APPENDICES

APPENDIX A: METHODS AND DATA

Appendix A1: Watershed Characterization

A variety of GIS data was used to characterize the Napa River basin and to conduct the various analyses performed for this project. Specifically, GIS was used to develop 40-foot contour lines, map the entire channel network, determine channel gradient, predict channel bed grain size, apply the SHALSTAB model, and map and analyze vegetation, land use and geologic coverages of the Napa River basin. The GIS metadata presented below describe the sources and characteristics of the various GIS coverages used in this study.

Digital Terrain Model (DTM) and 40-foot contours
Source Data: USGS 10-meter DEM (digital elevation model).

10-m DEMs for each USGS 7.5 minute quadrangle of the Napa River basin were assembled and then re-gridded to remove some of the source data artifacts (most notably the stair-step appearance in the low-gradient areas–a consequence of the source elevation data being stored as integer values). Two sink-filling routines were applied to the re-gridded quadrangles to remove sink artifacts.

Forty-foot contour data were generated from the re-gridded and sink-filled DTM using Arc/Info interpolation schemes.

Channel Network
Source Data: USGS 1:24,000 scale Digital Line Graph (DLG) hydrography; and
Extracted drainage areas.

The channel network for the Napa River basin was mapped using USGS 1:24,000 hydrography (blueline streams) to represent the base data for the basin. The bluelines fail to represent the full network drainage density and, therefore, a threshold-area methodology was applied to capture channels in low-order valleys. The extracted channels were then attached to the blueline data to produce the channel network for the entire basin. The technique uses drainage area data extracted from the DTM, and defines a channel wherever drainage area equals or exceeds 10 acres (approximately 4,000 square meters). This threshold value has been applied to coastal basins throughout Northern California and gives a reasonable approximation of the actual extent of the drainage density and channel locations, although the exact position of individual channel heads typically varies.

Channel Gradient
Source Data: Combined USGS DLG hydrography and threshold-area channel network; and
40-foot contour data.

Channel gradient was calculated by intersecting the combined blueline and threshold-area channel network with the 40-ft contours. Channel reaches were defined by the intersection of the individual contours with tributary junctions. Channel gradient for individual reaches was calculated by finding the elevation difference between contour intervals and dividing by the length of the reach. This vector-based approach is more robust and less error-prone than using DTM techniques exclusively.

Ideally, source contour data would be 1:24,000 scale USGS hypsography, but those data were unavailable for the Napa basin. The lack of hypsography DLG data necessitated the use of the 40-foot contour data interpolated from the DTM.

Predicted Grain Size of Channel Bed

Source Data: Drainage area grid;
Combined channel network; and
Hydraulic geometry relations (bankfull width versus drainage area).

Predicted bed particle size applies the threshold channel concept. This concept suggests that significant bedload transport in gravel-bed rivers only begins as flows reach or exceed bankfull stage. Full mobility is only reached when the critical shear stress for the median grain size (D_{50}) is exceeded. GIS-based, reach-averaged D_{50}'s are calculated using only the channel gradient and drainage area as variables[1].

The two variables required to calculate reach-based median particle size are drainage area and channel gradient, both GIS-derived. The former is used to calculate bankfull depth by applying a power law relationship between drainage area and field-measured values of bankfull depth. Channel gradient is calculated by intersecting the digital channel network with a GIS-based 40-ft contour theme. Channel reaches are defined by the intersection of the individual contours and by tributary junctions.

The median particle size calculation predicts *total* shear stress acting on a bed. The calculation ignores three factors which influence the calculation of shear stress available to move bed material: (1) channel planform morphology, (2) channel roughness (i.e., LWD), and (3) sediment supply. Where any or all of these are important, the bed resistance can be significantly greater, and predicted particle sizes will be larger than observed. These three factors are also indirect indicators of land management activities, and hence the difference between observed and predicted particle sizes may provide insight regarding land use alterations.

Predicted Shallow Landslide Hazard

Source Data: 10-meter DTM.

The physically-based shallow landslide prediction model (SHALSTAB) combines an infinite slope stability model and a steady-state hydrologic model to predict the potential for shallow landsliding across a landscape[2]. The model uses two topographic parameters, slope and drainage area, to differentiate areas of the landscape prone to shallow failure. The only source data necessary to run the model is the DTM. The model can be used in a parameter-free mode.

Vegetation and Land Use/Land Cover

Source Data: USGS land use/land cover data (based on 1992 Landsat imagery).

No post-processing was applied to these data.

Geology

Source Data: USGS digital version of a 1977 edition, 1:750,000 State Geology of California Map

No post-processing was applied to these data.

[1] The theory and some applications are described in more detail in: Buffington, JM; Montgomery, DR. Effects of hydraulic roughness on surface textures of gravel-bed rivers. *Water Resources Research*, 1999, vol.35(11):3507-3521, and Montgomery, D.R, W.E. Dietrich, and K. Sullivan. The Role of GIS in Watershed Analysis. In: *Landform Monitoring, Modeling and Analysis*. Edited by S.N. Lane, K.S. Richards, and J.H. Chandler. 1998. John Wiley and Sons. Ltd.

[2] The theory behind the model is explained more fully at the following website: http://socrates.berkeley.edu/~geomorph/shalstab/index.htm.

Appendix A2: Fish Occurrence Database

Methods

To characterize changes in the general patterns of fish species occurrence since the 1950s in the Napa River basin, a database was created using historical fish survey information.

The following sources of fish observation data were compiled and reviewed to create the database:

- CDFG fish surveys (1950s through present);
- Napa County RCD fish surveys (1990s through present); and
- EPA fish surveys, Robert Leidy (1993–1998).

A simple database was created in which each observation of a species was recorded along with the location and the year in which the observation occurred. Due to the variable means by which fish surveys were conducted, fish occurrence was characterized on a presence/absence basis and location was given only at the tributary level. Large differences in fish occurrence were documented between the tidally influenced reaches of the mainstem below the city of the Napa and the relatively small channel north of the City of Calistoga. Fish occurrence data recorded for the mainstem were, therefore, assigned to one of three river segments: below Trancas Street bridge; between Trancas Street bridge and Calistoga; and above Calistoga.

Fish occurrence data from CDFG and RCD were reviewed to determine the presence or absence of fish and the location of the survey. The Leidy surveys had already been entered into a database by the San Francisco Estuary Institute (SFEI) and data were mapped directly from that database into the database created for this analysis.

To assess general trends in the frequency of occurrence of salmonids versus other species in the fish community, a guild analysis was performed. Guilds are groups of organisms with roughly similar ecological roles. Due to the hypothesis that increased water temperature and introduced species have altered the composition of the fish community in the Napa River basin to the detriment of salmonids, non-salmonid fish documented in historical surveys were grouped according to guilds that reflected these issues. Guilds of non-salmonids were defined according to temperature affinity (i.e., species generally found in warm water versus cold water) and whether species were native or exotic to the Napa River system. The primary reference for this task was Moyle (2002). The following guilds were used: salmonids; warm water natives; cold water natives; and warm water exotics. A cold water exotic guild was not used in this analysis since the only cold water exotic species observed in the Napa River basin, the American shad, has only been observed in the lower part of the river during two surveys, one in the 1970s and one in the 1980s.

Results

The database was queried to create a comprehensive summary of the number of past surveys in which a particular species was observed. Data were grouped by tributary or mainstem section and by the decade when the observation was made (Table A2-1). Furthermore, the total number of surveys conducted on a tributary or mainstem section in a given decade was tallied to provide an indication of the level of survey effort at that site (Table A2-1).

Table A2-1. Napa River basin fish observation data by decade.

Survey Location	Decade	Number of Surveys	Salmonids			Other Species																													
			Oncorhynchus mykiss	*Oncorhynchus tshawytscha*	salmonid species	*Acanthogobius flavimanus*	*Acipenser transmontanus*	*Alosa sapidissima*	*Carassius auratus*	*Catostomus occidentalis*	*Cottus asper*	*Cottus gulosus*	*cyprinid spp.*	*Cyprinus carpio*	*Gambusia affinis*	*Gasterosteus aculeatus*	*Hesperoleucus symmetricus*	*Hysterocarpus traski*	*Ameiurus catus*	*Ictalurus punctatus*	*Lampetra tridentata*	lamprey species	*Lepomis cyanellus*	*Lepomis macrochirus*	*Leptocottus armatus*	*Menidia beryllina*	*Micropterus dolomieui*	*Micropterus salmoides*	*Morone saxatilis*	*Mylopharodon conocephalus*	*Pogonichthys macrolepidotus*	*Ptychocheilus grandis*	sculpin species	sucker species	sunfish species	unidentified fry
Mainstem Napa River																																				
Upstream of Calistoga	1960	3	1														1																1			
	1990	18	1							3	1	2			1	2	3						2	1								2				
Downstream of Trancas	1970	6						1										1							1			1	1		1					
	1980	24	1	3		4	2	1		1								1		1						1			5		4					
Trancas to Calistoga	1960	8	1							1						1	1		1				1									1	1			
	1980	6		1	1					1							1															1	1			
	1990	21								3	2	1				3	3	2						1			1			3		2				
Tributaries																																				
Bear Canyon Creek	1950	3	2							1																										
	1960	1	1																																	
	1970	2	1																														1			
Bell Creek	1960	13	3											1		2	2						2									1	1	1		
	1970	6	2													1	1					1	1													
	1980	9	3													1	2						1					1							1	
	1990	1																					1													
Carneros Creek	1950	1																																		
Chiles Creek	1950	6	1										1				1															1	1	1		
	1990	4															1															1	1	1		

Survey Location	Decade	Number of Surveys	Salmonids			Other Species																														
			Oncorhynchus mykiss	*Oncorhynchus tshawytscha*	salmonid species	*Acanthogobius flavimanus*	*Acipenser transmontanus*	*Alosa sapidissima*	*Carassius auratus*	*Catostomus occidentalis*	*Cottus asper*	*Cottus gulosus*	*cyprinid spp.*	*Cyprinus carpio*	*Gambusia affinis*	*Gasterosteus aculeatus*	*Hesperoleucus symmetricus*	*Hysterocarpus traski*	*Ameiurus catus*	*Ictalurus punctatus*	*Lampetra tridentata*	lamprey species	*Lepomis cyanellus*	*Lepomis macrochirus*	*Leptocottus armatus*	*Menidia beryllina*	*Micropterus dolomieui*	*Micropterus salmoides*	*Morone saxatilis*	*Mylopharodon conocephalus*	*Pogonichthys macrolepidotus*	*Ptychocheilus grandis*	sculpin species	sucker species	sunfish species	unidentified fry
Conn Creek	1950	1																																		
	1970	1	1																																	
	1980	5	1							1							1															1	1			
	1990	10	2							1	1	1				2	1				1											1				
Cyrus Creek	1960	3	1										1																				1			
	1980	1																																		
	1990	3	2														1																			
Dry Creek	1950	2	1														1																			
	1960	1	1																																	
	1970	6	2										1	1		1	1																			
	1980	8	4							1						1						1											1			
	1990	20	6							3		4				2	5																			
Dutch Henry Creek	1950	1	1																																	
	1980	2	1																																	
Garnett Creek	1970	9	2							2						1	2						2													
	1980	4	2														1																1			
Hopper Creek	1970	1																																		
	1980	1																																		
Huichica Creek	1960	2														1	1																			
	1970	1															1																			
	1980	11	4													1	3					1		2												
	1990	3	1													1	1																			
Kimball Canyon Creek	1950	1	1																																	

Survey Location	Decade	Number of Surveys	Salmonids			Other Species																													
			Oncorhynchus mykiss	*Oncorhynchus tshawytscha*	salmonid species	*Acanthogobius flavimanus*	*Acipenser transmontanus*	*Alosa sapidissima*	*Carassius auratus*	*Catostomus occidentalis*	*Cottus asper*	*Cottus gulosus*	*cyprinid spp.*	*Cyprinus carpio*	*Gambusia affinis*	*Gasterosteus aculeatus*	*Hesperoleucus symmetricus*	*Hysterocarpus traski*	*Ameiurus catus*	*Ictalurus punctatus*	*Lampetra tridentata*	lamprey species	*Lepomis cyanellus*	*Lepomis macrochirus*	*Leptocottus armatus*	*Menidia beryllina*	*Micropterus dolomieui*	*Micropterus salmoides*	*Morone saxatilis*	*Mylopharodon conocephalus*	*Pogonichthys macrolepidotus*	*Ptychocheilus grandis*	sculpin species	sucker species	sunfish species	unidentified fry
	1960	1																																		
	1990	6	1									1					1						1	1				1								
Milliken Creek	1950	1																																		
	1960	1	1																																	
	1970	6	3														1						1										1			
	1980	14	3						1	2							4						3										1			
	1990	11	2									2			1	1	2						2				1									
Montgomery/Dry Creek	1970	1																																		
Moore Creek	1990	1	1																																	
Murphy/ Tulocay Creek	1990	7	2							1						1	1																2			
Napa Creek	1950	1	1																																	
	1990	3								1	1						1																			
Nash Creek	1970	1																																		
Pickle/ Redwood Creek	1960	1	1																																	
	1970	1	1																																	
	1980	2	1														1																			
Rector Creek	1980	2	2																																	
Redwood Creek	1950	1	1																																	
	1960	5	3		2																															
	1970	1	1																																	
	1980	5	3													1	1																			
	1990	5	3							1							1																			
Ritchie Creek	1960	6	2		1												1																2			

Survey Location	Decade	Number of Surveys	Salmonids			Other Species																															
			Oncorhynchus mykiss	*Oncorhynchus tshawytscha*	salmonid species	*Acanthogobius flavimanus*	*Acipenser transmontanus*	*Alosa sapidissima*	*Carassius auratus*	*Catostomus occidentalis*	*Cottus asper*	*Cottus gulosus*	*cyprinid spp.*	*Cyprinus carpio*	*Gambusia affinis*	*Gasterosteus aculeatus*	*Hesperoleucus symmetricus*	*Hysterocarpus traski*	*Ameiurus catus*	*Ictalurus punctatus*	*Lampetra tridentata*	lamprey species	*Lepomis cyanellus*	*Lepomis macrochirus*	*Leptocottus armatus*	*Menidia beryllina*	*Micropterus dolomieui*	*Micropterus salmoides*	*Morone saxatilis*	*Mylopharodon conocephalus*	*Pogonichthys macrolepidotus*	*Ptychocheilus grandis*	sculpin species	sucker species	sunfish species	unidentified fry
	1970	3	2														1																			
	1980	4	2																														1			
Sage Creek	1950	1	1																																	
	1990	4	2														2																			
Sarco Creek	1990	4	1								1					1	1																			
Soda Creek	1950	1	1																																	
	1980	5	4																														1			
Sulphur Creek	1950	2	1														1																			
	1960	2	1																														1			
	1980	6	1													1	1					1											1			1
Suscol Creek	1950	1	1																																	
	1970	6	1												1	1	2																1			
	1980	2	1														1																			
	1990	7	1							1	1					1	1						1	1												
Tulucay Creek	1950	1	1																																	
York Creek	1970	5	2							1							1						1													
	1980	3	1		1																												1			

Source: CDFG surveys (1950s through present), Napa County RCD fish surveys (1990s through present), and R. Leidy (EPA) fish surveys (1993-1998).

Appendix A3: Dry Season Surface Water Conditions

A survey was conducted to obtain an overview of dry season surface water flow conditions in the Napa River basin and characterize the potential habitat level impacts of those flow conditions.

Methods

Survey reaches were selected from public access points, such as road crossings, pull outs, and bridges, from which it was possible to clearly view at least a 100–150 foot section of stream. This generally resulted in observations every 0.2 to 1.0 miles on tributary reaches surveyed and every 1 to 5 miles along the mainstem Napa River. At each site, the observer recorded GPS coordinates using a hand-held Garmin GPS and recorded the flow status of the reach. The following creeks were surveyed: Carneros, Redwood/ Napa Creek, Pickle Canyon, Browns Valley, Dry, selected road-crossings along Highway 29 and Silverado Trail, Dutch Henry, Sulfur, Tulocay, Soda, Chiles, Sage Canyon, Milliken, Sarco, and Huichica creeks.

In approximately one third of channels with flowing water, measurements were taken over a straight section of riffle to calculate discharge. Cross sectional area was estimated by measuring average width and depth where the flow estimate was made. Velocity was determined by measuring the travel time of a floating piece of orange peel over a length of 1–2 meters. Velocity measurements were repeated three to five times at each site.

Results

Results are presented in Section 6.5 of the main report and in Map 13.

Appendix A4: Fish Passage Barriers

Methods

To determine the locations and impacts of dams and other in-channel structures that might limit passage of anadromous salmonids, we reviewed existing information on barriers from the following sources:

- **California Department of Fish and Game (CDFG) surveys (1950s through present).** Data from these surveys varied because of the differences in methods and survey effort. Available CDFG file records of these surveys generally consisted of a narrative description of barriers and hand drawn maps or photocopied topographic maps on which dam locations were marked.

- **Napa County Resource Conservation District (RCD) field surveys (2001).** The RCD surveys on Garnett, Cyrus, Simmons, Dutch Henry/Biter, Ritchie, and Diamond Mountain creeks, and the upper Napa River were conducted during summer 2000 by uniformly trained survey crews. Locations of dams were determined in the field by measuring the distance of structures from known landmarks, such as bridges. These locations were then plotted on topographic maps to determine the approximate latitude and longitude of sites.

- **Department of Safety of Dams (DSOD).** DSOD maintains an inventory and database of basic information on dams that are considered large enough to pose a potential threat to public safety. This database provides latitude and longitude coordinates of each structure. After locations of dams were determined as accurately as possible using the DSOD data, sites were hand digitized into an ArcView GIS coverage of the 1:24,000 scale channel network (see Appendix A1) and given a unique identification number. The identification number was then used to link the site with a record in an Access database into which basic information about the structure was entered. The accuracy of dam locations on the base map is plus or minus ¼ mile. Locations of dams on streams for which there were repeated surveys or major dams for which information was available from a variety of sources, were more certain, as were dams located near distinctive geographic features. While the accuracy of dam locations is more than adequate to assess the cumulative effects of dams in the Napa River basin as a whole, the accuracy of dam locations should not be considered sufficient enough to attribute barriers or impacts to particular landowners.

- **GIS Data Sources.** Additional information on locations of barriers was gathered by analyzing USGS 1:24,000 scale coverages of water features and road networks. The first GIS analysis, for in-channel lakes or impoundments, was performed using the USGS coverage for surface water features to determine instances when features attributed as lakes, ponds, or reservoirs intersected the blueline channel network. Because natural lakes are rare in the Napa River basin, we assumed that features mapped as standing water that intersected streams are likely to be the result of artificial structures that could be barriers to fish passage. This analysis provided an independent estimate of the number of impoundment-related barriers existing in the Napa River basin. A second GIS analysis was performed to identify road and stream crossings, since road crossings frequently create barriers to salmonid passage. This GIS analysis was performed using the 1:100,000 scale USGS road network coverage intersected with the 1:100,000 scale USGS channel network coverage.

Results

Review of CDFG, Napa County RCD, and DSOD field survey data reveals that 69 potential barriers have been documented in the Napa River basin since the 1950s (Map 12). Many of these sites have not been resurveyed recently and in some cases, old barriers may no longer be in place (this appears to be the case on portions of Ritchie Creek).

For dams identified by the DSOD, drainage areas are provided which indicate that the five largest dams in the Napa River basin have a cumulative drainage area of 83 square miles (Table A4-1), or nearly 20 percent of the entire basin.

Table A4-1. Drainage areas of several tributary creeks upstream of major dams.

Creek Name	Drainage Area (mi^2)
Conn Creek	54
Rector Creek	10.7
Bell Creek	5.5
Milliken Creek	9.3
Kimball Creek	3.4
Total	**83**

Source: Department of Safety of Dams

The GIS analysis of on-channel lakes indicates that there are 227 cases where a channel is overlain by standing water (Map 13).

The GIS analysis of channels intersected by roads indicates 400 instances of roads crossing channels (Map 13).

Further discussion of results is provided in Section 6.4.1 of the main report.

Appendix A5: Mainstem Aerial Photograph Analysis

Methods

To determine changes in the morphology of the mainstem Napa River through time, we analyzed aerial photographs from 1940 and 1998. We used 1940 black and white aerial photographs (Approximately 1:18,000 scale) obtained from the Napa County Resource Conservation District. Current conditions were assessed using recent color aerial photographs (Approximately 1:20,000 scale) (taken by WAC in 1998). To more easily assess morphologic changes, both sets of photographs were enlarged by 400 percent on a high-resolution copier.

We analyzed photographs for the entire mainstem, and spot-checked the photographs in the field to ensure that our interpretations were correct.

Results

For illustrative purposes, we described three representative reaches of the mainstem in detail in the main report (Chapter 6, Section 6.1.1).

Appendix A6: Mainstem Extensive Habitat and Geomorphic Surveys

Methods

Channel surveys were conducted in October 2000 to assess the frequency of habitat types that are important to the success of salmonids and freshwater shrimp in the mainstem Napa River and to characterize the geomorphic attributes of the mainstem.

Site selection was driven by the need to describe the suitability of mainstem habitat for freshwater life history stages of chinook salmon and steelhead, as well as for all life history stages of California freshwater shrimp. In addition, sites with major tributary junctions were selected to determine whether passage for steelhead might be compromised at these sites. Information used to select sites for these surveys included:

- Observations made during initial reconnaissance surveys in August 2000;
- Analysis of current and historical aerial photographs (see Appendix A5);
- CDFG fish and habitat survey data; and
- Information from US Army Corps of Engineers engineering studies (WET, Inc. 1990).

Documented locations for California freshwater shrimp and chinook salmon spawning are located in the upper reaches of the Napa River between St. Helena and Calistoga. Therefore, we focused our surveys on this portion of the river. Seven reaches in this portion of the river were surveyed (Table A6-1).

Table A6-1. Mainstem Napa River extensive survey reaches.

Reach #	Starting Point	Starting Point River Mile	End Point	End Point River Mile	Distance (mi)	Nearest City
1	Zinfandel Ln.	34	Pope St.	36.2	2.2	St. Helena
2	Pope St.	36.2	Pratt Ave.	37.2	1	St. Helena
3	Deer Park Rd.	37.8	Lodi Ln.	38.4	0.6	St. Helena
4	Bale Ln.	40.7	Larkmead Ln.	41.8	1.1	St. Helena
5	Larkmead Ln.	41.8	Maple Ln.	42.9	1.1	Calistoga
6	Dunawael Ln.	43.8	Lincoln Ave.	45.4	1.6	Calistoga
7	Lincoln Ave.	45.4	Myrtledale Rd.	47.2	1.8	Calistoga

The extensive in-channel surveys to characterize the geomorphic state and availability of important habitat in the mainstem were conducted by two person teams consisting of a geomorphologist and a biologist. These surveys included both biological and geomorphic assessment to facilitate a more integrated description of geomorphic processes and physical habitat conditions for analysis species.

Habitat data collected included the abundance and size of gravel patches suitable for chinook salmon spawning (Table A6-2), as well as the abundance and length of undercut bank habitat for California freshwater shrimp (Table A6-3).

Geomorphic data collected included the relative size and frequency of pools, characterization of substrate particle size (D_{50}), observations of pool filling by fine sediment, entrenchment and aggradation, channel confinement, and bank erosion. Passage issues for spawning adult salmonids at the confluences of tributaries and the mainstem were also discussed.

Results

Results are discussed in Sections 6.1.1. 6.7, and 8.1 of the main report.

Table A6-2. Abundance and extent of suitable spawning habitat patches for chinook salmon in surveyed reaches of the mainstem Napa River.

Reach*	Minimum patch size (m^2)	Maximum patch size (m^2)	Average size of patches (m^2)	Frequency of patches (#/ km)	Abundance of habitat (m^2/km)
1	8	2,000	360	2.0	720
2	20	25	21	4.2	87
3	8	42	21	13	270
4	4	33	16	10	160
5	12	30	20	2.2	45
6	4	90	20	11	220
7	8	150	40	5.2	206

Average Spawning Habitat Abundance: 220 m^2/km
Total Spawning Habitat in All Reaches Surveyed: 3,300 m^2
*See Table A6-1 for reach descriptions.

Table A6-3. Abundance and length of suitable undercut bank habitat for California freshwater shrimp on the mainstem Napa River.

Reach**	Number of undercut banks	Total length of undercut banks (m)	Average length (m)	Frequency of undercut banks (#/km)	Abundance of undercut banks (m/km)
1	1	70	70	0.29	20
2	N/A	N/A	N/A	N/A	N/A
3	11	65	5.9	11	65
4	12	110	9.4	6.7	62
5	3	85	28	1.7	47
6	6	21	3.5	2.3	8.1
7	2	43	22	0.69	15
Totals	**35**	**400**	**11***	**2.4***	**27***

*Averages for all reaches.
**See Table A6-1 for reach descriptions.

Appendix A7: Turbidity

Methods

We sampled turbidity at 18 tributary and 6 mainstem sites in the Napa River basin following four storms between January 12 and March 3, 2001 (Map 10, Table A7-1). In addition, there was a limited turbidity sampling effort at 16 of the same tributary sites and 5 of the same mainstem sites, plus 1 new mainstem site, following a near bankfull event on January 2, 2002. Samples from individual tributaries were used to characterize turbidity in the basin as a whole. Specific tributaries were selected for sampling to ensure representation of all major streams of current and/or historical importance to salmonids and to ensure representation of the range of major geological units in the basin. Because we were relying on flow data from the USGS gage near St. Helena to determine when to start a particular storm sampling sequence to capture the recession limb of the hydrograph, we avoided tributary streams regulated by large dams that would have altered flow regimes. The specific sampling sites within tributaries were selected to maximize the sampled drainage area while also having a bridge crossing for safe and efficient sampling.

Turbidity measures how clear or muddy the water is (i.e., the degree of clarity or translucence). Turbidity is affected by suspended sediment, but other factors such as small floating organisms (i.e., phytoplankton, zooplankton, or bacterioplankton) or other organic matter (e.g., small fragments of dead plants) in the water column will also affect turbidity. Turbidity, rather than suspended sediment, monitoring is often used by aquatic biologists because it relates directly to conditions affecting visually oriented organisms, including visual predators such as juvenile steelhead (as well as fish, such as largemouth bass, that may prey on juvenile steelhead) (Waters 1995). Because we focused solely on turbidity as an indicator of potential impacts on fish feeding, and not on using turbidity as an indirect measure of suspended sediment load, our sampling needs differed from those often associated with turbidity monitoring.

According to the *Water Quality Monitoring Guidebook* (Oregon Plan 2001), developed with input by many agency and academic scientists as part of the Oregon Plan for Salmon and Watersheds: "Materials that cause turbidity tend to be evenly distributed in the water column and across the stream cross-section. Therefore a grab sample sufficiently represents the sample location. The sample can be collected at any point in the stream (either near the bank or the deepest part of this channel) by lowering the lip of the sample bottle below the surface of the water." We developed a modified approach to ensure that our sampling protocol was efficient, safe, and repeatable. We needed a device that could be used easily and safely by a single observer during storm conditions. The sampler used for this study was a 1-liter plastic bottle with an air inlet tube extending above the water surface and a water inlet tube with an inside diameter of 3/8 inch. The sampler filled gradually upon being lowered into the water column as air was displaced out the air outlet tube. The sampler was retrieved once the bottle was full. This device allowed us to sample water either by wading into the stream or by suspending the sampler on a rope and lowering it from a bridge. The design of this sampling device is similar to air-displacement samplers used by other investigators (Waters 1995).

A single grab sample in mid-channel at mid-depth is often used for turbidity monitoring, although depth- or flow-integrated samples are also used in some situations (Oregon Plan 2001, APHA 1998). We used the air displacement sampler described above to collect turbidity samples at each site by pulling the sampler across the middle 1/3 of the channel at approximately 1/3 of the total depth. Preliminary pilot studies confirmed that this method resulted in consistent readings (<5 percent difference between replicate samples) and yielded results similar to those obtained from more intensive sampling at multiple locations and depths across a channel cross-section to calculate a depth- or flow-integrated average turbidity reading. In cases when flows were very low, samples were taken from multiple discrete positions across the channel. Each sample contained about 750-1,000 ml of water and was shaken every 30 to 60 seconds while being stored for no more than 5 minutes prior to processing. The grab sample was processed by taking two 15 ml subsamples in vials and running them through a Hach 2100P portable nephalometric turbidometer. These methods were based on standard water quality assessment methods (APHA, 1998). We then calculated the average of these two subsamples for each site. The turbidometer can read values from 0–1,000 NTU with a resolution of 0.01 NTU[3].

Table A7-1. Locations and dates Napa River basin turbidity sampling.

Tributary		Days following storm of…				
		WY 2001				WY 2002
		Jan 12th	Feb 11th	Feb 25th	Mar 5th	Jan 2nd
Bear Canyon Creek		N/S	1, 3	0, 1, 3, 6	1, 3, 8	N/S
Carneros Creek at Route 121		0, 1, 3, 9	0, 1, 3	0, 1, 3, 6	1, 3, 8	10
Cyrus Creek		0, 1, 3, 9	0, 1, 3	0, 1, 3, 6	1, 3, 8	3, 10
Dry Creek at Solano Avenue		0, 1, 3, 9	0, 1, 3	0, 1, 3, 6	1, 3, 8	10
Garnett Creek		0, 1, 3, 9	0, 1, 3	0, 1, 3, 6	1, 3, 8	10
Huichica Creek		0, 1, 3, 9	0, 1, 3	0, 1, 3, 6	1, 3, 8	10
Milliken Creek		N/S	N/S	1, 3, 6	1, 3, 8	10
Napa River Mainstem	Napa River at Bale Lane	N/S	N/S	N/S	N/S	3
	Napa River at Deer Park Rd	0, 1, 3, 9	0, 1, 3	0, 1, 3, 6	1, 3, 8	10
	Napa River at Oak Knoll Rd	0, 1, 3, 9	0, 1, 3	0, 1, 3, 6	1, 3, 8	10
	Napa River at Trancas Street	0, 1, 3, 9	0, 1, 3	0, 1, 3, 6	1, 3, 8	N/S
	Napa River at Tubbs Lane	0, 1, 3, 9	0, 1, 3	0, 1, 3, 6	1, 3, 8	10
	Napa River at Yountville Cross	0, 1, 3, 9	0, 1, 3	0, 1, 3, 6	1, 3, 8	10
	Napa River at Zinfandel Lane	0, 1, 3, 9	0, 1, 3	0, 1, 3, 6	1, 3, 8	3, 10
Redwood Creek		0, 1, 3, 9	0, 1, 3	0, 1, 3, 6	1, 3, 8	10
Ritchie Creek		0, 1, 3, 9	0, 1, 3	0, 1, 3, 6	1, 3, 8	3
Soda Creek		0, 1, 3, 9	0, 1, 3	0, 1, 3, 6	1, 3, 8	10
Sulphur Creek		0, 1, 3, 9	0, 1, 3	0, 1, 3, 6	1, 3, 8	10
York Creek		N/S	1, 3	0, 1, 3, 6	1, 3, 8	10
Mill Creek		0, 1, 3, 9	0, 1, 3	0, 1, 3, 6	1, 3, 8	3, 10
Biter Creek		0, 1, 3	0, 1, 3	0, 1, 3, 6	1, 3, 8	10
Bale Slough		N/S	1	3, 6	1	N/S
Dutch Henry Creek below Biter Creek		0, 1, 3, 9	0, 1, 3	0, 1, 3, 6	1, 3, 8	10
Dutch Henry Creek above Biter Creek		0, 1, 3, 9	0, 1, 3	0, 1, 3, 6	1, 3, 8	10

[1] N/S = Not sampled

[3] More details on the turbidometer are available at http://www.hach.com/Spec/S2100P.htm.

We also sampled turbidity following a peak flow event on January 2, 2002 that was much larger than any observed during 2001. This event was close to the bankfull discharge as measured at the USGS gage on the Napa River near St. Helena. This storm was sampled 1–2 times depending on the site (Table A7-2), to verify that turbidities were not above the 20 NTU threshold following a near bankfull event. This January 2002 storm differed from the 2001 events because there was much more rainfall in the month prior to the event, which may have increased soil saturation relative to 2001 storms.

Results

We sampled four storms between January and March 2001 and one storm in January 2002. One storm in late January 2001 was not sampled because it was approximately the same magnitude as the January 2, 2001 storm. Table A7-2 lists the storms that were sampled as part of this study and estimated recurrence intervals based on a Log-Pearson Type III analysis of the historical record of the St. Helena gauging station. A fifth storm, which occurred in early January 2002, was selected for a limited sampling effort to reflect turbidity conditions following a larger, near-bankfull event that occured subsequent to an uncharacteristically wet period during the previous six weeks.

Table A7-2. Recurrence interval of storms sampled as part of the turbidity study.

Storm Date	Peak Flow (cfs)[1]	Recurrence Interval[2] (years)
January 12, 2001	352	1.04
February 11, 2001	380	1.04
February 25, 2001	952	1.07
March 3, 2001	2,702	1.25
January 2, 2002	3,292	1.36

[1] Daily average as measured at the USGS St. Helena Gage (number 11456000)
[2] Based on the daily average flow record at the USGS St. Helena Gage from 1929 to present

Figures A7-1 through A7-2 show the results of the turbidity analysis. To facilitate the comparison of turbidity measurements on different tributaries, the results in Figures A7-1a through A7-1f were plotted on top of the hydrograph from the USGS Napa River near St. Helena gage (number 11456000). While the timing and magnitude of peaks on the tributaries will vary substantially in detail from the timing and magnitude at St. Helena, the St. Helena gage data are provided as a general reference for flow status in the basin.

Figures A7-2a though A7-2f show plots of turbidity versus discharge at the same sites as Figures A7-2. These plots show that relative to the hydrograph at St. Helena (the St Helena gage was used as an indicator of the general flow status of the basin because its drainage area is smaller than that of the mainstem gage near the City of Napa and, hence, has a shorter lag in terms of approximating the timing of the return to baseflow conditions on the tributaries), turbidity for the individual tributaries was generally higher for a given discharge following the first storm peak compared with subsequent storms. This is likely due to the initial flushing of sediment that has entered the system and remained undisturbed since the previous rainy season.

The fall and winter of 2000–2001, when most of our turbidity sampling occurred, proved to be substantially drier than the same period in 2001–2002. The period of October 15, 2000 through the end of December 2000 produced approximately 8 inches of rain at the St Helena gage. Rainfall at the same location during the same period in 2001 totaled over 30 inches (a 375 percent increase). Furthermore, rainfall during the month of December differed dramatically between the two years, with 1.5 inches of rain in December 2000, compared with 18.5 inches during the same period in 2001 (> 1200 percent increase).

Such an increase in the overall amount and, particularly, the temporal concentration of rainfall has the potential to result in different sediment dynamics. Increased ground saturation resulting from early rainfall can mobilize near-channel earth flows and landslides that could contribute sediment to channels. The wetter conditions may also increase contributions from agricultural areas and roads. To determine whether the increased rainfall observed during the winter of 2001–2002 resulted in an increase in turbidity loading in the system, further turbidity sampling was performed following the near bankfull event on January 2, 2002. The data collected in this effort (Table A7-3), indicated that turbidity levels were consistent with those observed during the first year of sampling under drier conditions, and that baseflow turbidity again did not remain elevated to a point (i.e. above the 20 NTU threshold) that it would be expected to reduce feeding efficiency of juvenile steelhead.

Table A7-3. Turbidity measurements following the January 2, 2002 storm event.

Tributary	January 04, 2002		January 11, 2002	
	Discharge (cfs)[1]	Turbidity (NTU)	Discharge (cfs)[2]	Turbidity (NTU)
Cyrus Creek at Route 128	587	11.7	220	8.8
Dutch Henry Creek at Route 29	587	4.6	213	2.8
Mill Creek at Route 29	587	10.8	220	7.3
Napa River at Bale Lane	587	N/S	N/S	N/S
Napa River at Zinfandel Lane	587	18.7	219	8.2
Ritchie Creek at Route 29	587	11.6	N/S	N/S
Biter Creek at Route 29	N/S	N/S	212	3.1
Carneros Creek at Duhig Road and Ramal Road	N/S	N/S	225	6.3
Carneros Creek at Route 121	N/S	N/S	225	18.2
Dry Creek at Route 29	N/S	N/S	220	4.1
Garnett Creek at Route 29	N/S	N/S	218	3.8
Milliken Creek	N/S	N/S	211	4.5
Napa River at Deer Park Road	N/S	N/S	211	7.2
Napa River at Oak Knoll Road	N/S	N/S	209	11.3
Napa River at Tubbs Road	N/S	N/S	219	4.3
Napa River at Yountville Crossing	N/S	N/S	210	9.2
Redwood Creek at Redwood Drive	N/S	N/S	223	8.0
Simmons Canyon Creek	N/S	N/S	213	6.5
Soda Creek at Silverado Trail	N/S	N/S	210	2.7
Sulpher Creek at Pope Street	N/S	N/S	218	3.7
York Creek at Route 29	N/S	N/S	219	7.5

[1] Daily average discharge measured at the USGS gage near St. Helena (number 11456000)
[2] Instantaneous data from the USGS gage near St. Helena
[3] N/S = Not sampled

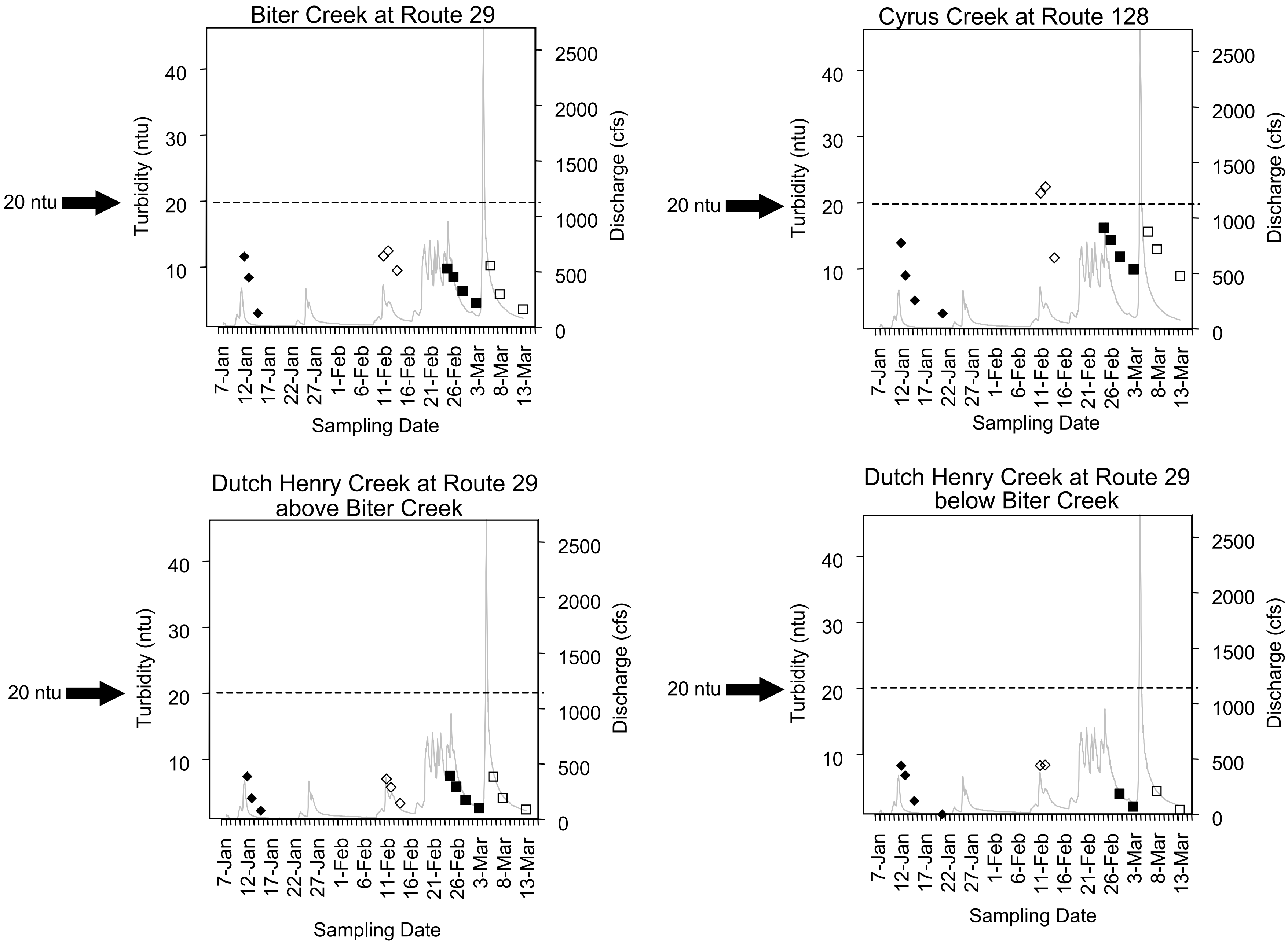

Figure A7-1a. Sampled turbidity measurements and discharge recorded at the USGS gage near St. Helena (no. 11456000) during water year 2001. 20 NTU, the conservative threshold value used in this analysis, is indicated with ➡. ♦ = first storm, ◇ = second storm, ■ = third storm, □ = fourth storm

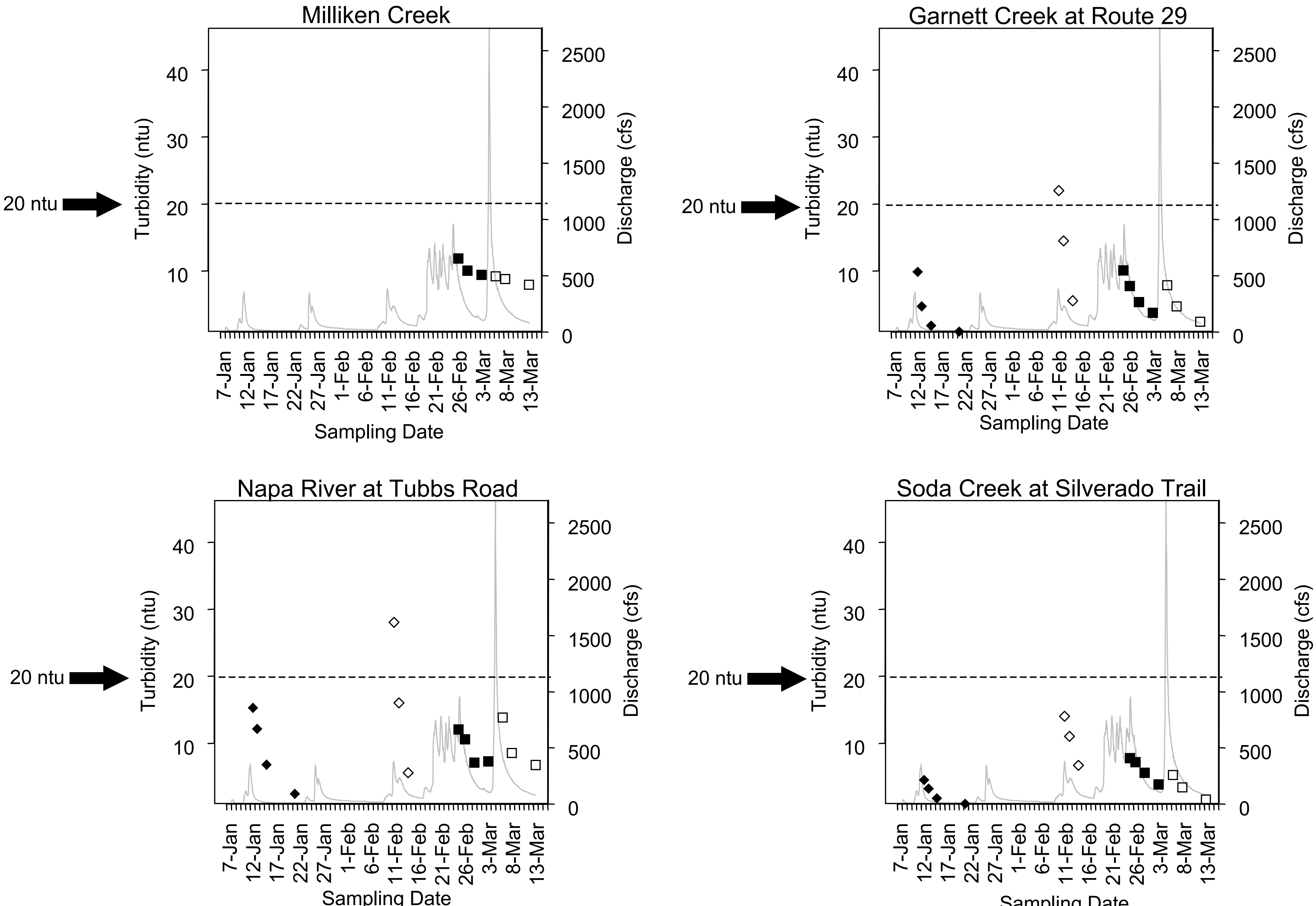

Figure A7-1b. Sampled turbidity measurements and discharge recorded at the USGS gage near St. Helena (no. 11456000) during water year 2001. 20 NTU, the conservative threshold value used in this analysis, is indicated with ➡. ◆ = first storm, ◇ = second storm, ■ = third storm, □ = fourth storm

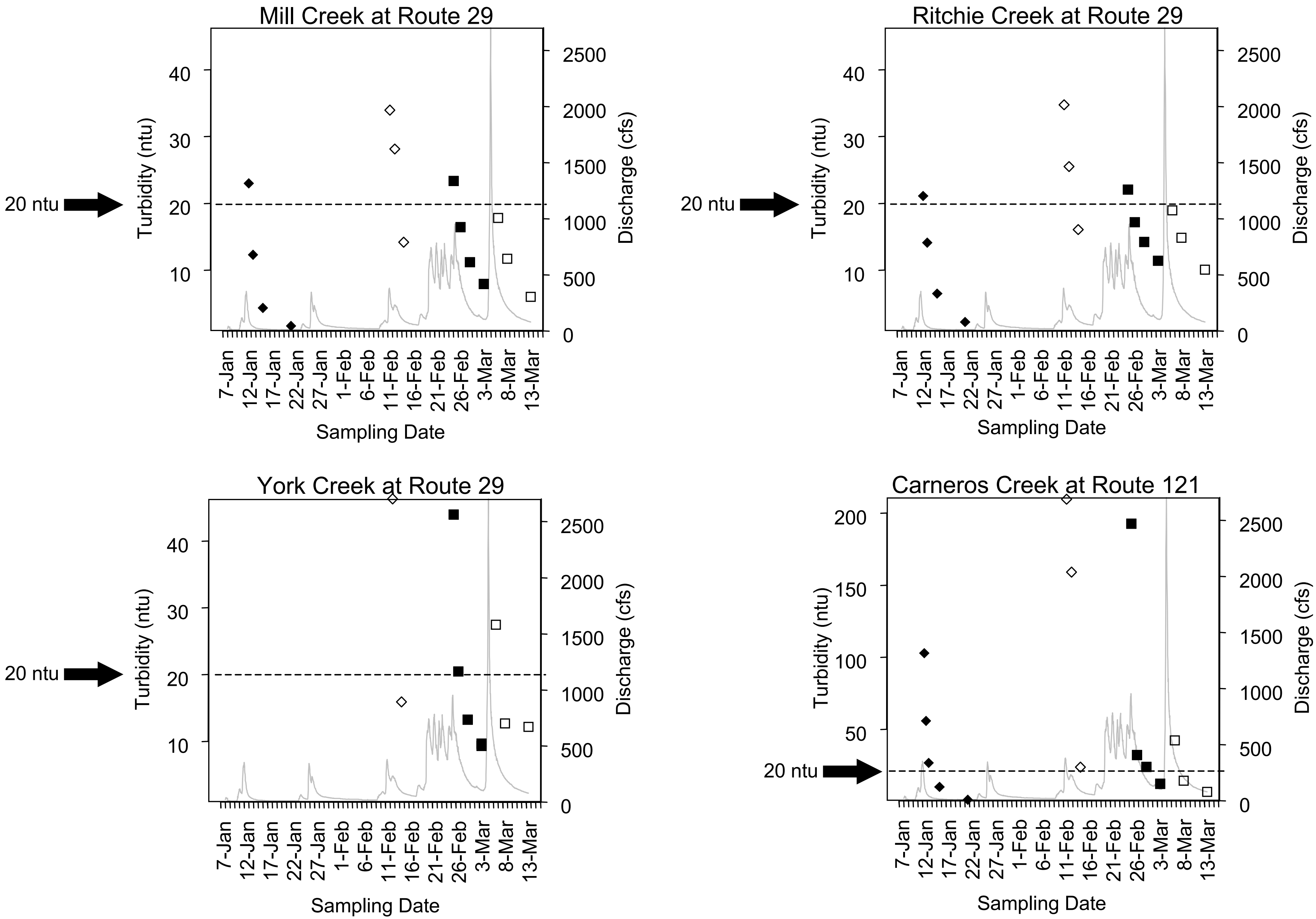

Figure A7-1c. Sampled turbidity measurements and discharge recorded at the USGS gage near St. Helena (no. 11456000) during water year 2001. 20 NTU, the conservative threshold value used in this analysis, is indicated with ➡ . ◆ = first storm, ◇ = second storm, ■ = third storm, □ = fourth storm

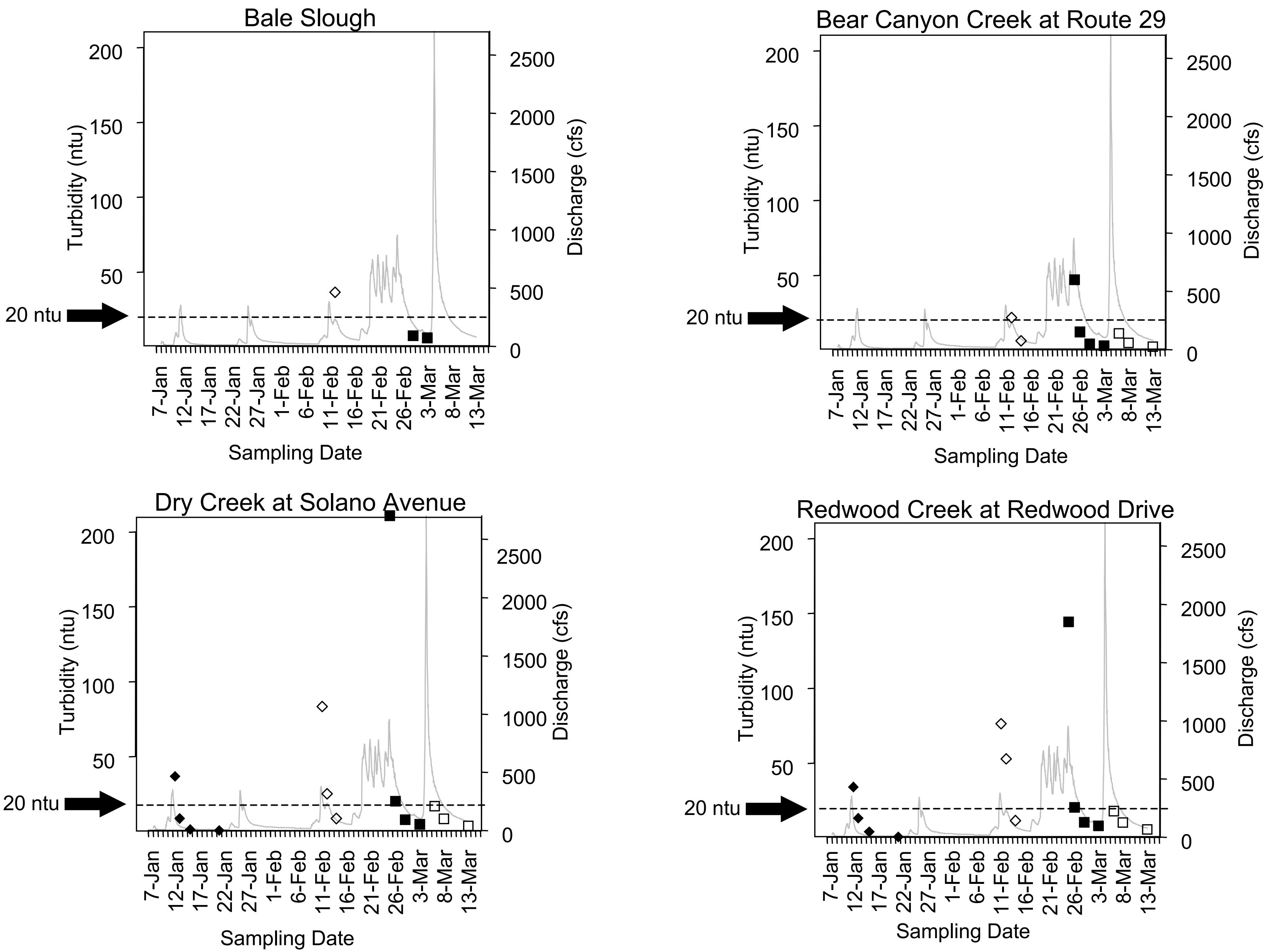

Figure A7-1d. Sampled turbidity measurements and discharge recorded at the USGS gage near St. Helena (no. 11456000) during water year 2001. 20 NTU, the conservative threshold value used in this analysis, is indicated with ➡ . ◆ = first storm, ◇ = second storm, ■ = third storm, □ = fourth storm

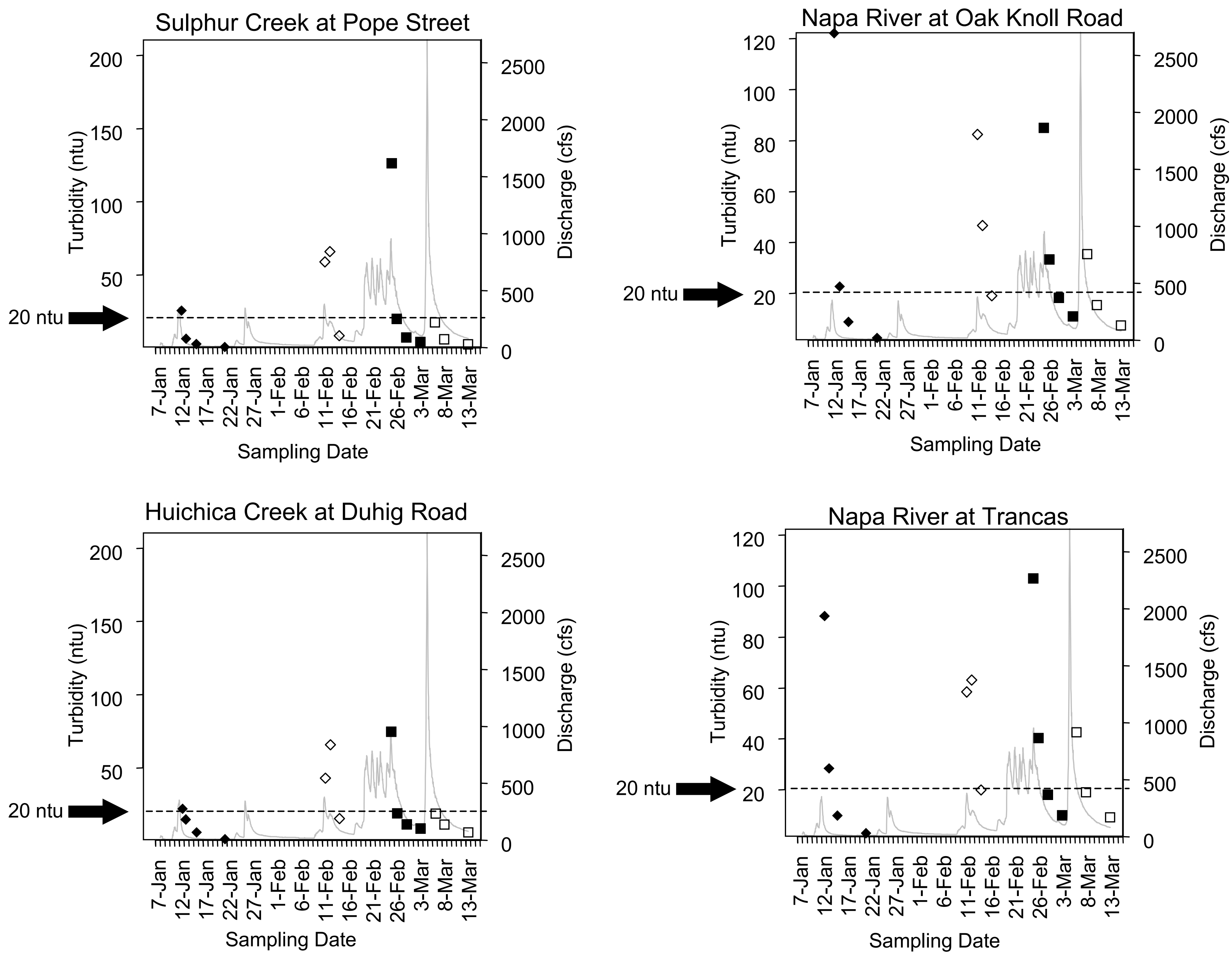

Figure A7-1e. Sampled turbidity measurements and discharge recorded at the USGS gage near St. Helena (no. 11456000) during water year 2001. 20 NTU, the conservative threshold value used in this analysis, is indicated with ➡ . ◆ = first storm, ◇ = second storm, ■ = third storm, □ = fourth storm

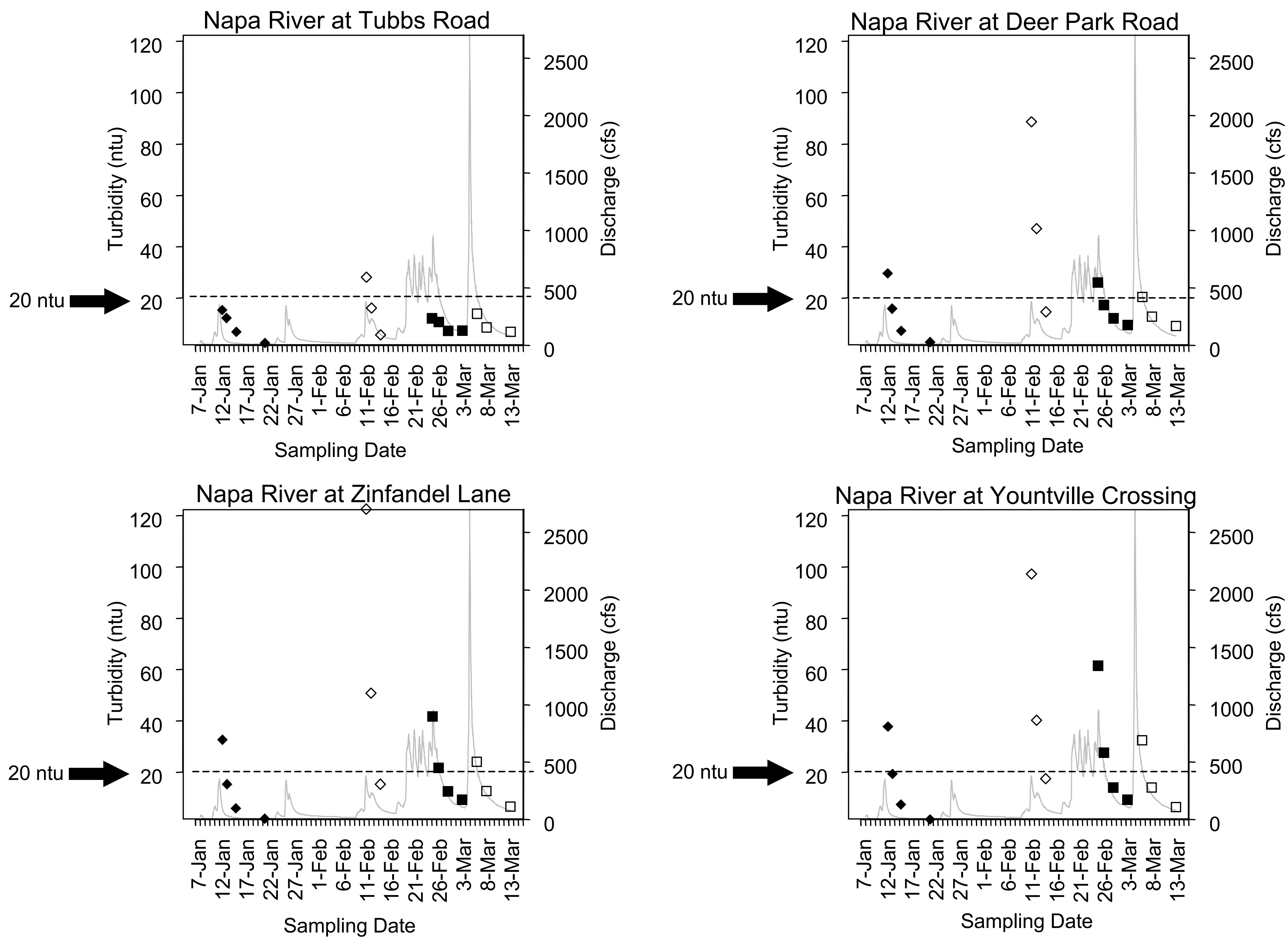

Figure A7-1f. Sampled turbidity measurements and discharge recorded at the USGS gage near St. Helena (no. 11456000) during water year 2001. 20 NTU, the conservative threshold value used in this analysis, is indicated with ➡ . ◆ = first storm, ◇ = second storm, ■ = third storm, □ = fourth storm

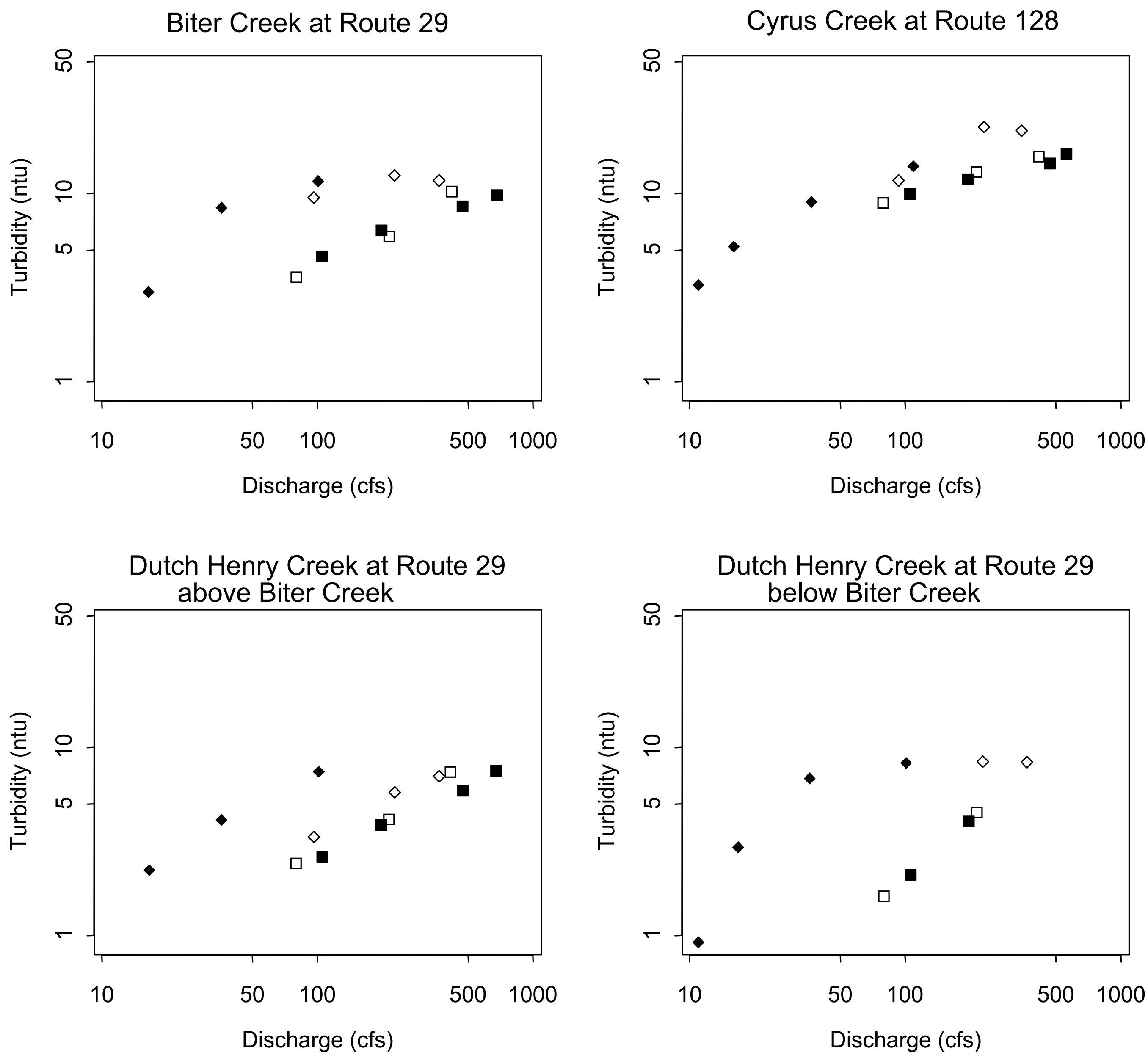

Figure A7-2a. A comparison of turbidity and discharge, recorded at the USGS gage near St. Helena (no. 11456000), at sampling sites within the Napa River watershed during water year 2001.

◆ = first storm, ◇ = second storm, ■ = third storm, □ = fourth storm

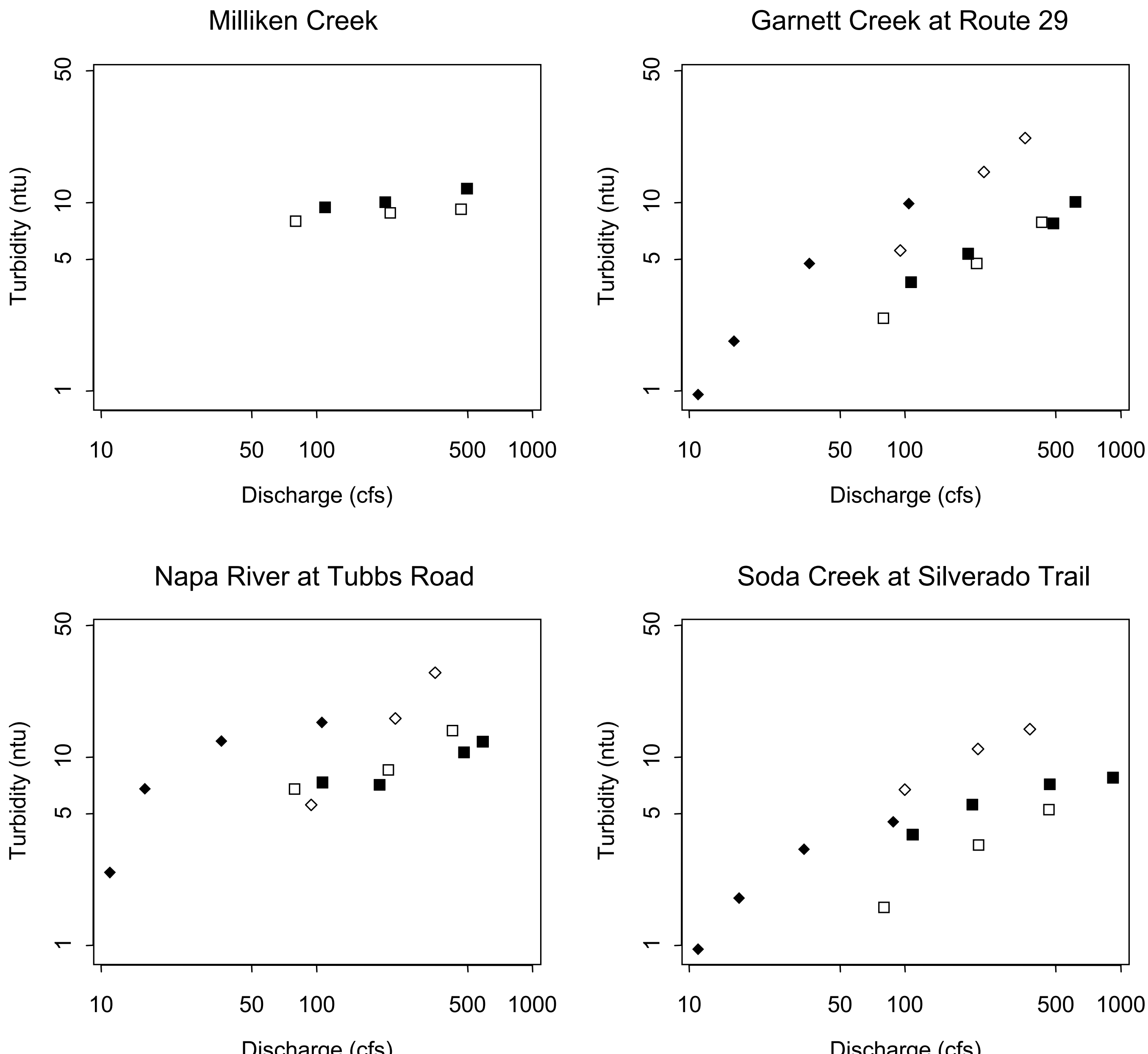

Figure A7-2b. A comparison of turbidity and discharge, recorded at the USGS gage near St. Helena (no. 11456000), at sampling sites within the Napa River watershed during water year 2001.

◆ = first storm, ◇ = second storm, ■ = third storm, □ = fourth storm

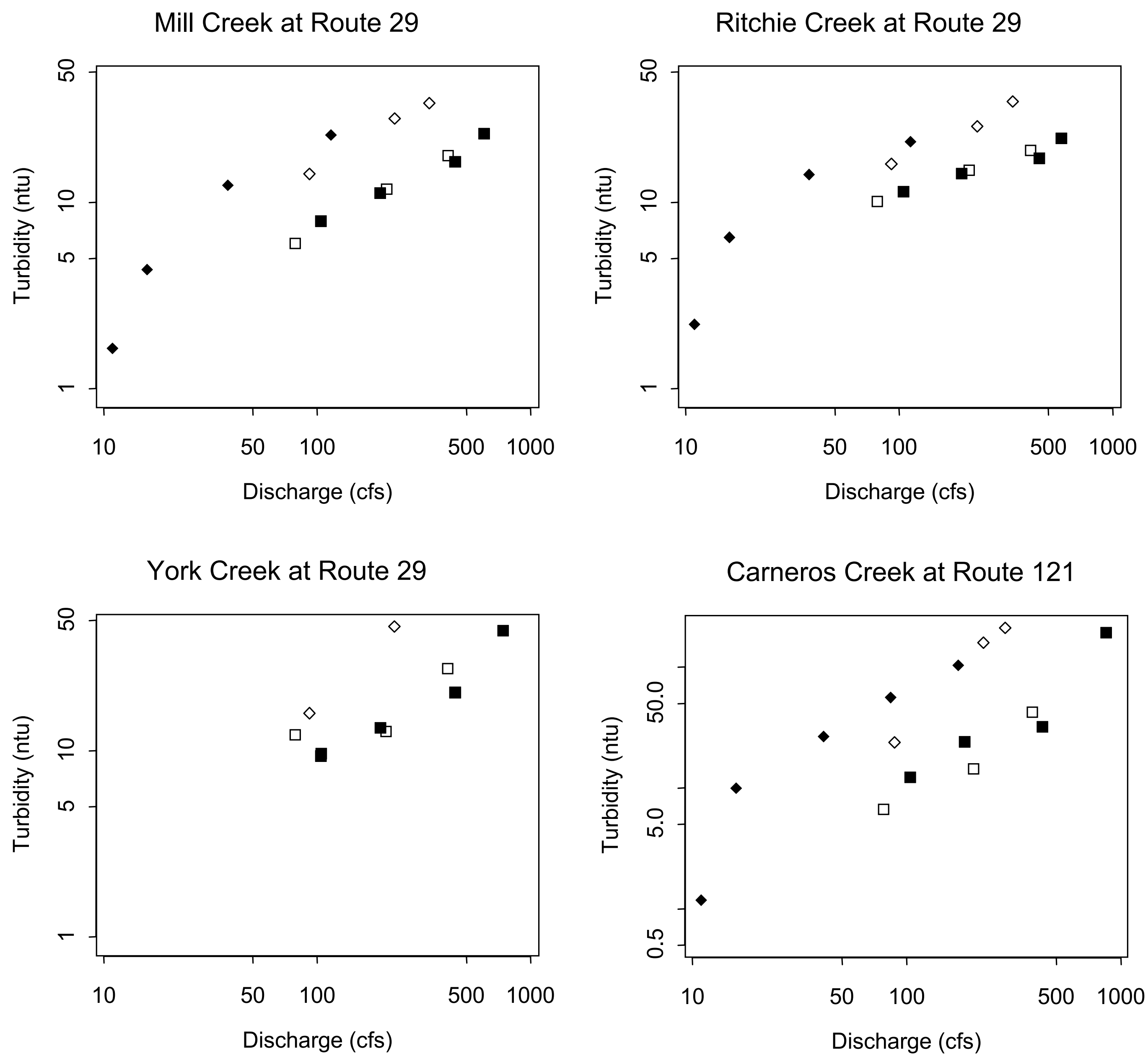

Figure A7-2c. A comparison of turbidity and discharge, recorded at the USGS gage near St. Helena (no. 11456000), at sampling sites within the Napa River watershed during water year 2001.

◆ = first storm, ◇ = second storm, ■ = third storm, □ = fourth storm

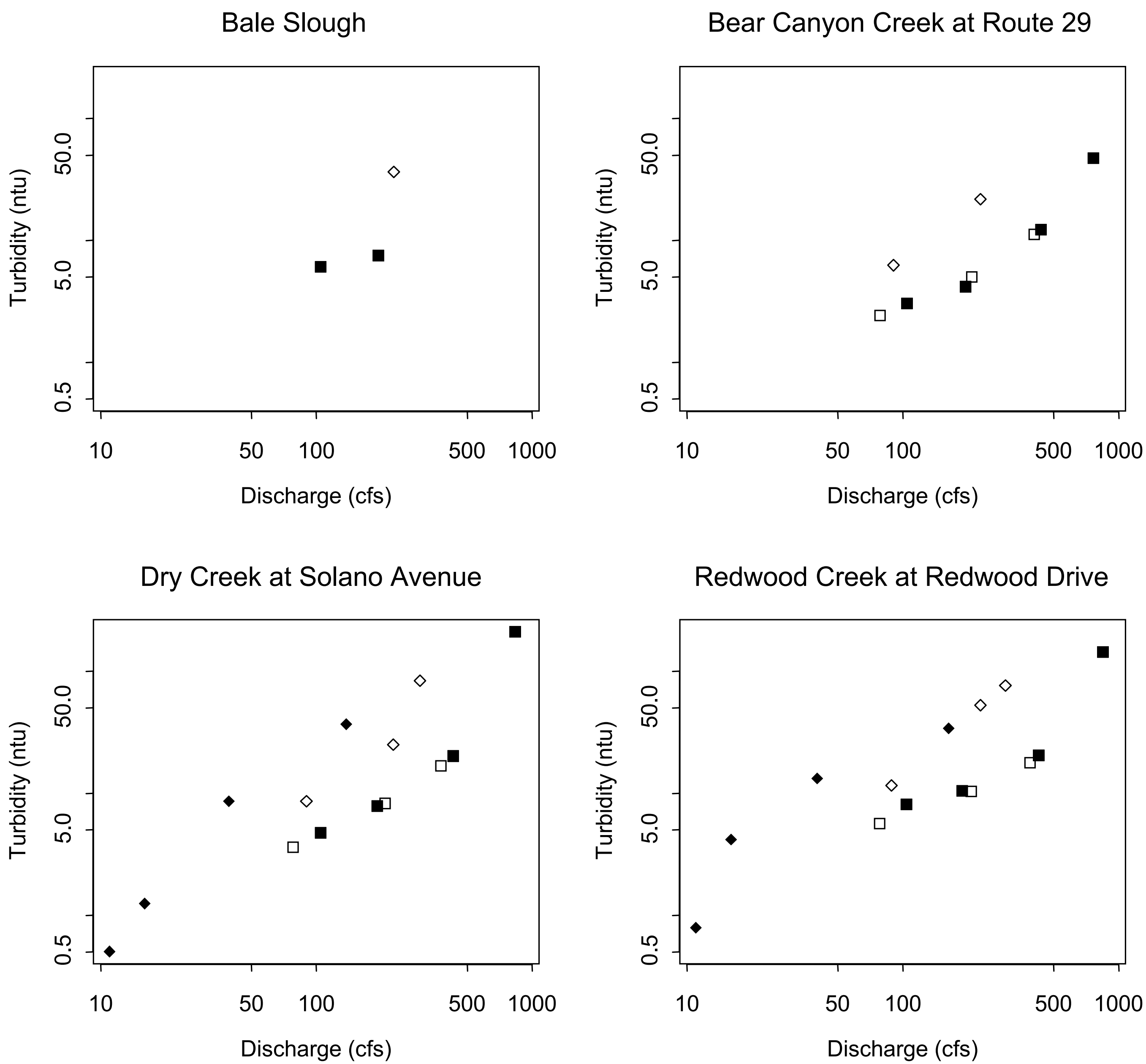

Figure A7-2d. A comparison of turbidity and discharge, recorded at the USGS gage near St. Helena (no. 11456000), at sampling sites within the Napa River watershed during water year 2001.

◆ = first storm, ◇ = second storm, ■ = third storm, □ = fourth storm

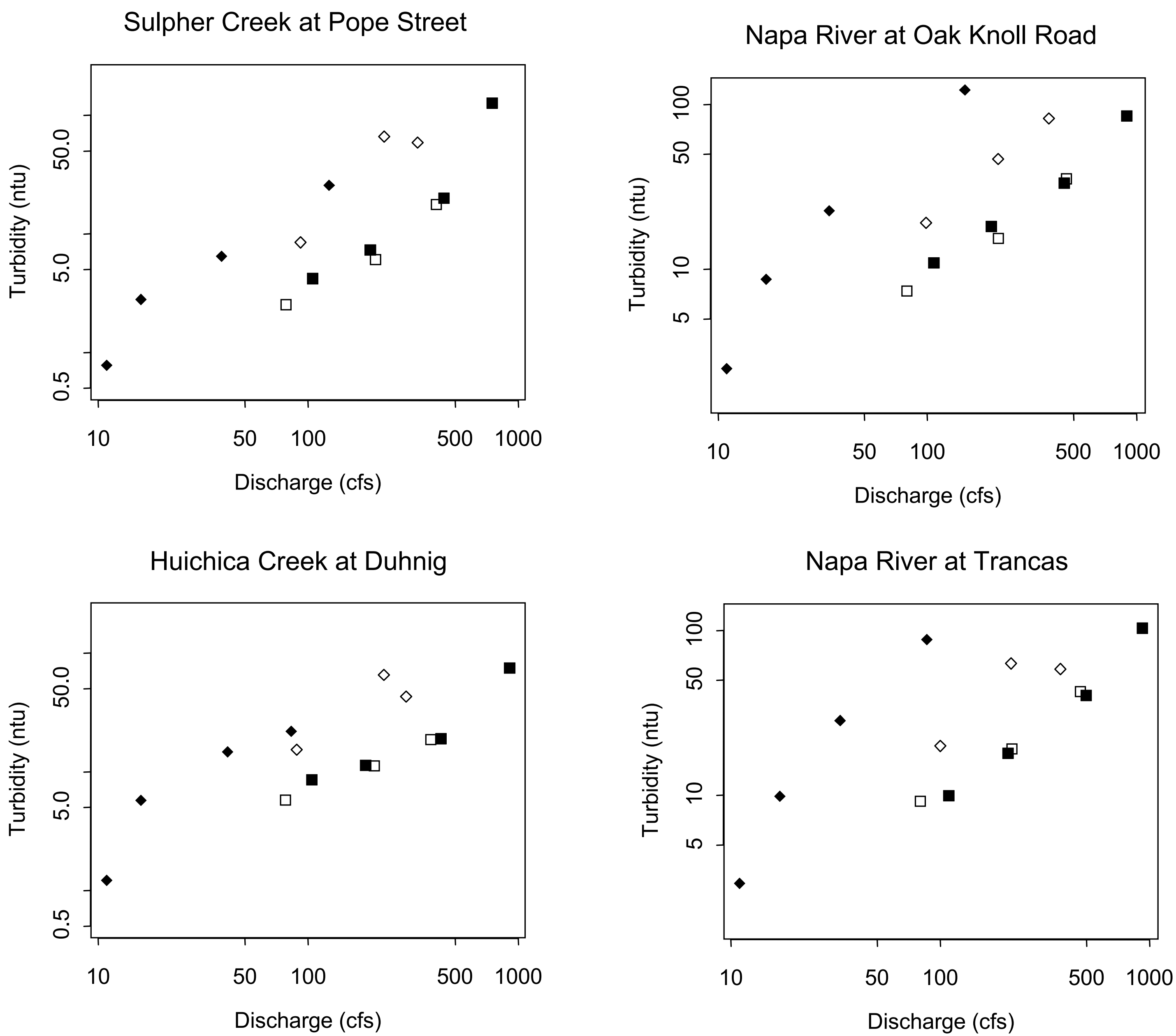

Figure A7-2e. A comparison of turbidity and discharge, recorded at the USGS gage near St. Helena (no. 11456000), at sampling sites within the Napa River watershed during water year 2001.

♦ = first storm, ◊ = second storm, ■ = third storm, □ = fourth storm

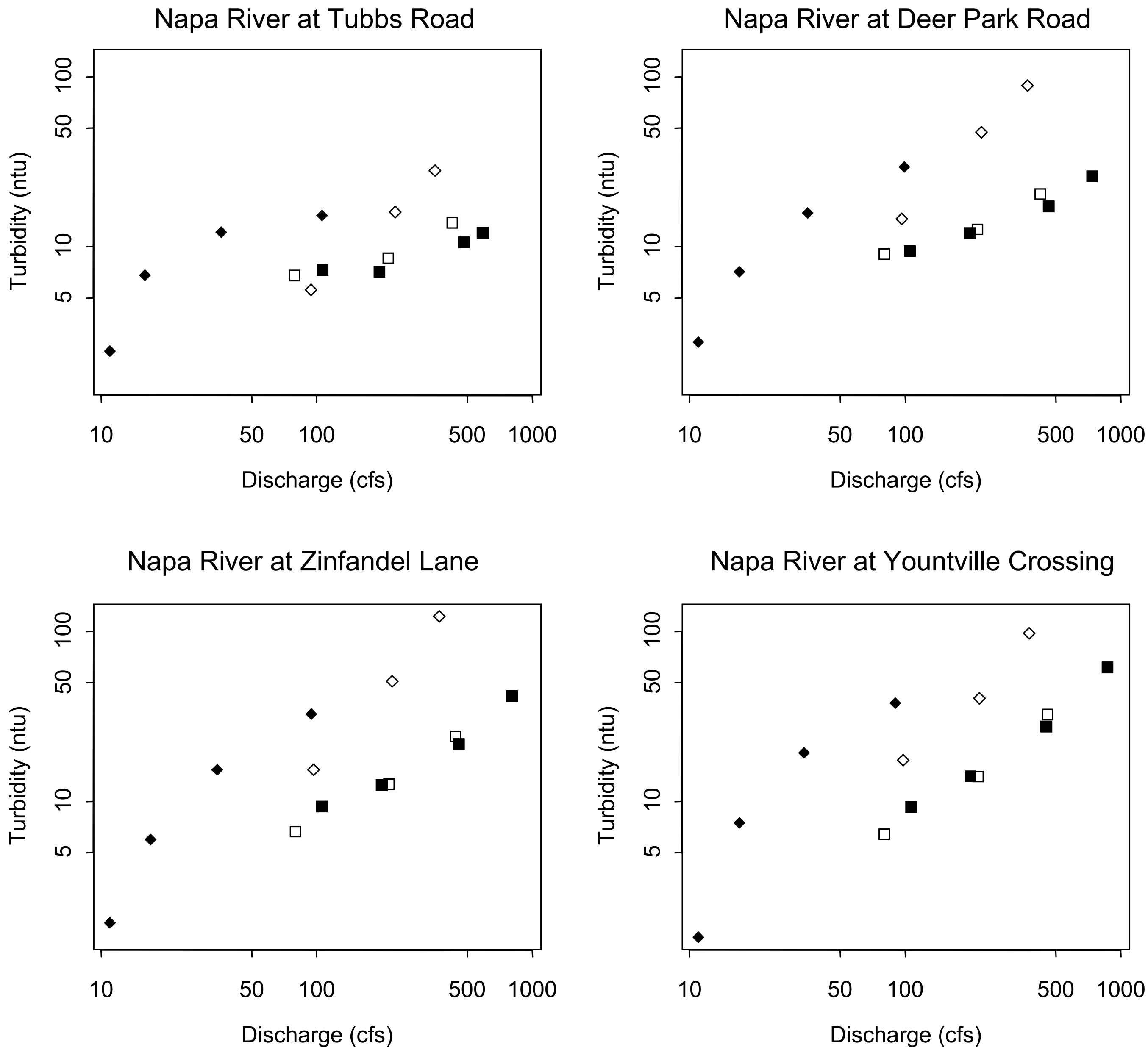

Figure A7-2f. A comparison of turbidity and discharge, recorded at the USGS gage near St. Helena (no. 11456000), at sampling sites within the Napa River watershed during water year 2001.

♦ = first storm, ◊ = second storm, ■ = third storm, □ = fourth storm

Appendix A8. Permeability

Methods

To determine the quality of streambed gravels for salmonid egg incubation and larval (alevin) rearing, substrate permeability was measured using a modified Mark IV standpipe (Terhune 1958, Barnard and McBain 1994). Gravels at potential spawning sites were mixed to a depth of 0.95 feet to simulate mixing and sorting conditions that would occur during redd construction by a spawning salmonid (see Kondolf and Wolman 1993 for more information on this topic). The standpipe used was 46.5 inches (118 cm) long, with a 1.0 inch (2.5 cm) inside diameter and a 1.25 inch (3.8 cm) outside diameter. The standpipe had a 2.75 inch-long band of perforations and was driven into the substrate so that the band of perforations extended in depth from approximately 0.64 to 0.86 feet below the bed surface. To reduce the potential for water 'slippage' down the pipe, the standpipe was held, but not forced in any direction, during the driving process.

Permeability was measured by using a Thomas vacuum pump (Model 107CDC20, powered by a 12-volt rechargeable battery) to siphon water out of the standpipe to maintain the water level inside the standpipe exactly one-inch lower than the surrounding water. By measuring the volume of water siphoned out of the standpipe over a measured time interval, it was thus possible to determine the recharge rate of the water level in the standpipe under a standard one-inch pressure head. At each spawning patch assessed, the standpipe was driven in once and five consecutive permeability measurements were taken.

The recharge rate (units of volume per time) data measured in the field were converted into permeability (units of length per time) using an empirically derived rating table (Barnard and McBain 1994) and adjusted with a correction factor that accounts for temperature related changes in water viscosity that can affect permeability results (Barnard and McBain 1994).

The mortality index was calculated using the permeability measurements and equations (1) and (2) as described in detail in Section 6.2.2 of the main report.

Appendix A9 provides details on how specific sample reaches were selected (permeability and pool filling sampling were done concurrently).

Results

The results of the permeability analysis and the mortality index calculation are given in Table A8-1 and Main Report Figure 6-3. Discussion of the results is provided in Section 6.2.2 of the main report.

Table A8-1. Summary of permeability sampling in the Napa River basin.

Stream Name	Site Description	Latitude	Longitude	Date	Spawning Patch[1]	Permeability (cm/hr)	Mortality Index
Napa River	At Bale Lane Bridge (MS1)	N38 33' 26.1"	W122 30' 18.9"	1/17/02	A	3,062	63%
				1/17/02	B	10,920	44%
	At Dunaweal Lane (MS2)	N38 34' 7.5"	W122 33' 15.8"	1/17/02	A	4,574	57%
	At Larkmead Lane (MS3)	N38 33' 38.7"	W122 31' 14.2"	1/17/02	A	23,885	33%
				1/17/02	B	23,013	33%
Bell Creek	Upstream of Silverado Road, adjacent to Glass Mountain Road	N 38 32'11.0"	W 122 29'09.7"	2/8/02	A1	683	85%
				2/8/02	A2	2,238	68%
Carneros Creek	Henry Road (middle Carneros)	N38 16' 23.5"	W122 21' 16.2"	2/9/02	A1	378	94%
				2/11/02	A2	262	100%
	End of Henry Road (upper Carneros)	N38 17' 53.9"	W122 22' 56.9"	2/9/02	A1	7,461	50%
	Withers Road (lower Carneros)	N38 14' 48.8"	W122 19' 57.2"	2/9/02	A1	276	99%
				2/9/02	A2	950	81%
Conn Creek	Conn Valley Road	N38 30' 55.4"	W122 24' 55.6"	2/10/02	A1	4,700	57%
				2/10/02	A2	5,601	54%
Cyrus Creek	Petrified Forest Road (upstream of Fiege Reservoir)	N38 34' 25.8"	W122 36' 14.7"	1/15/02	A	9,486	46%
				1/15/02	B	4,961	56%
	Shaw-Williams & Franz Valley Rd. intersection	N38 34' 53.2"	W122 36' 33.3"	1/15/02	A	10,077	45%
				1/15/02	B	1,066	79%
				1/15/02	C	2,161	68%
Diamond Mountain Creek	Diamond Mountain Road (upper Diamond Mountain)	N38 33' 53.8"	W122 34' 09.2"	1/16/02	A	6,822	51%
				1/16/02	B	6,415	52%
	HWY 128 and Diamond Mountain Road intersection (lower Diamond Mountain	N38 33' 57.6"	W122 33' 45.2"	1/16/02	A	1,856	71%
				1/16/02	B	2,587	66%
				1/16/02	C	2,306	67%
Dry Creek	West Oak Knoll Road (lower Dry)	N38 21'09.0"	W122 20'43.8"	2/10/02	A1	2,548	66%
				2/10/02	A2	3,585	61%
	Dry Creek Road (upper Dry)	N38 25' 20.3"	W122 28' 11.8"	2/10/02	A1	1,657	72%
				2/10/02	A2	4,816	56%
	Dry Creek Road, just below Oakville Grade (middle Dry)	N38 24' 22.0"	W122 35' 47.6"	1/18/02	A	30,717	29%
				1/18/02	B	8,721	48%
Dutch Henry Creek	Dutch Henry Canyon Road and Lommel Road intersection (upper Dutch Henry)	N38 34' 38.0"	W122 31' 6.6"	1/17/02	A	1,279	76%
				1/17/02	B	27,810	30%
	Near Larkmead Bridge (lower Dutch Henry)	N38 34' 3.0"	W122 31' 8.6"	1/17/02	3	9,661	46%
					5	4,758	57%
Garnett Creek	Mile 39 on HWY 29	N38 36' 15.7"	W122 35' 16.8"	1/15/02	A	7,810	49%
				1/15/02	B	1,163	77%
				1/15/02	C	10,979	44%
Heath Canyon Creek	Sulphur Spring Avenue	N38 29' 11.5"	W122 29' 11.5"	1/18/02	A	14,322	40%

Stream Name	Site Description	Latitude	Longitude	Date	Spawning Patch[1]	Permeability (cm/hr)	Mortality Index
Mill Creek	Bothe State Park, upstream of HWY 128/29 bridge	N38 32' 27.9"	W122 30' 28.8"	1/16/02	A	3,798	60%
				1/16/02	B	18,876	36%
	Bothe State Park, upstream of foot bridge	N38 32' 25.7"	W122 30' 34.7"	1/16/02	A	6,647	52%
				1/16/02	B	6,201	53%
Redwood Creek	Redwood Road (middle Redwood)	N38 18' 54.8"	W122 19' 57.5"	2/9/02	A1	6,250	52%
	Redwood Road (lower Redwood)	N38 20'29.8"	W122 23'16.1"	2/11/02	A1	2,849	64%
				2/11/02	A2	8,430	48%
	Redwood Road at Archer Tailor Preserve (upper Redwood)	N38 21' 15.3"	W122 25' 18.1"	1/18/02	A1	27,035*	31%
				1/18/02	A2	20,542*	35%
				1/18/02	B1	5,562*	54%
				1/18/02	B2	4,399*	58%
Ritchie Creek	Bothe State Park	N38 32' 56.7"	W122 31' 30.5"	1/17/02	1	6,676	51%
				1/17/02	2	349	95%
				1/17/02	A	4,806	56%
				1/17/02	B	1,483	74%
				1/17/02	C	2,519	66%
Sage Creek	Sage Canyon Road near HWY 128	N38 92' 23.1"	W122 19' 40.7"	2/10/02	A1	930	81%
				2/10/02	A2	7,771	49%
Sarco Creek	Hagen Road	N38 19' 25.2"	W122 14' 01.7"	2/8/02	A1	1,318	76%
				2/8/02	A2	1,667	72%
Soda Creek	Soda Canyon Road	N38 22' 13.0"	W122 17' 00.8"	1/18/02	A	13,314	41%
				1/18/02	B	11,608	43%
Soscal Creek	Soscal Creek Road, immediately east of HWY 29	N38 14'25.4"	W122 15'57.0"	2/9/02	A1	1,599	73%
				2/9/02	A2	2,626	65%
Sulfur Creek	Upstream of Sulfur Springs Resort	N38 29' 25.2"	W122 29' 55.3"	1/17/02	A	66,666	17%
				1/17/02	B	14,380	40%

* indicates that gravels at this site were not remixed because they appeared recently mobilized
[1] Spawning patch identification numbers or letters were assigned in the field to each individual gravel patch sampled.

Appendix A9: Pool Filling

Methods

To determine the impact of pool filling by fine sediment in the study reaches, we developed a rapid technique for estimating pool filling based on the V* technique developed by Hilton and Lisle (1993). The rapid technique is similar to the V* technique in that it estimates the proportion of the residual pool filled by fine sediment, where "residual pool" is defined as the scoured volume of the pool lying below the downstream grade control.

To validate the rapid method for estimating pool filling developed for this study, a subset of seven pools was selected for comparison to the more widely used V* method developed by Hilton and Lisle (1993). The seven sites were selected based on field estimates of pool filling, so that the two methods were compared over a range of levels of pool filling from near zero to greater than 50 percent. This range was selected because it reflected the total range of conditions observed during the study and included conditions ranging from those that were predicted to have no significant impacts on juvenile rearing habitat to conditions that would significantly reduce juvenile rearing habitat.

The rapid method involved estimating the volume of the residual pool by measuring the length, average width and maximum depth of water to determine the volume of water in the pool. The bottom of the pool was then probed extensively to identify the locations and surface areas of all patches of fine sediment within the residual pool. The depth of each patch of fine sediment was then measured in five locations to calculate the average depth of the deposit. Finally, a detailed sketch of each pool was drawn, showing the outline of the residual pool, location of fine sediment deposits, location of pool depth measurements, and any significant landmarks (e.g., riprap or large trees) that would be useful for locating the pool in the future.

Using the modified method, pool filling by fine sediment was calculated by dividing the estimated volume of fine sediments in each pool by the sum of the water volume and fine sediment volume.

$$\text{Pool filling (PF)} = \frac{\sum_{i=1}^{n} A_i d_i}{\sum_{i=1}^{n} A_i d_i + V} \qquad (1)$$

where A_i is the surface area, d_i is the depth of the *i*th sediment patch in the pool, and V is the total pool water volume.

As suggested by Hilton and Lisle (1993), a volume weighted mean was the statistic used to characterize pool filling by fine sediment at the reach level.

$$\text{Volume Weighted, Reach Averaged Pool Filling} = \frac{\sum_{i=1}^{n} PF_i \cdot PV_i}{\sum All\ Pool\ Volumes} \qquad (2)$$

Where PF_i is the pool filling and PV_i is the volume of the *i*th pool.

To assess general patterns of impact of fine sediment over an area the size of the Napa River basin, we needed to survey as many sites as possible. Reaches were selected based on fish habitat, slope, geologic, and access criteria. Reaches were selected that were known to, or could potentially, provide habitat to anadromous fish. Reaches upstream of dams were therefore included. Because pool filling is less likely to occur at slopes greater than two percent, reaches were selected in areas where channel slope was two percent or less. In addition, sites were selected to represent a variety of locations throughout the basin. The range of potential sampling sites was further narrowed based on whether permission could be obtained for access on private property. To ensure that sites meeting all of the habitat, gradient, geologic, and access criteria described above were adequate reflections of reach-wide conditions, a preliminary survey was conducted of all portions of the reach that could be viewed from public access points. In almost all cases, sites to which access was available appeared to accurately represent the conditions of the larger reach.

After obtaining permission to access the channel, reaches were selected that included five or six pools. In reaches where pools were scarce, the length of channel surveyed was increased from 1,000–2,000 feet before fewer than five pools was accepted as a sample size. A schematic drawing of the reach was made to illustrate the relative positions of pools and spawning patches. The GPS position at the upper and lower end of the selected reach was taken using a handheld Garmin GPS device to serve as a reference point from which the locations of pools and spawning patches were measured. Each pool in the reach was then assessed to estimate filling by fine sediment and permeability was sampled in two to three potential spawning gravel patches. All sites within reaches where measurements were taken were extensively documented with photographs.

For each pool in this comparison, measurements for the modified method of estimating pool filling were made first, then transects were established and measurements taken according to the V* protocol outlined by Hilton and Lisle (1993). The results of this comparison are shown in Figure A9-1. The solid line on Figure A9-1 represents a one-to-one relationship that would be expected if the two methods produced equivalent results. The rapid methodology was within 10 percent of the Hilton and Lisle (1993) methodology in all seven pools and, therefore, we believe that the rapid method is appropriate for studies in which data must be collected from a large number of pools over an extensive area in a short time period.

Results

The results of the pool filling analysis are shown in Table A9-1. (Note: Pools were numbered in the sequence in which they were assessed for each reach and for each day. Therefore, some reaches may have repeated pool numbers, where pools were assessed on different days, or the sequence of pool numbers in a day skips a number where a pool was not assessed because the water was too deep for our method (1 pool on Carneros Creek).)

Discussion of the results in provided in Section 6.2.2 of the main report.

Table A9-1. Estimates of pool filling in the Napa River basin.

Stream Name	Site Description	Latitude	Longitude	Pool #	Date	Pool Area (m^2)	Pool Volume (m^3)	Pool Filling
Bell Creek	Upstream of Silverado Road, adjacent to Glass Mountain Road	N 38 32'11.0"	W 122 29'09.7"	1	2/8/02	912	1847	1.2%
				2	2/8/02	1680	4527	1.0%
				3	2/8/02	565	283	0.0%
				4	2/8/02	247	217	1.0%
				5	2/8/02	467	492	5.0%
Carneros Creek	Henry Road (middle Carneros)	N38 16' 23.5"	W122 21' 16.2"	1	2/9/02	283	497	31.7%
				1	2/11/02	259	673	23.0%
				2	2/9/02	126	278	48.4%
				3	2/9/02	311	561	55.7%
				4	2/9/02	276	626	70.6%
	End of Henry Road (upper Carneros)	N38 17' 53.9"	W122 22' 56.9"	1	2/9/02	200	300	28.8%
				2	2/9/02	165	493	35.3%
				3	2/9/02	441	763	42.2%
				4	2/9/02	429	921	25.5%
	Withers Road (lower Carneros)	N38 14' 48.8"	W122 19' 57.2"	1	2/9/02	693	1264	12.3%
				3	2/9/02	473	1046	0.6%
				4	2/9/02	694	1780	9.0%
Chiles Creek	Pope Valley Road	N38 32' 7.3"	W122 20' 10.8"	1	1/18/02	110	171	1.6%
				2	1/18/02	214	580	1.4%
				3	1/18/02	251	431	2.8%
				4	1/18/02	276	774	16.9%
Conn Creek	Conn Valley Road	N38 30' 55.4"	W122 24' 55.6"	1	2/10/02	495	593	5.5%
				2	2/10/02	1590	4793	11.5%
				3	2/10/02	506	1551	6.5%
				4	2/10/02	1414	3280	5.2%
				5	2/10/02	130	220	2.0%
Cyrus Creek	Petrified Forest Road (upstream of Fiege Reservoir)	N38 34' 25.8"	W122 36' 14.7"	1	1/15/02	77	44	0.0%
				2	1/15/02	135	136	0.5%
				3	1/15/02	104	77	0.1%
				4	1/15/02	66	40	0.0%
				5	1/15/02	63	59	0.0%
				6	1/15/02	120	104	0.0%
	Shaw-Williams and Franz Valley Road intersection	N38 34' 53.2"	W122 36' 33.3"	1	1/15/02	99	90	4.8%
				2	1/15/02	71	95	1.1%
				3	1/15/02	69	42	0.6%
				4	1/15/02	110	75	2.0%
				5	1/15/02	177	142	0.7%
Diamond Mountain Creek	Diamond Mountain Road (upper Diamond Mountain)	N38 33' 53.8"	W122 34' 09.2"	1	1/16/02	198	264	0.1%
				2	1/16/02	130	175	1.3%
				3	1/16/02	63	50	0.0%
				4	1/16/02	92	127	3.3%
				5	1/16/02	104	104	0.2%
				6	1/16/02	112	75	0.1%

Stream Name	Site Description	Latitude	Longitude	Pool #	Date	Pool Area (m^2)	Pool Volume (m^3)	Pool Filling
	HWY 128 and Diamond Mountain Road intersection (lower Diamond Mountain)	N38 33' 57.6"	W122 33' 45.2"	1	1/16/02	184	315	2.7%
				2	1/16/02	163	206	0.0%
				3	1/16/02	82	93	0.0%
				4	1/16/02	188	151	0.1%
				5	1/16/02	170	192	0.0%
				6	1/16/02	141	141	0.0%
Dry Creek	West Oak Knoll Road (lower Dry)	N38 21'09.0"	W122 20'43.8"	1	2/10/02	1147	2356	2.7%
				2	2/10/02	1499	2118	5.6%
				3	2/10/02	950	954	0.4%
				4	2/10/02	492	1192	3.6%
				5	2/10/02	1352	1379	2.0%
	Dry Creek Road (upper Dry)	N38 25' 20.3"	W122 28' 11.8"	1	2/10/02	553	1418	32.4%
				2	2/10/02	578	1234	6.3%
				3	2/10/02	286	403	5.5%
				4	2/10/02	283	415	9.1%
				5	2/10/02	156	264	25.4%
	Dry Creek Road, just below Oakville Grade (middle Dry)	N38 24' 22.0"	W122 35' 47.6"	1	1/18/02	1162	2865	18.8%
				2	1/18/02	636	1316	3.3%
				3	1/18/02	628	2543	1.2%
				4	1/18/02	565	1369	9.1%
Dutch Henry Creek	Dutch Henry Canyon Road and Lommel Road intersection (upper Dutch Henry)	N38 34' 38.0"	W122 31' 6.6"	1	1/17/02	134	182	2.3%
				2	1/17/02	264	213	0.9%
				3	1/17/02	94	79	4.8%
	Upstream of Larkmead Bridge (lower Dutch Henry)	N38 34' 3.0"	W122 31' 8.6"	1	1/17/02	338	340	0.5%
Garnett Creek	Mile 39 on HWY 29	N38 36' 15.7"	W122 35' 16.8"	1	1/15/02	817	1639	0.3%
				2	1/15/02	353	353	0.0%
				3	1/15/02	283	568	0.5%
				4	1/15/02	942	1068	0.0%
Heath Canyon Creek	Sulphur Spring Avenue	N38 29' 11.5"	W122 29' 11.5"	1	1/18/02	358	486	1.7%
				2	1/18/02	188	189	0.2%
				3	1/18/02	283	283	0.0%
Mill Creek	Bothe State Park, upstream of HWY 128/29 bridge	N38 32' 27.9"	W122 30' 28.8"	2	1/16/02	113	188	0.0%
				3	1/16/02	104	104	0.7%
				4	1/16/02	88	116	9.0%
				5	1/16/02	71	71	0.2%
	Bothe State Park, upstream of foot bridge	N38 32' 25.7"	W122 30' 34.7"	1	1/16/02	181	337	0.0%
				2	1/16/02	59	98	0.0%
				3	1/16/02	157	210	0.2%
				4	1/16/02	66	84	0.5%
				5	1/16/02	39	21	0.0%
				6	1/16/02	124	83	0.0%
				7	1/16/02	71	49	2.2%

Stream Name	Site Description	Latitude	Longitude	Pool #	Date	Pool Area (m^2)	Pool Volume (m^3)	Pool Filling
Redwood Creek	Redwood Road (middle Redwood)	N38 18' 54.8"	W122 19' 57.5"	1	2/9/02	1689	4881	7.7%
				2	2/9/02	848	1301	0.0%
				3	2/9/02	836	1309	2.1%
				4	2/9/02	636	849	0.1%
	Redwood Road (lower Redwood)	N38 20'29.8"	W122 23'16.1"	1	2/11/02	459	589	1.2%
				2	2/11/02	94	102	1.5%
				3	2/11/02	224	231	3.0%
				4	2/11/02	283	464	2.5%
				5	2/11/02	565	1137	0.6%
	Redwood Road at Archer Tailor Preserve (upper Redwood)	N38 21' 15.3"	W122 25' 18.1"	1	1/18/02	118	141	0.0%
				2	1/18/02	47	41	0.0%
				3	1/18/02	94	94	0.1%
				4	1/18/02	160	128	0.1%
Ritchie Creek	Bothe State Park	N38 32' 52.4"	W122 31' 42.1"	1	1/17/02	196	198	0.6%
				2	1/17/02	198	319	9.0%
				3	1/17/02	85	93	8.9%
				4	1/17/02	173	228	4.2%
				5	1/17/02	101	121	0.2%
				6	1/17/02	102	109	0.0%
	Bothe State Park	N38 32' 56.7"	W122 31' 30.5"	1	1/17/02	164	146	2.3%
				2	1/17/02	38	18	2.2%
				3	1/17/02	94	63	0.9%
				4	1/17/02	44	35	0.6%
				5	1/17/02	55	74	0.5%
Sage Creek	Sage Canyon Road at HWY 128	N38 92' 23.1"	W122 19' 40.7"	1	2/10/02	565	1149	1.5%
				2	2/10/02	365	440	0.4%
				3	2/10/02	337	347	2.8%
Sarco Creek	Hagen Road	N38 19' 25.2"	W122 14' 01.7"	1	2/8/02	188	78	3.2%
				2	2/8/02	49	27	2.2%
				3	2/8/02	90	57	0.0%
				4	2/8/02	181	153	5.3%
				5	2/8/02	253	3381	0.1%
				6	2/8/02	164	121	27.6%
Soda Creek	Soda Canyon Road	N38 22' 13.0"	W122 17' 00.8"	1	1/18/02	347	370	0.0%
				2	1/18/02	236	188	0.0%
				3	1/18/02	589	595	1.0%
Soscal Creek	Soscal Creek Road, east of HWY 29	N38 14'25.4"	W122 15'57.0"	1	2/9/02	465	302	17.9%
				2	2/9/02	766	1452	1.5%
				3	2/9/02	188	126	0.6%
				4	2/9/02	133	212	0.0%
				5	2/9/02	57	38	0.0%
Sulfur Creek	Upstream of Sulfur Spring Resort	N38 29' 25.2"	W122 29' 55.3"	1	1/17/02	377	1085	7.4%
				2	1/17/02	157	618	23.7%
				3	1/17/02	59	67	0.0%
				4	1/17/02	518	1325	34.8%

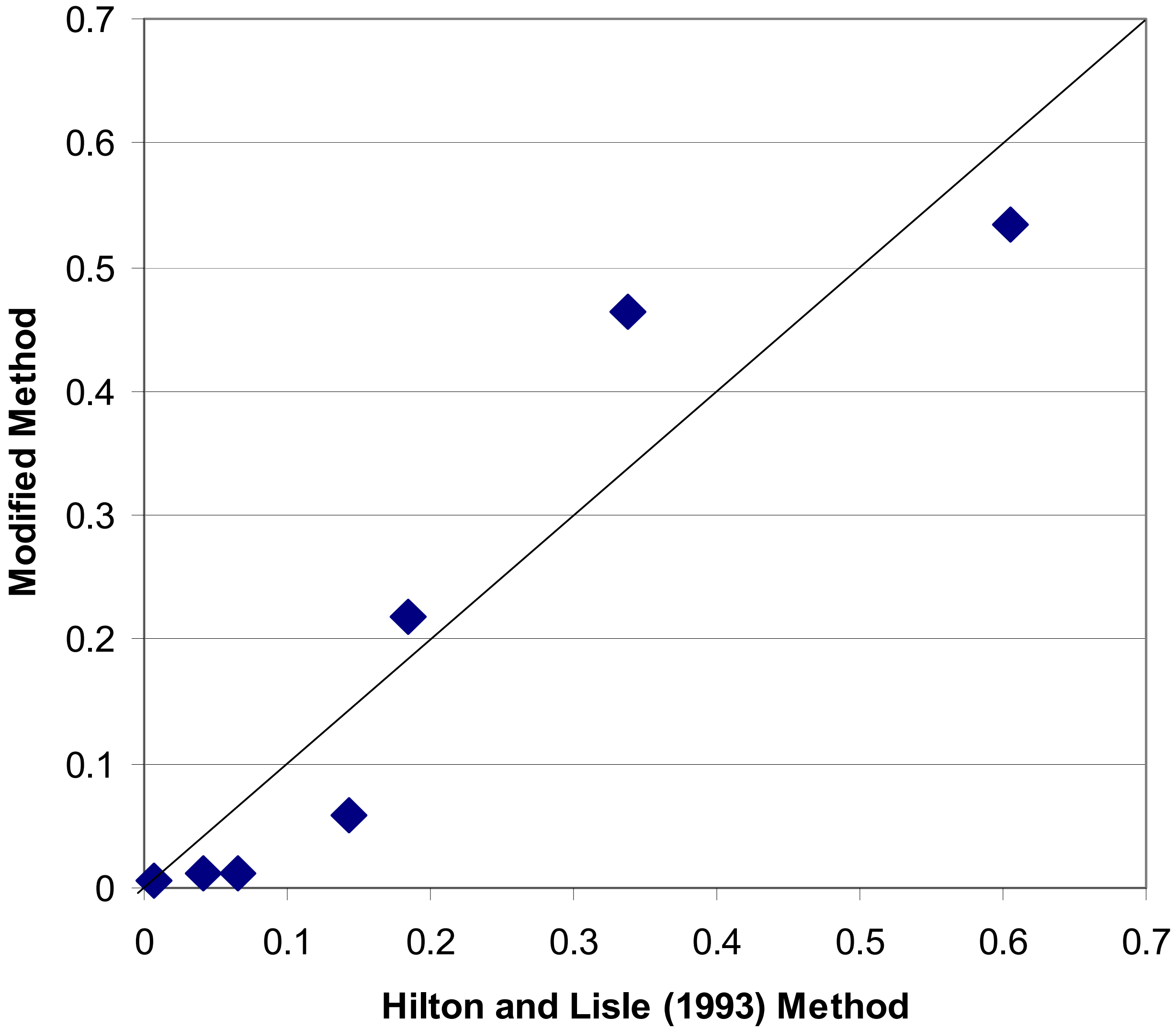

Figure A9-1. Comparison of the modified and Hilton and Lisle (1993) methods for estimating pool filling at pools sampled in the Napa River watershed.

Appendix A10: Temperature Monitoring

Methods

To determine whether water temperatures in the Napa River and its tributaries might be high enough to cause chronic or acute impacts on salmonids, extensive temperature monitoring was undertaken at 28 sites throughout the Napa River basin. Automatically recording thermographs were deployed at 22 sites on tributaries throughout the Napa River basin and six sites on the mainstem. Sites were selected to represent a wide variety of drainage areas, channel gradients and geologic land types present in the system (see Map 10). Thermographs used were Stowaway TidBits manufactured by Onset Computer Corporation (Pocasset, MA).

Thermographs were first deployed in early August 2000. All thermographs were set to record water temperature at 15-minute intervals and were retrieved, downloaded and redeployed in mid-November 2000. Based on review of the summer 2000 data, it was clear that three of the thermographs experienced dry (out of water) conditions over the course of the summer. As a result, these three thermographs were checked on July 12, 2001, found to be dry, and were relocated to nearby reaches with perennial flow. Final retrieval of 24 thermographs was made in mid November 2001. Four thermographs that were deployed for this final period were not retrieved (one due to vandalism, two due to apparent failure of the anchoring system, and one due to unknown reasons).

Results

Figures A10-1 through A10-14 show the results of temperature monitoring for each station. The plots show daily mean temperature (bold line), with daily maximum and minimum temperatures indicated by thin vertical bars.

It is important to note that channel desiccation was observed at several temperature monitoring sites during summer 2001 and that thermographs at these sites were subsequently relocated. These sites are noted in Figures A10-3, 6, and 14 with an arrow used to indicate the date on which the thermograph was relocated. After final retrieval in November 2001, careful review of temperature data for a number of other sites revealed patterns similar to the known desiccated sites, suggesting that drying sometimes occurred during the summer period at additional sites. We have annotated the data presented in Figures A10-3, 5, 6, 7, and 14 (using a gray box) to indicate time periods for which daily temperature patterns suggest that a particular thermograph was exposed directly to air (i.e., the pool had dried sufficiently to expose the thermograph).

Sections 6.3 and 6.6 in the main report discuss the biological implications of observed temperature patterns.

Figure A10-1a. Thermograph data from the Napa River, 2000-01.

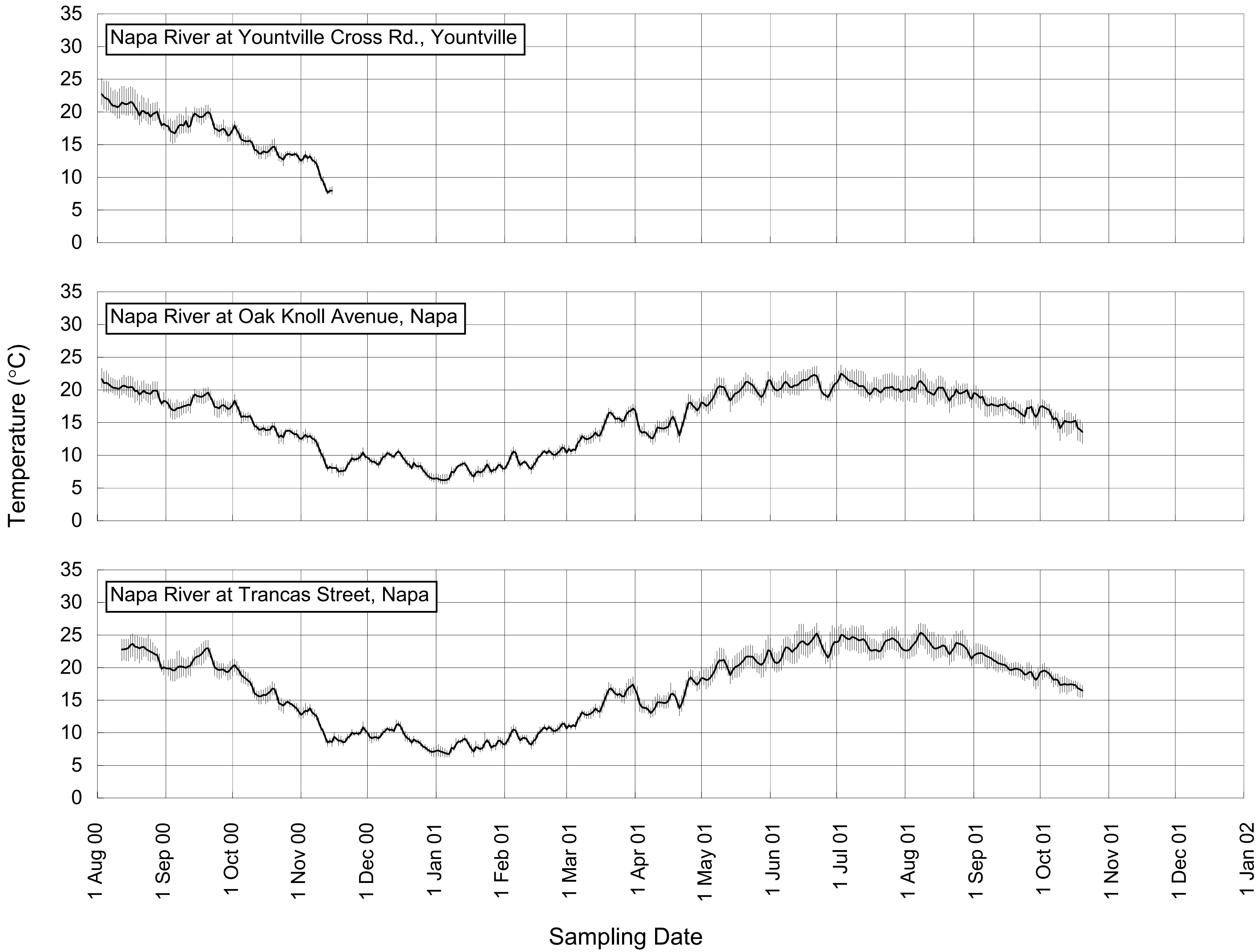

Figure A10-1b. Thermograph data from the Napa River, 2000-01.

The thermograph was not recovered from the Napa River at Yountville Cross Rd. site at the end of the second sampling period.

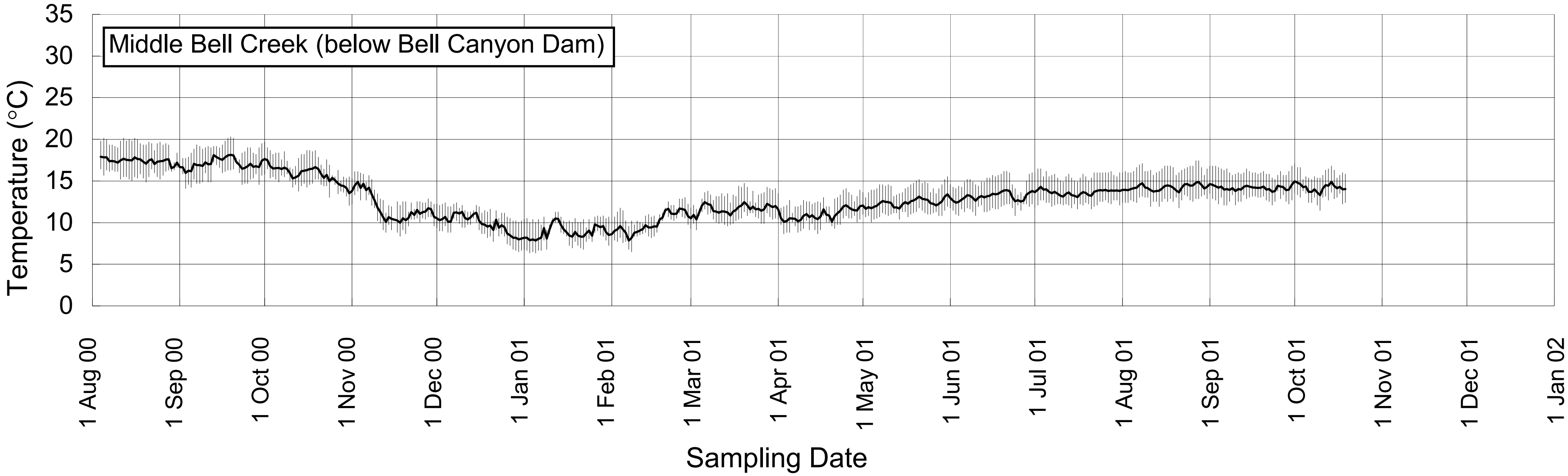

Figure A10-2. Thermograph data from Bell Creek, 2000-01.

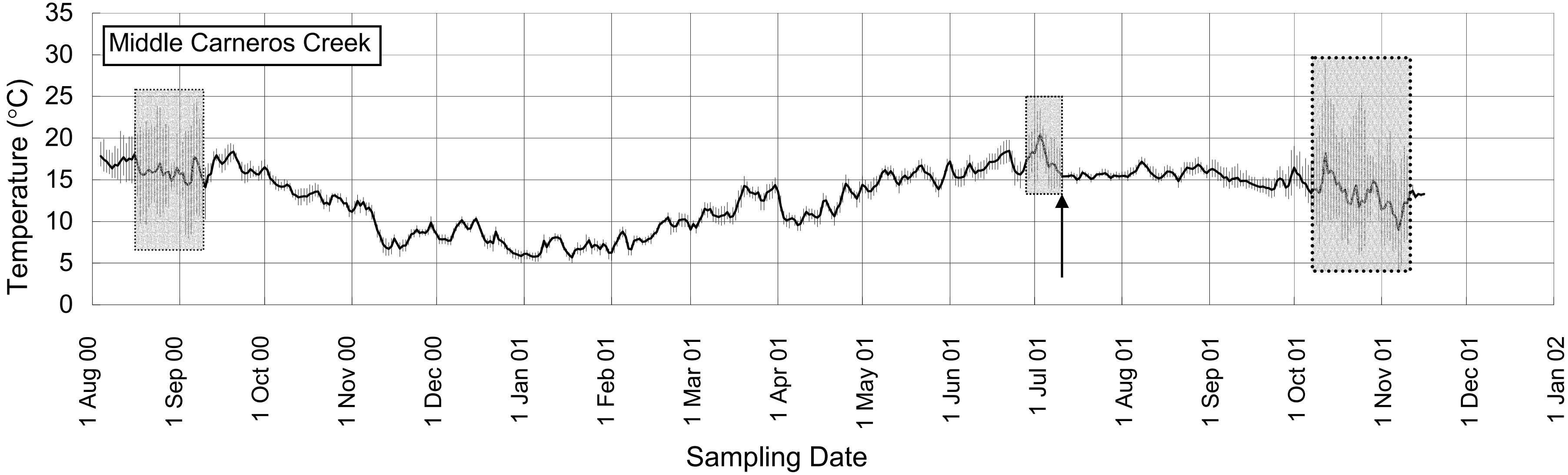

Figure A10-3. Thermograph data from Carneros Creek, 2000-01.

Arrow symbol (↑) indicates that drying of the monitoring site was observed and the thermograph was relocated to a nearby site with a wetted channel. Shaded boxes indicate portions of the sampling period during which the sampling site was known, or assumed, to have gone dry.

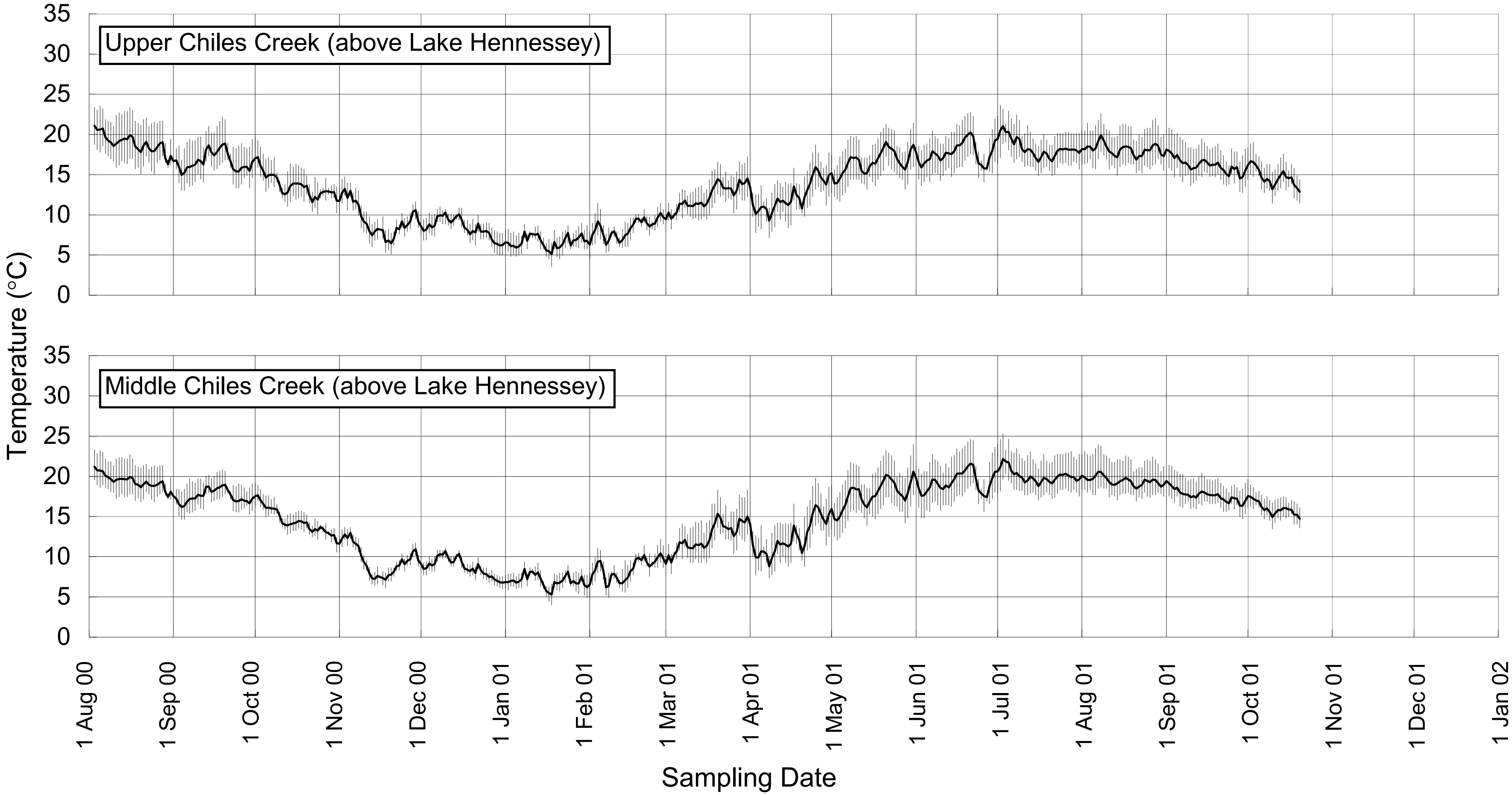

Figure A10-4. Thermograph data from Chiles Creek, 2000-01.

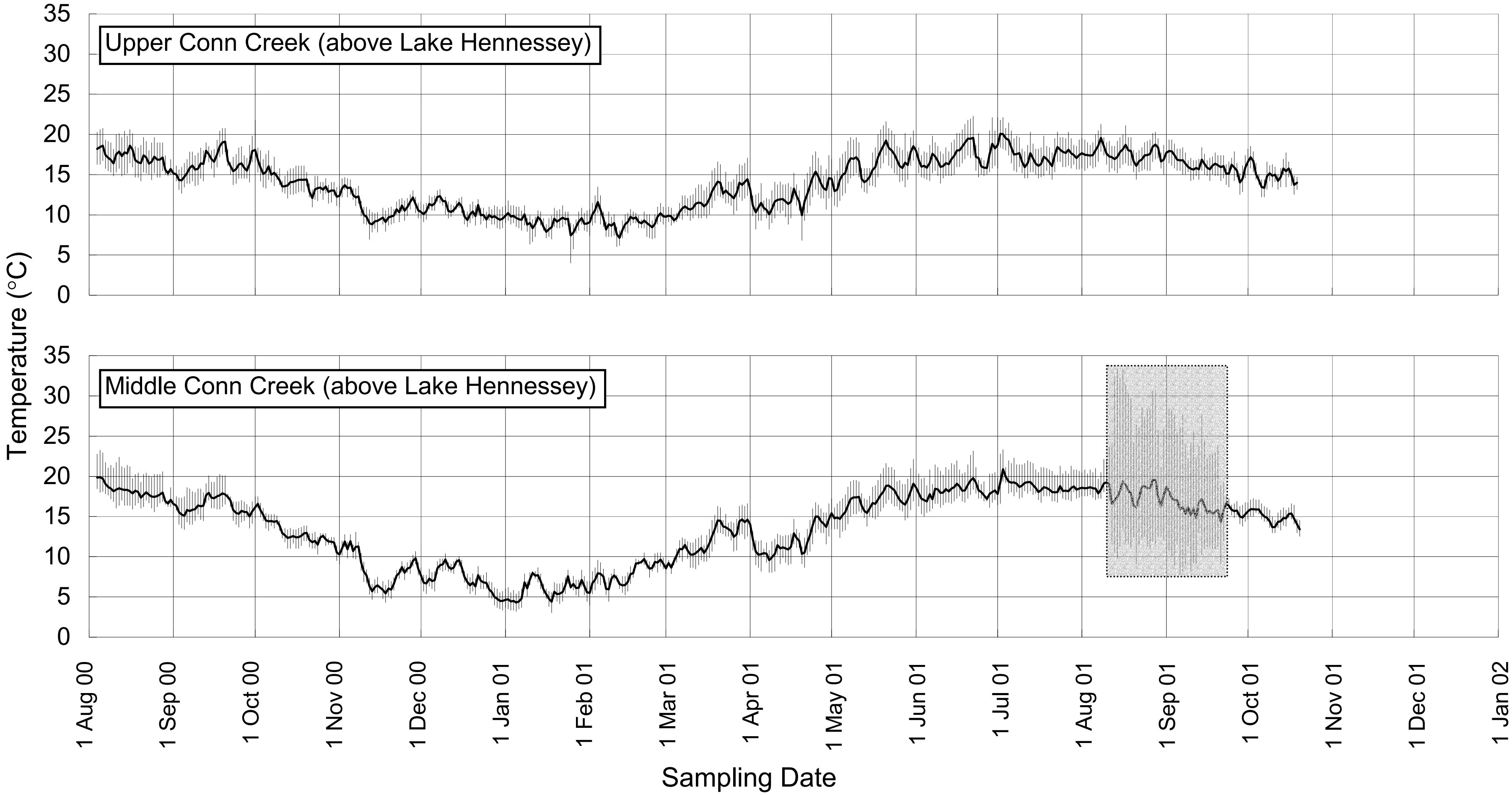

Figure A10-5. Thermograph data from Conn Creek, 2000-01.

Shaded boxes indicate portions of the sampling period in which the sampling site was known, or assumed, to have gone dry.

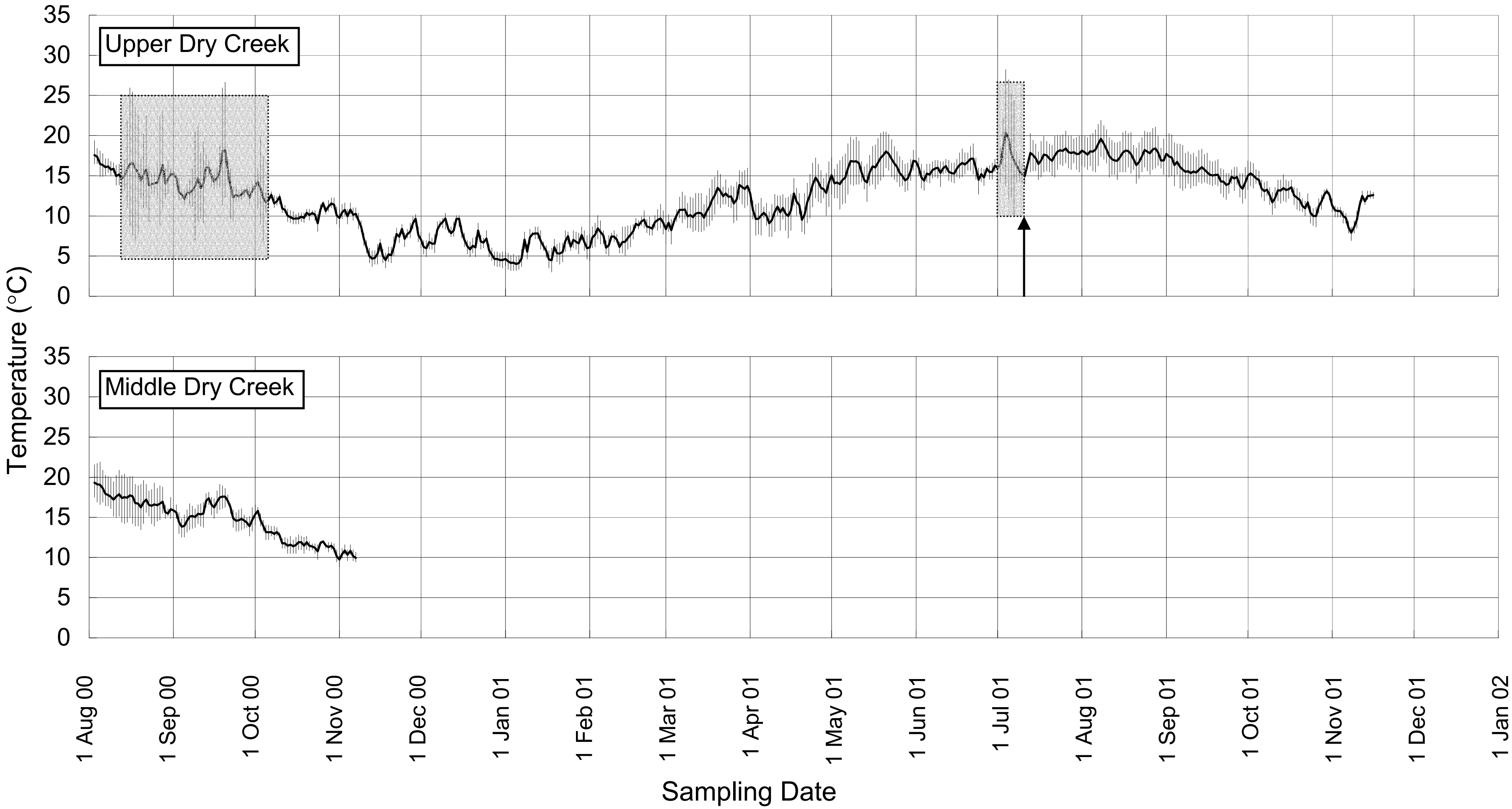

Figure A10-6. Thermograph data from Dry Creek, 2000-01.

Arrow symbol (↑) indicates that drying of the monitoring site was observed and the thermograph was relocated to a nearby site with a wetted channel. Shaded boxes indicate portions of the sampling period in which the sampling site was known, or assumed, to have gone dry. The thermograph was not recovered from the Middle Dry Creek site at the end of the second sampling period.

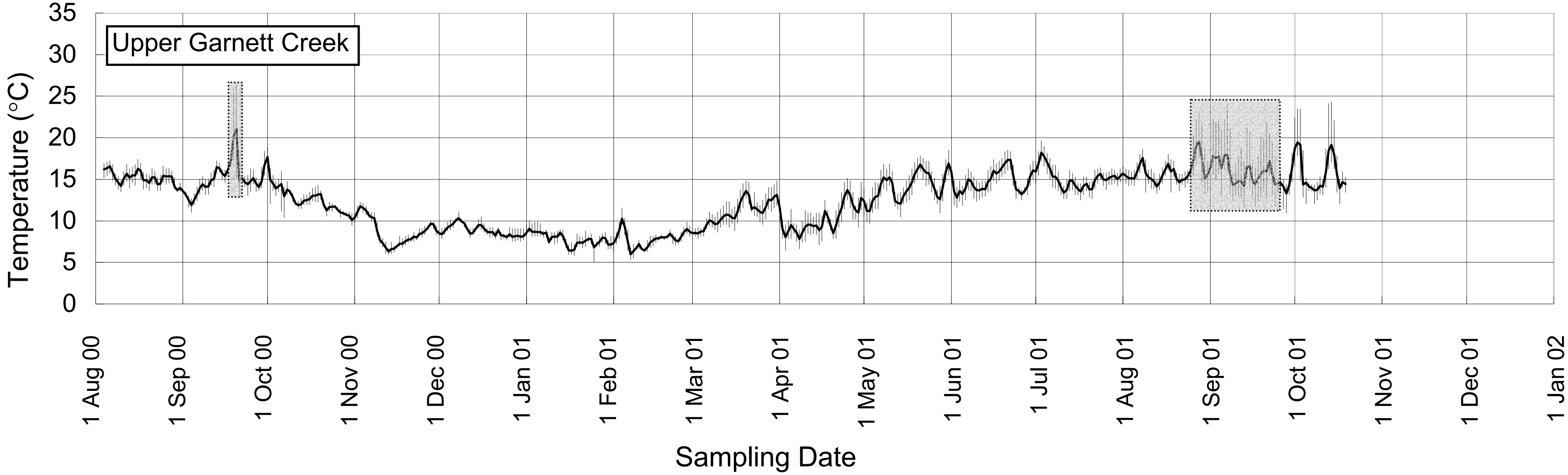

Figure A10-7. Thermograph data from Garnett Creek, 2000-01.

Shaded boxes indicate portions of the sampling period in which the sampling site was known, or assumed, to have gone dry.

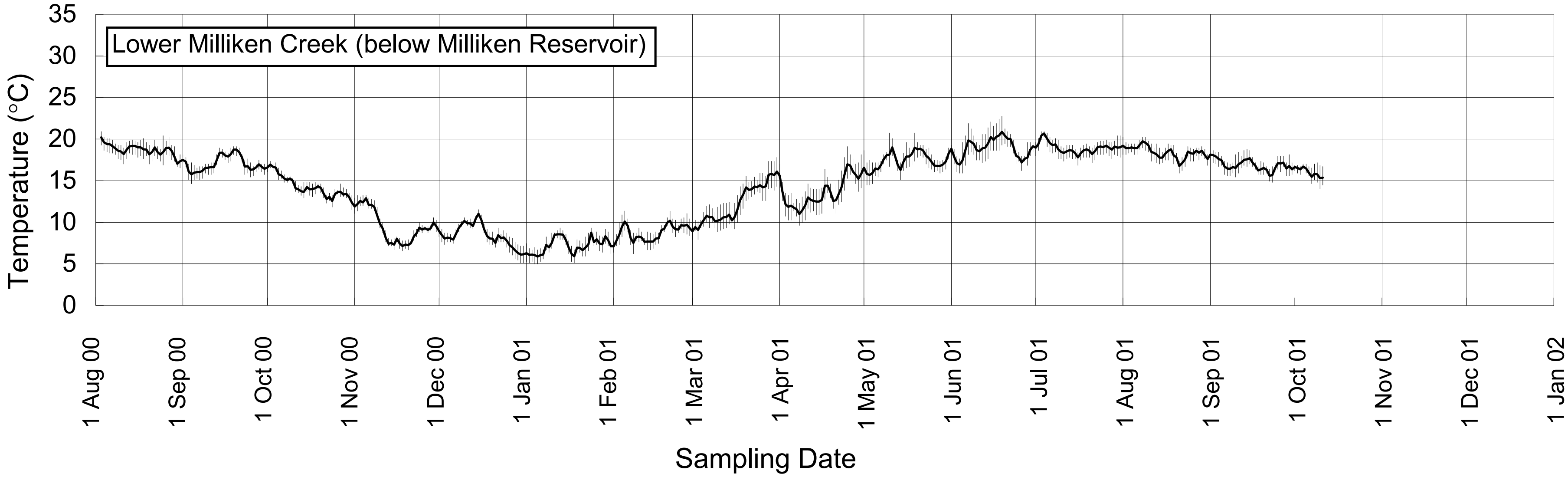

Figure A10-8. Thermograph data from Milliken Creek, 2000-01.

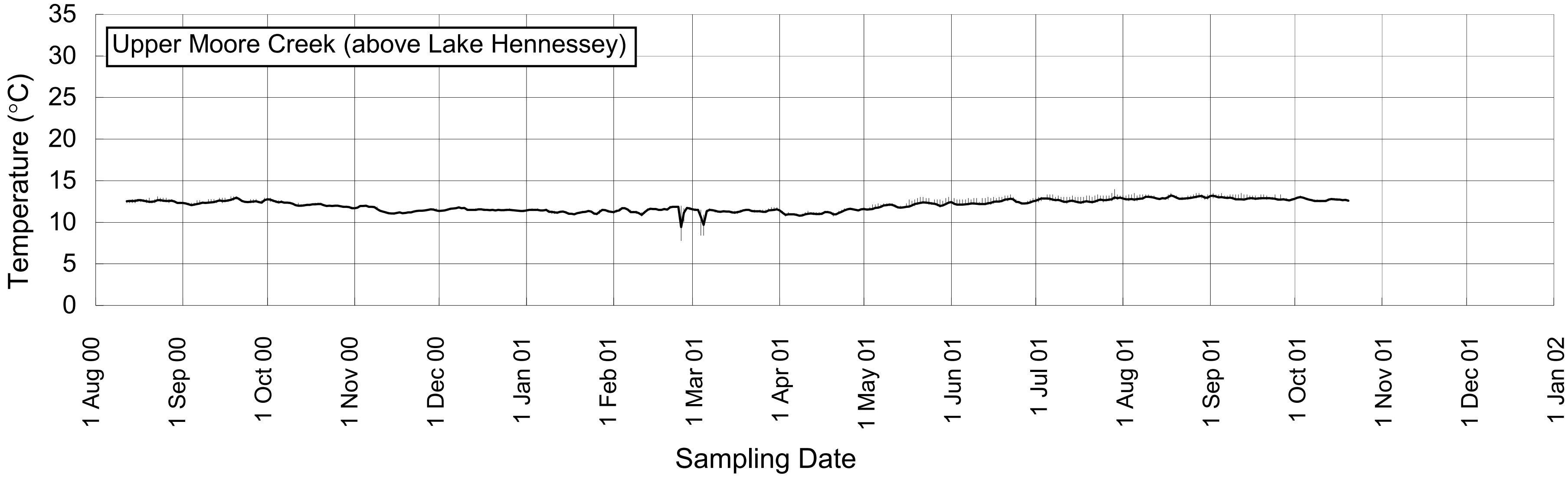

Figure A10-9. Thermograph data from Moore Creek, 2000-01.

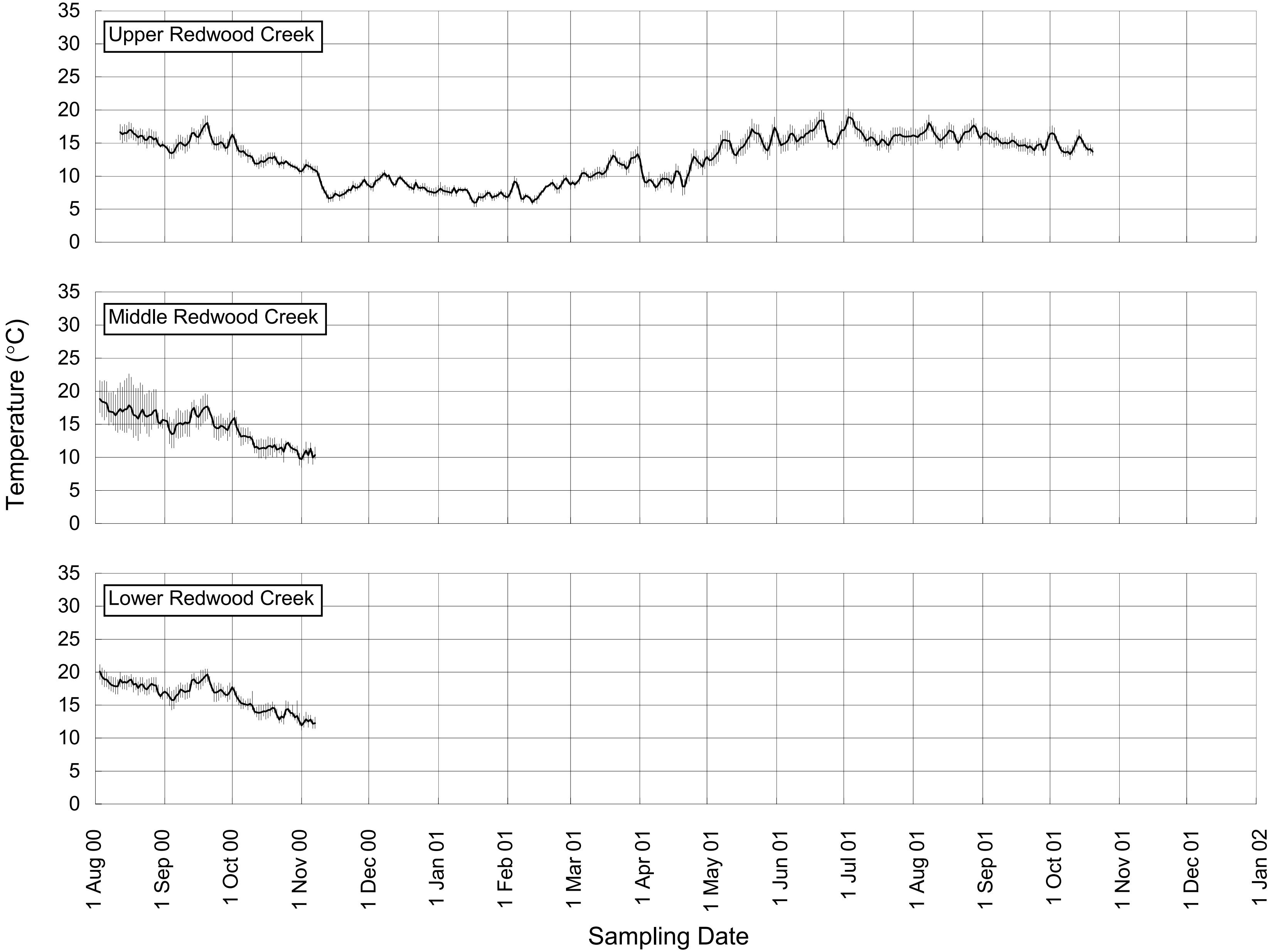

Figure A10-10. Thermograph data from Redwood Creek, 2000-01.

The thermographs were not recovered from the Middle and Lower Redwood Creek sites at the end of the second sampling period.

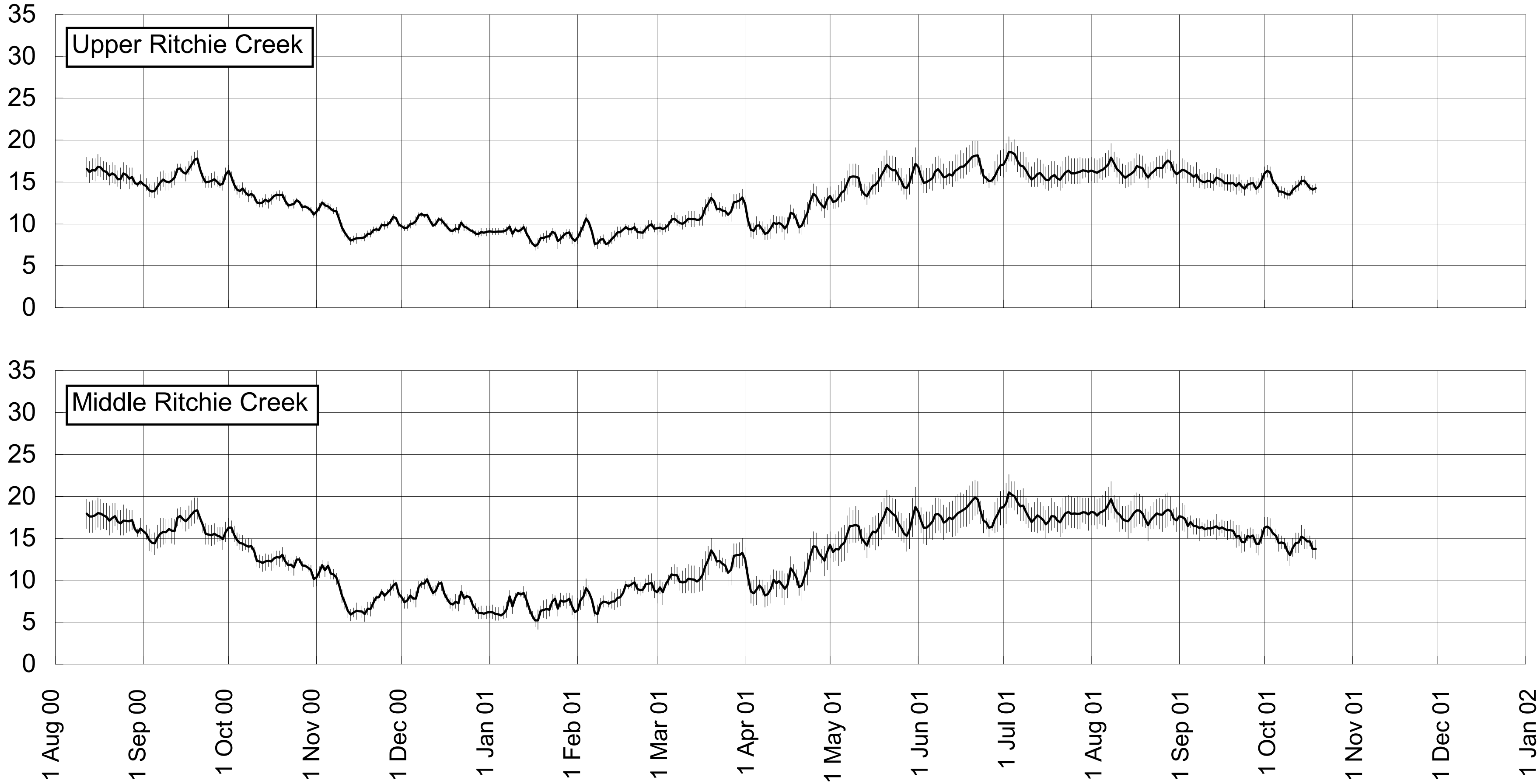

Figure A10-11. Thermograph data from Ritchie Creek, 2000-01.

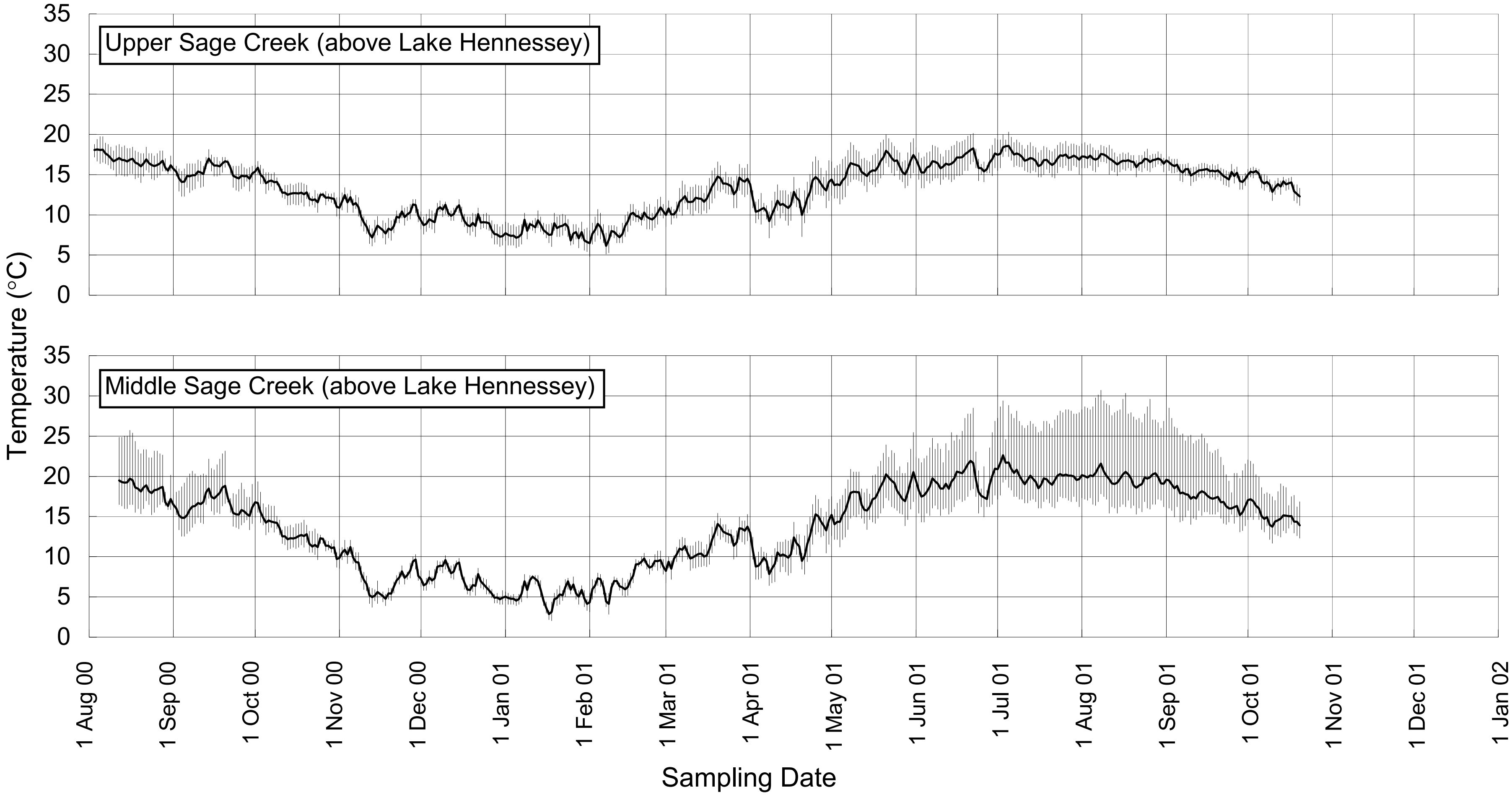

Figure A10-12. Thermograph data from Sage Creek, 2000-01.

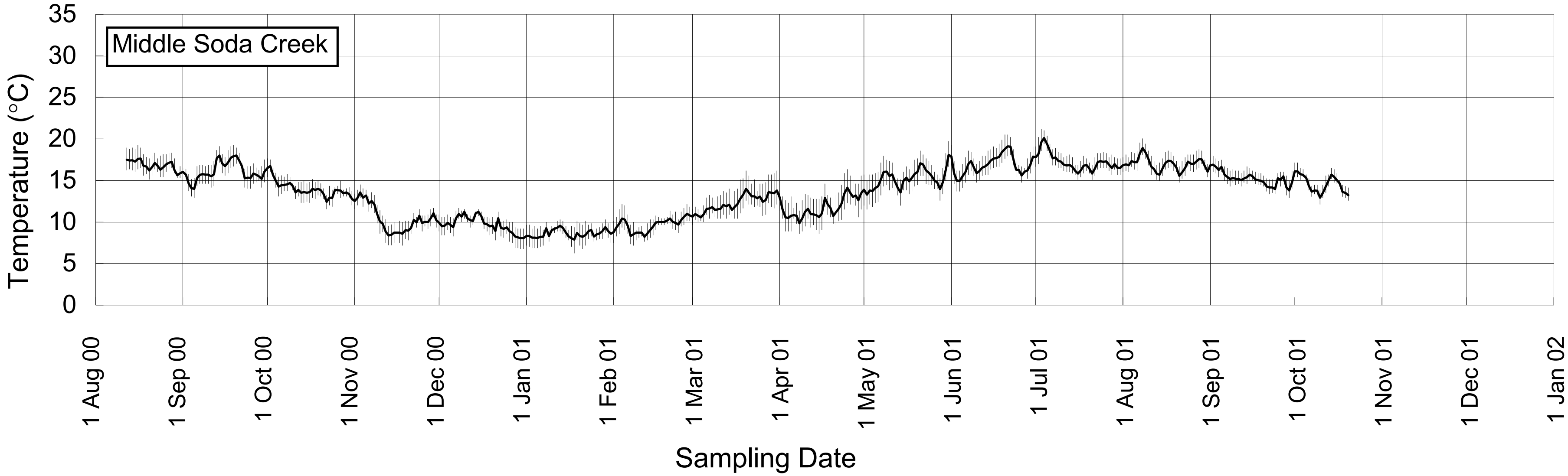

Figure A10-13. Thermograph data from Soda Creek, 2000-01.

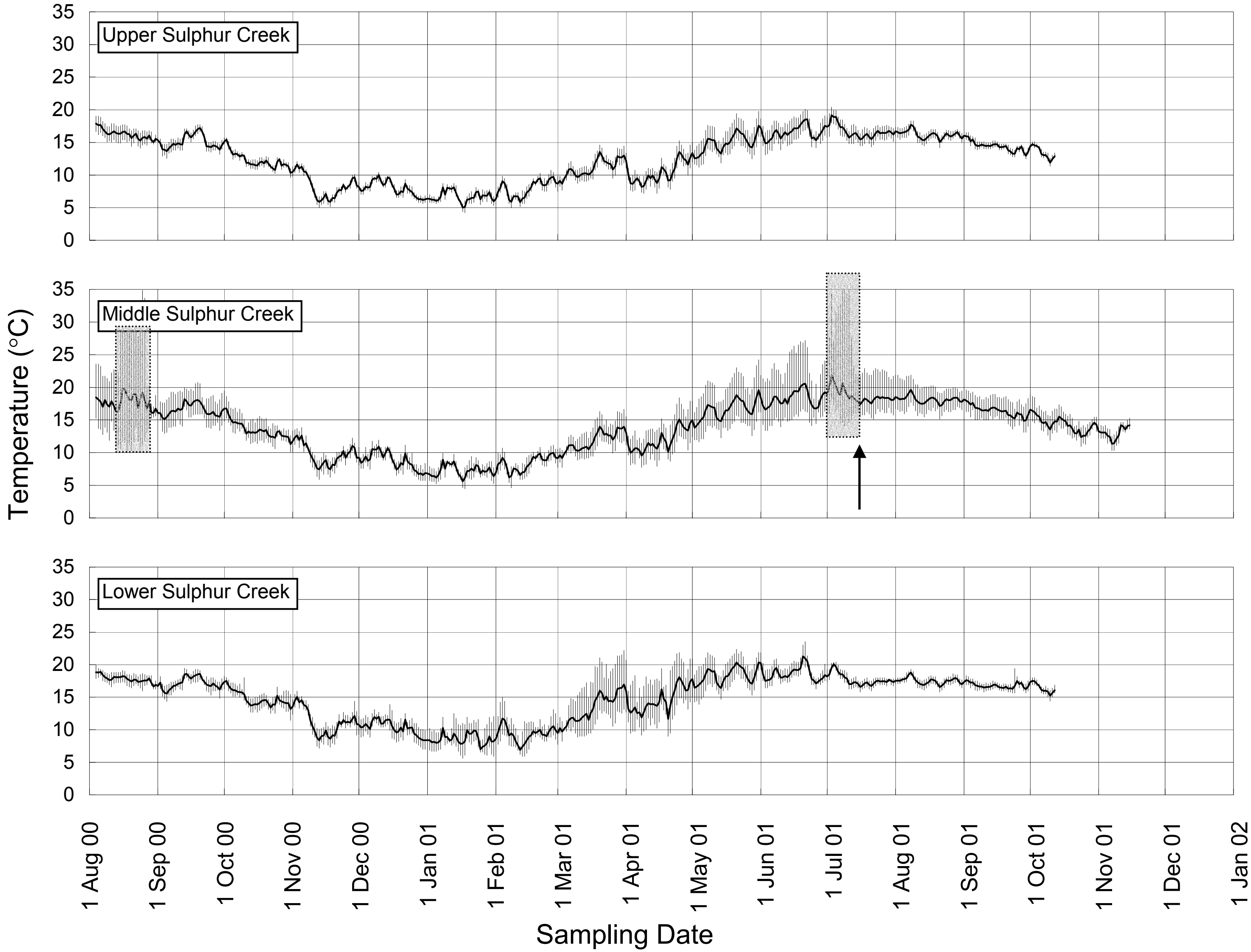

Figure A10-14. Thermograph data from Sulphur Creek, 2000-01.

Arrow symbol (↑) indicates that drying of the monitoring site was observed and the thermograph was relocated to a nearby site with a wetted channel. Shaded boxes indicate portions of the sampling period in which the sampling site was known, or assumed, to have gone dry.

Appendix A11: Steelhead Summer Growth

Methods

We conducted a pilot study of juvenile steelhead growth in summer of 2001 in two tributaries on the western side of the Napa River Basin—Ritchie Creek and Dry Creek. Reaches of these tributaries were selected to represent different levels of riffle/pool connectivity, with Ritchie Creek having larger riffles and somewhat better connectivity between riffles and pools due to higher flows, and upper Dry Creek having poorly developed riffles and lower flows.

The study consisted of an initial capture and marking effort between July 17 and July 19, 2001 in pools that were bounded by distinct upstream riffles. These pools were blocked off with fine mesh nets and fish in the pools were stunned with a Smith-Root backpack electrofisher and netted. Captured steelhead were then measured, weighed, and given individual marks, using subcutaneous elasto-polymer injections. Between September 26 and September 28, 2001, fish were recaptured using similar methods and changes in length and weight were recorded.

Results

The results of the recapture effort are summarized in Table A11-1. The recapture effort indicated that habitat fidelity was generally high, with most fish being recaptured in or near the same habitat unit in which they were marked and most having lost weight. These results are discussed in detail in Section 6.6 of the main report.

Table A11-1. Summary of 2001 mark-recapture efforts on Dry and Ritchie creeks.

Stream	Habitat Unit	Initial		Final	
		Weight (g)	Length (mm)	Weight (g)	Length (mm)
Dry Creek	Pool 1	37.9	151	32.2	148
		89.1	193	78.3	189
		52.4	171	50	166
		29.2	140	26.1	139
		32.6	142	28.3	140
	Pool 2	28.7	137	27.3	138
		27.4	133	28	139
		49.8	165	47.9	168
	Pool 3	69.2	185	66.8	187
		24.7	132	20.6	130
	Pool 4*	4.5	72	4.7	76
	Pool 4	82.8	200	70.6	197
		38.2	155	32.5	152
		1.4	50	1.9	53
	Pool 5	4.8	74	6.1	80
		182.8	270	159.9	267

Stream	Habitat Unit	Initial		Final	
		Weight (g)	Length (mm)	Weight (g)	Length (mm)
Ritchie Creek	Pool 1	14.5	111	12.5	111
		11.7	102	11.1	101
		32.5	141	32.2	142
		12.2	103	11.2	103
		2.6	58	2.8	61
		2.1	54	2.2	56
		5.8	78	5.3	77
		1.7	51	1.8	56
	Pool 2	8.8	95	7.5	93
		8.5	89	8.1	90
		2.1	58	2.7	61
		25.9	127	23.4	126
		12.6	103	12.1	103
		11.9	106	11.1	105
		2.7	61	3.7	69
	Pool 3	81.7	193	88.6	196

* Recaptured at different site (pool-riffle unit) than originally marked

Appendix A12: Steelhead Population Dynamics Modeling

Methods

A preliminary assessment of current habitat conditions for steelhead populations in the upper Napa basin was conducted within the framework of a population dynamics model. This assessment relies on fundamental concepts in population dynamics, particularly stock-recruitment analysis. The assessment performed here was based on limited field data from Ritchie Creek and is only intended to provide a preliminary, and conservative, indication of the degree to which steelhead smolt production might be limited by current channel conditions.

The population modeling exercise involved three basic steps: (1) collecting habitat-specific information regarding habitat quality and quantity from a suitable reach within the area of interest; (2) assigning density-independent survival and habitat-specific carrying capacity values for each salmonid life stage; and (3) integrating these values into a system of equations to express the impact of current salmonid habitat conditions on potential steelhead production. These three steps are described in further detail below.

Collecting Habitat-Specific Information

Habitat-specific information for this population modeling exercise was collected during a two-day field effort (May 25 and 26, 2000) in an approximately 100-meter reach of Ritchie Creek. The reach length included at least 20 channel widths to capture the natural variability of the channel and help ensure that the study reach was representative of the canyon reaches of Ritchie Creek where juvenile steelhead have been observed rearing (FONR, 2001).

Four basic habitat types (pool, riffle, glide, and cascade) were delineated within the surveyed reach (Figure A12-1) according to standard habitat mapping descriptions (Bisson et al. 1982, McCain et al. 1990). Mean length, width, and depth were estimated for each habitat unit, and maximum depth was measured within each unit. In addition to these habitat parameters, the area of potential spawning habitat (if present) was estimated. Spawning habitat area estimates were based on steelhead spawning habitat criteria reported in the literature, including a water depth of >24 cm (Smith 1973), flow velocities between 40 and 91 cm/s (Bovee 1978), and a particle size (D_{50}) of 10–46 mm (Kondolf and Wolman 1993).

Assigning Steelhead Life-history Parameters

Steelhead life history was separated into discrete stages having identifiable, and to some extent overlapping, habitat requirements. The life history stages for steelhead used in the analysis were: adult spawning, emergent fry, age 0+ summer rearing, age 0+ winter rearing, age 1+ summer rearing, age 1+ winter rearing, smolt, and ocean phase.

The population dynamics modeling approach that we used requires two kinds of biological parameters: (1) carrying capacity for each life stage (which describes the ultimate limits imposed by crowding and competition); and (2) quantities such as fecundity and density-independent survival rates (which describe the population dynamics under conditions for which the effects of crowding and competition can be ignored). These may be called density-dependent and density-independent factors, respectively. Table A12-1 summarizes the survival and carrying capacity parameters and literature sources used for the analysis.

Table A12-1. Density-independent survival and carrying capacity used in the steelhead population dynamics modeling of Ritchie Creek.

Life stage	Density-Independent Survival (*r*)	Carrying Capacity (K) (fish/m^2)			
		Pool	Riffle	Glide	Cascade
Spawner	1,115 [a]	0.23[b]	0.23 [b]	0.23 [b]	0.23 [b]
Age 0+summer rearing	0.2 [c]	0.39 [d]	0.58 [d]	0.61 [d]	0.0 [d]
Age 0+ winter rearing	0.55 [e]	0.39 [e]	0.58 [e]	0.61 [e]	0.0 [e]
Age 1+ summer rearing	0.8 [f]	0.19 [d]	0.12 [d]	0.11 [d]	0.0 [d]
Age 1+ winter	0.55 [e]	0.19 [e]	0.12 [e]	0.11 [e]	0.0 [e]
Smolt	0.6 [f]	N/A	N/A	N/A	N/A
Ocean	0.084 [g]	N/A	N/A	N/A	N/A

[a] the fraction female (0.5) * the fecundity (3,300) * egg survival (0.7)
[b] Source: Bjornn and Reiser (1991). This density is only applied to useable spawning area (i.e., not total habitat area).
[c] Source: Bjornn (1978)
[d] Source: Everest et al. (1987)
[e] estimated values based on Everest et al. (1987)
[f] estimated values based on Lestelle et al. (1996) and Nickelson et al. (1992)
[g] Source: ODFW (1997)

Population Modeling

The salmonid population modeling approach used in this analysis is based on stock-production theory (Ricker 1976). Stock-production theory characterizes the number of individuals of one life stage at one time (the production) as a function of the number in the same cohort of an earlier life stage at an earlier time (the stock). This approach is particularly well suited to situations where physical habitat is believed to be limiting, and where population dynamics can be plausibly separated into density-independent and density-dependent components, such as productivity (the ratio of stock to production that would be expected if there were no limits on population density) and carrying capacity (the maximum number of individuals of a given life stage that the habitat can support for the duration of that life stage).

The population model uses Beverton-Holt stock-production relationships for life stages for which habitat is potentially limiting (Ricker 1976). Such a relationship is completely determined by specifying productivity and a carrying capacity. The Beverton-Holt relationship is used in all situations where density-dependent relationships are expected. Linear stock-production relationships were used for life stages for which habitat is not thought to be limiting. The linear relationship is used when no natural density-dependence is evident (e.g., ocean survival) and *K* is set to some large value, typically the carrying capacity of the previous lifestage. For both relationships, *S* is the stock, *P* is the production, and the parameters are *r*, the slope near the origin (interpreted as a density-independent growth or survival rate), and *K*, a horizontal asymptote (interpreted as a carrying capacity). Figure A12-2 illustrates the two types of stock-production curves produced using the two different relationships.

Beverton-Holt: $P = \frac{rKS}{rS + K}$ Truncated linear: $P = \min(rS, K)$

Density-independent growth, or survival rate (*r*), of a population is the rate at which a population would be expected to grow if there were no limits on population density (i.e., intrinsic growth rate and slope at the origin). The values used in this analysis were developed based on values reported in the literature.

Carrying capacity is a measure of the maximum number of individuals the available habitat can support in the absence of any constraints imposed by population dynamics (survival-mortality) for the different life history stages of steelhead. Carrying capacity is calculated separately for each life history stage. To calculate total habitat carrying capacity for a specific life stage, the total area of each habitat type (e.g., pools) is multiplied by the maximum density for a specific life stage to yield carrying capacity for that habitat type. These carrying capacities are then summed for all habitat types. The type of stock production curve used to model each life history segment, as well as the values for *r* and *K* used in the analysis are provided in Table A12-2. Output from the population model is an estimate of the number of individuals of each life stage the habitat is expected to produce under current habitat conditions.

Table A12-2. Summary of the type of stock-production curves used for each life history segment in the analysis, and the parameters used to shape the curves.

Life History Segment	Model	r	K
Spawner to swim-up fry	Beverton-Holt	1,155 [a]	1,195 [b]
Swim-up fry to age 0+ summer	Beverton-Holt	0.7 [c]	788
Age 0+summer to age 0+ winter	Beverton-Holt	0.2 [d]	158
Age 0+ winter to age 1+ summer	Beverton-Holt	0.55 [e]	158
Age 1+ summer to age 1+ winter	Beverton-Holt	0.8 [c]	47
Age 1+ winter to smolt	Beverton-Holt	0.55 [e]	47
Smolt to ocean	Truncated Linear	0.6 [f]	N/A [g]
Ocean to spawner	Truncated Linear	0.084 [h]	N/A [g]

[a] r = the fraction female (0.5) * the fecundity (3,300) * egg survival (0.7)
[b] K = spawning area (4.5) * spawning density (0.23) * r (1,155)
[c] estimated values based on Lestelle et al. (1996) and Nickelson et al. (1992)
[d] Source: Bjornn (1978)
[e] estimated values based on Everest et al. (1987)
[f] estimated values based on Nickelson et al. (1992)
[g] habitat not considered limiting; value from previous life stage used.
[h] estimated values

Sensitivity Analysis

The model shown above characterizes the stock recruitment relations based on fixed assumptions about habitat quality and abundance. In particular, this model uses a swim-up fry to age 0+ survival rate of 0.7 (or a corresponding mortality of 0.3). The purpose of this limiting factors assessment, however, was to determine the sensitivity of steelhead populations in the surveyed section of Ritchie Creek to a range of permeability values relative to habitat availability as a constraint on population growth. To this end, the parameterized model was run using survival values ranging from 0 to 100 percent. The results of these variations in the survival rate were expressed in terms of the fraction of smolts produced at a given survival rate relative to the maximum production of smolts, given 100 percent egg survival.

Results

Habitat unit measurements for the study reach in Ritchie Creek are summarized in Table A12-3.

Table A12-3. Ritchie Creek steelhead habitat units and area.

Habitat unit dimensions					Usable steelhead habitat (m^2)				
Unit	**Type[1]**	**Average length (m)**	**Average width (m)**	**Area (m^2)**	**Spawn -ing**	**Age 0+ winter**	**Age 1+,2+ winter**	**Age 0+ summer**	**Age 1+,2+ summer**
1	HGR	10.1	3.6	36.36	0.5	6	3	21	3
2	LSPbo	7.5	3.3	24.75		4	2	12	4
3	HGR	3.8	2.3	8.74		5	3	2	0
4	LSPbo	3.4	2.3	7.82		4	3	6	2
5	HGR	1.7	2.1	3.57		1.5	1	1	0
6	MCP	4.3	3.3	14.19	0.5	3	2	7.5	3
7	HGR	7.8	2	15.6		4	3	8	1
8	MCP	7.2	3.5	25.2		1	1	12	4.5
9	POW	9.8	2	19.6		3	2	8	2
10	HGR	2.1	1.7	3.57		2	2	0.5	0
11	MCP	4.3	3.2	13.76		3	2	6	4
12	HGR	10.1	1.7	17.17		5	6	4	0.5
13	MCP	5.5	4.3	23.65		1	0	5	2.5
14	HGR	31.2	3.7	115.44	3.5	22	15	16	2
Reach-wide		**108.8**	**3.03**	**329.42**	**4.5**	**64.5**	**45**	**109**	**28.5**
Riffle		**59**		**184.85**	**4**	**41.5**	**30**	**44.5**	**5.5**
Pool		**42**		**128.97**	**0.5**	**19**	**12**	**56.5**	**22**

[1] HGR = high gradient riffle, LSPbo = lateral scour pool-boulder, MCP = mid-channel pool, POW = pocket water.

Sensitivity Analysis

The results of the sensitivity analysis are illustrated in Figure A12-3. The analysis demonstrates that large increases in smolt production can be expected relative to increases in embryo survival when embryo survival is very low to begin with (e.g., lower than 20 percent). However, the response of the system to improved embryo survival diminishes rapidly and even 30 percent survival is sufficient to produce approximately 80 percent of the maximum number of smolts expected under optimum habitat conditions (i.e., maximum [100 percent] permeability) for the Ritchie Creek reach. Increasing embryo survival from 30 to 50 percent produces only a 10 percent increase in smolt production, resulting in 90 percent of maximum production.

Caution should be used in extrapolating from these results, based on a single 100-meter reach in one tributary, to other tributaries in the Napa River basin. We feel that an expanded population dynamics modeling study could be a useful tool for evaluating potential benefits of alternative restoration strategies (e.g., what would be achieved by reducing fine sediment loading to improve spawning gravel permeability versus adding LWD to create more pool habitat or spawning gravel patches). We recommend that Phase II include quantitative habitat surveys and steelhead population modeling (see Appendix C).

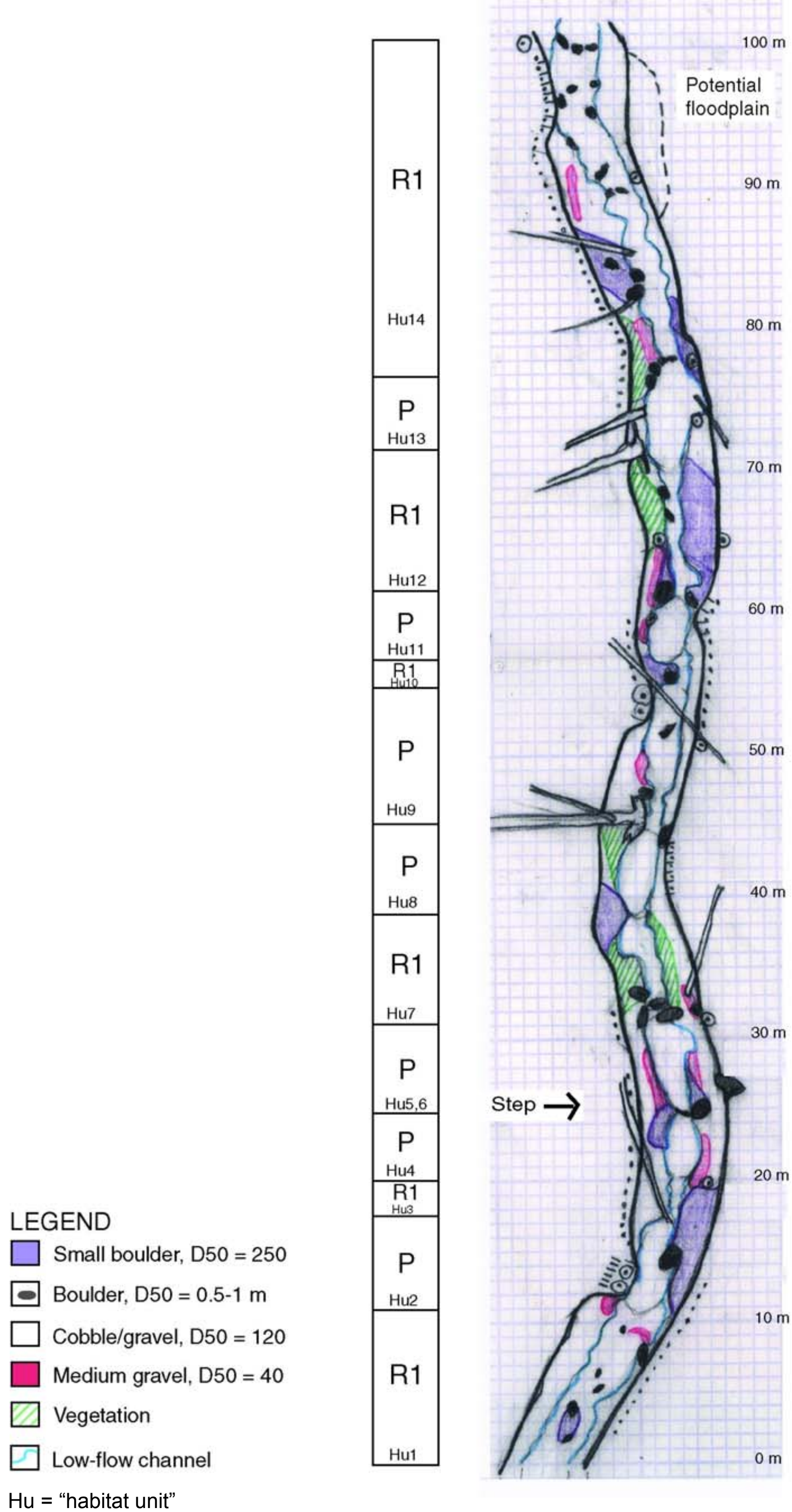

Figure A12-1. Planform sketch of Ritchie Creek detailing the distribution of habitat in a representative 100-meter reach. The habitat areas mapped were used in the salmonid production analysis performed to characterize the impact of egg-to-fry recruitment on the overall production of steelhead in this portion of Ritchie Creek.

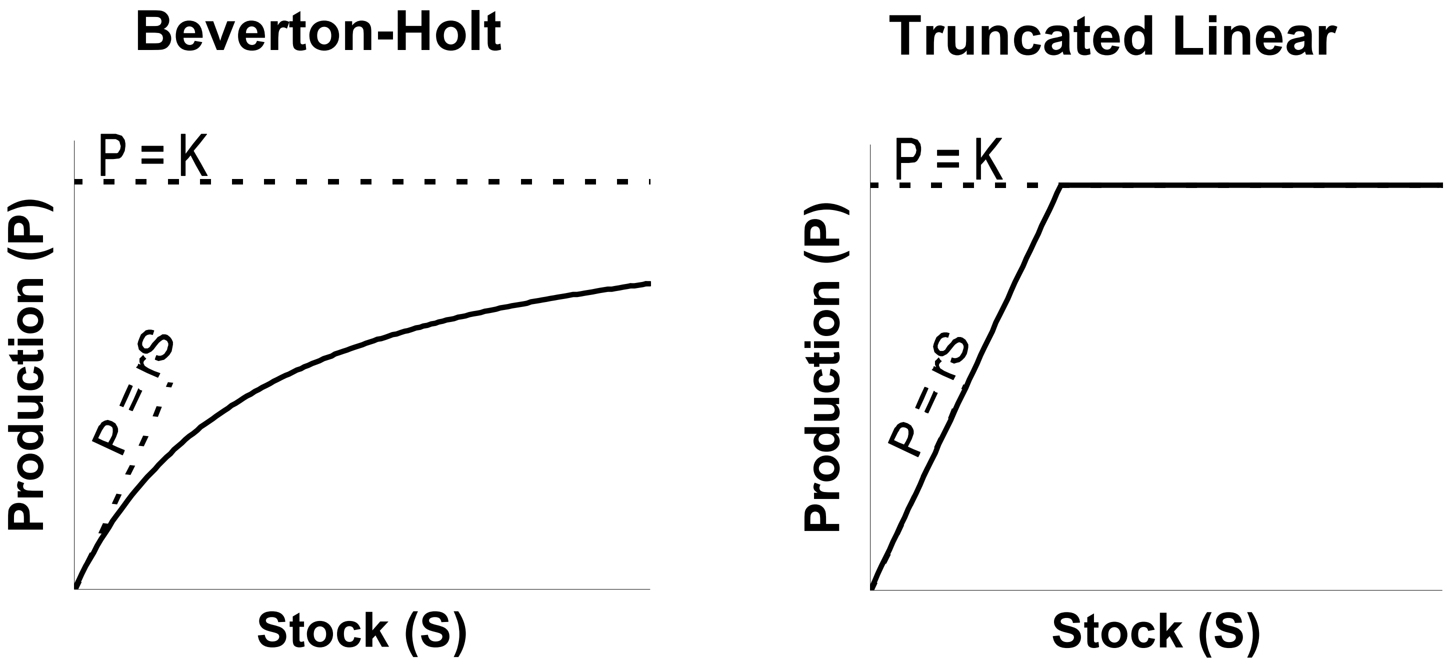

Figure A12-2. Examples of the stock-production curves produced using the Beverton-Holt and Truncated linear equations.

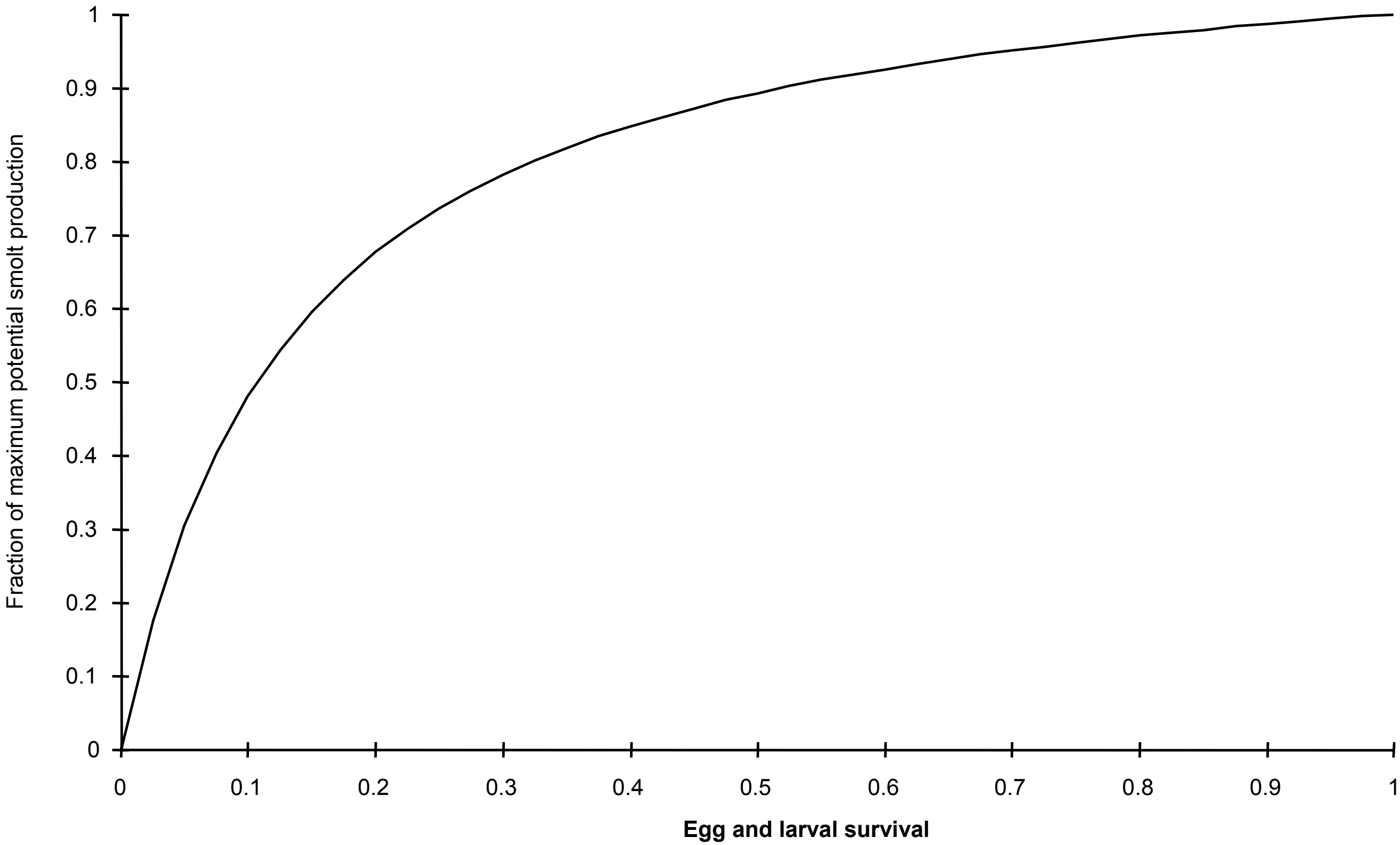

Figure A12-3. The expected response in terms of smolt production, given different levels of egg/larval survival. The modeling exercise used to derive these results assumed full use of available spawning habitat.

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APPENDIX B: ANALYSIS SPECIES SUMMARIES

B1 Chinook Salmon
B2 Steelhead
B3 California freshwater shrimp

APPENDIX B1: CHINOOK SALMON

Common Name: Chinook salmon (fall-run)
Scientific Name: *Oncorhynchus tshawytscha*

Status

Fall-run chinook salmon have been observed in the Napa River (Leidy and Sisco 1999). The National Marine Fisheries Service, however, believes that these populations, are not self-sustaining and are more likely present on an intermittent basis during favorable periods (NMFS 1999). Chinook salmon in the Napa River were therefore not included as an Evolutionary Significant Unit (ESU). However, fall chinook salmon in the California Coastal ESU (north of the Napa River) are listed as threatened, and those belonging to the Central Valley fall chinook salmon ESU are a candidate species.

Four runs of chinook salmon occur in California fall, late fall, winter, and spring (Leet et al. 1992, Allen and Hassler 1986, Mills et al. 1997). Fall-run populations (or “fall chinook”) occur throughout the species’ range and are currently the most abundant and widespread salmon runs in California (Mills et al. 1997). Winter-run populations are limited to the Sacramento River basin and were listed as endangered under the federal Endangered Species Act in 1994. Two apparently distinct stocks of spring-run chinook (or “spring chinook”) occur in California: a Sacramento-San Joaquin population and a Klamath-Trinity population (Moyle et al. 1995). Moyle et al. (1995) state that although other spring chinook populations may have existed in smaller coastal streams between these two basins, such as the Eel River, they have since been extirpated and there is no evidence of recent spawning in these streams.

Geographic Distribution

Chinook salmon are distributed in the Pacific Ocean throughout the northern temperate latitudes in North America and northeast Asia. In North America, they spawn in rivers from Kotzebue Sound, Alaska south to the San Joaquin River in California's Central Valley (Healey 1991). In California, larger populations are found in the Sacramento River and its major tributaries. Chinook salmon are also widely distributed in smaller California coastal streams north of San Francisco Bay (Allen and Hassler 1986). Fall chinook salmon have been observed in the Napa River near the town of Calistoga and up the base of the Kimball Canyon Dam (Leidy and Sisco 1999). It is unknown whether chinook use any of the Napa River tributary streams (Leidy and Sisco 1999).

Population Trends

Although the most abundant and widespread of salmon stocks in California, fall chinook abundance has fluctuated widely in recent decades, with some populations often reaching critically low levels. Adult returns in the Sacramento River basin since 1967 have ranged from >212,000 in 1986 to 62,000 in 1992 (Mills et al. 1997). Since 1967, fall chinook populations in the San Joaquin River basin have ranged from 36,000 in 1969 to approximately 1,000 in 1982 (Mills et al. 1997), with a general upswing in returns more recently. In the Klamath River basin, where fall chinook escapement has been estimated annually since 1978, populations have ranged from more than 113,000 naturally spawning adults in 1986 to approximately 12,000 in 1992 (Mills et al. 1997). Fall chinook returns to the Napa River are thought to be small and sporadic, with only occasional observations of spawning (Leidy and Sisco 1999). NMFS (1999) believes the fall chinook population in the Napa River generally consists of strays from other basins.

Life History

Overview

Chinook salmon vary in length of fresh and salt water residency, and in upstream and downstream migration timing (Healey 1991). Chinook salmon are the largest of the Pacific salmon species, reaching weights of up to 99 lb (45 kg). Chinook salmon have genetically distinct runs differentiated by the timing of spawning migration, stage of sexual maturity when entering fresh water, timing of juvenile or smolt outmigration, and other characteristics (Moyle et al. 1989).

Spring chinook typically spend up to one year rearing in fresh water before migrating to sea, perform extensive offshore migrations, and return to their natal river in the spring or summer, several months prior to spawning (these are also referred to as "stream-type" chinook). Fall (or "ocean-type") chinook migrate to sea during their first year of life—typically within three months after their emergence from spawning gravels—spend most of their ocean life in coastal waters, and return to their natal river in the fall, a few days or weeks before spawning (Moyle et al. 1989, Healey 1991).

Adult upstream migration and spawning

Adult chinook salmon migrate upstream from the ocean to spawn in their natal streams, although a small percentage may stray into other streams, especially during high water years (Moyle et al. 1989). In the San Francisco Bay populations, adult fall chinook typically return to fresh water between June and December (Maragni 2001). The age of returning adults ranges from two to five years, and in the Sacramento River is typically age four.

Adult chinook salmon appear to be less capable of negotiating fish ladders, culverts, and waterfalls during upstream migration than coho salmon or steelhead (Nicholas and Hankin 1989), due in part to slower swimming speeds and inferior jumping ability compared to steelhead (Reiser and Peacock 1985, Bell 1986). Cruising speeds, which are used primarily for long-distance travel, range from 0 to 3.3 ft/s (0 to 1 m/s) (Bjornn and Reiser 1991). Sustained speeds, which can be maintained for several minutes, range from 3.3 to 10.8 ft/s (1 to 3.3 m/s) (Bjornn and Reiser 1991). Darting speeds, which can only be sustained for a few seconds, range from 10.8 to 22.3 ft/s (3.3 to 6.8 m/s) (Bjornn and Reiser 1991). The maximum jumping height for chinook salmon has been calculated to be approximately 7.9 ft (2.4 m) (Bjornn and Reiser 1991).

Fall chinook spawning occurs from late September to December, with peak spawning occurring in late October (Maragni 2001). Upon arrival at the spawning grounds, adult females dig shallow depressions or pits in suitably-sized gravels, deposit eggs in the bottom during the act of spawning, and cover them with additional gravel. Over a period of one to several days, the female gradually enlarges the redd by digging additional pits in an upstream direction (Healey 1991). Redds are typically 108–183 ft^2 (10–17 m^2) in size, although they can range from 5.4–484 ft^2 (0.5 to 45 m^2) (Healey 1991).

Before, during, and after spawning, female chinook salmon defend the redd area from other potential spawners (Burner 1951). Briggs (1953) observed that the defended area could extend up to 20 ft (6 m) in all directions from the redd. Redds may be defended by the female for up to a month (Hobbs 1937). Males do not defend the redd but may exhibit aggressive behavior toward other males while defending spawning females (Shapovalov and Taft 1954). Both male and female adults die within two weeks after spawning (Kostow 1995), with females defending the redd until they become too weak to maintain position over the redd or die.

Egg incubation, alevin development, and fry emergence
Egg incubation generally lasts between 40–90 days depending on water temperature (Vernier 1969, Bams 1970, Heming 1982). The alevins remain in the gravel for two to three weeks after hatching and absorb their yolk sac before emerging from the gravels into the water column during April and May.

Juvenile freshwater rearing
Chinook may disperse downstream as fry soon after emergence; early in their first summer as fingerlings; in the fall as flows increase; or after overwintering in freshwater as yearlings (Healey 1991). Emergence of fall chinook in the Sacramento-San Joaquin typically occurs between December and March, and juveniles rear for four to seven months before outmigrating. Although fry typically drift downstream following emergence (Healey 1991), movement upstream or into cooler tributaries following emergence has been observed in some systems (Lindsay et al. 1986, Taylor and Larkin 1986).

Juveniles feed voraciously during summer, and display territoriality in feeding areas and are aggressive towards other juvenile chinook (Taylor and Larkin 1986, Reimers 1968). Experiments conducted in artificial streams suggest that aggressive behavior among juvenile chinook results in formation of territories in riffles and size hierarchies in pools having abundant food resources and relatively dense groupings of fish (Reimers 1968). Territorial individuals have been observed to stay closer to the substrate, while other individuals may school in hierarchical groups (Everest and Chapman 1972). At night, juvenile chinook may move toward stream margins with low velocities and finer substrates or into pool bottoms, returning to their previous riffle/glide territories during the day (Edmundson et al. 1968, Don Chapman Consultants 1989). Reimers (1968) speculated that intraspecific interactions or density-dependent mechanisms may cause downstream displacement of fry. Fall chinook typically out-migrate by June, and do not over-winter in freshwater.

Smolt outmigration and estuarine rearing
In the Sacramento-San Joaquin system, fall chinook smolt outmigration generally occurs from March to July (Maragni 2001). Most age 0+ outmigrants move downstream at sizes of 3.1 to 4.7 inches (8 to 12 cm) (Nicholas and Hankin 1989), while age 1+ outmigrants are generally larger than 4.7 inches (12 cm).

Juvenile chinook feed and grow as they move downstream in spring and summer; larger individuals are more likely to move downstream earlier than smaller juveniles (Nicholas and Hankin 1989). Juveniles that do not disperse downstream in their first spring may display high fidelity to their rearing areas throughout the summer rearing period (Edmundson et al. 1968).

Downstream migrants, especially those migrating at younger ages, typically spend up to several months feeding and growing in estuaries before entering the ocean. Agonistic behavior may decrease in these saline environments—juveniles in estuaries have been observed in aggregations of up to several hundred fish (Reimers 1968).

Ocean phase
When fall chinook salmon produced from the Sacramento-San Joaquin system enter the ocean they appear to head north, and rear off the northern California-southern Oregon coast (Cramer 1987). Fall chinook typically rear in coastal waters early in their ocean life.

Habitat Requirements

Adult upstream migration and spawning
Adult chinook salmon require water deeper than 0.8 ft (24 cm) and water velocities less than 8 ft/s (2.4 m/s) for successful upstream migration (Thompson 1972). Water temperatures for adult chinook holding and spawning are reportedly best when <61°F (16°C), and potentially lethal when >73°F (23°C) (Moyle et al. 1995).

Most chinook salmon spawn in the mainstem of large rivers and lower reaches of tributaries, although spawning has been observed over a broad range of stream sizes, from small tributaries 6.6–9.8 ft (2–3 m) in width (Vronskiy 1972) to large mainstem rivers (Healey 1991). Chinook prefer low-gradient (<3 percent) reaches for spawning and rearing, but will occasionally use higher-gradient areas (Kostow 1995). Spawning site (redd) locations are mostly controlled by hydraulic conditions dictated by streambed topography (Burner 1951). Redds are typically located near pool tailouts (i.e., heads of riffles) where high concentrations of intragravel dissolved oxygen are available.

Chinook are capable of spawning within a wide range of water depths and velocities, provided that intragravel flow is adequate (Healey 1991). Depths most often recorded over chinook redds range from 3.9 to 78 in (10 to 200 cm) and velocities from 0.5 to 3.3 ft/s (15 to 100 cm/s), although criteria may vary between races and stream basins (Tables B1-2). Fall chinook salmon, for instance, are able to spawn in deeper water with higher velocities, because of their larger size (Healey 1991).

Substrate particle size composition has been shown to have a significant influence on intragravel flow dynamics (Platts et al. 1979). Chinook salmon may therefore have evolved to select redd sites with specific particle size criteria that will ensure adequate delivery of dissolved oxygen to their incubating eggs and developing alevins (Table B1-3). In addition, salmon are limited by the size of substrate that they can physically move during the redd building process. Substrates selected likely reflect a balance between water depth and velocity, substrate composition and angularity, and fish size. As depth, velocity, and fish size increase, chinook are able to displace larger substrate particles.

Egg incubation, alevin development, and fry emergence
Suitable water temperatures, dissolved oxygen delivery, and substrate characteristics are required for proper embryo development and emergence. Review of the literature suggests that 42.5–57.5°F (5.8–14.2°C) is the optimum temperature range for incubating chinook salmon (Donaldson 1955, Combs and Burrows 1957, Combs 1965, Eddy 1972, Bell 1973, Healey 1979, Reiser and Bjornn 1979, Garling and Masterson 1985). Sublethal stress and/or mortality of incubating eggs resulting from elevated temperatures would be expected to begin at temperatures of about 58°F (14.4°C) for constant exposures (Combs and Burrows 1957, Combs 1965, Healy 1979).

Delivery of dissolved oxygen to the egg pocket is the major factor affecting survival-to-emergence that is impacted by the deposition of fines in the spawning substrate. Several studies have correlated reduced dissolved oxygen levels with mortality, impaired or abnormal development, delayed hatching and emergence, and reduced fry size at emergence in anadromous salmonids (Wickett 1954, Alderdice et al. 1958, Coble 1961, Silver et al. 1963, McNeil 1964, Cooper 1965, Shumway et al. 1964, Koski 1981). Silver et al. (1963) found that low dissolved oxygen concentrations were related to mortality and reduced size in chinook salmon and steelhead trout embryos. Data suggest that growth may be restricted day at oxygen levels below saturation (Silver et al. 1963). Fine sediments in the gravel interstices can also physically impair the fry's ability to emerge through the gravel layer, trapping (or entombing) them within the gravel (Phillips et al. 1975, Hausle and Coble 1976).

Juvenile freshwater rearing
Juvenile chinook salmon tend to use mainstem reaches and estuaries as rearing habitat more extensively than juvenile coho salmon, steelhead, and sea-run coastal cutthroat trout. Following emergence, fry occupy low-velocity, shallow areas near stream margins, including backwater eddies and areas associated with bank cover such as large woody debris (Lister and Genoe 1970, Everest and Chapman 1972, McCain 1992). As fry grow, they move into deeper and faster water further from banks (Hillman et al. 1987, Everest and Chapman 1972, Lister and Genoe 1970). Everest and Chapman (1972) observed at least small numbers of chinook fry in virtually all habitats sampled in early summer. Because chinook fry tend to be larger than coho fry upon emergence, they may tend to use areas with higher water velocities than coho (Murphy et al. 1989, Healy 1991). quiet, shallow water with cover. Everest and Chapman (1972) investigated habitat use of emergent chinook fry; they found fry using depths less than 60 cm (24 in) and water velocities less than 0.5 ft/s (15 cm/s). Tables B1-4 through B1-11 summarize information found in the literature on habitat requirements of chinook salmon during the summer rearing period.

Juvenile chinook salmon appear to prefer pools that have cover provided by banks, overhanging vegetation, large substrates, or large woody debris (LWD). Juvenile densities in pools have been found to increase with increasing amounts of cover (Steward and Bjornn, unpublished data, as cited in Bjornn and Reiser 1991). Water temperature may also influence juvenile habitat use. In the South Umpqua River basin, Roper et al. (1994) observed lower densities of juvenile chinook where water temperatures were higher, such as in the lower reaches of South Umpqua River tributaries. In areas where more suitable water temperatures were available, juvenile chinook salmon abundance appeared to be tied to pool availability.

Temperatures also have a significant effect on juvenile chinook growth rates. On maximum daily rations, growth rate increases with temperature to a certain point and then declines with further increases. Reduced rations can also result in reduced growth rates; therefore, declines in juvenile salmonid growth rates are a function of both temperature and food availability. Laboratory studies indicate that juvenile chinook salmon growth rates are highest at rearing temperatures from 65 to 70°F (18.3 to 21.1°C) in the presence of unlimited food (Clarke and Shelbourn 1985, Banks et al. 1971, Brett et al. 1982, Rich 1987), but decrease at higher temperatures, with temperatures >74°F (23.3°C) being potentially lethal (Hanson 1990).

Ecological Interactions

Interspecific interactions and competition
A number of studies have attempted to discern the influence of interspecific interactions between juvenile chinook salmon and other salmonids on habitat preference and migration patterns. Differences in timing of emergence and subsequent growth rates may result in spatial and/or temporal habitat segregation and may act to reduce interspecific competition between species in some areas. For example, in the Big Qualicum River, British Columbia, fall chinook and coho salmon both occupy stream margin (or lateral) habitats with cover during their first three months, but competition for rearing space is reduced by differences in emergence timing and growth rates (Lister and Genoe 1970). Lister and Genoe (1970) observed that juvenile chinook, perhaps because of their larger size, used higher water velocities in summer than juvenile coho salmon, and moved away from stream margins toward mid-channel areas earlier than coho. Although coho and chinook salmon exhibit some degree of habitat segregation on the microhabitat scale, they often inhabit similar regions of streams (Shirvell 1994, Lister and Genoe 1970).

Coho salmon have often been observed to be behaviorally dominant over juvenile chinook, and thus may influence chinook habitat use. Taylor (1991) found that in streams containing both coho and chinook, chinook were more likely to use higher velocity, shallow riffles, while coho formed hierarchies in low-velocity, deep pools. In study streams where coho were absent, chinook were more likely to inhabit pools, although chinook appeared to be most abundant in riffles, whether or not coho were present. Taylor (1991) suggested that species-specific differences in habitat preferences with coho preferring pools and chinook preferring riffles may be reinforced or exacerbated by behavioral dominance by coho.

In an experimental stream trough, Stein et al. (1972) found that juvenile coho dominated optimal feeding areas with high food availabilities, such as the upstream ends of riffles. In the same study, the presence of juvenile coho reduced growth rates of juvenile chinook and their access to optimal feeding positions. Stein et al. (1972) suggested that because fall chinook only rear for a short period in fresh water, the species may only require relatively small territories during this period, moving downstream before late summer flows reduce the amount of habitat available. Stein et al. (1972) concludes that chinook appear to be better adapted to rearing in mainstem and estuary areas, suggesting a greater tolerance for higher temperatures, whereas coho appear better adapted to rearing in cooler, small tributaries for more extended periods.

Everest and Chapman (1972) observed that differences in the timing of spawning and emergence between chinook and steelhead resulted in differences in size and reduced the potential for interspecific competition. They found that chinook and steelhead rearing in sympatry segregated habitat according to depth, velocity, and substrate characteristics (Everest and Chapman 1972). Age 0+ chinook typically occupied areas intermediate in depth, velocity, and distance from the stream margin compared to age 0+ steelhead (shallower, slower, and nearer the bank) and age 1+ steelhead, (deeper, faster, and further from the bank). Age 1+ chinook occupied similar microhabitats as age 1+ steelhead, but because most chinook outmigrated earlier in the year competition was reduced through temporal niche segregation (Everest and Chapman 1972). In the Rogue River of Oregon, Reedy (1995) found that juvenile fall chinook occupied areas closer to the water surface and with lower velocity than age 1+ steelhead, which typically used faster, deeper water.

In a study of tributaries in the South Umpqua River basin, Roper et al. (1994) found that age 0+ steelhead used a variety of habitat types, but juvenile chinook were concentrated in deeper pools. These authors suggested that different habitat preferences, rather than segregation by life history timing, limited interspecific interaction between steelhead and coho. In contrast, Hillman et al. (1987) found that in early summer, age 0+ steelhead and chinook tended to use similar habitats and suggested that a high potential appears to exist for competition between chinook and steelhead during the summer months.

Food web interactions

Juvenile chinook feed on invertebrate drift while rearing in fresh water (Healey 1991). Becker (1973) reported that in the Hanford Reach of the Columbia River, over 95% of their diet consisted of insects, especially adult chironomids. In estuaries, juvenile chinook may feed on algae, amphipods (usually *Corophium* spp.), fishes (e.g., northern anchovy, Pacific herring), and terrestrial insects (e.g., adult Diptera, ants) (Nicholas and Hankin 1989). In the ocean, chinook feed primarily on small fish such as herring, but also consume amphipods, crab megalopa, squid, and a variety of other organisms (Healey 1980). Adults generally do not feed during their freshwater spawning migration, relying instead on fat reserves for body maintenance and gonadal maturation.

Predators on eggs, alevins, and juvenile chinook salmon in rearing habitats include sculpin, trout and other piscivorous fish; river otters, mink, American dippers, mergansers, belted kingfishers, and great blue herons (Healey 1991, Reedy 1995).

Responses to Anthropogenic Watershed Disturbances

During their freshwater residence, chinook salmon tend to primarily occur in mainstem rivers and larger tributaries. Due to their greater accessibility, these were some of the first areas where anthropogenic disturbances such as logging, agriculture, and human settlement took place. Early valley-bottom logging and splash damming for log transport largely occurred in the mainstems of coastal rivers and thus was "particularly devastating" to chinook habitat (Lichatowich 1989). Because chinook habitat was degraded relatively early on in comparison to upper tributary habitats used by coho salmon and steelhead, historical population abundance is particularly difficult to estimate for this species. Conditions in coastal river habitat used by chinook salmon appear to have improved since the 1960s, however, and systems have recovered somewhat from certain types of prior damage (Nicholas and Hankin 1989).

Physical barriers to migration and movement
Dams have contributed to declines in chinook salmon populations in many areas of the Pacific Northwest (Nehlsen et al. 1991). Dams block or inhibit upstream and downstream migration to historical spawning and rearing areas if appropriate fish passage structures are absent or dysfunctional. Dams and their operations may also cause inundation of spawning and rearing habitat, turbine and spillway mortality, alteration of local hydrology and water temperature, interruption of sediment and large woody debris transport, and alteration of nutrient dynamics and food supplies (Collins 1976). Low oxygen levels in large, warm reservoirs may reduce the swimming abilities of juvenile fish, delaying downstream migration to the ocean and may extend the exposure of smolt outmigrants to disease and predation risks (Collins 1976). Thermal stratification in reservoirs may also harm outmigrating smolts, with surface temperatures being too warm and colder subsurface waters being deficient in oxygen (Collins 1976). Increased water temperatures in reservoirs typically create favorable conditions for competitors and predators of salmonids (Collins 1976).

Gas supersaturation immediately downstream of some dams and powerhouses can cause salmonid disorientation, disease, and mortality (Collins 1976). This occurs when pressurized or high-velocity is discharged into relatively calm water, (e.g., below dams, penstocks, and waterfalls) where entrapped air is forced into solution and river turbulence is locally insufficient to recreate ambient saturation. If fish cannot escape supersaturated water, gas bubbles may form within the skin, organs, and bloodstream, compromising performance and potentially causing death (Collins 1976).

Changes to hydrologic regimes
Changes to natural flow regimes may impact chinook salmon populations through changes to stimuli used for timing of upstream and downstream migrations, dewatering of redds, displacement of fry or juveniles, and/or scouring of spawning gravels. Rapid decreases in flow associated with hydropower operations may cause stranding, especially of recently emerged fry, since these fish prefer lateral stream margin habitat and are relatively weak swimmers (Hunter 1992). Woodin (1984, as cited in Hunter 1992) found that daytime ramping resulted in stranding of chinook fry, but observed reduced vulnerability to stranding at night. Vulnerability of chinook to stranding appears to decline once juveniles reach lengths of 2 to 2.4 in (50 to 60 mm) (Hunter 1992), although stranding of adults due to hydroelectric-related flow fluctuations has been documented (Hamilton and Buell 1976).

Flow fluctuations have been found to accelerate the rate of downstream migration among chinook juveniles in laboratory experiments (McPhee and Brusven 1976). Increased peak flows due to logging, grazing, or hydroelectric operations can reduce survival of eggs and alevins through displacement if gravels are mobilized; juveniles may also be displaced if suitable velocity refuges are lacking in rearing areas (Nicholas 1988). Conversely, dam operations that reduce peak flows may increase stability of spawning gravels and contribute to increased survival. Reduced instream flows due to diversions or reservoir storage may delay or halt adult and juvenile migrations, limit availability of holding pools, and reduce spawning habitat if minimum water depths are not met (Everest et al. 1985).

Changes to sediment dynamics
In general, increased supply of fine sediments to streams can reduce the suitability of spawning and rearing habitats by filling interstitial spaces between sediment particles, reducing intragravel flow and the delivery of dissolved oxygen to incubating eggs and developing alevins (Chapman 1988). Bjornn et al. (1977) found that survival to emergence of chinook declined when percentage of fine sediments (<0.3 in [6.5 mm]) in spawning substrate was greater than 20–30 percent. Sedimentation during the incubation and overwintering periods may also cause direct mortality by entombing eggs, alevins, fry, and juveniles. Chinook eggs may be more sensitive to reductions in dissolved oxygen than other salmonids, given their large size and small surface-to-volume ratio (Healey 1991). The filling of pools by sediment can reduce the amount of rearing habitat available to juvenile chinook. Bjornn et al. (1977) found that pool volume by half following the addition of sand reduced juvenile chinook abundance by over two-thirds. Sedimentation may also fill interstitial spaces used as velocity refuge by juvenile salmon during high flow events (Hillman et al. 1987).

Changes to large woody debris dynamics
Reduction of LWD within stream channels has been one of the most pronounced long-term effects of forest management on salmonids in North America (Hicks et al. 1991) and causes decreased frequency, depth, and complexity of pool habitat used by rearing juvenile and holding adult salmonids. Although pool habitat is an important geomorphic feature of channels where chinook salmon rear, it is likely not as important to chinook salmon as it is for coho salmon (see coho salmon species summary for further discussion of the effects of reduced LWD in streams). However, reduced LWD availability may also limit formation of backwater pools and complex lateral habitat used by emergent chinook salmon fry (McCain 1992).

Changes to stream temperatures and water quality
Logging and grazing practices that reduce riparian vegetation and stream channel shading may increase stream temperature, which may reduce survival of adult and juvenile chinook salmon. In the John Day River, Oregon, high summer water temperatures in mainstem areas appear to reduce usable habitat for juvenile rearing (Lindsay et al. 1986).

Table B-1. Adult spawning velocity criteria for fall chinook salmon.

VELOCITY CRITERIA			SOURCE	NOTES
Minimum	Maximum	Average		
1 ft/s (0.31 m/s)	3.5 ft/s (1.07 m/s)	2 ft/s (0.61 m/s)	Burner (1951)	Based on 143 redds in Kalama River, Washington. From summary table page 101. Note: Burner reports velocity as Acubic feet a second@, however, in the methods section he describes that surface velocity was measured. We therefore assume that an error was made and that numbers reported are meant to be velocity [ft/s] (not discharge [ft^3/s]).
1 ft/s (0.31 m/s)	3 ft/s (0.92 m/s)	1.3 ft/s (0.40 m/s)	Burner (1951)	Based on 89 redds in Toutle River, Washington. From summary table page 101. Note: Burner reports velocity as Acubic feet a second@, however, in the methods section he describes that surface velocity was measured. We therefore assume that an error was made and that numbers reported are meant to be velocity [ft/s] (not discharge [ft^3/s]).
0.186 m/s (0.62 ft/s)	0.805 m/s (2.66 ft/s)	0.497 m/s " 0.6509 (1.64 ft/s)	Smith (1973)	Based on 50 redds in 7 Oregon streams. Velocities were measured at 0.12 m (4.68 in) depth over undisturbed gravel just above the upstream edge of the redd and were recorded to nearest 0.01 ft/s (0.30 m/s). Velocity criteria were defined as the two-sided tolerance limits within which there was 95% confidence that 80% of the measurements would occur with a normal distribution.
0.336 m/s (1.12 ft/s)	0.756 m/s (2.49 ft/s)	0.545 m/s " 0.4762 (1.80 ft/s)	Sams and Pearsons (1963, as cited in Smith 1973)	Based on 107 redds in 4 western Oregon streams. Velocity values = mean water column velocity over redds. Velocity criteria were defined as the two-sided tolerance limits within which there was 95% confidence that 80% of the measurements would occur with a normal distribution.
37cm/s (1.21 ft/s)	189 cm/s (6.20 ft/s)		Chapman et al. (1986)	Range in facing velocities observed in a reach below the Priest Rapids Dam on the Columbia River with daily flow manipulations.
1.5 ft/s (45.73 cm/s)	2.5 ft/s (76.22 cm/s)	2.0 ft/s (60.98 cm/s)	Briggs (1953)	Range and average observed at 8 redds in Prairie Creek basin, northern California.
		2.35 ft/s 0.72 m/s	Hamilton and Remington (1962 as cited in Smith 1973)	AMean@ velocity over 12 redds in Coquille River, Oregon.

Table B1-2. Adult spawning depth criteria for fall chinook salmon.

DEPTH CRITERIA			SOURCE	NOTES
Minimum	Maximum	Average		
1 in (2.56 cm)	3.5 in (8.97 cm)	2 in (5.12 cm)	Burner (1951)	Based on 143 redds in Kalama River, Washington. Depths are average measurements measured from streambed to surface at each side and at upstream end of each redd.
1 in (2.56 cm)	3 in (17.95 cm)	1.3 in (3.33 cm)	Burner (1951)	Based on 89 redds in Toutle River, Washington. Depths are average measurements measured from streambed to surface at each side and at upstream end of each redd.
1.0 ft (0.305 m)		1.28 ft " 1.60 (0.389 m " 0.4891)	Smith (1973)	Based on 50 redds in 7 Oregon streams. Depths were measured over undisturbed gravel just above the upstream edge of the redd and were recorded to nearest 0.1 ft. Minimum depth was the limit above which 80% of measurements could be expected to occur with 95% confidence.
0.183 m (0.60 ft)		0.264 m " 0.2651 (0.866 ft " 0.870)	Sams and Pearson (1963, as cited in Smith 1973)	Based on 107 redds in 4 western Oregon streams. Depths were measured over undisturbed gravel just above the upstream edge of the redd and were recorded to nearest 0.1 ft. Minimum depth was the limit above which 80% of measurements could be expected to occur with 95% confidence.
0.220 m (0.71 ft)	1.983 m (6.51 ft)		Chambers et al. (1955, as cited in Smith 1973)	Based on 44 redds in mainstem Columbia River. Values are for Amost utilized ranges.@ Depth measured over undisturbed gravel just above upstream edge of redd.
0.381 m (1.25 ft)	0.686 m (2.25 ft)		Chambers et al. (1955, as cited in Smith 1973)	Based on 167 redds in Kalama and Coweman rivers. Values are for Amost utilized ranges.@ Depth was measured over undisturbed gravel just above upstream edge of redd.
		0.37 m 1.2 ft	Hamilton and Remington (1962, as cited in Smith 1973)	AMean@ depth over 12 redds in Coquille River, Oregon.
0.24 m 0.8 ft			Hamilton and Remington (1962, as cited in Smith 1973)	Considered minimum for Coquille River, Oregon
10 in (25.4 cm)	16 in (39.2 cm)	12.7 in (32.3 cm)	Briggs (1953)	Based on 8 redds in Prairie Creek basin, northern California.
	7 m (23 ft)		Chapman et al. (1986)	In reach with daily flow manipulations below a dam in the Columbia River.

Table B1-3. Adult spawning substrate criteria for chinook salmon.

SUBSTRATE CRITERIA (D_{50})	FISH LENGTH	SOURCE	NOTES
31.8 mm	101 cm	Burger et al. (1983) as cited in Kondolf and Wolman (1993)	Kenai River, Arkansas. N=4
22.0 mm	94 cm	Burger et al. (1983) as cited in Kondolf and Wolman (1993)	Benjamin Creek, Alaska. N=4
47.0 mm	90 cm	Vronskiy (1972) as cited in Kondolf and Wolman (1993)	Kamchatka River, Siberia; main stem. N=2
26.0 mm	90 cm	Vronskiy (1972) as cited in Kondolf and Wolman (1993)	Kamchatka River, Siberia; arm 1. N=2
16.0 mm	90 cm	Vronskiy (1972) as cited in Kondolf and Wolman (1993)	Kamchatka River, Siberia; arm 2. N=2
36.0 mm	90 cm	Kondolf and Wolman (1993)	Crooked Creek, Alaska. N=4 (entry #33)
34.0 mm	81 cm	Kondolf and Wolman (1993)	Yuba River, California. N=1 (entry #34)
54.0 mm	86 cm	Chambers et al. (1954, 1955) as cited in Kondolf and Wolman (1993)	Kalama River, Washington. N=13 (entry #35)
21.0 mm	86 cm	Chambers et al. (1954, 1955) as cited in Kondolf and Wolman (1993)	Snake River, Idaho. N=8 (entry #36)
50.0 mm	82 cm	Chambers et al. (1954, 1955) as cited in Kondolf and Wolman (1993)	Cispus River, Washington. N=7 (entry #37)
41.0 mm	82 cm	Chambers et al. (1954, 1955) as cited in Kondolf and Wolman (1993)	Imnaha River, Oregon. N=4 (entry #38)
35.0 mm	82 cm	Chambers et al. (1954, 1955) as cited in Kondolf and Wolman (1993)	American River, Washington. N=5 (entry #39)
51.0 mm	82 cm	Chambers et al. (1954, 1955) as cited in Kondolf and Wolman (1993)	Cowlitz River, Washington. N=8 (entry #40)
78.0 mm	86 cm	Chambers et al. (1954, 1955) as cited in Kondolf and Wolman (1993)	Columbia River, Washington. N=4 (entry #83)
21.0 mm	86 cm	Chambers et al. (1954, 1955) as cited in Kondolf and Wolman (1993)	Snake River, Idaho. N=10 (entry #84)
49.0 mm	86 cm	Chambers et al. (1954, 1955) as cited in Kondolf and Wolman (1993)	Kalama River, Washington. N=7 (entry #85)
42.0 mm	82 cm	Chambers et al. (1954, 1955) as cited in Kondolf and Wolman (1993)	Cowlitz River, Washington. N=8 (entry #86)
52.0 mm	82 cm	Chambers et al. (1954, 1955) as cited in Kondolf and Wolman (1993)	Imnaha River, Oregon. N=4 (entry #87)
37.0 mm	82 cm	Chambers et al. (1954, 1955) as cited in Kondolf and Wolman (1993)	Cispus River, Washington. N=7 (entry #88)
34.0 mm	82 cm	Chambers et al. (1954, 1955) as cited in Kondolf and Wolman (1993)	American River, Washington. N=5 (entry #89)
44.0 mm	84 cm	W.F. Van Woert and E.J. Smith, Jr. , unpublished data (1962, as cited in Kondolf and Wolman 1993)	Sacramento River, California. N=3
31.0 mm	84 cm	W.F. Van Woert and E.J. Smith, Jr. , unpublished data (1962, as cited in Kondolf and Wolman 1993)	Cottonwood Creek, California. N=12
52.0 mm	84 cm	W.F. Van Woert and E.J. Smith, Jr. , unpublished data (1962, as cited in Kondolf and Wolman 1993)	Cow Creek, California. N=3
66.0 mm	84 cm	W.F. Van Woert and E.J. Smith, Jr. , unpublished data (1962, as cited in Kondolf and Wolman 1993)	Battle Creek, California. N=3
22.0 mm	86 cm	Platts et al. (1979) as cited in Kondolf and Wolman (1993)	South Fork Salmon River, Idaho: Stolle Meadow. N=145
11.2 mm	86 cm	Platts et al. (1979) as cited in Kondolf and Wolman (1993)	South Fork Salmon River, Idaho: Poverty Area. N=310
16.5 mm	86 cm	Platts et al. (1979) as cited in Kondolf and Wolman (1993)	South Fork Salmon River, Idaho: Glory Area. N=80
24.5 mm	86 cm	Platts et al. (1979) as cited in Kondolf and Wolman (1993)	Johnson Creek, Idaho. N=100
10.8 mm	86 cm	Platts et al. (1979) as cited in Kondolf and Wolman (1993)	Bear Valley Creek, Idaho. N=20
15.2 mm	86 cm	Platts et al. (1979) as cited in Kondolf and Wolman (1993)	Elk Creek, Idaho. N=20
21.5 mm	86 cm	Platts et al. (1979) as cited in Kondolf and Wolman (1993)	Loon Creek, Idaho. N=20

SUBSTRATE CRITERIA (D_{50})	FISH LENGTH	SOURCE	NOTES
27.0 mm	86 cm	Platts et al. (1979) as cited in Kondolf and Wolman (1993)	Salmon River, Idaho: lower Decker site. N=5
13.2 mm	86 cm	Platts et al. (1979) as cited in Kondolf and Wolman (1993)	Salmon River, Idaho: upper Decker site. N=5
14.5 mm	86 cm	Platts et al. (1979) as cited in Kondolf and Wolman (1993)	Alturas Creek, Idaho. N=20
30.0 mm	82 cm	Shirazi et al. (1981) as cited in Kondolf and Wolman (1993)	Grants Creek, Oregon. N=4
37.8 mm	82 cm	Shirazi et al. (1981) as cited in Kondolf and Wolman (1993)	Rogue River, Oregon: Old Bridge. N=4
39.7 mm	82 cm	Shirazi et al. (1981) as cited in Kondolf and Wolman (1993)	Rogue River, Oregon: Hatchery. N=3
69.3 mm	82 cm	Shirazi et al. (1981) as cited in Kondolf and Wolman (1993)	Rogue River, Oregon: Sand Hole. N=3
59.0 mm	82 cm	Shirazi et al. (1981) as cited in Kondolf and Wolman (1993)	Rogue River, Oregon: Dam Site. N=1
35.0 mm	82 cm	Shirazi et al. (1981) as cited in Kondolf and Wolman (1993)	Rogue River, Oregon: Big Butte Creek. N=3
43.0 mm	86 cm	Chapman et al. (1984) as cited in Kondolf and Wolman (1993)	Columbia River (Venita), Washington. N=2
41.3 mm	90 cm	Kondolf and Wolman (1993)	Crooked Creek, Alaska. N=4 (entry #111)
35.0 mm	81 cm	Kondolf and Wolman (1993)	Yuba River, California. N=1 (entry #112)

Table B1-4. Fry early summer rearing velocity criteria for chinook salmon.

VELOCITY CRITERIA				LIFE STAGE NOTES	SOURCE	NOTES
Minimum	Maximum	Average	Preferred/ Optimal			
			AVery quiet@	35 mm (1.38 in)	Everest and Chapman (1972)	Most emergent fry
	<15 cm/s (<0.49 ft/s)		0.0 cm/s (0.0 ft/s)	<55 mm (<2.17 in)	Everest and Chapman (1972)	Most observations. Focal point velocity. Johnson Creek, Idaho. Interpreted from fig. 10.
	<30 cm/s (<0.98 ft/s)		15B30 cm/s (0.49B0.98 ft/s)	<55 mm (<2.17 in)	Everest and Chapman (1972)	Most observations. Surface velocity. Johnson Creek, Idaho. Interpreted from fig. 10.

Table B1-5. Fry early summer rearing depth criteria for chinook salmon.

DEPTH CRITERIA (use original units and sig figs, parentheses around converted values)				LIFE STAGE NOTES (e.g., fish size, season)	SOURCE	NOTES (e.g., methods, presence of other species, complicating factors)
minimum	maximum	average	preferred/ optimal			
			Shallow	Emergent fry	Everest and Chapman (1972)	Most emergent fry
	<0.60 m (<1.97 ft)		0.45 m (1.48 ft)	<55 mm (<2.17 in)	Everest and Chapman (1972)	Most observations. Johnson Creek, Idaho. Interpreted from fig. 10.

Table B1-6. Fry early summer rearing habitat criteria for chinook salmon not related to depth or velocity.

OTHER HABITAT CRITERIA: (e.g., substrate, cover type, distance to cover, gradient, minimum habitat area)	LIFE STAGE NOTES (e.g., fish size, season)	SOURCE	NOTES (e.g., methods, presence of other species, complicating factors)
Substrate			
Silt to 20 cm diameter rubble	35 mm (1.38 in)	Everest and Chapman (1972)	Most emergent fry
Sand	<55 mm (<2.17 in)	Everest and Chapman (1972)	Most observations. Johnson Creek, Idaho. Interpreted from fig. 10.

Table B1-7. Age 0+ summer rearing (late summer/fall) velocity criteria for chinook salmon.

VELOCITY CRITERIA (use original units and sig figs, parentheses around converted values)				LIFE STAGE NOTES (e.g., fish size, season)	SOURCE	NOTES (e.g., methods, presence of other species, complicating factors)
minimum	maximum	average	preferred/ optimal			
0.0 m/s (0 ft/s)	0.75 m/s (2.46 ft/s)			May to August 1966 and 1967	Everest and Chapman (1972)	Bottom velocity range. Sympatric and Allopatric w/ steelhead in Johnson Creek, Idaho. Interpreted from fig 8.
			0B0.30 m/s (0B0.98 ft/s)	May to August 1966 and 1967	Everest and Chapman (1972)	Bottom velocity highest densities. Sympatric and Allopatric w/ steelhead in Johnson Creek, Idaho. Interpreted from fig 8.
0.0 m/s (0 ft/s)	1.50 m/s (4.92 ft/s)			May to August 1966 and 1967	Everest and Chapman (1972)	Surface velocity range. Sympatric and Allopatric w/ steelhead in Johnson Creek, Idaho. Interpreted from fig 8.
			0B0.45 m/s (0B1.48 ft/s)	May to August 1966 and 1967	Everest and Chapman (1972)	Surface velocity highest densities. Sympatric and Allopatric w/ steelhead in Johnson Creek, Idaho. Interpreted from fig 8.
0.0 cm/s (0 ft/s)	0.75 m/s (2.46 ft/s)			August 1966	Everest and Chapman (1972)	Bottom velocity range. Sympatric w/ steelhead in Crooked Fork Creek, Idaho. Interpreted from fig 3.
			0B0.30 m/s (0B0.98 ft/s)	August 1966	Everest and Chapman (1972)	Bottom velocity highest densities. Sympatric w/ steelhead in Crooked Fork Creek, Idaho. Interpreted from fig 3.
0.0 cm/s (0 ft/s)	1.50 m/s (4.92 ft/s)			August 1966	Everest and Chapman (1972)	Surface velocity range. Sympatric w/ steelhead in Crooked Fork Creek, Idaho. Interpreted from fig 3.
			0.15B0.60 m/s (0.49B1.97 ft/s)	August 1966	Everest and Chapman (1972)	Surface velocity highest densities. Sympatric w/ steelhead in Crooked Fork Creek, Idaho. Interpreted from fig 3.
			12.1 cm/s (0.40 ft/s)	53 mm FL (2.12 in) June to July	Shirvell (1994)	Focal point velocities. Low flow (1.25 m^3/s). Experimental flow fluctuations (N=9)
			17.2 cm/s (0.56 ft/s)	53 mm FL (2.12 in) June to July	Shirvell (1994)	Focal point velocities. Medium flow (2.42 m^3/s). Experimental flow fluctuations (N=9)
			18.7 cm/s (7.37 ft/s)	53 mm FL (2.12 in) June to July	Shirvell (1994)	Focal point velocities. High flow (5.38 m^3/s). Experimental flow fluctuations (N=9)
	30 cm/s (0.98 ft/s)		1B20 cm/s (0.03B0.66 ft/s)	August to September	Murphy et al. (1989)	Highest densities. Taku River also has coho & sockeye. Surveyed Aug-Sept. Highest densities in river habitats.

VELOCITY CRITERIA (use original units and sig figs, parentheses around converted values)				LIFE STAGE NOTES (e.g., fish size, season)	SOURCE	NOTES (e.g., methods, presence of other species, complicating factors)
minimum	maximum	average	preferred/ optimal			
						Absent from beaver ponds and up-land sloughs.
		3B15 cm/s (0.10B0.49 ft/s)		August to September	Murphy et al. (1989)	Mean velocity in preferred habitat
0.0 cm/s (0 ft/s)	20 cm/s (0.66 ft/s)	10 cm/s (0.33 ft/s)		July	Hillman et al. (1987)	Focal point velocities in Red River, Idaho. Interpreted from Fig 4. N=94
4 cm/s (0.13 ft/s)	24 cm/s (0.79 ft/s)	12 cm/s (0.39 ft/s)		August	Hillman et al. (1987)	Focal point velocities in Red River, Idaho. Interpreted from Fig 4. N=101
0.0 cm/s (0 ft/s)	26 cm/s (0.85 ft/s)	13 cm/s (0.43 ft/s)		September	Hillman et al. (1987)	Focal point velocities in Red River, Idaho. Interpreted from Fig 4. N=86
4 cm/s (0.13 ft/s)	21 cm/s (0.69 ft/s)	15 cm/s (0.49 ft/s)		October	Hillman et al. (1987)	Focal point velocities in Red River, Idaho. Interpreted from Fig 4. N=68
0.0 cm/s (0 ft/s)	50 cm/s (1.64 ft/s)		<30 cm/s (<0.98 ft/s)	August to September	Rubin et al. (1991)	Mean column velocity in Cape Horn Creek and Camas Creek, Idaho. Interpreted from Table 2.
	25 cm/s (0.82 ft/s)	8.3 cm/s (0.27 ft/s)		78B81 mm (3.12B3.24 in) FL	Steward and Bjornn (1987)	Low flow (0.03 m^3/s) focal point velocity in experimental flume. N=63
	25 cm/s (0.82 ft/s)	7.9 cm/s (0.26 ft/s)		78B81 mm (3.12B3.24 in) FL	Steward and Bjornn (1987)	Medium flow (0.06 m^3/s) focal point velocity in experimental flume. N=76
	25 cm/s (0.82 ft/s)	9.5 cm/s (0.31 ft/s)		78B81 mm (3.12B3.24 in) FL	Steward and Bjornn (1987)	High flow (0.11 m^3/s) focal point velocity in experimental flume. N=103
0.0 ft/s (0 cm/s)	3 ft/s (91.44 cm/s)		<1 ft/s (<30.48 cm/s)	>55 mm (>2.17 in) FL	Stuehrenberg (1975)	Velocities at mid depth. Elk Cape Horn, and Marsh Creeks, Idaho. Interpreted from fig 8. N=1034
0.0 ft/s (0 cm/s)	0.7 ft/s (21 cm/s)	0.28 ft/s (8.5 cm/s)		>55 mm (>2.17 in) FL	Stuehrenberg (1975)	Focal point velocities. Idaho. From text pg. 27.
9 cm/s (0.30 ft/s)	73 cm/s (2.40 ft/s)			>65 mm (>2.56 in) FL	Lister and Genoe (1970)	Stream velocities. Big Qualicum River, B.C. N=38. Interpreted from table 4.
12 cm/s (0.39 ft/s)	30 cm/s (0.98 ft/s)			77-89 mm (3.08B3.56 in) FL	Konopacky (1984) as cited in Bjornn and Reiser (1991)	
6 cm/s (0.20 ft/s)	24 cm/s (0.79 ft/s)			age 0	Thompson (1972) as cited in Bjornn and Reiser (1991)	

Table B1-8. Age 0+ summer rearing (late summer/fall) depth criteria for chinook salmon.

DEPTH CRITERIA (use original units and sig figs, parentheses around converted values)				LIFE STAGE NOTES (e.g., fish size, season)	SOURCE	NOTES (e.g., methods, presence of other species, complicating factors)
minimum	maximum	average	preferred/ optimal			
0.0 m (0 in)	1.65 m (5.41 in)			May to August 1966 and 1967	Everest and Chapman (1972)	Range. Sympatric and Allopatric w/ steelhead in Johnson Creek, Idaho. Interpreted from fig 8.
			0.15B0.60 m (5.85B23.4 in)	May to August 1966 and 1967	Everest and Chapman (1972)	Highest densities. Sympatric and Allopatric w/ steelhead in Johnson Creek, Idaho. Interpreted from fig 8.
0.0 m (0 in)	1.05 m (3.48 in)			August 1966	Everest and Chapman (1972)	Range. Sympatric w/ steelhead in Crooked Fork Creek, Idaho. Interpreted from fig 3.
			0.6B0.9 m (23.4B35.1 in)	August 1966	Everest and Chapman (1972)	Highest densities. Sympatric w/ steelhead in Crooked Fork Creek, Idaho. Interpreted from fig 3.
			37.0 cm (13.40 in)	53 mm (2.12 in) FL June to July	Shirvell (1994)	Focal point depth. Low flow (1.25 m^3/s). Experimental flow fluctuations (N=9). Table 3
			34.4 cm (13.55 in)	53 mm (2.12 in) FL June to July	Shirvell (1994)	Focal point depth. Medium flow (2.42 m^3/s). Experimental flow fluctuations (N=9). Table 3
			36.1 cm (14.22 in)	53 mm (2.12 in) FL June to July	Shirvell (1994)	Focal point depth. Medium flow (5.38 m^3/s). Experimental flow fluctuations (N=9). Table 3
			9.4 cm (3.70 in)	53 mm (2.12 in) FL June to July	Shirvell (1994)	Focal point distance above bottom. Low flow (1.25 m^3/s). Experimental flow fluctuations (N=9). Table 3
			5.3 cm (2.09 in)	53 mm (2.12 in) FL June to July	Shirvell (1994)	Focal point distance above bottom. Medium flow (2.42 m^3/s). Experimental flow fluctuations (N=9). Table 3
			7.3 cm (2.88 in)	53 mm (2.12 in) FL June to July	Shirvell (1994)	Focal point distance above bottom. Medium flow (5.38 m^3/s). Experimental flow fluctuations (N=9). Table 3
20 cm (7.8 in)	120 cm (46.8 in)	44 cm (17.16 in)		July	Hillman et al. (1987)	Water depths in Red River, Idaho. Interpreted from Fig 3. N=94
25 cm (9.75 in)	70 cm (27.3 in)	45 cm (17.55 in)		August	Hillman et al. (1987)	Water depths in Red River, Idaho. Interpreted from Fig 3. N=101
20 cm (7.80 in)	80 cm (31.20 in)	49 cm (19.11 in)		September	Hillman et al. (1987)	Water depths in Red River, Idaho. Interpreted from Fig 3. N=86
10 cm (3.90 in)	105 cm (40.95 in)	62 cm (24.18 in)		October	Hillman et al. (1987)	Water depths in Red River, Idaho. Interpreted from Fig 3. N=68
0 cm (0 in)	140 cm (54.6 in)		80B100 cm (31.20B39. 00 in)	August to September	Rubin et al. (1991)	Depth in Cape Horn Creek and Camas Creek, Idaho. Interpreted from Table 2.
0 ft. (0 in)	4 ft (48 in) (122 cm)		0.5B2.0 ft (6B24 in) (15 cmB61 cm)	>55 mm (2.17 in) FL	Stuehrenberg (1975)	Water column depth. Elk Cape Horn, and March Creeks, Idaho. Interpreted from fig 7. N=1034
55 cm	60 cm			77B89 mm	Konopacky (1984) as cited in Bjornn and Reiser	

DEPTH CRITERIA (use original units and sig figs, parentheses around converted values)				LIFE STAGE NOTES (e.g., fish size, season)	SOURCE	NOTES (e.g., methods, presence of other species, complicating factors)
minimum	maximum	average	preferred/ optimal			
(21.45 in)	(23.4 in)			(3.08B3.56 in)	(1991)	
30 cm (11.70 in)	122 cm (47.58 in)			age 0	Thompson (1972) as cited in Bjornn and Reiser (1991)	

Table B1-9. Age 0+ summer rearing (late summer/fall) for chinook salmon not related to depth or velocity.

OTHER HABITAT CRITERIA: (e.g., substrate, cover type, distance to cover, gradient, minimum habitat area)	LIFE STAGE NOTES (e.g., fish size, season)	SOURCE	NOTES (e.g., methods, presence of other species, complicating factors)
Substrate			
Silt to 40 cm diameter	May to August 1966 and 1967	Everest and Chapman (1972)	Range. Sympatric and Allopatric w/ steelhead in Johnson Creek, Idaho. Interpreted from fig 8.
Silt and sand	May to August 1966 and 1967	Everest and Chapman (1972)	Highest densities. Sympatric and Allopatric w/ steelhead in Johnson Creek, Idaho. Interpreted from fig 8.
10 to >40 cm diameter (3.9 to >15.8 in)	August 1966	Everest and Chapman (1972)	Range. Sympatric w/ steelhead in Crooked Fork Creek, Idaho. Interpreted from fig 3.
20B40 cm diameter (7.9B15.8 in)	August 1966	Everest and Chapman (1972)	Highest densities. Sympatric w/ steelhead in Crooked Fork Creek, Idaho. Interpreted from fig 3.
0B5 in (0B13 cm)	>55 mm FL (2.17 in)	Stuehrenberg (1975)	Substrate diameter where chinook were found. Elk and Marsh Creeks, Idaho. Interpreted from fig 9. N=736

Table B1-10. Age 0+ rearing velocity criteria for chinook salmon [SEASON NOT SPECIFIED].

VELOCITY CRITERIA (use original units and sig figs, parentheses around converted values)				LIFE STAGE NOTES (e.g., fish size, season)	SOURCE	NOTES (e.g., methods, presence of other species, complicating factors)
minimum	maximum	average	preferred/ optimal			
	<15 cm/s (<0.49 ft/s)				Everest and Chapman (1972)	General comment from abstract
	18 cm/s (0.59 ft/s)				Konopacky (1984, as cited in Spence et al. 1996)	Dawn measurement.
	12 cm/s (0.39 ft/s)				Konopacky (1984, as cited in Spence et al. 1996)	Midday measurement.
	25 cm/s (0.82 ft/s)				Konopacky (1984, as cited in Spence et al. 1996)	Dusk measurement.
12 cm/s (0.39 ft/s)	30 cm/s (0.98 ft/s)			77B89 mm (3.0B3.5 in)	Konopacky (1984, as cited in Spence et al. 1996)	Reported as range
6 cm/s (0.20 ft/s)	24 cm/s (0.79 ft/s)				Thompson (1972, as cited in Spence et al. 1996)	Reported as range

Table B1-11. Age 0+ rearing depth criteria for chinook salmon [SEASON NOT SPECIFIED].

DEPTH CRITERIA (use original units and sig figs, parentheses around converted values)				LIFE STAGE NOTES (e.g., fish size, season)	SOURCE	NOTES (e.g., methods, presence of other species, complicating factors)
minimum	maximum	average	preferred/ optimal			
15 cm (0.49 ft)	30 cm (0.39 ft)				Everest and Chapman (1972)	General comment from abstract
30 cm (0.98 ft)	122 cm (4.00 ft)				Thompson (1972, as cited in Spence et al. 1996)	Reported as range
55 cm (1.80 ft)	60 cm (1.97 ft)			77-89 mm (3.0B3.5 in)	Konopacky (1984, as cited in Spence et al. 1996)	Reported as range

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APPENDIX B2: STEELHEAD

Common Name: Steelhead
Scientific Name: *Oncorhynchus mykiss*

Status
Two major genetic groups exist in the Pacific Northwest, consisting of a coastal and an inland group separated by the Cascade Range crest (Schreck et al. 1986, Reisenbichler et al. 1992). Napa River steelhead belong to the subspecies *O. m. irideus*, or coastal rainbow trout and steelhead, that extends east to the Cascades (Behnke 1992). Steelhead found in the Napa River basin belong to the Central California Coast evolutionarily significant unit (ESU) (NMFS 1997). This ESU extends from the Russian River to Aptos Creek, and includes tributaries to San Francisco and San Pablo bays eastward to the Napa River, excluding the Sacramento-San Joaquin River Basin. Winter runs of steelhead occur in the Napa River mainstem and tributaries. Critical habitat is designated to include all river reaches and estuarine areas accessible to listed steelhead in coastal river basins from the Russian River to Aptos Creek, and the tributaries to San Francisco and San Pablo bays (NMFS 2000).

Geographic Distribution
Steelhead are distributed throughout the North Pacific Ocean and historically spawned in streams along the west coast of North America from Alaska to northern Baja California. The species is currently known to spawn only as far south as Malibu Creek in southern California (Barnhart 1991, NMFS 1996a).

Population Trends
The National Marine Fisheries Service (NMFS 1996a) has concluded that populations of naturally reproducing steelhead have been experiencing a long-term decline in abundance throughout their range. Populations in the southern portion of the range have experienced the most severe declines, particularly in streams from California's Central Valley and south, where many stocks have been extirpated (NMFS 1996a). During the 1900s, 23 naturally reproducing populations of steelhead are believed to have been extirpated in the western United States. Many more are thought to be in decline in Washington, Oregon, Idaho, and California. Based on analyses of dam and weir counts, stream surveys, and angler catches, NMFS (1997) concluded that, of the 160 west coast steelhead stocks for which adequate data were available, 118 (74%) exhibited declining trends in abundance, while the remaining 42 (26%) exhibited increasing trends.

Accurate population estimates for the Napa River are not available (Skinner 1962, Leidy 1984, Leidy 2001). Steelhead stocks in California, however, have declined substantially. The current population of steelhead in California is roughly 250,000 adults, which is nearly half the adult population that existed 30 years ago (McEwan and Jackson 1996). Current estimates of all steelhead adults returning to San Francisco Bay tributaries combined are well below 10,000 fish (Leidy 2001).

Life History
Steelhead is the term used to distinguish anadromous populations of rainbow trout from resident populations. Much life history variability exists among steelhead populations; however, populations may be broadly categorized into two reproductive groups, most commonly referred to as either winter-run or summer-run. Steelhead in the Napa River are all winter-run.

Adult upstream migration and spawning
Steelhead return to spawn in their natal stream, usually in their fourth or fifth year of life, with males typically returning to freshwater earlier than females (Shapovalov and Taft 1954, Behnke 1992). A small percentage of steelhead may stray into streams other than those in which they were born. Winter-run

steelhead generally enter spawning streams from fall through spring as sexually mature adults and spawn a few months later in late winter or spring (Roelofs 1985, Meehan and Bjornn 1991, Behnke 1992).

Adult steelhead migrate upstream on both the rising and falling limbs of high flows, but do not appear to move during flood peaks. Some authors have suggested that increased water temperatures trigger movement, but some steelhead ascend into freshwater without any apparent environmental cues (Barnhart 1991). Peak upstream movement appears to occur in the morning and evening, although steelhead have been observed to move at all hours (Barnhart 1991).

Steelhead are among the strongest swimmers of freshwater fishes. Cruising speeds, which are used for long-distance travel, are up to 5 ft/s (1.5 m/s); sustained speeds, which may last several minutes and are used to surpass rapids or other barriers, range from 5 to 15 ft/s (1.5 to 4.6 m/s), and darting speeds, which are brief bursts used in feeding and escape, range from 14 to 27 ft/s (4.3 to 8.2 m/s) (Bell 1973, as cited in Everest et al. 1985; Roelofs 1987). Steelhead have been observed making vertical leaps of up to 17 ft (5.2 m) over falls (W. Trush pers. comm., as cited in Roelofs 1987).

During spawning, female steelhead create depressions in streambed gravels by vigorously pumping their body and tail horizontally near the streambed. Steelhead redds are approximately 4–12 in (10–30 cm) deep, 15-in (38-cm) in diameter, and oval in shape (Needham and Taft 1934, Shapovalov and Taft 1954). Males do not assist with redd construction, but may fight with other males to defend spawning females (Shapovalov and Taft 1954). Males fertilize the female's eggs as they are deposited in the redd, after which the female moves to the upstream end of the nest and stirs up additional gravel, covering the egg pocket (Orcutt et al. 1968). Females then move two to three feet upstream and dig another pit, enlarging the redd. Females may dig six to seven egg pockets, moving progressively upstream, and spawning may continue for several days to over a week (Needham and Taft 1934). A female approximately 33 in (85 cm) in length may lay 5,000 to 10,000 eggs, with fecundity being related to age and length of the adult female and varying between populations (Meehan and Bjornn 1991). A range of 1,000 to 4,500 eggs per female has been observed within the Sacramento Drainage (Mills and Fisher 1994, as cited in Leidy 2001). In cases where spawning habitat is limited, late-arriving spawners may superimpose their redds atop existing nests, resulting in mortality of eggs and alevins that were in the original redd (Orcutt et al. 1968).

Although most steelhead die after spawning, adults are capable of returning to the ocean and migrating back upstream to spawn in subsequent years, unlike most other Pacific salmon. Runs may include from 10 to 30% repeat spawners, the majority of which are females (Ward and Slaney 1988, Meehan and Bjornn 1991, Behnke 1992). Repeat spawning is more common in smaller coastal streams than in large drainages requiring a lengthy migration (Meehan and Bjornn 1991). Hatchery steelhead are typically less likely than wild fish to survive to spawn a second time (Leider et al. 1986).

Whereas females spawn only once before returning to the sea, males may spend two or more months in spawning areas and may mate with multiple females, incurring higher mortality and reducing their chances of repeat spawning (Shapovalov and Taft 1954). Steelhead may migrate downstream to the ocean immediately following spawning or may spend several weeks holding in pools before outmigrating (Shapovalov and Taft 1954).

Egg incubation, alevin development, and fry emergence

Hatching of eggs follows a 20- to 100-day incubation period, the length of which depends on water temperature (Shapovalov and Taft 1954, Barnhart 1991). In Waddell Creek (San Mareo County), Shapovalov and Taft (1954) found incubation times between 25 and 30 days. Newly-hatched steelhead alevins remain in the gravel for an additional 14–35 days while being nourished by their yolk sac (Barnhart 1991). Fry emerge from the substrate just before total yolk absorption under optimal conditions; later-emerging fry that have already absorbed their yolk supply are likely to be weaker (Barnhart 1991). Upon emergence, fry inhale air at the stream surface to fill their air bladder, absorb the remains of their yolk, and start to feed actively, often in schools (Barnhart 1991, NMFS 1996b). Survival from egg to emergent fry is typically less than 50% (Meehan and Bjornn 1991), but may be quite variable depending upon local conditions.

Juvenile freshwater rearing

Juvenile steelhead (parr) rear in freshwater before outmigrating to the ocean as smolts. The duration of time parr spend in freshwater appears to be related to growth rate, with larger, faster-growing members of a cohort smolting earlier (Peven et al. 1994). Steelhead in warmer areas, where feeding and growth are possible throughout the winter, may require a shorter period in freshwater before smolting, while steelhead in colder, more northern, and inland streams may require three or four years before smolting (Roelofs 1985).

Juveniles typically remain in their natal streams for at least their first summer, dispersing from fry schools and establishing feeding territories (Barnhart 1991). Peak feeding and freshwater growth rates occur in late spring and early summer. In Steamboat Creek, a major steelhead spawning tributary in the North Umpqua River watershed, juveniles typically rest in the interstices of rocky substrate in the morning and evening, and rise into the water column and orient themselves into the flow to feed during the day when water temperatures are higher (Dambacher 1991). In the Smith River of Oregon, Reedy (1995) suggested that rising stream temperatures and reduced food availability occurring in late summer may lead to a decline in steelhead feeding activity and growth rates.

Juveniles either overwinter in their natal streams if adequate cover exists or disperse as pre-smolts to other streams to find more suitable winter habitat (Bjornn 1971, Dambacher 1991). As stream temperatures fall below approximately 44.6°F (7°C) in the late fall to early winter, steelhead enter a period of winter inactivity spent hiding in the substrate or closely associated with instream cover, during which time growth ceases (Everest and Chapman 1972). Age 0+ steelhead appear to remain active later into the fall than 1+ steelhead (Everest et al. 1986). Winter hiding behavior of juveniles reduces their metabolism and food requirements and reduces their exposure to predation and high flows (Bustard and Narver 1975), although substantial mortality appears to occur in winter, nonetheless. Winter mortalities ranging from 60 to 86% for 0+ steelhead and from 18 to 60% for 1+ steelhead were reported in Fish Creek in the Clackamas River basin, Oregon (Everest et al. 1988, as cited in Dambacher 1991).

Juveniles appear to compete for food and rearing habitat with other steelhead. Age 0+ and 1+ steelhead exhibit territorial behavior (Everest and Chapman 1972), although this behavior may dissipate in winter as fish reduce feeding activity and congregate in suitable cover habitat (Meehan and Bjornn 1991). Reedy (1995) found that steelhead in the tails of pools did not exhibit territorialism or form dominance hierarchies.

Parr outmigration appears to be more significant in smaller basins, when compared to larger basins (Dambacher 1991). In some areas juveniles migrate out of tributaries despite the fact that downstream rearing habitat may be limited and survival rates low in these areas, suggesting that migrants are responding to density-related competition for food and space, or to reduction in habitat quality in tributaries as flows decline (Dambacher 1991, Peven et al. 1994, Reedy 1995). In relatively small tributaries with good rearing habitat located downstream, early outmigration may represent an adaptation to improve survival and may not be driven by environment- or competition-related limitations (Dambacher 1991). Steelhead may overwinter in mainstem reaches, particularly if coarse substrates in which to seek cover from high flows are available (Reedy 1995), or they may return to tributaries for the winter (Everest 1973, as cited in Dambacher 1991).

Rearing densities for juvenile steelhead overwintering in high-quality habitats with cobble-boulder substrates are estimated to range from approximately 0.24 fish/ft^2 (2.7 fish/m^2) (W. Trush, pers. comm., 1997) to 0.53 fish/ft^2 (5.7 fish/m^2) (Meyer and Griffith 1997). Everest and Chapman (1972) report age 0+ densities of 0.12 to 0.14 fish/ft^2 (1.3 to 1.5 fish/m^2) in preferred habitat in Idaho.

Smolt outmigration and estuarine rearing
At the end of the freshwater rearing period, steelhead migrate downstream to the ocean as smolts, typically at a length of 5.85 to 7.80 in (15 to 20 cm) (Meehan and Bjornn 1991). A length of 5.46 in (14 cm) is typically cited as the minimum size for smolting (Wagner et al. 1963, Peven et al. 1994).

Evidence suggests that photoperiod is the most important environmental variable stimulating the physiological transformation from parr to smolt (Wagner 1974). During smoltification, the spots and parr marks characteristic of juvenile coloration are replaced by a silver and blue-green iridescent body color (Barnhart 1991) and physiological transformations occur that allow them to survive in salt water.

Less is known regarding the use of estuaries by steelhead than for other anadromous salmonid species; however, the available evidence shows that steelhead in many systems use estuaries as rearing habitat. Smith (1990) concluded that even tiny lagoons unsuitable for summer rearing can contribute to the maintenance of steelhead populations by providing feeding areas during winter or spring smolt outmigration.

Estuarine rearing may be more important to steelhead populations in the southern half of the species' range due to greater variability in ocean conditions and paucity of high quality near-shore habitats in this portion of their range (NMFS 1996a). Estuaries may also be more important to populations spawning in smaller coastal tributaries due to the more limited availability of rearing habitat in the headwaters of smaller stream systems (McEwan and Jackson 1996). Most marine mortality of steelhead occurs soon after they enter the ocean and predation is believed to be the primary cause of this mortality (Pearcy 1992, as cited in McEwan and Jackson 1996). Because predation mortality and fish size are likely to be inversely related (Pearcy 1992, as cited in McEwan and Jackson 1996), the growth that takes place in estuaries may be very important for increasing the odds of marine survival (Pearcy 1992 [as cited in McEwan and Jackson 1996], Simenstad et al. 1982 [as cited in NMFS 1996a], Shapovalov and Taft 1954).

Steelhead have variable life histories and may migrate downstream to estuaries as age 0+ juveniles or may rear in streams up to four years before outmigrating to the estuary and ocean (Shapovalov and Taft 1954). Steelhead migrating downstream as juveniles may rear for one to six months in the estuary before entering the ocean (Barnhart 1991). Shapovalov and Taft (1954) conducted exhaustive life history studies of steelhead and coho salmon in Waddell Creek (Santa Cruz County, California) and found that coho salmon went to sea almost immediately after migrating downstream, but that some of the steelhead remained for a whole season in Waddell Creek lagoon or the lower portions of the stream before moving out to sea. Some steelhead individuals remained in the lagoon rather than moving out to sea and migrated back upstream and underwent a second downstream migration the following year. In Scott Creek lagoon (Santa Cruz County), Marston (1992, as cited in McEwan and Jackson 1996) found that half of the steelhead rearing in the lagoon in June and July of 1992 were less than 90 mm and appeared to be pre-smolts. Coots (1973, as cited in McEwan and Jackson 1996) found that 34% of juvenile steelhead in San Gregorio Creek lagoon captured in summer were juveniles less than 3.9 in [100 mm] in length. From these studies and others, it has been shown estuaries provide valuable rearing habitat to juvenile and yearling steelhead and not merely a corridor for smolts outmigrating to the ocean.

Ocean phase
The majority of steelhead spend one to three years in the ocean, with smaller smolts tending to remain in salt water for a longer period than larger smolts (Chapman 1958, Behnke 1992). Larger smolts have been observed to experience higher ocean survival rates (Ward and Slaney 1988). Steelhead grow rapidly in the ocean compared to in freshwater rearing habitats, with growth rates potentially exceeding 0.98 in (2.5 cm) per month (Shapovalov and Taft 1954, Barnhart 1991). Steelhead staying in the ocean for two years typically weigh 7 to10 lbs (3.15 to 4.50 kg) upon return to fresh water (Roelofs 1985). Unlike other salmonids, steelhead do not appear to form schools in the ocean. Steelhead in the southern part of the species' range appear to migrate close to the continental shelf, while more northern populations of steelhead may migrate throughout the northern Pacific Ocean (Barnhart 1991).

Habitat Requirements

Adult upstream migration and spawning
During their upstream migration, adult steelhead require deep pools for resting and holding (Puckett 1975, Roelofs 1983, as cited in Moyle et al. 1989). Deep pool habitat (>4.88 ft [>1.5 m]) is preferred by summer steelhead during the summer holding period. Steelhead need water with a minimum depth of 0.59 ft (18 cm) and maximum velocity of 8 ft/s (240 cm/s) for successful upstream migration (Thompson 1972, as cited in Everest et al. 1985). Relatively cool water temperatures (between 50 and 59°F [10^o and 15°C]) are preferred by adults, although they may survive temperatures as high as 80.6°F (27°C) for short periods (Moyle et al. 1989). Adult holding habitat requirements for steelhead are shown in Tables B2-1 and B2-2.

Areas of the stream with water depths from about 7 to 53 in (18 to 137 cm) and velocities from 1.97 to 3.77 ft/s (0.6 to 1.15 m/s) are typically preferred for spawning by adult steelhead (Moyle et al. 1989, Barnhart 1991). Pool tailouts or heads of riffles with well-oxygenated gravels are often selected as redd locations (Shapovalov and Taft 1954). The average area encompassed by a redd is 47–65.56 ft^2 (4.4–5.9 m^2) (Orcutt et al. 1968, Hunter 1973, as cited in Bjornn and Reiser 1991). Gravels ranging in size from 0.25 to 5.07 in (0.64 to 13 cm) in diameter are suitable for redd construction (Barnhart 1991). Steelhead pairs have been observed spawning within 3.94 ft (1.2 m) of each other (Orcutt et al. 1968). Bell (1986) indicates that preferred temperatures for steelhead spawning range from 39.0^o to 48.9^oF (3.9^o to 9.4^oC). Steelhead may spawn in intermittent streams, but juveniles soon move to perennial streams after hatching (Moyle et al. 1989). In the Rogue River drainage, summer steelhead are more likely to spawn in intermittent streams, while winter steelhead typically spawn in permanent streams (Roelofs 1985). Spawning habitat requirements for steelhead are shown in Tables B2-3 and B2-4.

Egg incubation, alevin development, and fry emergence
Incubating eggs require dissolved oxygen concentrations, with optimal concentrations at or near saturation. Low dissolved oxygen increases the length of the incubation period and cause emergent fry to be smaller and weaker. Dissolved oxygen levels remaining below 2 ppm result in egg mortality (Barnhart 1991). Information available in the literature indicates that preferred incubation temperatures range from 48.2 to 51.8°F (9 to 11°C) (McEwan and Jackson 1996, FERC 1993).

Juvenile freshwater rearing

Age 0+. After emergence from spawning gravels in spring or early summer, steelhead fry move to shallow-water, low-velocity habitats such as stream margins and low-gradient riffles and will forage in open areas lacking instream cover (Hartman 1965, Everest et al. 1986, Fontaine 1988). As fry increase in size in late summer and fall, they increasingly use areas with cover and show a preference for higher-velocity, deeper mid-channel waters near the thalweg (Hartman 1965, Everest and Chapman 1972, Fontaine 1988). In general, age 0+ steelhead occur in a wide range of hydraulic conditions (Bisson et al. 1988), appearing to prefer water less than 19.5 in (50 cm) deep with velocities below 0.98 ft/s (0.3 m/s) (Everest and Chapman 1972). Age 0+ steelhead have been found to be relatively abundant in backwater pools and often live in the downstream ends of pools in late summer (Bisson et al. 1988, Fontaine 1988). Age 0+ rearing habitat requirements are shown in Tables 5–12.

Age 1+ and older juveniles. Older age classes of juvenile steelhead (age 1+ and older) occupy a wide range of hydraulic conditions. They prefer deeper water during the summer and have been observed to use deep pools near the thalweg with ample cover as well as higher-velocity rapid and cascade habitats (Bisson et al. 1982, Bisson et al. 1988). Age 1+ fish typically feed in pools, especially scour and plunge pools, resting and finding escape cover in the interstices of boulders and boulder-log clusters (Fontaine 1988, Bisson et al. 1988). During summer, steelhead parr appear to prefer habitats with rocky substrates, overhead cover, and low light intensities (Hartman 1965, Facchin and Slaney 1977, Ward and Slaney 1979, Fausch 1993). Age 1+ steelhead appear to avoid secondary channel and dammed pools, glides, and low-gradient riffles with mean depths less than 7.8 in (20 cm) (Fontaine 1988, Bisson et al. 1988, Dambacher 1991).

As steelhead grow larger, they tend to prefer microhabitats with deeper water and higher velocity as locations for focal points, attempting to find areas with an optimal balance of food supply versus energy expenditure, such as velocity refuge positions associated with boulders or other large roughness elements close to swift current with high macroinvertebrate drift rates (Everest and Chapman 1972, Bisson et al. 1988, Fausch 1993). Reedy (1995) indicates that 1+ steelhead especially prefer high-velocity pool heads, where food resources are abundant, and pool tails, which provide optimal feeding conditions in summer due to lower energy expenditure requirements than the more turbulent pool heads. Fast, deep water, in addition to optimizing feeding versus energy expenditure, provides greater protection from avian and terrestrial predators (Everest and Chapman 1972).

Age 1+ steelhead appear to prefer rearing habitats with velocities ranging from 0.33–0.98 ft/s (10–30 cm/s) and depths ranging from 19.5–29.3 in (50–75 cm) (Everest and Chapman 1972, Hanson 1977, as cited in Bjornn and Reiser 1991). During the juvenile rearing period, steelhead are often observed using habitats with swifter water velocities and shallower depths than coho salmon (Sullivan 1986, Bisson et al. 1988), a species they are often sympatric with. In comparison with juvenile coho, steelhead have a fusiform body shape that is better adapted to holding and feeding in swifter currents (Bisson et al. 1988). Where the two species coexist, this generally results in spatial segregation of rearing habitat that becomes most apparent during the summer months. While juvenile coho salmon are strongly associated with low-velocity habitats such as pools throughout the rearing period (Shirvell 1990), steelhead will use riffles (age 0+) and higher velocity pool habitats (age 1+) such as scour and plunge pools in the summer (Sullivan 1986, Bisson et al. 1982). Habitat requirements of age 1+ and older steelhead are shown in Tables 13–19.

Preferred rearing temperatures range from 45.0 to 57.9°F (7.2 to 14.4°C), with optimum temperature for juveniles occurring from 50–55.0°F (10–12.8°C) and lethal temperatures occurring at 74.8°F (23.8°C) (Bell 1991). Preferred outmigration temperatures are <57°F (<13°C). In the Napa River, high summer water temperatures may be primary factor affecting juvenile rearing habitat (Leidy 2001).

Winter habitat

Steelhead overwinter in pools, especially low-velocity deep pools with large rocky substrate or woody debris for cover, including backwater and dammed pools (Hartman 1965, Swales et al. 1986, Raleigh et al. 1984, Fontaine 1988). Juveniles are known to use the interstices between substrate particles as overwintering cover. Bustard and Narver (1975) typically found age 0+ steelhead using 3.9–9.7 in (10–25 cm) diameter cobble substrates in shallow, low-velocity areas near the stream margin. Everest et al.

(1986) observed age 1+ steelhead using logs, rootwads, and interstices between assemblages of large boulders (39.0 in [>100 cm] diameter) surrounded by small boulder to cobble size (19.7–39.0 in [50–100 cm] diameter) materials as winter cover. Age 1+ fish typically stay within the area of the streambed that remains inundated at summer low flows, while age 0+ fish frequently overwinter beyond the summer low flow perimeter along the stream margins (Everest et al. 1986).

In winter, 1+ steelhead prefer water deeper than 17.5 in (45 cm), while age 0+ steelhead often occupy water less than 5.8 in (15 cm) deep and are rarely found at depths over about 23.4 in (60 cm) (Bustard and Narver 1975). Below 44.6^{o}F (7^{o}C), juvenile steelhead prefer water velocities 0.5 ft/s (<15 cm/s) (Bustard and Narver 1975). Spatial segregation of stream habitat by juvenile coho salmon and steelhead is less pronounced in winter than in summer, although older juvenile steelhead may prefer deeper pools than coho salmon (Bustard and Narver 1975). Overwinter habitat requirements of juvenile steelhead are shown in Tables 10–12, and in Tables 6–17.

Ocean phase

Little is known about steelhead use of ocean habitat, although changes in ocean conditions are important for explaining trends among Oregon coastal steelhead populations (Kostow 1995). Evidence suggests that increased ocean temperatures associated with El Niño events may increase ocean survival as much as two-fold (Ward and Slaney 1988). The magnitude of upwelling, which determines the amount of nutrients brought to the ocean surface and which is related to wind patterns, influences ocean productivity with significant effects on steelhead growth and survival (Barnhart 1991). Steelhead appear to prefer ocean temperatures of 48.2^{o}–52.7^{o}F (9^{o}–11.5^{o}C) and typically swim in the upper 30–40 ft (9–12 m) of the ocean's surface (Barnhart 1991).

Ecological Interactions

Food web interactions

Emergent fry initially feed on zooplankton and other microorganisms (Barnhart 1991). Juveniles feed on a wide range of items, primarily those associated with the stream bottom such as aquatic insects, amphipods, aquatic worms, fish eggs, and occasionally smaller fish (Wydoski and Whitney 1979). Juveniles may also feed on spiders, mollusks, and fish, including smaller steelhead (Roelofs 1985). Age 0+ steelhead prefer benthic invertebrates (Johnson and Ringler 1980); larger steelhead, having larger mouths, can consume a broader range of foods (Fausch 1991). In the ocean, steelhead feed on juvenile greenling, squids, amphipods, and other organisms (Barnhart 1991).

Adult summer steelhead apparently do not usually feed in fresh water and can endure long periods without food, during which time their stomachs shrink (Shapovalov and Taft 1954, Roelofs 1987). Summer steelhead, which spend longer periods in fresh water before spawning, may be more likely to feed in freshwater than adult winter steelhead. Food items taken by adults include caddisflies, mayflies, stoneflies, salmon eggs and, infrequently, other fish (Barnhart 1991).

Major predators of adult steelhead include humans, marine mammals, and large pelagic fish. Eggs may be eaten by macroinvertebrates, crayfish, and other fish. Juvenile steelhead may be preyed upon by garter snakes, piscivorous fish such as older salmonids (including steelhead), freshwater sculpins, introduced piscivorous fish (e.g., smallmouth bass, striped bass), mammals (e.g., river otter, mink), and piscivorous birds (e.g., mergansers, kingfishers, herons, ospreys, loons). Juvenile steelhead have been observed feeding on emergent fry (Shapovalov and Taft 1954).

Responses to Anthropogenic Watershed Disturbances

An anadromous life history and changes in habitat requirements at different life stages make steelhead vulnerable to a wide range of watershed disturbances, including dams, timber harvest, road construction, recreational use, and other human-related disturbances. The relative importance of anthropogenic and natural disturbances and of ocean conditions for controlling steelhead populations is uncertain. Coastal steelhead habitats, which historically consisted of old-growth temperate moist conifer forests with streams having high structural complexity, have been significantly altered (Kostow 1995).

Physical barriers to migration and movement
Dams without fish passage facilities block migration to historically available spawning and/or rearing areas, inundate spawning and rearing habitat beneath reservoirs, and alter hydrologic regimes, sediment and LWD budgets, water temperatures, nutrient cycling, and food supplies (Collins 1976). Where fish passage facilities are provided at dams, delays to upstream or downstream migration may occur, and stress, injury, or mortality may result from passage through juvenile bypass facilities.

Changes to hydrologic regimes
Changes to natural flow regimes may impact steelhead populations through changes to stimuli used for timing of upstream and downstream migrations, dewatering of redds, displacement of fry or juveniles, scouring of spawning gravels, and changes to the quality and quantity of habitat for different life stages. Rapid decreases in flow associated with hydroelectric project operations may cause stranding, especially of recently emerged fry because of their preference for stream margin areas of mainstem channels and because they are relatively weak swimmers (Hunter 1992). Vulnerability to stranding declines once juvenile steelhead reach lengths of 1.8 inches (45 mm) (R.W. Beck and Associates 1987). As juveniles grow, they are more likely to occupy deeper areas further from channel margins, reducing their susceptibility to stranding. Flow diversions may delay or stop adult migration if minimum water depths are not maintained (Everest et al. 1985).

Changes to sediment dynamics
Sedimentation of streams resulting from increased erosion may reduce spawning success of steelhead and the carrying capacity of juvenile rearing areas. Sedimentation due to land use activities has been recognized as a primary cause of habitat degradation for steelhead populations on the west coast (NMFS 1996a). Increased input of fine sediment resulting from natural or anthropogenic disturbance may be the principle cause of egg and alevin mortality in some areas (Shapovalov and Taft 1954). Filling of interstitial spaces with fine sediments reduces intragravel flow through redds, reducing dissolved oxygen concentrations and the rate of removal of metabolic wastes (Everest et al. 1985). Alevins that develop in oxygen-deficient gravels are smaller at emergence, placing them at a competitive disadvantage (Doudoroff and Warren 1965, as cited in Everest et al. 1985). Interstitial habitat used as cover by juvenile steelhead is also reduced if embedded in fine sediments. Bjornn et al. (1977) observed reduced juvenile steelhead abundance in Idaho streams characterized by a high degree of substrate embeddedness.

Accumulation of fine organic material in gravel, which may occur following logging or other land use disturbances, can also reduce the amount of dissolved oxygen available to incubating eggs, since the decay of this material consumes oxygen (Barnhart 1991).

Filling of pools with fine sediments can reduce carrying capacity of rearing habitats for juvenile salmonids (Bjornn et al. 1977). Sedimentation also fills interstitial spaces in the substrate that are used as velocity refuges by juvenile salmonids during high-flow events or low temperatures (Hillman et al. 1987) and may reduce aquatic invertebrate production and therefore reduce juvenile salmonid production (Crouse et al. 1981).

Reductions of bedload supply and/or changes in bed stability are downstream geomorphic effects often associated with dams (Williams and Wolman 1984, Ligon et al. 1995). Bedload is that portion of the sediment load carried by rivers that consists of larger particles, including spawning gravels, that are pushed along or near the bed, as opposed to suspended load (Leopold 1994). Dams can reduce spawning gravel availability in downstream reaches and cause development of a coarse, relatively immobile surface layer. Dams can cause a number of changes to channel morphology or fluvial processes that can have deleterious effects on stream and riparian habitats, including channel incision and/or widening, increased bank erosion, and reduced channel migration (Ligon et al. 1995).

Changes to large woody debris dynamics
Reductions in the amount of LWD in stream channels due to either past removal (stream cleaning) efforts or harvest of streamside trees may reduce the carrying capacity of these streams for juvenile anadromous salmonids, especially of the older age classes which may prefer deeper habitats, and may reduce the occurrence of deep pools used by adults during migration and holding (NMFS 1996a). Murphy et al. (1985, 1986) found that higher juvenile steelhead densities occurred in reaches with buffer strips adjacent to clearcuts than in reaches without buffer strips where LWD had been removed. Reduced LWD may also result in decreased retention of spawning gravels and of fine and coarse particulate organic matter and salmonid carcasses important for nutrient cycling and maintenance of macroinvertebrate communities.

Changes to stream temperatures and water quality
Factors that result in increased stream temperatures, such as large-scale clearcutting, removal of riparian vegetation, and changes to natural flow regimes may reduce steelhead populations both directly through increased mortality and indirectly through such factors as changes to growth rates or timing of emergence and downstream migration.

Warm water temperatures may favor competitors of juvenile steelhead, such as redside shiners (Reeves et al. 1987). Increases in water temperatures may also make juvenile anadromous salmonids more susceptible to mortality from diseases such as Flexibacter columnaris (Holt et al. 1975).

Reservoirs
Reservoir conditions can adversely affect anadromous fish populations. Reservoirs submerge spawning and rearing habitat, and juvenile anadromous fish traveling downstream through reservoirs may be subject to mortality through entrainment and predation by introduced or native fish species in these areas. Reservoir characteristics, including reduced water velocities, thermal stratification, and low dissolved oxygen levels may delay downstream migration and extend the exposure of smolts to disease and predation risks (Collins 1976, Spence et al. 1996).

Poaching and other impacts on adult holding habitat
Summer steelhead adults are vulnerable to human disturbance during their holding period. Holding steelhead are vulnerable to poaching, because they typically congregate in large numbers in a relatively small number of suitable pools. Steelhead fishing has been restricted in many areas in response to population declines, but the species remains vulnerable to poaching. Adult summer steelhead are especially vulnerable to poaching during summer low flows. Roelofs (1983, as cited by Moyle et al. 1989) has indicated that steelhead populations showing signs of severe declines tend to be in areas that are more accessible to people, while stable populations tend to be found in the most inaccessible streams. Poachers may capture adult steelhead by snagging, spearing, netting, trapping, shooting, or blasting (Roelofs 1987).

In both tributaries and the mainstem, increased human disturbance associated with recreational activities such as boating, swimming, or fishing may affect adult holding habitat; Moyle et al. (1989) indicate that these types of activities may stress adult fish and result in increased mortality in streams heavily used for recreation. These impacts would not affect winter steelhead, which do not require extended use of holding areas prior to spawning.

Estuary impacts

Estuary conditions may have an important influence on anadromous fish survival, since anadromous fish must pass through these areas during upstream and downstream migration and since estuarine rearing prior to ocean entry is a life history strategy used by many juvenile anadromous fish to increase marine survival (Giger 1972, Healey 1991, McMahon and Holtby 1992). Degradation of estuary habitats due to diking and filling, increased temperatures, introduction of piscivorous fish, sedimentation due to upstream impacts, and other human activities may have contributed to anadromous fish declines in California and in the Napa River.

Table B2-1. Adult holding velocity criteria for steelhead.

VELOCITY CRITERIA				SOURCE	NOTES (e.g., methods, presence of other species, complicating factors)
minimum	maximum	average	preferred/ optimal		
	2.44 m/s (8.01 ft/s)			Thompson (1972) as cited in Bjornn and Reiser (1991)	Race not specified.
			28.6 cm/s (0.94 ft/s)	Moyle and Baltz (1985) as cited in Spence (1996)	Race not specified, methods not stated.

Table B2-2. Adult holding depth criteria for steelhead.

DEPTH CRITERIA				SOURCE	NOTES (e.g., methods, presence of other species, complicating factors)
minimum	maximum	average	preferred/ optimal		
0.24 m (9.36 in)				Thompson (1972) as cited in Bjornn and Reiser (1991)	Race not specified.
300 cm (117 in)				Puckett (1975), Roelofs (1983) as cited in Moyle et al. (1989)	Race not specified.
			82 cm (31.98 (in)	Moyle and Baltz (1985) as cited in Spence (1996)	Race not specified, methods not stated.

Table B2-3. Adult spawning velocity criteria for steelhead.

VELOCITY CRITERIA				SOURCE	NOTES (e.g., methods, presence of other species, complicating factors)
minimum	maximum	average	preferred/ optimal		
Summer steelhead					
			23B155 cm/s (0.75B5.09 ft/s)	Cited in Moyle et al. (1989)	Source of data not provided.
0.431 m/s (1.41 ft/s)	0.915 m/s (3.00 ft/s)	0.683 m/s " 0.4823 (2.24 ft/s "1.58)		Smith (1973)	Based on 90 redds in the Deschutes River, Oregon. Velocities were measured at 0.12 m depth over undisturbed gravel just above the upstream edge of the redd and were recorded to nearest 0.01 ft/s. Velocity criteria were defined as the two-sided tolerance limits within which there was 95% confidence that 80% of the measurements would occur with a normal distribution.
0.488 m/s (1.60 ft/s)	0.909 m/s (2.98 ft/s)	0.698 m/s " 0.4423 (2.29 ft/s " 1.45)		Smith (1973)	Based on 46 redds in the Rouge River system, Oregon. Velocities were measured at 0.12 m depth over undisturbed gravel just above the upstream edge of the redd and were recorded to nearest 0.01 ft/s. Velocity criteria were defined as the two-sided tolerance limits within which there was 95% confidence that 80% of the measurements would occur with a normal distribution.
Winter steelhead					
			1.41B2.85 ft/s (43B87 cm/s)	Bovee (1978)	50% probability. Based on probability of use criteria, source of data is not clear.
0.387 m/s (1.27 ft/s)	0.869 m/s (2.85 ft/s)	0.628 m/s "0.5455 (2.06 ft/s " 1.79)		Smith (1973)	Based on 113 redds in 11 Oregon streams. Velocities were measured at 0.12 m depth over undisturbed gravel just above the upstream edge of the redd and were recorded to nearest 0.01 ft/s. Velocity criteria were defined as the two-sided tolerance limits within which there was 95% confidence that 80% of the measurements would occur with a normal distribution.
0.387 m/s (1.27 ft/s)	0.909 m/s (2.98 ft/s)	0.648 m/s " 0.5472 (2.13 ft/s " 1.80)		Sams and Pearson (1963) as cited in Smith 1973)	Based on 49 redds in 2 western Oregon streams. Velocity values = mean water column velocity over redds. Velocity criteria were defined as the two-sided tolerance limits within which there was 95% confidence that 80% of the measurements would occur with a normal distribution.
1.5 ft/s (45.73 cm/s)	2.5 ft/s (76.22 cm/s)	2.2 ft/s (67.07 cm/s)		Briggs (1953)	Range and average of velocities observed over 13 redds in Prairie Creek and Godwood Creek, California.
			15B54 cm/s (0.49B1.77 ft/s)	Carroll (1984) as cited in Barnhart (1991)	Not annotated. Range observed in a small tributary to the Klamath River.
		2.3B2.5 ft/s (70B76 cm/s)		Orcutt et al. (1968) as cited in Smith (1973)	Average velocities taken at 0.4 ft (12 cm) above 54 redds in Idaho.
			30B91 cm/s (0.98B2.99 ft/s)	Stober and Graybill (1974) as cited in Spence et al. (1996)	80% probability
			37B109 cm/s (1.21B3.58 ft/s)	Hunter (1973) as cited in Spence et al. (1996)	
			46B91 cm/s (21.51B2.99 ft/s)	Graybill et al. (1979) as cited in Spence et al. (1996)	80% probability

Table B2-4. Adult spawning depth criteria for steelhead.

DEPTH CRITERIA				SOURCE	NOTES (e.g., methods, presence of other species, complicating factors)
minimum	maximum	average	preferred/ optimal		
Summer steelhead					
0.244 m (9.52 in)		0.406 m " 0.4756 (15.83 in "18.55)		Smith (1973)	Based on 83 redds in the Deschutes River, Oregon. Depths were measured over undisturbed gravel just above the upstream edge of the redd and were recorded to nearest 0.1 ft. Minimum depth was the limit above which 80% of measurements could be expected to occur with 95% confidence.
			10B150 cm (3.9B58.5 in)	Cited in Moyle et al. (1989)	Source of data not provided.
Winter steelhead					
			0.78B1.79 ft (23.78B54.57 cm)	Bovee (1978)	50% probability. Source of data is not clear.
0.061 m (2.38 in)		0.417 m "0.3325 (16.26 in " 12.97)		Smith (1973)	Based on 113 redds in 11 Oregon streams. Depths were measured over undisturbed gravel just above the upstream edge of the redd and were recorded to nearest 0.1 ft. Minimum depth was the limit above which 80% of measurements could be expected to occur with 95% confidence.
0.244 m (9.52 in)		0.386 m " 0.4639 (15.05 in " 18.09)		Sams and Pearson (1963, as cited in Smith 1973)	Based on 49 redds in 2 western Oregon streams. Depths were measured over undisturbed gravel just above the upstream edge of the redd and were recorded to nearest 0.1 ft. Minimum depth was the limit above which 80% of measurements could be expected to occur with 95% confidence.
7 in (17.95 cm)	14 in (35.90 cm)	10.1 in (25.90 cm)		Briggs (1953)	Range and average of water depths taken at 13 redds in Prairie and Godwood creeks in California.
			12B29 cm (4.68B11.31 in)	Carroll (1984) as cited in Barnhart (1991)	Not annotated. Range measured over redds in a Klamath River tributary.
			18 cm (7.02 in)	Stober and Graybill (1974) as cited in Spence et al. (1996)	80% probability
			12B70 cm (4.68B27.30 in)	Hunter (1973) as cited in Spence et al. (1996)	
			27B88 cm (10.53B34.32 in)	Graybill et al. (1979) as cited in Spence et al. (1996)	80% probability
0.7 ft (21 cm)				Orcutt et al. (1968) as cited in Smith (1973)	Depths taken above 54 redds in Idaho.

Table B2-5. Fry early summer rearing velocity criteria for steelhead.

VELOCITY CRITERIA				LIFE STAGE NOTES (e.g., fish size, season)	SOURCE	NOTES (e.g., methods, presence of other species, complicating factors)
minimum	maximum	average	preferred/ optimal			
		5.2 cm/s "7.6 (0.17 ft/s"0.25)		Emergent fry, 33.2 mm (1.33 in) FL (n=240)	Shirvell (1990)	Mean values for six samples during altered flows using reservoir releases; artificially placed rootwads.

Table B2-6. Fry early summer rearing depth criteria for steelhead.

DEPTH CRITERIA				LIFE STAGE NOTES (e.g., fish size, season)	SOURCE	NOTES (e.g., methods, presence of other species, complicating factors)
minimum	maximum	average	preferred/ optimal			
		38.1 cm "4.3 (14.86 in "1.68)		Emergent fry, 33.2 mm (1.33 in) FL (n=240)	Shirvell (1990)	Mean values for six samples during altered flows using reservoir releases; artificially placed rootwads.

Table B2-7. Age 0+ summer rearing (late summer/fall) velocity criteria for steelhead.

VELOCITY CRITERIA				LIFE STAGE NOTES (e.g., fish size, season)	SOURCE	NOTES (e.g., methods, presence of other species, complicating factors)
minimum	maximum	average	preferred/ optimal			
			<15 cm/s (0.49 ft/s)	Emergent fry about 32 mm FL.	Everest and Chapman (1972)	Highest densities of juvenile fish observed in a range of habitat characteristics.
		21.2 cm/s " 2.99 (0.70 ft/s "0.10)		Early summer. 35.6 mm (1.42 in) FL.	Bugert et al. (1991)	Not annotated. Bankside and snorkel observations of fish habitat use.
			7.3 cm/s (0.24 ft/s)	Age 0. Season not stated	Moyle and Baltz (1985) as cited in Spence et al. (1996)	Methods not stated.
0.10 ft/s (3 cm/s)	0.85 ft/s (26 cm/s)	0.46 ft/s (14 cm/s)		32.4 mm (1.30 in) total length	Stuehrenberg (1975)	Measured the densities of fish using a range of habitat characteristics.
			6B49 cm/s (0.20B1.61 ft/s)	Age 0. Season not stated.	Thompson (1972) as cited in Spence et al. (1996)	Methods not stated.
			40 cm/s (1.31 ft/s)	Fish length=31B44 mm (1.24B1.76 in). Season not stated.	Bugert (1985) as cited Spence et al. (1996)	Methods not stated.
		12.4 cm/s " 10.4 (4.8 in " 4.1)	66B86 % occupied <20 cm/s in both seasons	<u>Summer</u>. Average total length 64.2 mm	Johnson and Kucera (1985)	Observations were made on the habitat utilization of 801 age 0+ steelhead in three Clearwater River tributaries, Idaho. Also examined available habitat. Bedrock Creek
		18.1 cm/s "17.4 (7.1 in " 6.8)				Big Canyon Creek
		16.6 cm/s "12.3 (6.5 in " 4.8)				Cottonwood Creek
		12.5 cm/s " 12.0 (4.9 in " 4.7)		<u>Autumn</u>. Average total length 84.5 mm	Johnson and Kucera (1985)	Methods; see above Bedrock Creek
		12.1 cm/s " 12.3 (4.7 in " 4.8)				Big Canyon Creek
		14.2 cm/s " 11.4 (5.5 in " 4.4)				Cottonwood Creek
			Approx. range 1B6 cm/s (0.03B0.20 ft/s)	Total length 2.5 cm (0.98 in) Late April and early May	Smith and Li (1983)	Focal point velocities measured at locations where fish were observed using direct observation in Vas Creek, California. Fish were then electrofished to obtain length data. Relative habitat availability was also determined. Α...steelhead selected focal points where water velocities were higher than those typically available in Vas Creek...our results probably underestimate mean water velocities at focal points...@ Invertebrate drift increased with water velocity. Data in this form is approximated from Figure 2 on page 176 of Smith and Li (1983).
			Approx. range 5B10	Total length 5 cm (1.95 in)	Smith and Li (1983)	Methods, see above.

VELOCITY CRITERIA				LIFE STAGE NOTES (e.g., fish size, season)	SOURCE	NOTES (e.g., methods, presence of other species, complicating factors)
minimum	maximum	average	preferred/ optimal			
			cm/s (0.16B0.33 ft/s)	Late April and early May		
			Approx. range 11B30 cm/s (0.36B0.98 ft/s)	Total length 7.5 cm (2.93 in) September to December	Smith and Li (1983)	Methods, see above.
			0.40B0.80 ft/s (12.20B24.39 cm/s)	June sampling; total length ranged 32B46 mm (1.28B1.84 in); average total length = 36.5 mm (1.46 in)	Sheppard and Johnson (1985)	Methods included both direct observations of fish focal points and seining of very small areas. Values are for mean current velocities. Tributaries to Lake Ontario, New York, with juvenile coho present. Range in which fish Apredominantly occurred.@ N=20. Summer flows were approximately 15B20 cfs (0.42B0.57 ft^3/s). AThe utilization of areas with higher current velocities in June may reflect the actual physical characteristics of the streams rather than behavioral preferences of these species because stream discharge, and hence, mean current velocities were higher during the June sampling period.@
			0.10B0.80 ft/s (3.05B24.39 cm/s)	October sampling; total length ranged 51B86 mm (2.04B3.44 in); average total length = 67.1 mm (2.68 in)	Sheppard and Johnson (1985)	Methods included both direct observations of fish focal points and seining of very small areas. Values are for mean current velocities. Tributaries to Lake Ontario, New York, with juvenile steelhead present. Range in which fish Apredominantly occurred.@ Flows in October were 60B70% lower than in June. N=42.

Table B2-8. Age 0+ summer rearing (late summer/fall) depth criteria for steelhead.

DEPTH CRITERIA				LIFE STAGE NOTES (e.g., fish size, season)	SOURCE	NOTES (e.g., methods, presence of other species, complicating factors)
minimum	maximum	average	preferred/ optimal			
			<15 cm (5.85 in)	Emergent fry about 32 mm FL.	Everest and Chapman (1972)	Highest densities of juvenile fish observed in a range of habitat characteristics.
			11.7 cm "0.63 (4.56 in " 0.25)	Early summer. 35.6 mm (1.42 in) FL.	Bugert et al. (1991)	Not annotated. Bankside and snorkel observations of fish habitat use.
			35 cm (13.65 in)	Age 0, season not stated	Moyle and Baltz (1985) as cited in Spence et al. (1996)	Methods not stated.
			<12 in (30.77 cm)	32.4 mm (1.30 in) total length	Stuehrenberg (1975)	Measured the densities of fish using a range of habitat characteristics.
			18B67 cm (7.02B26.13 in)	Age 0, season not stated.	Thompson (1972)	Methods not stated.
			24 cm (9.36 in)	Fish length=31B44 mm (1.24B1.76 in). Season not stated.	Bugert (1985) as cited Spence et al. (1996)	Methods not stated.
	40 cm (15.6 in) (<7% of observations > than 40 cm) Both seasons	13.6 cm " 8.0 (5.3 in "3.1)	5B25 cm (1.95B7.80 in) Both Seasons	Summer. Average total length 64.2 mm	Johnson and Kucera (1985)	Observations were made on the habitat utilization of 801 age 0+ steelhead in three Clearwater River tributaries, Idaho. Also examined available habitat. Bedrock Creek
		18.8 cm " 8.1 (7.3 in " 3.2)				Big Canyon Creek
		17.8 cm " 12.9 (6.9 in " 5.0)				Cottonwood Creek
		16.8 cm " 12.5 (6.6 in " 4.9)		Autumn. Average total length 84.5 mm	Johnson and Kucera (1985)	Methods; see above Bedrock Creek
		17.0 cm " 10.1 (6.6 in " 3.9)				Big Canyon Creek
		18.8 cm " 12.6 (7.3 in " 4.9)				Cottonwood Creek
			0.30B0.50 ft (9.15B15.24 cm)	June sampling; total length ranged 32B46 mm (1.28B1.84 in); average total length = 36.5 mm (1.46 in)	Sheppard and Johnson (1985)	Methods included both direct observations of fish focal points and seining of very small areas. Values are for mean current velocities. Tributaries to Lake Ontario, New York, with juvenile coho present. Range in which fish Apredominantly occurred.@ N=20. Summer flows were approximately 15B20 cfs (0.42 ! 0.57 ft^3/s). AThe utilization of areas with higher current velocities in June may reflect the actual physical characteristics of the streams rather than behavioral preferences of these species because stream discharge, and hence, mean current velocities were higher during the June sampling period.@

DEPTH CRITERIA				LIFE STAGE NOTES (e.g., fish size, season)	SOURCE	NOTES (e.g., methods, presence of other species, complicating factors)
minimum	maximum	average	preferred/ optimal			
			0.60B1.20 ft (18.29B36.59 cm)	October sampling; total length ranged 51B86 mm (2.04B3.44 in); average total length = 67.1 mm (2.68 in)	Sheppard and Johnson (1985)	Methods included both direct observations of fish focal points and seining of very small areas. Values are for mean current velocities. Tributaries to Lake Ontario, New York, with juvenile steelhead present. Range in which fish Apredominantly occurred.@ Flows in October were 60B70% lower than in June. N=42.

Table B2-9. Age 0+ summer rearing (late summer/fall) for steelhead not related to depth or velocity.

OTHER HABITAT CRITERIA: (e.g., substrate, cover type, distance to cover, gradient, minimum habitat area)	LIFE STAGE NOTES (e.g., fish size, season)	SOURCE	NOTES (e.g., methods, presence of other species, complicating factors)
5.7 " 0.43	Summer. Average total length 64.2 mm	Johnson and Kucera (1985)	Modified Wentworth scale: sand (4.0) gravel (5.0) cobble (6.0) boulder (7.0) bedrock (8.0). Bedrock Creek
5.9 " 0.42			Big Canyon Creek
5.6 " 0.42			Cottonwood Creek
6.2 " 0.47	Autumn. Average total length 84.5 mm	Johnson and Kucera (1985)	Modified Wentworth scale: see above. Bedrock Creek
6.1 " 0.46			Big Canyon Creek
6.1 " 0.40			Cottonwood Creek

Table B2-10. Age 0+ winter rearing velocity criteria for steelhead.

VELOCITY CRITERIA				LIFE STAGE NOTES (e.g., fish size, season)	SOURCE	NOTES (e.g., methods, presence of other species, complicating factors)
minimum	maximum	average	preferred/ optimal			
			0B15 cm/s (0B0.49 ft/s)	Size not stated.	Bustard and Narver (1975)	87.1% of observations within this range. Information collected by snorkeling and electrofishing. Velocities taken at focal points. Focal point velocities for age 0+ and 1+ steelhead increased significantly with rising temperatures above 4°C. Temperatures during sampling were generally less than 10°C.

Table B2-11. Age 0+ winter rearing depth criteria for steelhead.

DEPTH CRITERIA				LIFE STAGE NOTES (e.g., fish size, season)	SOURCE	NOTES (e.g., methods, presence of other species, complicating factors)
minimum	maximum	average	preferred/ optimal			
			0B15 cm (0B5.85 in)	Size not stated.	Bustard and Narver (1975)	Age 0+ steelhead were strongly associated with shallow water, often less than 15 cm deep. Information collected by snorkeling and electrofishing.

Table B2-12. Age 0+ winter rearing for steelhead not related to depth or velocity.

OTHER HABITAT CRITERIA: (e.g., substrate, cover type, distance to cover, gradient, minimum habitat area)	LIFE STAGE NOTES (e.g., fish size, season)	SOURCE	NOTES (e.g., methods, presence of other species, complicating factors)
Cover = rubble 10B25 cm (3.9B9.75 in) diameter (>50% observed under rocks <15 cm (<5.85) diameter)		Bustard and Narver (1975)	Information collected by snorkeling and electrofishing. Age 0 and 1+ coho salmon present.
Pool or Channel Type = shallow areas of low velocity near stream margin		Bustard and Narver (1975)	as above

Table B2-13. Age 1+ and older summer rearing velocity criteria for steelhead.

VELOCITY CRITERIA				LIFE STAGE NOTES (e.g., fish size, season)	SOURCE	NOTES (e.g., methods, presence of other species, complicating factors)
minimum	maximum	average	preferred/ optimal			
			12.8 cm/s "12.0 (0.42 ft/s "0.39	Estimated mean length=124 mm (4.96 in) n=122	Shirvell (1990)	Mean of six samples during altered flows using reservoir releases; artificially placed rootwads.
			60B90 cm/s (1.97B2.95 ft/s)	Age 1+, Summer. FL > 100 mm	Everest and Chapman (1972)	Highest densities of juvenile fish observed in a range of habitat characteristics. Values given are an average of values collected in sympatric and allopatric populations with chinook. Ranges given are for focal point velocities.
			19.4 cm/s (0.64 ft/s)	AJuvenile@	Moyle and Baltz (1985) as cited in Spence et al. (1996)	
			Approx. range 17B32 cm/s (0.56B1.05 ft/s)	Total length 10.0 cm (3.90 in) September to December	Smith and Li (1983)	Focal point velocities measured at locations where fish were observed using direct observation in Vas Creek, California. Fish were then electrofished to obtain length data. Relative habitat availability was also determined. A...steelhead selected focal points where water velocities were higher than those typically available in Vas Creek...our results probably underestimate mean water velocities at focal points...@ Invertebrate drift increased with water velocity. Data in this form is approximated from Figure 2 on page 176 of Smith and Li (1983).
			Approx. range 15B35 cm/s (0.49B1.15 ft/s)	Total length 12.5 cm (4.88 in) September to December	Smith and Li (1983)	Methods, see above. Data on larger fish is not included here because the authors considered their observations on larger fish to be likely biased.
0.15 ft/s (4.57 cm/s)	1.2 ft/s (36.59 cm/s)	0.52 ft/s (15.85 cm/s)		Mean total length between 114 and 151 mm (4.56B6.04 in)	Stuehrenberg (1975)	Measured the densities of fish using a range of habitat characteristics.

Table B2-14. Age 1+ and older summer rearing depth criteria for steelhead.

DEPTH CRITERIA				LIFE STAGE NOTES (e.g., fish size, season)	SOURCE	NOTES (e.g., methods, presence of other species, complicating factors)
minimum	maximum	average	preferred/ optimal			
			56.5 cm "13.4 (22.04 in "5.23)	Estimated mean length=124 mm (4.96 in) n= 122	Shirvell (1990)	Mean of six samples during altered flows using reservoir releases; artificially placed rootwads.
			60B90 cm (1.97B2.95 ft)	Age 1+, Summer. FL > 100 mm (3.9 in)	Everest and Chapman (1972)	Highest densities of juvenile fish observed in a range of habitat characteristics. Values given are an average of values collected in sympatric and allopatric populations with chinook. Ranges given are for focal point velocities.
			63 cm (24.57 in)	AJuvenile@	Moyle and Baltz (1985) as cited in Spence et al. (1996)	
0.5 ft (15.24 cm)				Mean total length between 114 and 151 mm (4.56B6.04 in)	Stuehrenberg (1975)	Measured the densities of fish using a range of habitat characteristics.

Table B2-15. Age 1+ and older summer rearing for steelhead not related to depth or velocity.

OTHER HABITAT CRITERIA: (e.g., substrate, cover type, distance to cover, gradient, minimum habitat area)	LIFE STAGE NOTES (e.g., fish size, season)	SOURCE	NOTES (e.g., methods, presence of other species, complicating factors)
Large substrate, >20 cm (7.80 in) diameter.	Age 1+, Summer. FL > 100 mm (3.9 in)	Everest and Chapman (1972)	Highest densities of juvenile fish observed in a range of habitat characteristics. Values given are an average of values collected in sympatric and allopatric populations with chinook. Ranges given are for focal point velocities.

Table B2-16. Age 1+ and older winter rearing velocity criteria for steelhead.

VELOCITY CRITERIA				LIFE STAGE NOTES (e.g., fish size, season)	SOURCE	NOTES (e.g., methods, presence of other species, complicating factors)
minimum	maximum	average	preferred/ optimal			
			0B15 cm/s (0B0.60 ft/s)	Age 1+	Bustard and Narver (1975)	78 % of fish were associated with water velocities <15 cm/s at temperatures < 7 ^{o}C. Information collected by snorkeling and electrofishing. Velocities taken at focal points. Focal point velocities for age 0+ and 1+ steelhead increased significantly with rising temperatures above 4^{o}C.

Table B2-17. Age 1+ and older winter rearing depth criteria for steelhead.

DEPTH CRITERIA				LIFE STAGE NOTES (e.g., fish size, season)	SOURCE	NOTES (e.g., methods, presence of other species, complicating factors))
minimum	maximum	average	preferred/ optimal			
			Mainly > 45 cm (17.55 in)	Age 1+	Bustard and Narver (1975)	Information collected by snorkeling and electrofishing. Age 1+ steelhead occupied a wide range of depths, but favored depths significantly deeper than age 0+ coho, and were found in depths mainly greater than 45 cm.

Table B2-18. Age 1+ and older rearing velocity criteria for steelhead [SEASON NOT SPECIFIED].

VELOCITY CRITERIA				LIFE STAGE NOTES (e.g., fish size, season)	SOURCE	NOTES (e.g., methods, presence of other species, complicating factors)
minimum	maximum	average	preferred/ optimal			
		10 cm/s (0.33 ft/s)		Age 1+	Hanson (1977) as cited in Spence et al. (1996)	Race not specified.
		15 cm/s (0.49 ft/s)		Age 2+	Hanson (1977) as cited in Spence et al. (1996)	Race not specified.
		15 cm/s (0.49 ft/s)		Age 3+	Hanson (1977) as cited in Spence et al. (1996)	Race not specified.
			19.4 cm/s (0.64 ft/s)	Ajuvenile@	Moyle and Baltz (1985) as cited in Spence et al. (1996)	

Table B2-19. Age 1+ and older rearing depth criteria for steelhead [SEASON NOT SPECIFIED].

DEPTH CRITERIA				LIFE STAGE NOTES (e.g., fish size, season)	SOURCE	NOTES (e.g., methods, presence of other species, complicating factors)
minimum	maximum	average	preferred/ optimal			
		51 cm (19.89 in)		Age 1+	Hanson (1977) as cited in Spence et al. (1996)	Race not specified.
		58 cm (22.62 in)		Age 2+	Hanson (1977) as cited in Spence et al. (1996)	Race not specified.
		60 cm (23.4 in)		Age 3+	Hanson (1977) as cited in Spence et al. (1996)	Race not specified.
			18B67 cm (7.02B26.13 in)		Stuehrenberg (1975) as cited in Spence et al. (1996)	Race not specified

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APPENDIX B3: CALIFORNIA FRESHWATER SHRIMP

Common Name: California Freshwater Shrimp
Scientific Name: *Syncaris pacifica*

Status

California freshwater shrimp were listed as federally endangered by the U.S. Fish and Wildlife Service in 1988 (53 FR 43884). California freshwater shrimp are also listed as endangered under the California Endangered Species Act.

Geographic Distribution

California freshwater shrimp are endemic to Sonoma, Napa, and Marin counties, where they historically inhabited many perennial, low elevation streams. The species is currently found in 17 watersheds in these three counties (USFWS 1998). Drainages containing populations of California freshwater shrimp include tributaries to the Russian River, coastal streams flowing directly into the Pacific Ocean, tributaries to Tomales Bay, and tributaries to San Pablo Bay. Two new populations and one population previously thought to be extirpated in the 1950s were discovered in 1991 and 1992 (CDFG 1992).

The current distribution of California freshwater shrimp is generally restricted and non-uniform. According to data from Serpa (1991), the median distance between occurrences of the shrimp was 3 km. Distribution within these stream reaches, however, was not continuous, as unsuitable habitat was often interspersed with suitable habitat supporting shrimp.

Morphological Characteristics

California freshwater shrimp are small (<50 mm total postorbital length) shrimp belonging to the family Atyidae. Juveniles shrimp and adult males are mostly transparent with randomly spaced dark chromatophores along their dorsal side. They are nearly invisible on leaf, twig, and submerged terrestrial vegetation substrates. Adult females exhibit similar color patterns when on the above habitats; however, when found on water-logged stems, tree roots, and beneath undercut streambanks, they may be dark brown to purple. These same females will quickly lose their coloration when removed from these microhabitats. Juveniles and adult males do not appear to have similar color-changing capabilities (Cox 2000).

Population Trends

The historical distribution of California freshwater shrimp is unknown, but the species probably once inhabited most perennial lowland streams in the Marin, Napa, and Sonoma county areas (USFWS 1998). Biologists believe that widespread alteration of lowland perennial streams has probably resulted in significant reductions in the species' range and abundance. Most of the California freshwater shrimp habitat that remains is located on private lands and is therefore unprotected. In 1992, CDFG (1992) identified most populations as declining; however, in 1996, the status of these populations was revised to stable (CDFG 1996). Although a recovery plan was published by USFWS in 1998, no recovery efforts are currently underway (USFWS 2000). More research is needed in order to assess the susceptibility of populations to various natural and/or anthropogenic disturbances and their risk of extinction.

Syncaris pacifica is the only extant member of its genus. *S. pasadenae*, which inhabited coastal streams in southern California, is now presumed extinct (Hedgepeth 1968). Factors for the decline of the species include habitat reduction, dams, erosion control, flood control, removal of riparian vegetation, stream alteration and channelization, introduction of non-native predaceous fish (e.g., sunfish), soil erosion, and livestock grazing (Eng 1981, Eng 1984, CDFG 1992).

Reproduction and Growth

The reproductive ecology of the California freshwater shrimp has not been formally described. Reproduction seems to occur once a year, with mating beginning in September. The shrimp exhibit relatively low fecundity; adult females produce approximately 50 to 120 eggs. The eggs adhere to pleopods (anterior abdominal appendages) through the winter months (December through March). Young postlarvae (approximately 6 mm in length) hatch from late May to early June after 8 to 9 months of incubation (USFWS 1998, Cox 2000). Larvae grow rapidly during the summer through a series of molts and reach a mean postorbital length of about 19 mm by fall. The growth rate declines as the summer progresses, although feeding continues throughout the year. Age 1+ shrimp are sexually mature and indistinguishable from adult shrimp by autumn (Cox 2000). Some shrimp apparently reproduce a second time. Late in their second summer, females begin to average about 6 mm longer than males and reach sexual maturity in about 1.5 years (Cox et al. 1994). Courtship and mating behavior have not been described. Although some atyid shrimp live only one year (De Silva 1988 as cited in USFWS 1998), California freshwater shrimp may live longer than 3 years (Eng 1981). No data are available regarding the timing and conditions that induce molting in these shrimp.

Activity and Movements

Basic information regarding the movements of this species is not known. In aquaria, these shrimp have been observed to remain motionless for long periods, clinging to plants and other objects (Hedpeth 1968, as cited in USFWS 1998). Field observations (Serpa 1991, as cited in USFWS 1998) suggest that downstream movements occur; however, these movements may be the result of displacement due to high stream flows. Upstream movements may occur, although no information on such movements was found during this review. High flows may hinder upstream movements since the shrimp are generally poor swimmers. Since shrimp are found upstream of long riffles and dried out stream sections (potential barriers to upstream migration), it is assumed that some mechanism for upstream dispersal exists (Cox, pers. comm., 2000).

Food Web Interactions

California freshwater shrimp are collector-gatherers, feeding on fine particulate organic matter. Food sources may include fecal matter, organic fines produced by physical abrasion and microbial maceration, senescent periphyton, phyto- and zooplankton, aquatic macrophyte fragments, and aufwuchs (a matrix of bacteria, extracellular materials, fungi, algae, and protozoa) (USFWS 1998). Presumably, the species' diet changes with food availability and age. Algae and plant matter may be more important during summer, with detritus and insects becoming more important in winter.

The shrimp's cryptic coloration and behavioral characteristics imply that predation has played an important role in the evolution of the species. Native resident roach, stickleback, and riffle sculpin probably only opportunistically feed on shrimp (Cox 2000). Turbidity likely provides some protection to shrimp from predation by fish. Juvenile coho salmon and steelhead, however, may feed on them. Sacramento pikeminnow may be an important predator of freshwater shrimp. Green sunfish may be an important introduced predator of freshwater shrimp. Although no cause-and-effect relationship has been established, in many cases, shrimp no longer occur in areas where sunfish are now present (Cox 2000). The species' low fecundity and late maturation make it particularly vulnerable to predation. Aquatic vertebrates such as turtles, salamanders, and newts may also occasionally feed on shrimp.

Habitat Requirements

California freshwater shrimp are found in low elevation (380 feet [<116 meters]), low gradient (generally <1%) coastal lowland streams that flow year-round or contain perennial pools (USFWS 1998). They are typically observed in quiet, moderately deep (30-90 cm), stream reaches with riparian and aquatic vegetation and structurally complex banks, exposed roots, overhanging woody debris, or overhanging vegetation. This species can tolerate seasonal temperature extremes, but not salty or brackish water (Cox et al. 1994). No data are currently available for defining the species' optimum temperature and/or stream flow requirements, or its temperature tolerances. It appears to be able to tolerate water temperatures 73°F (>23°C) and non-flowing stream conditions that would be detrimental to native salmonids (USFWS 1998). Under laboratory conditions, juvenile and mature shrimp have been observed to tolerate standing water at 80°F (27°C) for extended periods (USFWS 1998). No information was found regarding dissolved oxygen tolerances and/or preferences. Shrimp are generally not found in reaches with boulder or bedrock substrates. California freshwater shrimp are not known to be territorial, and home range size for the species is not known.

Reproductive
Specific reproductive habitat needs for this species were not found to be described in the literature.

Foraging
These shrimp have been observed foraging while positioned on pool bottoms and submerged twigs and vegetation.

Cover/Roosting
Although aquatic, this species is dependent on riparian vegetation for food and cover. During fall and winter, the shrimp is found beneath undercut banks with exposed fine root systems or dense overhanging vegetation, which provide protection from downstream displacement and high suspended sediment concentrations during winter high flows (Eng 1984, USFWS 1998). In addition to providing cover for shrimp, tree roots reinforce streambanks, enabling undercut banks to persist (Eng 1984). During spring and summer, shrimp move out from undercut banks and live on submerged leafy branches of riparian vegetation (Li 1981, as cited in USFWS 1998). These branches also collect detritus and serve as substrates for bacteria and other decomposers, providing a food source for the shrimp (Eng 1984). Although largely absent under current conditions, large woody debris jams may have historically provided important habitat for these species.

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APPENDIX C: DESCRIPTION OF PROPOSED PHASE II STUDIES

Approach

The purpose of the second phase of this project, as proposed to CALFED Ecosystem Restoration Program for funding, was to complete the process of documenting and refining the understanding of the potential limiting factors on analysis species populations that was begun in Phase I. Unfortunately our proposal was not funded. Therefore, absent additional funding from other sources, the Regional Board will not be able to conduct all of the types of studies that are described below. Based on results of Phase I, and in consideration of TMDL program requirements and projected funding, the Regional Board will conduct sediment budget and stream temperature studies in Phase II to inform its TMDL, and if funding is sufficient we may be able to continue juvenile steelhead growth research.

It does not appear feasible at this date for the Regional Board to fund many important study components proposed for Phase II including:

a) large woody debris dynamics;
b) physical barriers to fish passage;
c) baseflow reduction and hydrograph change;
d) historical analysis of tributary channel changes;
e) general salmonid research (timing and nature of adult immigration and juvenile outmigration (including importance of mainstem predation);
f) California freshwater shrimp (distribution, abundance, and relationship to natural processes and human activities); and
g) quantitative modeling on the basin scale of steelhead population dynamics.

We estimate the cost to fully develop Phase II, to be at least $800,000. The obvious benefit of conducting the complete and holistic study proposed for Phase II comes in the ability to compare and contrast potential environmental benefits and costs of a variety of management options and restoration project types on the reach, tributary, and watershed scales. We believe that such an integrated approach has obvious benefits to all stakeholders. The Regional Board will continue to seek funding independently, and in partnership with local efforts, to conduct some or all of the studies listed above.

Phase II: Proposed Studies

The proposed Phase II research program will include more intensive field studies, plot-based studies, and modeling, and will be used to develop a more quantitative understanding of the relationship between land and water management practices and their impacts on the river ecosystem. Phase II will provide a clearer story of what has happened in the watershed since arrival of European-Americans and provide much stronger evidence for cause-and-effect linkages among land use practices, sediment delivery and temperature loading, flow and physical habitat conditions, salmonid and freshwater shrimp population dynamics, and aquatic ecosystem health.

As in Phase I, the approach to Phase II will be to conduct hypothesis-driven studies that focus on life history stages and processes that are likely to limit overall production of our three analysis species: steelhead, chinook salmon, and California freshwater shrimp. To the extent funding allows, Phase II studies will also attempt to address broader issues related to factors affecting native aquatic biodiversity and aquatic ecosystem health.

In addition to building upon the work conducted during Phase I, during Phase II we will make use of high-resolution digital elevation data (4–5 m horizontal resolution DEMs with 15 cm vertical accuracy produced by airborne laser-swath mapping) and digital terrain models (DTMs) of the channel network and mass wasting (shallow and deep-seated landslide) hazards. These will be developed under the Napa River Basin Mapping Partnership project, which has been awarded funding by CALFED and the Regional Board and is scheduled to begin in July 2002 and to be completed by June 2003.

Phase II activities will continue to build on stakeholder relationships established during Phase I. Public workshops and status reports to keep stakeholders and interested parties involved will be imperative for a successful work plan and to provide feedback for potential restoration and management strategies. Outreach efforts with local, state, and federal agencies, citizen's groups (such as local watershed groups), and other interested parties will also be continued.

We recommend Phase II studies to be based on three basic themes derived from Phase I studies:

(a) process-based assessments of potential physical factors limiting abundance of analysis species,
(b) mechanistic studies to develop a quantitative understanding of the life history characteristics and resource requirements of analysis species, and
(c) quantitative population dynamics analysis.

Process-based assessments would build on our current understanding of sediment dynamics, physical barriers to fish passage, hydrology, water quality, and changes to channel conditions in the Napa River basin. Mechanistic studies would focus on testing specific hypotheses potentially limiting populations of the analysis species evaluated during Phase I. Finally, the quantitative population dynamics analysis would be used to evaluate current and historical conditions and generate recommendations for future watershed and river-riparian management. These themes are further described below.

Process-Based Assessment Of Potential Physical Factors Limiting Abundance Of Analysis Species

This assessment would include studies designed to test hypotheses regarding the ecological importance of various physical factors. These studies would also provide the foundation for much of the work on analysis species and the population dynamics analysis and synthesis proposed below.

Sediment dynamics. Traditional approaches to sediment source analysis (determining rates of sediment delivery to channels) typically involve inventory and quantification of dominant sediment sources over various temporal and spatial scales, utilizing extensive field surveys and aerial photograph analysis. This approach is not feasible in the Napa River basin (Napa River basin), however, in consideration of its large area, diverse conditions, limited public access, time and budget constraints. In order to gather the information needed to rapidly develop a sediment source assessment for the Napa River basin, we propose using traditional sediment budget techniques (e.g., Reid and Dunne 1996, Dietrich et al. 1982) complemented by state-of-the art GIS and digital terrain model (DTM) techniques designed to specifically address the challenges presented by the Napa River basin. Extensive review of literature would be performed to fill in data gaps on the types of erosional features and magnitudes of erosion rates typical for dominant processes in the Napa River basin.

Our approach would involve the following steps: (1) stratification of the watershed into geomorphic terrains or land types (i.e., areas expected to have similar sediment production characteristics under reference and disturbed conditions); (2) development of site-specific hypotheses about how land use, topography, and lithology affect upslope erosion and sediment delivery, and rates, to channels; (3) use of land type-specific intensive analysis, exploring mechanistic relationships between sediment production dynamics in order to estimate process-specific sediment production and delivery rates (aerial photo interpretation, field surveys, and GIS/DTM modeling techniques); and (4) use of an extensive analysis (aerial photograph interpretation and, possibly, helicopter surveys and LIDAR) to allow for landtype-based extrapolation of land type-specific sediment delivery from each sediment source to describe expected sediment sources and their magnitudes in the entire Napa River basin.

Large woody debris (LWD) assessment. Current LWD loadings in tributary channels would be quantitatively assessed to confirm the hypothesis that LWD is lower than would be expected under natural conditions in many parts of the basin. Using historical ecology and geomorphology techniques the studies would also assess whether past LWD removal has reduced winter refugia for juvenile steelhead. We plan to work with local tributary stewardship groups and the Napa RCD to develop funding opportunities for them to perform comprehensive surveys of channels (including LWD) and explore possible opportunities for LWD addition experiments, to develop a detailed understanding of the response of different channel types for additions of wood.

Physical barriers to fish passage. Many dams, both large and small, and numerous small diversions and road crossings (e.g., bridges, culverts, fords) occur along the Napa River and its tributaries. These structures have the potential to create permanent, seasonal, or temporary barriers to upstream or downstream fish passage. They might also reduce habitat connectivity for other species, including the California freshwater shrimp. Current information on known or potential barriers is extremely limited and only a coarse level analysis was conducted during Phase I. More information will be needed to verify locations and passability of existing barriers to test the hypothesis that physical barriers are limiting access to significant amounts of potential habitat. We plan to work with local tributary stewardship groups and the Napa RCD to identify funding sources for comprehensive surveys of channels. We would then analyze this information relative to a GIS basemap of habitat to evaluate the potential import of individual barriers and help stakeholders develop priorities

Baseflow reduction and hydrograph change. This task would involve qualitative assessment of: (1) effects of land management activities on quick flow volume; (2) effects of surface and ground water pumping on dry season flow persistence and magnitude; and (3) whether reach-scale aggradation in tributaries has resulted in former perennial flow going subsurface. Investigations would be conducted in tributary watersheds that are or were historically important streams for steelhead trout and/or freshwater shrimp, and where stewardship groups are actively engaged in management and restoration planning, such as Carneros, Dry, Ritchy, Soda, and Sulfur creeks.

Land use activities that reduce rainfall interception (e.g., conversion of forest to vineyard), infiltration capacity, and/or surface roughness, or which rely upon the installation of subsurface drainage systems (to drain fields rapidly) may cause significant increase in runoff rates during storms to the detriment of groundwater recharge and consequent dry season baseflow. To determine the significance of land use related increases to quick flow will involve: a) field surveys to identify dominant modes of storm runoff (Horton overland flow, natural soil pipes, engineered drainage, etc.), measure rainfall intensity and duration, measure infiltration rates, and describe soil profiles; b) review existing rainfall-runoff monitoring data collected by Napa County RCD; c) interpret time sequential aerial photographs (1940s, 1960s, 1980s, 1998) to map changes in land cover types through time.[can't use without accompanying flow data.]

Surface and ground-water pumping may have direct effects on spring and dry season baseflow persistence. Long-term ground water level data exist for approximately fifty wells in Napa Valley and adjacent alluvial fans. To evaluate long-term trends in view of seasonal variability, these data would be compared with the results of extensive surface flow surveys in spring, summer, and fall to characterize the spatial pattern of flow status throughout the basin. This would be combined with more intensive efforts to monitor groundwater elevation relative to local streambed elevation (surface discharge) by installing continuous recording water-level gauges at key sites. In addition to these field studies, existing hydrologic data for tributaries would be evaluated relative to available historical data (CDFG stream surveys, etc.) to determine whether extent of perennial and/or discontinuously wetted channels has been reduced since 1960s. Due to the fact that aggradation may result in subsurface flow by raising channel bed elevation above the water table, inchannel and helicopter surveys would be conducted in tributary reaches expected to be vulnerable to aggradation (i.e. streambed slope ≤ 3 percent). Field evidence, bridge surveys, historical photographs, landowner interviews, and aerial photo interpretation would also be used to evaluate channel aggradation and potential effects on flow persistence.

Temperature monitoring and modeling. In Phase II we would continue to be monitor temperature at a selection of the sites established during Phase I studies, adding new sites where needed to better document spatial and temporal patterns of stream temperature and to provide data to calibrate a temperature model for selected reaches. Using reconnaissance field visits, biological observations, aerial photograph interpretation, existing GIS vegetation coverages (USGS and USDA Forest Service), and historical analysis, we could compare the likely historical condition with the current extent and condition (particularly average height) of riparian vegetation to determine whether vegetation clearing has had an impact on stream temperatures. Finally, we would model effects on stream temperature under various scenarios (current, historical, potential future riparian management options) for selected portions of the perennial channel network in the basin. This type of model has been applied in a number of basins in California and Oregon, and was used to develop the first temperature TMDL in California (South Fork Eel TMDL, EPA 1999).

Analysis of changes in channel conditions. Physical changes to the Napa River and its tributaries during the 200 years since European settlement have been massive and rapid, and, in all likelihood, have significantly altered the way that water and sediment are transported through the system. However, a functional understanding of how these impacts have affected key physical factors has been hindered by the lack of sufficiently detailed information about reference condition. A focused research effort would investigate the historical character of natural streams and significant associated features such as discontinuous channels, distributary systems, braided channel systems, and riparian overstory. A wide range of historical documents, including early Spanish and American maps, surveys, written accounts, landscape paintings, and ground and aerial photography would be analyzed to document the historical channel network plan form, early channel depths (at known points for resurvey), and the width and linear extent of riparian vegetation. All historical features will be documented in terms of accuracy and uncertainty, following established methodologies. We propose that this task be carried out by the San Francisco Estuary Institute's (SFEI) historical ecology research team, which has developed a suite of successful methodologies for synthesizing historical data into technical products. This effort will benefit from resources already developed by SFEI's collaborative Napa Watershed Historical Ecology Project. This broad-based effort involves many local citizens helping to gather information about the history of the Napa watershed and will provide an information base allowing this substantial task to be completed cost-effectively. Geomorphologists, hydrologists, fisheries biologists, and riparian and aquatic ecologists will work closely with SFEI staff to direct the historical research toward information most useful for testing key hypotheses and developing conceptual models about historical conditions affecting the analysis species.

Mechanistic Studies and Life History Assessments of Analysis Species

General salmonid research. General monitoring of salmonids to assess timing of adult immigration for spawning and juvenile outmigraton (for both chinook salmon and steelhead) is greatly needed. Coordination with other state and federal agencies within the watershed to implement basin-wide monitoring could be sought. In addition, the importance of predation in the mainstem to outmigrating smolts and the importance of estuary rearing should also be explored. Predator abundance and distribution in the mainstem as well as stomach contents sampling could provide valuable information for salmonid population viability.

Steelhead. As preliminary studies during Phase I suggest, reduced flow and increased temperatures during summer months may potentially limit food availability and increase metabolism of juvenile steelhead, reducing overall growth. Studies similar to Phase I pilot growth studies would be conducted, ideally in conjunction with flow manipulations, to assess the effects of flow reductions on juvenile steelhead growth to determine seasonal growth patterns and size at outmigration. In addition to sampling juvenile steelhead, the study would be expanded to include sampling potential prey items. The potential effects of the abundance of macroinvertebrate food supply, both benthic and in the drift, could be compared with fish growth to determine whether food limits juvenile fish.

To address issues regarding habitat availability for freshwater lifestages of juvenile steelhead, we would seek opportunities to partner with the efforts of local agencies to collect detailed inchannel habitat data that would be appropriate for population dynamics modeling (see below). These surveys could be conducted in conjunction with barrier and/or surface surveys to maximize efficiency of efforts. It may also be necessary to conduct further gravel permeability sampling if subsequent habitat surveys demonstrate that our initial effort did not capture all possible types of spawning of gravels available in the basin.

In view of the frequency of barriers and dry reaches in the tributaries during the summer and fall, it would be critical to gain a detailed understanding of the temporal movements of juveniles within the system and their ability to use existing habitat. Information on the spatial distribution of habitat and timing of movement by juveniles is necessary to understand potential impacts of barriers and dry reaches.

Chinook salmon. High flows, potentially occurring several times in one season, may impact chinook salmon redds and decrease egg survival-to-emergence. To test this hypothesis, we suggest using artificial redds and scour cores to determine the types and recurrence intervals of flow that cause scour detrimental to redds.

California freshwater shrimp. Very little is known about the current distribution and abundance of California freshwater shrimp in the basin and there is a lack of rigorous data on preferences or use patterns for different types of potential habitat. In addition, the processes responsible for creating and maintaining critical habitat are unknown. The first step would be to conduct a comprehensive survey of population abundance in the Napa River basin. Initial sampling could focus on comparing shrimp abundance in various habitats to address habitat preference or utilization and documenting the distribution of different types of habitat throughout the Napa basin. Sampling would occur at locations where shrimp are known to occur, as well as other appropriate habitats, throughout the year, to determine life history characteristics and test the hypotheses that (1) the freshwater shrimp only occur in pools with well-developed undercut banks with well developed root mats and overhanging riparian vegetation, and (2) suitable habitat is relatively abundant in the mainstem and certain low-gradient reaches of some tributaries (such as Huichica Creek).

No integrated study has yet been undertaken to develop an understanding of the key processes and conditions involved in creating and maintaining appropriate habitat for this species. Reconnaissance-level channel surveys to develop hypotheses about the processes necessary to form undercut banks, and what is required to maintain them, as well as assessing the extent of potentially suitable undercut bank habitat within the Napa River basin would also be important in determining the life history constraints of this species.

Population Dynamics Analysis

This analysis will synthesize the information obtained from all Phase I and II studies through the construction of a reference model of natural processes and conditions (based on reconstruction of historical conditions prior to pre-European-American disturbances and on our empirical and theoretical understanding of natural river and watershed processes in the Napa River basin) and a model of current processes and conditions. These models would incorporate a mechanistic or process-based understanding of cause-and-effect relationships, and would therefore be able to help predict future conditions likely to occur under various management scenarios. In particular, the models would lead to quantitative modeling of population dynamics of the analysis species under different scenarios. The results of this data synthesis and modeling process could then be used to generate recommendations for watershed and river-riparian management (e.g., best or better management practices) and restoration (e.g., a prioritized list of restoration strategies and actions most likely to improve river ecosystem health and/or maintain or restore species of concern).

The watershed analysis functions like a forensic investigation: a means of reconstructing the processes that led to the impairment of beneficial uses. The reference model, which is developed through an iterative interdisciplinary process throughout the project, serves as a forensic tool throughout the watershed analysis from generation of initial hypotheses through evaluating BMPs and restoration priorities. For example, the reference model may indicate that pools are significantly shallower now as a result of (1) removal of LWD from channels (LWD causes deep pools to scour), (2) channel straightening, which would eliminate deep pools caused by bends in the channel, (3) decreases in peak flows below reservoirs allowing pools to fill in, or (4) channel aggradation and bank erosion due to increases in mass wasting or surface erosion from roads resulting in pool filling irrespective of peak flows.

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APPENDIX D: PUBLIC COMMENTS

Written comments to the Draft Technical Report and Executive Summary were provided by interested parties. Comments received prior to June 10 were considered in preparing the final draft of this Technical Report and the Executive Summary. Written comments were submitted by the following parties and are included in this appendix:

Bonsignore, N.F. (Wagner & Bonsignore)
Collins, L. (Watershed Sciences)
Elles, S. (Napa Valley Grape Growers Association)
Emig, J. (CDFG)
Graves, D.
Jones, P. (EPA)
Krevet, B.E. (FONR)
Lander, J. and P. Lowe (Napa County Department of Public Works)
Leidy, R. (EPA)
McGlochlin, L. (Napa Valley Resident, Registered Geologist)
McKee, L., R. Grossinger, and S. Newland (SFEI)
Malan, C. and I. Thomas (Sierra Club)
Weber, E. (University of California Cooperative Extension)

APPENDIX D: PUBLIC COMMENTS

Written comments to the Draft Technical Report and Executive Summary were provided by interested parties. Comments received prior to June 10 were considered in preparing the final draft of this Technical Report and the Executive Summary. Written comments were submitted by the following parties and are included in this appendix:

Bonsignore, N.F. (Wagner & Bonsignore)
Collins, L. (Watershed Sciences)
Elles, S. (Napa Valley Grape Growers Association)
Emig, J. (CDFG)
Graves, D.
Jones, P. (EPA)
Krevet, B.E. (FONR)
Lander, J. and P. Lowe (Napa County Department of Public Works)
Leidy, R. (EPA)
McGlochlin, L. (Napa Valley Resident, Registered Geologist)
McKee, L., R. Grossinger, and S. Newland (SFEI)
Malan, C. and I. Thomas (Sierra Club)
Weber, E. (University of California Cooperative Extension)

Wagner&Bonsignore
Consulting Civil Engineers, A Corporation

Nicholas F. Bonsignore, P.E.
Robert C. Wagner, P.E.
Paula J. Whealen
Monique Robbins, P.E.
Ryan E. Stolfus

May 24, 2002

Mr. Mike Napolitano
Regional Water Quality Control Board
1515 Clay Street, 14th Floor
Oakland, CA 94612

Re: **Comments on Draft Napa River Limiting Factors Analysis**

Dear Mr. Napolitano:

Thank you for the opportunity to comment on the referenced draft report. Our comments are as follows:

- The report mentions in several places that groundwater pumping may be having an adverse impact on in-stream flows (Table 7-2, for example), but no data or other supporting information appears to be provided or referenced to indicate such a link. Future detailed groundwater/surface water interaction studies are proposed in Appendix C for Phase 2. The text of the report should highlight the fact that additional studies are required to evaluate this hypothesis.

- With regard to sediment-related factors (discussion beginning on page ES-10), it appears paradoxical that gravel permeability and bed mobility were found to be limiting factors, while turbidity and pool filling were not. A discussion as to why some of these apparently interrelated factors are limiting while others are not would be helpful.

- It appears that most if not all of the factors considered are dependent to some degree on in-stream flows, yet the report is limited in its discussion of how in-stream flows have changed over time within some stream systems. While it may be obvious that the large municipal reservoirs have had an impact on in-stream habitat for some east-side tributaries, the potential affect of more numerous but much smaller diversions on west-side tributaries and other east-side tributaries is subtler. As shown in Table 3-1 of the report, the USGS operated gaging stations at various times in the past on Sulphur Creek and Dry Creek; Table 3-1 omits several other USGS gaging stations records that should be included.[1] Given that these records were collected prior to the onset of extensive hillside vineyard development, they likely provide an indication of near-unimpaired flow conditions in some or all of these tributaries, particularly for wet-season flows. A comparison of these older records with new

[1] The USGS operated gaging stations on Redwood Creek and Napa Creek (west side), and on Tulocay Creek (east side) during various time periods between 1958 and 1983.

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data might provide some insights as to whether some or all of the limiting factors are related to the increase or timing of diversions.

There have been some who have suggested that peak flows have increased due to hillside vineyard development, yet additional winter storage diversions, which might serve to offset peak flows, are discouraged (including those located in upper reaches well above spawning and rearing habitat). Without current flow data, evaluated in conjunction with studies of existing diversions, the effect of hillside development and winter storage diversions on peak and base flows remains an uncertainty. The reestablishment of stream gages at former gage sites, and installation of new gaging stations on other tributaries should be given serious consideration for future studies.

- We suggest that future studies include a comparative element to explore the question of why some tributaries are more fish-friendly than others. The Ecotrust survey, which provided information on the relative distribution of steelhead within the watershed, may provide a starting point for such studies. This survey indicated that the relative distribution of steelhead varied within adjacent tributaries. A comprehensive analysis of why certain tributaries were more supportive of steelhead than others might help direct future restoration efforts.

- One of the goals stated in the Preface is to "develop plans to restore the health of polluted bodies of water". Later, the Preface presents three bullet-point questions addressed by the report, the last of which pertains to actions needed to conserve or restore self-sustaining populations of threatened aquatic species. Against what standard or base line will the health of the system be measured? How will the recommended actions be evaluated for effectiveness? Is there some numerical goal or some other measurable standard that will be used to gauge progress under the TMDL process?

Very truly yours,

WAGNER & BONSIGNORE
CONSULTING CIVIL ENGINEERS

Nicholas F. Bonsignore, P.E.

cc: Martha Lennihan
Chris Howell

MISCB255.doc

Watershed Sciences
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Berkeley, CA 94707
(510) 524-8204
collins@lmi.net

Dear Mr. Napolitano, 5/24/02

Thank you for the opportunity to comment on the Draft Napa River Basin Limiting Factors Analysis (NRBLFA) that was released April 17, 2002. I have reviewed both the Executive Summary and the Technical Report. Some of my comments are general and relative to both documents, I hope you will find them constructive. Other comments are keyed to page and paragraph numbers.

General Comments

Based upon some of the information presented in the NRBLFA and my own interpretations, I offer a somewhat different hypothesis to consider regarding the changes that the Napa River has undergone.

I suggest the channel conditions described for the 1940's and shown in Figures 6a-c represent a highly disturbed and unstable channel network that has responded to over 100 years of very intensive land use practices. An initial hypothesis is that the historical channel that existed prior to non-native settlement *(lets refer to this as the pre-1800s channel)* was an anastamosing channel, not braided. The groundwater table would have been high enough to maintain perennially wet meadows and seasonal wetlands throughout the valley as suggested in your report. The wet meadows would have been loaded with insects that contributed to abundant food resources for native fish. The meadows could have had many small discontinuous channels and some tributaries may not have been connected to the mainstem. It is entirely possible that occasional beaver dams created backwater areas and "off-channel" habitats, especially on low gradient tributaries, but these creatures were extirpated by early fir traders.

Peak discharges in Napa River were likely smaller than today for several likely reasons: drainage density was less (no agricultural, drainage or road ditches), the effects of evapotranspiration were greater due to lush meadow and forest vegetation, there was more surface storage of water in wetlands, more tributaries may have been disconnected from the mainstem (unchannelized alluvial fans and channels that died-out on the valley floor), and high flows could diminish their peaks by spreading onto the floodplain/floodprone areas.

The sediment load should also have been low for several reasons: low numbers of shallow landslides, very low acreage of bare ground, well-vegetated stream banks, and tributary sediment load may have been disconnected from the mainstem since some of it was deposited on the alluvial fans. Anastamosing channels typically do not carry high loads of coarse sediments compared to braided channels.

Because many portions of the pre-1800's Napa River may have divided into multiple channels that were probably very well accommodated by riparian vegetation, the bankfull dimensions would have been narrower and deeper than the entrenched conditions of today or the braided conditions of the 1940s. Undercut banks and deeper pools were likely more abundant. I concur with the NRBLFA that the pre-1800's channel had access to its floodplain, and this is key to explaining what caused the channel to change from anastamosing to braided by the 1940's.

The 1940 pictures tell much of the story. Most of the valley floor that was either functional floodplain or floodprone had converted to croplands that were subjected to frequent plowing and other soil disturbances. When overbank flows occurred, which may have been frequent as stated in the report, floodwaters flowing back into the channel would have been loaded with sediment because of the abundance of bare soils. Drain and reclaim was the land ethic. The bottom lands were for farming and ranching. Napa Valley was systematically ditched to drain the valley in the winter and to irrigate it in the summer. Tidal marshes were reclaimed and overflow channels plowed over to increase croplands. Ditches were cut across the valley to drain the land. Ditches were built to connect tributaries to the mainstem to move water out of the valley more quickly *(in theory)*. Water flowing through all these bare ditches *(that weren't designed with stable geometry in mind)*, also provided substantial sediment loading and may have lead to increased water temperatures.

Erosion control practices were generally not even implemented until the 1930's. Such an overwhelming increase in sediment load caused the mainstem Napa River to aggrade its bed, create new avulsion channels, steepen its gradient, reduce its sinuosity, increase its bankfull width, and develop an over-widened braided condition with bar-pool morphology within the former anastamosing channels. As the channel filled, new avulsion channels were created. Not only did sediment supply increase but drainage density continued to increase as more roads, gutters, ditches and storm drains developed. Peak discharges effectively increased and caused further adjustments of hydraulic geometry in Napa River. As the photos indicate, radical changes had occurred on the valley floor that diminished overall vegetative cover, as well as the amount of insect habitat throughout the valley, not just aquatic habitat in riffles.

After sediment supply peaked, which may have been before the 1940's, the mode of the Napa River may have changed from braiding and avulsing to entrenching. Changes in technology caused new perturbations to the landscape. For example, dairies became automated and more cattle could be concentrated per area, and irrigation was automated and hundreds of small impoundments were developed. Land use changes coupled with incision of the mainstem Napa

River lowered the groundwater table and the amount of available baseflow. This may have reduced mature riparian vegetation and increased bank erosion rates, while young riparian vegetation established on small inset floodplains.

To achieve the objectives to help inform the Regional Board of its sediment TMDL process and to define cause and effect relationships between human land use activities, hypothesis concerning land use impacts could be more fully developed in the NRBLFA. Perhaps a matrix that incorporates a time line with expected land use impacts and channel response. This would help answer questions such as, was the Napa River much more impaired by sediment in the recent past (early 1900's) than it is today? If so, were some other limiting factors more important in the past than they are in the present such as temperature? Has the coarse component of sediment supply diminished as fine supply has increased and what are the implications? What is the current and future status regarding stability?

Through out the document I have read several references to the important impacts of predators as a limiting factor of the key species. I cannot, however, find a discussion or hypothesis of the kinds of predators (native or exotic) or reference to their abundance.

If so little was known about the freshwater shrimp species why was it chosen as an indicator species for Phase I? Could something else be used in combination with the shrimp, perhaps the native crawdad? The amount of potentially suitable habitat for the freshwater shrimp was assessed, but I did not see a discussion about whether these creatures were observed anywhere. Where they important food sources to salmonids?

Technical Report and Executive Summary Comments

Pg 9, Table 3-4. The table shows that a very high proportion of the watershed, 83.6%, is stable. It would be useful to have some discussion or develop a hypothesis for Phase I report that relates the shallow landslides stability potential to an expected importance of these modeled features as sediment sources to the channel. How do other watersheds compare where the model has tied supply to instability potential? Can the predicted high instability areas be correlated to the different geologic units shown in Map 3?

Pg 9, par 4. It is stated that the Napa Valley is differentiated into two geomorphic units, yet Map 5 shows 4 units for the valley and additional unit called uplands. The report has discussions for the headings of Alluvial Fans and Valley Fill, but no discussion for Uplands. It is also stated that important differences in topography, geology, and geomorphic processes between the two units exert important influences on stream morphology and ecological functions, yet it is difficult to find a discussion for each of these parameters for each of the (2, 4, 5?) conditions. For example, how is the geology in the alluvial fan causing a difference in channel geometry or ecological functions as opposed to the non-estuarine valley fills? What is the importance of the two non-estuarine valley fill units with regard to limiting factors? How are the streams different in sinuosity, entrenchment, confinement, and stability relative to bank erosion and bed incision/aggradation?

Map 5, Alluvial fan and Valley Fill areas. I have looked in the text and on the map key but cannot find any discussion or list of threshold criteria to establish these different map units. Are there certain limits of aerial extent, topographic gradient, elevation, or soils conditions that were used to identify the 3 valley fill types from alluvial fans and uplands? Why was it determined that the alluvial fans and valley fills of the tributaries would not be identified or will they be in Phase II? From the map it is not possible to tell why the low gradient areas of Huichica and Carneros Creeks are mapped as uplands instead of alluvial fans.

Pg 10, par 2. What are the tectonic features you are referring to that exert control on the mainstem Napa River? Is there a hypothesis about why the alluvial fans are bigger on the west side of Napa Watershed? The report states that the degree of consolidation in alluvial fans is expected to increases to the south as a result of a southward increase in size and age. It is then stated that resistance to erosion is expected to increase as well, but is this in reference to erosion from downcutting by surface flow over the fan, or to bank erosion by the mainstem Napa as it intersects tributary fans? It is mentioned that the lowermost subreaches of many of the main tributaries are wetted due to the influence of the Napa River groundwater table. Are these wet reaches in the alluvial fans or should this be discussed under the Valley Fill heading? This is somewhat confusing because it is mentioned later that many of the alluvial fan channels dry out.

Pg 10, par 5. It is stated that modern floodplain deposits are patchy and alluvial terraces underlie most of the valley floor. Is it meant that alluvial gravels underlie most of the valley floor while sandy or finer overbank deposits are patchy? What is the significance of this?

Pg 12, par 1. Should there be a cited reference for the regional hydrologic relationships used to estimate bankfull depths relative to drainage area? What is the additional in-channel resistance from that is not accounted for in the model?

Pg 13, par 1 (also pg ES-6, par 1). Is it possible to state what the land types were prior to conversion to vineyards? For example, what percentage of grazed versus open-space land was converted during this time frame?

Pg 13, Table 3-7. Why not have acres of tidal marsh as a cover type *(I assume this is not your category of Emergent Herbaceous Wetland)*?

Pg 27, Juvenile Rearing bullets. Shouldn't disease and parasites be listed, especially since it is listed for the shrimp (pg 28)?

Pg 28, 2nd bullet. A list of the types of predators expected and or confirmed relative to the geomorphic unit would be very helpful.

Pg 26 and 28, Adult Upstream Migration and Outmigration bullets. It might be worth mentioning that lack of light can create migrational barriers in "dark" storm drains/box culverts that might otherwise be considered passable during moderate to low flows. Should the low numbers of fish available for reproductive success be listed as an additional limiting factor?

Pg 32, par 5 (also ES-6, par 6). Based upon 1940 photographs it is stated that Napa River was historically a low-gradient, gravel-bedded stream exhibiting bar pool morphology, with mid-channel bars, islands, and multiple channels in unconfined reaches. This statement tends to lead the reader into thinking that the conditions of the 1940s represented the natural undisturbed conditions that existed prior land use activities, yet according to your earlier discussion (pg 13), there had already been abundant land use activities 100 years earlier that included crop farming, grazing, and logging. It is further stated that in unconfined reaches of the valley floor, the river was locally braided, with relatively broad, frequently inundated floodplains supporting well-established riparian vegetation. Is it possible that some of these locally braided reaches were relatively young avulsion channels with established riparian vegetation that was less than 100, 70 or 40 years in age? Also stated is that well-developed wetlands occurred in transitional areas between alluvial fans and the valley floor, and on the floodplains. Are the wetlands perennial or seasonal? What were the plan form differences in the tributaries on their fans and at their confluences with the mainstem Napa River? Are all the physiographic descriptions in this paragraph only relative to 1940's or to earlier historical conditions as well?

Pg 32. par 6 (also ES-7, par 2). The report next describes that prior to major anthropogenic disturbances, the Napa River had numerous side channels, and that the river would have had been connected to its floodplain in most locations. This is the only reference I can find that discusses conditions prior to the 1940's, yet it is difficult to tell if there is any difference from the conditions described for the 1940's. The river is reported to have incised an average of 6-8 ft from its mouth to Calistoga, but there is no reference time frame or rate. Is this since the 1940's or since non-native settlement? Has the loss of bedload sediment supply from dam construction *(as stated in the last sentence in this paragraph)*, possibly been compensated by the increased bedload supply caused by incision?

Pg 33, par 2 (also ES-7, par 3). A statement is made that the 'natural' bar-pool morphology *(I assume this is in reference to the braided condition that was discussed earlier)* has been converted into a series of long run-pools. This seems to infer that the 1940's condition was the stable pre-1800s characteristics. Why would a braided channel have been the historical condition? Since braided channels are inherently unstable due to high sediment supply, what would have caused this as a natural condition?

Pg 33, par 3 (also ES-7, par 4). A reference is made to slough habitats. This is confusing because sloughs are generally considered to be tidal, but I don't think that is what is intended in the reference.

Pg 33, par4 (also ES-7,par 5). The abundance of pools in the pre-1800's channel is discussed, particularly relative to increased amounts of LWD. Couldn't we also consider that more pools existed because the channel was more sinuous, it was narrower and deeper, and it had more base flow (as indicated by the higher groundwater table).

Pg 34, par 4. Can turbidity be sampled in drainage ditches? Can the drainage and road ditches be shown on a Phase II GIS map to show their impact on drainage density?

Pg 40, par 4. The NRBLFA hypothesizes that bed mobility is high, leading to frequent scour of redds. Could it be explained that the mobility is high now because of the entrenchment and containment of flood flows, whereas in the 1940's bed mobility was high because of the overwhelming supply of coarse sediments *(as conceptually discussed in paragraph 2, same page)*, hence the braided condition. In the pre-1800's channel, was bed mobility low due to the limited supply and lower peak discharges?

Pg 41, par 6. A reference is made that pools in steeper channels are less likely to be filled with sediment than those in shallower channels. Perhaps "lower gradient" is meant rather than shallower.

Pg 43, par 2. It is emphasized that the lack of pools is due primarily to lack of LWD. Can't an increase in width/depth ratio, and reductions in groundwater and sinuosity also account for lower pool numbers?

Pg 44, par 1. Is it possible that the braided channel condition shown in the 1940's may have had higher temperatures than today because the braided channel was much wider and thus minimized the shading effects of adjacent riparian vegetation?

Pg 45, par 5. It is stated that historically, about 300 miles of the 1,300 miles of stream channel were accessible and suitable to spawning. Is this in reference to the 1940's condition or the pre-1800's?

Pg 49, par 1. Alluvial fans/valley floor reaches are discussed as marginal habitat due to summer drying, even under historical conditions. This is confusing because I thought it was stated earlier that there were wetland areas at the transitions *(which would presumably indicate a high ground water table)*, so why wouldn't water be expected in the channels at these transitions?

Best Regards,
Laurel Collins

Napa Valley Grape Growers Association
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May 28, 2002

Mr. Mike Napolitano
SF Bay Water Quality Control Board
1515 Clay St., Suite 1400
Oakland, CA 94612

Dear Mr. Napolitano,

Thank you for the opportunity to comment on the Draft Napa River Basin Limiting Factors Analysis published on April 17, 2002. We appreciate the work conducted by Stillwater Sciences and the University of California producing the analysis of existing stream and riparian habitat conditions of the Napa River watershed.

After reviewing and discussing the draft report, the Napa Valley Grape Growers Association offers its support of the recommended actions:

- Reduce water temperatures where feasible by increasing stream shading through enhancement of riparian tree cover
- Develop high resolution topographic maps and watershed analysis modeling products
- Pursue opportunities to prevent increased delivery of sediment to channels
- Explore opportunities to reduce unnecessary or inefficient water use
- Ensure that potential sources of turbidity are not increased or exacerbated.
- Pursue barrier remediation projects to restore the steelhead run
- Increase retention of spawning gravels and the abundance of pools and cover in tributaries by strategically and cautiously adding large woody debris
- Enhance California freshwater shrimp habitat in the mainstem of the Napa River and Garnett and Huichica creeks

We acknowledge and agree with the report's conclusions on the complexity of defining the historical and present primary factors of the decline of certain native fish and aquatic wildlife species. We would also ask for clarification and inclusion in the final report of the urban impacts contributing to the decline of the watershed.

As agriculturists we support and will continue to participate in the many voluntary and collaborative watershed restoration programs while maintaining the position that further regulatory actions will need to be carefully balanced with protecting the economic viability of farming.

Sincerely,

Sandra Elles

Sandra Elles
NVGGA Executive Director

From: "John Emig" <JEmig@dfg.ca.gov>
To: <MBN@rb2.swrcb.ca.gov>
Date: 4/26/02 11:43AM
Subject: Re: Draft Executive Summary for Napa River Basin LimitingFactorsAnalysis

Mike: Thank you for providing the report for our review. Generally it is very well done and has covered the major limiting factors and provides good recommendations for restoration. Comments are as follows:

p. 3, 25, etc. refer to a large historical run of chinook. This should be referenced or otherwise documented. To my knowledge, chinook did not historically occur in the Napa River. The fish we have now are believed to be strays from the plantings of chinook in SF Bay. These plantings were from Central Valley hatcheries and were initiated in the early 1980s to improve returns by bypassing predation and diversions in the Delta area. The program has been successful in improving returns, but a byproduct has been the appearance of chinook in a number of SF Bay tributary streams where they were not found before.

p. 4, last sentence, "striped sea bass" should be "striped bass".

p. 22, 30. "glassy-winged sharpshooter" should be "blue-green sharpshooter".

Let me know if you have questions regarding these comments.

John

>>> "Michael Napolitano" <MBN@rb2.swrcb.ca.gov> 04/18/02 03:19PM >>>
Dear Folks:

To serve the public trust, and to fulfill the responsibilities of our agencies, the Coastal Conservancy and Regional Board funded a two-year study of stream-riparian habitat conditions in the Napa River watershed. The study, conducted by the University of California in collaboration with Stillwater Sciences, evaluated factors limiting populations of three species of rare or threatened native fish and aquatic wildlife in the Napa River watershed. The report addresses the following questions:

1) What are the primary factors causing the decline of certain native fish and aquatic wildlife species?
2) How important is sediment in causing these declines or in limiting populations of these species?
3) What actions are needed to conserve or restore self-sustaining populations of these rare or threatened aquatic species?

The Executive Summary of the draft report was posted today on the Regional Board website at http://www.swrcb.ca.gov/~rwqcb2 (under items for comment) and will also be post on the Coastal Conservancy website soon in the near future (http://www.coastalconservancy.ca.gov). The draft report in its entirety is scheduled for release and posting on April 26, 2002.

We look forward to receiving your comments. Comments received by May 17, 2002 will be considered in the final report, which will be released by June 14, 2002.

Comments should be submitted in writing to:

Mike Napolitano
Regional Water Quality Control Board
1515 Clay Street, 14th Floor
Oakland, California 94612

or via email to: mbn@rb2.swrcb.ca.gov

We appreciate you time and interest.

Best regards,

Mike Napolitano

CC: "Mike Rugg" <MRugg@dfg.ca.gov>

Mr. Mike Napolitano
Regional Water Quality Control Board
1515 Clay St., 14th Floor
Oakland, CA 94612

May 22, 2002

Dear Mike:

Thank you for the opportunity to comment on the executive summary of the draft Napa River Basin Limiting Factor Analysis. You, Dr. Dietrich and the team at Stillwater deserve high praise indeed for this excellent initial study. My comments will refer to Roman numeral and letter and to specific page numbers

III.B ES-6, "Groundwater pumping for frost protection" was essentially unnecessary from 1973 to 2000, largely due to the absence of spring frost. (See Nemani, et al. 2001.Asymmetric warming over coastal California and its impact on the premium wine industry. Climate Research. 19:25-34) The whole issue of groundwater elevations can be examined by use of the California Dept. of Water Resources well level data set, available at www.water.ca.gov in the Groundwater section. The data are available as tables or in graphic form. Also unexamined in this report is the effect of stream incision on groundwater levels.

The land use discussion does not give an adequate treatment of urbanization from 1960 to the present.

IV. ES- 7. The causes of stream incision in the whole basin and indeed in the entire region need to be discussed more completely. When did it begin? What were the likely triggering events? Is it continuing? How fast?

ES-10 The redwood and mixed evergreen forests were likely confined to the Mayacamas Range and the ponderosa pine/Douglasfir complex to Howell Mountain. Also, once again, the incision discussion is inadequate. Conn Creek's incision is likely a "hungry water" effect of the construction of Conn Dam.

IV A ES-14 The pool filling in Carneros Creek (two of the three sites mentioned) will be studied as part of the Carneros Creek Stewardship's characterization of the state of the watershed.

IV A ES-15 My calculations using Dr. Charles Dewberry's preliminary snorkel survey compared to the 1969 Anderson date reveal no change in juvenile fish numbers between the late 1960's and 2001, although I was unable to determine how large the "nursery " areas were in each report. (There is only year 2001 data available from the snorkel surveys.) This comparison needs to be done in more detail as soon as the 2002 data are available. There also needs to be some discussion of the effect of ocean conditions on salmonid abundance. It is not my intention to downplay the deleterious effect of anthropogenic change in the watershed, but much research points to the importance of the Pacific Decadal Oscillation to salmon and steelhead. (Taylor, G.H and C. Southards. 1997. Long-term Climate Trends and Salmon Population. Oregon State University Report on Climate and Salmon; Mantua, N.J. et al., 1996 A Pacific interdecadal climate oscillation with impacts on salmon production. Bulletin of the American Meterological Society,78:1069-1079)

IV D ES-18 Again, the well data from DWR need to be scrutinized, in addition to other sources of well data that may be volunteered by private landowners. Most permits for diversion have a diversion requirement and a season for diversion. Perhaps in future, each tributary needs an automatic gage accessible by telephone (Carneros Creek now has one) to insure adequate bypass flows. In addition, 2000-01 was a low rainfall year, so additional survey work is needed, as the report acknowledges.

A great deal of work on salmon and steelhead restoration is being done in the North Coast. No reference to this work is made in the draft. It would make more sense to integrate the efforts in the Napa River with work done in other watersheds. I was impressed by the amount of work on water temperature in the Garcia and Navarro drainages. There is no place for the luxury of re-inventing the wheel.

All of us at Saintsbury look forward to working with other stakeholders to help the Napa River in its restoration. This report is an essential step along the way.

Sincerely yours,

David Graves
General Partner
Saintsbury

From: <Jones.Paul@epamail.epa.gov>
To: Michael Napolitano <MBN@rb2.swrcb.ca.gov>
Date: 4/24/02 1:47PM
Subject: Napa River Basin Limiting Factors Analysis Executive Summary

Mike: both Diane and I have looked over the summary. We both think the report does a good job of saying what additional studies are necessary for Phase II. However, one of the big ticket items that I think is missing concerns the original issue we said would be addressed by this Phase I study, namely whether or not the listing is warranted (by answering the question "is the Napa River impaired by sediment?"). You and I made promises to lots of folks in Napa in those early presentations on the TMDL process that this would be the first question we would address. If it's in there, it's not apparent to me. I strongly recommend that you bring this out in the full report or any future revisions to the ES. And I would recommend that we talk about your answer to that question before it hits the street (as we already discussed). I can't offer an explanation as to why I overlooked this before when I was reviewing the draft, except to say that the conclusion section wasn't finished and I expected it to rise to the surface therein.

Also, we are not sure the report clearly answers the three questions on page ES-1 about: 1) the primary factors causing the decline of native fish; 2) how important sediment is in causing the declines, and 3) what actions are needed to conserve or restore the target species (beyond the general actions listed toward the end of each section). For question 2, for example, both the discussion and synthesis section and the recommendation section contain few direct references to sediment so as to warrant listing, and when you do, it's in the context of recommending future studies (e.g., under steelhead and sources of fine sediment or under gravel permeability and needing a detailed sediment budget).

Our overall general comment would be to: 1) clarify this issue of accepting or rejecting the sediment listing; and 2) clarify the answers to these three questions at the end of the document, addressing them one at a time, so that the reader can fully understand the implications of the report.

Paul

Paul Jones
US Environmental Protection Agency
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CC: <Fleck.Diane@epamail.epa.gov>, Bruce Orr <bruce@stillwatersci.com>

From: "Bernhard E Krevet" <krevet@attglobal.net>
To: "Michael Napolitano" <MBN@rb2.swrcb.ca.gov>
Date: 5/28/02 2:39AM
Subject: Re: Fwd: Last call for comments on Draft Napa River limiting factors report

Dear Mike,
I have read the executive summary and made both the summary and the detailed report available to FONR members. While we have not been able to compile a detailed analysis and feedback, Friends of the Napa River share the concerns expressed in the report. It appears that the aquatic conditions of the Napa River are worst than assumed and that fish passage barriers (in the tributaries), loss of riparian areas, incisions and sedimentation are key factors in the decline of fish habitat. This is particularly worrisome in the mainstem Napa River with the loss of floodplain throughout most of its length.

We encourage and support continuing studies and mapping of the current conditions. As you know, FONR is sponsoring several studies (e.g. Macroinvertebrate sampling, Fish Counts, Historical Ecology) using scientific methods recommended in the TMDL study. We believe the finding of these studies complement your findings and we recommend to include (reference to) them in the Final Report and in future Phase II studies.

We hope that, while further study is indicated, your recommendations to act quickly to improve the habitat limiting factors will be followed. Reduced run-off (sediment delivery), improved water use, removal of fish passage barriers, increasing retention of spawning gravel by adding large woody debris, to name a few of your recommendations, look like win-win proposals to improve fish and wildlife habitat while being economically feasible.

Thanks for your efforts to help protecting and restoring our River!
Bernhard Krevet.
707-254-9424

On Mon, 27 May 2002 14:48:19 -0700, Michael Napolitano wrote:

>Dear Bernhard, Clayton, Jeff, Karen, and Tyler:
>
>Any general or specific comments or feedback you would like to provide about the study would be very much appreciated. We will do our best to consider comments received before 10 AM tomorrow.
>
>Best regards,
>
>Mike Napolitano
>510-622-2397
>

CC: "FONR Board (bcc), FONR" <Napariv@aol.com>

NAPA COUNTY

DEPARTMENT OF PUBLIC WORKS

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ROBERT J. PETERSON
Director of Public Works
County Surveyor-County Engineer
Road Commissioner

June 10, 2002

Mr. Michael B. Napolitano
San Francisco Bay Water Quality Control Board
1515 Clay Street, Suite 1400
Oakland, CA 94612

RE: Draft Napa River Basin Limiting Factors Analysis

Dear Mr. Napolitano:

The Napa County Conservation, Development, and Planning Department and this Department are pleased to present to you our comments on the April 17, 2002 Draft Napa River Basin Limiting Factors Analysis released by the San Francisco Bay Water Quality Control Board.

In Napa County, science provides an important foundation for public policy. As you are aware, we have embarked on an extensive collaborative program to evaluate the Napa River watershed, and the limiting factors affecting our anadromous salmonids. Watershed management is a serious issue in Napa County, and demands a serious and well thought-out response. Therefore, we would recommend that the draft technical report be subjected to a rigorous technical peer review. The resulting comprehensive assessment would position your agency and ours to better formulate study plans, funding requests, and policy recommendations.

As you know, the Board of Supervisors recently created a Conservancy-Watershed Information Center Board and a Technical Advisory Committee to deal with watershed education, protection and management issues. With your concurrence, we would place the draft technical report before this Board and its technical advisory committee as their first order of business. We would like to be a partner in strengthening the draft technical report and believe that this would help us to achieve that goal.

We feel that the results of a peer review of this nature would better introduce the report to Napa County, including the various groups and stakeholders now active in the community. In that way, we could proceed from a draft technical report to a blueprint for focusing on and solving resource specific issues within our watershed.

Please feel free to contact me at 707.259.8179, if you have any questions.

Sincerely,

JON LANDER, PE
Principal Engineer

AND

PATRICK LOWE
Deputy Planning Director/Watershed Coordinator

CC: Charles Wilson
Bob Peterson

From: leidy.robert@epamail.epa.gov
Sent: Monday, May 20, 2002 11:48 AM
To: Michael Napolitano
Subject: Re: Napa River report questions!!!

Hi Mike,

I am sitting down to review your impressive report on the Napa River in the hopes of meeting your short deadline. I have an initial question regarding historical distributions of salmonids that may help my review. First, Section 3.4 (Fish Community Composition) suggests that the Napa River may have supported a "large run" of chinook salmon. I remember you asking me about chinook in the Npa River some time back. This statement appears to be based largely on habitat comparisons between the Napa River and Sonoma creeks, oral history interviews, and an unpublished report from the Sonoma Ecology Center. I do not doubt that the Napa River historically supported chinook salmon, but I am wondering about the basis of the information used to conclude that large runs may have been present. I would recommend that at a minimum the type and reliability of the references supporting this statement should be laid out in more detail. Otherwise, I'm afraid you may be open to criticism from some groups, especially since chinook salmon is one of analysis species. An alternative approach would be to emphasize that while chinook salmon were likely an historical component of the system, the more important aspect is that the species is here now in seemingly increasing numbers and likely will persist. (As an aside, I am not aware of any compelling data for the presence of a run of chinook salmon in Sonoma Creek either, but I admit I have not seen the Sonoma Ecology Center information. I am generally very suspect of anecdotal information on salmonid runs, especially when trying to distinguish differences between three species of salmon).

Second, in the same section of the report there is a statement that historically the Napa River is estimated to have supported a run of 2,000-4,000 coho salmon. There is no reference following this statement. I would be very interested in knowing what type of information is available to support this estimate. Is it the USFWS
(1968) report or Anderson (1969)? If so, what was their estimate based on? I am a little nervous about the coho estimate (although, again, I do not doubt that coho historically occurred in the Napa River), given that I am not personally aware of any compelling data verifying the existence of a run. On a related matter, I and others at CEMR in Oakland, are just about finished with an historical review of the status of coho salmon in the estuary, and we cannot find any reliable references for the Napa River or Sonoma Creek. Maybe you can help us out here?

I would be very interested in getting copies of the USFWS(1968) and Anderson (1969) reports, as well as the Sonoma Creek Ecology Center report. I may already have copies of the former two reports but I just moved and can't seem to locate them! If you could send them via fax (415-947-3537),or electronically to this address that would be great. These reports will help me in my review for the Napa report and in my research as well.

Please get back to me ASAP so I can factor in your views into my review. Thanks again for your great work!

Best,

Rob

ph: 415-972-3463

May 24, 2002

San Francisco Bay Water Quality Control Board
Attention: Mr. Michael Napolitano
1515 Clay Street, 14th Floor
Oakland, CA 94612

Subject: Comments on the Draft Napa River Basin Limiting Factors Analysis

Dear Mr. Napolitano:

I recently had the opportunity to review the subject document that is posted on the San Francisco Regional Water Quality Control Board web site. I found the document to be very detailed and informative.

I am a resident of Napa County and live in the vicinity of Carneros Creek. I am also a California Registered Geologist and California Certified Hydrogeologist with 18 years experience. As part of my graduate research at the Department of Hydrology and Water Resources at the University of Arizona, Tucson, I evaluated aquifer-stream interaction on the Carmel River, California. My research was in part funded by the Monterey Peninsula Water Management District, which at that time was trying to assess the impact of groundwater pumping in the alluvial aquifer in Carmel Valley and the potential effect on the discharge of the Carmel River. The District was particularly interested in the potential impact of pumping from wells on the aquatic habitat and riparian vegetation along the banks of the river. With this background, I offer my comments as follows:

Appendix C: Description of Proposed Phase II Studies

Process-Based Assessment of Potential Physical Factors Limiting Abundance of Analysis Species: Baseflow reduction and hydrograph change; third paragraph.

In this paragraph, there is mention of conducting surface flow surveys in spring, summer, and fall to evaluate the long-term trends in seasonal variability of surface flow. There is also mention that such effort would be combined with more intensive efforts to monitor groundwater elevation relative to local streambed elevation (surface discharge) by installing continuous recording water-level gauges at key sites.

My comments are as follows:

1) Understanding the contribution from base flow to a stream's discharge, that is whether a stream is "gaining" or "losing" along a particular reach, is crucial information for determining the degree of interaction and hydraulic connection between a stream and the subsurface strata containing the stream channel. On creeks that have upstream impoundments, contributions from base flow are particularly important during the late spring and summer months in order to sustain riparian vegetation and aquatic habitats.

However, the proposed Phase II studies make no mention of the process by which the creeks identified (e.g. Carneros, Dry, Ritchy, Soda, and Sulfur), will be studied to determine their gaining/losing (influent/effluent) character. The document mentions the installation of continuous recording water-level gauges at key sites, but unless there are several of these gauges (perhaps 5 to 7 gauging stations along each creek), a single gauge will only show whether the flow of the creek is increasing or decreasing at that particular location. Additionally, continuous recording gauging stations that utilize strip chart recorders and calculate flow based on stage-discharge relations tend to be less accurate at low flow conditions.

A far better method to determine the influent/effluent character of a creek would be to conduct synoptic discharge measurements in accordance with established procedures by the USGS (Buchanan and Somers, 1969; Riggs, 1972). This type of stream gauging requires the use of a Price AA or pygmy current meter to measure stream flow at increments along the cross-sectional area of the creek. Where the creek channel is fairly uniform (e.g. sandy and gravely locations) the accuracy of this method is probably 5% or better.

I would suggest that current meters be made available to stewardship groups so that trained volunteers could participate in stream flow monitoring programs. Stream flow monitoring would need to be conducted repeatedly, on a monthly or seasonal basis, at several predetermined locations along a creek. The data collected would then be compiled into hydrographs showing discharge versus distance from the mouth of the creek for each location that the discharge data was collected. A similar study by Kondolf et. al. (1987), utilized the same approach for quantifying base flow contributions on the Carmel River in respect to its effect on sustaining the riparian habitat.

2) In regard to "…intensive efforts to monitor groundwater elevation relative to local streambed elevation (surface discharge)…" I would suggest that care be given in selecting the wells to be monitored. The wells that are monitored should be inactive and represent a range of: (1) depths of penetration into the aquifer; and (2) distances from the creek channel.

However, it is important to consider that wells near a creek may penetrate a confined aquifer, an unconfined aquifer, or multiple confined and unconfined aquifers, and therefore the groundwater elevation map that is compiled from the monitoring data may be of limited use with regard to creek elevation. For example, in the lower reach of Carneros Creek the aquifer is confined, and the elevations of water levels measured in the wells in that area represent a potentiometric surface. Although the elevation of this potentiometric surface is similar to the elevation of the bottom of the creek channel, it is unlikely that the groundwater and surface water are hydraulically connected. This may or may not be the case in the upper reaches of Carneros Creek. Hence, the proposed Phase II studies should acknowledge the potential variation in aquifer systems in the vicinity of creeks and recognize that elevation monitoring of groundwater and stream flow may or may not be valid for characterizing base flow contributions.

Please don't hesitate to contact me (707) 322-3058 if you have any questions regarding my comments.

Sincerely,

Linda M. McGlochlin RG, CHG
P.O. Box 10403
Napa, CA 94581

References:

Buchanan, T. J. and W.P. Sommers. 1969. Discharge measurements at gaging stations. Tech. Water Resour. Invest. U.S. Geol. Surv., book 3, chapter A8.

Kondolf, G.M., L.M. Maloney, and J.G. Williams. 1987. Effects of Bank Storage and Well Pumping on Base Flow, Carmel River, Monterey County, California. Journal of Hydrology 91, 351-369.

Riggs, H.C., 1972. Low-flow investigations, Tech. Water Resource. Invest. U.S. Geol. Surv., book 4, chapter B1.

San Francisco Estuary Institute

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May 21st, 2002

To: Mike Napolitano
From: Lester McKee, Robin Grossinger, and Sarah Newland
Subject: Comments on Stillwater's Draft

Dear Mike,

Please find below comments from members of the watershed program staff at SFEI. We remain open to discussion with you and staff of Stillwater Sciences either on more specific details on these comments or on aspects of our own projects in the Napa River watershed and how we can work synergistically to improve management in Napa and other watersheds of the Bay Area.

Sincerely
Lester McKee Ph.D.
Watershed Program Manager

<u>Comments from Lester McKee, SFEI</u>

We would like to see some text inserted into the document that addresses the following general comments and therefore set up some hypotheses and objectives that need to be addressed in the next phase of TMDL work in Napa and in the future in other listed streams of the Bay Area. We add, without reservation, that none of us are fish biologists. We approach the report from a physical and landscape science perspective.

The main comments I wish to make relate to the assumptions that are implicit in the report yet are not well addressed either through comprehensive literature review or empirical data collection.

Assumption: Changes in fish populations in the Napa River are a result of human modifications to the watershed and these can be addressed through the development of sound management strategies.

There are references to general declines in fish populations in California and Napa over the past 50 or so years. Do those declines occur in all watersheds of California? If not, why not? Are populations of rainbow trout in pristine watersheds declining as well? If so, what does that suggest about the causes of decline in other watersheds?

1. Is there any world literature that suggests that fish populations can go through periods of high population and periods of low population for natural reasons such as disease, competition, periodic or cyclic habitat changes?
2. The document does not address the alternative hypothesis that much of the change in fish population could be caused by periodic changes in climate and associated changes in channel form and riparian function.

Assumption: Climate does not influence fish populations in Napa: We know that the Bay Area (and California) undergoes periods of consecutive drought dominated years at the decadal time scale. Luna Leopold suggests on page 9 of his book that the rivers of western United States can go through periods of healing and periods of rapid change associated with climate. Inman and Jenkins 1999 (J. Geol V.107) discuss climatic effects on sediment fluxes in California Coastal Rivers. Is it possible that the populations of fish in the Napa were abnormally high during the 1940-60s due to plenty of complex habitat on the mainstem during a drought-dominated period (a period of healing and channel vegetation development)? Subsequently during the flood-dominated period of channel incision that has apparently followed, the channels have simplified and incised (perhaps because of climate rather than human encroachment – i.e. humans may have taken advantage of channel simplifications rather than actively causing them). It is possible that you have data and observations that can reject climatic factors outright, otherwise it will be necessary to determine in the next phase what proportion of impact is associated with climate changes relative to anthropogenic influences and how natural and climatic changes cause periodic fluctuations in habitat and fish populations. Human influences can be managed to an extent at the local level, climate cannot.

The longest running climatic record in the Bay Area is that of San Francisco (back to 1850). That record can be obtained from Jan Null, Golden Gate Weather Services. I am certain that it could be used to extrapolate Napa's climatic record back to 1850 so that the limiting factors analysis and geomorphology of the watershed can be placed in a longer-term climatic context. Furthermore, tree ring data can be used to construct climatic records back further (see for example Meko et al. 2001: J. American Water Res. Assoc. V37). In addition, SFEI is working with groups in Napa using tree ring analysis for various purposes in relation to vegetation pattern reconstruction and climatic reconstruction – Robin Grossinger can provide further discussion.

<u>Comments from Robin Grossinger, SFEI</u>

Thanks for the opportunity to review the report. Following are several brief comments, which we would be happy to discuss further at your convenience. In general, my comments focus on the analysis of historical landscape change presented in the report. This analysis is described as a limited effort in the Introduction; we would concur and would strongly suggest that a more robust analysis be conducted before specific recommendations about the system are developed in phase 2. We provide some recommendations in this regard below. These are based specifically on our experiences in the ongoing Napa Watershed Historical Ecology Project and, generally, in our experiences with historical analysis in the Bay Area and western United States.

1. Historical Data Set. The report infers major historical changes in the characteristics of the mainstem channel of Napa River and its tributaries. These are central to its conclusions, but based upon a very limited data set. No documents from the Spanish era, early American settlement, or even prior to 1940 are utilized, despite the presence of an extensive historical record in this region. This results in a difficult and not well-explained extrapolation of relatively recent historical data to represent pre-European conditions, with no substantive analysis of the potential impacts of over a century of intensive European land use and climatic variation on these data. A much broader data set is needed to make well-defensible conclusions about the nature and causes of landscape changes during this complex period.
2. Land Use. For example, pre European characteristics of the channel network are based almost exclusively upon 1940 aerial photographs. While this is a convenient data source to obtain, it reflects over a century of intensive European land use. With the use of earlier documents, the significant changes can be determined. Without this information, much of the geomorphic process evidenced in the 1940 photography is overlooked. For example, in Figure 6-1b, 1940 photograph actually reflects the recent reposition of soda Creeks Junction with Napa River by over two miles, and a likely high flow channel is actually visible in the upper photograph and in part in the modern photograph in the form of an agricultural pond made from the old channel. Similarly, substantial speculations are made about the Junction of dried Creek and Napa River in figure 6-1c, including the probable location of the former main channel. In fact, mid-19th century historical documents, including legal testimony by local surveyors, described this area as a broad tule marsh, specifically noting the absence of a clear channel. Also in this area, several tributaries with relatively straight lower reaches can be seen. We're finding evidence that these, and many of the tributaries did not actually maintain channel connections to the mainstem, instead flowing into seasonal wetlands. This major change to channel morphology, which actually increases the amount of low gradient channel, and would significantly alter the delivery of water and sediment to the mainstem, has taken place in large part by 1940 and thus is not addressed at all in the report.

In both of these examples, the figure captions provide some speculation about land use effects but no actual investigation or analysis. It may be argued that a more detailed level of interpretation and analysis is required for subsequent efforts. However, the sum total of data-limited analyses throughout the watershed, such as the ones examined here, potentially raises questions about the overall depth of understanding of the relationship between land use, climate, and physical process within the watershed.

<u>Comments from Sarah Newland, SFEI</u>

I think there is a typo on page 6. "The flood of record at the St. Helena gauge between 1929 and 1996 was 16,900 cfs in February 1987." Should that be 1986?

In Section 3.2.2 The Valley Floor and Alluvial Fans, would it be appropriate to site: Sowers, J.M., Noller, J.S., and Lettis, W.R., 1998. Quaternary geology and liquefaction susceptibility, Napa, California 1:100,000 quadrangle; a digital database. U.S. Geological Survey Open File Report OF 98-0460. 12 p.

We collected detailed data on the geomorphology of Soda Creek. Our data can be used to help refine the observations made on the larger Napa River system. We found:

- The channel morphology of Soda Creek closely matches Stillwater's findings on page 11. In Soda Creek, reaches with slopes up to 0.14 were dominated by large boulders, and the channel tended to be step-pool and cascade morphology. Reaches with slopes between 0.02 and 0.10 tended to be step-pool, and were also dominated by boulders and bedrock. Finally, reaches with slopes between 0.008 and 0.02 were pool-riffle or plane bed, with much smaller grain sizes.
- LWD did not play a large role in Soda Creek. In the 18% of the total channel length where detailed LWD data was collected, only 8 pieces of LWD were forming or were associated with a pool. However, many live standing trees within the bankfull channel were helping to shape the morphology of the channel. With the exception of 2 reaches, the riparian vegetation is fairly continuous, providing shade and a source of LWD recruitment.
- Grain size data for each reach downstream of a natural fish migration barrier (Soda Canyon Falls) show that D50 ranges between 32 and 79 mm, well within the published steelhead preferred spawning gravel size range. We found many small patches of finer grains were deposited along the edges of the channel, in pools, or in the wake of large boulders. Also, fine gravel was often deposited between the larger cobbles in these reaches. Although Soda Creek does not produce unusually large amounts of sediment, we do not believe that the quantity of spawning gravel is a limiting factor. We are planning on collecting bulk sediment samples this summer to help assess the quality of these spawning gravels.
- Downstream of the fish migration barrier, we measured 33 pools, with the majority larger than 4 m^3. These pools were primarily lateral scour pools, step-pools, and main channel pools. In Soda Creek, the pools with the greatest residual pool depth were located in reaches with slopes ranging from 0.02 to 0.04. Although we did observe sediment deposits in some pools, pool filling by fine sediment does not appear to be a severe problem in Soda Creek, mostly because of the geology of the watershed, and the low intensity landuse within the basin.
- Ephemeral flow conditions limit salmonid migration and habitat. The lower and middle alluvial fan portions of Soda Creek dry up, usually by June. This limits out migration by spawned out adults and juveniles. The lack of flow also limits summer rearing habitat to a small reach of channel immediately downstream of the fish migration barrier, which is fed by groundwater flow upstream of this location.

- We have only come across one second-hand source that said that Soda Creek used to flow continuously throughout the summer. All evidence since the 1940's and 1950's suggest that the drying of Soda Creek occurs annually. However, we are working with the hypothesis that a localized reach in the middle alluvial fan dries up much more rapidly because of a wedge of sediment associated with possible channel modification and the emplacement of grade control associated with an old masonry bridge. Other tributaries could be prone to this same process, thus affecting salmonid migration.
- Like many other tributaries to the Napa River, Soda Creek is highly entrenched in its lowest reaches. The lowest 800 m of channel (downstream of Silverado Trail) is experiencing the most bank erosion and bar deposition of any reach. The concrete culvert underneath Silverado Trail provides grade control upstream of this reach.

These observations on Soda Creek may help in the assessment of other tributaries to the Napa River, and may provide some suggestions for future studies. During 2002, SFEI will finish fieldwork in Soda and move efforts to the study of Sulphur and Carneros Creeks. The data will be made available for the TMDL effort as per our verbal and contractual agreements. We remain open to suggestions on modifications to our study design.

NAPA COUNTY
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P.O. Box 644, Napa, CA 94559-0644

May 21, 2002

Michael B. Napolitano
Associate Engineering Geologist
Regional Water Quality Control Board
1515 Clay Street, 14th Floor
Oakland, Calif. 94612

Comments on the Napa River Basin Limiting Factors Analysis

I) Sediment –Related Impacts

1) Pool Filling-The initial study found that pool filling with fine sediments did not appear to be substantial in the watershed. Some creeks did have some evidence of substantial pool filling and a recommendation for further study was suggested. What depth of study is recommended, should all tributaries be surveyed for pool filling and then those that show substantial pool filling be further studied for sources of fine sediment?

   Since only 17 tributaries were studied shouldn't this be in context to the total number of named tributaries being 53 named tributaries on the USGS maps? Pools we found during the benthic survey and the fish survey show significant sediment in pools. This statement in the Executive Summary seems limited. Such as Rector above the dam, Hopper, Dry at the alluvial plan and Bell as examples. Are you going to survey above dams for infilling of pools?

2) Turbidity-The study of turbidity was done to determine if turbidity affected the feeding opportunities. It was found that turbidity did not pose a significant limitation to feeding by steelhead based on the current study. Many people

have interpreted the turbidity study to indicate that sediment is not a problem in the Napa River System.

Turbidity was sampled at six locations on the main stem of the Napa River, Tubbs Road, Deer Park, Zinfandel Lane, Yountville Cross Rd., Oak Knoll Rd. and Trancas. The third storm event in Feb of 2001 shows the river flow rate elevated above 250 cfs at St. Helena for 7 to 8 days. The turbidity was sampled on the recession limb of the hydrograph. This storm event shows five peaks in the flow over the 8-day period, which means that five rain events passed through the region during this period. Table A7-1 shows three samples for the Feb 25th storm, the plots show four samples please clarify? The turbidity at Tubbs Road did not exceed the 20 ntu threshold and only the peak exceeded the threshold at Deer Park Road. At the other four locations it appears that the turbidity would have been over the 20 ntu threshold for the 8 day storm event period. If the turbidity exceeds the 20 ntu threshold for seven to eight days does this become a significant factor for fish feeding in the main stem of the Napa River down stream of Zinfandel Lane? If a series of storm events over a two week period or more would keep the turbidity elevated above 20 ntu would this become a significant factor?

Another effect that is apparent in the turbidity plots of Figure A7-1 and A7-2 is that the turbidity increases as the sample points move down the main stem of the river. The slope of the plot of turbidity verses discharge increases as the sample points move down the main stem. This seems to indicate the sediment loading into the main stem increases as the river flows down through the valley. What is the significant of this fact? How does it relate to the land uses on the valley floor since the valley floor widens down stream of Zinfandel Lane and there are no urban areas on the valley floor between Zinfandel Lane and Trancas except for the Town of Yountville?

Is turbidity in the main stem a problem for migrating and foraging fish? Turbidity in the main stem appears to be significant as the locals observe thick muddy water in the river at Napa and Trancas. It appears that Napa Creek brings into the main stem significantly turbid water from the west side. Results and discussions on page 50 relate emaciated fish to lack of food. However, could it also be that the water quality is poor causing weakened fish that are not feeding properly or utilizing their food properly? First year benthic macro invertebrate sampling indicates that food supply is probably adequate for most streams.

3) Gravel Permeability-The study indicated that sediment causing low permeability in the gravel beds was reducing fry survival to about 50 percent. The study recommended that no increase in sediment delivery to the Napa River System and preferably there should be a reduced sediment delivery. Local government officials have made statements during public hearings that since the turbidity was determined to not be a problem then they also believe that sediment flow into the river system is not a problem. There needs to be a

condensed summary that clearly states the factors identified as limiting and not limiting in a table format, which also includes recommended actions for the factors identified as limiting. This may help to prevent misinterpretation of the study. Doesn't this statement relate to the tributaries and not the main stem. This needs to be addressed more fully. Will the TMDLs address turbidity in the main stem of the Napa River.

4) Bed Mobility-It was found that gravel bars in the main stem would be subject to scour, which would reduce the survival of fry. The tributary beds were more stable and there was no predicted increase in bed mobility. It was recommended to add large woody debris to the tributaries to increase retention of spawning gravel and promote pool formation. There was no recommendation for stabilizing the gravel bars in the main stem. What actions can be taken on the main stem to increase spawning gravel bars and to stabilize these bars?

   TMDL's are supposed to recommend remedies that are feasible. Recovery of the main stem is feasible since vines/agriculture can me moved or phased back to allow for restoration. This appears critical in the case of Chinook Salmon. Shouldn't the TMDL process step up to the problem since we have no other resource to help with this situation? The TMDL has taken too long to get going and the Chinook Salmon habitats are critically diminished . The TMDL seem to give up on the situation and take a fatalistic view on recovery of this species. Can you do more in the second phase to make recommendations that will help recover Chinook habitats? The stakeholders want Salmon in the river. This TMDL will set the pace for other rivers. If you set the bar too low then it becomes the standard. We want high achievable standards that are feasible. Removing vines is feasible and that is what we are talking about doing. We want to give back where we took too much. The EPA and the SWQCB can get us going in the right direction.

   Dr. Luna Leopold did a velocity study through the RCD on the Napa River and he stated that increased rate of flow was causing stream and riverbank instability. This was causing the river to become unstable. This is not discussed in this TMDL executive summary. It appears that increased flows are barely discussed. Dr. Leopold hypothesized that hillside deforestation have caused increased rate of runoff and have altered the hydrograph/peak flows of the Napa River

II) Fish Migration Barriers

1) Structural Fish Passage Barriers-The study identified a number of potential man made barriers; road stream crossings (400 sites), large dams (5), and small lakes or reservoirs (220) that overlap tributary channels. The California Environmental Quality Act (CEQA) has been in effect for the last 25 years. The State Water Resources Control Board is supposed to review water

diversions for environmental impacts under CEQA. Many of the small reservoirs would have been constructed in the past 25 years. CEQA review should have been done for these small reservoirs and the water diversions they represent by the State Water Resources Control board for impacts that would effect fish. Has the State Water Resources Control Board adequately reviewed water diversions and in stream dams to protect the steelhead habit? The TMDL's should be recommending inter-agency coordination and cooperation. The SWB must be involved when it comes to water diversion.

2) Flow-related Barriers-Many of the tributaries of the Napa River have a large number of water diversions, such as Murphy Creek. This has resulted in a lowered flow rate in the last ten years on many of these tributaries. Carneros Creek and Huicihia Creek have probably been over allocated for water diversions. Why has the CEQA review not protected fish habit from water diversions allowed by the State Water Resources Control Board?

III) Nutrient and Pathogen are pollutants listed as impairing the Napa River. This study has not addressed this. When it comes to nutrient loading of the river we are seeing deleterious conditions occurring to the river. This study must address this limiting factor. Could the effects of fertilizers be causing the fish to be underweight? The executive summary states that the smolts are underweight and this water chemistry is not being discussed or evaluated. Pathogens should be discussed as well. Why is the TMDL process leaving this important pollutants out of the process of evaluation?

IV) Other of concern and comments:

1. Why isn't salt-water intrusion into the Napa River main stem being addressed in context to water diversion and ground water extraction?
2. On page 11 of the Executive Summary it states that *the dominant vegetation in the valley floor terrain is an agricultural crop, orchards and vineyards.* A more accurate statement would be: the dominant vegetation in the valley floor is vineyards and some orchards and row crops.
3. On page 16 Sarco and Suscol creeks had medium steelhead counts. Suscol creek is the only creek that had steelhead on the valley floor.
4. According the Dr. Dewberry, historically Steelhead was found in all reaches of the River system suggesting that this species is plastic including main stem. The Executive Summary is not clear about this.
5. Page 29 Salmonid Adult Upstream Migration: Rector Creek and Conn Creek have been completely dewatered during the summer months due to no water being released from the dams.
6. Page 41, 3rd paragraph, last sentence *indicating that the bed has potentially coarsened and fines have infiltrated through the immobile surface layer.* (tributary or mainstem?)
7. Page 55 first paragraph: *smaller since the mainstem provided only a small portion of the potential spawning and rearing habitat historically present in*

the basin. Dr. Dewberry states that Steelhead are found to be plastic and that their range of habitats are highly varied. The valley floor could have been viable habitats.

8. Executive summary does not discuss what the fate of the Napa River and related streams will be if remedies are not implemented.
9. The Executive Summary fails to put an economic valuation on natural resources and what this will cost us financially when the riparian resource is gone. Dismissal of the Chinook situation due to cost etc. is to quickly done and should not be eliminated from vigorous recovery planning that is feasible. When human monetary needs are put above natural resource recovery and species importance it become inequitable and not sustainable or hopeful. The people who care about delisting of the river from the impaired status expect a high standard of recovery for the watershed. Alternative strategies that are dismissed here should be listed and explained.

Sincerely,

Chris Malan

Chris Malan

Irving E. Thomas

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To: "'mbn@rb2.swrcb.ca.gov'" <mbn@rb2.swrcb.ca.gov>
Date: 5/1/02 1:46PM
Subject: Napa report edits

Hi Mike,

I just read through the Napa River Limiting Factors Analysis and found two errors in reference to Pierce's disease and riparian management strategies. The insect mentioned in the text is the glassy-winged sharpshooter. That insect is not present in Napa County (and there are considerable efforts being made to keep it out!) The bug we do have that is the one spreading PD from riparian zones to vineyards is the blue-green sharpshooter.

So, on pages ES-22 and ES-30, replace "glassy-winged sharpshooter (Homalodisca coagualta)" with "blue-green sharpshooter (Graphocephala atropunctata)".

Let me know if you have any questions.

Ed

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