Stream Channel Conditions and Fallen Old-Growth Redwood Trees in Humboldt Redwoods State Park

February 24, 2003

California Department of Forestry and Fire Protection

In Consultation With

California Department of Conservation, California Geological Survey

California Department of Parks and Recreation

Executive Summary

A multi-agency team has investigated allegations that old-growth trees in Humboldt Redwoods State Park were damaged during the storms of December 2002 as the result of timber harvesting practices in the upstream drainages of Bear and Jordan Creeks. Based on field observations and review of aerial photographs, the team determined how many trees had fallen adjacent to stream channels, or were otherwise adversely affected by these storms, in the lower reaches of watersheds with intensive timber operations and in other watersheds that were largely undisturbed in or near the Park. Additionally, the team attempted to determine what caused the old-growth trees to fall and the extent to which upstream land use activity was involved. The team has reached the following conclusions:

- Three large old-growth redwood trees and 10 small, young conifers and hardwoods fell into the Bear Creek floodplain at the Quigley Grove site of old-growth redwoods during the winter of 2002/2003. No additional old-growth tree loss was observed in the other creeks flowing through the Park. In lower Jordan Creek, where there had been allegations of trees being buried by coarse sediment, no newly buried trees were observed. However, previously buried lower trunks of several redwoods in this drainage have been re-exposed by recent sediment transport out of the watershed.

- It is likely that December 2002 streamflows continued an on-going process of bank undercutting at Quigley Grove in the Bear Creek watershed that caused the three large trees to fall. High storm winds may also have been an important mechanism in toppling two of these trees that shared a common root-mass. Geomorphic mapping revealed no evidence to suggest that the channel in this location was dramatically impacted by the recent flooding or by land use activities that have occurred since 1997.

- While past harvesting prior to the winter of 1996/1997 may have contributed to adverse impacts at the Quigley Grove site during the 1996/1997 storms, the HCP/SYP prescriptions in effect for PALCO since March 1999 do not permit the types of practices that were associated with much of the earlier landsliding, including ridgeline to inner gorge clearcuts. There is no evidence that harvesting conducted within the past 3 years has adversely impacted the lower part of the channel at the Quigley Grove site.

- In the less disturbed Squaw and Cow Creek reference watersheds, it is apparent that large numbers of trees, including large old-growth redwoods, have fallen and continue to fall into the stream channels. The resulting large wood incorporation is known to improve fish habitat and be beneficial to stream channels. No large old-growth trees appear to have fallen in the lower part of Cow Creek in December 2002, but large old-growth redwood trees had fallen along the channel in the previous few years. One very large old-growth redwood and two moderately sized Douglas-fir trees fell in the lower 1,200 feet of Squaw Creek in December 2002.

To determine the effect of land use, the team evaluated streams with upstream timber harvesting and streams with mostly undisturbed watersheds. Bear, Jordan, and Greenlaw Creeks are small tributary basins that flow directly into the Eel River. Most of the acreage in these watersheds is utilized for commercial timber production and only the lowest stream reaches are part of the Park. Cow and Squaw Creeks are relatively undisturbed basins that are located entirely within the Park and flow into Bull Creek, which joins the Eel River just

upstream of Bear Creek. All of these watersheds are underlain by sedimentary rocks of the Franciscan Complex that are highly erodible and prone to landsliding. The combination of this unstable terrain and heavy winter storms in 1996/1997resulted in extensive landsliding and channel aggradation in the lower reaches of Bear and Jordan Creeks.

Total rainfall during the month of December 2002 was the highest on record at Scotia, which is located approximately 8 miles to the north of the Bear Creek drainage. However, the large monthly total did not include exceptionally large individual storm events. The largest one-day storm total for this station in December 2002 had a recurrence interval of less than 5 years, while the recurrence interval for the highest 3-day total was slightly greater than 10 years. Stream discharge recurrence interval data for the five watersheds included in this study can be approximated from flows in the Bull Creek watershed, where peak discharge in December 2002 was approximately a 10-year event. In contrast, the 1996/1997 flood had a recurrence interval between 25 and 50 years and is the largest flow recorded since water year 1961, when the Bull Creek gaging station was established.

Aerial photograph analysis and detailed geomorphic mapping of the Bear Creek channel where the three old-growth redwoods fell in December 2002 were conducted to help determine what caused these trees to fall in this area. This work revealed that a steep 30 foot alluvial bluff face appears to have been largely formed during the 1996/1997 winter, and subsequent streamflow appears to have been directed toward the bluff face for several years. A large debris jam formed behind an old-growth redwood that fell into Bear Creek at this site between 1997 and 2000. This debris jam is diverting most of the streamflow to the northern edge of the floodplain along this bluff, where the Quigley Grove of old-growth redwoods is located, and is undercutting the bank where the three large trees have fallen. In the channel of lower Bear Creek, coarse sediment is being transported out of the drainage and the active channel is now approximately at its natural grade at this site.

The conclusions presented here are based on the best available information that could be collected within the time frame available for the study. Continued monitoring and data collection are necessary to validate these findings.

Stream Channel Conditions and Fallen Old-Growth Redwood Trees in Humboldt Redwoods State Park

Introduction

This report describes the findings of an investigation into damage to old-growth redwood trees in Humboldt Redwoods State Park, Humboldt County, that was initiated on February 3, 2003. The investigation was requested by California Department of Forestry and Fire Protection (CDF) Deputy Director for Resource Management Ross Johnson in response to charges that damage has occurred to Humboldt Redwoods State Park trees in the lower portions of the Bear Creek and Jordan Creek drainages as the result of timber harvesting practices upstream of the Park lands.

Questions were raised regarding possible damage to the old-growth redwood trees in at least three forums. First, an internet website [www.salmon-forever.org] posted photographs and text alleging that damage has occurred to Humboldt Redwoods State Park (Park) property due to debris torrenting[1] on upstream industrial timberlands during winter storms in December 2002. Second, testimony was presented by Mr. Jesse Noell at the North Coast Regional Water Quality Control Board (NCRWQCB) meeting held on January 23, 2003 in Santa Rosa. Mr. Noell stated that there was damage to Humboldt Redwoods State Park resulting from logging on industrial timberlands upstream of the State Park. Third, CDF Director Andrea Tuttle was questioned by Senator Byron Sher regarding reported damage to Humboldt Redwoods State Park trees at the Senate Natural Resources Committee hearing on "Old-Growth Forests" held on January 28th in Sacramento.

In addition, a letter was written by Senator John Burton to California State Park and Recreation Commission member Joseph Cotchett dated January 28, 2003, expressing concern regarding "recent reports that at least twelve ancient redwood trees were toppled in Humboldt State Park from destructive logging and flooding activities."

An organizational meeting for the current investigation was held on February 5, 2003, with participants from the California Department of Fish and Game (DFG), North Coast Regional Water Quality Control Board (NCRWQCB), Department of Conservation (California Geological Survey, CGS), California Department of Parks and Recreation (DPR), and CDF present. Field work for the current investigation was conducted on February 6-7 and February 10, 2003. DFG did not participate in the field review. During the organizational meeting, it was agreed that the following three critical questions would be investigated:

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[1] DMG (1997), now known as CGS, states that debris flow/torrent tracks are characterized by long stretches of bare, generally unstable stream channel banks that have been scoured and eroded by the extremely rapid movement of water-laden debris. They commonly are caused by debris sliding or the failure of fill materials along stream crossings in the upper part of a drainage during high intensity storms.

1. How many trees fell, or were otherwise affected, in the December 2002 storms within the channel zones of Bear, Jordan, and Greenlaw Creeks and in nearby reference streams?

2. What are the casual mechanisms for the observed impacts?

3. To what extent are the causal mechanisms related to land use activity?

The field team attempted to collect the best available information to address these questions in the limited time frame available for this study. Continued monitoring and data collection is necessary to validate the findings reported in this document. The Pacific Lumber Company's existing monitoring stations (PALCO 2001a) and other monitoring efforts in these watersheds can be used to provide information related to these questions.

Agencies and individuals participating in the field portion of the investigation were:

California Department of Forestry and Fire Protection
Pete Cafferata, RPF[2] – Forest Hydrologist, Sacramento Headquarters
George Johnson, RPF[2]– Weott Area Forester, Humboldt-Del Norte Unit
Jim Erler, RPF[2] – Watershed Assessment Forester
California Department of Conservation, California Geological Survey
Mark Smelser – Certified Engineering Geologist
Jim Falls – Certified Engineering Geologist (Bear Creek site only)
Steve Werner – Registered Geologist (Bear Creek site only)
Burt Hardin – Certified Engineering Geologist (Bear Creek site only)
North Coast Regional Water Quality Control Board
Diana Henrioulle-Henry, P.E. – Senior Water Resource Control Engineer (Headwaters Unit)
California Department of Parks and Recreation
Steve Horvitz – Southern Area Manager, North Coast Redwoods District (Bear Creek site only)

Background Information

Descriptive Information on the Study Watersheds

The Bear Creek watershed is approximately 5,450 acres in size and is a tributary to the Eel River located eight miles to the south of Scotia. The majority of the basin is used for commercial timber production, with about 95 percent of the watershed owned by the Pacific Lumber Company (PALCO). Land use history is described in detail by Pacific Watershed Associates (PWA 1998). The area harvested from 1992 through 2001,

[2] Mr. Cafferata's RPF number is 2184, Mr. Johnson's RPF number is 1786, and Mr. Erler's RPF number is 2323.

combined with pending Timber Harvesting Plans in 2001, was 2,491 acres for all types of harvesting (Munn 2001).

The Jordan Creek watershed is a relatively small basin that flows directly into the Eel River near the town of Stafford, about five miles upstream of Scotia. The watershed drains approximately 3,000 acres and the elevation at the ridgeline is 2,840 feet. Nearly all of the basin is used for commercial timber production and is owned by PALCO.

Greenlaw Creek is the smallest of the three managed watersheds observed, with an approximate acreage of 1,300 acres. As with the Bear and Jordan Creek basins, the majority of the watershed is utilized for commercial timber production.

The Cow Creek watershed is approximately 1,500 acres, located entirely within Humboldt Redwoods State Park, and is a tributary of Bull Creek, which joins the Eel River upstream of Bear Creek. Currently, DFG collects information in Cow Creek on large wood loading and habitat types present, and conducts anadromous fish surveys (S. Downie, DFG, Fortuna, written communication). This basin provides a relatively undisturbed comparison to the watersheds described above, with approximately 93 percent of the watershed remaining unlogged and seven percent logged in the 1950s and 1960s (H. Alden, Gualala Redwoods Company, personal communication).

Squaw Creek is approximately 3,000 acres, located entirely within the Park, and is another tributary of Bull Creek. Information is available on large wood loading, habitat types present, anadromous fish use, pool volumes, pool depths, gravel composition, and other parameters (Knopp 1993, S. Downie, DFG, written communication). Approximately 60 percent of the old-growth forest remains, with logging occurring in the 1950's and 1960's. The majority of the roads on the upper slopes have not been treated to reduce erosion (P. Vaughan, Associate Engineering Geologist, DPR, Eureka, personal communication).

Channel Changes in Bear Creek and the Quigley Grove Site

Historic aerial photographs indicate that logging in the Bear Creek watershed began in the early 1940s. PWA (1998) reports that between 1947 and 1966, over 90 percent of the watershed was either selectively logged or clearcut and that 90 percent of the contemporary road network was in place. Most of this harvesting had been accomplished using both tractor and cable yarding techniques. Such management was typical of the time and is generally considered “intense” (PWA 1998, p. 16). In December 1964, near the height of intense harvesting activities and maximum ground disturbance, high-intensity winter rainstorms occurred along the North Coast. These storms triggered widespread landsliding, road failures, and debris torrenting in Bear Creek (PWA 1998). In particular, PWA (1998, p. 18) notes that most landsliding occurred on steep inner gorge slopes along stream channels.

The extensive ground disturbance caused by the intense harvesting operations is one of the factors that may have contributed to the widespread landsliding triggered by the storms. PWA (1998) concludes that an exact relationship between timber harvesting and rates of landsliding could not be determined because the entire watershed had been logged. However, a brief comparison made by CGS of aerial photographs taken in 1954, 1963, and 1965 indicates that many geomorphic changes took place between 1954 and 1963. In particular, the 1954 photographs show widespread harvest-related ground disturbance prior to the very high rainfall in 1955. The 1963 photographs show the Bear Creek floodplain as relatively wide and unvegetated. Both the 1954 and 1963 photographs show fresh-appearing debris slides, but the 1963 photographs appear to show a significant increase in debris sliding in some of the small subwatersheds prior to the 1964 floods. These observations indicate that the impacts of the 1955 and 1964 floods and the relationship between timber harvesting and rates of landsliding may be better determined by analyzing other aerial photographs that may be available between 1947 and the present.

In December of 1996, Bear Creek and the surrounding region received over 22 inches of rain, including a moderately high intensity storm on December 31, 1996. The combination of high antecedent rainfall and the moderately high intensity storm triggered numerous landslides throughout coastal Northern California, including the Bear Creek watershed and others nearby such as Jordan Creek and Bull Creek (Spittler 1998). One consequence of the storm and landsliding was debris torrenting along Bear Creek. Following the debris torrenting, the channel was described as broad, barren, and flat with little in-stream structure (Spittler 1998).

PWA (1998) reported that at the time of the 1996/1997 storm event, approximately 37 percent of the Bear Creek watershed was in a state of “recently harvested” (i.e., harvesting had occurred within the last 15 years). They also reported that 85 percent of the landslide related sediment delivery came from the recently harvested portion of the watershed, and that 75 percent of the 1996/1997 landsliding occurred on inner gorge slopes (PWA 1998, p. 18). This is similar to observations reported by Spittler (1998) and Smelser (2001). Moreover, increased landsliding along inner gorge slopes is also what was observed following the 1964 storms (see discussion above). Smelser (2001) reviewed the 1996/1997 debris torrenting in the Bear Creek watershed and found that most debris sliding occurred in the most sensitive subwatersheds. Those “sensitive” subwatersheds are described as debris slide amphitheaters with inner gorges that were subject to “ridgeline-to-inner gorge” clearcutting within approximately 5 years.

The geomorphic changes in Bear Creek associated with the 1996/1997 winter storms and debris torrent were inventoried by Pacific Watershed Associates (PWA 1998), who reported that the Bear Creek channel was aggraded 4 to 9 feet. PWA also documented reworking and flushing of much sediment from the watercourse and estimated that half of the sediment stored in the channel in early 1997 was flushed out during the winter of 1997/1998. Between 1998 and the present (February 2003), changes in the Bear Creek stream channel have been monitored and documented by PALCO (2001a) and PWA. These monitoring efforts appear to show that the watercourse has cut through the aggraded sediment deposits and re-occupied its pre-1997 channel level at several locations (PALCO 2001a and 2001b).

The total volume of rain measured at Scotia during the month of December 2002 exceeded that of both December 1964 and December 1996 by several inches. Peak stream discharge in Bear Creek, however, was likely to have been considerably lower in December 2002 when compared to 1996/1997, and also lower than December 1964, based on measurement in Bull Creek (see Hydrologic Information section of this report). Some landslides and channel changes within the Bear Creek watershed have been reported by PALCO, private citizens, and various agency representatives. However, compared to the impacts of the 1964 and 1996/1997 storm events, the reported impacts appear to be significantly less severe.

January 2003 Field Work in Bear Creek

Prior to the current investigation, the NCRWQCB received a complaint in early January 2003 that debris torrenting had occurred in the Bear Creek watershed during the December 2002 storms and that significant damage had occurred in the watershed as a result of improper logging practices. This complaint led to an inspection of the Bear Creek watershed on January 8, 2003, and was undertaken by an interagency team to review the impacts of the December 2002 storms. Representatives from CDF, DFG, CGS, and the NCRWQCB along with PALCO personnel toured much of the Bear Creek stream channel. One previously existing landslide feature was found to be actively depositing sediment in the watercourse. This landslide was determined not to be associated with any recent past or current logging activity (G. Marshall, CGS, Eureka, personal communication). While numerous occurrences of bank caving or rill erosion were observed, no evidence of debris torrenting in the Bear Creek channel was observed (Marshall 2003). In addition, in-channel bars, terraces, and channel complexity (pools and large wood) present before the storms appeared to be essentially intact with only minor amounts of sediment (patches of sand several inches thick) deposited on the bars (Marshall 2003). State Park lands were not observed during this early January inspection.

Regional Geology of the Subwatersheds

The managed watersheds (Bear Creek, Jordan Creek, and Greenlaw Creek) flow to the north and discharge into the Eel River. The lower reaches of these creeks fall within the boundaries of the State Park, and each is spanned with bridges for vehicle traffic on the Avenue of the Giants and Highway 101, which both parallel the Eel River. Along Highway 101, the Greenlaw Creek bridge is about three-quarters of a mile east of the Jordan Creek crossing, and the Bear Creek bridge is just over 2.5 miles east of the Greenlaw Creek crossing. In this area, Highway 101 generally follows the contact between steep bedrock uplands to the south and the generally flat Eel River floodplain and associated terraces to the north. Consequently, a complex interfingering of Eel River and tributary floodplain deposits underlies most of the land under the jurisdiction of the Park.

Mapping by Spittler (1982 and 1983b) shows the bedrock underlying the three watersheds is largely composed of sedimentary rocks (siltstone, shale, sandstone, and mudstone) of the Franciscan Complex Coastal Belt that are highly sheared in places. McLaughlin and others (2000) describe these rocks as predominately sandstone and argillite (hard claystone) that exhibit a range of deformation states from shattered and penetratively sheared melange to intact ridge-forming blocks. The mapping by Spittler (1982 and 1983b) and McLaughlin and others (2000) shows the lowermost reach of Bear Creek to be underlain by a thin sliver of the Yager Terrane and a block of undifferentiated Wildcat Group rocks. McLaughlin and others (2000) describe the Yager Terrane rocks in this area as sheared and highly folded mudstone. Spittler (1982 and 1983b) notes that the siltstone and claystone of the Yager often disaggregate by slaking (rapid disintegration) when wetted. The Wildcat Group rocks in this area are mudstone, shale, sandstone, and siltstone with a minor component of conglomerate (Spittler, 1982 and 1983b). Geomorphic mapping by Spittler (1982 and 1983b) shows the three watersheds to be sculpted by debris sliding that has formed debris slide amphitheaters and inner gorges. More recent geomorphic mapping associated with timber harvesting plans in these watersheds also documents the presence of numerous large and dormant deep-seated landslides.

The unmanaged watersheds, Cow Creek and Squaw Creek, lie deeper within the Park and discharge into Bull Creek. Squaw Creek flows to the north, Cow Creek flows to the south, and Bull Creek flows east to its confluence with the South Fork of the Eel River. As the crow flies from the center of the Bear Creek watershed, the Cow Creek watershed lies almost 3.5 miles to the southeast, and the Squaw Creek watershed lies about 5.5 miles to the south. Mapping by Spittler (1983a) and McLaughlin and others (2000) show that approximately 75 percent of the Cow Creek watershed and the entire Squaw Creek watershed are underlain by the sheared and highly folded mudstone of the Yager Terrane. The remaining 25 percent of the Cow Creek watershed (the northwest corner) is mapped as the shattered and penetratively sheared melange of the Franciscan Complex Coastal Belt (McLaughlin and others 2000). Like Jordan Creek, Bear Creek, and Greenlaw Creek, geomorphic mapping by Spittler (1983a) shows most of the Cow Creek and Squaw Creek watersheds to have been sculpted by debris sliding that has formed debris slide amphitheaters and inner gorges.

Hydrologic Information

Precipitation Data for December 2002

The two closest sources of rainfall data for the Bear Creek watershed area are the community of Scotia and High Rock Conservation Camp. The Scotia gage is located approximately 8 miles to the north of the Bear Creek watershed. Daily data is recorded at Scotia by Mr. Don Bryant, an employee of the Pacific Lumber Company, and supplied to the National Weather Service in Eureka. Daily precipitation is also recorded by CDF at the High Rock Conservation Camp, located approximately five miles from the Bear Creek watershed.

During the month of December 2002, a total of 27.44 inches of precipitation was recorded at the Scotia station (Bryant 2002) and 31.31 inches was measured at the High Rock Conservation Camp station. When the total of 27.44 inches of rain measured at Scotia for the month of December 2002 is compared to historic monthly totals reported by the Western Regional Climate Center (www.wrcc.dri.edu), the December 2002 rainfall amount is the highest on record for both the month of December and for all the months (since 1931). For December totals, 1955 is the second highest with 22.88 inches, 1996 is third highest with 22.58 inches, and the 1964 rain amount is sixth highest with 18.37 inches. The month with the highest total before December 2002 was January 1995, with 26.41 inches.

The highest one-day December 2002 rainfall totals were 3.70 inches on December 14th and 4.94 inches on December 16th at Scotia and High Rock Conservation Camp, respectively. The highest 3-day totals were 9.20 inches from December 14th to December 16th at Scotia and 10.88 inches from December 14th to December 16th at High Rock Conservation Camp (see Figures 1 and 2).

Rainfall depth duration frequency data is available for the Scotia station (Goodridge 2000), with a period of record that extends from 1927 to 1999 (excluding 1930-1931). This shows that a 1-day, 2-year recurrence interval event is expected to produce 3.47 inches of rainfall, and a 1-day, 5-year event is 4.67 inches. Similarly, a 3-day, 10-year event is expected to produce 8.87 inches, while a 3-day, 25-year event is 10.40 inches (Table 1). Therefore, while the highest one-day total for the Scotia station in December 2002 was less than a 5-year event, the 3-day total was a large and infrequent storm with between a 10 and 25-year event recurrence interval. This total can best be described as slightly greater than a 10-year rainfall event for the 3-day period.[3] Long-term rainfall depth duration frequency data was not available for the High Rock Conservation Camp station.

The December 2002 rainfall totals described above for the Scotia-Weott area, with the highest 3-day total in mid-December, can be compared to those reported for the Eureka-Arcata-McKinleyville area of Humboldt County. Mr. John Lovegrove, National Weather Service, Eureka, reported that the rainfall event from December 26th to December 28th was larger for the Eureka station than the rainfall recorded from December 14th to December 16th at that station. The National Weather Service office in Eureka recorded 6.79 inches of rain on December 26th, a new all-time 24 hour rainfall record for the station, with an additional nearly 2 inches on December 28th, for a storm total of nearly 9 inches. Unofficial rainfall data measured by Dr. Robert Ziemer, USFS-Pacific Southwest Research Station, Chief Research Hydrologist (retired) in McKinleyville shows that 7.05 inches fell from December 14th to December 16th (midnight to midnight) in McKinleyville. For the period from December 26th to December 28th, the total at McKinleyville was 9.10 inches (R. Ziemer, written communication).

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[3] The five day total for Scotia from December 13th to December 17th was 12.05 inches, which also falls between a 10 year (10.75 inches) and 25 year (12.58 inches) recurrence interval.

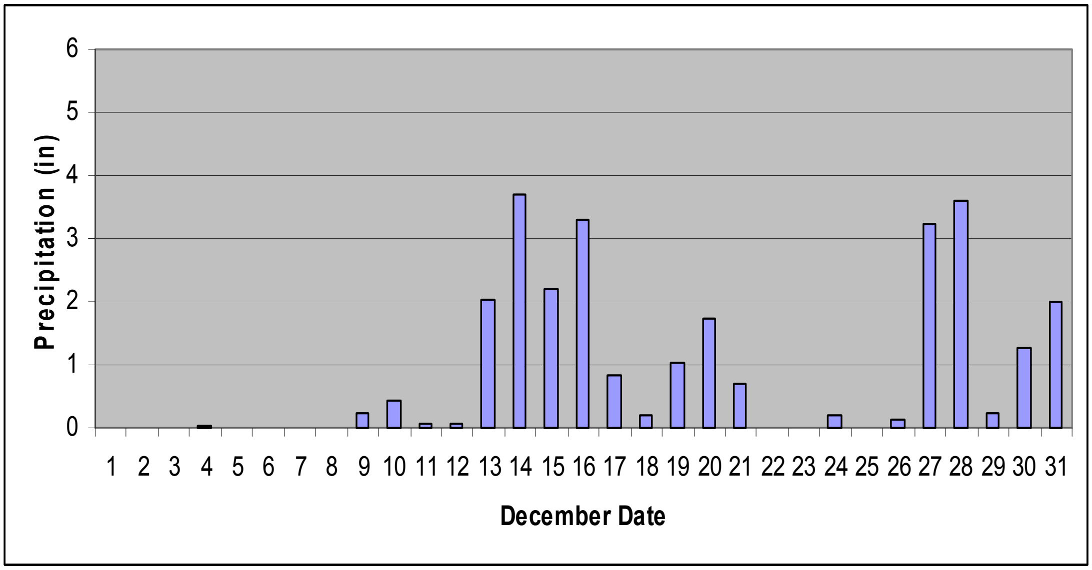

Figure 1. December 2002 daily precipitation amounts for Scotia, California (data provided by the NWS, Eureka).

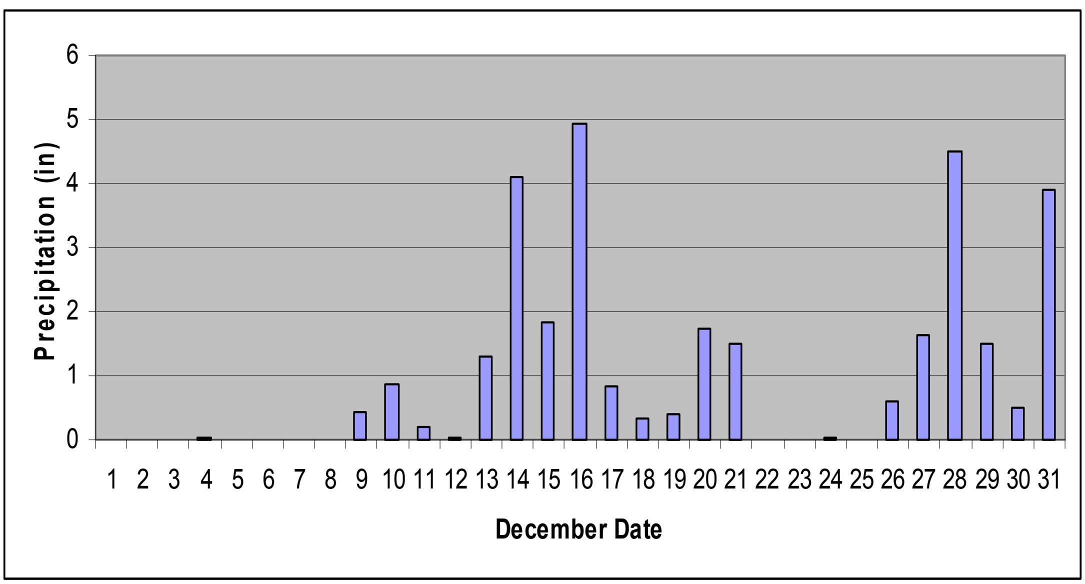

Figure 2. December 2002 daily precipitation amounts for High Rock Conservation Camp, located near Weott, California (data provided by the California Department of Forestry and Fire Protection).

Table 1. Recurrence intervals for 3-day precipitation totals for Scotia, California (Goodridge 2000).

Recurrence Interval (years)	3-Day Precipitation Total (in)
2	5.59
5	7.60
10	8.87
25	10.40
50	11.49
100	12.54
200	13.55
500	14.79

Stream Discharge Data for December 2002

The stream discharge recurrence interval data for the Bear Creek watershed can be approximated by using data from the Bull Creek watershed, which is directly adjacent to the upper part of the Bear Creek basin. Discharge has been recorded at Bull Creek by the USGS since water year 1961 (see Figure 3).[4] The station has a drainage area of 28.1 square miles, or 17,984 acres, which is about three times larger than the Bear Creek drainage (approximately 5,446 acres). The highest instantaneous peak discharges recorded for Bull Creek occurred on December 22, 1964 (6,520 cfs), January 16, 1974 (5,830 cfs), December 16, 1982 (5,880 cfs), January 9, 1995 (6,400 cfs), and December 31, 1996 (7,830 cfs). The December 31, 1996 flood had a recurrence interval between 25 and 50 years (see Table 2) and is the largest flow recorded since water year 1961, when the Bull Creek gaging station was established. The December 1964 flood had a recurrence interval between 10 and 25 years.

Provisional December discharge data for the Bull Creek gaging station is available from the California Department of Water Resources, Division of Flood Management, on their California Data Exchange Center (CDEC) website (see Figure 4). This data shows that the highest instantaneous peak discharge for the Bull Creek station for that month occurred on December 16th, with a value of 5,970 cfs. Provisional data for Bull Creek from the USGS indicates that the maximum instantaneous daily peak during December 2002 was actually 5,760 cfs (Mr. Greg Susich, USGS, Eureka, personal communication). Mr. Susich stated that there was considerable channel scour and aggradation during the month at this station and adjustments for correct stage height were necessary to allow proper determination of discharge.

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[4] USGS Station 11476600, Bull Creek near Weott, California. Data available online at http://waterdata.usgs.gov

The U.S. Geological Survey annual peak flow frequency analysis computer program (version 4.1, February 2002) was used to analyze the Bull Creek instantaneous annual peak flow data for water years 1961 through 2001.[5] Using this analysis with the provisional December 2002 discharge data for Bull Creek revealed that the peak discharge of 5,760 cfs was very close to a 10-year recurrence interval event (see Table 2). This result is consistent with the 3-day precipitation data recurrence intervals discussed above.

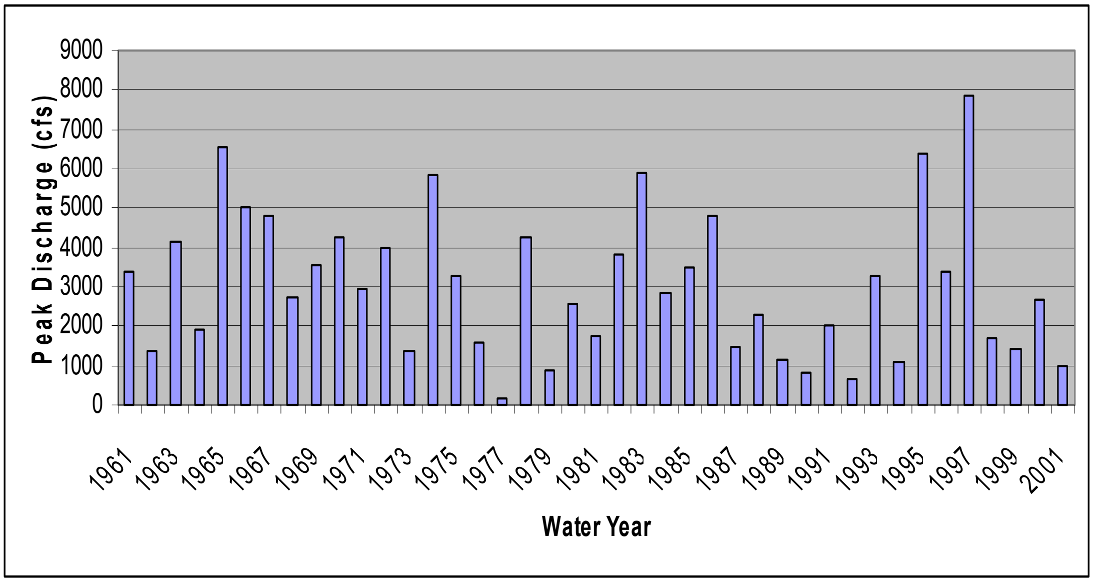


Figure 3. Instantaneous annual peak discharge values for the USGS Bull Creek gaging station located near Weott, California.

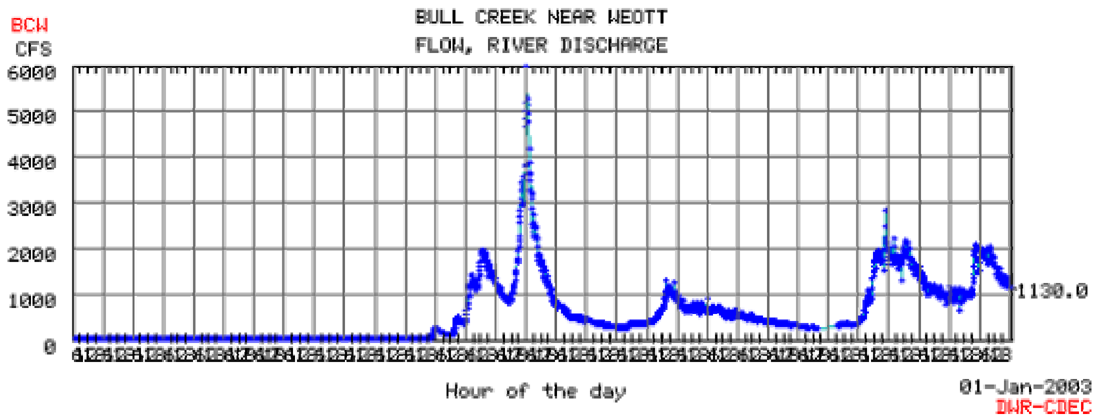
Table 2. Annual flood peak recurrences for the Bull Creek gaging station, determined using the USGS PEAKFQ software program.

Recurrence Interval (years)	Peak Discharge (cfs)
2	2,631
5	4,418
10	5,673
25	7,293
50	8,507
100	9,719
200	10,930
500	12,530

5 USGS surface water software, program titled PEAKFQ (DOS), version 4.1, Flood-Frequency Analysis based on Bulletin 17B. The software is available online at: http://water.usgs.gov/software/peakfq.html

BULL CREEK NEAR WEOTT *(BCW)*

Elevation: 269' · EEL R basin · Operator: US Geological Survey
Sensor ID number *8277*



Data from 12/01/2002 00:00 through 01/01/2003 00:00 · Duration: 31days
Max of period: 5970 · Min of period: 4.19

Figure 4. Provisional December 2002 discharge for the USGS Bull Creek gaging station, as provided online by the DWR, California Data Exchange Center (CDEC) website.

Field Methods and Detailed Study Site Location

The portions of Bear Creek, Jordan Creek and Greenlaw Creek that are within the Park, and a short portion of Bear Creek that is upstream of the Park, were field inspected on February 6, 2003. For comparison, information on tree loss from less disturbed watersheds was also recorded; the lower portion of Cow creek was examined late in the afternoon of that day, and the lower portion of Squaw Creek was observed on the morning of February 7th. Cow Creek and Squaw Creek are two identified “reference streams” in the Park that are recognized for their relatively undisturbed condition (BOF 2002). These reference streams are monitored regularly by PALCO and DFG for various physical and biological characteristics for comparison with those of streams in watersheds with timber operations (PALCO 2001c, S. Downie, DFG, Fortuna, written communication). Measurements of large wood loading are included in PALCO’s monitoring program for these streams.

Diameters of trees which fell during the winter of 2002/2003 were measured when possible with a diameter tape (D-tape). Detailed field notes regarding tree loss and channel conditions were recorded by individual field team members. Additionally, digital photographs were taken of significant observation points in each of the five study watersheds.

The reach of Bear Creek where large redwood trees fell in December 2002 is an approximate 500-foot stretch of the riparian corridor adjacent to Quigley Grove in the Park. For purposes of discussion, this area is defined as the Quigley Grove study site. This section of stream channel is approximately 1,000 feet upstream from the Highway 101 bridge and about 200 feet downstream from the property line between the Park and PALCO.

The large old-growth trees that comprise Quigley Grove are growing on a series of ancient fluvial terraces that lie between 12 and 30 feet above the north side of the active channel. An inventory of conifers growing on this site (500 feet along the channel and 300 feet to the north of the bluff face) revealed that there are approximately 45 old-growth trees on the flat (approximately 100 feet on average from the bluff face) and about 35 additional old-growth trees on the slopes further away from the channel. Also, there are approximately 70 young conifers on the flat and about 50 young conifers further upslope. To assist CDF in its investigation of the fallen trees, CGS surveyed and mapped this 500-foot study reach (Smelser 2003). The purpose of the mapping was to characterize the spatial elements of the study site, quantify the number of fallen trees, and evaluate potential casual mechanisms. This information was considered essential to answering the three critical questions posed by the investigative team.

The geomorphic mapping was conducted on February 10, 2003 by two two-person teams using pocket transits (compasses) and measuring tapes. Given the limited time to conduct the mapping and the stated focus of the mapping endeavor, no elevation data was measured. Because of the urgency surrounding this investigation, and the relatively coarse surveying techniques, all map data and subsequent findings are preliminary and are specific only to the Quigley Grove area. The map data and subsequent discussion of findings are preliminary and should only be used to clarify the impacts to the Park resources at Quigley Grove and evaluate the reasonableness of possible causal mechanisms.

Field Observations

Overview of the Five Watersheds

It is apparent that the channel of Bear Creek within the Park boundary is actively changing. The winter of 1996/1997 produced large scale slides and debris torrents that deposited large quantities of coarse sediment and organic material from the hillside into the stream channel. The December 2002 storm events reactivated some existing slide features in the upper portions of the watershed, though not in recently harvested areas (G. Marshall, CGS, Eureka, personal communication), and excavated sediment from the lower portion of the channel (Sullivan 2003). Detailed descriptions of the stretch of the Bear Creek channel where the old-growth trees fell in December 2002 are provided in the following section.

The section of Jordan Creek that lies within the Park boundary extends downstream from the Highway 101 bridges to the mouth of the Eel River. It was reported that redwood trees along this section of the channel were buried in December 2002 by sediment transported downstream from the industrial timberlands upstream of the Park. The field team did not observe any recently fallen large trees or recently buried trees along this section of the creek. Rather, several redwood trees along the edge of the floodplain appeared to have been recently re-exposed. Evidence for this conclusion includes moss lines and residual sediment clinging to the bark of the trees several feet above the current level of the floodplain. Additional evidence is the presence of adventitious roots that grew through the bark of the trees during the time of burial. Because of the dramatic stream flows documented in the region during 1996/1997 and the generally youthful appearance of the adventitious root system, these trees are assumed to have been buried during the 1996/1997 storm discharges. During the December 2002 flood event, much of this sediment appears to have been washed away.

Greenlaw Creek was not mentioned in the reports of damage to old-growth trees, but has been included in the field review of current channel conditions because it lies between Bear Creek and Jordan Creek and its lower channel flows through Humboldt Redwoods State Park. As with Jordan Creek, the field team did not observe any recently fallen large trees along the banks of the channel within the Park boundary. The gravel bars in the stream channel are supporting numerous red alder sprouts of a size consistent with having sprouted following the 1997 flood event. Currently, there is relatively little large wood in the stream channel. The lower portion of the channel, below the Park boundary, is a broad gravelly floodplain with a poorly defined braided stream channel. Further down, the channel becomes better defined within thickets of red alder, but the channel was not inspected to its confluence with the Eel River because it had passed onto privately owned, rural residential property.

Cow Creek, one of the reference streams in the Park, had a closed canopy of redwood trees over it from its mouth at Bull Creek to the Mattole Road, where the road crosses Cow Creek along the north side of Bull Creek Flat. Where the channel crosses the flat, it is sinuous and appears to have been in place for some time. There was a considerable amount of fine sediment along the banks and in the depositional reaches of the channel and streambed gravels were generally embedded in fine sediment. Water flowing in the channel was noticeably turbid without significant recent rainfall (Henrioulle-Henry 2003). Several artificial structures designed for fish habitat restoration were observed in the channel. Upstream of the Mattole Road crossing, a significant amount of bank and hillslope instability was identified. The channel is influenced by numerous fallen old-growth trees and large woody debris in the channel in several locations, and the channel is actively eroding its banks where it is being diverted by large wood. Some of these trees were estimated to have fallen about one year ago, and some had come down several years in the past.[6]

[6] The field team did not determine the mechanism(s) that caused the old-growth trees to fall in the Cow and Squaw Creek watersheds.

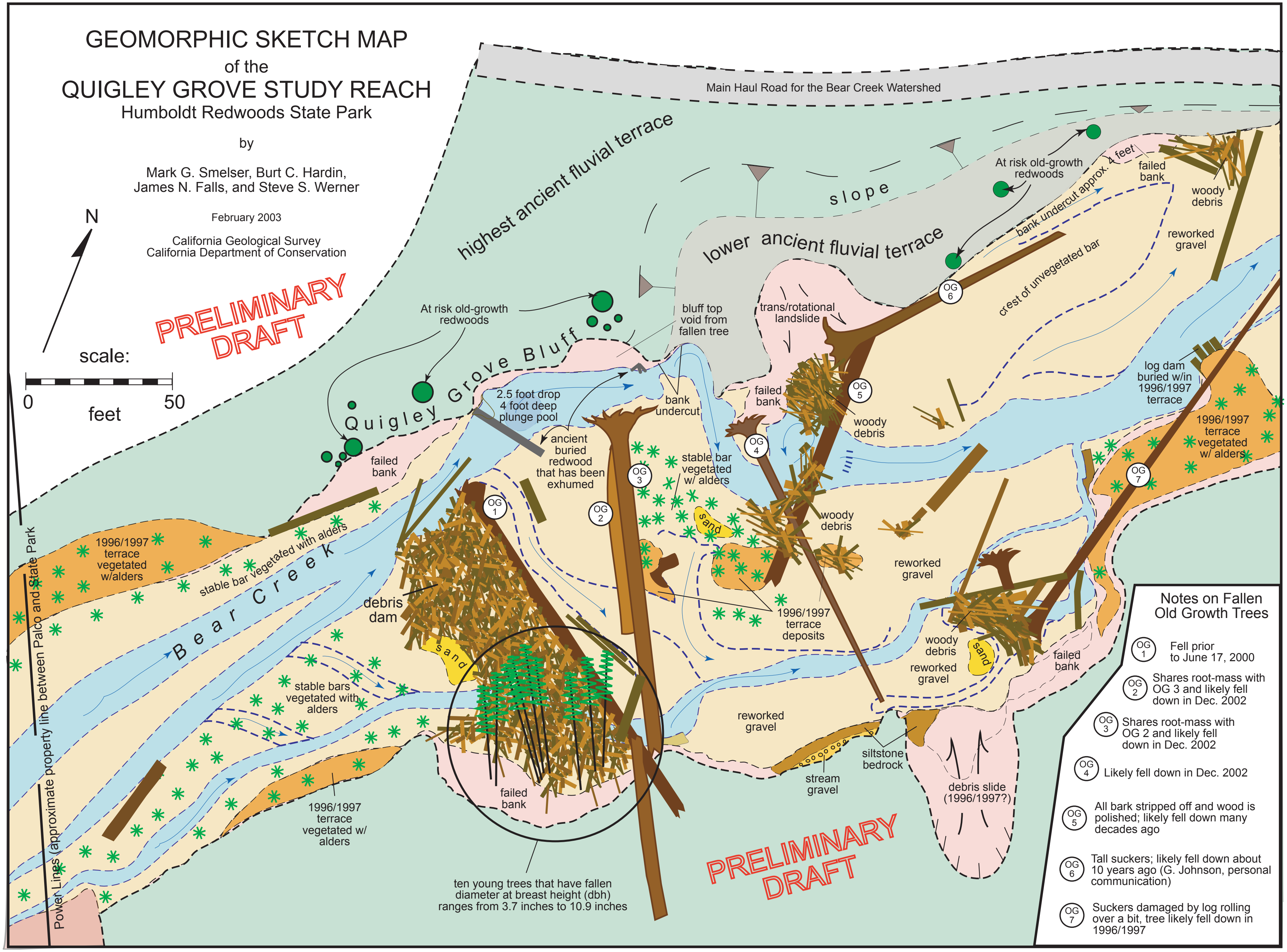
Squaw Creek is a tributary to Bull Creek from the south side of the Bull Creek drainage. The lower approximately one-quarter mile of the channel was investigated by the field team (Cafferata and Johnson only) above its confluence with Bull Creek. The entire observed section was on the Bull Creek floodplain. Fish habitat improvement structures were located along the length of the observed stream, with some appearing functional and others having been damaged or left suspended above the water due to changing channel conditions. At a distance of approximately 700 feet from the mouth, a 5 foot diameter redwood, originally situated on the bank of the stream, had fallen across the stream, and diverted its flow into the bank, creating a sediment source. The tree appears to have fallen a few years ago, perhaps during the 1997 storm event. Two Douglas-fir trees (26 and 14 inches in diameter) in this general area fell during the December 2002 storms, depositing additional sediment in the stream. At approximately 1,200 feet upstream from the mouth, an 8 foot diameter (estimated) old-growth redwood situated at the edge of the channel fell away from the stream, leaving its root wad suspended over the stream.[6] The Squaw Creek channel was not examined above this fallen 8 foot tree.

Bear Creek/Quigley Grove Study Site Observations

Throughout the study reach, the active floodplain averages approximately 100 feet in width (Map Sheet 1). For the purposes of this study, the active floodplain is defined as that broad expanse of gravel and stream channels constrained within the steep valley walls and the remnant terraces of stored 1996/1997 sediment (Map Sheet 1). At its narrowest point, the active floodplain is 75 feet wide and its widest point is 140 feet across. One of the more striking features within the study reach is a debris jam that extends almost fully across the floodplain. This debris jam appears to have been created as water ponded and woody debris accumulated behind a fallen old-growth tree. Above the debris jam, water flows in well-defined channels with established mid-channel and lateral bars that are vegetated with a multi-story canopy of young alders. The debris jam effectively diverts the flow of water towards the margins of the floodplain, and streamflow below the debris jam is divided into multiple threads with severe bends and varying widths. One important distinction between the downstream portion of the floodplain and that above the debris jam is that the downstream portion lacks a well-defined channel stabilized with bars that are vegetated with alders. At several locations along the margins of the floodplain are terrace surfaces covered with leaves and vegetated with grass and alders. These surfaces lie approximately 4 feet to 7 feet above the active channel. Given the youthful vegetation and height above the active channel, these surfaces are interpreted to be remnants of the 1996/1997 aggradation described by PWA (1998).

At the debris jam, the main flow of water is directed toward the left (looking downstream) edge of the floodplain, where it flows along the base of a 31-foot high, vertical to overhanging, unvegetated slope made up of stratified fluvial sediment. This steep and overhanging slope lies below the Quigley Grove of large old-growth redwoods. For purposes of discussion, this high and steep slope is defined as Quigley Grove Bluff (Map Sheet 1).

Map Sheet 1 to Accompany Preliminary Geomorphic Characterization of Bear Creek at Quigley Grove, Memorandum Submitted to CDF.



Observations Regarding the Bear Creek Fallen Trees and High Stream Flows

Aerial photographs dated September 7, 1996 (before the 1996/1997 debris torrenting) show the Bear Creek floodplain at Quigley Grove to be relatively wide compared with reaches upstream, and the active channel appears to follow along the right (looking downstream) side of the floodplain. At this location, a prominent linear obstruction is visible that stretches across the floodplain and appears to be a fallen old-growth tree. Evidence of a prominent bluff face at Quigley Grove is not apparent on these photographs. Aerial photographs taken in the summer of 1997 (after the debris torrenting) show the Bear Creek floodplain to be uniformly wider and straighter along much of its course. A comparison of the 1996 and 1997 photographs indicates that some of this “straightening” occurred along the left bank at the Quigley Grove study site where a significant amount of earth material appears to have been eroded. The 1997 photographs also show Bear Creek streamflow directed toward the base of Quigley Grove Bluff. Aerial photographs taken in the summer of 2000 shows Bear Creek streamflow was still directed toward Quigley Grove Bluff and an old-growth redwood had fallen into the creek channel. This fallen tree is now the primary obstruction behind which the contemporary debris jam has formed. For purposes of discussion, this fallen tree is defined as the debris-jam-linchpin. Additionally, the 2000 photograph shows Quigley Grove Bluff void of vegetation, which indicates recent or ongoing erosion.

The aerial photographic evidence indicates that in the Quigley Grove area of Bear Creek, large trees have fallen into the floodplain in the past, the 1996/1997 debris torrenting likely created the steep Quigley Grove Bluff face, and streamflow has been directed toward Quigley Grove Bluff for several years prior to December 2002. This streamflow likely caused accelerated erosion of the bluff face and likely contributed to the toppling of the old-growth tree that is visible in the 2000 photographs and which is now the debris-jam-linchpin.

Within the Quigley Grove study reach, seven fallen redwood trees that have a DBH (diameter at breast height) of 3 feet to 7 feet were found (Map Sheet 1). Three of these seven large trees appear to have fallen within the last several months. One individual redwood tree had a diameter of 37.2 inches; the larger bole of a double redwood tree had a diameter of 81 inches at 8 feet from the root mass, while the second bole had a diameter of 42 inches at 15 feet up from the same root mass. The diameter of this root mass is approximately 15 feet. These diameter measurements were made at the closest accessible points above DBH, and are only intended to indicate relative sizes of the fallen trees. Evidence used to conclude that the other four trees have been down for several years includes: fallen trees visible in aerial photographs, the presence of well-established sprouts growing out of the fallen trees, oxidized wood, trunks completely stripped of bark and polished, and partial burial in sediment. Of the three large redwood trees that fell down recently, the two that appear to share the same root mass lie adjacent to one another on the floodplain. This double-tree appears to have fallen from atop Quigley Grove Bluff (highest ancient terrace level) as evidenced by the presence of a shallow, unvegetated pit along the bluff edge above the fallen trees. The single tree appears to have fallen from a lower terrace level position and lies approximately 40 feet downstream from the double-tree. In addition to the fallen old-growth trees, ten young trees have recently fallen along the right edge of the floodplain. These trees are young conifers and hardwoods with DBH values that range from 3.7 inches to 10.9 inches.

The presence of near vertical to overhanging slopes along the Quigley Grove Bluff strongly indicates that the downed old-growth trees fell into the floodplain because lateral support beneath the root-mass had eroded. It is also reasonably clear that Quigley Grove Bluff was created by stream erosion and undercutting along the base of the slope. As discussed previously, the presence of the debris jam indicates ponding of water, and the presence of the main low-flow channel along the left valley wall suggests that the debris jam was breached at this location. Such a breach likely concentrated streamflow against the base of Quigley Grove Bluff. It is reasonable to assume that concentrated streamflow would erode the friable earth materials (fluvial sediments), undercut the slope, and cause additional mass wasting. However, a flood channel immediately downstream of the debris-jam-linchpin (fallen old-growth redwood), indicates that water flowing around the debris jam “expanded” and flowed transversely across the floodplain (Map Sheet 1). Streamflow expansion around an obstruction is commonly accompanied by an eddy current immediately downstream of the obstruction. Immediately downstream of the debris-jam-linchpin is a sorted deposit of gravel that partially buries the linchpin log and lies adjacent to the flood channel. It appears likely that this gravel was deposited as streamflow expanded, slowed, and eddied following escape from behind the debris jam. The presence of the flood channel, and local deposit of gravel, indicates that all stream power, during the highest flows, was not directed along the base of Quigley Grove Bluff.

The presence of the shallow pit along the bluff edge above the fallen double tree indicates that about 6 feet of the 15-foot diameter root mass were still implanted just prior to the tree toppling onto the floodplain. This means that the tree did not fall because its entire root mass was undermined. Conversely, 9 of the 15 feet of root mass were undercut. While stream flows have undercut a portion of the root mass, it is also possible that the 1996/1997 erosion had left the trees precariously perched along the bluff edge and high winds during December 2002 blew the trees over. Observations of large old-growth redwood trees which fell during the winter of 2002/2003 were made in several areas of the Park away from stream channels and those trees likely fell as the result of high winds coupled with saturated soil conditions.

The contemporary channel configuration indicates that December 2002 streamflows were also directed around the right side of the debris jam and likely eroded the right bank causing the stand of smaller trees to fall. It should be noted that the debris comprising the jam is relatively small wood accumulated behind a single fallen tree. This suggests that maximum streamflows were not extremely high (i.e., not considerably greater than a 10-year recurrence interval flood event). Otherwise, very high flows would likely have transported much of this small wood downstream. Moderate flood flows are also indicated by flood debris (bark, small wood, roots, etc.)

captured by several alders growing on the mid-channel bar immediately upstream of the debris jam. This flood debris generally lies within one foot above the bar surface and therefore indicates only moderate flood flows. Additionally, alders growing on the mid-channel bar and within small side channels appeared to be healthy and vibrant, which strongly indicates that the bars remained stable during the highest flows of December 2002. These observations are consistent with those made further upstream by Marshall (2003).

Several pieces of ancient old-growth redwood exposed in the active channel and buried within the stratified fluvial sediment are exposed in the Quigley Grove Bluff face. This wood was buried under 30 feet of fluvial sediment before the old-growth trees of Quigley Grove were established. In particular, one of these embedded logs forms an important channel control at the base of Quigley Grove Bluff. More specifically, this log has stabilized the upstream channel by preventing channel incision from migrating upstream. Moreover, this log, and the fact that the active channel flows over it, strongly indicates that the active channel currently occupies a very low elevation and is not aggraded.

Additional evidence that this section of Bear Creek is not aggraded, and is flowing at a relatively low level, is a bedrock exposure of massive siltstone (Wildcat Group) on the right side of the valley wall. This siltstone is unconformably overlain by loose fluvial gravel that is resting on a horizontal and planar scour surface. This exposure of scoured bedrock capped by fluvial sediment appears to define an ancient channel bottom that is approximately five feet above the current channel bottom. Collectively, the scoured bedrock and exhumed ancient logs suggest active channel downcutting and support the PALCO monitoring results that show the channel to be flushing out the large sediment load that was deposited during the 1996/1997 debris torrenting (PALCO 2001a). Thus, it appears that the available stream power in this watershed is sufficient to move and flush the sediment produced in the watershed.

As described earlier, the downstream portion of the floodplain at the Quigley Bluff study site is lacking vegetated bars. Additionally, the left bank is undercut approximately 4 feet and approximately 10 feet of this undercut bank has failed just recently after the high flows. Currently, the stream in this part of the study area follows the right edge of the floodplain along the base of a remnant terrace of the 1996/1997 deposit. The terrace surface is approximately 7 feet above the active channel, and the deposit indicates that following the 1996/1997 debris torrenting, this section of the floodplain contained a significant volume of stored sediment. Since only a small portion of this terrace remains, much erosion of sediment has occurred in this area since 1997. The current lack of alders and stable channel bars in this area suggests that this area was reworked during the recent high flows. Additional channel adjustments in this area may cause further bank erosion.

Answers to the Critical Questions

1. **How many trees fell, or were otherwise affected, in the December 2002 storms within the channel zones of Bear, Jordan, and Greenlaw Creeks and in nearby reference streams?**

Response: At the Quigley Grove site in the Bear Creek watershed, three large old-growth redwood trees (but only two old-growth root-wads) have fallen into the floodplain within the last few months. Additionally, ten small (young) conifer and hardwood trees have recently fallen into the floodplain. No additional old-growth tree loss was observed in the remainder of the Park portion of Bear, Jordan, and Greenlaw Creeks.

In the reference watersheds, no large old-growth trees were determined to have fallen in the lower part of Cow Creek in December 2002, but large old-growth redwood trees have fallen along the channel zone in the last few years. One very large old-growth redwood fell along Squaw Creek in December 2002, along with two moderately sized Douglas-fir trees in the lower 1,200 feet. In these less disturbed reference watersheds, it is apparent that large numbers of trees, including large old-growth redwoods, have fallen and continue to fall into the stream channels. From the perspective of stream function, it is accepted by the scientific community that the input of large wood into stream channels is beneficial, creating structurally diverse and complex habitats required by anadromous fish species (Keller and Tally 1979, Bisson et al. 1987, Bilby and Ward 1991). In July 2000, California Forest Practice Rule 14 CCR 916.9(i) was implemented at the request of state and federal fisheries and wildlife agencies to specifically encourage the recruitment of large wood into stream channels. This rule states in part that "recruitment of large woody debris for aquatic habitat in Class I anadromous fish-bearing or restorable waters shall be ensured by retaining the ten largest DBH conifers (live or dead) per 330 feet of stream channel length that are the most conducive to recruitment to provide for the beneficial functions of riparian zones."

2. **What are the causal mechanisms for observed impacts?**

Response: At the Quigley Grove study site in the Bear Creek drainage, the steep bluff face appears to have been largely formed during the 1996/1997 winter and subsequent streamflow appears to have been directed toward the Quigley Grove Bluff face for several years prior to the 10-year recurrence interval flood event that occurred in December 2002. At least one old-growth tree fell from the grove between 1997 and 2000. It appears that a debris jam was created during December 2002 and may have concentrated stream flow toward both the left and right banks. It is likely that the concentrated stream power along the right bank caused bank erosion that impacted the ten young trees. Concentrated stream power along the left bank likely caused similar bank erosion and subsequent toppling of the single, large tree located on the lower ancient terrace. As for the double old-growth tree, it appears reasonable that the tree was overhanging the bluff face prior to December

2002. It seems equally likely that either additional bluff face erosion and/or high winds could have caused this tree to fall.

3. To what extent are the causal mechanisms related to land use activity?

Response: December 2002 produced record amounts of monthly rainfall and approximately a 10-year recurrence interval flood event. Overall, the impacts associated with the 2002 storms appear to be significantly less in Bear Creek than those documented in 1964 and 1996/1997. In particular, there is no evidence of recent debris torrenting along Bear Creek (Marshall 2003). Those observations are consistent with what was observed at the Quigley Grove site. More specifically, the flood flow depths in the channel above the debris jam appear to have been relatively shallow. The bars and side channels above the debris jam are well vegetated with a multi-story canopy of young alders and there is no evidence of major channel adjustment (either erosion or sedimentation) in this upper reach. Exposures of the ancient log serving as a channel control and scoured bedrock above the existing floodplain indicate that the study reach is currently more downcut rather than aggraded. In summary, there is a general lack of evidence suggesting extraordinarily high flood flows and/or significant channel adjustment immediately upstream of the Quigley Grove Bluff. Thus, at the Quigley Grove study site, above the debris jam, there is no readily observable evidence to suggest that the channel was dramatically impacted by the record high monthly rainfall, the 10-year recurrence interval flood event, or land use activities that have occurred since 1997.

Debris sliding and torrenting on areas that had been harvested prior to the winter of 1996/1997 may have adversely impacted the Quigley Grove site in Bear Creek. However, practices required in Timber Harvesting Plans approved since the PALCO HCP/SYP was signed in March 1999 have changed considerably. The HCP/SYP interim prescriptions (prior to watershed analysis) for PALCO timberlands do not permit the types of harvesting practices that were associated with much of the earlier landsliding—including ridgeline-to-inner gorge clearcuts. For example, a review by Smelser (2001) found that for three Timber Harvesting Plans approved in 2001, none of them included ridgeline to inner gorge clearcuts, and the actual harvesting was proposed for slopes outside of the debris slide amphitheater and far upslope of the inner gorge. The channel impacts observed following the December 2002 storm events in lower Bear Creek do not indicate that significant new landsliding took place (Marshall 2003) and there is no evidence that harvesting within the past three years has adversely impacted the lower part of the channel network at the Quigley Grove site.

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Appendix A – **Photographs**

Figure A-1. Root wad from the large double old-growth redwood tree which fell in the Bear Creek watershed in December 2002.

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Figure A-2. The bole of the larger old-growth redwood tree which fell in the Bear Creek watershed in December 2002.

Figure A-3. View of the large double old-growth redwood tree in the Bear Creek watershed from above the active channel zone.

Figure A-4. Field team investigating the redwood tree which fell between 1997 and 2000 and caused the accumulation of large wood immediately above the site where the large double redwood fell in the Bear Creek drainage in December 2002.

Figure A-5. View of the redwood which fell between 1997 and 2000, and the debris jam which accumulated above it from above the active channel zone.

Figure A-6. Close up view of the debris jam which formed above the redwood tree which fell between 1997 and 2000 in the Bear Creek watershed.

Figures A-7 and 8. Lower Bear Creek near the Avenue of the Giants Bridge showing downcutting through past coarse sediment deposits.

Figure A-9. Lower Jordan Creek near the entrance into the Eel River.

Figure A-10. Lower Jordan Creek redwood tree with adventitious roots exposed by recent downcutting.

Figure A-11. Lower Jordan Creek redwood tree with adventitious roots exposed by recent channel downcutting.

Figure A12. Lower Greenlaw Creek from the Avenue of the Giants bridge.

Figure A-13. Large wood which has entered the Cow Creek watershed, tributary of Bull Creek, in Humboldt Redwoods State Park.

Figure A-14. Large old-growth redwoods the fell across the Cow Creek channel approximately one year ago.

Figure A-15. Lower portion of the Squaw Creek basin, tributary of Bull Creek in Humboldt Redwoods State Park. Note evidence of removal of large wood which probably occurred in the 1960s or 1970s.

Figure A-16. Lower portion of Squaw Creek approximately 700 feet from the mouth showing accumulation of large wood which has likely entered the channel zone since stream clearance activities occurred.

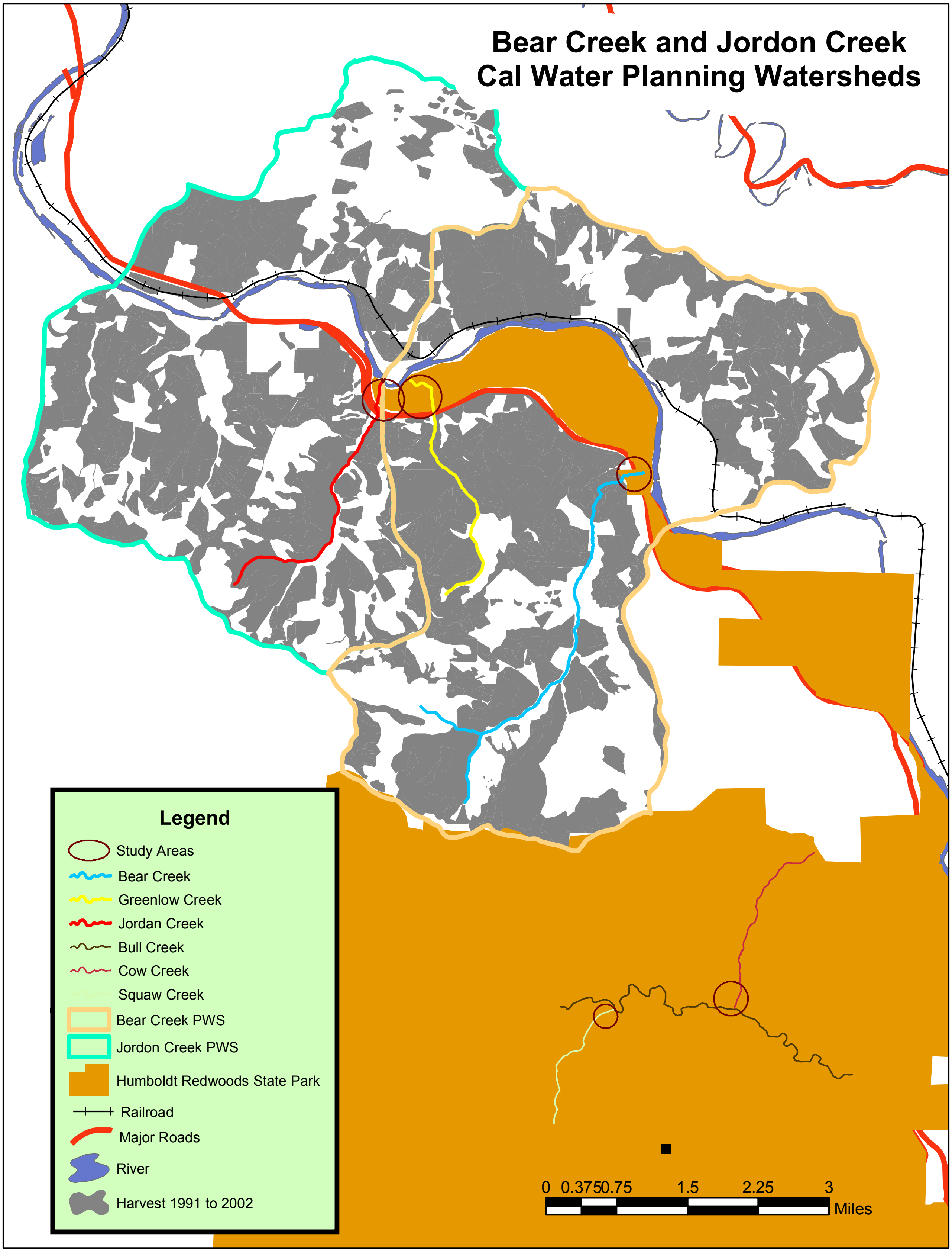
Figure A-17. Lower Squaw Creek where a Douglas-fir tree fell across the channel during the winter of 2002/2003.

Figure A-18. Close up view of a Douglas-fir tree which entered the lower Squaw Creek channel during the winter of 2002/2003.

Figure A-19. Large eight foot diameter old-growth redwood which fell during the winter of 2002/2003 in lower Squaw Creek.

Figure A-20. Root wad from the large old-growth redwood tree which fell in lower Squaw Creek during the winter of 2002/2003.

Appendix B – GIS Maps



Bear Creek and Jordon Creek
Cal Water Planning Watersheds
Legend
Study Areas
Bear Creek
Greenlow Creek
Jordan Creek
Bull Creek
Cow Creek
Squaw Creek
Bear Creek PWS
Jordon Creek PWS
Humboldt Redwoods State Park
Railroad
Major Roads
River
Harvest 1991 to 2002
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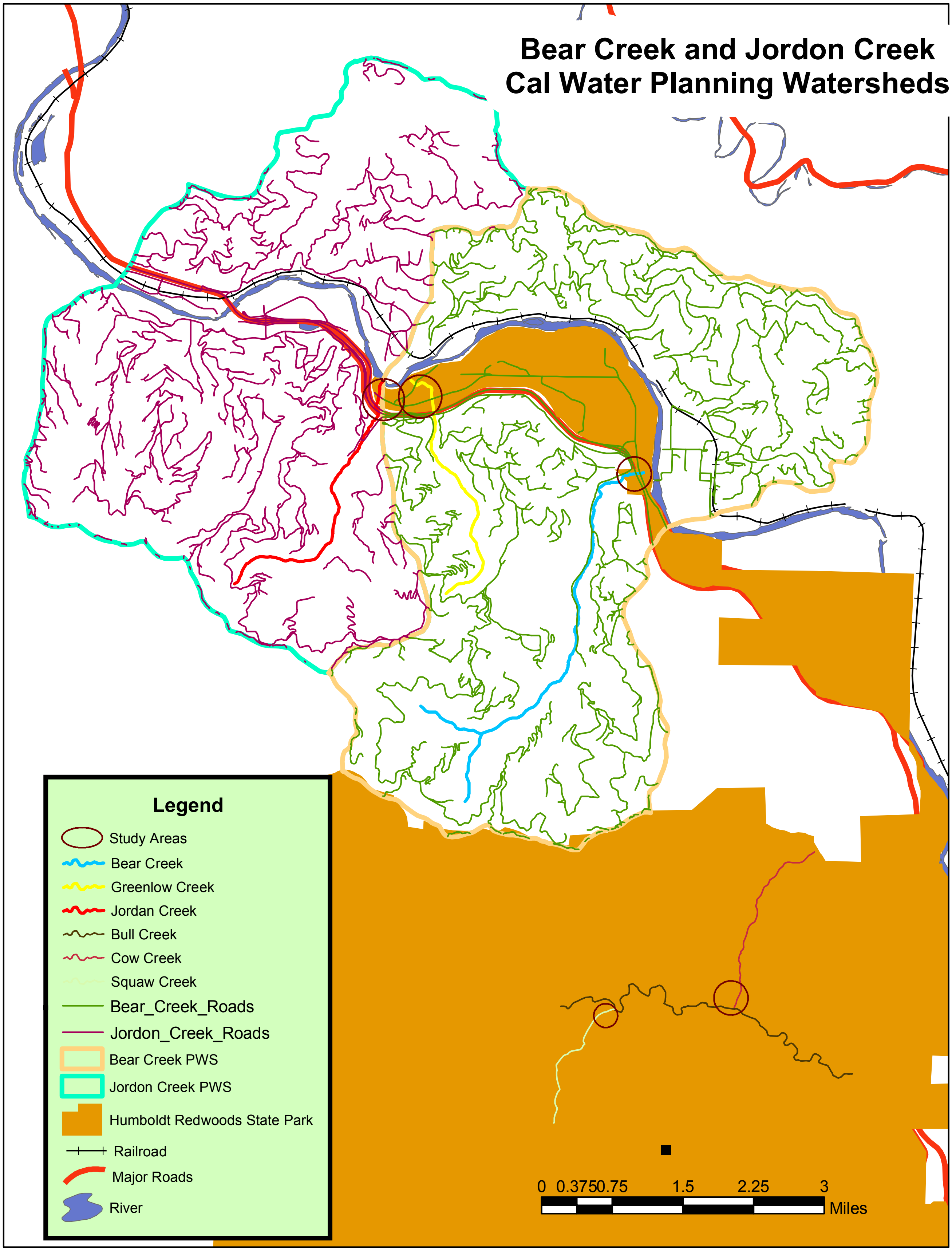
Miles


Bear Creek and Jordon Creek
Cal Water Planning Watersheds
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Jordan Creek
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Squaw Creek
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Jordon_Creek_Roads
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Railroad
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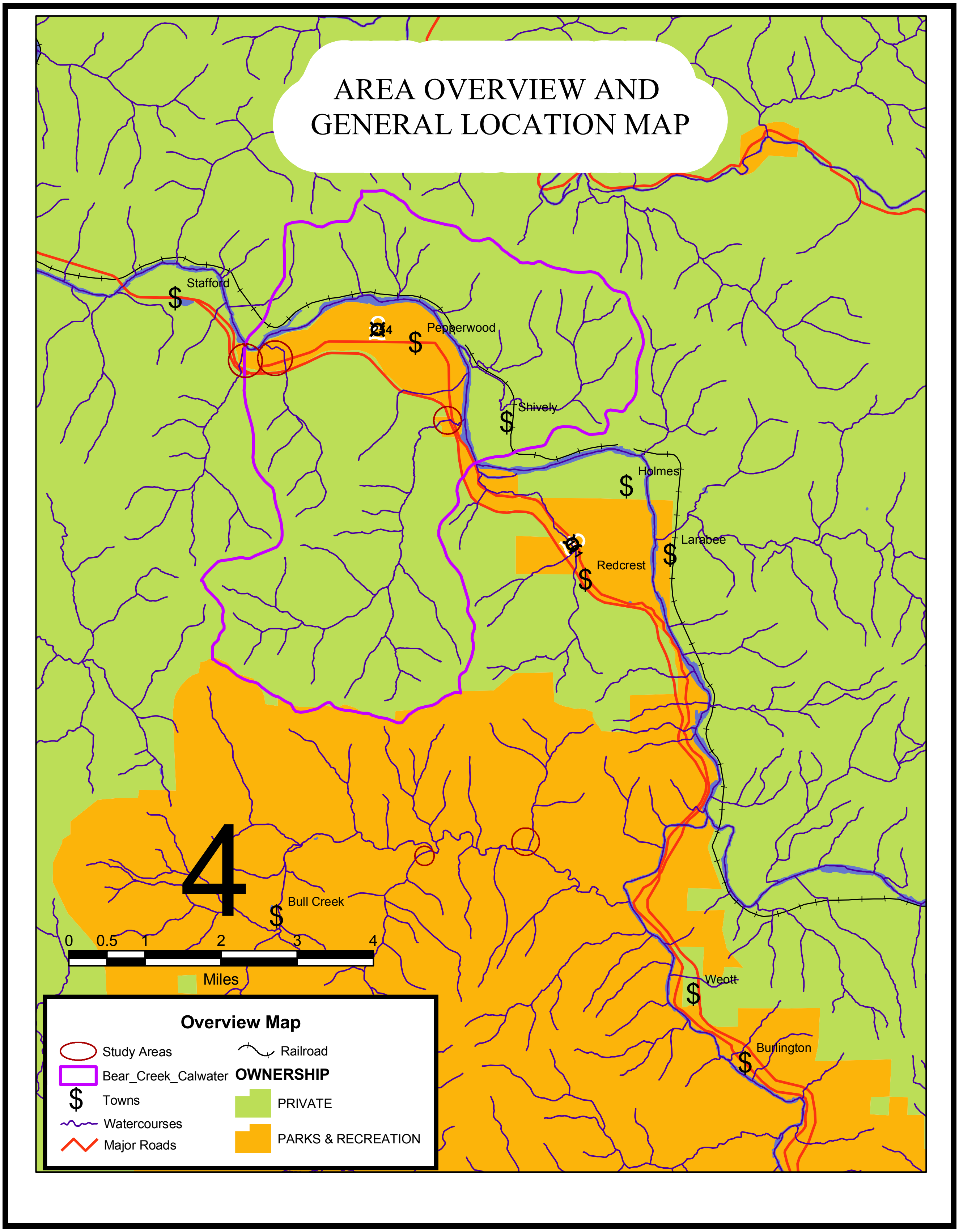
AREA OVERVIEW AND
GENERAL LOCATION MAP
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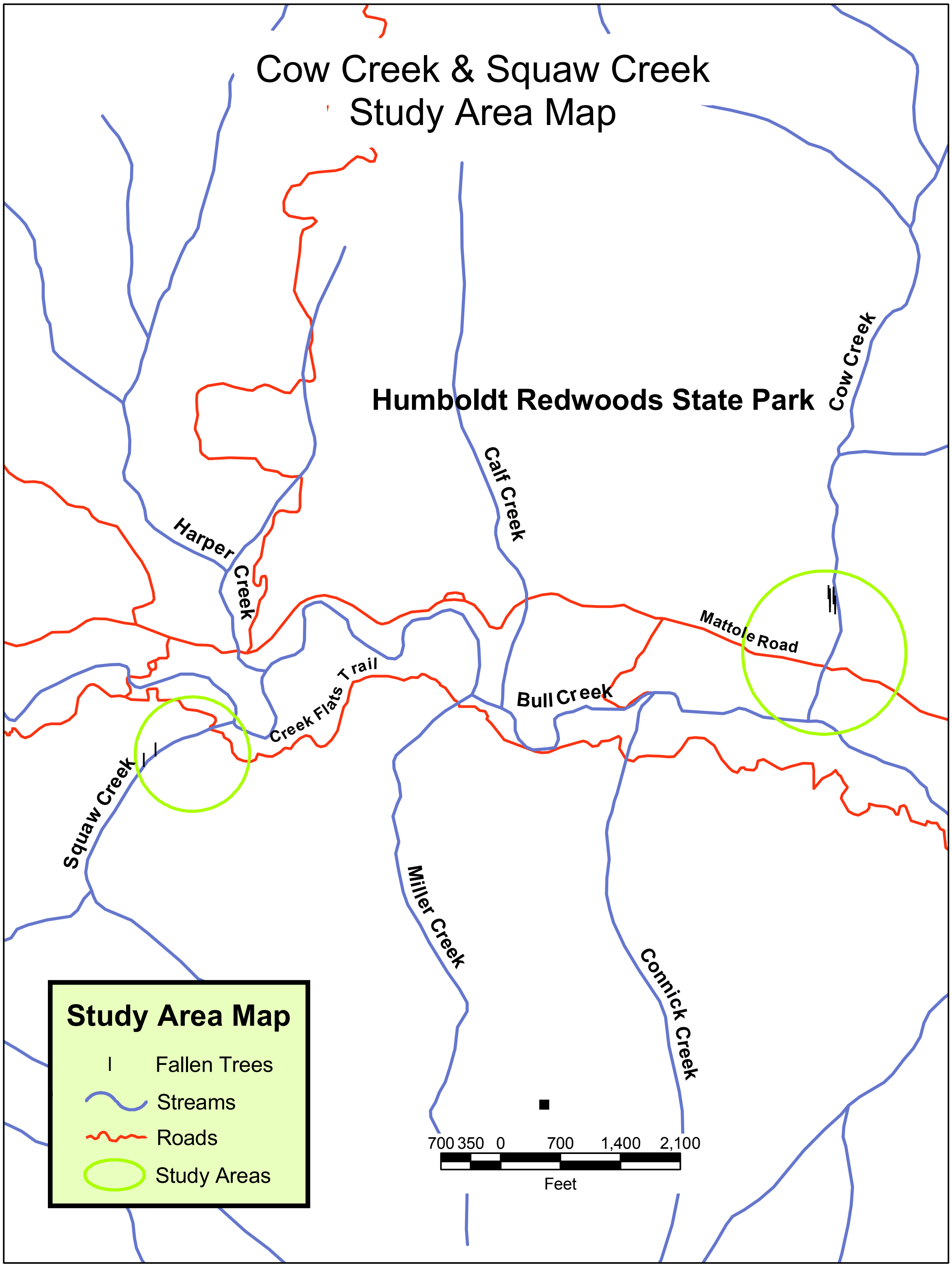
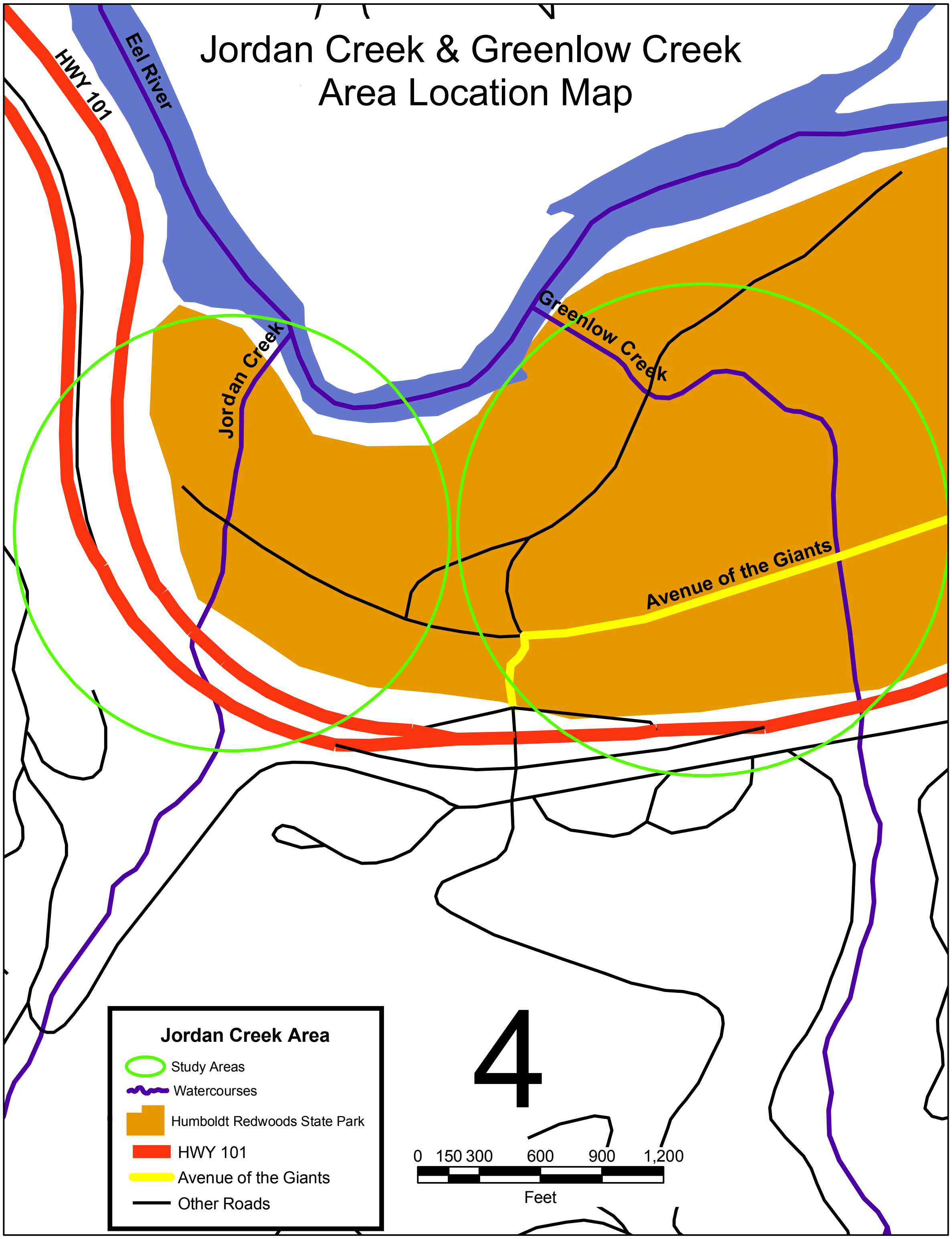
Pepperwood
Shively
Holmes
Larabee
Redcrest
Bull Creek
Weott
Burlington
254
4
0
0.5
1
2
3
4
Miles
Overview Map
Study Areas
Bear_Creek_Calwater
Towns
Watercourses
Major Roads
Railroad
OWNERSHIP
PRIVATE
PARKS & RECREATION


Cow Creek & Squaw Creek
Study Area Map
Humboldt Redwoods State Park
Cow Creek
Calf Creek
Harper Creek
Mattole Road
Bull Creek
Creek Flats Trail
Squaw Creek
Miller Creek
Connick Creek
Study Area Map
Fallen Trees
Streams
Roads
Study Areas
700 350 0 700 1,400 2,100
Feet

Bear Creek Tree Locations


Jordan Creek & Greenlow Creek
Area Location Map
Eel River
HWY 101
Jordan Creek
Greenlow Creek
Avenue of the Giants
Jordan Creek Area
Study Areas
Watercourses
Humboldt Redwoods State Park
HWY 101
Avenue of the Giants
Other Roads
4
0 150 300 600 900 1,200
Feet