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Central Coast CCoWS Watershed **Studies**

Garrapata Creek Watershed **Steelhead Barrier Assessment**

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Preface

Garrapata Creek and two major tributaries support habitat for threatened steelhead along the Big Sur coast of central California. This report presents an inventory of potential steelhead migration barriers in the watershed. The barriers were located and fully described in text and photography. Barrier removal or modification was prioritized, based upon both the potential positive and negative impacts improvement actions would have upon steelhead spawning habitat.

Disclaimer

Many of the logjams and debris piles are unstable and potentially dangerous if modified. The Watershed Institute and it staff shall not be liable for any damages or injuries that may occur while attempting to improve steelhead passage, or as a consequence of implementing the strategies recommended in this report, or derivative documents.

Document Format

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1. Executive Summary and Conclusions

Migration Impediments

During the summer of 2004, logjams and near-channel sediment sources were assessed within the Garrapata Creek Watershed. In Garrapata Creek barriers to steelhead migration were assessed in the lower 5.9 km (19415 ft), from the ocean to Garrapatos Road. Log and debris jams were assessed in Joshua Creek from its confluence with Garrapata Creek up to the natural migration limit – a natural waterfall > 12 m (40 ft) in height. Barriers and near channel conditions were assessed in Wildcat Creek up to the natural limit to salmonid migration – a natural cascade/waterfall structure approximately 7–8 m (25–30 ft) in height.

Within the main stem of Garrapata Creek a total of 14 structures were observed and recorded as potential barriers to upstream migration. These structures consisted of log/debris jams and waterfalls. Observations of small and passable accumulations of large woody debris were noted but not described in the present report. Logjam density (excluding waterfalls) for the entire assessed reach was 1.9 km⁻¹. However, there was considerable difference in logjam density between the steeper upstream reaches and the lower gradient downstream reaches. Logjam density in the upper 1.38 km of the watershed was 5.8 km⁻¹ compared to 0.7 km⁻¹ in the downstream 4.59 km assessed. Three bedrock/boulder waterfalls that could be potential barriers due to downstream pool volume reduction were also observed.

Several large log/debris jams were observed in the upper two-thirds of the assessed reach of Joshua Creek. Logjam density for the total assessed reach was 9.5 km⁻¹. Based on the observed accumulation of woody material and sediment, these jams have likely been in place for a long period of time. Observations of the woody material indicated that the source of woody debris were from both natural processes (stream bank erosion, windthrow) and past logging activity.

Two significant debris jams were observed in 0.32 km of Wildcat Creek. Fine sediment accumulation in the channel bed was present however at lower quantities than Joshua and parts of Garrapata Creek. Spawning habitat was moderately suitable at best. Like Joshua, the total length of stream accessible to spawning salmonids is limited due to a significant waterfall/cascade approximately 0.32 km upstream of the confluence with Garrapata Creek, however in-channel conditions such as substrate and habitat complexity were of higher quality (i.e. undercut banks and deeper complex pools).

Sediment Accumulation

In Garrapata both coarse and fine sediment accumulation behind logjams was significant. Many of these logjams are now large grade control structures that form large steps in the channel. Although only surface sediments were observed, the stored material likely consists of a mixture of coarse and fine deposits. Downstream pools (those at the base of the debris jams) also had accumulations of fine sediments, although during periods of high streamflow it is likely these pools scour to some extent.

The release of accumulated sediment to downstream spawning habitat is of significant concern when considering the improvement of these barriers.

Prioritization for Barrier Modification

Future enhancements of the debris jams have conflicting outcomes. In Garrapata Creek, the larger and impassable barriers appear to have been in place for some time and have since become stream gradient control features. Their removal may jeopardize the stability of the surrounding hillslopes, roads and homes that are immediately adjacent to the creek. Also, the release of a substantial load of stored sediment would likely have adverse impacts on spawning habitat downstream, which could potentially take decades to restore. Efforts in Garrapata Creek should be focused on improving structures downstream of the larger impassable barriers (i.e. gb01–gb04).

In Joshua Creek, the amount of potential spawning habitat is limited (i.e. 1.05 km to the natural migration boundary). The removal or enhancement of the larger debris jams further upstream would be costly due to the limited accessibility to the sub-watershed and the amount and size of debris material need to be removed. More importantly, the sediment released from these obstructions could potentially lead to adverse conditions to downstream spawning habitat in Garrapata Creek, where debris jams are not present. Efforts should be focused on improving smaller structures further downstream (i.e. jb01-jb06) and those in Garrapata and Wildcat Creeks.

Wildcat Creek is easily accessible on foot through the Big Sur Landtrust Property (Glen Deven Ranch). The better accessibility, limited number of debris jams, their lower cost for enhancement, and the minimal volume of accumulated fine sediment, increases Wildcat Creek's priority for enhancement. These two structures were given High priority for improvement.

Any major debris enhancement projects in the watershed should be done after the primary sediment source(s) have been discovered and repaired. Further, the cumulative impacts of barrier modification to downstream habitat should be considered and heavily weighted. Therefore, all modification project(s) to logjams should be implemented over an extended period of time, in order to ensure that sediment is slowly released downstream.

Sediment Sources

During a rapid traverse through the lower watershed, no significant sediment sources were observed. Few smaller sources were observed in both Garrapata and Joshua Creeks. Small landslides, failed banks and exposed banks due to vegetation removal were the observed causes of sediment loading. High sediment accumulations in the streambed are the result of upstream sources that were not observed.

2. Background and Study Area

Introduction

The Watershed Institute of California State University Monterey Bay (CSUMB) was contracted through the Garrapata Watershed Council (GWC) to assess specific watershed parameters in Garrapata, Joshua, and Wildcat Creeks, up to the limit of historic salmonid migration in the watershed. The overall purpose of this project involves conducting original data collection and field observations to determine priorities for restoration activities benefiting riparian habitat and steelhead trout (*Oncorhynchus mykiss*).

Funding for the assessment was provided through a watershed restoration grant from the California Department of Fish and Game (CDFG).

Project Objectives

The primary objectives of this study were to:

- Assess the condition of all migration barriers
- Prioritize the migration barriers for restoration
- Make recommendations for barrier removal or modifications
- Description of possible methods of barrier removal or modifications that would restore fish passage.
- Characterize near-channel watershed problems that could affect anadromous fisheries, based upon a visual inspection of the near-channel environment during a rapid foot traverse. Observations include locations and qualitative descriptions of large landslides and tall unstable banks.

Study Area

The Garrapata Creek Watershed is located in Monterey County, approximately 10 miles south of Carmel, California (Fig. 2.1). The Watershed drains approximately 27.7 km² (10.7 mi²) of primarily chaparral/scrub lands, canyon forests, and light residential development (PWA, 2003). The Watershed consists of three major streams, Garrapata Creek and its two tributaries Joshua and Wildcat Canyon Creeks. All three streams are perennial. For a more detailed discussion on the hydrology of the Garrapata Creek Watershed, see – Smith et al. (2004).

The watershed supports three species of Special Status including the Federally Threatened South Central Coast ESU steelhead (*Oncorhynchus mykiss*), Federally Threatened California red-legged frog (*Rana aurora draytonii*), and the Federally Endangered Smith's blue butterfly (*Euphilotes enoptes smithi*) (CDFG, 2004).

Climate

The Garrapata Creek Watershed has a Mediterranean Climate with coastal maritime influences. Generally, summer and fall are warm and dry, while winters are cool and wet. Wind and fog are dominant features of the local climate. Cooler micro-climates exist in the canyons under the dense riparian forests, while warmer and windier conditions are more common on the Watershed's chaparral and scrub covered hill slopes. Average precipitation is approximately 76.6 cm (30.2 in) with most occurring between November and March (See Smith et al. 2004 for a more in-depth coverage of this).

Geology

The watershed is almost entirely underlain by Cretaceous "hornblende-biotite-quartze diorite of the Soberantes Point formation," a granitic rock with low landslide susceptibility, but high erosion susceptibility.

Pervasive fracturing and faulting in this rock formation and the cumulative anthropogenic impacts to the landscape combine to create a source of excess fine sediment in the creeks.

For a more detailed discussion on the geology and geomorphology of the Garrapata Watershed, see - Smith et al. (2004).

Land Use

The watershed is predominantly rural/natural land. Much of it is privately owned (88%), with 49% of the total watershed protected through government ownership or conservation easements (GWC, online) (See Figure 2.1). The privately owned parcels consist of both large ranches as well as smaller residential lots (PWA, 2003).

Logging no longer occurs in the watershed and there are no approved operations at present (PWA, 2003). However, past logging operations as well as private road construction have created adverse







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environmental conditions throughout the watershed (Titus et al. 2001; PWA, 2003). Log and sediment debris have accumulated in the watershed's streams, which has led to decreased rearing and migration habitat for steelhead (Titus et al. 2001; PWA, 2003).

Vegetation

The coastal bluffs and hill slopes support primarily coastal scrub and maritime chaparral communities. The lower riparian corridor hosts a mixed riparian community. Common riparian trees species include red alder (*Alnus rubra.*), willow (*Salix spp.*), and occasionally cottonwood (*Populus spp.*).

Further up the canyons, the dominant riparian species shits to second growth coastal redwood (*Sequoia sempervirens*) and tanoak (*Lithocarpus densiflorus*) and the adjacent hill slopes support primarily chaparral communities with mixed evergreen forests on the north-facing slopes (Nedeff, 2004).

Non-native blue gum (*Eucalyptus globulus*), Monterey pine (*Pinus radiata*), and Monterey cypress (*Cupressus macrocarpa*) are also found in scattered populations throughout the watershed, especially in the lower reaches of Garrapata Creek. Blue gum is also found higher up on the hill slopes within the chaparral communities.

For a more detailed discussion of the vegetation resources in the Garrapata Creek Watershed, see Nedeff (2004).

Steelhead Background

In 1997, the South-Central California Coast Steelhead trout Evolutionary Significant Unit (ESU) was listed as a Federally Threatened Species under the Endangered Species Act (ESA) of 1973. This ESU extends from the Pajaro River Watershed (included) south to, but not including the Santa Maria Watershed (CDFG, 2004).

Steelhead Life History

Steelhead trout are the anadromous (ocean-going) form of rainbow trout. Unlike other salmonids, steelhead are repeat spawners, meaning they are capable of returning to the ocean after spawning and then usually return to the same watershed the following year to spawn (Shapovalov and Taff, 1954).

Juvenile steelhead usually rear 1-2 years in freshwater before they begin to smolt and enter the ocean. Smolting is the physiologic transition juvenile steelhead undergo that enables them to adapt to saltwater conditions (Shapovalov and Taff, 1954).

Growth rate and size are critical factors in determining when a juvenile steelhead will begin to smolt (Smith, 2002). Smolting can occur after one year if the fish reach large enough sizes. In small, well-shaded coastal streams, annual growth rates are generally low due to limited insect production – a result of the reduced primary production. However, productive coastal lagoons can provide suitable habitat for rapid growth (Smith, 1990).

While in the stream, juvenile steelhead can use a wide variety of meso-habitats (i.e. pool, riffle, or run) depending on habitat availability. In less shaded streams with warmer summer temperatures and suitable flow, juvenile steelhead will primarily feed on drifting insects in riffles or pool heads (Smith and Li, 1983).

In winter, adult steelhead generally return to their natal stream (stream of birth) after 1 or 2 years in the ocean (Shapovalov and Taff, 1954). Spawning can occur over a large period, usually between December and March. In most Central Coast streams, steelhead begin to migrate upstream once stream flows increase and the sandbar at the river mouth is opened. If accessible, steelhead will use the upper most reaches of the watershed for spawning as long as there are no severe barriers (i.e. logjams, dams, elevated road culverts etc.).

Female steelhead dig nests, or redds, usually in the transition zones between pools and riffles, (also called pool tails) and where substrate is coarse (i.e. large gravel or cobble). The eggs can be fertilized by an accompanying male steelhead or by a smaller resident male rainbow trout.

Spawning success is highly dependent on time. Nests built early in the season (i.e. December or January) are susceptible to being destroyed by later storms, while nests built later in the season are less likely to be destroyed (Smith, 2002). In addition, reproductive success is dependent on suitable water quality conditions (i.e. relatively clear, cool, well oxygenated water). Fine sediment

accumulations (clay, silt, or sand) can clog the pore spaces between coarser sediment particles of the redds that are critical for efficient oxygen delivery to the eggs.

History of Steelhead in Garrapata Creek Watershed

Two documents outline existing studies of steelhead in the Garrapata Creek Watershed: Titus et al. (2001) and PWA (2003). Surveys conducted by CDFG were completed in 1981, 1990, and most recently in 1998 (Titus et al. 2001; PWA, 2003).

In the 1960's, trout in a privately owned hatchery on Garrapata Creek were diagnosed with whirling disease. Whirling disease is caused by a protozoan, *Myxosoma cerebralis*. As quoted in Titus et al. (2001), *"Evidentially, the disease spread into the creek itself as uninfected fish placed in the creek became infected."* By 1975, the disease was not detected throughout the watershed or in the trout farm.

The 1981 surveys resulted in the opinion that the Watershed was "not regarded as a probable salmonid production area" (PWA, 2003).

During the 1990 surveys, which included four mark and recapture reaches, data revealed that steelhead were present in Garrapata and Wildcat Canyon Creeks. CDFG noted that there were several barriers due to landslides, logjams, and falls/chutes including a 9 m waterfall. They also noted that many of these barriers were impassable to adult steelhead. The best spawning habitat was found upstream of the 9 m waterfall and therefore inaccessible to anadromous fish (both past and present). The lower reaches of Garrapata Creek did have some suitable spawning habitat and was "free of barriers" (Titus et al. 2001). Sedimentation, decomposed granite, was also noted as a significant problem with specific reference made to lowered pool volume and smothering of riffles. Sediment trapped behind structures in the stream was also responsible for creating barriers to adult migration (Titus et al. 2001). It was determined that sedimentation, likely a result from road construction and logging, "*was identified as the primary factor limiting steelhead production in the Garrapata Creek drainage* (Titus et al. 2001)."

Fish densities in the four study sites were as follows from upstream to downstream: 26.0, 1.0, 13.3 trout in the mainstem of Garrapata Creek, and 1 trout in Wildcat Canyon Creek, referred to here as Wildcat Creek.

In November of1998, CDFG biologists found 18 steelhead (size not documented) within 100 feet of stream in lower Garrapata Creek approximately 0.4 km (0.25 miles) from the lagoon (PWA, 2003).

During the present study, young-of-the-year salmonids, and possibly yearlings were observed throughout Garrapata Creek, with higher occurrences in the lower two-thirds of the assessed area.

In Wildcat Creek sedimentation was "formally" noted as a problem as far back as 1964 base on invertebrate sampling and trout bioassays (Titus et al. 2001). CDFG surveys conducted in 1981, resulted in the opinion that the sub-watershed was not "regarded as a probable salmonid

production area" (Titus et al. 2001; PWA, 2003). Channel substrate particle size was still a problem as of 1988.

Impediments to Steelhead Passage

Logjams

The presence of in-stream large and small woody debris (LWD & SWD) is of significant importance to the ecology of lotic systems. LWD can influence the physical characteristics of a stream by its ability to assist is creating channel form and by creating storage for sediment and organic matter (Bisson et al. 1987; Naiman et al. 2002). LWD is also a benefit to various aquatic organisms. It creates complex structure that aids in the development of pools and backwater areas within the stream channel that can be used as shelter, especially during high winter stream flow (Smith and Harden, 2001; Naiman et al. 2002; Leicester, 2003; Montgomery et al. 2003).

However, land use activities such as clear-cut logging can increase the amount of woody material in the stream channel above natural levels (Bisson et al, 1987). Much of the coastal California redwood forests were cut long during the 19th and 20th centuries – including the Garrapata Creek Watershed. Left over debris from such cuttings can eventually accumulate in the stream channel in addition to the natural load of woody debris. In the steep, entrenched channels of the upper watershed (especially Garrapata and Joshua Creeks) the woody material can become anchored at the confined, narrow points in the stream channel and eventually plug with woody debris and sediment. Overtime, the logjams can increase in both height and length (length up and down the stream channel). Once the jams plug, streamflow begins to spill over and/or through the debris, thus creating adverse conditions for both upstream and downstream migrating fish. The formation of large barriers creates a stepped channel form and dissipates the stream's total energy at spilling plunge pools (Keller and Talley, 1979 as sited in Napolitano, 1998).

In general, there are a number of physical factors associated with logjams that influence whether or not they are passable to adult migrating steelhead (although outmigrating juvenile steelhead should be considered as well). Many of the following factors are dependent on available streamflow.

- Height overall height of the barrier is usually the determining factor.
 - Presence of plunge "jumping" pool (Steelhead can leap up to 10 ft, however they need deep pools to gain momentum and speed for their jump)
 - Stuart Ratio In general, a minimum of 1:1.25 ratio of barrier height to pool depth is needed for successful migration - although this can vary slightly (Powers and Orsborn, 1985).
- Channel position How much of the channel cross-section is blocked by the debris?.
- # Of possible routes total number of possible routes over, through, under the impediment.
- Ability to scour In sandy channels, the bottom of a logjam will often scour during higher winter flows enabling fish to migrate through or under the debris (Smith and Harden, 2001). If channel substrate is larger and coarser, then it is less likely to scour underneath.
- Spilling type straight fall or projected/blasting?
 - \circ Channel geometry at spilling zone narrow = projected, wide = spilling.

There are a number of factors that can influence the residence time of logjams or LWD. Channel morphology is critical. Confined, entrenched channels, well armored with bedrock, can accumulate large woody debris especially if past land use activities have left substantial woody material available. In flat, wider channels, often associated with downstream reaches, the stream can eventually flow around or scour underneath the debris. Often woody structures can trap alluvium deposits that are beneficial to salmonids and they create complex habitat for over-wintering juvenile steelhead (Montgomery et al. 2003).

Scherer (2004) concluded that the main factors influencing woody debris decomposition include climate, tree species (e.g. chemical content), piece size (e.g. diameter and length), decay class or position (e.g. suspended, buried, fully submerged) active major decomposition processes (e.g. respiration and leaching or fragmentation), site conditions (e.g. temperature, moisture levels, oxygen and carbon dioxide levels), bed stability, channel morphology, flood intensity and riparian forest composition. The species of the woody material is also critical. Conifers, especially redwood, are much more resistant to decay than riparian hardwood species. Redwood and other conifer logs are also denser than hardwood species (size being equal) and are therefore not as easily transported by streamflows.

Waterfalls

Waterfalls and cascades can also be potential barriers to steelhead migration (Powers and Orsborn, 1985; Smith and Harden, 2001). These structures can often partition habitat between resident and anadromous forms of rainbow trout.

As noted above, the maximum height steelhead can jump is in part dependent on jumping pool depth (i.e. Stuart Ratio). Powers and Orsborn (1985) note that that steelhead can leap up to 3.3 m (10.9 ft), although Evans and Johnstone (1980; as cited in Powers and Orsborn, 1985) suggest that a vertical drop of 1.8 m (6 ft) or more should be considered a barrier for all salmonids.

Several natural waterfalls of different sizes occur in the Garrapata Creek Watershed. The natural limit to salmonid migration in Joshua and Wildcat Creeks terminates at significant waterfalls or steep cascades greater than 6.1 m (20 ft) in height. A series of three consecutive smaller waterfalls, ranging from 1.75 m (7.5 ft.) to 1.4 m (4.6 ft.) occurs in the middle reaches of Garrapata Creek, with the largest occurring first, or downstream, in the series.

Near-channel Sediment Sources

Near channel sediment sources are defined here as areas where sediment is currently contributing to the active channel. These include both natural and anthropogenic related sources. Natural sources include landslides and large exposed banks prone to erosion. Smaller sources include exposed sediments from root wads or fallen tree cavities as well as smaller landslides and exposed stream banks.

Anthropogenic sources include unpaved and improperly placed roads, gully formation from failed road drainage culverts, and exposed banks due to active clearing of riparian vegetation.

3. Methods

Field Assessment

All streams were assessed by a rapid foot traverse through the watershed. Joshua and Wildcat Creeks were assessed up to the first natural migration barrier (i.e. large waterfall) and Garrapata Creek was assessed up to the Garrapatos Road Bridge. Several large logjams were observed below Garrapatos Road and were likely the limit to migration.

A hip-chain was used to document the distance/location of each logjam and near-channel sediment source. Global Positioning Systems (GPS) were not used due to dense overhead vegetative cover. In Garrpata Creek, All distances were measured in reference from the terminus of the watershed (i.e. Garrapata Creek Lagoon) and in Joshua and Wildcat Creeks all distances were measured in reference to their confluences with Garrapata Creek. The distance of each major road crossing and tributary confluence were noted for calibration purposes.

Each logjam was assessed on a number of criteria including:

- Size of structure (height vertical; width across channel; and length longitudinal length)
- Presence of leaping pool
- Depth of leaping pool
- Spilling (i.e. is the logjam clogged with debris to the point where stream flow spills over the top)
- Number of possible migration routes (i.e. left bank, center, right bank, underneath, overtop)
- General substrate particle size beneath and downstream of the structure (i.e. sand, gravel, cobble, boulder, bedrock)
- Material (quantity and description i.e. log species)

The locations of near-channel and stored sediment sources were also noted. Near-channel sediment sources are defined here as exposed sediment (i.e. non-vegetated) within the active flood-prone channel width. Examples include, recent landslides, lateral erosion, or exposed stream banks due to active vegetation removal. Stored sediments are sources of sediment that have been accumulated behind a structure such as a logjam.

Where possible, estimates of the exposed or stored sediment volume were made at each location. Data on the stored sediment volumes were then used to in the logjam enhancement prioritization process.

The location of each feature (i.e. logjam or sediment source) was converted into a GIS layer. The location of each significant structures such as the HWY 1 bridge and stream confluences were used to calibrated a routed California Department of Fish and Game (CDFG) stream path vector

layer. The distance of each assessed feature was then correlated to the calibrated stream path using the ESRI Arc GIS suite.

Priorities for Modification

Priorities for structure modification were assessed on a number of factors. Ideally, the largest and most severe structures should receive the highest priority because they are the likely determinants to fish migration. However, in this watershed efforts to improve several large barrier structures could jeopardize downstream habitat through the release of accumulated sediments.

The following criteria were used to prioritize current structures for future improvement or restoration in the short-term: a) structures that were donwnstream of large impassable logjams were given higher priority, b) structures that would provide significant increases in upstream habitat were given higher priority over structures with limited or no upstream available habitat, c) structures that were easily accessible and or cheap to improve were given higher priority over inaccessible, larger, and therefore more costly barriers, d) structures that were partial barriers and that would likely become barriers with the additions of more material were given higher priority over more easily passable structures or those that were complete barriers, and finally e) structures with minimal fine sediment accumulations were given a higher priority over structures with high volumes of stored fine sediments.

4. Observations of Fisheries Habitat Quality

Stream habitat

In addition to logjam and sediment source occurrences, general observations of fisheries habitat were made during the rapid foot traverse through the watershed. These observations included visual descriptions of in-stream fine sediment accumulations, substrate embeddedness, water temperatures, occurrence of larger pools (Fig. 4.1), as well as the frequency of fish visually observed in the channel. Also, preliminary observations of the Garrapata Creek lagoon were made during a single visit in early July.

Fine sediment accumulation in the lower reaches of Garrapata Creek (between the lagoon and the Joshua Creek confluence) was minimal to moderate and noticeably increased leading up to the Joshua confluence. One pool of relevant size was observed between the lagoon and the Joshua Confluence. Between the Joshua confluence and approximately 0.2 km downstream of the Wildcat confluence, fine sediment accumulations were minimal and available spawning habitat and pools were observed. Approximately 0.2 km downstream of the Wildcat Creek confluence up to Garrapatos Creek Road, fine sediment accumulations and embeddedness increased substantially. Some areas with narrow, confined channel widths had lower amounts of fine sediment accumulations, presumably due to higher flow velocities and greater scour capabilities.

Based on observations of in-channel habitat conditions, the best habitat quality for salmonids in Garrapata Creek occurred in the reaches downstream of the Wildcat Creek Confluence, especially between the Joshua and Wildcat confluences. This also coincides with the frequency of fish visually observed in the channel, although to confirm this, more accurate sampling methods are recommended.

In Joshua Creek, fine sediment accumulations and embeddedness was significant throughout. At present, spawning habitat is substantially limited due to obstructions and poor substrate conditions. The lack of pools was also attributed to high sediment accumulations – no significant pools were observed below the large waterfall. Few observations of fish were made in Joshua, all of which were made in the lower 300 m of stream (i.e. below the first major barrier).

Wildcat Creek had minimal fine sediment accumulations and limited embeddedness of coarse particles. Refuge such as undercut banks, pools, and passable small woody debris accumulations were found throughout this short reach of stream. Few fish were observed in this stream, however this could be due to the abundance of shelter.

Summer water temperatures were cool throughout the watershed. Most temperature measurements were recorded in the later morning hours. In March, water temperatures were 11°C just downstream of Garrapatos Creek Road. In early June, temperatures in the downstream reaches of Garrapata Creek were 12.5°C. Water temperatures in Joshua Creek were 12.0 °C on the same day. Further upstream in Garrapata Creek, water temperatures remained at 12 and 13°C during visits in late June and early August respectively.



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Figure 4.1 Location of large pools in the Garrapata Creek Watershed during summer low flow conditions.

Lagoon Observations

The Garrapata Creek Lagoon was visited on July 1st 2004. At this time, the lagoon was narrow with the deepest embayments along the bedrock bluffs to the north (right bank). From upstream to downstream, there were differences in water quality and habitat type within the lagoon. Furthest upstream, a transition zone existed where the Garrapata Creek stream habitat, fed into a broad backwater habitat that was well vegetated with emergent vegetation (Fig. 4.2). Some fish were observed here, however the species was not identified. Water depths averaged approximately 0.25 m.

Further downstream, a broad riffle of coarse substrate connected the upper vegetated areas into the eastern of two main embayments of the lagoon (termed here as eastern and western embayments) (Fig. 4.3). Threespine stickleback (*Gasterostreus aculeatus*) were observed at the downstream base of this riffle. At this point emergent vegetation was minimal to none. The eastern embayment (Fig. 4.4) was shallow, 0.3 m on average, with a deeper scoured channel (~0.5 m depth) along the northern bluffs.

The western embayment was located against the sand bar and the northern bluffs. The sandbar was opened along the left bank, although minimally (Fig. 4.5). Water depths were deepest in the western embayment with a maximum depth measured of 1.45 m near the center-right bank portion of the pool.



Figure 4.2 The eastern half of the Garrapata Creek Lagoon. This area was the transition zone between stream habitat and lagoon habitat. The main embayment of the lagoon is against the bluffs in the upper right corner of the photo. Photo: Joel Casagrande, 1 July 2004.



Figure 4.3 The broad riffle shown here (looking upstream) separated the eastern backwater areas (upstream) to the main lagoon embayments (downstream). Note the kelp accumulations in the foreground indicating the upstream extent of wave action. Photo: Joel Casagrande, 1 July 2004.



Figure 4.4 A view of the eastern of the two main embayments shown at the base of the bedrock bluffs at the center of the photo. Photo: Joel Casagrande, 1 July 2004.

July surface water temperatures in the lagoon were slightly warmer (14°C) than upstream stream water temperatures. Both salinity and dissolved oxygen probes were not available during the visit; however, conductivity, which can be correlated with salinity, was measured using a hand-held Oakton conductivity meter. Surface conductivity measurements were taken at both the east and west embayments, as well as upstream in the vegetated backwater areas shown in Figure 4.2. Conductivity levels in the upstream backwater area were 320 μ S while at the east and west embayments they were 670 and 1100 μ S respectively. The presence of freshwater in the lagoon and more conductive waters near the sandbar indicates the lagoon is influenced by ocean wave in-wash during summer months. However, with perennial freshwater entering the lagoon, the concentration of salt in the upper half of the lagoon is kept to a minimum. In summer, the availability of such a transitions zone between saltier water near the bar and freshwater upstream are ideal conditions for rearing steelhead. However, at extreme low flow conditions, the broad riffle (Fig. 4.3) connecting freshwater habitats with more saline habitats may make migrations between the two bodies difficult.

The Garrapata Lagoon appears to be a dynamic system. The sandbar that separates the lagoon from the ocean is narrow and quite often it is open to the ocean in summer – possibly due to either ocean wave disturbance or human influences.

The use of the lagoon for rearing and smolting by juvenile steelhead is unknown. Studies should be conducted to determine its suitability and potential for steelhead production. Data that should be included in such studies are: seasonal fish sampling (seine) for size and age distributions, seasonal water quality data (specifically salinity, dissolved oxygen, and temperature), seasonal changes in oceanic inputs, and seasonal availability of macroinvertebrate species.



Figure 4.5 The western main embayment of the Garrapata Creek Lagoon. Note the sandbar is open along the left side. Photo: Joel Casagrande, 1 July 2004.

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5. Garrapata Creek

Migration Impediments (Logjams and Waterfalls)

Structure gb01

Description

This logjam is located upstream of the Joshua Creek confluence, approximately 2982 m (9783 ft) upstream of the Garrapata Creek Lagoon (Fig. 5.1) (Fig. 5.2 & Table 5.1). A large key log with a diameter of nearly 1 m spans the entire channel width and is anchored behind several large living trees. This log extends several feet onto the floodplain on both sides. The source of the tree is of natural fall. Flow underneath is clogged with accumulated small and medium sized woody debris and sediment. The height of this structure is 1.4 m with a pool 0.2 m deep at its base, although the pool has marginal room to scour.

Problem

The height of the structure and the lack of a deep jumping pool at the base create moderately difficult passage conditions except during at higher flows (Table 5.1). This structure, unless scoured underneath, could potentially be a difficult barrier for up-migrating steelhead, even at higher flows. The presence of logs, small woody debris and sediment on top of the structure is evidence that water spills over this structure and does not scour a path beneath.

Recommendations

This structure should be improved immediately. Using a hand or chain saw, cut/notch the main



Figure 5.1 Structure gb01 looking upstream. Photo: Joel Casagrande, 8 June 2004.

log in the center creating a 1.5 m (4–5 ft) wide gap for increased passage. If possible, pivot remaining ends so that the inside ends are pointed downstream at an approximately 45°. Remove accumulated small and medium woody debris from upstream side, and if possible, shovel fine sediment accumulations out of active channel. Some small and medium sized woody debris was removed in the field. More work to be performed to increase passage.

	ID	Structure Type	Distance (m)	Distance (ft)	Severity (0–5, 0 easy passage)	Recommended Action
	gb01	Logjam	2982	9783	3	Cut main log through center into smaller pieces. Clear passage underneath.
	gb02	Logjam	3089	10135	2	Cut main log through center into smaller pieces. Clear passage underneath.
	gb03	Logjam	3485	11435	2	Cut main logs along left bank. Cut main log along right bank drop.
	gb04	Logjam	4529	14860	5	Cut and remove portions of the jam.
	gb05	Waterfall	5015	16452	4	Move large log piece and coarse sediment from plunge zone in the pool.
	gb06	Waterfall	5024	16482	3	Cut and remove log from spilling area.
	gb07	Boulder waterfall	5072	16640	4	None- no action needed this is a natural structure.
	gb08	Logjam	5167	16951	5	None - significant barrier and stream gradient control structure.
	gjb09	Logjam	5181	16999	5	Future: Overtime, remove all debris by hand and cut and remove larger logs.
						Future: Remove all debris possible by hand. Cut tanoak
	gb10	Logjam	5197	17051	3	log into small pieces. Leave other woody material as habitat.
	gb11	Logjam	5280	17322	5	None - significant barrier and stream gradient control structure.
						Future: Starting upstream, remove all small woody
	gb12	Logjam	5330	17486	4	debris possible by hand. Cut/notch larger logs logs in center and pivot in channel remove from channel.
						Future: Starting upstream, remove all small woody
	gb13	Logjam	5482	17986	5	debris possible by hand. Later, cut/notch larger logs and
						leave in channel.
_	gb14	Logjam	5846	19182	4	Future: Starting upstream, remove all small and medium debris possible by hand.

Table 5.1 Structure type, severity, and recommended action for improvement for structures found in Garrapata Creek.

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Description

Structure gb02 is a logjam formed by a key log, in this case a large pine tree. The tree spans the entire channel with and is lodged within dense riparian vegetation on both banks (Fig. 5.3). It is located approximately 3089 m (10135 ft) upstream of the lagoon and approximately 107 m upstream of gb01. The height of the structure at its lowest point is 1 m with a small pool roughly 0.4 m deep at its base. Flow underneath is clogged with small woody debris and a moderate amount of sand and coarse sediment. The presence of small woody debris accumulated on top of the large log suggests that this structure spills during winter flows.

Problem

The height of the structure and the lack of a deep jumping pool at the base create difficult passage conditions, although the downstream pool may scour some to create better jumping conditions for steelhead. The large woody material also serves as decent complex habitat, creating resting spots for up-migrating fish. Although it is likely passable at higher flows, this logjam does have the potential to increase in size and degree of difficulty for successful passage.

Recommendations

Using a hand or chain saw, cut the main log creating a 1-1.25 m (3-4 ft) wide opening along the right bank. Leave remainder of the structure in place as important habitat. Small debris and three medium sized logs were removed from backside of the structure and placed higher on the bank. This created a small path underneath, however this will likely clog in the near future unless the large key log is notched.



Figure 5.3 Structure gb02 looking upstream. Photo: Joel Casagrande 8 Jun 2004

Description

Structure gb03 is located 3485 m upstream of the lagoon, or approximately 396 m upstream of structure gb02 (Table 5.1). This structure consists of several large tanoak and redwood logs that have become wedged behind standing snags and have accumulated a substantial amount of woody debris as well as some sediment. The small jump on the right bank side is approximately 0.8 m high from the surface of the water with a shallow pool approximately 0.1 m deep, although this could scour deeper during winter flows.

Problem

The structure is passable during winter flows along the right bank side if it doesn't clog with debris. This site could potentially clog in the future. The left bank side is nearly clogged, although it could be improved relatively easily. A deep undercut bank exists along the right bank side at the base of the key log shown in Figure 5.4, which serves as important habitat feature for salmonids and possibly red-legged frogs.

Recommendations

Clear and remove small and medium sized woody debris from left bank (right side of Figure 5.4) to create a second passage way along left bank. Cut a piece of the main log approximately 2.5 m (~8 ft) in length from the left bank. Leave remainder of woody material in place as habitat.



Figure 5.4 Structure gb03 looking upstream. Photo: Joel Casagrande 8 June 2004.

Description

Structure gb04 is located 4529 m (14380 ft) upstream of the Garrapata Creek Lagoon and approximately 104 m (340 ft) upstream of gb03. It completely spans the entire channel width and has accreted over 2 meters of debris consisting of large redwood and tanoak logs as well as a significant amount of fine sediments (Fig. 5.5). The structure height is over two meters with no developed pool at the downstream edge to assist in jumping. The pool has been filled with fine sediments (i.e. sand).

Problem

During low flow conditions, streamflow percolates through the accumulated material with no clear path for migration. At high winter flows, water spills from the top creating a significant barrier to migration. The amount of material accumulated indicates that there is no flow underneath the barrier that would permit successful passage. At present, this is a difficult migration barrier at all flow levels. Due to the severity of this logjam and because there is approximately 500 m of relatively suitable spawning/rearing habitat upstream, improvements should be addressed as soon as possible.

Recommendations

Starting upstream, remove excess small and medium woody material. Larger logs impacting passage should be cut/notched at their lowest point. All attempts should be made to use the larger woody material for habitat features in the local vicinity. Larger logs not directly affecting fish passage should be left in place as important habitat features. If possible, remove sediments using shovels and buckets to higher, level ground.



Figure 5.5 Structure gb04 looking downstream from back side of barrier. Note the sediment accumulations on the left. Photo: Joel Casagrande 11 August 2004.

Description

Structure gb05 is a bedrock waterfall that is 2.3 m in height from the surface of the water. It is located approximately 5015 m (16452 ft) upstream of the lagoon and approximately 487 m (1600 ft) from the previous barrier (Table 5.1). The waterfall spills at a 90° angle to the downstream channel and spills onto accumulated coarse sediments and a large redwood log segment, which has been buried by accumulated fine sediments in the pool below. The pool depth averages 0.75 m at current flow conditions and approximately 1.25 m at higher flows, based on waterline markings on bedrock lining the pool (Figs 5.6a & 5.7b).

Problem

The spilling angle, velocity, and height create challenging conditions for salmonid migration. The accumulation of debris in the spill zone, blocking the most suitable jumping position in the pool, further complicates this structure. This could be a natural barrier even without the added debris based on the 90° spilling angle and powerful projecting streamflow velocities during winter.

Recommendations

Cut and remove the log piece and coarse sediments from the spilling zone to better attract fish.



Figure 5.6a Structure gb05. Photo: Joel Casagrande 11 August 2004.



Figure 5.5b Accumulated debris and log in the downstream pool. Note the erosion and scour of moss and lichen from the bedrock across from the spilling waterfall. This illustrates the 90° angle of the spill. Photo: Joel Casagrande 11 August 2004.
Description

Structure gb06 is also a bedrock waterfall approximately 9.1 m (30 ft) upstream from gb05 (Fig. 5.7). The height of the structure is 1.6 m from the surface of the water. The maximum downstream pool depth was 0.5 m with an estimated high water depth of 1.0 m, based on high water lines on the adjacent rocks. Significant accumulations of sediment were found in the pool, which would likely scour to some degree during periods of higher streamflow.

Problem

The accumulation of sediment has limited the depth of the pool and thus created conditions less favorable for successful migration. There is a fork shaped log, which extends into the thalweg, or the lowest point in the active channel. The lower end of the log presents no benefit to fish habitat in the spill zone and it could potentially be a hindrance to leaping fish if not washed away during future winter storms.

Recommendations

Cut the log at the forked junction, leaving the upstream half as woody structure in the stream. In time the pool will likely re-scour but only after upstream sediment sources are located and contained.



Figure 5.7 Structure gb06 looking upstream. Photo: Joel Casagrande 11 August 2004.

Description

Structure gb07 is a boulder/log waterfall of natural origin (Fig. 5.8). It is located approximately 49 m (160 ft) upstream of gb06. The height of the structure at its lowest point is 1.9 m with a downstream pool depth of 0.55 m at current flow levels and possibly 1.0 m at higher levels. Fine sediments have accumulated in the pool, therefore reducing the pool volume.

Problem

The height of the structure and lack of adequate pool depth downstream create a difficult passage here at all flow levels. This is likely to be passable only at higher flows.

Recommendations

Because this is a natural occurrence, no recommendations for improvement are warranted. In time the pool will likely re-scour but only after upstream sediment sources are located and contained.



Figure 5.8 Structure gb07 looking upstream. Photo: Joel Casagrande 11 August 2004.

Description

This structure is located approximately 5167 m (17000 ft) upstream from the Garrapata Creek Lagoon (94 m upstream of gb07). It is a large barrier consisting of logs, several large boulders, and a large rootwad at the top (Fig. 5.9). Its height is approximately 2.5–2.75 m from the surface of the water and there is no pool present at the downstream end. Underneath passage is blocked by substantial sediment and woody debris accumulation. Currently, streamflow is spilling/percolating through the structure approximately 2 m above the surface of the current downstream channel.

Problem

The height of this structure and lack of pool make this a complete barrier at all flow conditions (Table 5.1). There is no passage beneath and the change in elevation indicates that this is a significant grade control. Also, this structure is situated in a narrow reach in the channel that is well anchored behind several large living trees and protruding bedrock from the adjacent stream banks. If modified, it is likely a logjam will form here again in the future due to the confined nature of the channel.

Recommendations

At present, no modifications should be made to this structure due to high efforts, cost, and threat to downstream habitat – See Section 8: Structure Prioritization.



Figure 5.9 Structure gb08 looking upstream. Note accumulated sediment at downstream side. Photo: Joel Casagrande 12 September 2004.

Description

Structure gb09 is a large accumulation of woody debris and sediment that spans the entire width of the channel (Fig. 5.10). It is located 5181 m upstream of the lagoon and approximately 15 m upstream of gb08 (Table 5.1). The logjam is approximately 1.5 m in height and there is a shallow pool of 0.25 m at the downstream side. During low flow conditions, streamflow percolates through the accumulated debris. Sediments accumulated at the upper heights of this structure indicates that winter flows spill from the top creating a large jump.

Problem

The height of the debris and the absence of a passage underneath make this structure difficult to pass during all streamflows. Significant improvement would be needed to create passage. Spawning habitat upstream is poor due, in part, to the presence of consecutive barriers and the lack of suitable substrate for spawning. Sediment storage behind this structure is substantial.

Recommendations

Currently poor habitat upstream therefore improvement may not be warranted. Starting at the upstream extent of the debris pile, remove small and medium sized woody debris by hand out of the channel. Cut larger logs that are attracting and accumulating material. A small amount of woody debris was removed in the field; more must be removed in order to increase access.



Figure 5.10 Structure gb09 looking downstream from the backside of the barrier. Photo: Joel Casagrande 12 September 2004.

Description

Structure gb10 is a short logjam consisting primarily of tanoak logs and small woody debris accumulations. It is located approximately 15 m upstream of gb09. The height of this structure is approximately 1 m with no pool downstream. Flow underneath is blocked by dense accumulations of small woody debris (Fig. 5.11).

Problem

This is a relatively minor obstruction that could be improved easily by one individual. The lack of a pool at the downstream end creates a difficult jump for fish. Fish gaining access to this point in the watershed is unlikely based on current barriers downstream.

Recommendations

Clear small woody debris from the base of the larger tanoak log crossing the channel. This would improve conditions enough for suitable access, however material will likely clog again in the future. To avoid this, use a hand or chain saw to cut the large tanoak log into smaller pieces. Leave log shown along left side of Fig. 5.11 in place as habitat.



Figure 5.11 Structure gb10 looking upstream. Photo: Joel Casagrande 12 September 2004

Description

Structure gb11 is a large impassable barrier consisting of several large and medium sized redwood logs, a significant accumulation of stored sediment and human garbage such as metal and plastic piping (Figs 5.12 & 5.13). The logjam is situated in a narrow confined reach approximately 83 m (275 ft) upstream of gb10. Underneath passage is blocked and streamflow currently spills/percolates through the accumulated sediment and wood debris. In winter, the left bank appears to be the route where the highest concentration of flow occurs. This path contains a double jump – the first (lowest) is 1.9 m, immediately followed by a 0.6 m step. Above the second step there is a difficult entanglement of debris that a fish must navigate through. A shallow pool exists at the base of the left bank side that was 0.3 m max depth.

Problem

The height of this structure and its complexity and the lack of a deep pool at the base make this a complete barrier to fish at all flows (Table 5.1). This location is extremely difficult to access with the proper machinery needed to improve this feature. Some local resdients suggest that this strucutre has been here since the 1930's.

Recommendations

At present, no modifications should be made to this structure due to high efforts, cost, and threat to downstream habitat – See Section 8: Structure Prioritization.

Several suggestions have been made on how to best improve this strucutre. One was to install two smaller structures downstream of the present barrier. This would create three smaller, more passable jumps as opposed to one large jump at the present barrier. Logs and other materials to create these structures would be taken from the present barrier and anchored into the channel with cables. Members of the project's Technical Advisory Committee (TAC), and the representative from CDFG, did not fully accept the idea of adding more structures to the stream. This site is likely prone to having debris jams on a natural cycle due to the confined nature of the channel reach. If this barrier were removed or enhanced, it is likely that a new strucutre would form in the future. Also, the upper banks are steep and inaccessible to heavy machinery that would be needed to construct these structures effectively. In addition, there is a substantial volume of sediment stored behind this structure. Any significant modification of the present logjam would likely release an adverse amount of fine sediment downstream, thus jeapordizing current spawning habitat downstream in the watershed. The TAC and CDFG would like to focus efforts on evaluting logjams and debris obstacles downstream of this barrier and finding the source of this decomposed granite farther up in the watershed.



Figure 5.12 Structure gb11 looking upstream along left bank. Photo: Joel Casagrande 12 September 2004.



Figure 5.13 Sediment accumulation at structure gb11. This 2 m staff was driven 1.5 m into the bed approximately 5 m upstream of the logjam. Photo: Joel Casagrande 30 March 2004.

Description

Structure gb12 is located approximately 49 m (160 ft) upstream of gb11 (Table 5.1). It consists of several large and medium sized redwood logs that span the entire channel width (Figs 5.14 & 5.15). Sediment accumulation is moderate primarily consisting of coarse material (i.e. cobbles). The height of the structure is 1.7 m and the downstream pool is approximately 0.5 m at its deepest. The pool does provide good complex habitat (Fig. 5.16), especially along the left bank where the pool extends back underneath the overhanging logs.

Problem

The height of the structure and the lack of a deep pool make this a difficult structure to pass. Water currently spills through a narrow opening due to accumulated small woody debris (Fig. 5.15). It is unlikely adult steelhead reach this structure due to downstream impediments.

Recommendations

Remove small and medium sized woody debris from the backside of the logjam. This would increase the opening along the left bank and possibly allow for transport of accumulated coarse substrate, therefore equilibrating the difference in bed elevations.



Figure 5.14 Structure gb012 looking upstream. Photo: Joel Casagrande 12 September 2004.



Figure 5.15 Structure gb12 looking downstream from upstream of the barrier. Photo: Joel Casagrande 30 March 2004.



Figure 5.16 Structure gb12 looking towards the left bank showing complex pool conditions downstream of the logjam. Photo: Joel Casagrande 30 March 2004.

Description

Structure gb13 is a logjam that spans the entire channel width. It consists of a single key log that has trapped a significant amount of small woody debris and sediment upstream (Fig. 5.17). It is located approximately 5482 m (17986 ft) upstream of the Garrapata Creek Lagoon, or approximately 152 m (500 ft) upstream gb12. Passage underneath is not possible due to the accumulated debris. The height at the lowest point in the structure was approximately 1.6 m and there was no pool present at the downstream side. Large cobbles and boulders at the base of the jam limit the ability for the stream to scour significantly.

Problem

The height of the structure, lack of a jumping pool and the lack of a clear passage underneath make this a difficult barrier to pass at all flows. It is unlikely that steelhead reach this structure due to several significant barriers downstream.

Recommendations

Starting upstream, remove all small and medium sized woody debris out of the channel. Cut a section from the middle of the main log and remove from the channel, leaving the ends along the bank as habitat features. There is a road adjacent to the left bank that could be used to transport woody material.



Figure 5.17 Structure gb13 looking upstream. Photo: Joel Casagrande 12 September 2004.

Description

Structure gb14 is located approximately 5847 m (19182 ft) upstream of the Garrapata Creek Lagoon. The logjam consists of a large accumulation of small and medium sized woody debris that is over 15 m in length (upstream) and approximately 2 m in height at its base (Fig. 5.18). Streamflow underneath is present, however it appears that there is not a clear path for fish passage.

Problem

The length, height and complexity of this structure make this a likely barrier to fish at all flows. However, it is highly improbable that steelhead reach this location in the watershed due to several large barriers downstream.

Recommendations

To increase habitat for resident trout, clear small and medium sized woody debris by hand from the channel. The road adjacent on the left bank could be used to transport the material to an appropriate disposal site. Larger pieces can be left in the channel as habitat complexity as long as they are not likely to cause a future logjam.



Figure 5.18 Structure gb14. This picture, taken from standing on top and looking upstream, shows approximately half of the logjam present at this site. Photo: Joel Casagrande 12 September 2004.

Migration Impediments (Concrete Control Structures)

In addition to the logjams and waterfalls, there is one low-relief concrete control on lower Garrapata Creek. This is located at the pump house/stream gage approximately 1,466 m (4,809 ft.) upstream of the lagoon (Fig. 5.19). The structure stands approximately 0.4 m above the downstream water surface and no pool is present at its base. There is also a large piece of concrete in the spill zone below the apron that could limit leaping access for fish. At low flow, the apron creates a barrier to juvenile fish and during low winter runoff events it may form a temporary barrier to up-migrating adult steelhead. Sediment accumulation upstream is minimal and consists of a mixture of fine and coarse sediments. Note: the details for this structure are not present in Figure 5.2, Table 5.1, or Table 8.1.

This structure could be easily modified using a sledgehammer or a jackhammer to improve passage. To improve low flow passage, create a notch in the center of the structure to reduce the height and to better attract fish. The large concrete slab lying just downstream of the apron (center of Fig. 5.19) should be moved away from the spill zone to create better access for fish.

Temporary improvements were made during field reconnaissance in early June. A small route along the right bank was created by removing accumulated debris.



Figure 5.19 Concrete slab/apron on lower Garrapata Creek. Photo: Ken Ekelund, December 1, 2004.

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6. Joshua Creek

Migration Impediments (Logjams and Waterfalls)

Structure jb01

Description

This logjam structure was caused naturally due to a large redwood tree that was undercut and fell into the stream channel. It is located approximately 364 m (1195 ft) upstream of the confluence with Garrapata Creek (Fig. 6.2 & Table 6.1). The logjam's height along the left bank is 1.75 m and along the right bank it is 1.0 m. A clear path underneath this structure could not be determined (Fig. 6.1).

Problem

The height of this structure and the lack of a pool at the downstream end make this a difficult structure to pass. However, a clear path may be present underneath the structure. In addition, spawning and rearing habitat upstream is poor and there are several more complicated barriers above this (Table 6.1).

Recommendations

Remove small and medium sized woody debris that has accumulated upstream. Improve a path along both the right and left banks by cutting larger logs. Leave largest log and rootwad in place as habitat.



Figure 6.1 Structure jb01 looking upstream along left bank. Photo: Joel Casagrande 2 June 2004.

ID	Structure Type	Distance (m)	Distance (ft)	Severity (0-5, 0 easy passage)	Recommended Action
jb01	Logjam	364	1195	3	Improve passage along right and left bank by cutting and removing sections of larger logs near the banks.
jb02	Logjam	427	1400	4	Cut main logs and remove.
jb03	Logjam	447	1466	3	Cut center log and remove.
jb04	Logjam	524	1718	4	Clear path along left bank. Leave rootwad/stump in place as complex habitat feature.
jb05	Logjam	621	2039	4	Overtime cut/notch logs starting from top of jam.
jb06	Logjam	642	2106	4	Overtime cut/notch logs starting from top of jam.
jb07	Logjam	745	2444	4	None- limited habitat upstream and sediment release is substantial.
jb08	Logjam	799	2620	5	None– limited habitat upstream and sediment release is substantial.
jb09	Logjam	841	2759	5	None– limited habitat upstream and sediment release is substantial.
jb10	Logjam	979	3214	5	None– limited habitat upstream and sediment release is substantial.
jb11	Waterfall	1051	3448	5	None-natural limit to migration

Table 6.1 Structure type, severity, and recommended action for improvement for structures found in Joshua Creek.

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Description

Structure jb02 is a logjam located approximately 427 m (1400 ft) upstream of the confluence with Garrapata Creek or 198 m (650 ft) upstream of structure jb01. The logjam has a double jump that drains towards the right bank side. The first jump is approximately 0.75 m tall and the second jump is 0.25 m tall (Fig. 6.3). At current flow rates the streamflow is spilling/percolating through the tangled debris below the second step. At higher streamflow there is a larger secondary route along the right bank and it is likely water spills over the entire structure at the highest flow levels. A shallow scour pool has formed at the base of the structure that is 0.25 m deep. Significant accumulations of sediment occur both upstream and downstream of the structure.

Problem

The height and complexity of logjam and the lack of a jumping pool create difficult conditions for fish passage. Underneath passage is blocked entirely by accumulated woody debris and sediment.

Recommendations

Remove or cut larger logs that are forming jumps along the right bank side. Leave the remainder of the structure in place as habitat complex habitat including the larger moss covered log shown in the foreground of Figure 6.3.



Figure 6.3 Structure jb02. View is from the right bank – downstream is to the right. The small waterfall shown (at top) here is the second jump. Photo: Ryan Lockwood, 3 June 2004.

Description

Structure jb03 is log/debris jam located approximately 447 m (1466 ft) upstream of the Garrapata Creek confluence, or 20 m (66 ft) upstream of structure jb02. The jam was created by several key logs that span the entire width of the channel, which have accumulated small woody debris and sediment (Fig. 6.4). The height of the structure is 1.1 m above the surface of the water downstream and there was no jumping pool present at the downstream edge.

Problem

The lack of a pool and the overall height of the structure create a moderately difficult obstacle to pass during lower flows. Likely passable at higher flows.

Recommendation

Cut pieces of key logs through the center and remove. Adjust positions of larger boulders and other woody material to reduce the height of the structure by allowing for transportation of accumulated sediments. Some small and medium sized woody debris removed. The hole between the log and the boulder at the bottom of Figure 6.4 was created after removal of debris. Figure 6.4 was taken after removal of material. More material to be removed.



Figure 6.4 Structure jb03 looking downstream. Photo: Joel Casagrande 3 June 2004

Description

Structure jb04 is a natural feature created by existing rootwads that have trapped sediments and small woody debris forming a two step sequence along the left bank (Fig. 6.5). It is located approximately 524 m (1718 ft) upstream of the Garrapata Creek confluence or approximately 76 m (250 ft) upstream of jb03. The first step is approximately 0.5 m tall while the second is 1.0 m. No pool occurs at the base of the structure, which is covered with sand deposits.

Problem

The height of the structure and the lack of a jumping pool increase the difficulty of migration passage.

Recommendations

Remove small and medium woody debris along the left bank route. Decrease second jump by adjusting/removing accumulated debris and sediment. Leave large rootwad shown in center as habitat feature (See Fig. 6.5).



Figure 6.5 Structure jb04 looking upstream. Photo: Joel Casagrande 3 June 2004.



Figure 6.6 Structure jb04 looking at the left bank route. Photo: Joel Casagrande 3 June 2004.

Structure jb05

Description

Structure jb05 is a large logjam consisting of several large redwood logs as well as accumulated debris and sediment (Figs 6.7 & 6.8). It is located 621 m (2039 ft) upstream of the Garrapata Creek confluence or 98 m (320 ft) upstream of structure jb04. Currently the only path for migration would be along the left bank, however this path is complex and difficult in its current condition. The lowest jump along the left bank is 1 m high and there are no pools for leaping. Streamflow would have to be substantial to increase chances of successful passage.

Problem

The height and complexity of this structure in addition to the lack of pools within create difficult migration passage conditions. Improvement of the left bank route would be needed to increase fish passage success.

Recommendations

A clear path free of jumps and debris should be created along the left bank. Several medium to large sized logs should be notched along the left bank of the channel.



Figure 6.7 Structure jb05 looking upstream. Backpack is directly in front of the left bank path. Photo: Joel Casagrande 3 June 2004



Figure 6.8 Structure jb05 looking downstream from upstream along the left bank. Photo: Joel Casagrande, 3 June 2004.

Description

Structure jb06 is an accumulation of woody debris and sediment that spans the entire channel width. It is located approximately 21 m (70 ft) upstream of structure jb05. At its lowest height the structure is approximately 1 m above the downstream water surface. No pool was observed at the downstream end of the structure and sediment accumulation upstream was significant. Currently streamflow percolates through the accumulated debris and likely spills during higher streamflows.

Problem

The height of the debris pile and the lack of a jumping pool create adverse conditions for migration at this location. Improvements are necessary to increase migration success over this structure. However, spawning and rearing habitat upstream is of poor quality and limited availability.

Recommendations

Due to the accumulated sediment volume upstream of the logjam, improvements to this structure should be made with caution and over an extended period of time to ensure a slower release of sediment. Remove small and medium woody debris from the channel starting from the top of the structure. In time, cut larger logs that are uncovered as the stored sediment is transported downstream. An alternative method for the removal of sediment would be to shovel and remove the accumulated sediments up to a flat terrace somewhere above the stream channel where they can be disposed of by spreading over the forest floor.



Figure 6.9 Structure jb06 looking downstream from upstream side. Note accumulated sediments. Photo: Joel Casagrande 3 June 2004.

Description

Structure jb07 is large logjam consisting of several large redwood logs in addition to a significant amount of stored sediment that extends approximately 5 m upstream (Figs 6.10 & 6.11). This logjam is located approximately 745 m (2444 ft) upstream of the Garrapata Creek confluence, or 104 m (340 ft) upstream of structure jb06 (Table 6.1). The height of the structure is 2.0 m above the downstream water surface.

Problem

The height of the debris and the lack of a jumping pool create adverse conditions for migration at this location. Significant amounts of woody debris and sediment would have to be removed to improve passage.

Recommendations

Due to limited upstream habitat and accessibility to fish, improvements of this structure would not result in a considerable increase in spawning and rearing habitat. Efforts should be spent downstream and in other streams in the watershed.

No recommendations for improvement.



Figure 6.10 Structure jb07 looking upstream. Photo: Joel Casagrande 3 June 2004.



Figure 6.11 Structure jb07 looking at the upstream half of the accumulation. Photo: Joel Casagrande 3 June 2004.

Description

This barrier is the largest non-waterfall structure found in this sub-watershed. It is located 799 m (2620 ft) upstream of structure jb07. Several large redwood logs, resulting from natural recruitment into the channel have accumulated to form a 4 m tall complete barrier (Fig. 6.12). A substantial volume of sediment and debris has accumulated behind the structure to form a significant grade control structure in the channel. The narrow channel conditions at this location are likely prone to having debris jams. During summer conditions streamflow was percolating through the debris and accumulated sediment several meters upstream of the logjam. There was no clear path underneath the structure.

Problem

The height of this logjam and accumulation of flow underneath have created a complete barrier to steelhead migration. This area is not accessible to heavy machinery that would be required to improve this structure.

Recommendations

The inaccessibility of this structure and the limited benefit to improvement does not warrant the effort needed to improve this structure. Efforts should be focused downstream of this and/or in other streams in the watershed.



Figure 6.12 Structure jb08. Photo: Joel Casagrande 3 June 2004.

Description

Structure jb09 consists of a large accumulation of large woody debris and sediment that is anchored behind a large standing snag in the center of the channel and is a complete barrier to migration (Fig. 6.13). It is located approximately 43 m (140 ft) upstream of structure jb08. During summer conditions, streamflow percolates through the accumulated debris several meters upstream of the structure. In winter, higher streamflows spill over the large rootwad structure of the standing snag along the left bank (Fig. 6.14).

Problem

The height of this logjam and lack of flow underneath have created a complete barrier to steelhead migration (Table 6.1). This area is not accessible to heavy machinery that would be required to improve this structure.

Recommendations

The inaccessibility of this structure and the limited benefit from improvement does not warrant the effort needed to improve this structure. Efforts should be focused downstream of this and/or in other streams in the watershed.



Figure 6.13 Structure jb09. Photo: Joel Casagrande 3 June 2004.



Figure 6.14 Structure jb09 looking upstream during winter streamflow conditions. Photo: Ken Ekelund 24 January 2004.

Description

Structure jb10 is a large logjam consisting of several redwood logs and accumulated sediment. It is located 980 m (3214 ft) upstream of the Garrapata Creek confluence or approximately 455 ft upstream of structure jb09. The height of the structure is 2 m above the downstream water surface and there is no jumping pool at the base.

Problem

The height of the structure and the lack of a jumping pool create an impassable barrier to fish migration. Several barriers downstream of this structure would prevent access to this location of the stream.

Recommendations

The inaccessibility of this structure and the limited benefit to improvement does not warrant the effort needed to improve this structure. Efforts should be focused downstream of this and/or in other streams in the watershed.

No photo available

Description

The limit to anadromous migration without the presence of downstream barriers is a 15 + m (50 ft) waterfall located approximately 1051 m (3448 ft) upstream of the confluence of Garrapata Creek (approximately 70 m upstream of structure jb10) (Table 6.1).

Problem

The natural waterfall is the limit to steelhead migration.

Recommendations

No recommendation needed. Natural limit to migration.



Figure 6.15 Structure jb11. Photo: Joel Casagrande 3 June 2004.

Migration Impediments (Concrete Control Structures)

In addition to the logjams on Joshua Creek, a small concrete control structure is present on lower Joshua Creek approximately 137 m (450 ft.) upstream of the confluence with Garrapata Creek (Fig. 6.16). It stands approximately 0.40 m above the downstream water surface and there is no pool at the downstream end. At present, this structure is only a potential barrier for up-migrating adults during periods of low runoff.

The concrete control apron on Joshua Creek could be improved using a sledgehammer to either completely remove or create a lower notch in the center, although this could jeopardize the effectiveness of the road culvert directly upstream. Note: details of this structure are not included in Figure 6.2 or Tables 6.1 & 8.1.



Figure 6.16 Concrete control structure on Joshua Creek at the footbridge near the confluence of Garrapata Creek. Photo: Ken Ekelund, December 1, 2004.

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7. Wildcat Creek

Migration Impediments (Logjams and Waterfalls)

Structure wb01

Description

This debris jam is located 88 m (290 feet) upstream of the confluence with Garrapata Creek (Fig. 7.3 & Table 7.1). It is anchored behind narrow banks of the channel due in part to local geologic constraints as well as the presence of large streamside trees (Fig. 7.1). Woody material and minimal sediment accumulation extends upstream for several meters (Fig. 7.2). Materials include several medium to large redwood logs that have fallen into the channel due to bank erosion and through fluvial transport, with additional small woody debris accumulations at the upstream edge. Some small woody debris was removed during the site visit including much of the material shown at center of Figure 7.1.

Problem

The height and complexity of this logjam can result in difficult passage during lower streamflow volumes. Future clogging would significantly increase the severity of this structure. The accumulation of fine sediment accumulation is low.



Figure 7.1 Structure b01 in Wildcat Creek. Photo: Joel Casagrande 12 September 2004.

Recommendations

Based on the low effort required to increase potential spawning habitat to up-migrating steelhead during winter, the benefits of slightly modifying this structure are warranted. Although the amount of available habitat is limited, the quality of habitat upstream appears to be suitable for spawning activity. Remove SWD from the channel and cut/notch main logs in the center channel to prevent future clogging. **Some small woody debris removed in field**.



Figure 7.2 Structure b01 looking downstream after small woody debris was removed. Larger logs at center should be cut to prevent future clogging. Photo: Joel Casagrande 12 September 2004.

ID	Structure Type	Distance (m)	Distance (ft)	Severity (0–5, 0 easy passage)	Recommended Action
wb01	Logjam	88	290	3	Cut main logs with hand saw and remove from channel.
wb02	Logjam	226	740	2	Clear an easier path along the left bank. Cut and remove logs that may accumulate additional material.
wb03	Waterfall	315	1035	5	None- natural limit to migration.

 Table 7.1 Structure type, severity, and recommended action for improvement for structures found in Wildcat Creek.

Wildcat Creek 61



Description

Structure wb02 is located approximately 226 m (740 ft) upstream of the confluence with Garrapata Creek (Table 7.1). This structure is approximately 1.6 m in height at center and right bank (Fig. 7.4), but a shorter, more passable route exists along the left bank (0.5 m from the downstream bed elevation). The woody debris provide complex habitat for juvenile trout, especially during winter. Flow underneath this structure was clogged with woody debris and coarse sediments, suggesting that possible fish passage is best achieved along the left bank. However, it is likely this route is only available at higher flows.

Problem

The height of the structure and the lack of a pool at the downstream edge limits passage over the top of this material. Modifying this structure would only provide access to approximately 91 m (300 ft) of stream prior to the natural migration limit (wb03). However, only slight modifications would be required to better improve steelhead passage along the left bank.

Recommendations

A few individuals with hand or chain saws can easily improve this logjam. On the right bank side, SWD should be removed by hand to allow passage under or around the larger logs. On the left bank, passage should be improved by cutting larger logs that are accumulating woody debris and forming several small yet difficult steps, especially during low runoff events.



Figure 7.4 Structure b02, a logjam, looking upstream. Photo: Joel Casagrande, 12 September 2004.

Description

This structure is a steep waterfall cascade complex that is approximately 7.5-8 m (25-30 ft) in height and is located 315 m (1035 ft) upstream of the confluence of Garrapata Creek (Table 7.1)(Fig. 7.5).

Problem

The height of the falls creates an impassable barrier to all fish at all flow levels.

Recommendations

This is a natural migration limit. No recommended action warranted.



Figure 7.5 This waterfall cascade complex (~ 8 m high) is a steep natural barrier to adult steelhead migration. Note the 2-meter staff at right for scale. Photo: Joel Casagrande, 12 September 2004.
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8. Structure Prioritization

Highest priority for barrier modification was given to barriers that a) were below large impassable barriers, b) would provide an increase in the available habitat, c) were the least difficult or costly to improve (access and materials/labor needed), d) had minimal accumulations of fine sediments and e) may become significant barriers in the future and therefore reduce current spawning habitat (Tables 8.1 & 8.2). Low priority was given to structures that had a combination of several of the following criteria: a) those that were above large impassable and costly barriers, b) where improved access would not result in significant habitat gains, c) required significant labor/costs to modify, and/or d) those that would potentially have a negative impact both downstream (i.e. release of sediments) and upstream/locally (i.e. instability to adjacent roads, landslides). Medium priority was given to those structures that were below large impassable barriers but were either too costly to improve due to materials needed or access or the amount of habitat gained was limited.

Based on these criteria, ten structures were given High priority, four structures were given Medium priority and 11 structures were given Low priority in the assessed reaches (Table 8.1). Note that these prioritizations should be considered for more short-term oriented goals. Structures given "Low" priority status can be considered for long-term planning.

In Garrapata Creek, High priority was given for structures gb01-gb04 because they are easily accessible through the Glen Deven Ranch, relatively easy to improve, and could potentially become significant barriers if additional material was added (Table 8.1). Also, the amount of habitat available upstream of these locations was significant, especially for gb01-gb03. In Wildcat Creek, structures wb01& wb02 are listed as High priority due to better habitat suitability and availability as well as better accessibility through the Glen Deven Ranch. These structures also have the potential to increase in size. Structures jb01-jb04 are given High priority because they are easily accessible and would not require substantial effort to improve, although the increase in upstream habitat is relatively minimal. Also, sediment accumulations at these sites are low compared to those further upstream in Joshua Creek.

Structures given Medium priority include gb05 and gb06 in Garrapata Creek and jb05 and jb06 in Joshua Creek. These are not as readily accessible and the modifications required at gb05, jb05, and jb06 require an increase in labor as well as the equipment/materials needed. Also, sediment accumulation at structures jb05 and jb06 is more substantial, especially jb06 (Table 8.2).

In general, habitat availability in Joshua Creek is significantly more limited due in part to a high density of structures, many of which are likely impassable during most flow levels. Sediment storage at many of these structures is significant and therefore its potential release through the improvement of these structures poses an immediate threat to more suitable habitat present downstream in Garrapata Creek (Table 8.2). Structures jb07–jb10 were given Low priority due to inaccessibility, significant labor costs, and sediment accumulation volumes (Figs 8.1 & 8.2). Even if improved, many of these barriers are situated in narrow confined points in the channel and will likely clog again in the future.

Structure ID	Distance from ocean (m)	Upstream of impassable barrier? (+ easily accessible, - inaccessible)	Accessible for enhancement (+ accessible; - not accessible)	Labor/effort required (+ minimal labor required; – high labor required)	Upstream Habitat Availability (+ habitat available; - limited habitat)	Sediment Storage (+ low sediment storage; - high sediment storage)	Priority
Garrapata C	reek			•			
gb01	2982	+	+	+	+	+	High
gb02	3089	+	+	+	+	+	High
gb03	3485	+	+	+	+	+	High
gb04	4529	+	+	+	+	_	High
gb05	5015	+	-	+/-	-	+	Medium
gb06	5024	+/-	-	+	-	+	Medium
gb08	5167	+/-	-	-	-	-	Low
gjb09	5181	-	-	+	-	-	Low
gb10	5197	-	-	+	-	-	Low
gb11	5280	-	-	-	-	-	Low
gb12	5330	-	+	+	-	-	Low
gb13	5482	-	+	+	+	-	Low
gb14	5846	-	+	-	unknown	+	Low
Joshua Cree	k						
jb01	364	+	+	+	-	+	High
jb02	427	+	+	+	+/-	-	High
jb03	447	+	+	+	-	+	High
jb04	524	+	+	+	-	+	High
jb05	621	+	+	+	-	-	Medium
jb06	642	+/-	-	+	-	-	Medium
jb07	745	+/-	-	-	-	-	Low
jb08	799	-	-	-	-	-	Low
jb09	841	-	-	-	-	-	Low
jb10	979	-	-	-	-	-	Low
Wildcat Cre	ek						
wb01	88	+	+	+	+	+	High
wb02	226	+	+	+	+	+	Hiah

 Table 8.1 Benefits and costs to modification and level of suggested priority of structure improvement. Also estimated sediment accumulation is noted for many.

Note: Labor required for improvement of structures includes: distance and accessibility to the structure, materials need to improve (i.e. heavy machinery, saws, and number of people).

Structure gb07 is not shown because it is a natural waterfall with no improvements needed.

Structures gb08-gb14 were also given Low priority. Structure gb08 is a complete barrier to migration at all flows and is immediately followed by several large structures upstream. Sediment accumulation is significant and access for improvement is limited for structures gb08-gb11. Structures gb08 and gb11 are the largest and most difficult in this stream and are currently significant grade control features (Fig. 5.13). Their improvement could jeopardize the stability of the roads and hill slopes adjacent to the streams channel. Structures gb13 and gb14 are easily accessible and would not require significant labor, however because they are inaccessible to adult steelhead, they are not currently a problem with respect to migration issues.

The improvement or removal of the larger structures does come with inherent risks that could adversely impact both downstream habitat and local hill slope stability. It is imperative that the release of sediment from large logjams is monitored following any improvement or removal of the larger structures in the watershed. This will also assist in the documentation of the spatial and temporal impacts it will cause to downstream spawning habitat.

Also, careful observation of the local slope conditions should be evaluated prior to and following the improvement or removal of any of the large structures, especially those that are current grade control structures in the stream channels.

ID	Structure Type	Distance (m)	Distance (ft)	Estimated upstream sediment accumulation					
Garrapata Creek									
gb01	Logjam	2982	9783	Minimal					
gb02	Logjam	3089	10135	27 m³					
gb03	Logjam	3485	11435	15 m ³					
gb04	Logjam	4529	14860	Significant - difficult to assess					
gb05	Waterfall	5015	16452	None					
gb06	Waterfall	5024	16482	None					
gb08	Logjam	5167	16951	Significant - difficult to assess					
gjb09	Logjam	5181	16999	Significant – difficult to assess					
gb10	Logjam	5197	17051	120 m ³					
gb11	Logjam	5280	17322	240 m³					
gb12	Logjam	5330	17486	15 m ³					
gb13	Logjam	5482	17986	48 m³					
gb14	Logjam	5846	19182	Unable to measure					
Joshua Cre	eek								
jb01	Logjam	364	1195						
jb02	Logjam	427	1400	Significant - difficult to assess					
jb03	Logjam	447	1466	22 m³					
jb04	Logjam	524	1718	2 m ³					
jb05	Logjam	621	2039	Significant - difficult to assess					
jb06	Logjam	642	2106	150 m ³					
jb07	Logjam	745	2444	40 m³					
jb08	Logjam	799	2620	Significant - difficult to assess					
jb09	Logjam	841	2759	75 m³					
jb10	Logjam	979	3214	128 m³					
Wildcat Creek									
wb01	Logjam	88	290	Minimal – coarse sediments					
wb02	Logjam	226	740	Minimal – coarse sediments					

 Table 8.2 Estimated upstream sediment accumulation for each structure assessed in the

 Garrapata Creek Watershed.

Note: Sediment accumulation volumes are rough estimates based on general measurements of length (along the stream axis) depth (vertical accumulation of sediment), and width (lateral/cross section). At some structures, accumulated logs and other debris made it difficult to measure the accumulation of sediment, however it was noted if sediment was noticeably significant.



Figure 8.1 Significant sediment accumulation at Structure jb09. The upstream side is shown on the right and the downstream side is shown at left. The height of the structure approximately 2.0 m above the downstream channel and sediment is backed up for several meters. Photo: Joel Casagrande 3 June 2004.



Figure 8.2 Fine Sediment accumulation behind Structure jb07 (looking downstream from upstream of the logjam). Here summer flow percolates into the accumulated sands 2–3 m upstream of the logjam (bottom/center of picture) and seeps out at the downstream base of the logjam. Photo: Joel Casagrande 3 June 2004.

9. Near-channel Conditions

During a rapid foot traverse up the lower Garrapata Creek Watershed, assessments were made of near channel conditions, with specific attention made to local sediment sources. All landslides, large exposed banks and rootwad cavities showing signs of possible sediment yield into the active channel were noted.

No significant sediment sources (i.e. large landslides or bank failures) were observed in the reaches assessed. Small sources of sediment were observed sporadically throughout the watershed, however most of these did not appear to be unnatural or of any significance with respect to overall sediment contribution. General observations of in-channel accumulation of fine sediments, or substrate embeddedness, were also noted throughout.

Garrapata Creek

In general, the stream banks of lower Garrapata Creek were well protected by dense riparian vegetation. In-channel fine sediment accumulation on average was moderate with some areas having high accumulations and others with little or no accumulations.

Two potential sediment sources were observed in the lower reaches of Garrapata Creek. An exposed bank, due to vegetation removal and maintenance, was observed approximately 524 m (1720 ft) upstream of the Garrapata Creek Lagoon. It was estimated that 70–100 m of stream bank were bare with only scattered mature trees in place (Fig. 9.1). At present, this bank is not along an active cut-bank therefore minimizing its erosion potential.



Figure 9.1 Unprotected banks in lower Garrapata Creek. This photo was taken looking upstream at about the midpoint of the entire bare reach. Photo: Joel Casagrande 1 July 2004.

One small landslide was observed in lower Garrapata Creek approximately 1369.5 m (4582 ft) upstream of the Garrapata Creek Lagoon (Figs 9.2 & 9.3). Loose sediment currently ready for transport was quantified by measuring the length (along stream axis), height (up the bank) and estimated depth, or thickness of loose sediments. The volume of exposed loose sediment at this slide was estimated at approximately 39 m³.



Figure 9.2 Small landslide in lower Garrapata Creek. The staff shown is 2 meters in length. Photo: Joel Casagrande 2 June 2004.



Figure 9.3 Emergent vegetation growing along the toe of the slide. Young alders are also shown growing nearby. The stream is shown in the lower left corner. Photo: Joel Casagrande 2 June 2004.



Figure 9.4 Significant bank scour above structure gb04. The current streamflow is obscured by foliage in the lower right corner of the photo. Photo: Joel Casagrande 11 August 2004.

Further upstream, there is an increase in both the gradient of the stream and adjacent slopes, and a decrease in the average channel width and forest understory density. No landslides were observed in these reaches. Eroded banks and rootwad cavities from toppled redwoods were more frequently observed however these too were fairly infrequent and are natural features. A large eroded/exposed bank was observed along the left bank of Garrapata Creek just upstream from Structure gb04, or approximately 4531 m (14867 ft) upstream from the lagoon (Fig. 9.4). The bank is actively eroding into the creek. This is evident by the lack of vegetation growing along the toe of the stream channel. The volume of loose sediment currently available was approximately 210 m³. This volume could increase if erosion and undercutting of the bank continue and there is potential for several standing trees to fall into the creek.

Joshua Creek

Sediment accumulation in the stream channel is a serious problem in Joshua Creek. Based on visual observations, substrate percent embeddedness is near 100% at many locations. No pools of considerable size were observed; all observed pools were shallow (< 0.5 m deep). Pool volume loss was the result of fine sediment deposition and accumulation.

Although severely impacted with fine sediments, few active sediment sources were observed in Joshua Creek below the large waterfall. An exposed rootwad was noted at Structure jb01 along the right bank (Fig. 9.5). Scouring at the base of a wooden boardwalk's support columns suggests recent erosion.



Figure 9.5 Exposed rootwad along the right bank at Structure jb01. Wood buttresses in background appeared to be becoming exposed due to bank scour. Photo: Joel Casagrande 02 June 2004.

One moderate sized bank failure was observed in Joshua Creek that was actively contributing sediment to the stream (Figs 9.6 & 9.7). This was located on the left bank approximately 637 m (2091 ft) upstream of the Garrapata Creek confluence.



Figure 9.6 This bank failure in Joshua Creek is currently contributing sand-sized material to Joshua Creek. Photo: Joel Casagrande 3 June 2004.



Figure 9.7 The toe of the failed bank with large clusters of sand that have recently fell into the wetted stream channel. Note young vegetation growing suggesting this is an active and recent slide. Photo: Joel Casagrande 3 June 2004.

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