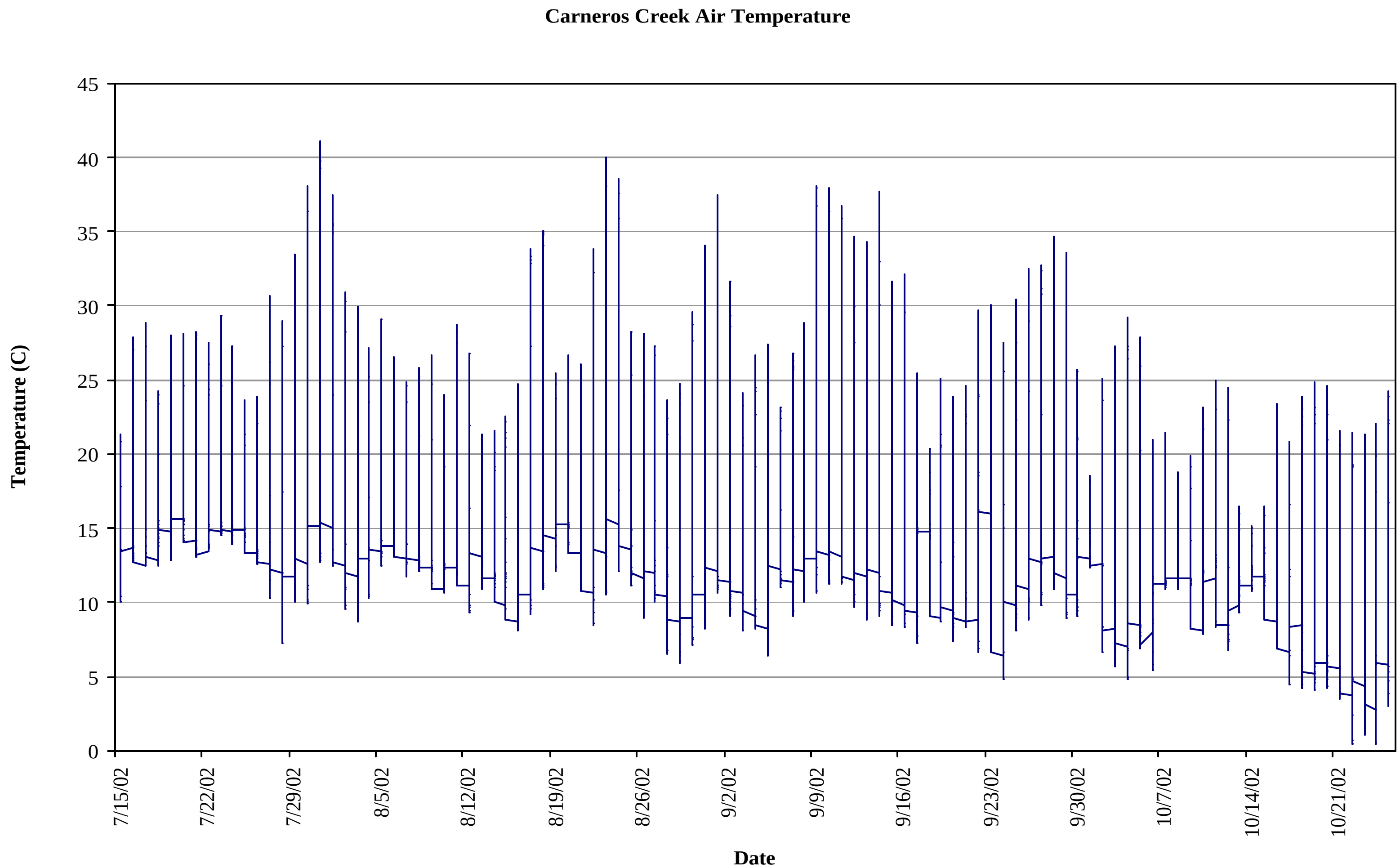


FIGURE 6.2: Water temperature results for Carneros Site 03 in the middle reach of Carneros Creek. This bedrock pool is typical of pool habitats throughout the middle stream reach in terms of substrate, mean depth, canopy density, and cover.

FIGURE 6.3- Air temperatures taken from the Carneros Creek stream-gaging sight on Old Sonoma Bridge. Temperatures were recorded at fifteen minute intervals.



CARNEROS Site 1 (CAR-TL-01) facing upstream 7/24/02

CARNEROS Site 3 (CAR-TL-03) facing downstream 8/27/02

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