Lower Klamath River Sub-Basin Watershed Restoration Plan

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I. Introduction

The Yurok People have inhabited the lands of and sustained themselves upon the resources of the Klamath River for centuries. They were probably the first "commercial" fishermen in the region as they sometimes traded their surplus catch, as well as fishing rights and territory, for needed supplies and regalia. Indeed, the Tribe's entire culture is largely based upon the Klamath River and its associated fish populations.

The Yurok Tribe is the largest aboriginal tribe in the state of California, with approximately 4,000 enrolled members. The Yurok people are amongst the few aboriginal inhabitants in California with a land base. The Tribe's ancestral lands make up an area of approximately 320,000 acres. What is now the Yurok Indian Reservation was created by federal actions between 1853 and 1891. The Reservation encompasses a strip of land one mile wide on each side of the Klamath River, from just upstream of its confluence with the Trinity River at Weitchpec, California, to its mouth at the Pacific Ocean.

At this time, 5,090 acres of the 59,000-acre Yurok Reservation are held in trust status. Simpson Timber Company owns more than 85% of the land within the boundaries of the reservation, as well as the surrounding ancestral lands. A smaller portion of the Reservation consists of public lands managed by Redwood National/State Parks, the U.S. Forest Service (USFS), the Bureau of Land Management (BLM), and a few other private landholdings.

Today, only a fraction of historic anadromous fish runs return to spawn in the Klamath River and its tributaries. Although many factors have contributed to these declines in native fish runs, degradation of freshwater habitat has been pervasive in the Klamath River Basin. Kier and Associates (1991) note that "the fish habitats of the basin have been greatly diminished in extent and value in the past century by the construction of impassable dams and by stream diversions and sand and silt from mining, logging, grazing, road development, and floods."

The declining health and productivity of the Klamath River's anadromous fisheries is of great economic and cultural concern to the Yurok Tribe. To proactively address this decline, the Tribe has initiated a large-scale, coordinated watershed restoration effort in the Lower Klamath sub-basin. This sub-basin, as defined in the Klamath Restoration Program's Long Range Plan (Kier and Associates 1991), includes all Klamath tributaries downstream of the confluence of the Trinity River, encompassing a drainage area of approximately 450 square miles. The Long Range Plan states that, "the low number of anadromous salmonids in the Lower Klamath tributaries is directly related to sediment problems...Only changes in land use management and large scale watershed stabilization efforts can effectively address these problems and begin the process of recovery of the Lower Klamath tributaries" (Kier and Associates 1991).

The Lower Klamath Restoration Partnership (LKRP), composed of representatives of the Yurok Tribe Natural Resources Department, Simpson Timber Company, the California State Coastal Conservancy, and the Northern California Indian Development Council was formed in 1995. This Project Advisory Committee was formed in order to facilitate a coordinated approach to watershed restoration planning and to find innovative solutions to resource management issues between private landowners, Tribal interests, and public agencies. The Yurok Tribe is providing personnel, administration, planning, and logistical support for The Lower Klamath Restoration Partnership. The Yurok Tribal Fisheries Program and the Watershed Restoration Program will direct implementation of this restoration plan for the Lower Klamath River sub-basin. Simpson Timber Company will provide access to their Lower Klamath land holdings, heavy equipment support, materials and supplies, and financial and logistical support. The California Coastal Conservancy will facilitate the overall Lower Klamath River Restoration Program, providing funding for both planning and project implementation.

It is the goal of the Yurok Tribe to restore aquatic habitat conditions within Lower Klamath River tributaries to a level that supports viable, self-sustaining populations of native salmonids. These goals will be accomplished through treatment of road networks and upslope sediment sources, improvement of instream and riparian habitats, and through interaction with public and private landowners to implement improved long-term land management practices in the sub-basin. Specific goals of the Lower Klamath Sub-Basin Restoration Plan include:

- **Protect and restore existing healthy areas first**. Protection of key areas is much more certain and less expensive than the restoration of degraded areas. In addition, relatively healthy areas provide the source populations for recovery in other locations. On the other end of the spectrum are watersheds that have undergone extreme habitat degradation. These watersheds could absorb large amounts of money and effort with little chance of recovery in the foreseeable future. Restoration in these areas should be postponed until protection and restoration efforts are completed in areas that are more productive.

- **Improve stream/riparian habitat in priority watersheds**. A corollary to protection of "the best," is restoration of "adjunct" habitats that historically supported healthy fish populations but are currently lightly to moderately degraded. Efforts to improve watershed and aquatic conditions in these areas will likely aid fish populations in the long term.

- **Provide jobs training and quality employment opportunities**. Implementation of watershed restoration activities will provide long-term stable employment opportunities for qualified tribal applicants. Many of the potential long-term restoration activities, such as road de-commissioning, would involve technical skills requiring specialized training.

The Yurok Tribe will rely on sound scientific methods and principles to plan, implement, and monitor all watershed restoration activities within the Lower Klamath sub-basin. By adhering to this scientific approach, the restoration needs of the sub-basin will be addressed in a credible, prioritized manner. Only through such a systematic approach can the habitat needs of Lower Klamath salmonid populations be fully addressed and in turn the sub-basin restoration goals be met.

II. Current Watershed Conditions

A. Fisheries

Despite the extensive and on-going history of land management activities in the Lower Klamath sub-basin, historical data on physical and biological conditions within the Lower Klamath tributaries is virtually non-existent. In particular, at the time YTFP was formed, data on historic and current conditions of aquatic habitat and fish population status throughout the Lower Klamath were scarce. In addition, there was a significant data void in the lower Klamath River and its tributaries regarding water quality and hydrologic conditions and the relationship of these parameters to the various life history stages of native fish populations.

These baseline data are essential information in order to formulate and prioritize meaningful watershed restoration prescriptions. In addition, such data provide a means to evaluate implemented watershed restoration projects and assess long-term physical and biological trends. In order to address this lack of baseline data, YTFP formed the Habitat Assessment and Biological Monitoring Division (Hab/Bio Division) in 1995. This division's goal is to collect necessary data to assess current conditions within each of the fish-bearing Lower Klamath tributaries, as well as implement long-term monitoring projects to meet trend monitoring and project assessment needs.

In the five years since its inception, the Hab/Bio Division has completed numerous assessment projects and established several long-term monitoring programs throughout the Lower Klamath sub-basin (Figure 1). A detailed summary of these activities can be found in the Yurok Tribe's Strategic Natural Resource Management Plan (Yurok Tribe 2000). The collected data have provided YTFP staff with the means to assess current biological and physical habitat conditions across each of the fish-bearing Lower Klamath tributaries, providing vital information for the prioritization of each tributary for restoration activities.

1. Species Status, Distribution, and Trends

Beginning in 1996, the Hab/Bio Division initiated a multi-year inventory of fish species presence, distribution, and relative abundance throughout each of the Lower Klamath tributaries (Voight and Gale 1998; YTFP Unpublished Data 1997-1999). These inventories utilized snorkeling and electrofishing techniques to assess and monitor the presence, distribution and relative abundance of each salmonid species and age class throughout all portions of each Lower Klamath tributary. By revisiting each drainage on an annual basis throughout the study period, YTFP has not only been able to assess their status, but also document year-to-year variation and spatial use trends for all species and age classes present.

In addition to these inventories, the Hab/Bio Division has been conducting ongoing salmonid outmigrant trapping in Blue, Hunter, and McGarvey Creeks beginning in 1995 (Gale et al. 1999; Hayden and Gale 1999; White et al. 2000; YTFP Unpublished Data

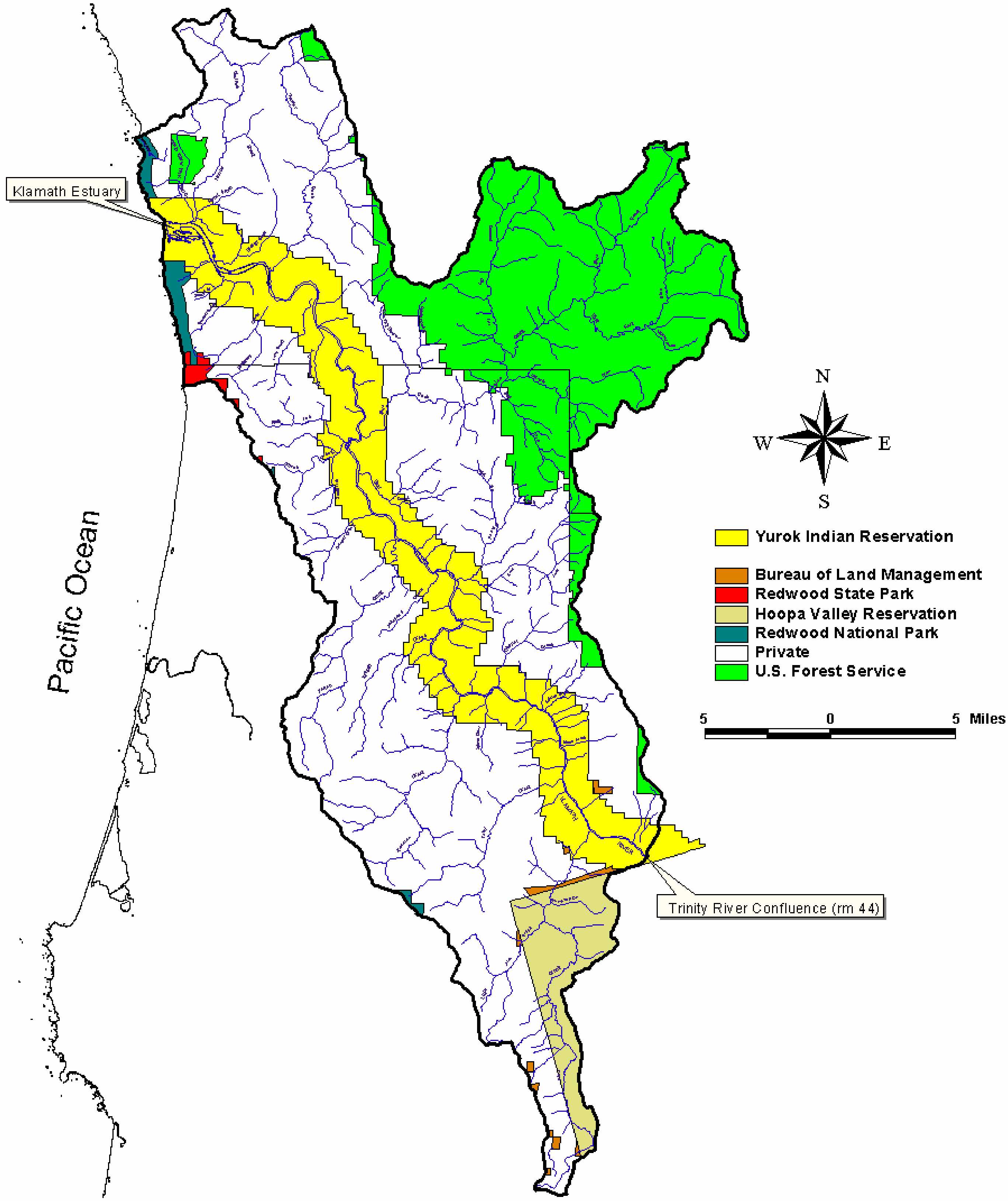


Figure 1. Lower Klamath River Sub-basin, California.

1997-1999). The Hab/Bio Division has also continuously conducted salmonid spawning ground surveys throughout several Lower Klamath tributaries beginning in 1994 (Gale et al. 1998; Voight 1998a; YTFP Unpublished Data 1995-1999). All of these activities have enhanced our knowledge and understanding of fish species status and distribution in the Lower Klamath sub-basin.

A summary of aquatic species presence for each of the inventoried Lower Klamath tributaries is located in Table 1. It should be noted that given the qualitative nature of the fish species inventories, the failure to observe a species in a given tributary does not confirm absence from that particular drainage. In some cases, species may utilize a portion of a tributary that did not receive sampling, and/or a species may utilize a tributary at a time of the year when sampling did not occur. In cases where YTFP has suspected that selected species may have been missed due to such reasons, efforts have been made to expand sampling both spatially and temporally during subsequent sampling seasons. Additionally, it should be noted that presence refers to the observation of at least one individual of the given species within the given tributary during the four-year sampling period. Presence does not take into account species abundance or distribution within a tributary, nor does it consider any year-to-year variability in species presence.

A qualitative summary of salmonid abundance for each of the inventoried Lower Klamath tributaries is located in Table 2. Qualitative abundance categorization in this table is based on the professional judgement of YTFP staff following extensive review of collected data from each tributary. Abundance not only refers to numbers of a given species observed in relation to other observed species, but also relates observed densities to the quantity of appropriate habitat available for that species.

Chinook Salmon

In general, chinook salmon were present in at least the lower gradient reaches of all the larger Lower Klamath tributaries, as well as several smaller tributaries (Table 1). Chinook were typically observed in low numbers and/or present only sporadically in each of these tributaries (Table 2). Blue Creek is the only Lower Klamath tributary in which high densities of chinook salmon were consistently observed during the study period (Figure 1). In particular, YTFP has observed extensive utilization of the mainstem and Crescent City Fork Blue Creek by chinook since annual fall snorkel surveys were initiated in 1994 (Gale et al. 1998; YTFP Unpublished Blue Creek Spawning and Outmigrant Data 1997-1999). Terwer Creek appears to consistently support a smaller but viable chinook run, although existing data is insufficient to accurately assess chinook population abundance and status in this drainage (Figure 1). Chinook salmon have consistently been observed in the Hunter Creek basin, although numbers of adult spawners and juvenile outmigrants have been highly variable since monitoring was initiated in 1996. Non-natal rearing by juvenile chinook in several smaller tributaries was also suspected based on presence observations where spawning does not seem likely to have occurred (Voight and Gale 1998).

Table 1. Summary of aquatic species presence by tributary, lower Klamath River, CA 1996-2004.

Tributary	Chinook Salmon	Coho Salmon	Steelhead	Coastal Cutthroat Trout	Resident Rainbow Trout	Pacific/Brook Lamprey	Prickly/Coastrange Sculpin	Speckled Dace	Threespine Stickleback	Klamath Small Scale Sucke	Pacific Giant Salamander	Yellow Legged Frog	Tailed Frog
High Prairie Creek	n	y	y	y	n	y	y	y	y	y	y	y	y
Hunter Creek													
- Mainstem	y	y	y	y	n	y	y	y	y	y	y	y	y
- East Fork	y	y	y	y	n	n	y	n	n	n	y	n	y
- Mynot Creek	y	y	y	y	n	y	y	y	y	y	y	n	n
- Kurwitz Creek	n	n	y	y	n	n	y	n	n	y	y	n	y
Hoppaw Creek													
- Mainstem	y	y	y	y	n	y	y	y	y	y	y	n	y
- North Fork	n	y	y	y	n	n	y	y	y	y	y	n	y
Saugep Creek	y	y	y	y	n	y	y	y	y	y	y	n	n
Waukell Creek	n	y	n	y	n	y	y	y	n	n	n	n	n
Terwer Creek													
- Mainstem	y	y	y	y	n	y	y	y	y	n	y	y	y
- East Fork	n	y	y	y	n	n	y	n	n	n	y	n	y
McGarvey Creek													
- Mainstem	y	y	y	y	n	y	y	y	y	y	y	y	y
- West Fork	n	y	y	y	n	y	y	y	y	y	y	y	n
Tarup Creek	y	y	y	y	n	y	y	y	y	y	y	y	n
Omagaar Creek	n	y	y	y	n	n	y	y	n	n	y	y	y
Blue Creek													
- Mainstem (below barrier)	y	y	y	y	y	y	y	y	y	y	y	y	n
- Mainstem (above barrier)	n	n	n	n	y	n	n	n	n	n	y	n	n
- East Fork	n	n	n	n	y	n	n	n	n	n	y	n	n
- Crescent City Fork	y	y	y	y	y	n	y	n	n	n	y	n	n
- Nickowitz Creek	y	n	y	n	y	n	y	n	n	n	y	n	n
- Slide Creek	n	n	y	n	y	n	y	n	n	n	y	n	n
- West Fork	y	y	y	n	n	n	y	y	n	n	y	n	n
Ah Pah Creek													
- Mainstem	y	y	y	y	n	n	y	y	n	n	y	y	y
- North Fork	y	y	y	y	n	n	y	y	n	n	y	n	y
- South Fork	n	y	y	y	n	n	y	y	n	n	y	n	y
Bear Creek													
- Mainstem	y	y	y	y	n	n	y	y	y	y	y	y	y
- North Fork	n	n	y	y	n	n	y	n	n	n	y	y	y
Surpur Creek	n	n	y	y	n	n	y	y	n	n	y	y	n
Little Surpur Creek	n	y	y	y	n	n	y	y	n	n	y	y	n
Tectah Creek	y	y	y	y	n	y	y	y	y	n	y	y	y
Johnsons Creek	y	y	y	y	n	n	y	y	n	y	y	y	y
Pecwan Creek													
- Mainstem	y	y	y	y	n	n	y	y	n	y	y	y	n
- East Fork	n	n	n	n	y	n	n	n	n	n	y	n	n
- West Fork	n	n	n	n	y	n	n	n	n	n	y	n	y
Mettah Creek													
- Mainstem	y	y	y	y	n	n	y	y	n	n	y	y	n
- South Fork	n	n	y	y	n	n	n	n	n	n	y	y	y
Roaches Creek	y	y	y	n	y	y	y	y	y	n	y	y	n
Morek Creek	n	n	y	n	n	n	y	n	n	n	y	y	y
Cappell Creek	n	y	y	n	y	n	y	n	n	n	y	n	n
Tully Creek													
- Mainstem	n	y	y	n	n	n	y	n	n	n	y	y	n
- Robbers Gulch	n	n	y	n	n	n	n	n	n	n	y	n	n

Table 2. Summary of salmonid abundance by tributary, lower Klamath River, CA 1996-1999.

	Chinook				Coho				Steelhead/RBT				Cutthroat			
Tributary	**H**	**M**	**L**	**NP**	**H**	**M**	**L**	**NP**	**H**	**M**	**L**	**NP**	**H**	**M**	**L**	**NP**
High Prairie Creek				X			X				X		X			
Hunter Creek																
- Mainstem		X					X			X				X		
- East Fork			X				X			X				X		
- Mynot Creek			X				X			X				X		
- Kurwitz Creek				X				X		X				X		
Hoppaw Creek																
- Mainstem			X				X			X			X			
- North Fork				X			X			X			X			
Saugep Creek			X				X				X			X		
Waukell Creek			X				X				X		X			
Terwer Creek																
- Mainstem		X					X		X						X	
- East Fork				X				X	X							X
McGarvey Creek																
- Mainstem			X				X		X				X			
- West Fork				X			X			X			X			
Tarup Creek			X				X			X			X			
Omagaar Creek				X			X				X			X		
Blue Creek																
- Mainstem (below barrier)	X						X		X						X	
- Mainstem (above barrier)				X				X		X						X
- East Fork				X				X		X						X
- Crescent City Fork	X					X			X						X	
- Nickowitz Creek			X					X	X							X
- Slide Creek				X				X	X							X
- West Fork			X					X	X							X
Ah Pah Creek																
- Mainstem				X			X				X			X		
- North Fork				X				X		X				X		
- South Fork				X		X					X			X		
Bear Creek																
- Mainstem			X				X				X				X	
- North Fork				X				X			X			X		
Surpur Creek				X				X			X			X		
Little Surpur Creek				X			X				X					X
Tectah Creek			X				X		X					X		
Johnsons Creek			X				X				X		X			
Pecwan Creek																
- Mainstem			X				X		X						X	
- East Fork				X				X	X							X
- West Fork				X				X	X							X
Mettah Creek																
- Mainstem			X				X			X			X			
- South Fork				X				X			X		X			
Roaches Creek			X				X		X							X
Morek Creek				X				X		X						X
Cappell Creek				X				X	X							X
Tully Creek																
- Mainstem				X				X	X							X
- Robbers Gulch				X				X	X							X

Coho Salmon

Coho salmon were observed in more tributaries than chinook, but were typically found in very low densities relative to other salmonid species (Tables 1-2). In general, they were only observed in the lower reaches of most tributaries, and in at least a few cases their presence appeared to be attributable to non-natal rearing (Voight and Gale 1998; YTFP Unpublished Fish Inventory Data 1997-1999). Crescent City Fork Blue Creek was the only tributary where sizable numbers of juvenile coho were consistently observed (Figure 1). YTFP has consistently observed large numbers of young-of-the-year (YOY) coho rearing throughout the Crescent City Fork. In middle and upper tributary reaches juvenile coho have been observed outnumbering other salmonid species. Relatively large numbers of YOY coho were also observed in lower South Fork Ah Pah Creek during 1997, but abundance during subsequent years has been variable. Additional data are required to better document their status in this tributary.

Steelhead

Steelhead were observed in every fish-bearing tributary sampled in the Lower Klamath sub-basin, with the exception of Waukell Creek (Table 1). Given the scant amount of sampling that has occurred in Waukell Creek, additional inventories need to be conducted in future years before their presence can be ruled out. With the exception of the Blue Creek drainage, steelhead relative abundance was greater than that of either chinook or coho, but less than coastal cutthroat trout (Voight and Gale 1998). Steelhead have the widest distribution and are the most abundant anadromous salmonid in the Blue Creek basin (Gale et al. 1998; Hayden 1998). Blue Creek provides ideal spawning and rearing habitat for steelhead, leading the California Department of Fish and Game to describe it as "the best steelhead producing stream in the entire Klamath Basin" (O'Brien 1973). In tributaries with sympatric steelhead/cutthroat populations (all Lower Klamath tributaries downstream of and including Mettah Creek, excluding Blue Creek and tributaries - Figure 1), steelhead numbers declined progressively upstream and resident steelhead/rainbow trout were not found upstream of barriers in these streams (Voight and Gale 1998). In drainages with no documented cutthroat presence (upstream of Mettah Creek) steelhead appeared abundant throughout all reaches and were present upstream of anadromous barriers as resident trout (Voight and Gale 1998).

Coastal Cutthroat Trout

We observed coastal cutthroat trout in all Lower Klamath tributaries downstream of and including Mettah Creek (Table 1). The only exception to this were three of the four anadromous-accessible Blue Creek tributaries (Table 1). No cutthroat were observed in any tributaries upstream of Mettah Creek. Cutthroat were typically found in either medium or high abundance throughout their Lower Klamath range, and were typically more abundant in upstream reaches (Voight and Gale 1998). Coastal cutthroat trout possess the most flexible life history of any Pacific salmonid (Johnson et al. 1994; Northcote 1997). This flexibility likely explains their wide distribution over a variety of habitats, including several resident populations located upstream of anadromous barriers. Blue Creek is the only exception to this observation, where a small cutthroat population is typically observed with limited distribution (Gale 1997; Hayden 1998). Mainstem

Terwer and Pecwan Creeks also contain low numbers of cutthroat. Cutthroat are present in select Terwer tributaries and are the sole salmonid present in the upper reaches.

2. Instream Habitat and Riparian Conditions

Beginning in 1996, the Hab/Bio Division initiated an extensive habitat and riparian inventory in the Lower Klamath sub-basin, in order to address the paucity of existing physical habitat data. Habitat typing inventories (100% sampling) were conducted throughout all anadromous fish-bearing Lower Klamath tributaries during 1996-1997 using methods detailed in Flosi et al. (1998). In addition, Large Woody Debris (LWD) inventories (100% sampling) were conducted during 1998 throughout the same tributaries using the CDFG methodology (Flosi et al. 1998). A summary of selected habitat and riparian parameters for each tributary is located in Table 3.

The Blue Creek drainage contains the highest quality habitat and riparian conditions of all the Lower Klamath tributaries. The upper 2/3 of the drainage, including its four largest tributaries, are all located within the Six Rivers National Forest (SRNF) (Figure 1). The majority of the SRNF holdings are protected as part of the Siskiyou Wilderness Area, while most of the remaining holdings are currently classified as Late Successional Reserve (FEMAT 1993). Timber harvesting, road construction, and related land management activities have been minimal in the USFS portion of Blue Creek, with no such activities planned in the near future. These portions of the drainage contain pristine fish habitat and are essential to the overall water quality in the basin. In addition to this protective status, Blue Creek's high annual discharge levels aid in flushing instream sediment, maintaining high quality spawning habitat throughout the drainage.

In contrast to conditions found in upper Blue Creek, the remainder of the Lower Klamath sub-basin has been subjected to extensive timber harvesting and related road construction over the last 60 years (see Section II-C). These activities, in conjunction with naturally fragile hillslopes and large flood events, have resulted in substantial streambed sedimentation, reduced channel and streambank stability, and an overall reduction in quality and quantity of instream fish habitat. While conditions vary between tributaries due to geologic and geomorphic differences, most Lower Klamath tributaries suffer from low habitat diversity, reduced quantity and complexity of fish cover, excessive sedimentation and substrate embeddedness, and reduced channel stability (Table 3; YTFP Unpublished Data 1996-1997). These deficiencies likely hinder successful spawning and emergence, limit the quality and quantity of rearing habitat for juvenile salmonids, increase competition and predation, alter composition of available food organisms (macroinvertebrates), and in general reduce overall survival of salmonids from spawning to emigration.

Past Lower Klamath logging practices have resulted in the removal of virtually all mature conifers from tributary riparian areas. The riparian corridor serves a critical role in the

Table 3. Summary of physical habitat and riparian parameters by tributary, lower Klamath River, CA 1996-1998.

Tributary	Drainage Size (sq. mi.)	Stream Order	Dominant Channel Type	Pool:Flatwater:Riffle Ratio	% Pools >=3ft Max. Depth	Ave. Shelter Rating	Prim./Sec. Cover Type	Prim./Sec. Substrate Type	Ave. Embeddedness (%)	Ave. Canopy Closure (%)	% Conifers in Canopy	Existing LWD Density (# pieces/mile)	Total Future LWD Density (# pieces/mile)	% Future LWD Composed of Live Conifers	% Future LWD Composed of Deciduous Trees <2' Dia.	Sub-surface Flow Severity
High Prairie Creek	4.2	2	A-4	46:44:10	7.1	31.5	LWD/BL	GR/SC	25-50	80%	23%	N/S	N/S	N/S	N/S	M
Hunter Creek																
- Mainstem	23.8	4	C-4	43:50:07	48.4	20.0	BL/LWD	GR/SC	50-75	79%	10%	186	328	14.9%	55.5%	H
- East Fork		3	B-4	26:73:01	10.5	18.8	LWD/BL	GR/SL	50-75	88%	7%	351	456	13.0%	55.4%	M
- Mynot Creek	4.9	2	F-4	49:48:03	5.3	23.7	TV/BL	GR/SA	50-75	76%	15%	209	381	33.8%	32.7%	H
Hoppaw Creek																
- Mainstem	4.9	3	F-4	37:39:24	1.7	15.7	LWD/SWD	GR/SC	50-75	91%	11%	275	413	24.4%	28.4%	H
- North Fork		2	A-4	62:11:27	2.0	17.1	LWD/BL	GR/SC	50-75	95%	27%	537	556	41.8%	23.5%	L
Saugep Creek	1.7	2	F-4	38:56:06	2.5	11.4	TV/SWD	GR/SL	50-75	84%	0%	N/S	N/S	N/S	N/S	L
Terwer Creek																
- Mainstem	32.8	4	B-3	36:52:12	32.9	67.1	BL/WW	BL/GR	0-25	61%	18%	169	512	21.9%	12.3%	M
- East Fork		3	A-2	35:59:07	13.7	84.7	BL/WW	BL/GR	25-50	71%	5%	264	519	20.7%	11.8%	N/A
McGarvey Creek																
- Mainstem	8.6	3	C-4	70:26:04	18.5	27.8	LWD/SWD	GR/SC	50-75	89%	8%	359	907	7.4%	61.4%	M
- West Fork		2	C-4	74:20:06	11.4	30.2	LWD/SWD	SL/GR	50-75	94%	11%	445	1,129	6.4%	68.9%	N/A
Tarup Creek	4.9	3	C-4	71:19:10	25.8	20.5	LWD/SWD	GR/SC	50-75	97%	7%	228	515	12.1%	59.2%	H
Omagaar Creek	2.5	2	B-4	35:52:13	5.0	19.4	LWD/BL	GR/SC	25-50	95%	10%	233	641	14.7%	56.4%	H
Blue Creek																
- Mainstem (below barrier)	128.3	5	C-2	23:61:16	88.4	14.2	BL/WW	BL/LC	25-50	41%	34%	N/S	N/S	N/S	N/S	N/A
- Crescent City Fork	13.4	4	B-2	27:61:12	51.3	17.2	BL/WW	LC/BL	25-50	87%	42%	169	569	56.1%	16.6%	N/A
- Nickowitz Creek	12.4	3	B-2	25:66:09	22.0	14.8	BL/WW	GR/SC	25-50	90%	27%	135	567	39.8%	31.4%	N/A
- Slide Creek	5.7	2	A-2	19:65:16	42.4	18.5	BL/WW	LC/BL	25-50	38%	77%	94	538	69.3%	2.3%	N/A
- West Fork	9.7	3	B-2	30:62:08	44.3	17.5	BL/WW	LC/GR	50-75	86%	12%	216	590	12.7%	41.3%	N/A
Ah Pah Creek																
- Mainstem	16.3	4	B-3	33:61:06	3.8	16.2	LWD/SWD	GR/SA	25-50	84%	8%	394	778	19.9%	54.0%	M
- North Fork		3	B-4	40:54:06	11.1	15.9	LWD/SWD	GR/SC	25-50	82%	9%	262	777	27.7%	53.4%	M
- South Fork		2	A-2	34:63:03	5.4	12.7	SWD/LWD	GR/SA	25-50	89%	9%	400	890	21.0%	48.4%	M
Bear Creek																
- Mainstem	19.3	3	A-2	38:47:15	9.8	74.1	BL/WW	BL/LC	25-50	73%	8%	188	323	26.2%	16.6%	H
- North Fork		3	B-3	32:52:16	6.3	78.4	BL/WW	BL/GR	25-50	77%	7%	312	533	23.4%	10.8%	N/A
Surpur Creek	5.7	3	B-3	73:23:04	19.9	16.5	BL/SWD	GR/SC	50-75	89%	6%	321	677	21.5%	46.2%	L
Little Surpur Creek	2.7	2	A-2	64:35:01	19.7	13.2	SWD/BL	SC/GR	50-75	93%	10%	255	486	21.1%	59.9%	L
Tectah Creek	19.9	3	B-3	48:45:07	27.8	18.6	BL/LWD	LC/SC	25-50	86%	11%	131	559	23.0%	49.5%	M
Johnsons Creek	3.4	2	B-3	69:27:04	15.6	15.6	BL/UC	SC/GR	50-75	94%	3%	116	474	3.5%	73.9%	H
Pecwan Creek (Lower Mainstem)	27.7	4	B-2	24:62:14	45.0	22.2	WW/BL	GR/BL	50-75	74%	31%	N/S	N/S	N/S	N/S	L
Mettah Creek																
- Mainstem	10.7	3	B-2	40:51:09	11.2	30.0	BL/WW	GR/SC	50-75	86%	17%	112	150	14.5%	12.5%	L
- South Fork		2	B-2	24:64:12	7.1	29.1	WW/BL	GR/SC	50-75	89%	22%	181	143	4.6%	20.4%	N/A
Roaches Creek	29.5	4	B-2	46:49:05	37.7	31.0	BL/WW	GR/BL	50-75	78%	30%	34	112	35.5%	8.2%	L
Morek Creek	4.0	2	A-2	24:51:25	4.6	18.9	BL/WW	GR/BL	50-75	85%	34%	78	309	4.5%	80.6%	L
Cappell Creek	8.6	2	A-2	43:30:27	18.6	21.8	WW/BL	BL/GR	50-75	79%	41%	N/S	N/S	N/S	N/S	L
Tully Creek																
- Mainstem	17.3	3	B-3	24:71:05	34.7	14.8	BL/WW	BL/GR	25-50	79%	8%	106	254	12.9%	9.9%	L
- Robbers Gulch		2	B-3	39:52:09	12.5	13.5	BL/SWD	SC/BL	50-75	84%	8%	166	363	10.3%	3.1%	N/A

Cover Type Codes: LWD= Large Woody Debris SWD=Small Woody Debris BL=Boulder WW=Whitewater TV=Terrestrial Vegetation UC=Undercut Bank

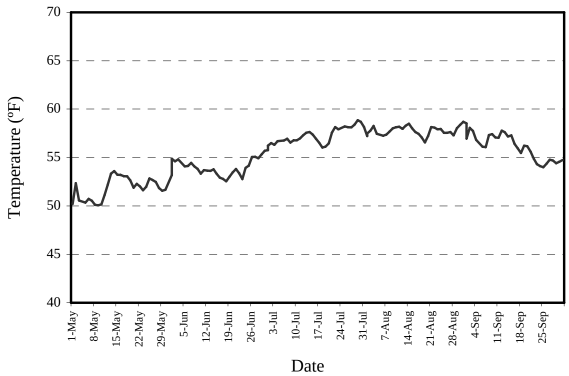
Substrate Codes: SL=Silt/Clay SA=Sand GR=Gravel SC=Small Cobble LC=Large Cobble BL=Boulder function of an aquatic system, interfacing the actual stream channel with the terrestrial environment. Riparian vegetation is essential for the stabilization and protection of streambanks, as a source of LWD for habitat formation, for filtering sediment and nutrients, and for producing shade and instream fish cover, habitat for terrestrial macroinvertebrates, and as a source of leaf litter energy input.

Conifers (of all ages/sizes) comprise less then one third of the riparian canopy in lower Klamath tributaries (USFS portions of Blue Creek excluded), with conifers constituting <15% of the riparian canopy in the majority of these tributaries (Table 3). Instead, tributary riparian areas are composed almost exclusively of deciduous tree species (predominantly red alder - *Alnus rubra*). Alders are a poor substitute for conifers in regard to stabilizing streambanks, maintaining channel stability, and for providing long-term habitat formation and fish cover once they enter the stream as LWD. In addition, YTFP lower Klamath tributary inventories indicate that large woody debris identified as potentially recruitable to stream channels consist predominantly of live deciduous trees less then two feet in diameter (Table 3). Live conifers, on the other hand, comprise on average less then 25% of the potentially recruitable LWD. In contrast, USFS portions of Blue Creek contain riparian canopies where live conifers comprise between 27-77% of the total canopy and represent 40-70% of the potentially recruitable LWD.

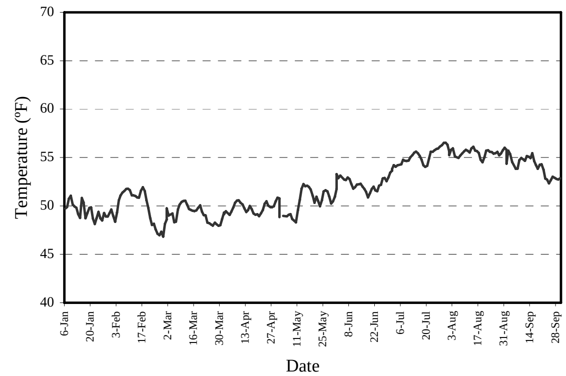
3. Water Quality and Quantity

YTFP initiated a large-scale water temperature-monitoring program in the Lower Klamath tributaries beginning in 1995. These activities were undertaken in order to assess whether water temperature is a limiting factor to survival and/or health of tributary salmonid populations. To date, five years of monitoring have revealed that tributary water temperature consistently remains within acceptable tolerances identified for the salmonid species present (Figures 2-4) (Bell 1991). The annual variation in average daily water temperature is less then 10ºF in the majority of the Lower Klamath tributaries, with the summer maximum temperature never exceeding 60ºF in most of these watersheds (Figure 1). Lower Blue Creek contains the highest recorded summer water temperatures of all monitored tributaries (Figures (3-4), which is likely due to Blue Creek's large size, open canopy and reduced channel confinement found in the lower reaches. Despite these elevated temperatures, Lower Blue Creek water temperatures still fall within acceptable tolerances for salmonids throughout the year.

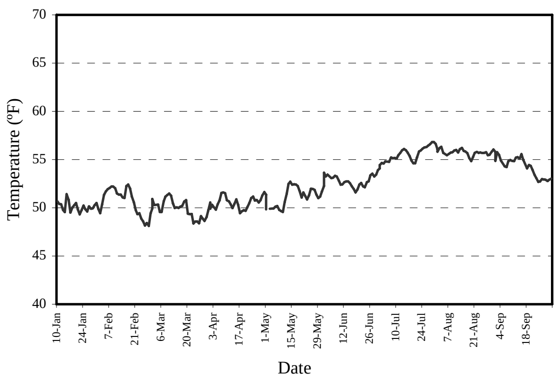
Once emigrating salmonids have exited Lower Klamath tributaries, however, they must contend with water temperature in the mainstem Klamath River that often exceeds upper tolerable thresholds for salmonids (Figure 5). In addition to high water temperature, mainstem dissolved oxygen levels may fall below those considered acceptable for juvenile salmonids, although insufficient data exists to make this determination.



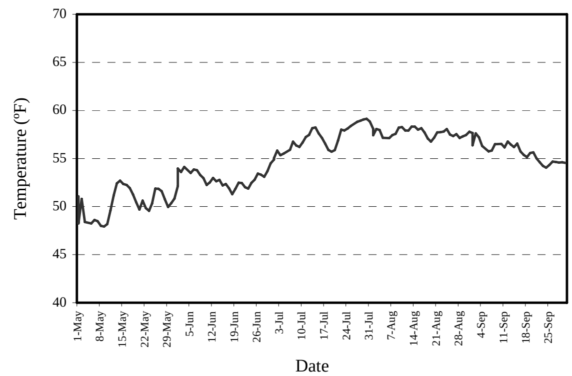
McGarvey Creek, May-September, 1996



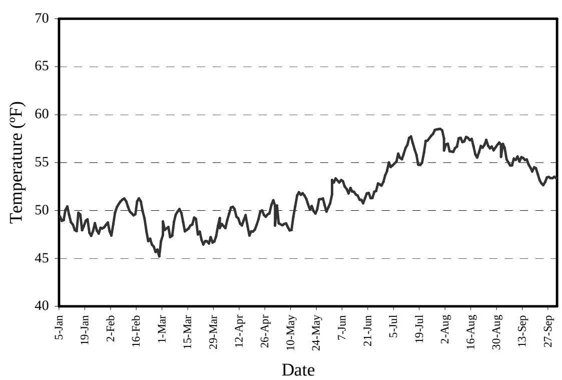
Omagaar Creek, January-September, 1996



Tarup Creek, January-September, 1996



Bear Creek, May-September, 1996



Surpur Creek, January-September, 1996

Figure 2. Average daily stream temperature, selected lower Klamath tributaries, 1996.

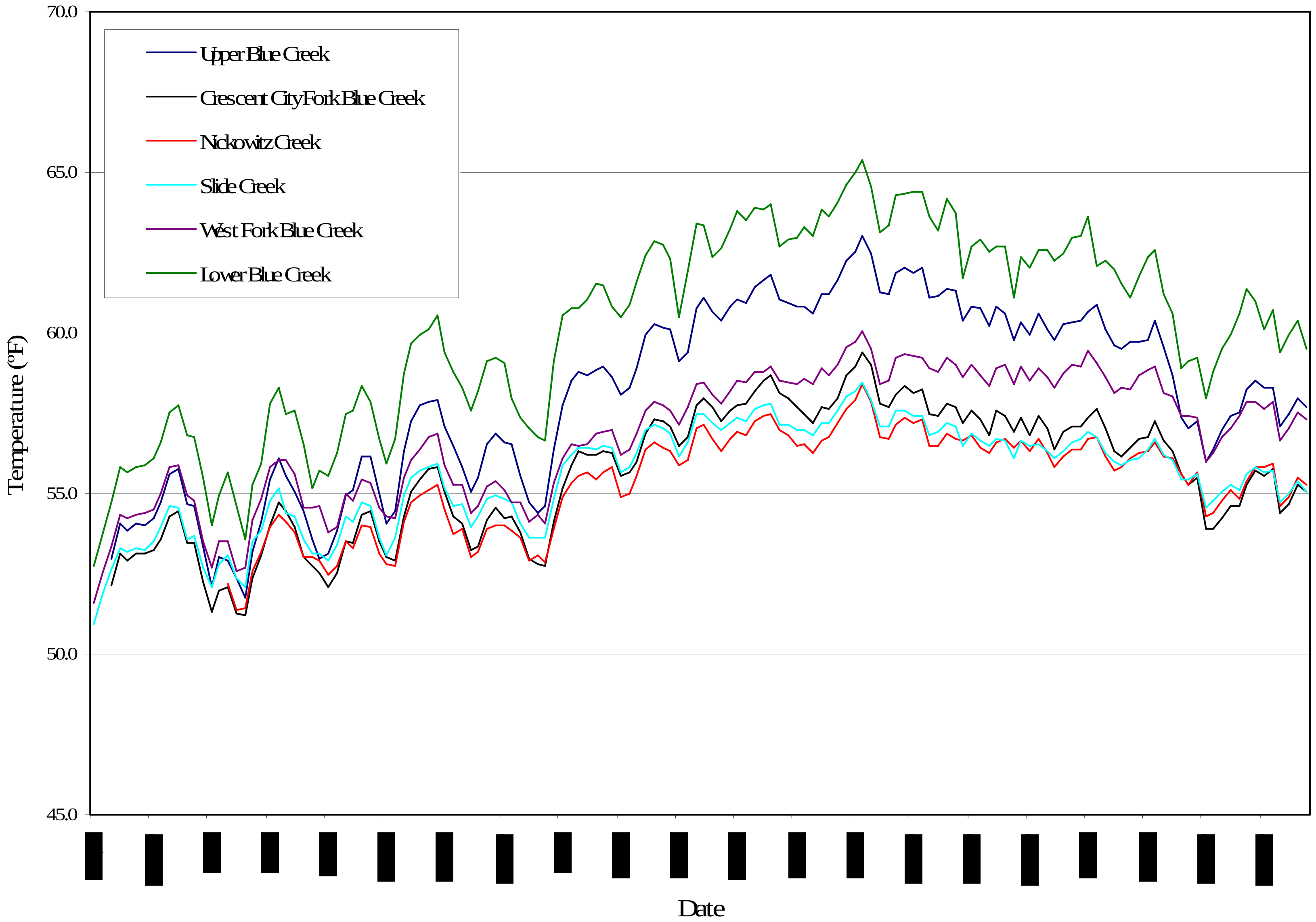


Figure 3. Average daily water temperature, Blue Creek and selected tributaries, lower Klamath River, California, May - September, 1997.

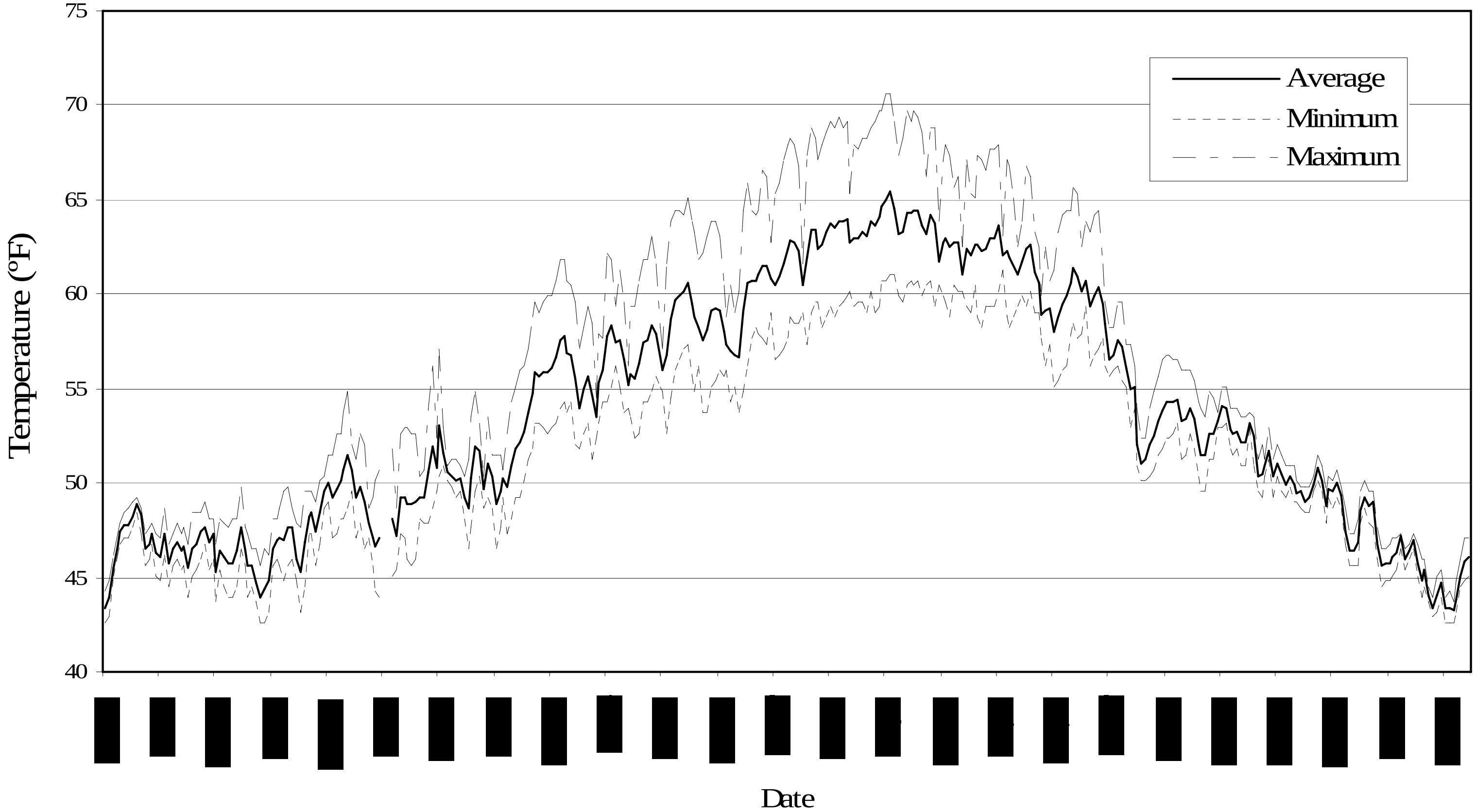


Figure 4 Daily average, maximum, and minimum water temperature, lower Blue Creek, lower Klamath River, California, 1997.

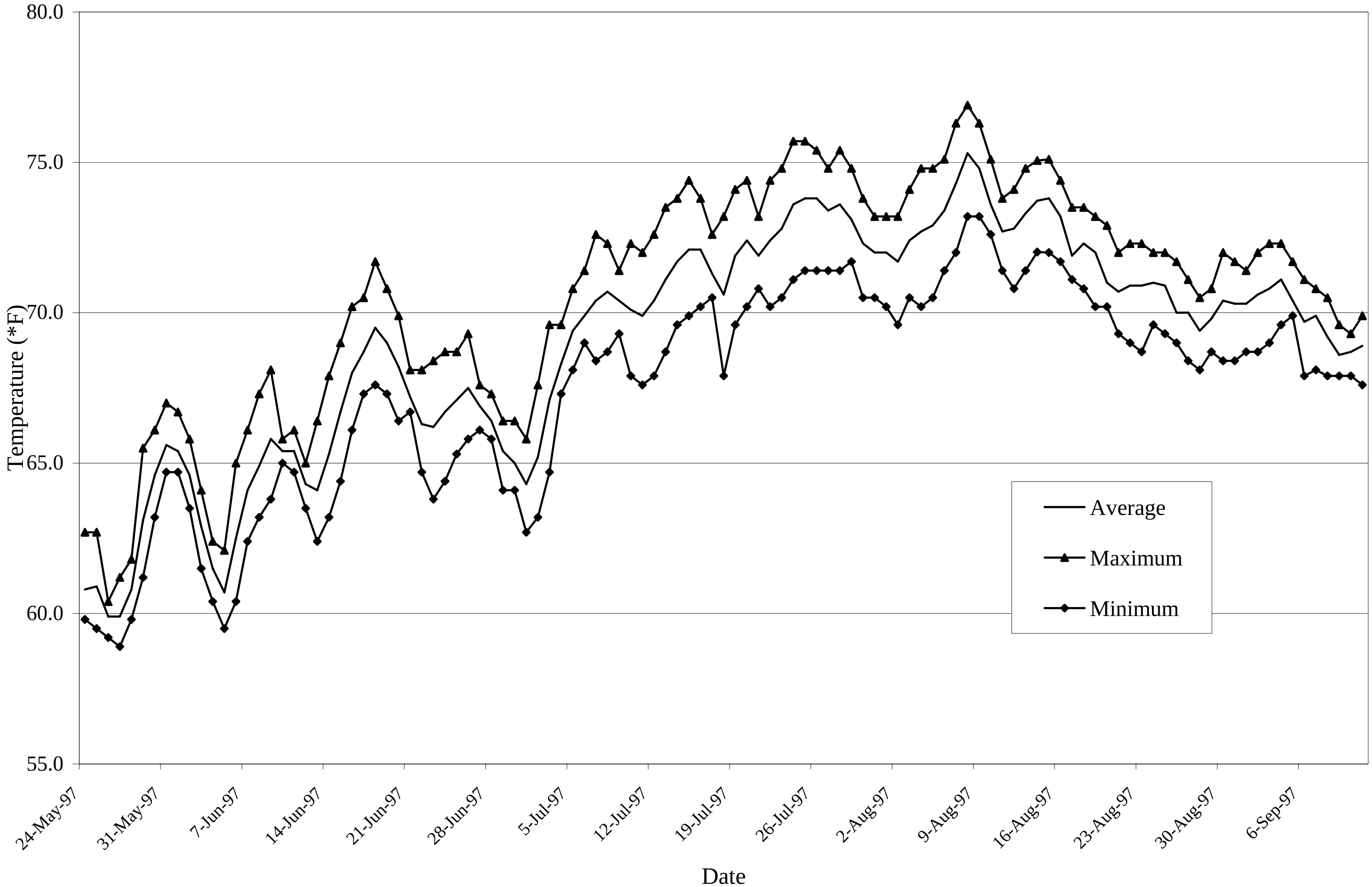


Figure 5. Average daily, maximum & minimum water temperature, lower Klamath River near Omagaar Creek, May - September, 1997.

The Lower Klamath sub-basin receives the highest level of precipitation in the Klamath Basin, with average annual rainfall of up to 100 inches, 75% of which occurs between November and March (Helley and LaMarche 1973). Historic US Geological Survey (USGS) stream discharge data for Lower Klamath tributaries is only available for Lower Blue Creek for the period 1965-1978. This data reveals both the extreme annual flow fluctuations that occur in the Lower Klamath basin, as well as the wide range of annual peak flows that occurred during the period of record. Average daily stream discharge over this period ranged from 43 cubic feet per second (cfs) on November 1, 1965 to 24,000 cfs on March 2, 1972 (Figure 6). Peak flow levels during this period exceeded 30,000 cfs on three different occasions and routinely exceeded 10,000 cfs (USGS historic flow data). The extreme flood event of December 22, 1964, although outside the period of record, was estimated to peak at 48,000 cfs (USGS historic flow data). The recurrence interval of this flood event, based on geomorphic evidence as well as radiocarbon analysis and tree ring counts of material entrained in historic Blue Creek flood deposits, is estimated to be at least 100 years (Helley and LaMarche 1973).

While substantial rainfall and corresponding flow levels are typically present in Lower Klamath tributaries during the "wet season" (October-April), most tributaries experience some period of subsurface flow during the remainder of the year. In general, most tributaries dry up initially at the mouth and go subsurface for varying distances until substantial fall/winter rain arrives. This condition is associated primarily with excessive sedimentation and corresponding stream channel aggradation within the tributary, as well as deposition of sediment from the mainstem Klamath. The result is the formation of large gravel bars and deltas at the tributary mouths, which require either high river levels and/or substantial tributary flow to establish connectivity between the tributary and the mainstem Klamath. In addition to tributary and mainstem aggradation, substantial water withdrawals from mainstem Klamath and Trinity River dams and upstream water diversions from primary Klamath Basin tributaries such as the Shasta and Scott Rivers has exacerbated this problem by causing an alteration of the mainstem Klamath hydrograph and a net reduction of the water table during summer and fall months. Depending on the subsurface flow severity for a given tributary, it may require several substantial rainfall events and/or a substantial increase in the mainstem river level before access is reestablished for migrating adult salmonids. In addition, a lack of significant rainfall during spring months may result in a loss of connectivity with the mainstem during critical juvenile emigration periods.

To better assess the severity of this problem for each of the Lower Klamath tributaries, the Hab/Bio division initiated a stream mouth access monitoring program in 1996. This monitoring effort, which has been conducted continuously to date, involves visiting the confluence of each tributary via jetboat and/or vehicle and assessing flow level and fish access feasibility on a weekly basis throughout the year. Summaries of fish access periodicity for each Lower Klamath tributary for 1996-1999 are located in Figures 7-10.

Blue Creek is the only Lower Klamath tributary that maintains adequate fish access from the mainstem Klamath year-round (Figures 7-10). Five other tributaries have maintained year-round flow during at least one of the four years. Of these five, only Tully Creek maintained perennial flow during all four years and none of the five provided perennial

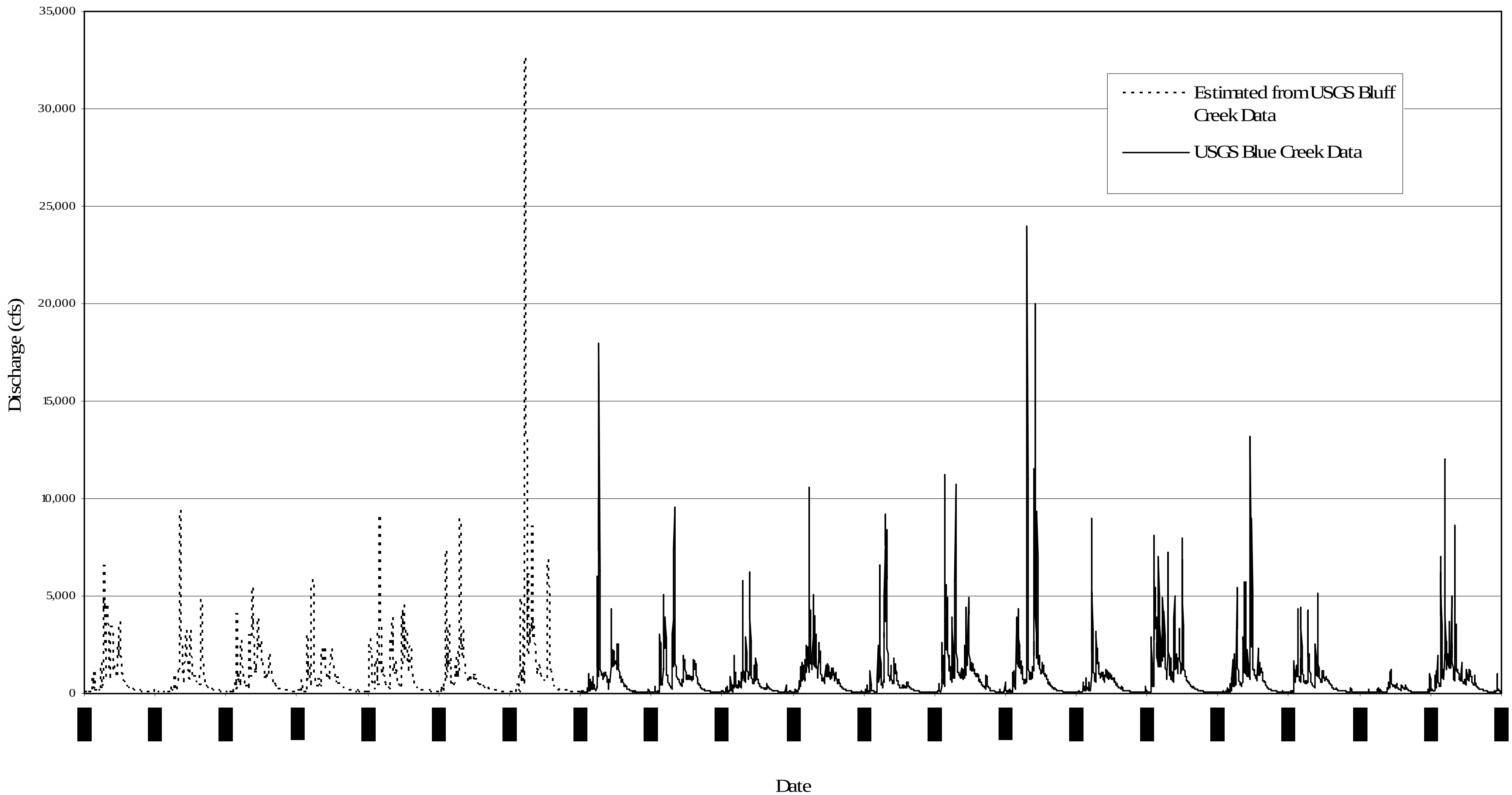


Figure 6. Average daily stream discharge, lower Blue Creek, lower Klamath River, California, 1958-1978.

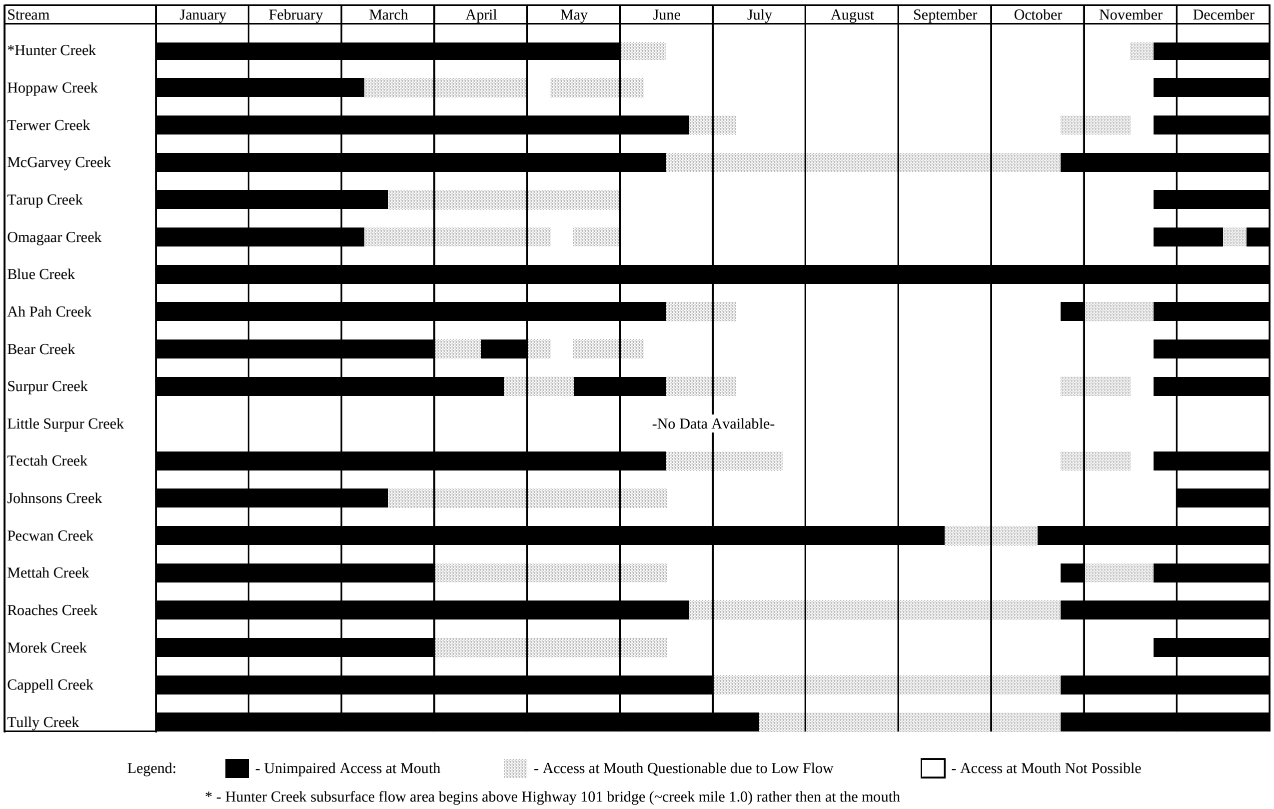


Figure 7. Fish access perdiodicity in lower Klamath River tributaries, California, 1996.

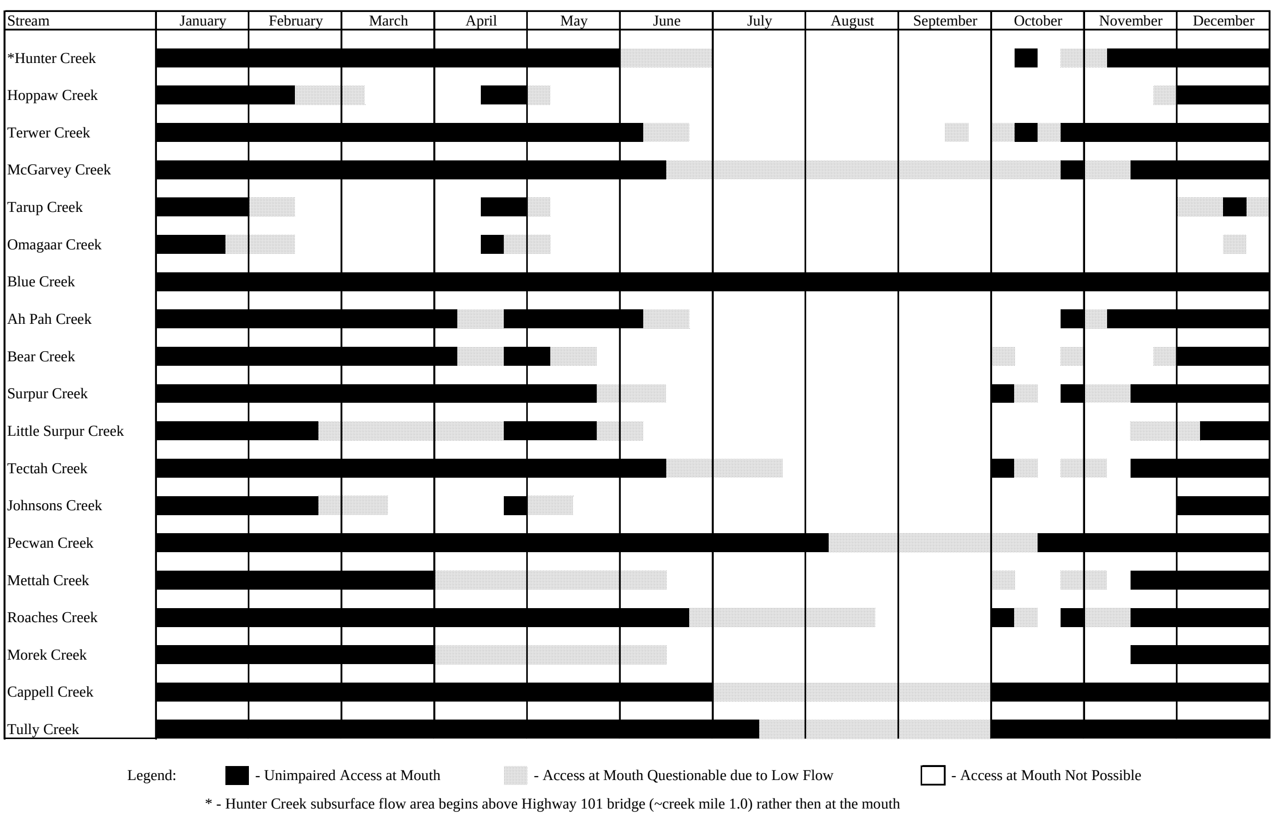


Figure 8. Fish access perdiodicity in lower Klamath River tributaries, California, 1997.

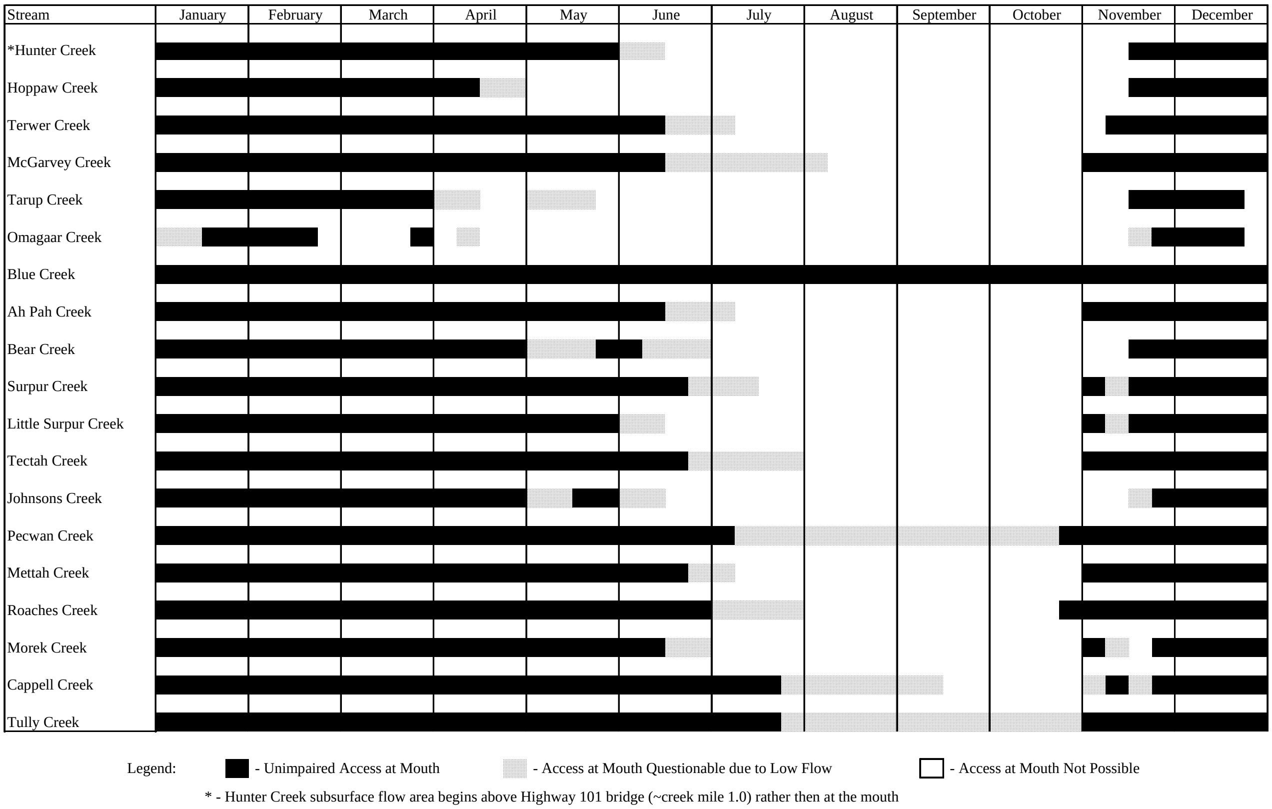


Figure 9. Fish access perdiodicity in lower Klamath River tributaries, California, 1998.

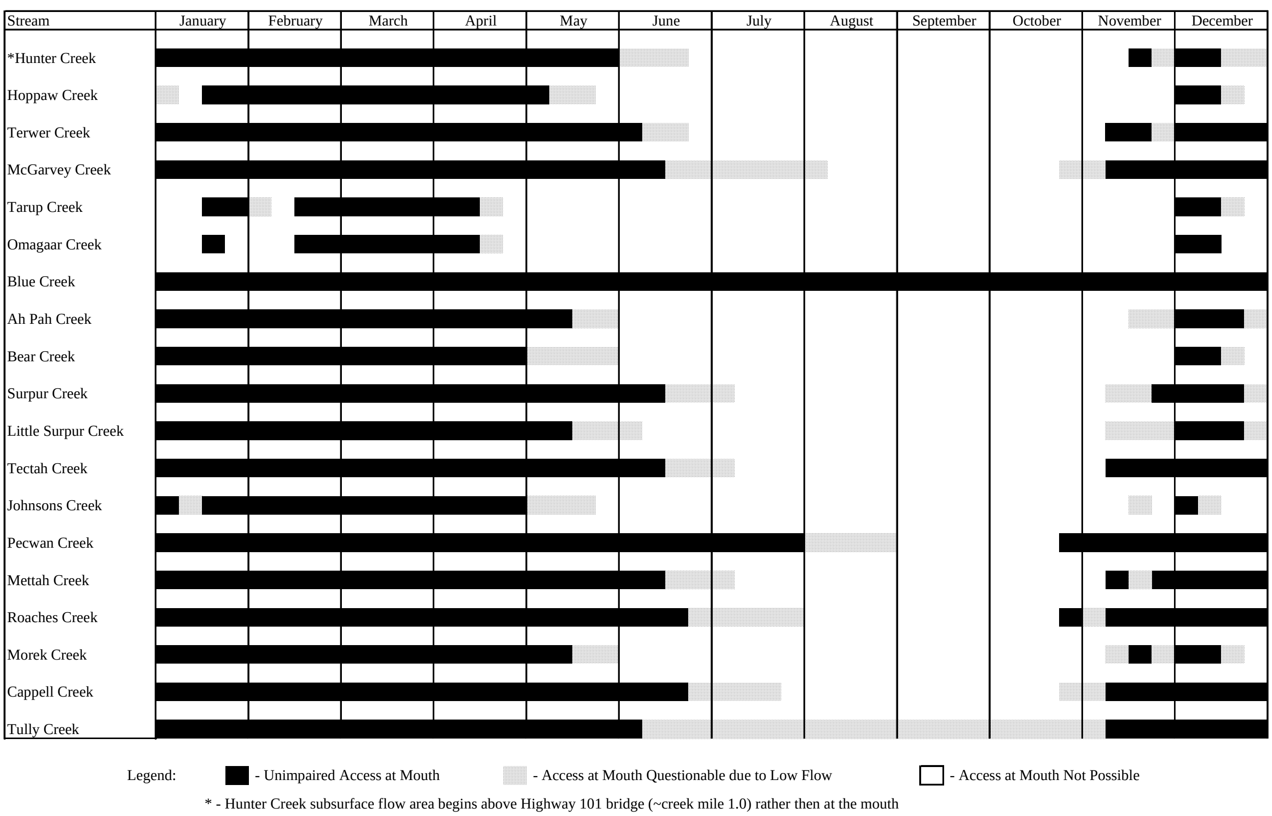


Figure 10. Fish access perdiodicity in lower Klamath River tributaries, California, 1999.

adult fish access (flow level was insufficient to provide access during some portion of the year). It should be noted that Pine Creek was not included in this assessment effort due to its location upstream of Coon Creek Falls and hence the increased difficulty in reaching its confluence throughout the year. Infrequent observations, however, suggest that Pine Creek likely also maintained perennial flow throughout the monitoring period, although persistence of fish access during this period is unknown.

Several smaller tributaries consistently experienced severe connectivity problems with the mainstem throughout the monitoring period. These tributaries included Hoppaw, Tarup, Omagaar, Bear, and Johnsons Creeks (Figures 7-10). All of these creeks typically required several significant rain events before flow was reestablished with the mainstem Klamath. In addition, these creeks were always the first to flow subsurface in the spring, as well as typically experiencing periods of intermittence during winter and early spring months in the absence of continued/frequent rain events. All of these creeks experienced a disruption or complete cessation of flow during critical juvenile emigration periods for most if not all of the four-year monitoring period (Figures 7-10).

Most intermediate-size drainages (i.e. Hunter, Terwer, Tectah and Mettah Creeks) are able to maintain consistent flow throughout the winter and spring months (Figures 7-10). Consequently, they appear to provide a more consistent window for emigrating juvenile salmonids to exit the system. They are, however, dependent on fall rain events to reestablish mainstem connectivity, which three years out of the four didn't occur until late November. During fall/winter 1999, this reestablished flow was only temporary, with access again being interrupted until rain resumed in early January (Figures 7-10). These connectivity problems in late fall and winter can hinder the passage of adult salmon which typically migrate in October and November in the Lower Klamath. The exact impact of this flow intermittence on immigrant salmon is unknown, but it is presumed to hinder successful spawning in selected tributaries during at least some years.

Future stream flow monitoring efforts will attempt to associate mainstem Klamath River flow levels, dam releases, fall rain events, and stream access in an effort to determine what combination of river flow and rain are necessary to reestablish flow in each tributary. In addition, the amount of subsurface channel will be investigated more closely within each tributary during all periods of intermittence. This will provide a more accurate assessment of how much habitat is lost to rearing fish within these tributaries during these periods.

B. Lower Klamath Geology

Rocks that underlie the Lower Klamath River Basin have been divided into 2 main geological packages. The lowest portion of the basin, from the river's mouth up to around Pecwan, is located within a belt of rocks known as the "Franciscan Formation" ("KJf" in Figure 11). This rock package includes sedimentary and igneous rocks of a sub-marine origin[1]. A package of older metamorphic rocks crops out above Cappell, and extends above and beyond Pine Creek. This metamorphic package includes rocks of the

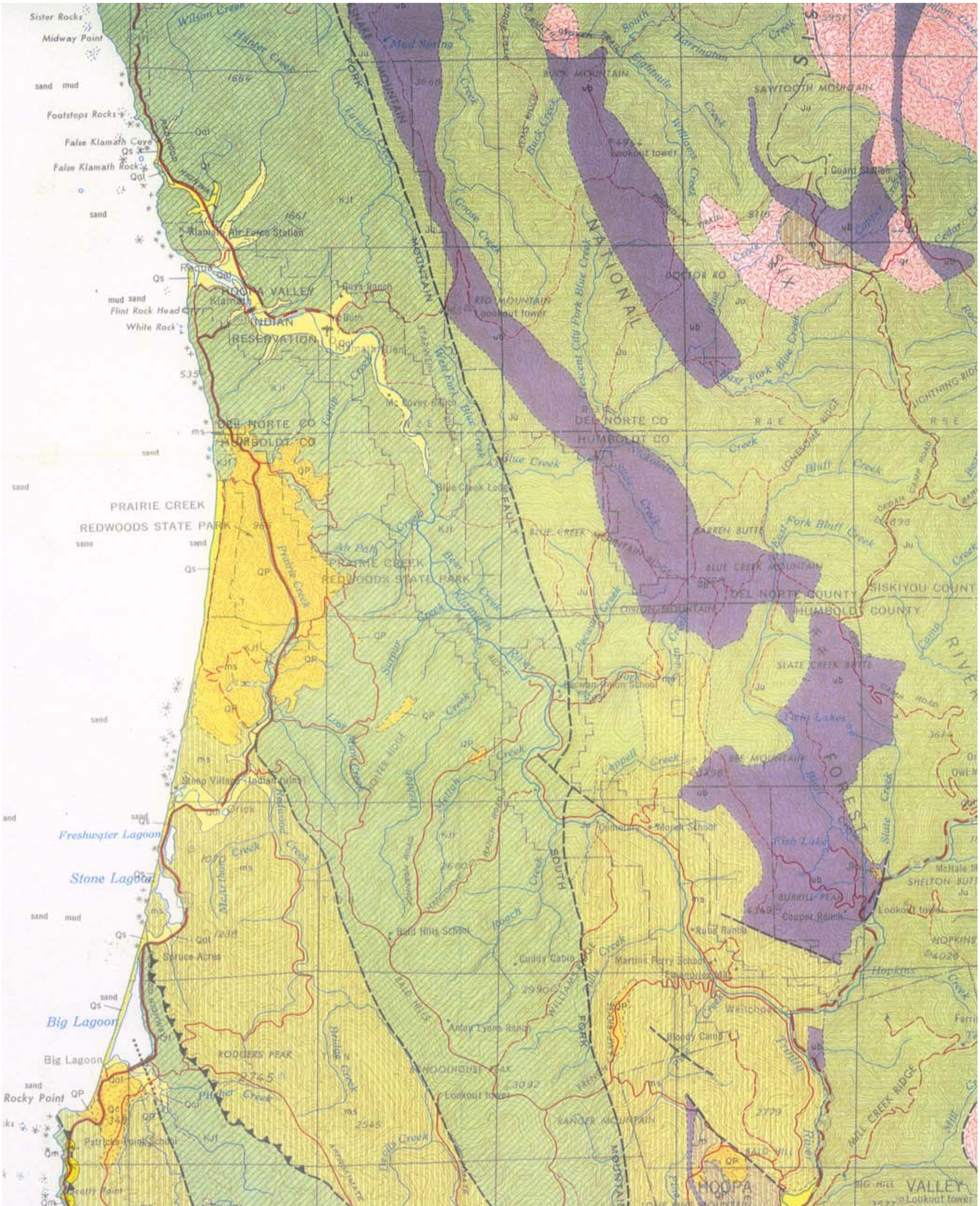


Figure 11. Major geologic features in the Lower Klamath River sub-basin, California.

“Galice” and “Josephine” Formations. The rocks of both geological packages are the products of materials that were deposited within an ancient ocean basin.

The Franciscan Formation

Rocks of the Franciscan Formation underlie essentially all of Northern California’s Coast Range. According to Frazier and Schwimmer (1987), the Franciscan rocks of the Lower Klamath Basin region formed during the Jurassic and Cretaceous geological time periods (approximately 67 to 144 million years ago). Gray-green sandstones named “greywacke” dominate the Franciscan rock package, which also includes relatively thin layers of shale, limestone, and chert. The sandstones and shales received their ingredients from sediments that were originally deposited by rivers onto the coastal margins of ancestral California. Over the eons, these sediments piled up onto a relatively shallow-water continental shelf. Earthquakes and continuous sedimentation along the outer edge of the shelf eventually caused disruption of the sediments such that their materials were carried by undersea “debris torrents” down into a deep-sea trench. Even today, avalanche-like torrents spill sedimentary debris off the edge of Northern California’s continental shelf, and down tens-of-thousands of feet into a deep-sea trench.

Deep-sea trenches are like gigantic gouges into the sea floor, and account for the greatest ocean depths on Earth. These “gouges” steadily become filled-in, as the layers of sediments from above continue to pile up through time. Near the bottom of the pile, the more deeply buried sediments withstand extremely high pressures that compact and cement their components together into layers of rock. Thus, the sandy layers of sediment solidify into sandstones. Silty-clay layers become “shales.” The layers of calcium-rich “shell-oozes” consolidate into limestone, while the silica-rich oozes more typically segregate into rounded “chert” nodules within the limestones[2]. Geologists believe that in this manner, the sedimentary rocks of the Franciscan Formation were born. Harris and Tuttle (1984) note that within Redwood National Park, the pile of Franciscan rocks is greater than 50,000 feet thick.

The same fault-related earthquakes that discharge coastal sediments down into the trenches are also responsible for lifting these once deeply-buried sedimentary rocks up into coastal mountain ranges. The floor of the Pacific Ocean has been sliding under California’s continental margin, which has been “scraping” Franciscan rocks out of a deep-sea trench, and uplifting them into the mountains of California’s Coast Range (Figure 11).

The Metamorphic Rock Package

A package of older metamorphic rocks ("ms" in Figure11) is exposed to the east of the Franciscan formation. A large fault zone separates the two rock packages. The metamorphic package includes two main geological rock formations, known as the “Galice” and “Josephine” Formations. Their rocks are considered to be earlier Jurassic

[1]A glossary of terms can be found in Appendix X, at the end of this report.

[2]These chert nodules are extremely hard, and were cherished by the Yurok people as tools and cooking stones.

then the Franciscan Formation, perhaps 152 to 166 million years old (Frazier and Schwimmer 1987). Galice rocks are "schists," which are metamorphic (i.e. altered) equivalents of rocks similar to those of the Franciscan Formation. These schists were originally sediments that piled up on the oceanic floor, but were then dragged so deeply beneath the continental margin, as the ocean floor sank, that they were "cooked" by extremes of pressure and temperature. They eventually re-crystallized into rocks that look like they're made up of compressed stacks of shiny leaflets.

At the great depths at which these schists were formed, iron-rich magma (from beneath the ocean floor) was squeezed up into faults and fractures within the metamorphic package, and then cooled enough to harden. This magma was intruded into the very faults along which the metamorphic rock package was shoved up into mountains. During uplift, the extreme pressures of shearing along these fault zones smeared and altered the magmatic rocks into "serpentine," the most common metamorphic rock of the Josephine Formation. Serpentines are generally green and greasy in appearance, and are occasionally soft enough to be carvable as "soapstone." Outcrops of serpentine may also contain pockets of much harder material known as "jade."

The metamorphic rock package was faulted up into the core of California's coastal mountains, and was eventually exposed along the earth's surface by prolonged erosion. Long and narrow exposures of Josephine serpentine extend along the metamorphic rock belt, and delineate some of the faults along which these rocks were thrust into mountains. Indeed, local exposures of Josephine rocks are located along the fault zone that separates Franciscan sedimentary rocks from Galice metamorphic rocks (Figure 11). Because of a strong geographical affinity between Franciscan rocks and the California Coast Range, the fault zone that divides the Franciscan package from the metamorphic rock package is considered the geological division between the "Coast Range," and the "Klamath Mountains" (Alt and Hyndman 1989).

Geological History

There has been relatively little geologic change over the past 70 million years, since the youngest known Franciscan rocks were created. A deep-sea trench still lingers about 50 miles off the coast of northernmost California. Its "ditch-like" depths are so choked with sediments that spill down off the continental shelf, that little evidence of its location can be found on bathymetric maps (Alt and Hyndman 1989). Modern sediments must be millions of years away from being added to the Coast Range, since rocks of the Franciscan Formation continue to rise up there today, at a fingernail's growth rate.

It actually wasn't until the early Tertiary geological period (somewhere between 36 and 58 million years ago) that the first rocks of the Franciscan Formation were thrust into the Coast Range (Harris and Tuttle 1984). The climate at that time was subtropical, and millions of years of warm rains deeply weathered the mountain soils into an orange, iron/aluminum-rich clay (Alt and Hyndman 1989). Later in the Tertiary (~5-24 million years ago), the sea advanced across the early Coast Range, creating a chain of mountain islands that were separated by shallow ocean basins. A few volcanoes started to erupt, mainly beneath the sea. Shallow ocean sediments and volcanic deposits collected in these basins, which can now be seen around Crescent City, and the Mad and Little River Valleys (Harris and Tuttle 1984).

By 3 million years ago, most of the coastal ranges that exist today were being exposed as dry land, and high-gradient streams were depositing thick orange gravel (now called the Gold Bluff Formation) into newly carved valleys. Extensive marine (wave-cut) terraces were developing along the coastline (Harris and Tuttle 1984). During the Pleistocene glacial epoch (100,000-2 million years ago), world sea level dropped about 200 feet, as seawater was locked up into ice caps. Flat marine terraces emerged, and rose out of the sea on the shoulders of rising mountains.[3] As the Coast Range continued to rise, deposits of stream gravel, of the Gold Bluff Formation, were uplifted onto ridge tops.

Over the last 100,000 years, the coastal mountains have continued to rise (as evidenced today by frequent modern earthquakes), but the coastline itself has begun to sink. This has resulted in "drowning" the mouths of river valleys (such as the Klamath's), which has led to the formation of sand-barred coastal lagoons. Geologists theorize that as the sea floor has continued to descend beneath the continent, it has jammed so much sedimentary material into the deep-sea trench that it's begun to pull the entire continental shelf (and coastline) down, along with it (Alt and Hyndman 1989). This type of ocean floor subsidence obviously leaves the trench-filling sediments intensely fractured, sheared, and contorted. Alt and Hyndman (1989) noted that the Franciscan sedimentary rocks were, "…so thoroughly folded and sheared that some large outcrops look as though they have been stirred with a stick."

Indeed, the Franciscan rocks have become so extensively deformed that they are now highly susceptible to causing landslides on hill slopes. In fact, both the Franciscan and metamorphic rock packages have been so pervasively broken into clay-gouged fault zones that the entire Lower Klamath River Basin is subject to substantial landslide erosion; particularly when coupled with the heavy seasonal precipitation that the region experiences. According to Harris and Tuttle (1984), "landslides are so abundant in this area that they cause more downslope movement of material than any other geologic process—including stream action."

Most recently, erosion within the Lower Klamath Basin has been greatly accelerated by human activities. Extensive timber harvesting has exposed topsoil, and have thus compromised the protection that vegetation normally provides through interception of rain wash, and through root tensile strength. Road building, to support logging, has connected thousands of miles of drainage ditches to Lower Klamath tributaries, thus greatly increasing the overall amount of surface erosion. Failure of poorly constructed road-fill platforms, particularly at stream crossings, has sent millions of cubic yards of debris into the tributaries, thus damaging aquatic habitat. All of this is especially true during major storm events. Harris and Tuttle (1984) observed that "gully formation, the loss of rich topsoil, and streams choked with debris are all consequences of man's…exploitation of the redwoods. Each year, millions of dollars' worth of property damage is done by landslides (and flooding) in the northern Coast Ranges."

[3] Crescent City and McKinleyville are both built on these elevated terraces.

C. Timber Management History

Timber harvest activities currently account for the greatest percentage of erosion-related problems within the Lower Klamath sub-basin. According to Balance Hydrologics, Inc. (1995), "erosion related to poorly designed, abandoned or poorly maintained logging roads may be equal to or greater than the all sum of natural erosion processes occurring elsewhere in the basin." The most logical way to begin remediation of these problems is to study the scope and history of previous damage. Information about the problems and failures of the past can help us understand, forecast, plan for, and prevent potential failures and problems in the future. The best way to obtain the overview of an area's erosion history is with the aid of historical aerial photographs. Simpson Timber Company maintains an exceptional archive of aerial photographs, dating back to the 1930's. These photographs include collections obtained from outside companies and governmental agencies.

Detailed evidence of timber cutting, road building, and landslides are all displayed exactly as they appeared when the photos were originally taken. A comparison of these details, over differing years of aerial photography, can help recreate the land management history of an evolving landscape. A thorough study of the logging-related changes that have occurred across the Lower Klamath sub-basin during the past half-century has now been completed. This study satisfies ten informational objectives that were targeted by the LKRP:

1. To identify all areas of timber harvest within each watershed.
2. To differentiate the method(s) of timber harvest used for each cut unit (e.g., clear-cutting vs. selective harvest; tractor skidding vs. cable yarding).
3. To differentiate each cut unit by its approximate[4] year of harvest.
4. To identify the core road network for each watershed.
5. To differentiate roads and road-reaches by their approximate[4] year(s) of construction.
6. To identify all landslides within each watershed.
7. To differentiate landslides by their approximate years of development.
8. To compile all of this information onto maps, at a scale of 1:24,000, for practical review.
9. To compare/contrast the histories of timber cutting, road development, and landslide development, in an attempt to identify cause-and-effect relationships.
10. To analyze road densities and associated stream-crossing densities for input into the Restoration Potential Prioritization Matrix.

[4] "Approximate," since each "photo-year" of aerial photography actually displays the changes to a landscape that have developed over a range of years (since the preceding photo-year).

Wherever possible, this air photo study was performed with the use of:

- Photo coverage's representing each decade since the beginning of local aerial photography.
- Air photo years that best bracket major regional storm events—in order to identify any "surges" in erosional (i.e., landslide) activity that may have resulted from heavy rains & flooding.

Owing to significant gaps in the availability of air photo coverage, these two ideals were not always attainable. For example, during the 1940's and 1950's, no known photo coverage was made over the watersheds that lie north of the Klamath River mouth. Evidently, no company or agency had any practical or economic need for photographs covering the area during that time.

Air Photo Indices: A complete set of air photo index maps, which show the locations of all of the photographs that were utilized in the production of this report, have been compiled and are available from YTFP upon request. The mapped locations of the centers of each photo are shown, along their respective flight lines. These photo centers are identified by photo-year and photo-number information. Data gaps are also identified upon these maps as missing flight lines.

Data Compilation: Once all the appropriate and available photo-year coverages were identified for each watershed, the photos were assembled and viewed in pairs beneath a stereoscope. The land management data, which was needed to satisfy the study's informational requirements, was manually transferred onto paper compilation maps. Simpson Timber Company provided GIS base maps for this purpose.

Data Storage: YTFP is currently digitizing all of the interpreted data into a GIS-based format (ArcView software). The resulting layers of digital data will be maintained within the electronic files of the Yurok Tribal Watershed Restoration Division.

1. Timber Harvest History

For more than a century, timber harvest has remained the main economic staple for the Lower Klamath sub-basin's portion. Commercial harvests began in the mid- to late-1890's, but at that time only locally impacted the forests. Aerial photographs indicate that by the early-1940's, clear-cutting had begun in many of the tributary watersheds. The advent of powerful hydraulic technologies allowed timber cutting to quickly spread across the Klamath Basin. Kier and Associates (1991) noted that intensive logging didn't begin on most Lower Klamath watersheds until the 1950's, but since then has covered more than 80% of the regional land area, including the removal of old-growth from riparian zones. A logging explosion took place in the late-1960's. By 1969, nearly 50% of the Lower Klamath sub-basin had been logged. Between 1966 and 1969 alone, more than one-forth of the area of the entire Lower Basin was harvested. By 1994, nearly all remaining stands of old-growth had been removed.

According to Balance Hydrologics Inc. (1995), “Simpson currently plans harvest levels of about 4,200 acres per year, based on recent replanting histories. Rotation ages for economical trees are assumed to be 50 years for redwood stands, and 60 years for Douglas fir. Much of the remaining second- and third-growth is not expected to be harvested for many years, as it was cut during the 1950’s through 80’s.."

A variety of timber harvest information has been gathered from various air photo analyses, which is summarized in Table 4. The maps from which this information was collected, are listed numerically along the left-hand margin of the Table (next to their respective watersheds). Also listed beside each watershed is its respective area (in square miles), and the relative percentage of the Lower Klamath sub-basin that this area occupies. The bulk of the Table provides columns of descriptive timber harvest information for each watershed, which is tabulated according to the year of the air photo source. This information is purely subjective, and was collected by visually analyzing the maps for identifiable patterns. Once this information has been digitized into GIS, quantitative calculations will be made possible and interpretability will be greatly enhanced. The data is presented entirely in percentages, and has three parts:

1. The percentage of the watershed that was identified as harvested on a designated air photo-year.
2. The percentage of that year’s timber harvest that was identified as clear-cut units (shown in parentheses).
3. The percentage of that year’s timber harvest that was identified as cable-yarded units (shown preceded by an asterisk).

Classification of these cut unit types becomes important because of inherent differences in their erosional characteristics. For the purposes of this database, any cut unit that is not designated as a “clear-cut” is assumed to be a “selective harvest” unit (i.e., a percentage of trees are left behind for re-seeding, ground protection, and later harvest.). Selective harvest units are almost exclusively tractor skidded units. So are clear-cuts. As such, these two harvest types share the many runoff-diversion problems that are characteristic of skid trail development. A small percentage of clear-cuts are actually cable-yarded units, requiring few or no skid trails, and producing far fewer erosional problems.

A tally of the total percentage of logging that was accomplished using cable-yarding techniques is located to the right of the main database, and is labeled “%Cable Yarded.” This percentage represents the relative portion of cable yarded units per watershed, per air photo-year. The “%Total Sub-basin Logged” column, located immediately left of “%Cable Yarded," illustrates a variance in overall percentage totals such that some add up to more than 100%, while others total less than 100%. This variability reflects the fact that some of the watersheds have undergone second-growth harvests (thus >100% of the total area has been logged), while others are not yet fully logged off (as represented by <100%). Certain watersheds can never be fully logged off, since their land surfaces are not entirely wooded. Some of the Timber Harvest History maps show prairies, flood plains, and other features that lack marketable timber.

Table 4. Timber harvest history by air photo year and tributary, Lower Klamath River tributaries, California.

Tributary	Drainage Area (mi^2)	% Total Sub-basin Area	% Watershed Logged Per Year – Years of Available Air Photos: 1948	1954	1955	1956	1958	1960	1962	1966	1968	1969	1972	1975	1978	1981	1984	1988	1991	1994	1997	% Total Sub-basin Logged	%Cable Yarded	Tributary
Mainstem Ah Pah	6.7	2.2%	0%	66%	0%	3%	12%			0%		12%	1%	0%	0%	5%		0%		0%		99%	3%	**Mainstem Ah Pah**
North Fork Ah Pah	6.7	2.2%	0%	13%	0%	28%	3%			0%		14%	1%	13%	0%	14%	1%	0%		0%		87%	68%	**North Fork Ah Pah**
South Fork Ah Pah	2.5	0.8%	0%	35%	0%	12%	65%			0%		71%	0%	17%	1%	3%		0%		0%		204%	1%	**South Fork Ah Pah**
Bear	9.2	3.0%	0%	0%	0%	15%	0%			0%		22%	0%	22%	13%	0%		21%		6%		99%	2%	**Bear**
Blue (Lower)	39.6	12.9%	0%	0%	0%	0%	0%			14%		0%	0%	29%	0%	0%		19%		1%		63%	1%	**Blue (Lower)**
Blue (West Fork)	13.6	4.4%	0%	0%	0%	0%	1%			8%		0%	0%	36%	0%	0%		10%		7%		62%	12%	**Blue (West Fork)**
Cappell	8.5	2.8%	0%	0%	0%	0%	10%			0%		0%	8%	59%	1%	0%		21%		12%		111%	0%	**Cappell**
High Prairie	3.5	1.1%	0%	0%	0%	0%	0%			0%		11%	0%	25%	0%	0%		0%		16%		52%	63%	**High Prairie**
Salt	2.3	0.8%	0%	0%	0%	0%	0%			0%		23%	0%	36%	0%	0%		0%		0%		59%	0%	**Salt**
Hoppaw	4.3	1.4%	10%	0%	0%	0%	0%			0%		12%	0%	32%	0%	0%		0%		16%		70%	38%	**Hoppaw**
Hunter/Mynot	23.4	7.6%	0%	0%	0%	0%	0%			0%		33%	0%	44%	0%	0%		0%		14%		91%	50%	**Hunter/Mynot**
Johnsons	2.8	0.9%	0%	0%	0%	52%	0%			19%		0%	0%	0%	0%	0%		58%		0%		129%	2%	**Johnsons**
McGarvey (incl. W. Fk.)	8.9	2.9%	11%	1%	0%	0%	5%		10%	5%		32%	20%	0%	0%	2%	10%	3%	2%	2%		103%	1%	**McGarvey (incl. W. Fk.)**
Mettah	10.4	3.4%	0%	0%	0%	34%	0%	40%		0%		0%	23%	0%	0%	0%		8%		4%		109%	1%	**Mettah**
Morek	4.0	1.3%	0%	0%	0%	0%	80%			0%		0%	0%	0%	84%	0%		0%		4%		168%	5%	**Morek**
Omagaar	2.3	0.8%	0%	0%	0%	0%	14%			0%		54%	0%	12%	0%	0%		14%		5%		99%	8%	**Omagaar**
Pecwan	27.5	9.0%	0%	0%	0%	0%	22%			0%		42%	0%	8%	0%	13%		0%		5%		90%	2%	**Pecwan**
Pine (Non-Hoopa Portion)	13.3	4.3%	0%	11%	0%	0%	18%			8%		0%	3%	0%	0%	3%		0%		1%	1%	45%	2%	**Pine (Non-Hoopa Portion)**
Roaches	29.3	9.6%	3%	19%	0%	0%	0%			10%		45%	0%	0%	0%	2%		2%		4%		85%	10%	**Roaches**
Saugep	1.1	0.4%	0%	0%	0%	0%	0%			0%		0%	39%	0%	61%	0%		0%		0%		100%	0%	**Saugep**
Surpur	5.8	1.9%	0%	0%	0%	0%	41%			63%		0%	31%	0%	0%	0%		19%		0%		154%	0%	**Surpur**
Little Surpur	2.6	0.8%	0%	0%	0%	0%	37%			55%		0%	0%	0%	0%	0%		12%		14%		118%	0%	**Little Surpur**
Tarup	5.1	1.7%	0%	0%	0%	0%	12%			0%		66%	0%	26%	0%	0%		0%		1%		105%	0%	**Tarup**
Tectah	20.1	6.6%	0%	4%	0%	0%	11%			77%		0%	0%	0%	0%	0%		0%		0%		92%	12%	**Tectah**
Terwer	31.9	10.4%	1%	0%	0%	0%	0%			0%		21%	0%	23%	0%	0%		0%		27%		72%	51%	**Terwer**
Tully	17.6	5.7%	5%	0%	0%	0%	82%			1%		0%	0%	0%	0%	52%		0%		5%		145%	0%	**Tully**
Waukell	3.2	1.0%	6%	0%	30%	0%	0%			0%	44%	0%	4%	0%	20%	0%		0%		0%		104%	0%	**Waukell**
Sub-Basin Totals[1]:	**306.2**		**1%**	**5%**	**0%**	**3%**	**12%**	**1%**	**0%**	**11%**	**0%**	**17%**	**3%**	**16%**	**2%**	**5%**	**0%**	**6%**	**0%**	**7%**	**0%**	**90%**	**15%**	

[1]Lower Klamath Sub-Basin Weighted Averages

Another column, labeled "%Total Sub-Basin Cable Yarded" indicates the relative percentage of the entire Lower Klamath sub-basin that each watershed's "%Cable Yarded" figure represents. The sum of these weighted percentages is the bottom of the "%Total Sub-Basin Cable Yarded" column. This total indicates that approximately 10% of the Lower Klamath sub-basin has been harvested by cable-yarding methods, over the duration of the historical air photos used in this study.[5]

The final row of data, at the bottom of the table, lists the combined percentage totals (in weighted averages) for each year of timber harvest operations throughout the Lower Klamath sub-basin. This represents the overall percentage of the basin that was logged over a relatively short range of years. For example, a look at the bottom of the 1958 column indicates that 13% of the entire Lower Klamath sub-basin was logged during the period between 1956 and 1958. A thumbnail sketch of the timber harvest history for the entire Lower Klamath sub-basin can be made from the bottom-most data field. Cumulative percentages for the sub-basin illustrate a steady increase in overall logging activity through the 1950's, to a peak in 1969, with a sudden decline at the turn of the 1980's, and with periodical increases thereafter. It is important to combine this tabulated information with the provided maps for a much more thorough understanding of the timber harvesting trends across the Lower Klamath River Basin.

2. Road Construction History

Information about the construction of logging roads within the Lower Klamath sub-basin was also gathered during the air photo analysis and has been compiled onto maps of the tributary watersheds. Interpretive data from these maps has been tabulated into Table 5. As would be expected, the vast majority of roads were constructed concurrent with the harvest operations that they supported, so the tabulated road data parallels that of the Timber Harvest History (Table 4).

Table 5 summarizes the history of road development for each watershed. The respective watershed maps are listed numerically along the left margin of the table. The tabulated road data is purely qualitative and highly subjective. Visual estimates of the relative percentages of color-coded road lengths and densities were recorded while inspecting the maps. Thus, for Mainstem Ah Pah Creek (at the top of the table), it is estimated that 25% of the roads were constructed by the time the 1948 air photos were taken. Fifty-four percent were built by 1954, 20% more by 1958, and only a few short road spurs had been added by 1966, representing only 1% of the total road package.

Map 1B illustrates the geographical distribution of these Ah Pah roadways, and indicates that they become progressively younger from the watershed's headwaters down to its mouth. Obviously, logging and associated road-building began along the ready-made access off the old Redwood Highway. During the 1940's, this highway traversed the watershed's headwaters ridges. From there, logging activities generally progressed

[5] It should be noted that early investigators failed to differentiate cable yarded units for six of the listed watersheds, thus skewing related data toward low-end values.

Table 5. Road construction history by air photo year and tributary, Lower Klamath River tributaries, California.

Tributary	Drainage Area (mi^2)	% Total Sub-basin	Miles of Roads	Road Density (mi/mi^2)	# Stream Crossings	Stream Xing Density ($\#/mi^2$)	% Road Construction by Air Photo Year																	Total %
							1948	1951	1954	1955	1956	1958	1960	1966	1968	1969	1972	1975	1978	1981	1984	1988	1994	
Mainstem Ah Pah	6.7	2.2%	77.6	11.6	201	30			64%		18%					13%	5%							100%
North Fork Ah Pah	6.7	2.2%	43.2	6.4	216	32			45%		15%					32%	8%							100%
South Fork Ah Pah	2.5	0.8%	19.8	7.9	109	44			36%		33%					12%	17%			1%				99%
Bear	9.2	3.0%	61.5	6.7	337	37					16%					44%		19%					20%	99%
Blue (Lower)	39.6	12.9%	143.1	3.6	439	11								54%				31%					15%	100%
Blue (West Fork)	13.6	4.4%	36.7	2.7	456	34								61%				32%					7%	100%
Cappell	8.5	2.8%	41.7	4.9	156	18										70%		23%		7%				100%
High Prairie	3.5	1.1%	19.7	5.6	67	19	9%									31%			31%				29%	100%
Salt	2.3	0.8%	11.4	5.0	46	20	31%									50%			14%				5%	100%
Hoppaw	4.3	1.4%	29.4	6.8	153	36	5%									59%		12%	5%				19%	100%
Hunter/Mynot	23.4	7.6%	134.3	5.7	585	25	2%									49%		4%	28%				18%	101%
Johnsons	2.8	0.9%	12.1	4.3	81	29					60%			37%								3%		100%
McGarvey (incl. W. Fk.)	8.9	2.9%	65	7.3	308	35	10%		20%			20%		30%		1%	15%		3%		1%			100%
Mettah	10.4	3.4%	62.8	6.0	353	34					28%		70%									2%		100%
Morek	4.0	1.3%	22.6	5.7	74	19						24%							60%	17%				101%
Omagaar	2.3	0.8%	12.7	5.5	61	27						20%				30%		39%				11%		100%
Pecwan	27.5	9.0%	124.6	4.5	590	21	15%									45%		10%					30%	100%
Pine (Non-Hoopa portion)	13.3	4.3%			241	18						24%				34%				33%			10%	101%
Roaches	29.3	9.6%	150.9	5.2	671	23			29%					56%						7%		5%	3%	100%
Saugep	1.1	0.4%	8.8	8.0	27	25				3%									97%					100%
Surpur	5.8	1.9%	68.2	11.8	146	25						41%		59%										100%
Little Surpur	2.6	0.8%	20	7.7	86	33						67%		31%								2%		100%
Tarup	5.1	1.7%	37.7	7.4	161	32										51%		33%					16%	100%
Tectah	20.1	6.6%	112.5	5.6	566	28			21%			12%		49%				11%	4%	1%		2%		100%
Terwer	31.9	10.4%	174.4	5.5	737	23	4%									37%			25%				34%	100%
Tully	17.6	5.7%	98.9	5.6	273	16			32%			42%		7%						18%			1%	100%
Waukell	3.2	1.0%	33.7	10.5	109	34	2%			1%					15%		30%		51%					99%
Sub-Basin Totals[1]:	**306.2**		**1,623.3**	**5.3**	**7,249**	**24**	**3%**	**0%**	**9%**	**0%**	**3%**	**7%**	**2%**	**21%**	**0%**	**20%**	**1%**	**10%**	**7%**	**4%**	**0%**	**1%**	**12%**	100%

[1]Lower Klamath Sub-Basin Weighted Averages

downstream, reaching the watershed's mouth, at the Klamath River, by 1958. For most of the Lower Klamath River Basin, logging of the tributary watersheds was initiated either at the mouth (along the Klamath River), or off roads that followed the headwater ridges. These were typically the locations where the easiest entry-access could be achieved.

The total number of stream crossings per watershed is listed to the right of the watershed names in Table 5. This is the only truly quantitative data within the table. The numbers were generated by methodically counting up the number of places where mapped roads are shown crossing the mapped creeks that are located within a respective watershed boundary. For the Ah Pah, McGarvey, and Tectah watersheds, the counted numbers were found to be quite comparable (i.e., within a couple of percent) to the actual number of crossings that were inventoried during the detailed upslope assessments (see Section (IV-A).

The bottom of Table 5 shows the weighted cumulative percentages of the roads (per construction year) that were built throughout the entire photo history of the Lower Klamath River Basin. As an example, the 1969 peak in logging activity (Table 4) is easily identifiable as a peak in road construction activity (16%) for the same year. In other words, 16% of the roads that were built between (pre-)1948 and 1994, throughout the sub-basin were constructed in 1969.

Once the mapped road information has been transferred into GIS digital format, other observations will become readily available. For example, the actual number of road miles, per construction-year, per square mile of watershed (i.e., a "road-age density"), could easily be generated by computer, utilizing the various color-coded road-age layers for GIS manipulation. In this manner, precision percentage numbers will eventually be produced for Table 5.

3. Landslide History

During the air photo study, the locations of landslides were noted and transferred onto compilation maps, in accordance with their respective (photo-year) age ranges. The mapped information was then interpreted into tabulated data. All landslide data is quantitative, and has been generated through the laborious tallying of numbers of slides (by age category) that are located within the various watersheds. Landslide data has been divided into 2 parts, as shown in Tables 6-7. Debris torrent data was separated into its own table, in an effort to avoid confusion. Debris torrent data was generated for 17 of the watersheds, but was either overlooked or ignored during mapping by early investigators.

A quick glance at any of the watershed landslide maps that were generated during the course of this study indicates that at least 95% of the slides have delivered some portion of their hillslope debris into a stream. This obviously represents a very significant amount of sediment-producing material.

Table 6. Landslide history by air photo year and tributary, Lower Klamath River tributaries, California.

Tributary	Drainage Area (mi^2)	Erosion Hazard Rating	Number of interpreted Slides (* = Number of interpreted anthropogenic slides) — Years of Available Air Photos: 1948	1951	1954	1955	1956	1958	1960	1966	1968	1969	1972	1975	1978	1981	1984	1988	1994	1997	Totals/Watershed	% Road Related
Mainstem Ah Pah	4.9	H			7 (6*)			2 (1*)		15 (14*)		1*	0	5*	1*	0	0				31 (28*)	90%
North Fork Ah Pah	9.4	H			0			1*		2*		6 (2*)	0	4*	0	0	0				13 (9*)	69%
South Fork Ah Pah	1.6	H																				
Bear	9.2	H	0									14 (6*)		37 (21*)					0		51 (27*)	53%
Blue (Lower)	31.8	M-H	14 (4*)							34 (15*)				63 (37*)					4 (3*)		115 (59*)	51%
Blue (West Fork)	11.1	H	5 (3*)							38 (18*)				87 (50*)					6 (4*)		136 (75*)	54%
Cappell	8.5	M-H		1								7 (5*)		13 (6*)		3			0		24 (11*)	46%
High Prairie/Salt	5.6	H	0									4 (2*)		17 (9*)	0				17 (6*)		38 (17*)	45%
Hoppaw	4.33	H	1									4*		24 (10*)	7 (5*)				19 (12*)		55 (31*)	56%
Hunter/Mynot	23.75	H	7 (1*)									4*		59 (34*)	5*				96 (30*)		171 (74*)	44%
Johnsons	2.9	H					1			3 (1*)			1*					1*			6 (3*)	50%
McGarvey (incl. W. Fk.)	8.9	H																				
Mettah	10.1	H					0		13 (5*)									13	7 (1*)		33 (6*)	18%
Morek	4	M-H						0							4	3 (2*)			0		7 (2*)	29%
Omagaar	2.25	H	1									3*		1*				3 (1*)	2		10 (5*)	50%
Pecwan	27.6	M-H	0									19 (6*)		28 (6*)					3 (2*)		50 (14*)	28%
Pine (Non-Hoopa portion)	~11	H						4 (3*)		0	0					29 (5*)			0	0	33 (8*)	24%
Roaches	29.4	H	7 (2*)		83 (55*)					Incl. in '69		131 (78*)		42 (17*)					8 (4*)		271 (156*)	58%
Saugep	1.1	H	0			0					0		0		0				3		3	0%
Surpur	5.8	H						2*		5 (3*)			9 (3*)			1					17 (8*)	41%
Little Surpur	~2.6	H						0		1			0			0					1	0%
Tarup	5.1	H	0									22 (9*)		10 (5*)				1	6 (4*)		39 (18*)	46%
Tectah	20.1	H	13		17 (7*)			24 (7*)		27 (14*)				34 (20*)	16 (5*)			24 (9*)			155 (62*)	40%
Terwer	31.9	H	18 (3*)									93 (42*)		135 (52*)	0				105 (46*)		351 (143*)	41%
Tully	17.6	H			11			117 (4*)		0						0			0		128 (4*)	3%
Waukell	3.2	H	0		1						0		0		0				1		2	0%
Sub-Basin Totals[1]:	~293.73		66 (13*)	1	119 (68*)	0	1	150 (18*)	13 (5*)	125 (67*)	0	308 (162*)	10 (4*)	559 (277*)	33 (16*)	36 (7*)	0	42 (11*)	277 (112*)	0	1,729(760*)	T=44%/A=39%

[1]**Lower Klamath Sub-Basin Weighted Averages**

Table 7. Debris Torrent history by air photo year and tributary, Lower Klamath River tributaries, California.

Tributary	**Number of interpreted Slides (* = Number of interpreted anthropogenic slides)**																**Totals**
	Years of Available Air Photos																
	1948	**1951**	**1954**	**1956**	**1958**	**1960**	**1966**	**1969**	**1972**	**1973**	**1975**	**1978**	**1981**	**1988**	**1994**	**1997**	
Bear	0							0			0				0		0
Cappell		0						0			1		1*		0		2 (1*)
High Prairie/Salt	0						Incl. In '69	1			0	3 (2*)			0		4 (2*)
Hoppaw	0						Incl. In '69	0			1*	5 (2*)			0		6 (3*)
Hunter/Mynot	2						Incl. In '69	4*			2*	32 (19*)			16 (4*)		56 (29*)
Johnsons				0			1*		1*					0			2*
Mettah						4*								0	1		5 (4*)
Morek					0							1*	1*		0		2*
Omagaar	0							0			0			1*	0		1*
Pine (Non-Hoopa portion)					1*		0	0		0			4 (3*)		0	0	5 (4*)
Roaches	1*		18 (11*)				Incl. In '69	49 (27*)			6				3		77 (39*)
Surpur					0		0		0				1*				1*
Little Surpur					0		0		0				0				0
Tarup	0							12 (5*)			5 (3*)			0	0		17 (8*)
Tectah	1		0		6		10 (1*)				10 (9*)	2		2*			31 (12*)
Terwer	2						Incl. In '69	18 (10*)			0	23 (11*)			1*		44 (22*)
Tully			0		2 (1*)		0						0		0		2 (1*)
Sub-Basin Totals[1]:	6 (1*)	0	18 (11*)	0	9 (2*)	4*	11 (2*)	84 (46*)	1*	0	25 (15*)	66 (35*)	7 (6*)	3*	21 (5*)	0	255 (131*)

[1]Lower Klamath Sub-Basin Weighted Averages

Table 6 shows a tally of the number of landslides that have occurred within each Lower Klamath watershed, by their respective year of air photo identification. Relevant maps are listed numerically along the left margin of the table. Some of the slides have been classified as "anthropogenic," or human-caused. These slides are denoted with asterisks. By definition, anthropogenic slides are slope failures that are triggered by the (direct or indirect) activities of Man. Anthropogenic slides are most commonly road related, and therefore appear either above, or (more commonly) below a road reach. Landslides below a road are usually debris torrents, which are triggered by failure of the road prism. Landslides that occur above a road are generally cut-bank failures, triggered by the undercutting of a hillside during road bench construction.

Complete tallies of natural and human-related landslides are shown within the database (Table 6), and a brief comparison of their relative numbers illustrates that anthropogenic slides typically account for slightly less than half of the total. They are, therefore, slightly outnumbered by their natural counterparts, within the Lower Klamath sub-basin.

The actual percentages of road-related landslides per watershed are listed in the "%Rd. Related" column, to the right of the database. The Erosion Hazard Rating (E.H.R.) is also listed on the left of the spreadsheet. This rating, which is based upon the rock type, soil type, slope angle, and road densities within each watershed, appears to have no correlation with the percentages of road-related slides that actually occur.

Table 7 is a variation of Table 6 (minus Erosion Hazard Ratings), as it relates to debris torrents. The total numbers of debris torrents are included within the landslide totals (and anthropomorphic totals) that are listed in Table 6. Debris torrent information was broken out in an effort to keep the landslide table manageable. It is included here only for the sake of completeness.

<u>Landslide Age vs. Road Construction Age</u>

Watershed "restorationists" generally purport that a time lag of twenty to thirty years is necessary to "age" a newly constructed road toward its eventual demise through fill-failure. Theory has it that the organic materials that are buried within the road-fill require that amount of time to rot and collapse, which generates the initial cracks that lead to eventual road disintegration, with subsequent landslides.

This does not appear to be the case for the roads of the Lower Klamath River Basin. A comparison of the map-based information, that was compiled during the air photo survey, suggests that, throughout the Lower Klamath watersheds, the photo-ages of landslides tend to correlate with the photo-ages of the respective roads along which they occur. One notable exception is Hunter Creek, where a large number of 1994-vintage landslides are found along 1969-vintage roads. Local pockets of slides exhibit 6- to 9-year time lags, but for the most part, the timing of the landslides correspond with the construction timing of their host roads, indicating that these roads commonly fail shortly after construction.

Storm Tested Roads

Ideally, the landslide history data shown in Table 6 would provide a basic breakdown of the roads that are poised towards failure, and those that have weathered the storms of time. By bracketing the air photo landslide data around major storm years, (i.e., 1955, 1964, 1972, 1975, 1982, 1986, and 1997), and by comparing the number of landslides before and after each storm event, it should be possible to identify any increasing landslide activity, and further to focus attention onto those generations of roads which are chronically failing. Increased slide activity should occur along those roads that are most prepared for failure.

Eventually, the bulk of unstable material along these roads will have failed, their landslide activity will begin to diminish (even during storms), and they will no longer pose as much of a threat. Storm bracketing would then identify the next generation of roads that would come into play.

This bracketing approach to road risk assessment is dependent upon chronological data. The more closely any chronological data can be related through time, the greater the confidence of interpretation. Unfortunately, there are significant temporal and spatial gaps in the archival photo coverage, and consecutive photo-year coverage for any one area are just not available. Table 6 indicates that for the major storm years, it is virtually impossible to locate any air photo sets that could be used as either before or after data for the Lower Klamath sub-basin. An inventory of all Lower Klamath air photo sets, outside of of what was available for this study, should be conducted to determine whether adequate coverage exists for this analysis.

Transportation Master Plan

One of the original objectives set forth for the Lower Klamath Restoration Plan is completion of a Transportation Master Plan for the entire Lower Klamath sub-basin. This plan would classify all Simpson Timber Company roads as either “permanent” (roads requiring continuing maintenance} or “decommissioned” (those roads that are no longer needed, and therefore require either partial or complete removal). Completion of such a plan will require extensive coordination and communication between members of the Yurok Tribe and the Simpson Timber Company. This communication has been ongoing and has so far resulted in Road Classification Maps 1D (for Ah Pah), 7D (for McGarvey), and 16D (for Tectah Creek watersheds). YTWRD will continue to work with Simpson to finalize planing for the remainder of the Lower Klamath road networks.

D. Non-Forestry Land Management History

While timber harvesting is the predominant land management activity in the Lower Klamath sub-basin, additional activities take place and/or are proposed for site-specific areas. While these activities are relatively minor in the context of the entire sub-basin, they potentially are having (or could have) a significant impact on fish populations and associated habitat within individual tributaries. Consequently, it is essential that these activities and appropriate restorative measures be identified in order to lessen their impacts on anadromous salmonid populations.

1. Livestock Grazing

Only a small portion of the Lower Klamath sub-basin contains suitable terrain for livestock grazing. Cattle are actively grazed on privately owned pastures in Salt, lower Hunter/Mynot, and lower Terwer Creeks. The cattle are typically rotated between pastures in these areas over the course of the year, with each pasture receiving some level of grazing pressure between 6-9 months a year on average. Portions of all of these pastures are subject to inundation by high creek flows on an annual basis, as well as less frequent flooding by the mainstem Klamath River and estuary. All of these pastures are located within the floodplain of the Klamath River. The Hunter, Mynot and Salt Creek pastures were established through leveeing of the Hunter Creek slough, an estuarine channel that previously extended up through present day Salt Creek to the mouth of High Prairie Creek. The Terwer Creek pastures were established on a large flood terrace on lower Terwer Creek near the confluence with the Klamath River. Cattle are also grazed on the Klamath River bar at the confluence of Tarup Creek.

In addition to these grazing operations, a population of feral cattle has become established in lower Blue and Bear Creeks. These cattle originated from a domestic herd in the vicinity of Pecwan, which have remained unmanaged since they migrated to lower Blue/Bear Creeks approximately 10 years ago. Several generations of offspring have been observed by YTFP over the past six years and few if any of these cattle still possess brands. This wild herd has slowly extended its range within Blue Creek, and as of the last two years has been observed as far upstream as the mouth of Slide Creek, near the lower boundary of the Siskiyou Wilderness Area. It appears that this population has split off into multiple herds as their numbers and range has expanded.

The potential effects of livestock grazing on anadromous fish and their habitat are summarized as follows:

- **Degradation, reduction or elimination of riparian vegetation**. Livestock grazing can alter or eliminate riparian areas through direct grazing of riparian vegetation, trampling of stream banks, stream channel widening and aggradation, degradation and compaction of stream bank soil, and lowering of the water table (Fleischner 1994; Platts 1990, 1991). Livestock more typically graze riparian areas than upland zones due to flatter terrain, availability of water and shade, and presence of more succulent vegetation (Fleischner 1994; Platts 1991).

- **Stream channel and bank degradation.** Livestock grazing in and/or adjacent to stream channels can negatively impact salmonid habitat through increased sedimentation, stream bank trampling, reduction in stream shading and instream cover, channel widening and aggradation, and reduction in instream habitat diversity (Fleischner 1994; Platts 1990, 1991).

- **Reduction in Water Quality.** Livestock grazing can negatively impact stream water quality by increasing water temperature, decreasing dissolved oxygen levels, altering nutrient and suspended sediment levels, and increasing bacterial populations (Fleischner 1994; Platts 1990, 1991).

2. Gravel Mining

There presently is only one commercial gravel mining operation within the Lower Klamath River tributaries, located in lower Hunter Creek (Figure 1). This operation extracts 5,000-15,000 cubic yards of gravel from multiple sites in lower Hunter Creek on an annual basis, with extraction activities typically occurring in late summer and early fall. In addition to the Hunter Creek gravel operation, similar plans have been proposed in the past for lower Terwer Creek (McBride 1990). Simpson Timber Company routinely extracts gravel from lower Hoppaw Creek (Figure 1) during the summer months in an attempt to address channel aggregation and flood risk in the channelized lower reaches of this tributary.

The majority of past and proposed gravel mining projects have involved extraction of gravel from mainstem Lower Klamath gravel bars. While these activities may negatively impact the lower Klamath River channel and associated fish populations, these operations fall outside of the geographical area addressed by this plan (Lower Klamath tributaries). Gravel extraction has also previously been proposed as a means to address the large deltas that have formed at the mouths of several Lower Klamath tributaries, but no such activities have been undertaken to date.

Extraction of gravel in and near anadromous fish streams can cause deleterious impacts to salmonid populations and their habitats. The potential effects of gravel extraction activities on anadromous fish and their habitat are summarized as follows:

- **Extraction of bed material causes streambed degradation**. Degradation can extend upstream and downstream of an extraction site. Headcutting, erosion, increased velocities, and concentrated flows can occur upstream of the extraction site due to a steepened river gradient (OWRRI 1995). Natural deposition of gravel “armors” the streambed, stabilizes banks and bars whereas removal of this armored layer causes scour and sediment movement (OWRRI 1995). When the streambed surface is removed, the finer subsurface particles become vulnerable to erosion at lower flows. Gravel removal may also reduce gravel delivery to downstream spawning areas (Furniss et al. 1991).

- **Gravel extraction increases suspended sediment, sediment transport, water turbidity, and gravel siltation** (OWRRI 1995). Salmon redds downstream of extraction sites are susceptible to deposition of displaced sediments resulting in egg suffocation or suppressed fry emergence. Fine sediments decrease survival of incubating fish eggs as blockage of interstitial spaces by silt prevents oxygenated water from reaching the eggs and removal of metabolic wastes (Chapman 1988;

Reiser and White 1988). High silt loads may also inhibit juvenile and adult fish behavior, feeding, migration, or spawning (Bisson and Bilby 1982; Bjornn and Reiser 1991; OWRRI, 1995). In addition, operation of heavy equipment in the channel bed can directly destroy spawning habitat and produce increased turbidity and suspended sediment downstream (Kondolf 1994a).

- **Streambed degradation changes channel morphology** (Collins and Dunne 1990; Kondolf 1994a,b). Gravel removal can cause a high likelihood for diversion of flow through the extraction site. Gravel bar skimming creates a wide, flat cross section, eliminates confinement of the low flow channel, and results in a thin sheet of water at base flow (Kondolf, 1994a). Shallow water depths associated with mined areas could impede upstream migration of anadromous salmonids during low flows, affect water quality, and reduce habitat diversity.

- **Removal or disturbance of instream roughness elements during gravel extraction activities negatively affects the quality and quantity of anadromous fish habitat**. Instream roughness elements such as large woody debris (LWD) help to provide structure to the stream ecosystem and provide critical habitat for salmonids (Koski 1992; Naiman et al. 1992; OWRRI 1995). Roughness elements function in controlling channel morphology and stream hydraulics, in regulating the storage of sediments, gravel and organic materials, and in creating and maintaining habitat diversity. The importance of large woody debris has been extensively documented, and its removal results in an immediate decline in salmonid abundance (e.g.: see citations in Hicks et al. 1991; Koski 1992; OWRRI 1995; Reeves et al. 1991).

- **Gravel extraction activities can damage the riparian zone.** Koski (1992) states that the carrying capacity of a given stream to produce salmonids is controlled by the structure and function of the riparian habitat. This habitat includes stream banks, riparian vegetation, and vegetative cover. Damaging any one of these components will result in negative impacts to the stream ecosystem. Stream bank destabilization can occur and leads to increased erosion rates and sediment delivery. Loss of riparian vegetation can lead to reduced shading and loss of overhanging vegetative cover. Destruction of riparian trees directly affects the supply of recruitable woody debris available to the stream channel.

3. Hydroelectric Development

No hydroelectric facilities currently exist in any Lower Klamath tributaries. A small-scale hydroelectric project has been planned in lower Pecwan Creek in order to supply Pecwan and Wautek (Johnsons) with electrical power. Tentatively the project is designed to include a water diversion structure within the mainstem ("West Fork"), just upstream of the Simpson Bridge Crossing. Water diverted from this structure would be transported in ≈15" diameter pipe down the ridge between the North and East Forks to a power generation facility that would be located near the North and East Fork confluence. At this point, the water would be returned to the stream channel. An additional water diversion from the East Fork of Pecwan Creek is also being considered, with this water being transported down the same route to the same power generation facility. A similar facility has been proposed for Cappell Creek as well, although specific design and location has not been determined. Both of these projects are tentatively on hold pending collection of stream discharge data.

Potential fisheries-related impacts associated with small-scale hydroelectric projects include impingement and entrainment of fish in diversion structures, alteration of stream habitat due to inundation and dewatering, changes in water quality and sediment transport, and alteration and fluctuation of natural flow regimes (Rochester 1984). The types and magnitudes of potential impacts resulting from this project need to be assessed after additional project plans are made available.

A hydroelectric project was previously proposed for the Blue Creek drainage in 1981 (Erickson 1981). This project, a “small water diversion turbine plant,” was shelved shortly thereafter following the inclusion of portions of Blue Creek in the Siskiyou Wilderness Area. It is unlikely to resurface given the land management status of Federal lands in the Blue Creek basin.

4. Urbanization and Development

The effects of population growth and related development are very site-specific within the Lower Klamath sub-basin. The principal population areas near fish-bearing tributaries are Requa, Klamath and Klamath Glen in the lower portion of the sub-basin, and Wautek (Johnsons) and Pecwan in the upper portion of the sub-basin. Primary development activities undertaken in these areas include:

- **Stream channelization and levee construction (flood control).** The channelization and leveeing of streams results in a loss of stream meanders and sinuosity, increased channel confinement and downcutting, a reduction in habitat complexity diversity, increased water velocities, and accentuated peak stream flows (Chapman and Knudson 1980; Scott et al. 1986; USDA et al. 1998). In addition, these activities typically involve the removal of riparian vegetation and channel obstructions such as large woody debris (USDA et al. 1998).

  Portions of the following tributaries have been subjected to these activities: Salt, High Prairie, Hunter, Mynot, Hoppaw, Waukell, and Terwer Creeks (Figure 1). Salt and lower Hunter Creeks historically flowed into Hunter Creek slough, a long arm of the Klamath estuary that extended upstream through present day Salt Creek to the High Prairie Creek confluence. Levee construction eliminated this estuarine slough and both Salt and lower Hunter Creek were channelized through present day pastureland. Hunter Creek levees extend upstream from its mouth to the upper end of the Hunter Creek subdivision (2.5 miles), while the Salt Creek levees extend just upstream of the Requa Road bridge crossing (0.5 miles). High Prairie Creek was subsequently channelized between its confluence with Salt Creek and the Highway 101 bridge crossing (1000 feet). Similarly, levees were built along lower Mynot

Creek between its confluence with Hunter Creek and the housing development upstream of the Margaret Keeting School.

The lower half of Hoppaw Creek flows through a historic Simpson Mill site before passing through a Highway 101 interchange and the old Klamath townsite and into the Klamath estuary. Consequently, the lower two miles of Hoppaw Creek have been subjected to levee construction, channel realignment, and channelization in an attempt to minimize flooding of these industrial and residential areas.

Waukell Creek was realigned and channelized during the relocation of Highway 101 following the 1964 flood. This one mile reach, located adjacent to Highway 101, includes a long concrete spillway that is a complete barrier to upstream fish passage.

A levee was constructed around the Klamath Glen housing community following the 1964 flood. This levee extends along the lower 0.5 miles of Terwer Creek, between its confluence with the Klamath and the Highway 169 Bridge Crossing.

- **Domestic Water Withdrawals**. Established domestic water systems are currently withdrawing water from the following fish-bearing tributaries: Salt (well), High Prairie (well), Hunter (well), and Cappell Creeks (instream diversion). Potential impacts associated with domestic water withdrawal include lowering of the water table and reduced stream flows, as well as impingement and entrainment of fish at diversion structures. With the exception of Cappell Creek, all lower Klamath tributary water supplies originate from wells, and therefore impingement and entrainment of fish is not an issue. Similarly, the Cappell Creek diversion is located upstream of fish-bearing stream reaches and hence these impacts do not exist with this water supply. The water quantities diverted at each location are not presently known, but are assumed minor in relation to available supply. Nonetheless, these quantities should be determined and potential impacts assessed.

- **Garbage Dumps**. The only established garbage dump located within a Lower Klamath tributary is the Saugep Creek Refuse Transfer Station. Del Norte County operates this facility, which has been established at this location for several years. This facility was previously an on-sight dump located immediately adjacent to the stream channel prior to the establishment of the existing transfer station (A. Nova, personal communication). While many illegal dumps exist along the Lower Klamath River, none currently exist within any fish-bearing Lower Klamath tributaries.

III. Watershed Prioritization Process

In the Long Range Plan of the Lower Klamath Restoration Program, Kier and Associates (1991) state that "The low number of anadromous salmonids in the Lower Klamath Tributaries is directly related to sediment problems. …Only changes in land use management and large-scale watershed stabilization efforts can effectively address these problems and begin the process of recovery of the Lower Klamath tributaries. …Only by reducing the sediment supply of the entire Klamath River Basin, and allowing time for natural recovery, can the current problems be fully resolved."

Naturally high erosion rates in the Lower Klamath sub-basin have been exacerbated substantially over the last 60 years due to anthropogenic activities. Timber harvest and its associated road construction and maintenance have played the key role in increasing sediment delivery to streams. According to Balance Hydrologics, Inc. (1995) "erosion related to poorly designed, abandoned or poorly maintained logging roads may be equal to or greater than the all sum of natural erosion processes occurring elsewhere in the basin."

Deteriorated watershed conditions that have been identified as reducing biological diversity and limiting the recovery of anadromous fisheries resources include road-related factors such as:

- Excessive sediment, including fines and/or coarse material.
- Altered hydraulics due to road encroachment.
- Altered runoff regimes from roaded and cut hill slopes.

The aquatic populations of these watersheds can be protected through employment of protective land use practices, including the implementation of erosion prevention and restoration work on hill slopes that have already been disturbed by past land management activities.

A. Prioritization Matrix Development

Given the expansive geography of the Lower Klamath sub-basin and the large number of fish-bearing tributaries, it was necessary to devise a methodology for prioritizing the order in which each tributary received watershed restoration activities. The Yurok Tribal Fisheries Program and Watershed Restoration Program have collected and compiled an extensive amount of watershed assessment data across the entire Lower Klamath sub-basin (see Section II). It was necessary to develop a means to synthesize all of this information into a quantified ranking of upslope restoration priority for each tributary. While there are other restoration needs beyond upslope remediation, erosion control is the dominant restorative need in the sub-basin. In many cases, it is necessary that upslope restoration supercede other restoration activities in order for our approach to effectively address problems in the watershed (see Section IV-B).

YTFP developed a ranking matrix that incorporates biological, instream, and upslope parameters. Each parameter, defined below, was developed based on data that was available uniformly across all 30 anadromous fish-bearing tributaries. This was important to ensure that the rank of select tributaries was not biased due to a lack of data. It was also deemed important that the three parameters (biological, instream, and upslope) be weighted evenly in the scoring process. Consequently, two categories were established for each of the three parameters, resulting in six total scoring criteria. Each of the criteria was scored on a scale of 1-5, with a maximum total score of 30 possible. Stream drainage area was used as a tiebreaker in order to rank between streams that received equal scores, with larger watersheds receiving priority. This was based on the assumption that all other things being equal, a larger drainage has a greater production potential once habitat conditions are improved.

The first two parameters were developed with the intent of ranking streams based on the diversity and significance of fish populations and the overall condition and accessibility of instream habitat. The goal was to prioritize the streams that are in the best biological and physical condition, following a "protect the best, restore the rest" philosophy. The upslope parameter was then added, factoring in road and stream crossing densities as indicators of the quantity of upslope restoration that likely needed to occur. This is based on the assumption that high densities of road and stream crossings equates with high levels of potential road-related erosion sites that need to be treated. In summary, the approach was to rank watersheds highest for upslope restoration activities that were in the best biological and physical condition, and that likely had the largest number of erosion sites that were in need of treatment. Tributaries that were less biologically diverse and significant, had poorer habitat conditions, and/or had fewer potential upslope treatment sites were correspondingly ranked lower for restoration activities.

B. Ranking Criteria Descriptions and Definitions

<u>Anadromous Salmonid Diversity</u>

This parameter is a biological indicator of current anadromous fish species diversity with respect to the historical status of fish populations. Between 1996-1999, YTFP has conducted fish presence/distribution surveys throughout all anadromous-accessible lower Klamath streams. Although historical fish presence data are sparse for some tributaries, many streams possess sufficient records with which to gage historical fish species presence. Current data are considered 1980-present, with an emphasis on the data collected 1996-1999. This parameter also takes into account the consistency of presence throughout the 1996-1999 sampling period. In particular, streams in which given species were consistently observed during each year were ranked higher then those where the species was only sporadically observed. Ratings are from 1(low) to 5 (high).

- **(5)** Four anadromous salmonid species regularly present vs. documented historical occurrence.
- **(4)** Four anadromous salmonid species documented in current data, but at least

one of the species has only been sporadically observed.

- **(3)** At least two anadromous salmonid species regularly present, with potential sporadic presence of others. Possible loss of species utilization vs. documented historical data. Historical data may be lacking.
- **(2)** One anadromous salmonid species regularly present, with the sporadic presence of at least one other species. Possible loss of species utilization vs. documented historical data. Historical data may be lacking.
- **(1)** One anadromous salmonid species present, with no documented occurrence of other species in current data. Possible loss of species utilization vs. documented historical occurrence, or no documentation of anadromy. Historical data may be lacking.

Relative Biological Importance

Biological importance rates the relative significance of selected tributaries to salmonids- does the drainage in question fulfill a critical role within a larger area? Examples include source areas (broodstock), thermal refugia, and off-channel overwintering habitat. This parameter is designed as a filter to distinguish between tributaries that receive equal rating for Anadromous Salmonid Diversity. While an equal number of anadromous salmonids may have been documented in two tributaries, this parameter addresses which is fulfilling a more critical role for Lower Klamath fish populations. Ratings are from 1 (low) to 5 (high).

- **(5)** Selected tributary of crucial biological importance to salmonid populations in the lower Klamath basin.
- **(4)** Selected tributary has low-moderate biological importance to salmonid populations in the lower Klamath basin.
- **(3)** Selected tributary has moderate biological importance to salmonid populations in the lower Klamath basin.
- **(2)** Selected tributary has low-moderate biological importance to salmonid populations in the lower Klamath basin.
- **(1)** Selected tributary has relatively small biological importance to lower Klamath basin salmonid populations.

Channel & Riparian Condition

This component assesses the overall channel and riparian condition of the selected Lower Klamath tributaries. Characteristics considered include: channel and bank stability, aquatic habitat diversity and complexity, quantity and complexity of available fish cover, substrate distribution and embeddedness, riparian vegetative cover, and overall quality of spawning and rearing habitat for anadromous salmonids. Ratings are from 1 (low) to 5 (high).

- **(5)** Existing instream habitat and riparian canopy are in a relatively pristine condition and are providing top-quality salmonid spawning and rearing habitat for all species present.
- **(4)** Existing instream habitat and/or riparian canopy are providing high quality salmonid spawning and rearing habitat for all species present. Some evidence of channel and/or riparian degradation are present, but as of yet does not appear to be significantly limiting salmonid production and survival.
- **(3)** Existing instream habitat and riparian canopy are in moderate condition. The tributary possesses the necessary habitat for most/all species present, but channel degradation is likely limiting production and survival to some degree.
- **(2)** Existing instream habitat and riparian canopy are noticeably degraded in large portions of the tributary. This channel degradation is likely resulting in a moderate limiting of salmonid production and survival.
- **(1)** Existing instream habitat and riparian canopy are in poor condition. Extensive aggradation and channel instability is prevalent throughout the drainage. This channel degradation is likely resulting in a significant limiting of salmonid production and survival.

<u>Habitat Connectivity</u>

Habitat connectivity ratings are based on the relative level of aquatic habitat isolation within an impacted basin. Factors such as severity of subsurface flows at creek mouths, intermittent stream segments, and presence and magnitude of fish barriers are considered. Connectivity for both adult and juvenile age classes is also considered. This parameter is designed as a filter to distinguish between tributaries that receive equal rating for Channel and Riparian Condition. While two tributaries may be equally rated for habitat conditions, which is providing access to a larger quantity of habitat during a longer period of the year? In addition, which tributary is providing more unlimited access for adult immigration and juvenile emigration? Ratings are from 1 (low) to 5 (high).

- **(5)** Tributary has adequate perennial flow to provide uninhibited access for adult and juvenile migrations. Additionally, tributary provides unencumbered access for salmonids throughout all anadromous stream reaches.
- **(4)** Tributary has adequate perennial flow to provide access for adult and juvenile migrations during all critical migrational periods. Additionally, tributary possesses only minor passage hindrances in any anadromous stream reach.
- **(3)** Tributary has sub-surface flow conditions during portions of juvenile and adult migrational periods, although tributaries typically maintain access during the majority of these periods. Tributary may possess passage hindrances in select anadromous stream reaches.

- **(2)** Tributary has sub-surface flow conditions during significant portions of juvenile and adult migrational periods, has substantial portions of available habitat dry up during summer/fall months, and/or has significant barriers that limit access upstream reaches.
- **(1)** Tributary has sub-surface flow conditions during more then half of juvenile and adult migrational periods and has substantial portions of available habitat dry up during summer/fall months. Tributary may also have significant barriers that limit access upstream reaches.

Road Density

This parameter is based on data provided from analysis of Lower Klamath tributary GIS coverage. The ratings are based on the range of road density values for all Lower Klamath tributaries, with the upper end of the ratings being the highest measured road density from all tributaries. Ratings are from 1 (low) to 5 (high).

- **(5)** Tributary has a road density between 9.6 and 12.0 road miles/square mile
- **(4)** Tributary has a road density between 7.2 and 9.6 road miles/square mile
- **(3)** Tributary has a road density between 4.8 and 7.2 road miles/square mile
- **(2)** Tributary has a road density between 2.4 and 4.8 road miles/square mile
- **(1)** Tributary has a road density between 0.0 and 2.4 road miles/square mile

Stream Crossing Density

This parameter is based on data provided from analysis of Lower Klamath tributary GIS coverage. The ratings are based on the range of stream crossing density values for all Lower Klamath tributaries, with the upper end of the ratings being the highest measured stream crossing density from all tributaries. Ratings are from 1 (low) to 5 (high).

- **(5)** Tributary has a stream crossing density between 25.6 and 32.0 stream crossings/square mile
- **(4)** Tributary has a stream crossing density between 19.2 and 25.6 stream crossings/square mile
- **(3)** Tributary has a stream crossing density between 12.8 and 19.2 stream crossings/square mile
- **(2)** Tributary has a stream crossing density between 6.4 and 12.8 stream crossings/square mile
- **(1)** Tributary has a stream crossing density between 0.0 and 6.4 stream crossings/square mile

C. Restoration Prioritization Matrix

Table 8. Lower Klamath tributaries watershed restoration prioritization matrix.

Sub-Basin	Anadromous Salmonid Diversity (1-5)	Relative Biological Importance (1-5)	Channel & Riparian Condition (1-5)	Habitat Connectivity (1-5)	Road Density (1-5)	Stream Crossing Density (1-5)	Total (1-30)	Rank (1-30)
Salt Creek	2	2	2	2	2	1	11	26
High Prairie Creek	2	1	3	1	2	2	11	25
Hunter Creek	5	4	2	2	2	2	17	11
Hoppaw Creek	4	3	2	1	3	3	16	12
Waukell Creek	2	1	1	1	4	3	12	24
Saugep Creek	2	1	1	2	3	2	11	30
Terwer Creek	5	5	4	3	2	2	21	3
McGarvey Creek	4	4	3	4	3	2	20	5
Tarup Creek	4	2	2	1	3	2	14	22
Omagaar Creek	3	1	2	1	2	2	11	29
Blue Creek								
- Mainstem	5	5	5	5	2	2	24	1
- West Fork	3	3	3	4	2	3	18	8
- Slide Creek	1	3	4	4	1	1	14	20
- Nickowitz Creek	2	3	4	4	1	1	15	13
- Crescent City Fork	5	5	5	5	1	1	22	2
Ah Pah Creek								
- Mainstem	3	3	2	2	5	3	18	9
- North Fork	3	2	3	3	2	2	15	14
- South Fork	3	3	2	2	4	5	19	7
Bear Creek	3	2	2	2	3	3	15	15
Surpur Creek	3	1	1	2	4	3	14	21
Little Surpur Creek	1	1	1	2	3	3	11	28
Tectah Creek	4	5	3	3	2	3	20	4
Johnsons Creek	4	3	2	2	2	2	15	16
Pecwan Creek	3	2	3	2	2	2	14	18
Mettah Creek	4	4	3	4	2	2	19	6
Roaches Creek	3	3	3	3	2	3	17	10
Morek Creek	1	1	3	2	2	2	11	27
Cappell Creek	1	2	3	2	2	2	12	23
Tully Creek	1	3	3	3	2	2	14	19
Pine Creek	3	3	3	3	1	1	14	17

IV. Restoration Actions

A. Upslope Remediation

Upslope watershed restoration work encompasses all activities that are related to the remediation of water diversions and erosional problems within a watershed, which occur upon the slopes above a stream, and have the potential to deliver sediment into its waters. The most critical erosion and/or chronic sediment sources in any watershed are treated by the following means:

- **Road and skid trail decommissioning/obliteration:** abandoned roads, or ones that are considered damaging to stream channels and riparian zones, need to have unstable fill and stream crossings excavated, compacted surfaces scarified, and diversion potentials eliminated. This decreases the road density, and prevents the eventual failure of non-maintained culverts and disintegrating "Humboldt" crossings.

- **Road upgrade/improvements** for erosion control through:
  - excavation of unstable side-cast or uncompacted fill (e.g., along the outside edge of a landing, or the inside approach to an incised stream crossing).
  - upgrading culverts and stream crossings.
  - installation of critical rolling dips to prevent stream diversions.
  - installation of ditch relief culverts, and re-grading of the road platform.

- **Slope stabilization:** landslide prevention techniques include revegetation, dewatering, and buttressing of potential and active slides and earth flows.

The success of in-stream restoration efforts is largely dependent upon addressing upslope conditions and sediment sources. Balance Hydrologics, Inc. (1995) observe that "a disciplined understanding of the connection between hillslope conditions and channel conditions may improve prospects for 'successful' channel projects which could be implemented early on in the restoration program." It is now generally recognized that if upper watershed areas are managed properly, streams and creeks will naturally recover to a self sustaining, productive condition.

In order to limit and prevent further damage to fish habitat and to improve the conditions of sediment-impacted streams, the following general principles for active land use management in forested areas, where roads have been developed, have been recommended as up-slope restoration tasks (Hartsough 1989; Furniss 1989; Weaver 1986):

- Prevent erosion wherever possible.
- Minimize the future risks of eroded material entering streams.
- Ensure that fish migration is provided for at stream/road crossings.
- Reduce or avoid the alteration of hillslope drainage patterns.

1. Lower Klamath Sub-Basin Upslope Restoration Objectives

The primary, long-term objective for the Yurok Tribe's Watershed Restoration Program is the reduction of sediment delivery to the Klamath River and its lower tributaries in the most cost-effective way possible. Every effort will be made to address all substantial sediment sources.

This long-term watershed restoration goal also fulfills two principal Tribal objectives:

1. To return the Klamath River fisheries to the healthiest possible condition.
2. Provide jobs training and employment opportunities for Yurok Tribal members.

The development of the technical skills and the long term availability of watershed restoration jobs for tribal members is a primary objective and component of the Yurok Tribe's Restoration and Strategic Plans for the Lower Klamath River. In order to implement a large-scale restoration project, there needs to be a large qualified workforce available. The Tribe will continuously couple its watershed restoration program with on-the-job training, to create a professional workforce of Yurok members and staff. Tribal staff will become skilled in all aspects of current "best science" restoration techniques. The training will include members of management, restoration technicians, site supervisors, and heavy equipment operators, all in an effort to create fully integrated teams.

2. Yurok Watershed Restoration Program Responsibilities

The Yurok Tribe's Watershed Restoration Program will be the lead in acquiring funding and providing the day-to-day management of on-the-ground upslope restoration activities. YTWRP will continue to provide personnel, training, administration, planning, and logistical support for the upslope portion of this Restoration Plan. The Watershed Restoration Program now has the organizational structure to implement this plan for the Lower Klamath River sub-basin. The Program's responsibilities will include the following:

1. Providing the financial stability to achieve successful assessments and implementation.
2. Maintain a good working relationship with Simpson Timber Company, who will in turn provide access to the watersheds under their ownership, and who will assist with and share the expense of restoring Lower Klamath Basin tributaries.
3. Upon award of funding, the YTWRP will provide personnel to complete a watershed assessment and produce a report that will identify, prescribe and estimate treatment costs for restoration implementation projects throughout the next prioritized watershed. Analyses shall include:
   - Road/hillslope inventories.
   - Road treatments and geomorphic maps.

- Contract-ready prescriptions and site layout.
- Quality assurance through oversight of management.
- The scientific protocol and guidelines that describe inventory methods and site preparation used within the planning area.
- Before and after photo documentation and monitoring.

3. Training for Yurok Restoration Program Staff

The initial training of personnel for upslope restoration work has already been completed. The Yurok Tribal Watershed Restoration Program (YTWRP) now employs several individuals who are qualified to implement upslope restoration activities and to train future personnel for support of a continuing upslope program.

In the future, heavy equipment operators with logging and/or construction experience may be given preference, and hired under contract to be trained in the techniques for "deconstructing" roads and related erosional problems. Observations made during the initial training programs indicate that experienced operators generally learn more quickly, and operate with a higher overall production rate, because they don't have to learn the rudiments for operating their machines.

Before the Yurok Tribe's up-slope remediation program could begin, workers had to be hired and trained in the techniques of the discipline. The overall goal was initially to provide training and quality assurance for 3-6 YTWRP staff, including:

1. Watershed Analysis Training:
   - Stereoscopic air photo analysis techniques.
   - Surveying and preparation of prescriptions.
   - Volume and treatment cost estimating.
   - Complete oversight and responsibility for QA/QC.
   - Preparation and submission of final reports.

2. Heavy Equipment Application/Training:
   - Geomorphic mapping.
   - Geomorphic prescription, layout and design.
   - Logistical planning: fill storage site, equipment, surficial flow, and operational management.
   - Heavy equipment restoration techniques: on-site and site-specific instruction.
   - On-site implementation supervision: observations, management decisions, and safety.
   - Ability to demonstrate and foster a productive working environment.

The initial phase of the training program took place during the winter of 1996-1997, and entailed the assessment and inventory of sites requiring remediation work within the McGarvey Creek watershed. The Yurok Tribe chose this watershed as a pilot program within the Lower Klamath sub-basin for upslope remediation and training. This drainage was selected based on its size, overall condition, and its relative proximity to the Yurok Tribal office in Klamath. Pacific Watershed Associates (McKinleville, CA) provided the initial assessment training under contract. This training consisted of the presentation of concepts in the office (including literature review, air photo interpretation, and computer data entry and analysis) and practical field activities. Field instruction included introduction to problem identification (recognition of existing and potential erosion sources), tape and clinometer survey methods, air photo mapping techniques and data collection techniques.

Beginning in October 1997, YTWRD assumed responsibility for watershed assessment training. A total of seven Tribal employees from the Klamath field office received several weeks of training in road inventory assessment procedures and erosion prevention practices within the Ah Pah Creek watershed. Yurok Tribal staff who had been trained the previous season provided the training.

On June 8, 1998, the final phase of training began with an 18-week training and implementation program. Eighteen Tribal members were employed in the program, which was broken into two phases:

1. A six week long “classroom” phase that taught the basic principles and methodologies currently used by watershed restoration technologists.

2. A twelve week long training/implementation phase, consisting of practical (hands-on) field experience, including the skills and duties of ground personnel and heavy equipment operators.

This training continued through October 1998. It was contracted from and provided by TerraWave Systems, Inc. (Ashland, OR), and took place within the McGarvey and Ah Pah Creek watersheds, again as part of the pilot project for the Yurok upslope restoration program within the Lower Klamath sub-basin. The field training/implementation took place along several roads within those watersheds that had been prioritized during the assessment-work training of 1996-1997.

Implementation Training Approach

The upslope implementation was designed around the principles and standards employed by the Watershed Restoration Program of Redwood National Park (Orick, CA). The trainers stressed an interdisciplinary approach to watershed restoration, in which ground personnel, site managers, and program managers were all given a basic understanding of each other’s skills, goals, and duties, such that they became a more integrated team.

Ground personnel were taught how to perform geomorphic investigations, and how to prescribe, design, survey, layout, and implement labor-intensive treatments. They were further trained to assist and supervise heavy equipment operations, and to provide logistical support during the project.

Heavy equipment operators were trained to perform restoration treatments, as prescribed by ground personnel. Thus, they were taught how to physically effect road and skid trail decommissioning/obliteration; to excavate unstable fill in stream and/or "Humboldt" type crossings; to excavate unstable fill at potential and active slides and earth-flow locations; to scarify compacted surfaces for accelerated revegetation; and to eliminate any diversion potentials. The majority of their operational skill-level training actually took place during their work in the implementation phase of the program.

Four of the 18 Tribal members that attended the training/implementation program of 1998, had received previous instruction in watershed assessment work. Eight of the graduates from the training program worked as field technicians for winter (1998-1999) assessment work in the Tectah Creek watershed. During the summer of 1999, six graduates from the program were employed as heavy equipment operators for the Yurok Tribe's continuing restoration efforts in McGarvey, Ah Pah, and Tectah Creeks, and in Redwood National Park.

During the summer of 1999, six additional Tribal members were hired as trainees for continued implementation/training within the McGarvey and Ah Pah Creek watersheds. This time their conceptual (classroom) training was handled in-house, and their heavy-equipment training was provided, under contract, through three Tribal elders who have extensive operational experience.

4. Upslope Watershed Restoration Approach

The Tribe will continue to follow the logical approach to watershed restoration that is outlined in the Klamath Restoration Program's Long Range Plan (Kier and Associates 1991):

1. Perform an **initial prioritization** of approximately 30 delineated Lower Klamath River tributaries known to contain anadromous fish populations.

2. Once a tributary has been prioritized as an immediate candidate for restoration, a **detailed watershed assessment** is performed. A prioritized inventory of cost-effective erosion prevention projects is developed for implementation.

3. Based on the detailed assessment, the most cost-effective **erosion prevention projects are implemented**.

The initial prioritization work is now complete, and described in detail within this Restoration Plan (see Section III). However, the prioritization and guidelines for upslope work may be modified as our knowledge increases and credible science dictates.

Assessment work typically takes place in the wintertime, when field technicians can actually witness, first-hand, the relative effectiveness and failure of existing drainage and erosion patterns. Implementation follows assessment, in the summertime, when the weather is dry and conducive to the use of heavy equipment for remediation of drainage and erosional problems. Implementation of upslope watershed restoration work is followed by in-stream restoration work. In general, i-stream structures are not effective until chronic sources of sediment have been removed from above.

5. The Detailed Watershed Assessment

There are two main objectives for road inventory and assessment projects:

1. To perform a physical inventory of existing and potential sediment sources which are likely to deliver sediment into a creek.

2. To develop a prioritized listing of cost-effective erosion control and erosion prevention projects that will provide for the long-term protection of anadromous fish populations within a watershed.

A detailed watershed assessment consists of an inventory of potential sediment sources throughout a watershed, and is principally limited to those human-caused (anthropogenic) sources that can be most easily treated. The assessment ultimately identifies the distribution and nature of past erosion. These inventories are required to locate, quantify, analyze, and make recommendations for treatment of current and potential fluvial and mass movement erosion problems.

The inventory is primarily aimed at forest roads, because they are often identified as the most common and important human-caused sources of sediment in managed watersheds. Roads are also the most easily treated sediment sources within a watershed because they offer relatively easy access. The overall objective is to “storm-proof” road systems and to prevent or minimize accelerated sediment yield to stream channels during future large storm events.

Road System Inventory: Initially, a complete inventory of the road network is prepared, identifying those roads that are closed, abandoned, or part of a currently active road system. This is done using maps and records from the landowner, coupled with the analysis of any historical aerial photography that is available for a watershed. Air photo analysis can determine which roads have weathered major storms and which roads have not yet been “storm-tested.” It is then possible to evaluate how older roads responded to past storm events, and to deduce which roads are most likely to fail during future storm events. Old, unneeded roads and highly storm-impacted roads may be recommended for decommissioning.

Prior to the writing of this Restoration Plan, air photo analyses for the entire Lower Klamath River sub-basin were completed and the results are described in Section II-C.

Field Assessment: The next step is to conduct a 100% (walking) field inventory of potential sediment sources along the road system, along with other potentially treatable sediment sources throughout the basin. Most of the effort is focused on roads, because that is where preventable erosion primarily occurs. The field assessment also identifies any potential work sites on major skid trails and along stream banks and channel side-slopes. The end result is a list of potential sediment source/erosion sites, compiled onto a mapped overview of the hydrologic conditions and diversion potentials within the watershed.

Geomorphic Mapping: A portion of the field assessment process entails mapping of the locations of and spatial relationships between all erosion sites requiring remediation. These maps are also used to help identify drainage diversions that are located up-slope from roads to be decommissioned, such that these diversions can be corrected at their source. It would be pointless to treat a diversion problem on a road to be decommissioned, if the source of the problem is above the road and can ultimately fail back onto the road after decommissioning has been completed.

Other information that is noted on the location map includes the site number, type of site, erosion potential, erosional features such as landslides, debris torrents, washed out stream crossings, springs/seeps, and all culvert locations (including ditch-relief culverts). Landmark-features, such as dry swales, landings, and old-growth snags/stumps were sometimes added for location-reference in the field. Some of the symbols used for mapping these features are shown in Figure 12 (symbols adapted from Redwood National Park's Restoration Department).

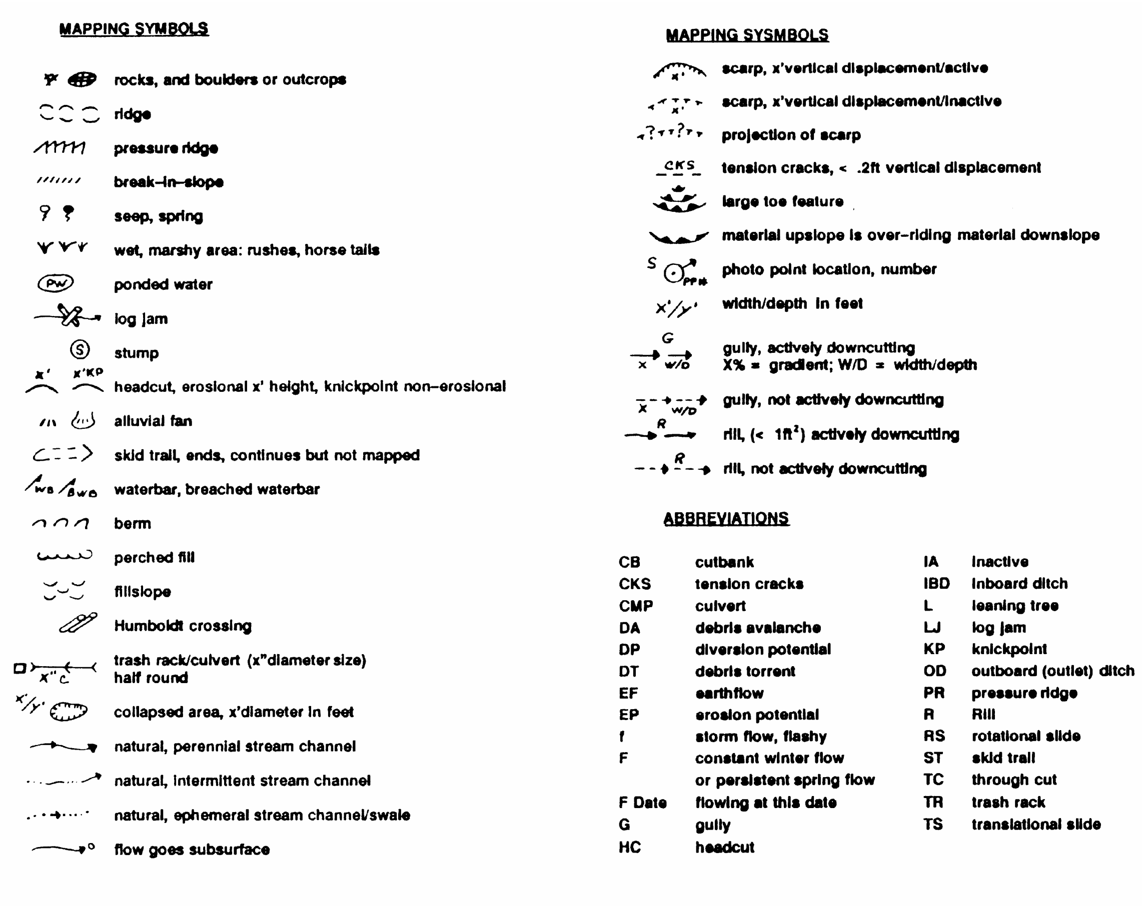


Figure 12. Symbols used for identifying geomorphic features on erosion site field maps.

Site Prescription and Layout: Following the field inventory, a prioritized list of cost-effective erosion prevention projects is developed for implementation. Once the potentially treatable erosion sites have been identified and prioritized, general prescriptions for erosion control and erosion prevention are developed for each major source of treatable erosion that, if left untreated, would likely result in sediment delivery to fish-bearing streams. In general, prescriptions include information about the types of heavy equipment needed, general labor-intensive treatments required, and time- and cost-estimates for each work site.

After the geomorphic investigations are completed, remedial treatments are identified for each problem site, and then "prescribed" in notes, upon maps, and on survey flagging (at the site) for the heavy equipment operator to see. The limits of the excavation work are also flagged, and given three-letter code designations to let the operator know his/her whereabouts within the site. For example, the top and bottom of an excavation are flagged as “TOP” and “BOT,” respectively. Other three-letter designations include IBR (in-board road), OBR (out-board road), OBF (out-board fill), LEC (left edge of cut), REC (right edge of cut), CTH (cut to here), and FTH (fill to here). This procedure is generally referred to as road “lay-out.”

The process of identifying treatments (”prescriptions”) for erosional problems begins at the end of the road where decommissioning will begin. Since heavy equipment cannot move across a road after it has been decommissioned (without damaging the work), decommissioning is essentially done while “backing out” of a road. Cross-sectional illustrations of the road prescriptions that are commonly used are shown in Figure 13.

The field crew also measures a profile across each excavation site, using either a survey tape/clinometer or a laser range finder. The profile is run along a line from the TOP to the IBR, then across the road bench to the OBR, and down to the BOT. From this profile, a set of formulas is used to estimate the volume of road fill material that needs to be excavated during decommissioning. An example of a site profile (including the formulas used to estimate fill volume) is shown in Figure 14.

Assessment Report: In the final stage of the assessment process, a report is developed which outlines areas within the watershed that would benefit most from cost-effective erosion control and erosion prevention work. The cost-effectiveness of treating a work site is defined as the average amount of money spent to prevent one cubic yard of sediment from entering or being delivered to a stream system. Ideally, one medium-sized watershed per year should be inventoried and assessed for the amount of work and cost necessary for restoration to its full production potential.

6. Implementation of Restoration Prescriptions

The most common implementation tasks for “erosion-proofing” of forest roads include:

- excavation of unstable side-cast or uncompacted fill (e.g., along the outside edge of a landing, or the inside approach to an incised stream crossing).
- upgrading culverts and stream crossings.
- installation of critical rolling dips to prevent stream diversions.
- installation of ditch relief culverts, and re-grading of the road platform.

In terms of permanent “upgrade” roads, the landowners will work priority treatments into their long-range plans for “storm-proofing” the watershed. Basically, any permanent and seasonal road upgrading remains the responsibility of the landowner, once YTWRD staff identifies the locations and recommendations.

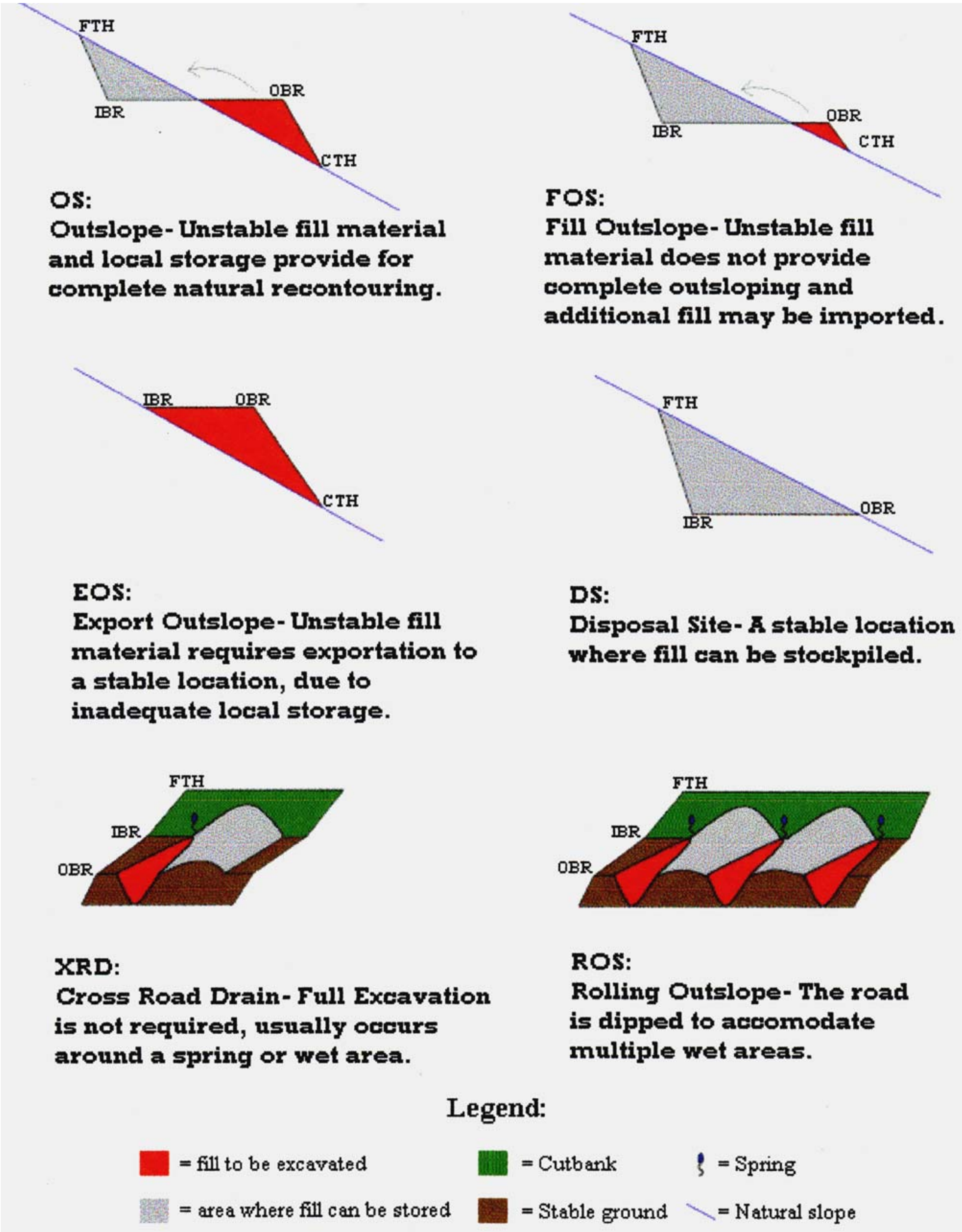


Figure 13. Road prescription illustrations.

Worksheet For Stream Crossing Volumes

Site#: ________ Date: ________

1. Field Measurements (marked with asterisk)
2.

L1 4	ft.	D1 3	ft.
L2* 22	ft.	D2 9	ft.
L3 35	ft.	L4* ____	ft.
S1* ____	deg.	S2* ____	deg.
SL1* ____	ft.	SL2* ____	ft.
W1* 15	ft.	W2* 39	ft.
CW1* 3	ft.	CW2* 3	ft.
US Grade* ____	deg.	DS Grade* ____	deg.

For Type 4 crossings

Angle deg.	Distance ft.	Code (UES, Top, IBR, OBR, BOT, LES, TRN)
0	0	UES
-39	20	TOP
+23	4	IBR
-3	22	OBR
-30	40	BOT
-32	20	LES

2. Cross-Sectional Area Calculations:

	Erosional:	Excavation:
A1 = D1 (W1 + CW1)/2 =	27 ft^2	____ ft^2
A2 = D2 (W2 + CW2)/2 =	189 ft^2	____ ft^2

3. Volume Calculation for each Section:

V1 = A1 x L1 / 2.5 =	43 ft3	____ ft^3
V2 = ((A1 +A2) / 2) L2 =	2,376 ft^3	____ ft^3
V3 = A2 x L3 / 2.5 =	2,646 ft^3	____ ft^3

4. Erosional Volume (E_V) = 5,065 ft^3 / 27 = 188 yd^3 (E_V = V1 +V2 + V3)
4. Excavation Volume = ____ ft^3 / 27 = ____ yd^3

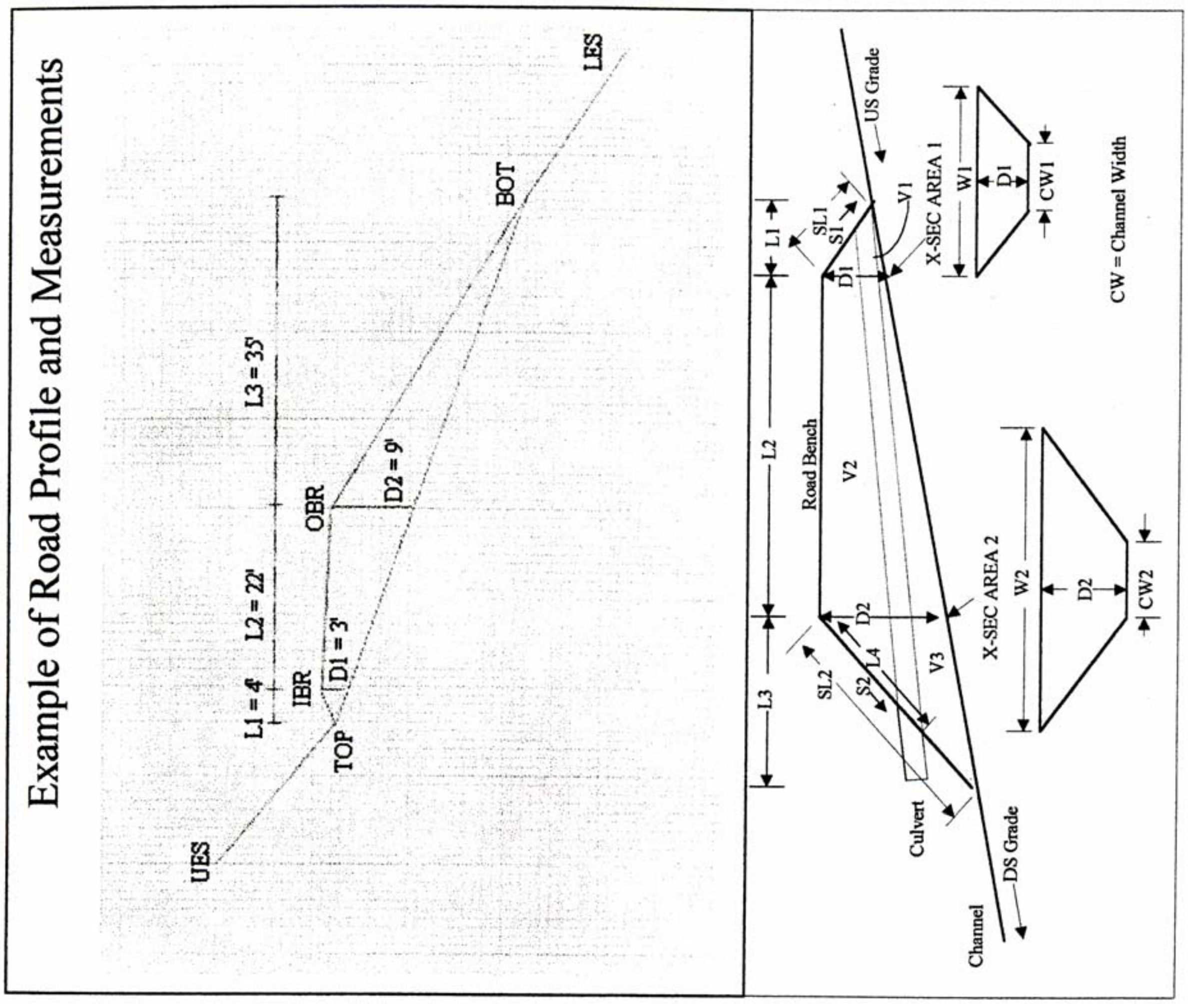


Figure 14. Example of an upslope treatment site profile and fill volume worksheet.

Ground personnel are in charge of site management. This includes overseeing the work done by heavy equipment operators. It is the responsibility of the site supervisors to insure that the operators excavate fill down to the original natural-ground surface. This surface is approximated by:

- locating excavated stumps, and using them as indicators of original base level.
- identifying discolored (organic rich) soil horizons, presumably at the level of buried topsoil.
- imitating the contours of surrounding natural slopes.

Ground personnel are also responsible for correcting water diversions (e.g., across or along roadways), by ensuring that all diverted surface drainage is redirected into natural channels. Ground crews monitor the work done by heavy equipment operators and their machinery. By tracking an operator’s equipment work vs. down-time in a notebook, ground personnel can perform comparative analyses of the relative efficiencies of each worker and operator team (i.e., a bulldozer & excavator working in tandem). Since heavy equipment time is the most expensive part of a project, each pair of dozer/excavator operators work as a coordinated unit, thus making them as cost-effective as possible. Both operators have to develop teamwork, to ensure that they don’t move dirt more times than necessary, and to reduce the time lost in waiting for each other to perform his or her respective tasks.

Initially, bulldozers are used to brush open those roads that are chosen for hydrologic decommissioning. The dozer operators are generally sent to “prepare” the fluvial and mass movement work sites (by removing as much fill material as possible) ahead of the excavators. Next, each dozer/excavator team begins working in tandem to remove all targeted fill from the site. The excavators will typically “switch-back” down to the bottom of the fill margin, and then feed material up to the bulldozers. The dozer operators then push this material up a ramp-like road, to an off-site disposal area. Disposal areas typically include the backsides of stable landings, proximal skid trails, through-cuts, and FOS sites. Sometimes a site is so large that an excavator has to “double-bale” its fill material (i.e., shovel it twice) up to a bulldozer, for removal.

As an operator-team retreats along the road they are working, the bulldozer usually “scarifies” remaining portions of the road platform with its rippers. This helps break up the compaction that results from years of heavy equipment travel, aiding soil percolation and revegatation of the worksite.

Working Restrictions: All implementation work occurs during the “dry” season. No upslope restoration activity is performed within sensitive wildlife zones, except during the appropriate time of year. When work is to be implemented at stream crossings (e.g., pulling crossings, upgrading culverts, etc.), all efforts are made (i.e., temporary crossing diversion, filter buffer zones, etc.), to keep sediment from reaching the streams. Heavy equipment is never allowed to work in active stream channels without appropriate mitigation measures.

7. Post-Work Site Survey

At the end of the field season, a post-excavation volume inventory is taken of all stream crossings that have been removed by heavy equipment. This "post-work site survey" is used to appraise the effectiveness and accuracy of the volume-estimation process that is currently used by Tribal field workers.

The post-work site surveys are performed in essentially the same manner as the surveys performed during prescription and layout work. Using either a survey tape/clinometer or a laser range finder, the field crew measures a profile along the bottom of the (now-excavated) stream channel. This profile is run from the original TOP flag down to the BOT flag. An additional (cross-sectional) profile is measured from the LEC-to-the-REC flags, incorporating the slope angles of the channel walls and the stream-bottom channel width. Utilizing the same set of formulas used to estimate the volume of road fill material in Figure 14, the actual volume of fill material that has been excavated from each stream crossing is determined, and compared with the pre-work field estimates. The percentage accuracy is then calculated from these comparisons.

8. The McGarvey/Ah Pah "Pilot" Restoration Program

The Yurok Restoration Program's work within the McGarvey and Ah Pah Creek watersheds acted as a "pilot" program, not only for the training of upslope restoration techniques, but as an opportunity to gain valuable experience and to eliminate the "bugs" associated with any first-time activity. Experiences there have influenced how the program will proceed in the future. Many of the protocols that were established by the Watershed Program (for standard usage in future programs) were developed out of the observations and wisdom gathered over 3 years of working/training within those two drainage basins. What has worked in McGarvey/Ah Pah will be utilized in other watersheds. What did not work, won't.

This is the very essence of watershed restoration work. It is an evolving discipline, and its effectiveness is not yet fully understood. Like the discipline itself, the Yurok Tribe's Restoration Program, along with the Watershed Restoration Plan, should be treated as living, evolving entities that are necessarily expected to undergo modifications through time. The Program has to continue to learn from its successes and failures, and to adapt to its ever-changing environment. This document will continue to be revised, augmented, and updated, as expanding information and necessity dictate.

B. In-Channel and Riparian Restoration

Extensive financial and human resources have been invested in instream habitat restoration over the last 20-30 years in salmonid streams throughout the Pacific

Northwest. These efforts have typically been undertaken with the intention of utilizing human-built stream structures to enhance physical habitat quality and quantity in drainages where anthropogenic activities have degraded aquatic conditions. Unfortunately, these well-intentioned activities have often resulted in very limited and/or short-term benefits. This is primarily due to pre-project planning activities failing to properly consider fluvial processes and watershed limiting factors. These sorts of restoration projects are likely to be ineffective if channel stability and form are not properly considered and/or if they are undertaken in drainages where fish populations are limited by factors other then the physical habitat that the project is attempting to create.

Within the Lower Klamath tributaries, YTFP has attributed poor instream habitat conditions to excessive upslope erosion and logging-related activities that have been conducted within the stream channel and riparian corridors. While most stream reaches are lacking in natural instream structure and habitat diversity, excessive watershed erosion and aggraded, unstable stream channels typically have resulted in a low success rate for human-placed stream structures. The removal of nearly all mature conifers from throughout these tributaries over the last 60 years (excluding upper Blue Creek and tributaries) has likely resulted in an alteration of the "wet season" stream hydrograph. In particular this change in vegetative canopy and slope cover has likely resulted in peak discharge levels of an increased intensity and shorter duration following storm events. These increased peak flows in turn likely decrease the longevity and stability of artificial stream structures.

Treatment of upslope erosion sources is identified as the primary restoration activity for all Lower Klamath tributaries in order to address the principal limiting factor up front (see Section IV-A). Once these activities are initiated and priority upslope treatment sites are remediated, it is recognized that an indeterminate amount of time will be required for the watershed's sediment budget to come into equilibrium. In addition, coniferous revegetation of riparian areas is a long-term process. As a result, instream structures and related restorative techniques may be necessary in select drainages in order to provide short-term improved habitat conditions until a fully functional, well vegetated stream corridor can be naturally reestablished.

YTFP will assess the need for instream restoration activities in a given tributary once upslope restoration needs have been identified and prioritized, and treatment of the high priority sites has been completed. The only exception to the process will be the treatment of anthropogenic migrational barriers (i.e. logjams, impassible culverts). Such barriers can sever access to large quantities of suitable salmonid spawning and rearing habitat. Since their removal or treatment can be a very cost-effective means of increasing usable salmonid habitat, it is prudent to address these problems on a case-by-case basis outside of the tributary prioritization process.

The following is a summary of potential instream/riparian restoration activities that will be utilized in the Lower Klamath sub-basin:

- **Riparian revegetation.** Reestablishment of mature conifers within tributary riparian corridors is a primary instream restoration objective. Only when a healthy, diverse riparian canopy is reestablished will proper bank and channel stability, as well as long-term natural LWD recruitment be achieved. Possible techniques include planting and maintenance (regular brush clearing) of conifers and native non-alder hardwoods within riparian areas. In addition, the manual release of existing immature conifers within riparian areas is likely an effective means of accelerating conifer reestablishment and succession. This would be accomplished through removal and/or girdling of adjacent alders and brush. Additionally, the revegetation of recently decommissioned streamside roads is a very effective means of reestablishing conifers along stream corridors. Decommissioned road segments are denuded of competing vegetation and scarified to facilitate soil percolation and reduce compaction. These efforts provide an excellent opportunity to reestablish conifers within these areas, giving the trees achance to become established before competing vegetation can limit their survival. During winter 1999, YTFP planted 7,500 bare-root (12"-18") redwood (*Sequoia sempervirens*) and Douglas fir (*Psuedotsuga menziezii*) trees on five miles of roads decommissioned by YTWRD along fish-bearing portions of Ah Pah and McGarvey Creeks. Similar activities will be undertaken on all future streamside road segments decommissioned within the Lower Klamath sub-basin. Methods for planning, implementing and maintaining revegetation projects are detailed in Flosi et al. (1998) and USDA et al. (1998).

- **Streambank stabilization.** Streambank stabilization projects will be designed and implemented in areas where floodplain vegetation is degraded and natural streambank stability is low. The intent of these projects will be to curb accelerated erosion associated with unvegetated streambanks. Target areas will be stream reaches in which degraded streambanks are composed predominantly of fine-textured soils (i.e. clay, silt, and sand). Where feasible, such projects will be designed to incorporate fish cover elements in addition to bank stabilization and protection. Such elements will aid in moderating bankside flow velocities and increase cover complexity. Such projects are not only potentially beneficial in stabilizing streambanks and reducing fine sediment input to the stream channel, but also in creating high quality overwintering habitat for juvenile salmonids. Project design will be site specific, utilizing such techniques as log and/or boulder wing-deflectors, native material revetment, willow baffling, and log and live vegetation bank armoring and crib walling (Flosi et al. 1998; USDA et al. 1998).

- **In-channel habitat restoration.** In tributary reaches where instream habitat quantity, diversity, and/or complexity are found to be deficient, placement of instream habitat improvement structures may be warranted. As stated above, such activities will only be undertaken in tributaries where larger watershed problems such as upslope erosion have first been addressed. Such measures would be intended to provide improved habitat conditions until such a time that a fully functioning stream corridor and adequate natural sources of LWD have been reestablished. Project goals would include increasing stream carrying capacity for fish species in which habitat for a particular life history stage is currently impaired or limiting. This would include increasing the quantity and quality of available spawning habitat, juvenile summer rearing and overwintering habitat, and holding cover and habitat for migrating and spawning adult salmonids. Potential instream structures and techniques will be site specific to address a given tributary's habitat deficiencies. All structures will be constructed with natural materials (boulders, logs and rootwads) and will be designed utilizing the most suitable structure(s) for the morphological channel type present in the target stream reach (see Rosgen 1996). Potential stream structure types are detailed and discussed in Flosi et al. (1998), USDA et al. (1998), and Rosgen (1996).

C. Non-Forestry Land Management Action Plan

Given the site specific, sporadic, and/or conceptual nature of the non-forestry related land management activities identified in Section II-D, it is not feasible to address these issues based on the tributary prioritization process. Instead, each of these activities will be addressed as identified below.

1. Livestock Grazing

Due to the limited extent and site-specific nature of livestock grazing within the Lower Klamath tributaries, these land-use activities will be addressed by YTFP independently of the tributary prioritization process. Recommendations for each of the grazing areas, as well as addressing the feral cattle population, are identified below.

Hunter/Mynot/Salt Creek Cattle Grazing

In order to address poor streambank, channel and riparian conditions in lower Hunter, Mynot, and Salt Creeks, the California Conservation Corps (CCC) installed livestock exclusionary fencing in 1998 around all pastures downstream of Requa Road. Prior to this fencing project, grazing activities notably degraded these portions of lower Hunter and Mynot Creeks. In addition to the fencing activities, the CCC, in conjunction with the California Department of Fish and Game (CDFG) installed several bank stabilization structures along these stream reaches in order to increase channel stability and habitat diversity. The CCC has also completed extensive revegetation activities throughout the livestock-excluded riparian areas. The project has been highly successful, with noted habitat improvements within lower Hunter Creek and successful establishment of riparian tree species throughout the reach.

YTFP will work with the CCC to plan additional restoration activities necessary within this area. This includes additional instream and bank stabilization work within lower Hunter and Mynot Creeks, additional riparian planting as necessary, and additional exclusionary fencing between the current project area and the confluence of Hunter and Salt Creeks with the Klamath estuary.

Additional livestock grazing occurs in Hunter Creek pastures between the Hunter Creek subdivision and the Highway 101 bridge crossing. Given Hunter Creek's steep streambanks and channelized nature through most of this reach, it does not appear that these grazing activities are directly impacting the stream channel. YTFP will further investigate this stream reach and determine if any mitigative restoration projects are necessary. Grazing also occurs in pastures along Salt Creek, upstream of the Requa Road bridge crossing. Given Salt Creek's steep, incised channel through much of this area, along with the presence of beaver ponds at the upstream end, it does not appear that livestock are actively degrading the stream channel. YTFP will further investigate streambank and riparian impacts within this area and recommend restorative measures as necessary.

Terwer Creek

No exclusionary fencing presently exists along the grazed portions of lower Terwer Creek. Fencing is typically installed across the stream channel annually in order to keep cattle from moving upstream onto Simpson Timber Company property. The effectiveness of this barrier is not presently known. CDFG has not previously attempted to install exclusionary fencing due to lower Terwer Creek's highly aggraded and braided, meandering channel (J. Schwabe, personal communication). Several areas of raw, eroding banks are present throughout the reach, and the channel is heavily denuded of riparian vegetation. YTFP will further investigate the feasibility of installing exclusionary fencing, as well as streambank revetment and riparian planting to address channel degradation within this reach.

Blue and Bear Creek Feral Cattle Populations

All feral cattle populations should be removed from the Blue and Bear Creek drainages, as well as any other tributaries where they may have become established. YTFP will work with Simpson and/or the original livestock owner to have these cattle rounded up and permanently relocated from the area. Once the population has been removed, YTFP will initiate a lower Blue Creek floodplain revegetation program in order to reestablish vegetation in this heavily denuded portion of the drainage.

2. Gravel Mining

Any gravel mining activities existing or undertaken in Lower Klamath tributaries should be designed so that their primary goal is to minimize adverse impacts on fish populations and their habitats (Yurok Tribe 2000). YTFP will work with gravel operators, project proposers, and regulatory agencies to tailor any gravel management plans to meet these objectives. The following are lists of generalized project and management recommendations to meet this goal. These recommendations are not inflexible, and should be considered subject to revision as the body of relevant scientific knowledge is enhanced and expanded. In addition, site-specific characteristics may require flexibility in the application of these principles.

Project Recommendations

1) Abandoned stream channels on terraces and inactive floodplain should be used preferentially to active channels, their deltas, and floodplains. Wherever possible,

gravel extraction sites should be situated outside the active floodplain and excavation should not occur from below the water table.

2) Larger rivers and streams should be used preferentially to small rivers and streams. The disturbance from gravel extraction activities would be proportionally smaller in larger systems (that have more gravel and wider floodplains vs. smaller systems), thereby reducing the overall impacts on fish populations.

3) Gravel bar skimming should only be allowed under restricted conditions. Gravel should only be removed during low flows, and from above the low-flow water level. Berms and buffer strips must be used to control stream flow away from the site. Final grading of the extraction site should not significantly alter the flow characteristics of the river during periods of high flows (OWRRI 1995). Monitoring should occur to ensure that bar skimming is not adversely affecting gravel recruitment downstream of the extraction site or channel morphology either upstream or downstream of the site.

4) Pit excavations located on the adjacent floodplain or terraces should be separated from the active channel by a buffer. Since active channels can shift into floodplains, pit excavations should be buffered to maintain separation from the active channel. These buffers should be designed to withstand long-term flooding or inundation on a time scale of decades (Kondolf 1993: 1994a).

5) Turbidity levels should be monitored and maximum allowable turbidity levels for anadromous fish should be enforced.

6) Removal or disturbance of instream roughness elements during gravel extraction should be avoided. If roughness elements are disturbed or removed during extraction operations, they should be replaced or restored to pre-disturbance conditions.

7) Gravel extraction operations should be managed to avoid or minimize damage to riparian habitats. Extraction in vegetated riparian areas should not occur. Undercut and incised vegetated banks should not be altered. Woody debris in the riparian zone should be left undisturbed or restored if impacted. Operation of heavy equipment in riparian zones should be restricted. Gravel stockpiles, wastes, and or vegetative debris from operations should not be stored in riparian areas.

8) Cumulative impacts of gravel extraction operations to anadromous fishes and their habitats should be addressed by the appropriate resource managers. Other land use activities in a given watershed may compound any direct impacts associated with gravel extraction operations, and should be properly investigated and described in any gravel management plan.

9) An integrated environmental assessment, management, mitigation strategy, and monitoring program should be part of any gravel extraction operation. Protocols set forth in the National Environmental Policy Act (NEPA) should be followed in

the preparation of environmental assessments. Management should be used to implement plans to prevent or minimize negative impacts. A mitigation and restoration strategy drawn from NEPA regulations should be included in any gravel management program and these mitigations should occur concurrently with extraction activities. Monitoring should be used to determine if the assessments were correct, to detect environmental changes, and support future management decisions. NMFS recommends that either a mitigation fund established by the gravel operators, or royalties from the extraction operation be designated to fund the mitigation and restoration programs as well as effectiveness monitoring (Schmitten 1996).

Management Recommendations

1) A management plan that details the proposed project, including locations, methods, timing, duration, and proposed extraction volumes should be submitted to the appropriate Federal, State, and local agencies.

2) Prior to extraction, comprehensive surveys/research should be conducted to document baseline biological and physical data, evaluate possible environmental impacts, and formulate measures to prevent/minimize environmental impacts.

3) Monitoring of permitted operations needs to occur to verify environmental safeguards. An annual review process should be established for permits to determine if fishery management objectives are being met. Extraction rates and volumes should be closely regulated. Impacts to the riverbed, banks and bars upstream and downstream of the extraction site should be surveyed regularly. Species distributions and abundance in the given system should be documented regularly. Water quality parameters should be also monitored. Mitigation and restoration should be ongoing processes, with continual monitoring for effectiveness.

4) A site-specific long-term monitoring and restoration program should be developed and implemented to continue after the specific gravel extraction project is completed.

Gravel Mining to Address Tributary Aggradation

Various individuals and entities have proposed gravel mining as a means to address aggradation, sub-surface flows, and fish access problems in the lower reaches and/or mouths of various Lower Klamath tributaries. In order to address the potential of gravel extraction solely as a means to improve anadromous fish habitat, YTFP references a study that investigated gravel delta formation at the mouth of lower Klamath River tributaries (Payne and Associates 1989). The final report concluded that "…delta excavation and [gravel] disposal would be very expensive and ineffective due to the volume of sediments stored in the tributaries which would allow the deltas to quickly rebuild." This observation is also applicable to gravel deposits located in upstream reaches of these tributaries.

Some have also asserted that gravel extraction might result in the beneficial downstream accumulation of quality spawning substrate, but this is refuted by Furniss et al. (1991), who state that these gravels tend to be easily mobilized. Spawning activity in these unstable areas will typically be unsuccessful. YTFP believes that any attempt to rationalize gravel extraction in tributary habitats as a viable or meaningful restoration method would be misguided.

3. Hydroelectric Development.

YTFP will coordinate with all entities and individuals that propose small-scale hydroelectric development project(s) within fish-bearing Lower Klamath tributaries, as well as any regulatory agencies responsible for project permitting or licensing. The primary goal of any such project should be to minimize adverse impacts on fish populations and their habitats. YTFP will work on development and implementation of small-scale hydroelectric projects to ensure that all phase of the project meet this primary goal.

It is imperative that an adequate feasibility study is conducted, including a thorough collection and analysis of stream hydrological data and a complete aquatic inventory. Adequate stream discharge data must be collected to fully understand the drainage's annual hydrograph. Only with this knowledge can an assessment of appropriate minimum flow levels during project operation be determined. It is also essential that the presence and distribution of fish species within the project tributary be understood so that potential project impacts can be fully analyzed.

YTFP considers it prudent only to construct a hydroelectric project within a non-anadromous fish-bearing tributary, or else construct the project wholly upstream of anadromous stream reaches. The hydroelectric turbine and water outflow must be located upstream of anadromous stream reaches, such that any water withdrawn from the stream channel is returned upstream of an anadromous barrier. Additionally, no off-channel water storage facility should be incorporated into the project that would require a temporary, partial dewatering of the stream channel in order to fill. In essence, the project design should be a flow-through hydroelectric system that returns all water to the stream such that the full, natural stream hydrograph exists throughout all anadromous stream reaches.

Minimum flow requirements must be established for the portion of stream channel between the water intake and outflow. The minimum flow levels must be adequate to protect resident fish populations and/or aquatic organisms residing within the project area. It is imperative that the project be designed so that these minimum flows will always be met. Project design must incorporate intake screening or other method to prevent impingement or entrainment of aquatic organisms.

4. Urbanization and Development.

The development activities discussed in Section II-D are very site and issue specific, and hence it is not necessary to address associated problems based on the tributary prioritization process. Each identified activity and the necessary actions are listed below.

Stream channelization and levee construction

A primary goal in addressing these impacts is the prevention of any further stream channel alteration and/or estuarine reclamation projects. YTFP will work closely with regulatory agencies and proposing entities to ensure that any future streamside development plans meet this primary goal. Additionally, a primary goal is the undoing, where feasible, of any such activities that have been implemented in the past.

All of the levee construction and stream channelization identified in Section II-D occurred along private property and/or was an integral component of flood control planning. Ideally levees should be removed from these stream reaches and stream channels should be contoured to reestablish stream meanders, flood plains and other natural geomorphic features. Additionally, reestablishing estuarine sloughs and backwaters in the lower reaches of Hunter and Salt Creeks should be a primary goal. Logistical constraints such as potentially jeopardizing highway and road right-of-ways, increased flooding potential of developed areas, and loss of pastureland likely stand in the way of readily achieving this goal.

YTFP has identified Hunter, Mynot, and Hoppaw Creeks as the tributaries most impaired by channelization and leveeing. The altered reaches of all three of these drainages are located primarily on private land and involve multiple bridge crossings under State Highway 101 and select county roads. While reestablishing natural fluvial morphology in select portions of these tributaries may not be feasible, there are substantial portions that could potentially be addressed.

Lower Hunter Creek (between the Hunter Creek subdivision and the mouth) could benefit substantially from the reestablishment of a natural meandering flood plain, as well as a reestablishment of properly functioning estuarine habitat in it's lowermost reach. This would likely entail purchasing at least portions of the private land along this stream reach, as well as working with Cal Trans and Del Norte County to ensure the stability and continuous utility of Highway 101 and Requa Road bridge crossings. The reach downstream of the Highway 101 bridge crossing should receive priority treatment due to its perennial cold water flow (Hunter Creek typically flows subsurface upstream of Highway 101 during the dry months). Improvement of channel, floodplain, and estuarine conditions in this reach would not only be highly beneficial to natal fish populations, but would serve as a high quality refugia area for fish rearing in the Klamath estuary. The lower reach of Mynot Creek, between the Highway 101 bridge and its confluence with Hunter Creek, could readily be interfaced into such a project.

The reach of Hoppaw Creek flowing through the old Simpson mill site (mill now defunct) would benefit greatly from floodplain widening and channel realignment. The stream channel was historically relocated to its existing location along the north edge of the mill site. Excavation of a portion of the mill site along the current stream channel margin, and subsequent reestablishment of stream meanders and a wider, more usable floodplain would greatly enhance habitat within this reach, as well as aiding to address aggradation problems present in the existing channelized reach. Such a project is conceptual in nature, but if funds were to become available and landowner willingness to be provided, YTFP and YTWRP would solicit the design and engineering input of qualified specialists to ensure that the desired goals were achieved.

Domestic Water Withdrawals

Presently all domestic water withdrawals from lower Klamath tributaries occur via a well or else water is withdrawn upstream of fish-bearing reaches. YTFP will investigate the quantity and timing of water withdrawn from each of these facilities to determine if they may be having a detrimental effect on available water for aquatic species. Given the relatively small size of each of these water systems, YTFP does not anticipate that this is the case. In the event a problem is identified, YTFP will work with the diverting entity to either improve water system efficiency, provide off-channel storage system so withdrawals can occur in non-critical periods, and/or locate alternative water sources. YTFP will also work closely on any future water supply systems that are proposed for fish-bearing lower Klamath tributaries.

Garbage Dumps

Presently the only known garbage dump that may be potentially affecting a lower Klamath tributary is located in Saugep Creek. YTFP will work with the Yurok Tribe Environmental Program (YTEP) to implement water quality monitoring in the vicinity of this facility. In the event that contaminants are determined to be entering the stream channel at levels that are deleterious to fish populations, YTFP will formulate clean-up and restoration plans to address the problem.

D. Artificial Propagation

In recognition of the depleted status of fall chinook populations throughout the Lower Klamath Basin, YTFP may elect to utilize artificial propagation as tool for enhancing the recovery of these populations in the Lower Klamath tributaries. These efforts will be focused in tributaries that are known to have historically and/or currently sustained fall chinook and where ongoing restoration activities are expected to increase current carrying capacities. Artificial propagation programs will be designed as a means to help "jump-start" dwindling wild populations in tributaries where restoration activities have already addressed the factors currently limiting wild fish production. The protection and restoration of native fish populations will be the primary goal guiding the design and implementation of any artificial rearing projects. The following guidelines, adopted from the Pacific Rivers Council (Nehlsen 1996) and a study commissioned by the Yakima/Klickitat Tribes (Kapuscinski and Miller 1993), will guide the development of artificial propagation projects within the Lower Klamath sub-basin:

1. Spawning, rearing, and migration habitat necessary to support life history diversity and productivity is restored concurrently with the artificial propagation program.

2. Only wild broodstock are used, and broodstock collection is designed to maintain the genetic character of the target wild population.

3. Hatchery rearing operations are designed to maintain "wild" behavioral, physiological and genetic characteristics similar to those of the target population, to maximize post-release survival and minimize negative effects on the target population.

4. Releases of juvenile fish are designed to maintain the genetic character of the target population. They are also designed to minimize negative ecological impacts on the target population and maximize total juvenile survival by addressing identified production bottlenecks in the watershed.

5. A coded wire tag (CWT) will be implanted in all released fish, along with an accompanying adipose fin clip. This will allow artificially propagated fish to be readily identified and will allow an annual assessment of wild and hatchery contribution to the system. Straying and harvest rates can also be determined based on CWT recoveries.

6. The genetic and life history characteristics of the target population are carefully monitored.

7. The use of artificial propagation for restoration purposes should be considered a "short-term" emergency measure. If within one or two generations, wild fish have not begun to return to self-sustaining levels, efforts should be made to identify the factors limiting the recovery of wild stocks. Failure of the target populations to return to self-sustainable levels indicates fundamental problems that hatchery operations have not addressed.

8. Where populations are so small that the aforementioned guidelines are not viable options, the best recovery strategy may be to initiate captive breeding of all or part of the population, concurrent with habitat restoration.

V. Long-Term Monitoring Plan

A. Purpose and Utility

A long-term monitoring and assessment plan is necessary in order for YTFP to provide informed input into Lower Klamath River Basin watershed restoration and land management planning. In addition, these efforts provide staff with long-term baseline data to assess the effectiveness of implemented restoration projects, to monitor the trend of ESA-listed fish species, and to monitor any physical and/or biological changes resulting from anthropogenic activities.

YTFP will rely on sound scientific methods to assess and monitor all watershed restoration activities within the Lower Klamath sub-basin. By adhering to this scientific approach, YTFP can ensure that sub-basin restorative projects are adequately addressing the goals of the Lower Klamath Restoration Partnership. Additionally, these activities provide YTFP with the necessary data to provide input into land management activities within the sub-basin. Long-term monitoring facilitates an adaptive management approach (through a data feedback loop). An adaptive management policy allows resource managers to identify management-related impacts and alter management activities to minimize future negative effects. This approach will aid in our efforts to restore a watershed's landscape function toward the dynamic equilibrium of near-natural conditions.

B. Physical Monitoring

YTFP will coordinate with Simpson Timber Company to ensure that YTFP's physical monitoring activities are complimentary to similar projects being implemented by Simpson's biological staff. The following methods will be utilized to monitor physical habitat changes over time within Lower Klamath tributaries:

- **Water quality monitoring**. Changes in water quality over time can provide a means to determine if restoration goals are being met. This monitoring can also be utilized to identify negative trends in water quality. Once such a trend is detected, YTFP can focus assessment efforts to determine the source of the degradation. Parameters to be monitored include water temperature, dissolved oxygen, and turbidity. Water quality monitoring stations will be established within both treated and untreated drainages to track tributary-level trends. In addition, YTFP will conduct additional turbidity monitoring on a site-specific basis within select drainages to monitor turbidity trends in relation to upslope remediation projects. Turbidity is often to used for project monitoring by comparing measurements upstream and downstream of the activity area (MacDonald et al. 1991).

- **Water quantity monitoring.** Timber harvesting, road construction, and related management activities in a watershed can alter peak flow size, low flow volume, and/or annual water yield (Armour and Platts 1983; MacDonald et al. 1991). Rate of flow and fluctuation in discharge are indentified as two of the most important abiotic factors affecting lotic fish populations (Hynes 1970, as cited in Armour and Platts 1983). Long-term stream discharge monitoring in treated and untreated watersheds will enable YTFP to relate how restoration activities affect the stream hydrograph.

YTFP will establish stream gaging stations within selected Lower Klamath tributaries for the purpose of collecting stream hydrograph data. These gaging stations will be equipped with continuous-recording stage-height loggers, which will be set to record gage height on a 30 minute interval throughout the year. Weekly stream discharge measurements will be taken throughout the year at the gaging station in order to calibrate the logger and create a gage height-discharge relationship curve. Discharge measurements will also be taken during all peak flow events to increase reliability of this curve.

- **Stream habitat and riparian monitoring.** Long-term stream channel and riparian monitoring is essential for YTFP to determine if restoration goals are being met. Physical parameters to be monitored will include channel cross-sections and thalweg profiles, bed material composition, habitat complexity and diversity, LWD quantity and composition, and riparian canopy composition. Methods to be employed are detailed in Armour and Platts (1983), Flosi et al. (1998), Harrelson et al. (1994), MacDonald et al. (1991), and Platts et al. (1983). YTFP is also developing a methodology to assess winter habitat conditions within the Lower Klamath tributaries. Such information would fill critical data gaps on winter habitat conditions under varying flow levels, providing insight into restorative measures necessary to enhance any winter habitat deficiencies.

- **Photo documentation.** All phases of the implementation work are photo-documented as part of an ongoing effort to improve the effectiveness of future restoration efforts. Pre- and post-restoration photo point localities are established along the entire lengths of the roads that receive work, to evaluate the results of that work and to monitor the recovery of the watershed through time. Photos are taken of all implementation work sites, from the most descriptive angles and viewpoints. All photo points are consecutively numbered, and are marked in the field with yellow-flagged monuments.

  In the future (perhaps every 2 to 3 years), YTFP should purchase and review new flight lines of aerial photographs that cover the areas of completed upslope restoration work. Air photo interpretation could become an additional tool for identifying and documenting any physical changes to the watershed that might result from their activities. Utilizing the complete collection of 1997 aerial photographs as a baseline for comparison, we could monitor revegetation rates, identify developing problem areas, and continue tracking the landslide history and overall effectiveness of the upslope program.

C. Biological Monitoring

- **On-going activities.** YTFP has already undertaken extensive biological assessment and initiated several monitoring projects (see Section II-A). The Hab/Bio Division will continue to refine and develop these activities as necessary to provide pertinent baseline biological data from throughout the Lower Klamath sub-basin. In particular, YTFP will continue to expand and improve it's outmigrant trapping efforts on Lower Klamath tributaries in order to generate quantitative emigration data for salmonid species from these drainages. YTFP will also continue and expand Blue Creek fall/winter snorkel surveys in order to maintain this long-term database on Lower Klamath late-fall chinook populations. Other similar efforts will be developed and expanded in additional Lower Klamath tributaries, with the goal of enhancing knowledge of adult salmonid trends and temporal and spatial life history variability.
- **Restoration Effectiveness Monitoring.** The Hab/Bio Division established permanent fish sampling reaches throughout McGarvey Creek to monitor changes in species/age-class distribution and abundance in response to barrier modification projects implemented in 1998 (Voight 1998b). YTFP is continuing to expand this project temporally and spatially to adequately monitor salmonid population changes in McGarvey Creek in response to watershed restoration activities. YTFP will design similar projects on a site-specific basis to assess the effectiveness of various restoration proposals intended to directly enhance fish populations.
- **Regional Population Estimation.** The Hab/Bio division will be initiating a coho salmon regional estimation project throughout the sub-basin in summer 2000. This project, funded by the National Marine Fisheries Service, is designed to quantitatively assess summer standing crops of age 0+ coho on a regional level. YTFP intends to conduct these inventories on a long-term basis to monitor coho population trends on a sub-basin scale. YTFP also hopes to incorporate similar survey techniques for additional salmonid species, as well as coordinate these efforts with spring outmigrant trapping projects in order to assess overwinter survival within the tributaries.
- **Proposed Activities.** YTFP is developing plans to assess and monitor aquatic macroinvertebrate populations in the Lower Klamath sub-basin. Aquatic macroinvertebrates are potentially useful as indicators of water, riparian and stream channel quality (MacDonald 1991; Platts et al. 1983). Most macroinvertebrates possess limited mobility and have a relatively short life span, making them well suited for assessing site-specific impacts and serving as an indicator of past environmental conditions. Since these benthic organisms are a major food source for salmonids, an assessment of their density and species diversity could be an important tool in assessing salmonid limiting factors (Platts et al. 1983). Macroinvertebrate species richness and diversity can serve as indicators of riparian condition, water quality, primary production levels, and substrate composition and sedimentation levels. As a result, macroinvertebrate monitoring could be a valuable tool for assessing whether Lower Klamath sub-basin restoration goals are being achieved.

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