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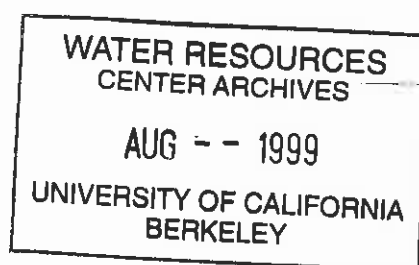
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Sources of large woody debris in Olema Creek
and effects on channel morphology

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LA 222: Hydrology for Planners

Abstract

This study examined Olema Creek, Marin County, California to observe the effect of large woody debris (LWD) on local channel morphology and to determine man-made obstructions to LWD passage.

We surveyed a 600 foot longitudinal profile and found seven pools within the study reach. Five out of the seven pools occurred adjacent to LWD accumulations. Closer examination of LWD accumulations revealed the importance of root wads as key members in pool formation. LWD encouraged sediment deposition and gravel bar formation, influencing channel sinuosity.

We found bridges in the catchment potentially obstruct the very largest pieces of LWD, box culverts potentially obstruct passage of wood >8 feet in length or 3 feet diameter, and round culverts as obstructions to LWD >4 feet in length or diameter. In our study reach we found most LWD to be greater than 8 feet long or wider than 4 feet. If the size of LWD in the tributaries is similar to the size LWD found in our study reach, culverts could hamper or completely block LWD passage.

Purpose

This study examined the effect of LWD on local channel morphology in Olema Creek, a small coastal stream near Point Reyes, CA, through a detailed survey of channel conditions and LWD accumulations. We also examined bridges and culverts in the watershed, comparing the size of openings to the size of LWD, to determine which structures could potentially obstruct wood transport during high flows.

Introduction

Fallen trees, branches, and logs are important influences on the local channel morphology of rivers and streams in the western United States. This large woody debris (LWD) is a primary component in pool formation, the degree of channel meandering, bank stability, and variability in channel width (Bilby and Bisson 1998). The frequency of LWD in rivers and streams is a factor in the distribution of aquatic habitat types, such as pools, riffles, and runs (Montgomery et al. 1995).

LWD originates in the forest and is deposited through mass wasting, tree mortality, bank undercutting, and windfall (Bryant 1983; Gregory et al. 1991). Human activities responsible for LWD input include timber harvest, streamside construction, and road construction.

LWD migrates downstream during high flows. The accumulation of flood-borne debris behind bridges presents a public safety hazard. Debris can clog openings, reducing flow area and increasing water velocity. Higher water velocity leads to increased scour and potential failure of structures (Hamill, 1999). To reduce blockage, watershed managers often remove wood (Singer and Swanson, 1993). After large storms, damage caused by obstructed flows is typically blamed on wood, not on structures. Watershed managers react by removing more wood, rather than modifying bridges and culverts.

Study site

Physical Setting

Olema Creek (Figure 15) drains a 15 mi² catchment along the San Andreas fault zone. The 8.5 mi channel flows from its headwaters into Lagunitas Creek near Point Reyes Station. Lagunitas Creek eventually empties into a tidal marsh at the head of Tomales Bay.

We observed a 15-30 foot strip of riparian vegetation lining both sides of Olema Creek. Prominent tree species included California Bay (*Umbellularia californica*), red and white alder (*Alnus oregana* and *Alnus rhombifolia*), oak (*Quercus* spp.), willow (*Salix* spp.) and an occasional Sycamore (*Platanus racemosa*). Noted understory species were stinging nettle, poison oak, and Periwinkle (*Vinca major*).

Perennial and ephemeral tributaries draining the Bolinas and Inverness Ridges feed Olema Creek. Although we observed thin margins of riparian vegetation along the tributary channels, the majority of the slopes were grazed pasture. In several locations cattle were grazing along tributary banks, and at one tributary cattle were in the water.

Methods

Channel survey

We surveyed a 600 foot reach of Olema Creek near the Fivebrooks recreation area, approximately 4 miles from the creek mouth (Figure 15). The survey recorded the longitudinal profile of the thalweg, center line and water surface slope (Gordon et al. 1992). We made a detailed sketch map recording pool locations, LWD accumulations,

and dominant vegetation types. We surveyed channel cross-sections at four LWD accumulations and at one location between LWD accumulations.

Size and frequency of LWD

At LWD accumulations, we counted and measured each piece along the A (long) and B (intermediate) axes (Figure 16). The A-axis was typically the length of the LWD and the B-axis was the greatest diameter. Often the B-axis was taken from the diameter of the root wad. These dimensions were based on dimensions used in measuring rocks, where the A-axis is the greatest dimension of the rock and the B-axis is the widest point perpendicular to the A-axis (Wolman, 1954). We felt these dimensions most accurately reflected the potential for LWD to become trapped by bridges or culverts.

Size of bridge and culvert openings

We visited 11 structures in the Olema Creek watershed (Figure 15). Four bridges crossed the main channel, while seven culverts directed flow from tributaries into the main channel. At each structure we measured the height and width of the opening (bridges and box culverts) or the diameter (round culverts). We compared bridge and culvert dimensions to the size of observed LWD to identify possible obstructions to LWD passage.

Results

Channel survey

The longitudinal profile and sketch of the study reach showed a channel composed of riffle and run habitats separated by seven pools (Figures 13 and 14).

Woody debris occurred adjacent to five out of seven pools.

Six deposits of LWD occurred in the study reach: two log jams, three individual trees that lay across the channel, and one undercut root wad of a still-standing tree. Five out of six LWD accumulations occurred near pools (Figure).

Size and frequency of LWD

Large woody debris with a diameter (measured at the B axis) of 0.5 to 1.0 feet occurred most frequently in the study reach (7 out of 21 pieces), while no pieces of 4.1 to 7.0 feet diameter occurred (Figure 6). The largest piece measured 20 feet in diameter.

The most frequently occurring length of large woody debris (measured at the A axis) was 5.1 to 10.0 feet and the largest piece observed in the study reach measured 50 feet in length (Figure 7).

Comparison of bridge and culvert openings to LWD size.

The height of the four bridge openings on Olema Creek ranged from 10.7 to 15 feet and the width ranged from 15 to 20 feet (Table 1). Box culverts ranged from 3.0 to 7.0 feet in height and from 3 to 8 feet in width. All round culverts were 4 feet in diameter.

One piece of LWD (>10 feet diameter; Figure 8) was larger than the height of all bridge openings, and four pieces were larger than the height of all box culverts. The

smallest box culvert (at McLean Ranch) would not pass 8 pieces of LWD (LWD >3.0 feet diameter).

The width of all bridges was less than the diameter of one piece of LWD (LWD >10ft diameter; Figure 9). The widths of three box culverts were less than the diameter of three pieces of LWD (LWD >8.0ft diameter), while one box culvert (Tributary 1) was narrower than the diameter six pieces of LWD (LWD >3.0ft diameter).

The width of all bridges was less than the length of seven pieces of LWD (LWD >20.0 feet length; Figure 10) and width of box culverts was less than the length of 14 pieces of LWD (LWD > 15.0 feet length).

The diameter of all round culverts was less than the diameter of four pieces of LWD and less than the length of all observed pieces of wood (Figures 11 and 12).

Discussion

LWD and channel morphology.

In the study reach, LWD appeared to be a dominant factor in channel morphology. All pools, except two, formed from scour around wood deposits (Figure 14). This appears consistent with Montgomery et al. (1995) who found that pool spacing in Alaska and Washington streams depends on the amount of woody debris and on stream characteristics (e.g. slope, width). In the Queens River, a coastal river in northwest Washington, Abbe and Montgomery (1996) found that LWD jams are initiated by "key member logs". We observed that each LWD deposit in our study reach included a root wad, suggesting root wads serve as "key member logs" in Olema Creek and are important to pool formation.

At cross-section 1, a log jam formed around the root wad of a still-standing tree (Figure 1). The scour depression is visible between stations 15 and 20 (Figure 13). The pools at cross-sections 2 and 5 formed around root wads of fallen trees lying perpendicular to the channel (Figures 2 & 5). The deepest parts of the pools correspond to the location of the root wads. The pool at cross section 1 was deeper and wider than the pools at cross sections 2 and 5 suggesting jams composed of transported LWD and root wads have a different effect on channel morphology than jams composed solely of root wads.

LWD appeared to influence the sinuosity of Olema Creek. Between cross-sections 2 and 3, a gravel bar formed downstream of a root-wad scour hole and upstream of a fallen bay tree (Figure 14). Willow seedlings colonized the point bar, fixing it in place. The point bar directed water flow to the opposite bank causing erosion. At cross-section 3 sediment accumulated behind a tree that lay across the channel (Figure 3). This forced water flow around the root wad, forming an "S" curve in the channel.

LWD transport and bridges

The two bridges upstream of our study reach had passage widths of 15.7 and 16 feet (Table 1). The absence of imported LWD larger than 4 feet diameter or 25 feet length could be attributed to the passage widths of the bridges and culverts. We found no direct evidence of LWD accumulation at these structures, but removal of LWD accumulations at bridges is common. In Soquel Creek, Santa Cruz County, CA, watershed managers remove wood to reduce clogging of bridges and culverts in the catchment (Singer and Swanson, 1983). An alternative explanation for the absence of large imported LWD could exist if upstream reaches lacked mature riparian vegetation.

However, in a reconnaissance survey of upper reaches, we found riparian vegetation was as abundant as in our survey reach. Perhaps large pieces of wood may remain stationary because they are too large to be moved by average flood events in Olema Creek. If this were true these LWD would move downstream only when they rot or break into smaller pieces. To explore this alternative we would need to ascertain the critical discharge for mobilization of large pieces of wood in Olema Creek, requiring long-term tracking of tagged LWD. Such a long-term project was beyond the scope of this study.

Bridge and culvert passage height could restrict passage of floating LWD. Although our survey found that most bridge heights exceeded the width of the largest pieces of wood, during high flows the height difference between water surface and bridge bottoms or culvert tops is reduced. Reduce passage can increase incidence of clogging leading to structure failure (Hamill, 1999).

All of the box culverts we measured in the Olema Creek catchment have the potential to obstruct LWD > 8 feet in length or width (figure 17). All of the round culverts potentially obstruct LWD > 4 feet in length or width. In our study reach we found most wood to be greater than 8 feet long and a significant portion wider than 4 feet diameter. If the size of LWD in the tributaries is similar to the size of LWD found in our study reach, these culverts could hamper or completely block LWD passage.

Conclusion

This paper shows the importance of LWD to pool formation and location in Olema Creek. A survey of bridge and culvert openings in the catchment reveals that bridges may restrict passage of the biggest pieces of LWD, while culverts may restrict

passage of most or all wood. Any attempt to restore ecological processes to Olema Creek must consider the potential effect obstructions have on aquatic habitat formation.

Since LWD was integral in the formation of scour pools and gravel bars, obstructions could decrease or alter habitat important to stream biota.

References

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Table

Structure type	Name	Location	Height (ft)	Width (ft)	Diameter (ft)	Comments
Bridge	Olema Marsh Bridge	Olema Marsh	10.7	15.0	N/A	20 foot main span flanked by 1 foot piers. 15 foot and 19.7 foot side spans.
Bridge	Olema Bridge	Downtown Olema	13.0	20.0	N/A	23 foot span and 20 foot span separated by 2 foot pier.
Box culvert	McLean Ranch 1	McLean Ranch	3.0	8.0	N/A	3.0 foot drop from culvert
Box culvert	McLean Ranch 2	Upstream of McLean Ranch	4.0	5.0	N/A	5.0 foot drop from culvert.
Bridge	Fivebrooks 1	Downstream Fivebrooks	15.0	15.7	N/A	3 spans: 17.5ft, 15ft, and 16.7 ft separated by 1.5ft piers.
Bridge	Fivebrooks 2	Upstream Fivebrooks	15.0	16.0	N/A	3 spans: 17ft, 16ft, and 16ft separated by 1ft piers.
Box culvert	Trib 1	Just upstream of Fivebrooks	4.0	3.0	N/A	
Box culvert	Trib 2	Upstream of above	7.0	6.0	N/A	4ft drop from culvert.
Round culvert	Trib 3	Upstream of above	N/A	N/A	4.0	
Round culvert	Private	Private road	N/A	N/A	4.0	
Round culvert	Olema Culvert	Olema Headwaters	N/A	N/A	4.0	

Table 1—The dimensions of bridges, box culverts, and round culverts observed in Olema Creek. Note that all bridges have support piers that reduce the width of the possible opening size. We recorded the width between piers, but reported the smallest width that may obstruct LWD passage. Three box culverts dropped several feet into Olema Creek, presenting possible obstructions to fish migration.

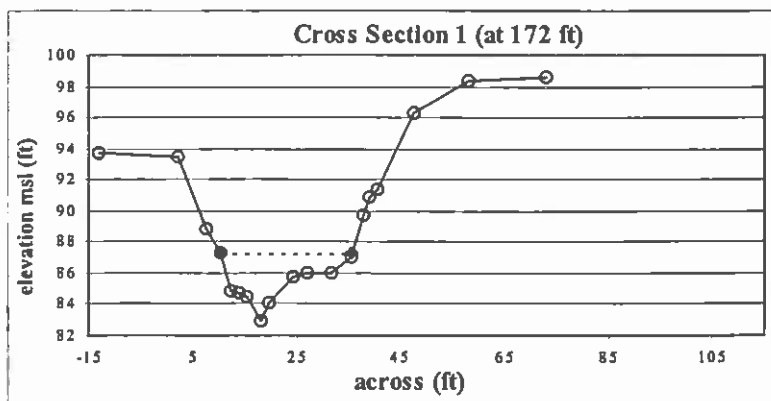


Figure 1—Cross-section 1 taken at log-jam.

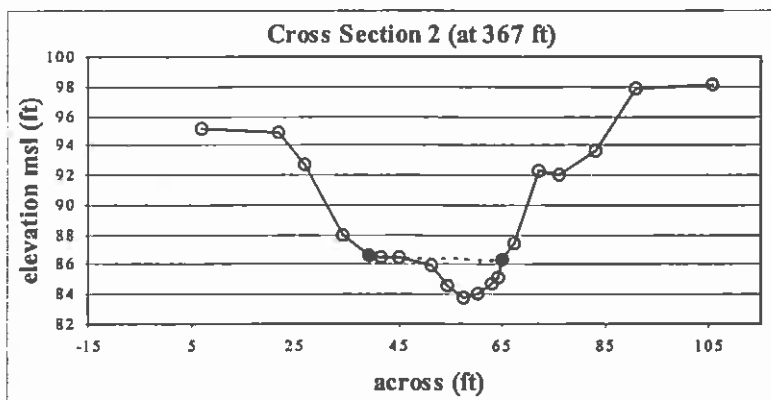


Figure 2—Cross-section 2 taken at root-wad scour hole.

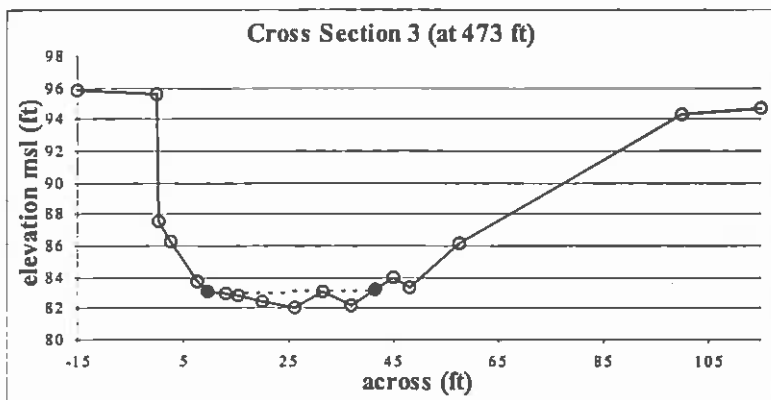


Figure 3—Cross-section 3 taken at buried tree with root wad.

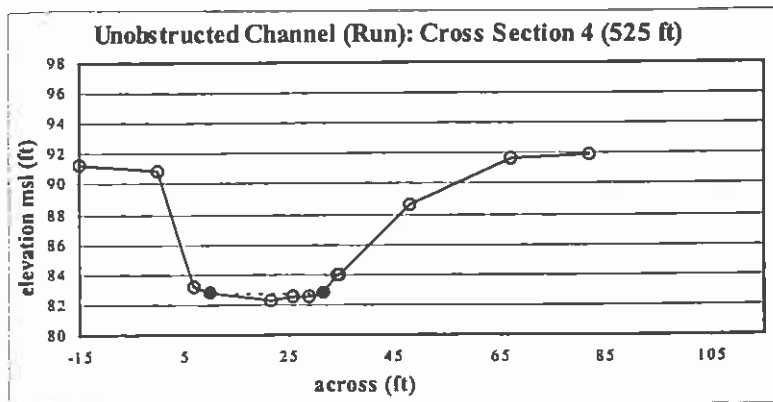


Figure 4—Cross-section 4 taken between LWD accumulations.

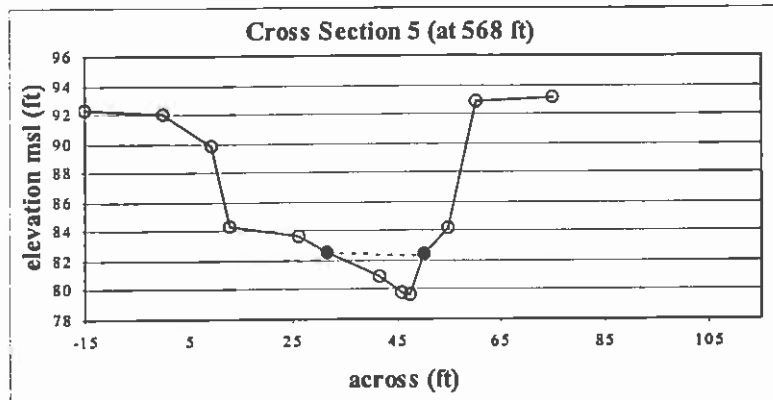


Figure 5—Cross-section 5 taken at root-wad scour hole.

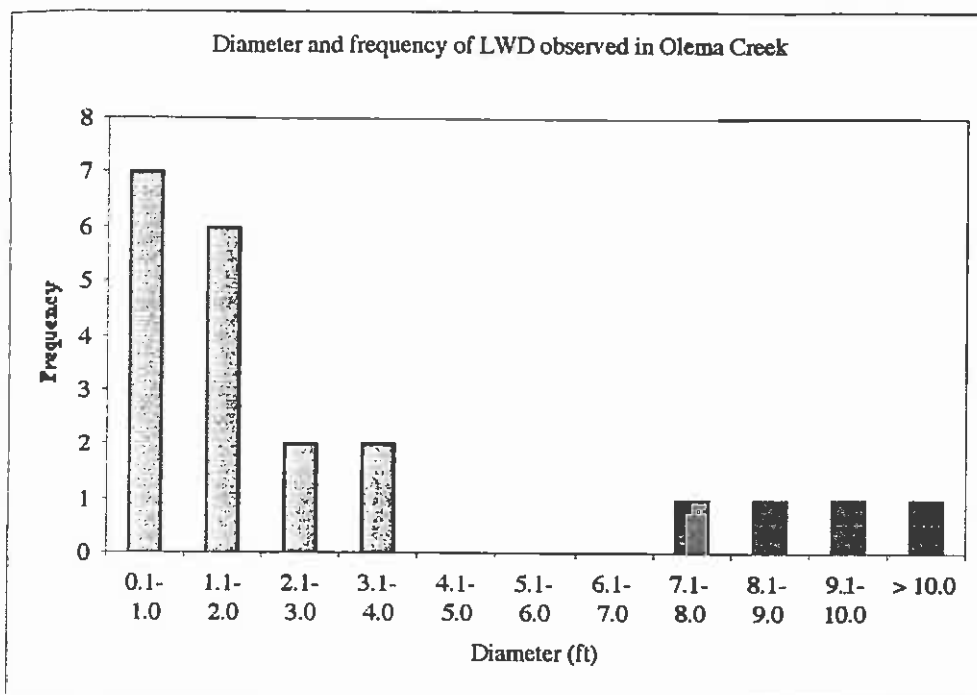


Figure 6—Diameter (B or intermediate axis) of large woody debris observed in the study reach near Fivebrooks in Olema Creek. We measured diameter at the B (intermediate) axis.

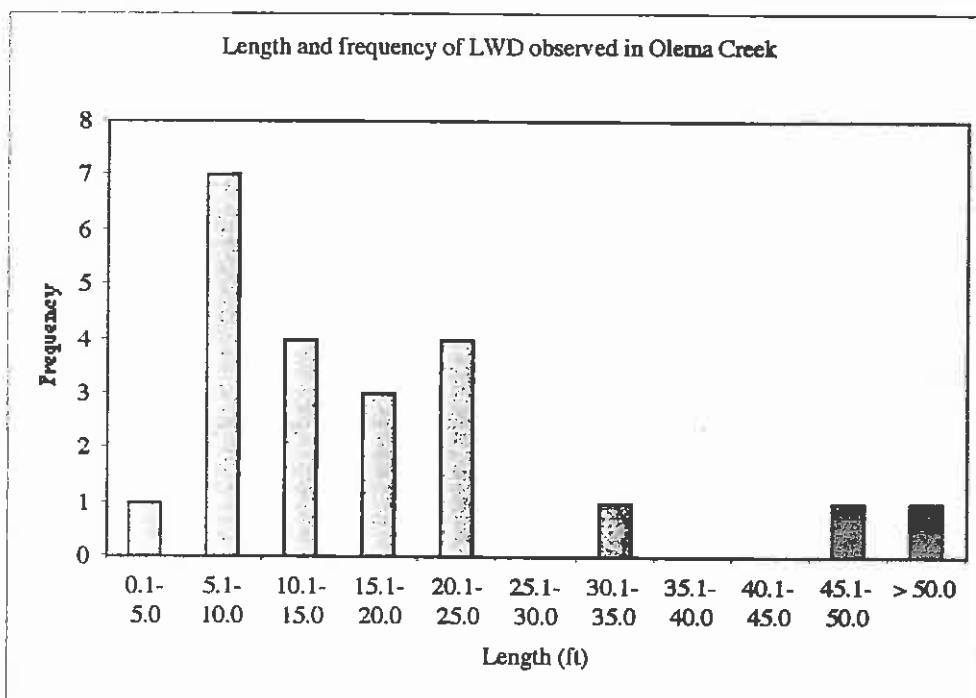


Figure 7—Length (A or longest axis) of large woody debris observed in the study reach near Fivebrooks in Olema Creek.

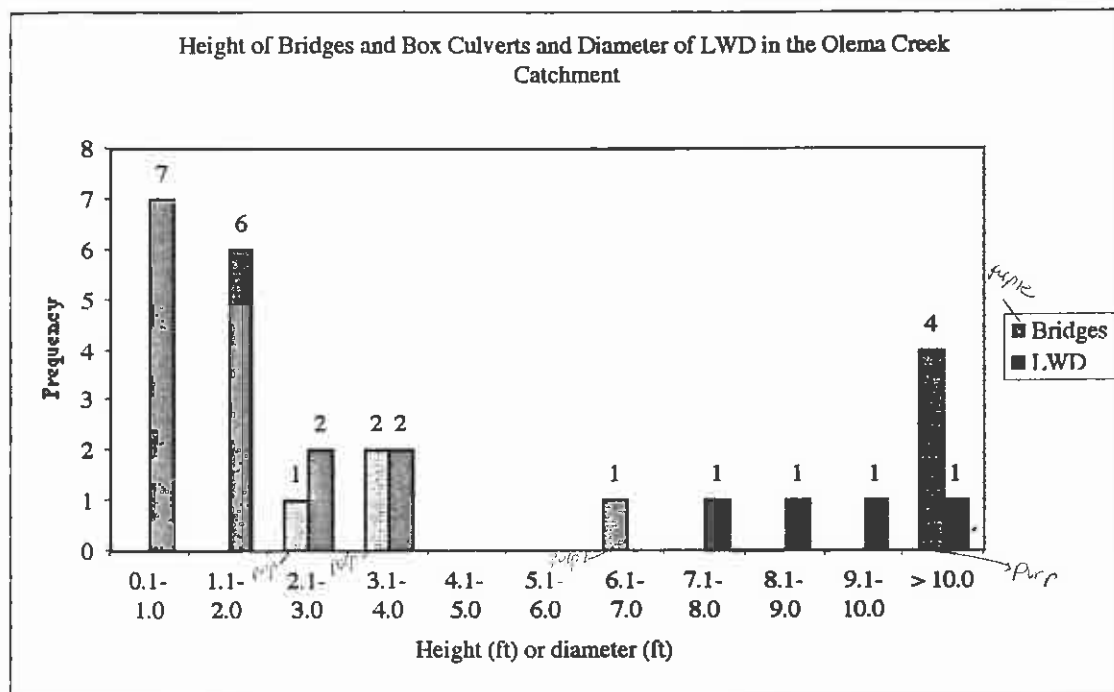


Figure 8—Height of bridges and box culverts compared to the diameter of LWD (measured at the B axis) observed in Olema Creek at the study reach near Fivebrooks. All four bridges spanned Olema Creek and were greater than 10ft in height. Box culverts directed tributaries into Olema Creek and ranged in height from 3 to 7 ft. Bridges appear to obstruct passage of only the biggest pieces of wood. Box culverts appear to block passage of intermediate sized wood.

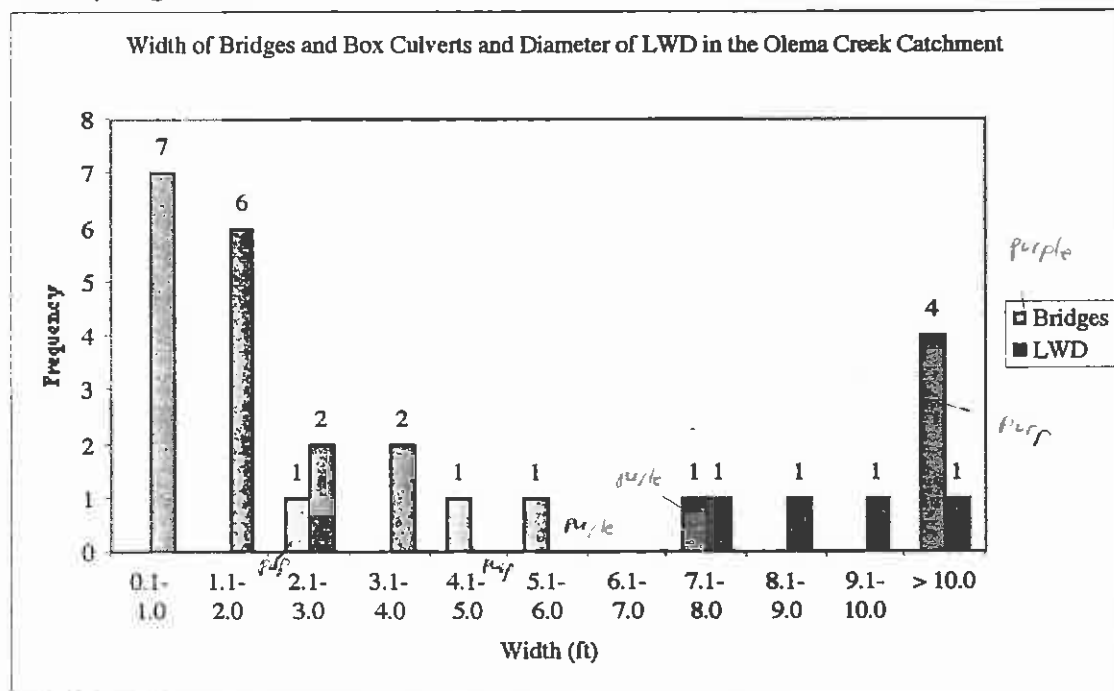


Figure 9—Width of bridges and box culverts compared to the diameter of LWD (measured along the B axis) observed in Olema Creek at the study reach near Fivebrooks. All four bridges were between 15.0 and 20.0ft in width, wider than all but one piece of LWD. Three out of four box culverts were narrower than four pieces of LWD, while the box culvert at McLean Ranch was less than 8 pieces.

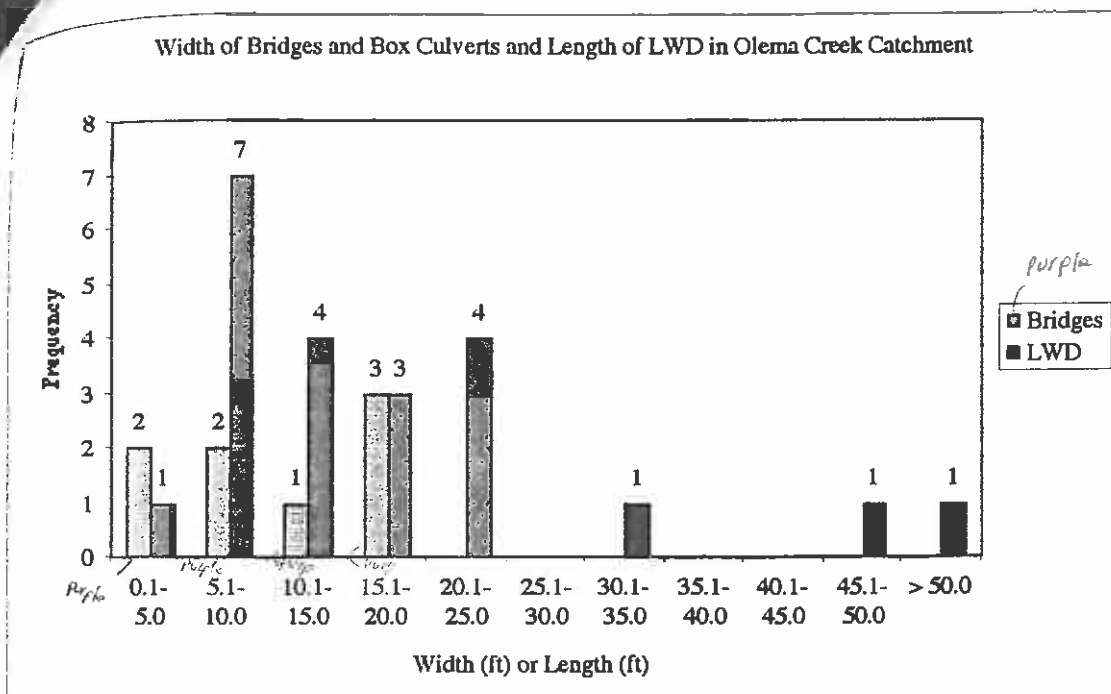


Figure 10—Width of bridges and box culverts compared to the length of LWD (measured along the A axis) observed in Olema Creek at the study reach near Fivebrooks. All four bridges spanned Olema Creek, were supported near the middle with piers and ranged in width from 15 to 20 ft. Box culverts directed tributaries into Olema Creek and ranged in width from 3 to 8 ft. All bridges may obstruct wood longer than 15.0 ft in length. Box culverts may obstruct wood longer than 8.0ft in length.

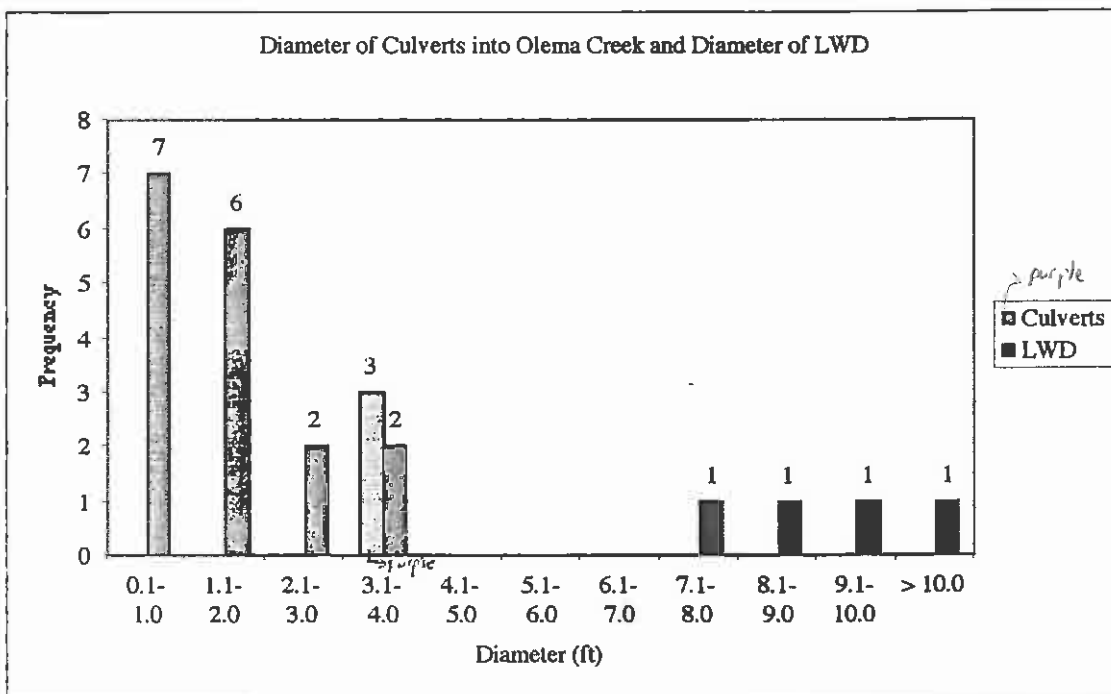


Figure 11—Diameter of round culverts directing flow from tributaries into Olema Creek compared to the diameter of LWD (measured at the B axis) observed in the study reach near Fivebrooks. Round culverts potentially obstruct LWD larger than 7.0ft in diameter.

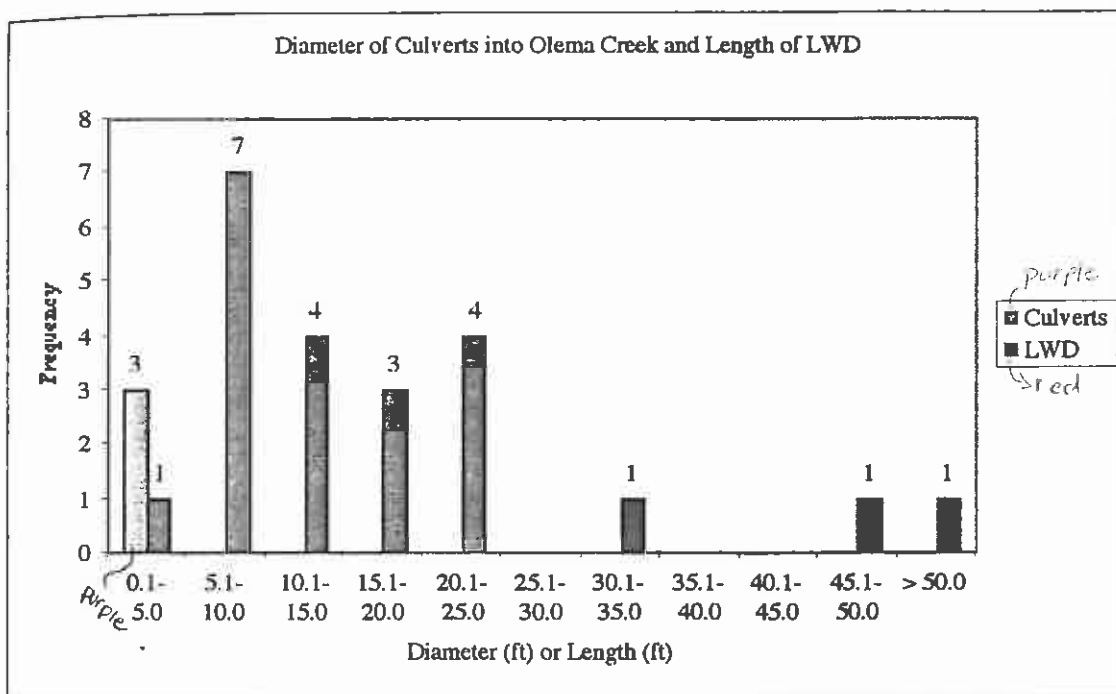
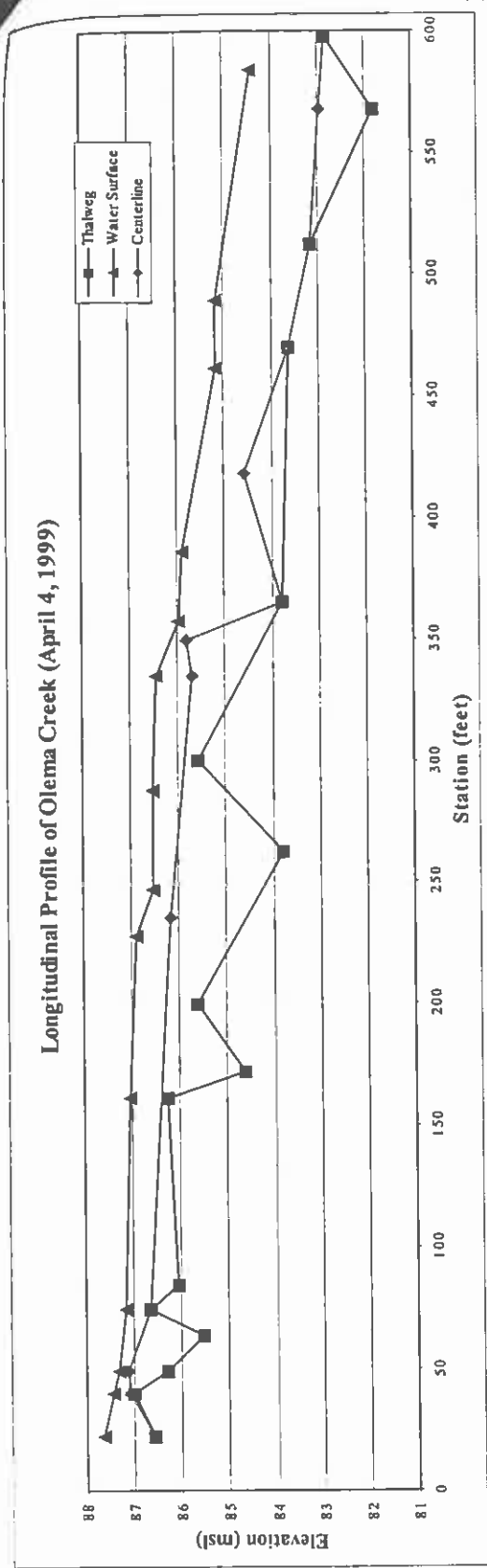


Figure 12—Diameter of round culverts directing flow from tributaries into Olema Creek compared to the length of LWD (measured along the A axis) observed in the study reach near Fivebrooks. Round culverts potentially obstruct LWD greater than 5.0ft in length.



Figure

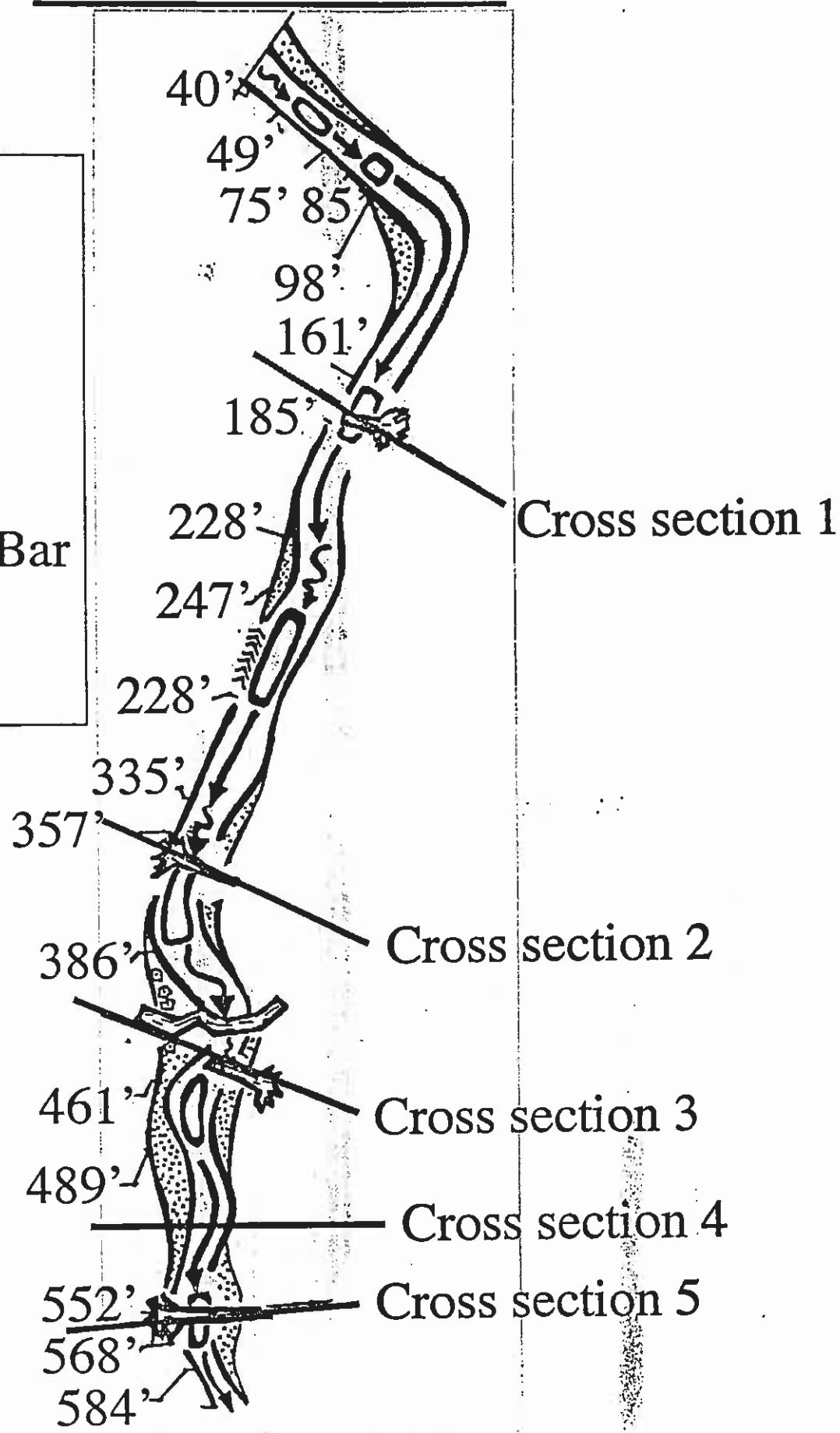
Figure 13—Longitudinal profile of study reach. Arrows indicate cross-sections.

Olcma Creek

Figure 17

Legend

-  Pool
-  Riffle
-  Run
-  LWD
-  Gravel Bar
- 



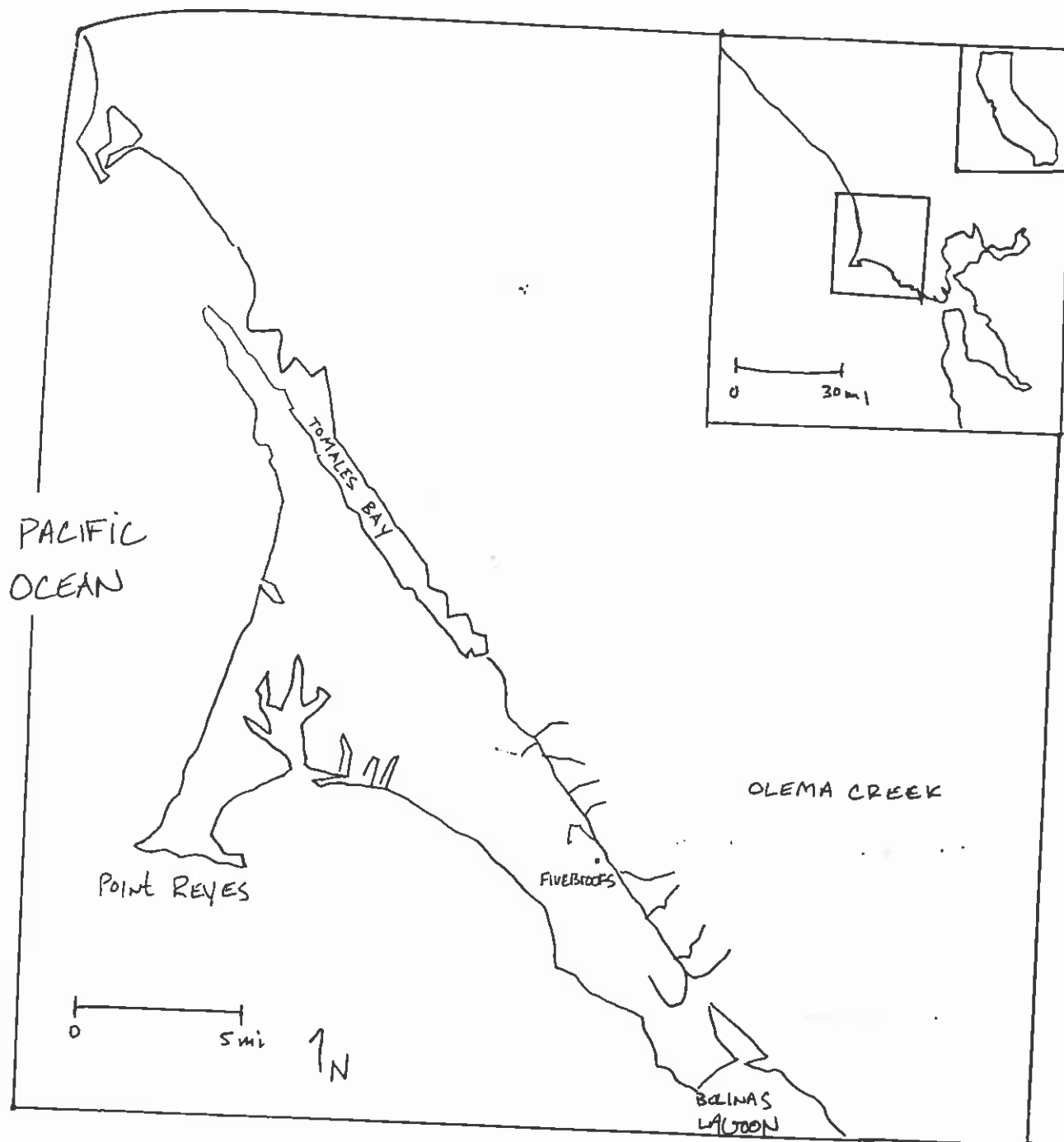


Figure 15.--The Olema Creek watershed drains 15.4 mi² in Marin county, California before entering Tomales Bay. Note the location of Fivebrooks recreation area (Figure adapted from Niemi and Hall 1996).

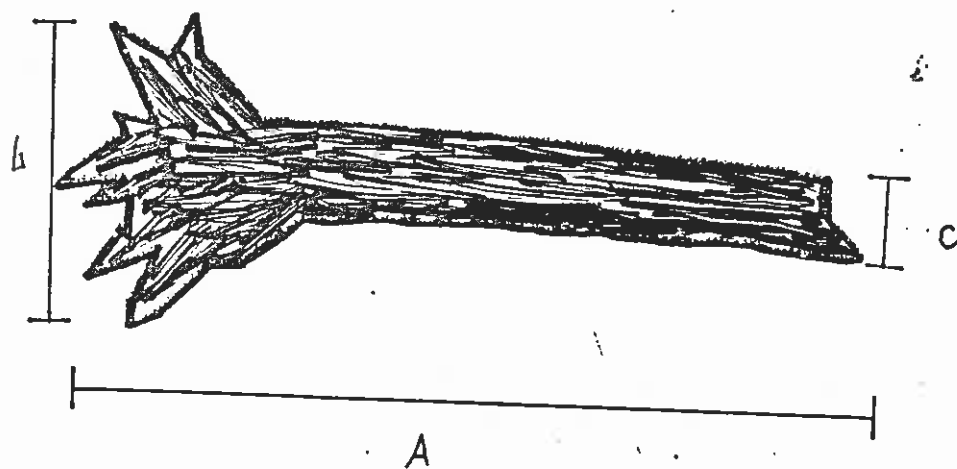


Figure 16.--A piece of large woody debris as measured in Olema Creek. The length was recorded at the "A," or long axis, and the diameter was measured at the "B," or intermediate axis. Note the "C" axis, or the small axis, which was not used in this analysis.

(Figure 17)

