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Leah MacCarter
*Watershed Institute*

Julia Fields
*Watershed Institute*

Douglas Smith
*California State University, Monterey Bay*, dosmith@csumb.edu



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Leah MacCarter
Julia Fields
Douglas Smith (Ph.D.)



Publication No. WI-2016-05

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## The Watershed Institute

Division of Science and Environmental Policy
California State University Monterey Bay
http://watershed.csumb.edu

100 Campus Center, Seaside, CA, 93955-8001
831 582 4696 / 4431

Contact:
dosmith@csumb.edu

# Preface

The following report documents the Fall 2015 locations and characteristics of large woody debris (LWD) along the lower reach of the Carmel River in California, from Camp Steffani Road to the Carmel Lagoon. The report includes an ArcMap GIS project and electronic spreadsheets containing the data.

### This report may be cited as:

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### Previous LWD survey reports:

2013:

ENVS 660, CSUMB Class. Beck E, Geisler E, Gehrke M, Goodmansen A, Leiker S, Phillips S, Rhodes J, Schat A, Snyder A, Teaby A, Urness J, Wright D. 2013. A Survey of Large Wood on the Carmel River: Implications for Bridge Safety Following San Clemente Dam Removal: The Watershed Institute, California State Monterey Bay, Publication No. WI-2013-04, 46 pp.

2003:

Smith, D.P. and Huntington, P., 2004. Carmel River large woody debris inventory from Stonepine to Carmel Lagoon, Fall 2003: Watershed Institute, California State University Monterey Bay, Publication No. WI-2004-01, 72 pp.

2002 pilot study:

Smith, D.P., Huntington, P, and Harter, K., 2003. Carmel River Large Woody Debris Inventory from San Clemente Dam to the Lagoon Fall 2002: Watershed Institute, California State University Monterey Bay, Publication No. WI-2003-13, 38 pp.

# Acknowledgements

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- Larry Hampson (MPWMD)
- Thomas Christensen (MPWMD)
- Amelia Olson (CSUMB)

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# Executive Summary

Large woody debris (LWD) serves multiple functions in stream channel morphology, ecology, and risks in the Carmel River. For example, it provides services and habitat for several life stages of steelhead trout, improves riparian habitat for terrestrial species, fosters hydraulic habitat complexity in the channel, bridges aquatic and terrestrial habitats, influences streambank stability, and can impact flood frequency and bridge safety.

LWD abundance in the lower Carmel River has been influenced by the San Clemente Dam since it was built in 1922. The dam was removed from the river in fall of 2015, before the 2016 water-year runoff. We are conducting a before-and-after dam removal study to assess the changes in LWD that will occur as a result of dam removal. This report documents the position and general description of all LWD in the lower Carmel River immediately before the 2016 water-year runoff. These data provide a clear picture of the "before" dam removal state of LWD that can be compared to future inventories performed "after" dam removal.

In fall 2015, there were approximately 785 instances of single or multiple LWD in the 23.6 km long study reach. The average density of LWD in the river was 33.3 LWD/km. Density varied from 20 LWD/km to 52 LWD/km within the study reach, but no downstream trends were present. Most LWD comprised single, partially-decomposed pieces that were not embedded in the bank or bed, and that measured between 15 cm and 30 cm in diameter and from 1.5 m to 3.0 m in length.

The average density of LWD in the river increased from 20.5 LWD/km (471 pieces) in 2003 to 33.3 LWD/km (785 pieces) reported here. LWD density increased overall and within all 15 sub-reaches of the study area. The increase in LWD is likely the result of long-term MPWMD management activities that fostered native riparian tree growth along the lower Carmel River. Recent drought conditions may have accelerated the recruitment as large willows and cottonwoods died back.

# Introduction

Large woody debris (LWD) has a significant impact on ecological and geomorphic processes in river systems (Daniels 2006); it provides ecosystem benefits and influences channel stabilization but can also damage river infrastructure and increase flood frequency. LWD is transported downstream in the thalweg during large discharge events (CSUMB 2013; Lagasse et al. 1991). It provides hydraulic roughness, improves river connectivity to the floodplain, and facilitates bed scour and pool formation necessary for successful steelhead spawning and anadromous fish habitat (Collins et al. 2011). Many riparian plant and animal species depend on LWD to provide protection and retain moisture in intermittent pools (Tabacchi 1998). Migrating LWD also has the potential to damage bridges and riverside properties during high flow events (Lyn et al. 2003).

Dams inhibit the transport of LWD downstream and impact the natural hydrology and ecology of reaches below impoundments by minimizing large discharge events (Graf 2006). As a result, typical services provided by LWD are restricted, leading to a loss of habitat for aquatic and riparian species. The San Clemente Dam (SCD), located 18.5 miles inland from the Pacific Ocean in the Santa Lucia Mountains of California's Central Coast, was removed from the Carmel River in 2015. During its life, the reservoir storage capacity was reduced from 1,425 acre-feet in 1922 to approximately 70 acre-feet in 2008 due to sedimentation (Alberola 2012). The reservoir had trapped both sediment and large wood for the intervening 93 years.

The Carmel River Re-route and San Clemente Dam Removal (CRRDR) project began July 2013 to restore flow dynamics in the Carmel River (Boughton et al. in review). The CRRDR reconnected the upper Carmel watershed, allowed movement of LWD to lower reaches, and improved federally listed steelhead migration. A 2013 wood census found significantly higher abundances of LWD above the former SCD; high runoff events are likely to transport LWD previously sequestered behind the dam down the channel (CSUMB 2012, CSUMB 2013, Fig. 2). The lower Carmel River is predicted to experience a greater impact from dam removal due to increased flow and a low channel slope (Boughton et al. in review).

We surveyed the density and distribution of LWD in the Carmel River below the former SCD before the 2016 water- year runoff following the methods described in the California State Monterey Bay (CSUMB) 2003 LWD inventory (Smith 2004). We focused on the Carmel Valley from Camp Steffani Road to the Carmel Lagoon (23.57 km, Fig. 1). The data provide a baseline to assess changes in LWD before-and-after dam removal.

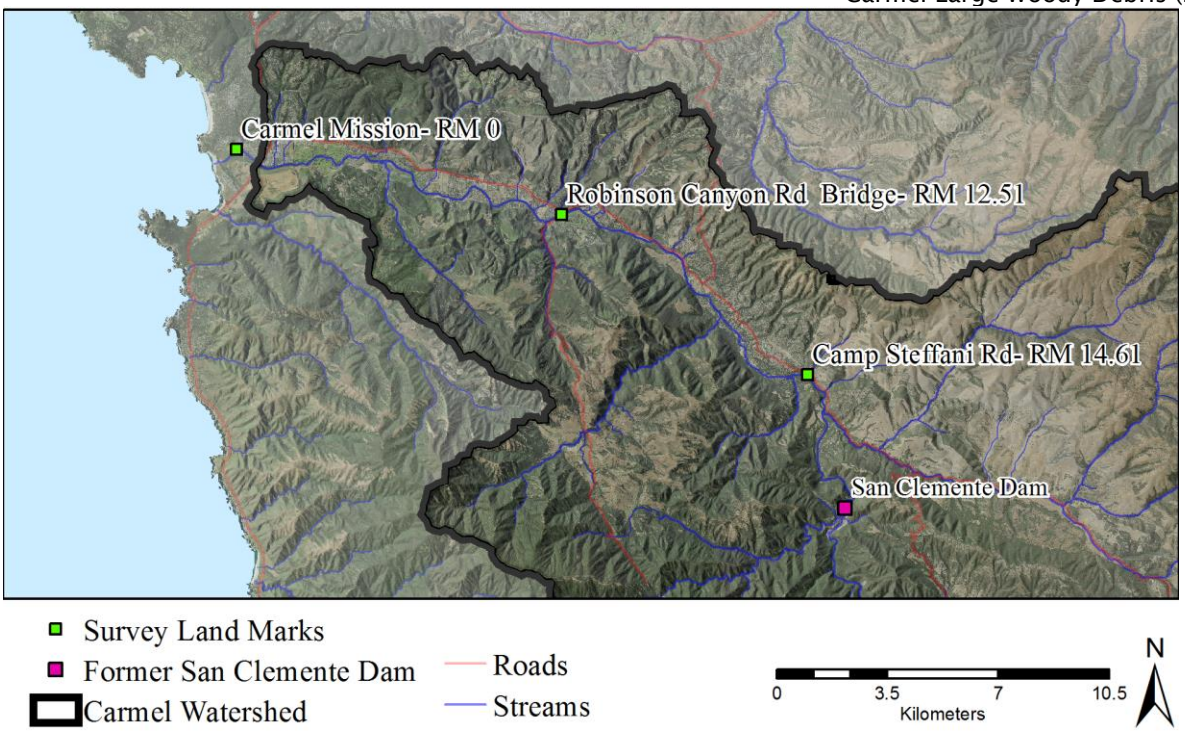



Figure 1. Survey area overview below former San Clemente Dam, Carmel Watershed, CA.

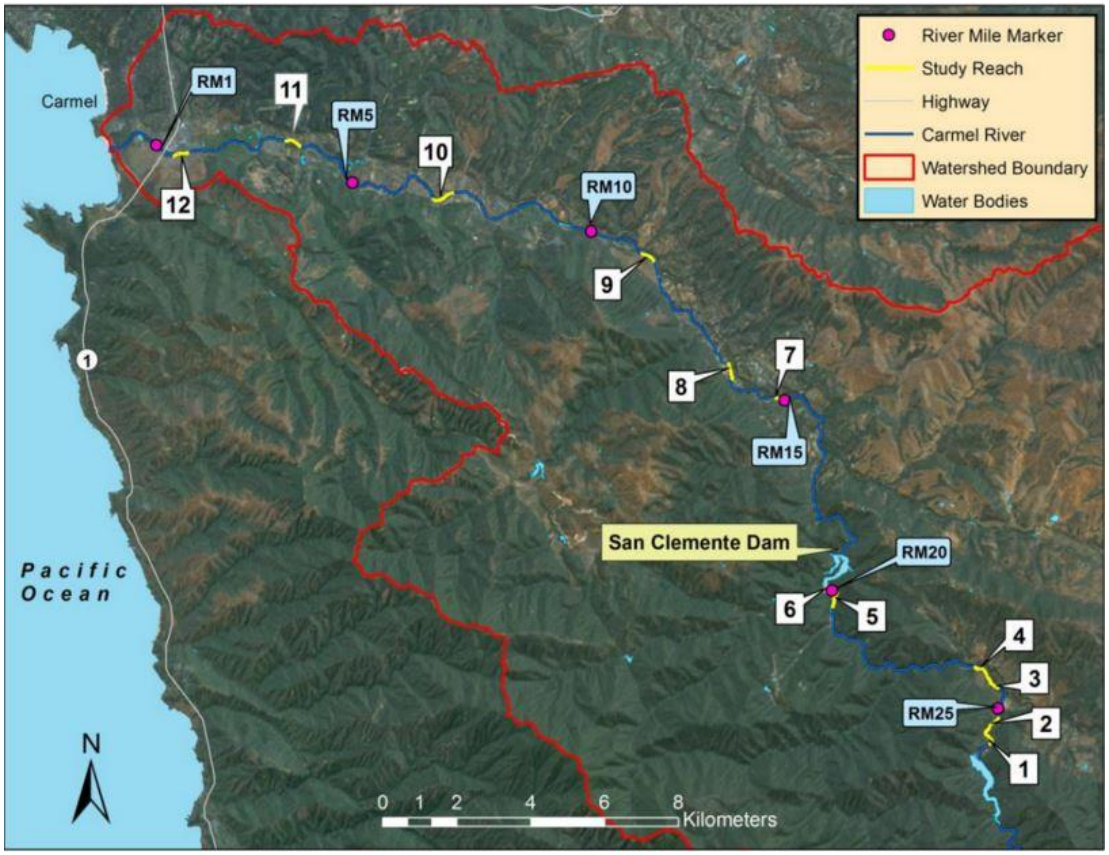



Figure 2. Sample sites of the 2013 LWD survey completed by CSUMB students. The 2013 LWD survey found significantly more wood upstream of the dam (CSUMB 2013).

# Methods

Following the Smith and Huntington (2004) survey protocol, we inventoried all single pieces of wood with a diameter and length of at least 15 cm and 1.5 m, respectively. LWD was included if it occurred in the active channel of the Carmel River. The active channel was defined as approximate bankfull channel estimated to convey approximately the 1.5 to 2 year flow. We identified bankfull when two of three following indicator criteria were met:

1. A consistent break in slope to a lower angle indicating the presence of a significant floodplain
2. ≥ 50% vegetated cover
3. A fining in surface sediment particle size.

We recorded LWD that had the greatest potential to move within the channel and documented whether they were positioned in the active channel or in the area connecting the active channel to the floodplain (Table 1, Appendix A, B). Pieces found in the intermediate area were recorded as <50% within the active channel. Several instances of LWD occurred on the floodplain and were recorded when they had the potential to be recruited at high flow conditions. The study did not include all floodplain areas because they were not usually accessible; the inclusion or exclusion of perichannel wood has the potential to vary between inventories.

When two or more qualifying pieces of LWD were touching, we considered them a "multiple" piece occurrence. We documented the approximate length and width of the accumulation, the average length and width of the pieces within the accumulation by size categories, and the number of LWD that were touching (Appendix A, B). We noted the presence of rootballs for both

**Table 1. Data fields for Carmel LWD. See Appendix A for category descriptions and Appendix B for a sample data sheet.**

| Category | Description |
|---|---|
| Date, reach, surveyors | General reach name assigned |
| Location | Eastings and northings in feet (NAD 1983 California State Plane Zone IV) |
| Log type | Single, multiple, +/- rootball |
| Width (cm) | LWD diameter in centimeters (15 cm minimum, measured in size classes) |
| Length (m) | LWD length in meters (1.5 m minimum, measured in size classes) |
| # Pieces | Estimated number of LWD pieces in a multiple |
| Condition | Degree of wood decay |
| Embedment | How well anchored the wood is in the bed or vegetative bank |
| Part of channel | Main channel, <50% in active channel, not in active channel |
| Bank Location | Location of the wood on river right, river left, or main channel. |
| Type of Substrate | Visual approximation of median grain size beneath LWD |
| Estimated Length | Approximate length of LWD accumulations and jams (m) |
| Estimated Width | Approximate width of LWD accumulations and jams (cm) |
| Comments | |

single and multiple LWD occurrences. We recorded rootballs separately if they had a diameter and length of at least 15 cm and 1.5 m respectively and were detached from the trunk.

We visually approximated the dominant substrate directly below LWD as sandy, pebbles, cobble, or boulders.

LWD embedment was documented according to how well it was anchored in the vegetative bank or the streambed. Pieces of LWD that were not buried in sediment were considered not embedded. LWD that were incompletely embedded in either the streambed or vegetative bank were marked as partially embedded and pieces that were entrenched along their entire length were recorded as fully embedded.

We recorded the condition of LWD as less than 5% decomposed, partially decomposed, or greater than 75% decomposed (Appendix A, B). Pieces that still had the majority of their bark and smaller branches intact were marked as less than 5% decomposed. Pieces were considered greater than 75% decomposed if they easily broke apart.

In the fall of 2015 (September 26 – October 31), 15 reaches of the Carmel River were surveyed for LWD (Fig. 3). From upstream to downstream, these reaches were:

1. Camp Steffani Road to Lower Circle
2. Lower Circle to Rosie's Bridge (2015 only)
3. Rosie's Bridge to deDampierre
4. deDampierre to the Carmel Valley Trail and Saddle Club/ Borronda Road
5. Borronda Road to Garland Park Stables
6. Garland Park Stables to Garland Park
7. Garland Park to the Narrows
8. Narrows to Scarlett Road
9. Scarlett Road to Robinson Canyon Road
10. Robinson Canyon Road to Schulte Road
11. Upstream Schulte to Downstream Schulte
12. Schulte Road to Quail Lodge Golf course
13. Quail Lodge Golf Course to Via Mallorca Road
14. Via Mallorca Road along the Rancho Cañada Golf Course
15. Rancho Cañada Golf Course to the head of the Carmel Lagoon.

The 2015 census re-inventoried reaches from the 2003 survey by Smith and Huntington (2004), with the exception of approximately 0.9 km from the top of Camp Steffani Road to Stonepine Bridge (Table 2). The 2015 survey included an additional river segment from Lower Circle to Rosie's Bridge that was not inventoried in 2003. The end of each reach was the starting point for the next reach.

Camp Steffani Road marked the upper limit of the 2015 study. We ended the survey in the Carmel Lagoon when the water became too deep to wade during low-flow conditions. This point was approximately in-line with the Carmel Valley Mission.

We recorded LWD locations with a handheld Trimble GeoExplorer-III receiver set to SBAS real-time processing. We did not differentially correct the GPS coordinates in Pathfinder Office. We had to manually input several LWD occurrences into ArcMap due to transfer errors in Pathfinder Office; we approximated their locations in relation to LWD logged before and after the missing data based on the time they were recorded.

We created maps using ArcMap (v.10.2) GIS that displayed each single and multiple LWD occurrence over a high resolution NAIP digital orthophoto.

We compared the 2015 results to LWD censuses completed in 2003 and 2013 to identify trends in the distribution and density of wood and to assess how the amount and composition of LWD below the SCD has changed over time.

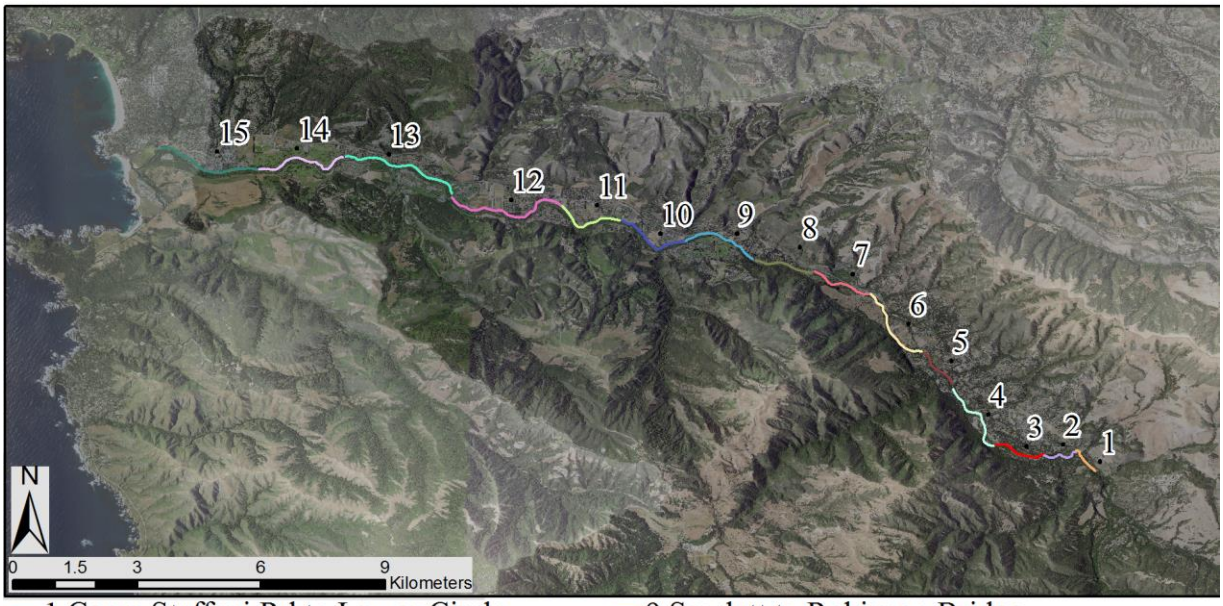



**Figure 3. Lower Carmel Valley surveyed reaches and LWD based upon 2003 Smith and Huntington survey.**

## Results

There were approximately 785 instances of single or multiple LWD occurrences within the 23.6 km (14.6 mi) surveyed (Fig. 4). 85.6% of occurrences were between 15 cm and 30 cm in diameter and 47% were 1.5 to 3.0 meters long (Fig. 5, 6). The average density of LWD in the river was 33.3 occurrences per kilometer (Table 2). Tables 2 through 7 summarize LWD for the fifteen reaches. See Appendix A for descriptions of the data collected.

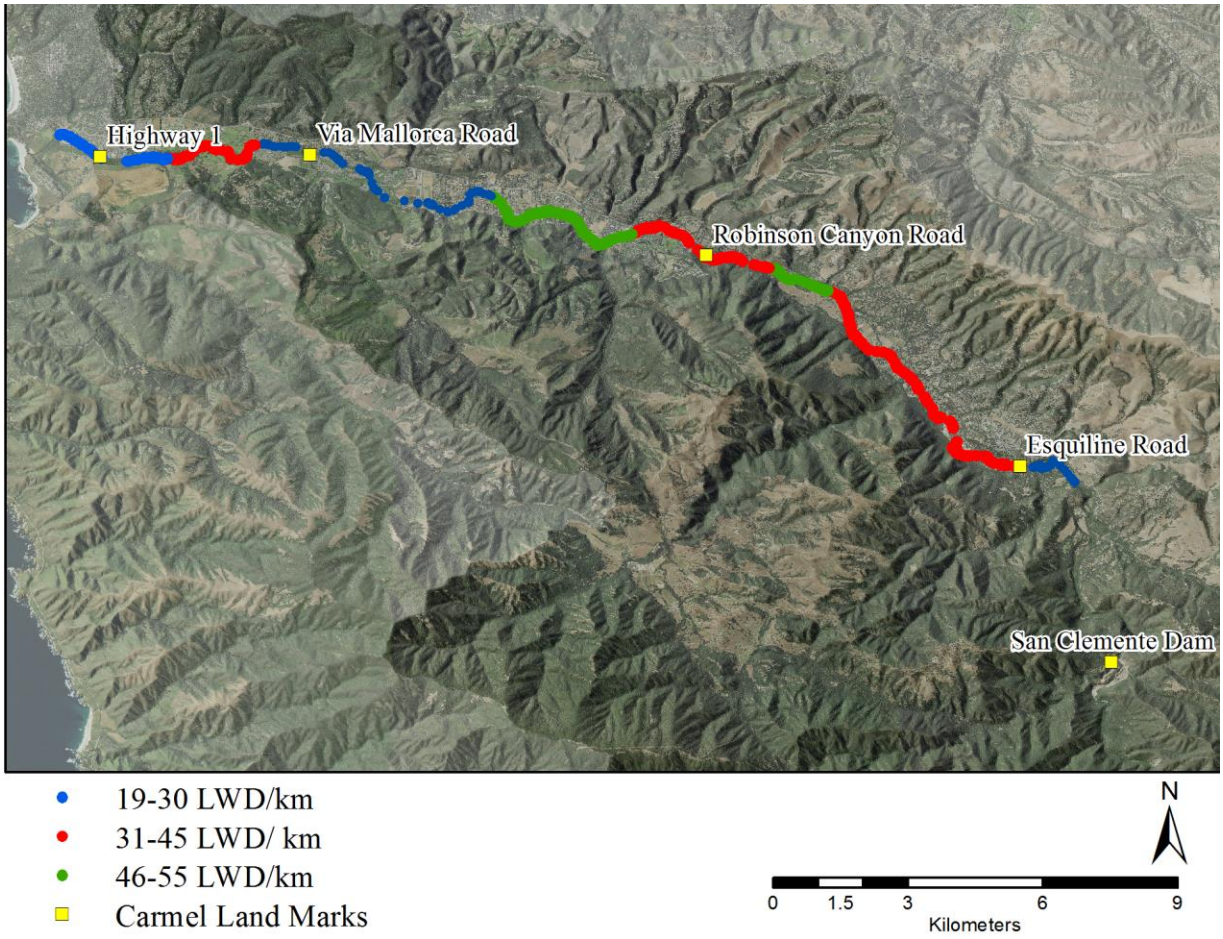



**Figure 4. Occurrences of single and multiple pieces of LWD per km depicted for each surveyed reach. Occurrences/km increased from 2003 survey for all reaches.**

Table 2. Positions of fifteen sample reaches in 2015 LWD survey of the Carmel River, California. Right column is the frequency of single pieces and accumulations per kilometer.

| Reach | Reach length (km) | Cumulative Distance (km) | Cumulative Distance (mi) | Occurrences of LWD | LWD/ km |
|---|---|---|---|---|---|
| **Camp Steffani-Lower Circle** | 0.65 | 23.6 | 14.6 | 13 | 20 |
| **Lower Circle-Rosie's Bridge** | 0.73 | 22.9 | 14.2 | 17 | 23 |
| **Rosie's Bridge-De Dampierre** | 1.04 | 22.2 | 13.8 | 36 | 35 |
| **De Dampierre-Borronda** | 1.83 | 21.2 | 13.1 | 82 | 45 |
| **Borronda-Garland Stable** | 0.88 | 19.3 | 12.0 | 34 | 39 |
| **Garland Stable-Garland Park** | 1.96 | 18.4 | 11.4 | 67 | 34 |
| **Garland Park-Narrows** | 1.18 | 16.5 | 10.2 | 61 | 52 |
| **Narrows-Scarlett** | 1.24 | 15.3 | 9.5 | 53 | 43 |
| **Scarlett-Robinson** | 1.55 | 14.1 | 8.7 | 48 | 31 |
| **Robinson-Upstream Schulte** | 1.63 | 12.5 | 7.8 | 78 | 48 |
| **Upstream Schulte-Down Schulte** | 1.56 | 10.9 | 6.7 | 72 | 46 |
| **Downstream-Quail Lodge** | 2.58 | 9.3 | 5.8 | 54 | 21 |
| **Quail Lodge-Via Mallorca** | 2.50 | 6.7 | 4.2 | 49 | 20 |
| **Via Mallorca-Rancho Canada** | 2.06 | 4.2 | 2.6 | 55 | 27 |
| **Rancho Canada- Lagoon** | 2.18 | 2.2 | 1.4 | 66 | 30 |
| **Total and Weighted mean[1]** | | **23.6** | **14.6** | **785** | **33.3** |

1. Average is weighted by the length of each reach.

Table 3. Summary statistics for 2015 LWD survey of the Carmel River showing LWD occurrence type and whether a rootball was present. See data descriptions in Appendix A.

| # | Reach | Occurrences of LWD | LWD Occurrence Type (% of total reach) | | | |
|---|---|---|---|---|---|---|
| | | | Single | Multiple | Rootball Only | Rootball |
| 1 | **Camp Steffani-Lower Circle** | 13 | 85% | 15% | 0% | 15% |
| 2 | **Lower Circle-Rosie's Bridge** | 17 | 82% | 12% | 6% | 6% |
| 3 | **Rosie's Bridge-De Dampierre** | 36 | 94% | 3% | 3% | 17% |
| 4 | **De Dampierre-Borronda** | 82 | 87% | 12% | 1% | 13% |
| 5 | **Borronda-Garland Stable** | 34 | 85% | 12% | 3% | 12% |
| 6 | **Garland Stable-Garland Park** | 67 | 84% | 16% | 0% | 18% |
| 7 | **Garland Park-Narrows** | 61 | 89% | 10% | 2% | 13% |
| 8 | **Narrows-Scarlett** | 53 | 87% | 11% | 2% | 8% |
| 9 | **Scarlett-Robinson** | 48 | 83% | 15% | 2% | 13% |
| 10 | **Robinson-Upstream Schulte** | 78 | 90% | 8% | 3% | 9% |
| 11 | **Upstream Schulte-Downstream Schulte** | 72 | 88% | 10% | 3% | 13% |
| 12 | **Downstream Schulte-Quail Lodge** | 54 | 87% | 11% | 2% | 13% |
| 13 | **Quail Lodge-Via Mallorca** | 49 | 90% | 8% | 0% | 10% |
| 14 | **Via Mallorca-Racnho Canada** | 55 | 96% | 2% | 2% | 20% |
| 15 | **Rancho Canada-Lagoon** | 66 | 89% | 11% | 0% | 3% |
| | **Total and Weighted Means[1]** | **785** | **81%** | **10%** | **2%** | **12%** |

1. Averages are weighted by the number of occurrences of LWD in each reach.

**Table 4. Summary statistics for 2015 LWD survey of the Carmel River showing LWD bank location and underlying substrate for each reach. See data descriptions in Appendix A.**

| | Bank Location (% of total reach) | | | Substrate (% of total reach) | | | |
|---|---|---|---|---|---|---|---|
| Reach # | Main Channel | River Left | River Right | Sandy | Pebbles | Cobble | Boulders |
| 1 | 23% | 38% | 38% | 15% | 38% | 46% | 0% |
| 2 | 18% | 35% | 47% | 24% | 24% | 47% | 0% |
| 3 | 11% | 58% | 31% | 11% | 31% | 56% | 0% |
| 4 | 21% | 54% | 26% | 24% | 32% | 43% | 0% |
| 5 | 6% | 35% | 59% | 41% | 26% | 29% | 0% |
| 6 | 22% | 19% | 58% | 31% | 34% | 34% | 0% |
| 7 | 20% | 31% | 48% | 34% | 7% | 56% | 2% |
| 8 | 9% | 49% | 42% | 45% | 6% | 45% | 2% |
| 9 | 8% | 48% | 44% | 42% | 15% | 38% | 2% |
| 10 | 13% | 41% | 40% | 31% | 45% | 22% | 0% |
| 11 | 22% | 28% | 36% | 22% | 36% | 36% | 1% |
| 12 | 17% | 31% | 52% | 30% | 19% | 48% | 2% |
| 13 | 18% | 37% | 39% | 14% | 45% | 37% | 4% |
| 14 | 20% | 31% | 47% | 29% | 38% | 27% | 4% |
| 15 | 17% | 33% | 36% | 52% | 33% | 14% | 0% |
| **Wt. mean[1]** | **15%** | **35%** | **39%** | **29%** | **26%** | **35%** | **1%** |

1. Averages are weighted by the number of occurrences of LWD in each reach.

**Table 5. Summary statistics for 2015 LWD survey of the Carmel River showing the condition of LWD for each reach. See data descriptions in Appendix A.**

| | Condition (% of total reach) | | |
|---|---|---|---|
| Reach # | <5% Decomposed | Partially Decomposed | >75% Decomposed |
| 1 | 31% | 46% | 23% |
| 2 | 18% | 71% | 12% |
| 3 | 22% | 58% | 19% |
| 4 | 16% | 72% | 12% |
| 5 | 41% | 50% | 9% |
| 6 | 18% | 69% | 13% |
| 7 | 15% | 72% | 13% |
| 8 | 34% | 57% | 9% |
| 9 | 23% | 69% | 8% |
| 10 | 14% | 82% | 4% |
| 11 | 15% | 79% | 6% |
| 12 | 11% | 83% | 6% |
| 13 | 6% | 73% | 20% |
| 14 | 24% | 60% | 16% |
| 15 | 18% | 68% | 14% |
| **Wt. mean[1]** | **17%** | **66%** | **10%** |

1. Averages are weighted by the number of occurrences of LWD in each reach.

**Table 6. Summary statistics for 2015 LWD survey of the Carmel River showing LWD embedment for each reach. See data descriptions in Appendix A.**

| | Embedment (% of total reach) | | | | |
|---|---|---|---|---|---|
| Reach # | No embedment | Partially in bed | Partially in veg bank | Fully in bed | Fully in veg bank |
| 1 | 62% | 8% | 31% | 0% | 0% |
| 2 | 71% | 12% | 12% | 6% | 0% |
| 3 | 69% | 0% | 31% | 0% | 0% |
| 4 | 61% | 12% | 20% | 6% | 0% |
| 5 | 62% | 9% | 26% | 3% | 0% |
| 6 | 64% | 10% | 22% | 3% | 0% |
| 7 | 61% | 11% | 26% | 2% | 0% |
| 8 | 45% | 11% | 42% | 2% | 0% |
| 9 | 58% | 4% | 38% | 0% | 0% |
| 10 | 71% | 5% | 22% | 3% | 0% |
| 11 | 64% | 3% | 29% | 3% | 1% |
| 12 | 56% | 11% | 31% | 2% | 0% |
| 13 | 49% | 16% | 27% | 6% | 0% |
| 14 | 51% | 13% | 29% | 7% | 0% |
| 15 | 50% | 9% | 35% | 6% | 0% |
| **Wt. mean[1]** | **55%** | **8%** | **26%** | **3%** | **0%** |

1. Averages are weighted by the number of occurrences of LWD in each reach.

**Table 7. Summary statistics for 2015 LWD survey of the Carmel River showing whether LWD was part of the active channel for each reach. See data descriptions in Appendix A.**

| | Part of Channel (% of total reach) | | |
|---|---|---|---|
| Reach # | In Active Channel | <50% in Active Channel | Not in Active Channel |
| 1 | 54% | 38% | 8% |
| 2 | 47% | 41% | 12% |
| 3 | 42% | 36% | 22% |
| 4 | 55% | 39% | 6% |
| 5 | 62% | 35% | 3% |
| 6 | 64% | 36% | 0% |
| 7 | 69% | 28% | 3% |
| 8 | 55% | 38% | 8% |
| 9 | 46% | 44% | 10% |
| 10 | 56% | 42% | 1% |
| 11 | 54% | 42% | 3% |
| 12 | 69% | 31% | 0% |
| 13 | 57% | 35% | 6% |
| 14 | 78% | 20% | 2% |
| 15 | 70% | 27% | 3% |
| **Wt. mean[1]** | **54%** | **34%** | **5%** |

1. Averages are weighted by the number of occurrences of LWD in each reach.

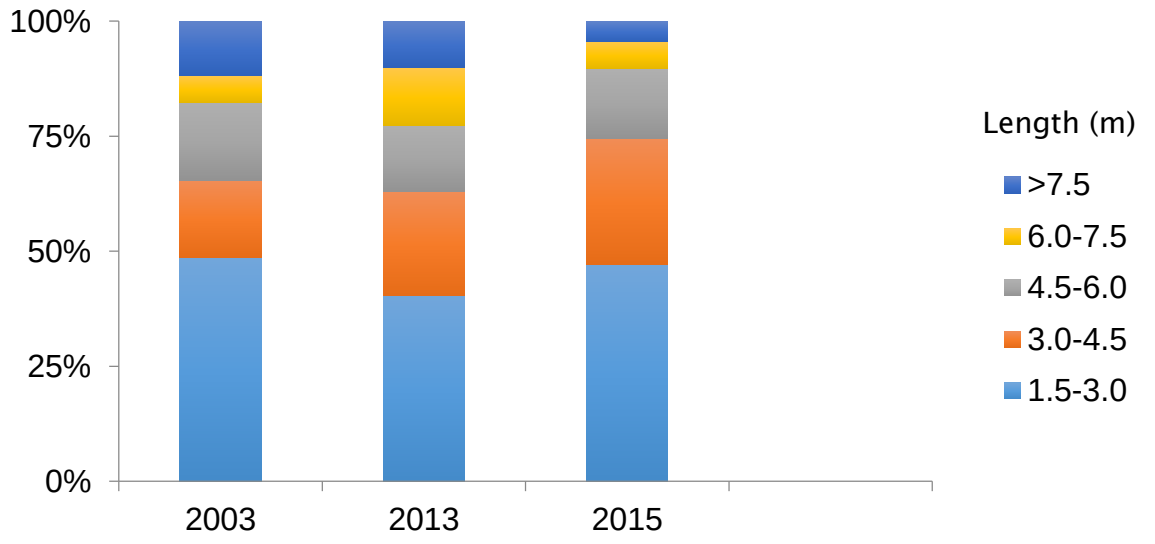
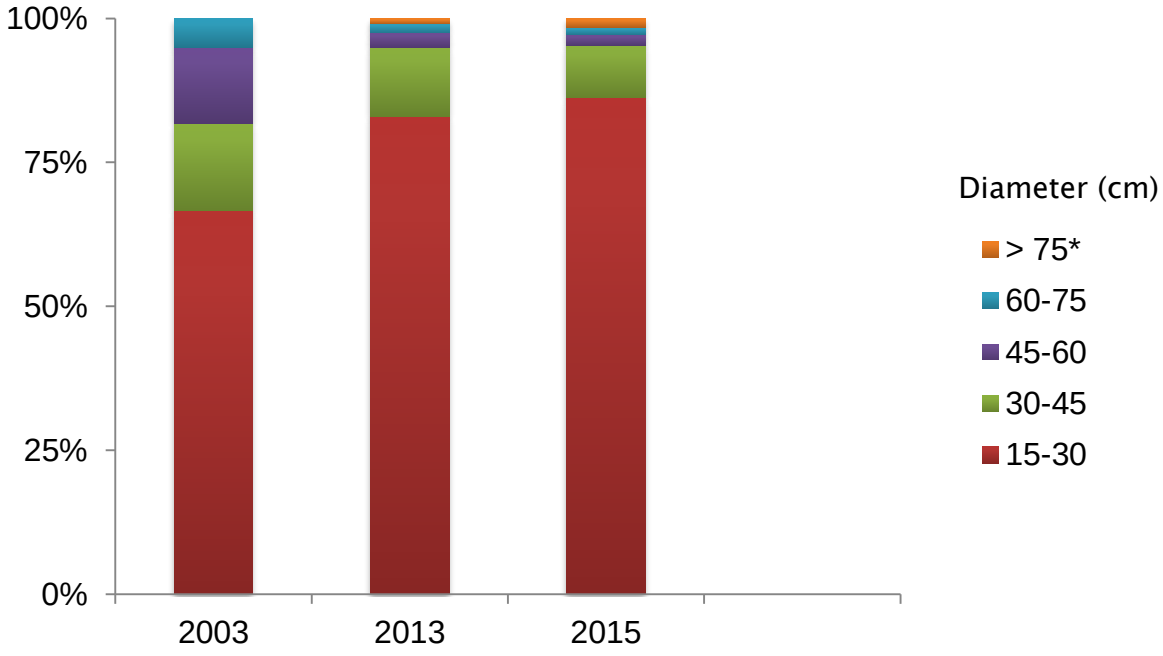
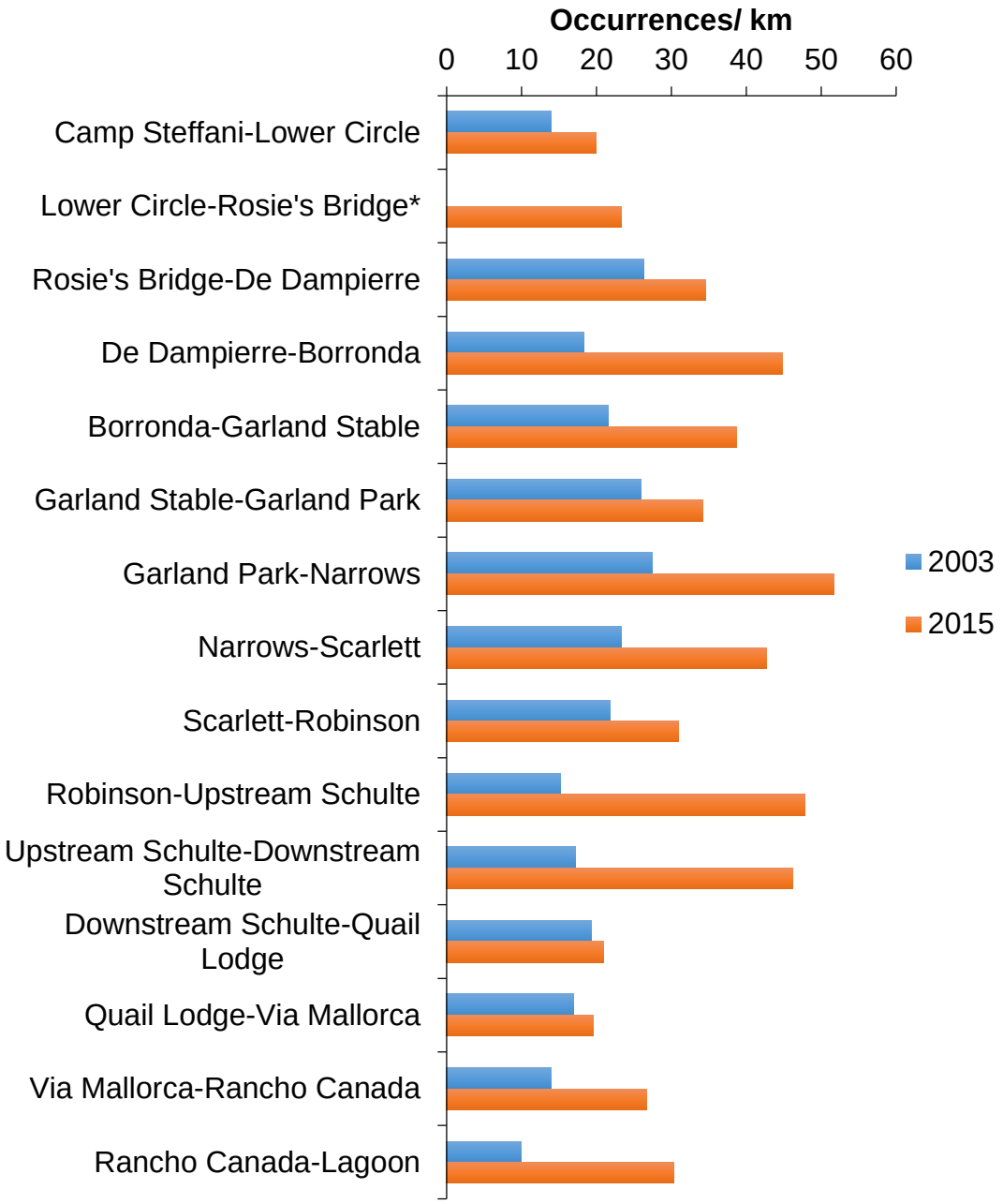



**Figure 5. Percent of LWD in each length class by year. The 2003 and 2015 surveys represented ~24 km while the 2013 study surveyed 600 m.**



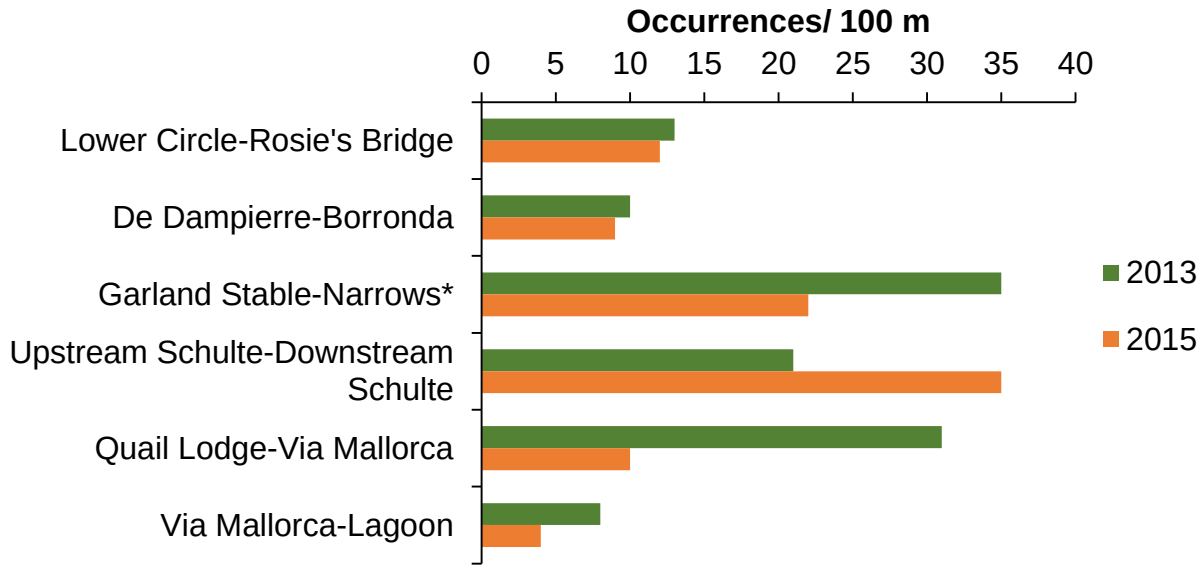

* 2003 did not use the > 75 cm size category, the largest measurement was > 60 cm.

**Figure 6. Percent of LWD in each diameter class by year. The 2003 and 2015 surveys represented ~24 km while the 2013 study surveyed 600 m.**




* Lower Circle to Rosie's Bridge was not surveyed in 2003.

**Figure 7. Occurrences of large woody debris (LWD) per kilometer by reach for 2003 and 2015. Accumulations were considered as a single occurrence.**




*The Garland Stable-Narrows 100m reach surveyed in 2013 spanned the divide between two of the 2015 reaches.

**Figure 8. Occurrences of large woody debris (LWD) for 100 m stretches within the specified reach for 2013 and 2015. Accumulations were considered as a single occurrence.**

LWD densities increased along the entire study area from 2003 to 2015; all reaches had more LWD present in 2015 (Fig. 7). The comparison between the 2013 and 2015 surveys was less consistent; Upstream Schulte-Downstream Schulte had more wood in 2015 and the other 100 m sections had less than 2013 (Fig. 8). Hydrographs of the Carmel River from gages at Robles del Rio (Esquiline Rd.) and Carmel (near Via Mallorca) depict discharge from 2002 to 2015 with arrows indicating the time that LWD surveys occurred (Fig. 9, 10).

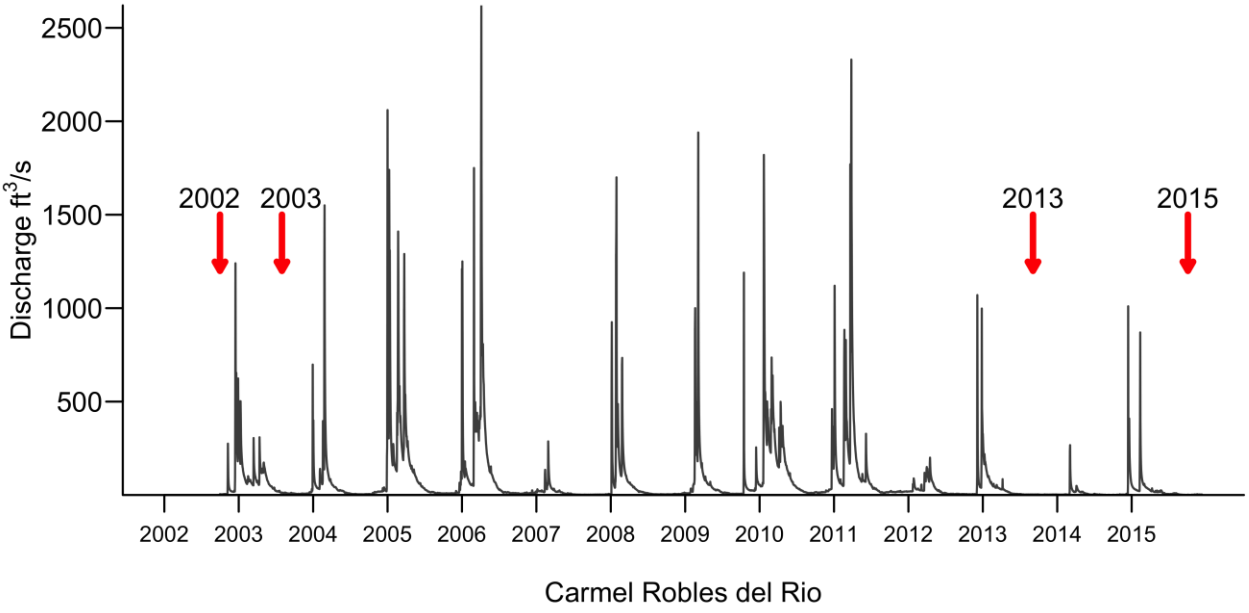



**Figure 9. Hydrograph of mean daily stream flow for the Robles del Rio gage on the Carmel River. Red arrows indicate when LWD surveys took place.**

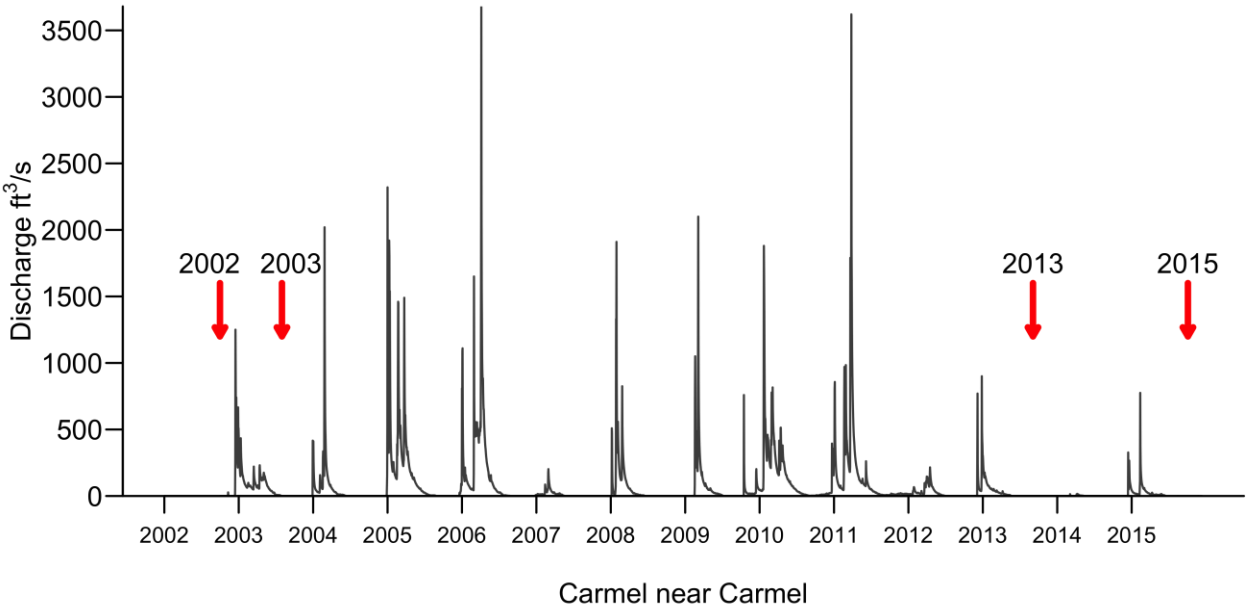



**Figure 10. Hydrograph of mean daily stream flow for the Carmel gage at Via Mallorca on the Carmel River. Red arrows indicate when LWD surveys took place.**

## Discussion

Increased observances of LWD in the active channel since 2003 may be the result of maturation of improved riparian vegetation conditions along the river corridor. The MPWMD has managed LWD and riparian vegetation in the lower Carmel channel since 1988. The 2006 EIR for Aquifer Storage and Recovery Phase 1 required the district to implement a Riparian Habitat Program (RHP) to mitigate the impact of reduced groundwater availability on vegetation by establishing supplemental watering sites along the corridor (MPWMD 2012). As a result, riparian corridors developed robust vegetation and produced larger limbs.

Large storm events in 2005, 2006, and 2011 likely increased growth of riparian vegetation; however, persistent drought and higher than average temperatures caused many riparian species to die back. The MPWMD riparian monitoring report showed that willows and cottonwoods experienced high stress from reduced groundwater availability in 2014 and predicted “some dieback on their outer most branches” (MPWMD 2014). The hydrographs of the Carmel River were consistent with these observations and indicated extremely low mean daily stream flows in 2014 (Fig. 9, 10). The success of the RHP irrigation program led to sustainability of riparian vegetation in the presence of reduce water availability which increased the recruitment potential of LWD within the managed corridor.

We observed reduced density and accumulation of LWD in areas near residences and with greater river channel access. This result was consistent with the densities of LWD found in 2003 and 2013. We attribute this reduction to golf courses and homeowners periodically clearing the channel to reduce flood risk. The RHP required MPWMD to dismantle debris accumulations that posed a threat to bank stability and infrastructure. As a result of this management protocol many pieces of LWD were cut short and did not meet the size requirements of our survey.

We recognize the potential for variation between the 2003, 2013, and 2015 surveys such as observer bias and differences in active channel delineation. The 2003 and 2015 surveys were conducted by the same individuals throughout the study. In contrast, the 2013 study was completed by 11 individuals each observing separate sites which may have increased the instance of errors between observers. Additionally, defining the active stream channel proved difficult in braided reaches such as Borronda to Rosie’s Bridge. Dense willow growth in lower channel segments could disguise LWD occurrences.

The CSUMB (2013) survey reported elevated occurrences of LWD upstream of the San Clemente Dam, and therefore predicted that LWD density would increase in the lower Carmel River when the dam was removed. Comparing this study with future surveys of LWD occurrences in the lower Carmel River will allow managers to quantify the effects of dams on LWD density.

# Appendix A: Data Category Descriptions

| Category | Characteristic | Description |
|---|---|---|
| **Reach** | | Name of the stretch of Carmel River surveyed |
| | | LWD locations recorded using easting and northing in feet (NAD 1983 California State Plane Zone IV) |
| **Piece #** | | LWD were assigned a unique ID as they were recorded |
| **LWD Occurrence Type** | Single | A single piece of LWD at least 15 cm by 1.5 m |
| | Multiple | 2 or more touching pieces of LWD |
| | Rootball | Rootball only, tree no longer attached |
| **Type of Substrate** | Sandy | Sediment <2 mm, assessed qualitatively without gravelometer |
| | Pebbles | Golf ball sized, assessed qualitatively without gravelometer |
| | Cobble | Fist-sized, assessed qualitatively without gravelometer |
| | Boulders | Cinderblock size or larger, assessed qualitatively |
| **Rootball present** | Yes/ No | Rootball attached to LWD or not |
| **Part of Channel** | Yes | LWD >50% in active channel |
| | <50% active channel | LWD partially in active channel, but >50% was in the floodplain |
| | No | LWD just outside the active channel that had the potential to be recruited into the river at high flow conditions |
| **Length (m)** | 1.5 m size classes | LWD length in meters (1.5 m minimum) |
| | | 1.5-3.0, 3.0-4.5, 4.5-6.0, 6.0-7.5, >7.5 |
| | | For multiple pieces, this was the average log length |
| **Width (cm)** | 15 cm size classes | LWD diameter in centimeters (15 cm minimum) |
| | | 15-30, 30-45, 45-60, 60-75, >75 |
| | | For multiple pieces, this was the average log diameter |
| **Length of Accumulation** | | Multiple pieces only, approx. length of entire accumulation (m) |
| **Width of Accumulation** | | Multiple pieces only, approx. width of entire accumulation (cm) |
| **# Pieces in Accumulation** | | Multiple pieces only, # pieces LWD present |
| **Condition** | <5% decomposed | Bark intact, smaller branches present |
| | Partially decomposed | Bark missing, branches deteriorating |
| | >75% decomposed | Would break apart if stepped on |
| **Embedment** | No embedment | LWD not buried in sediment at all |
| | Partially in river bed | LWD embedded in the streambed along part of its length |
| | Partially in vegetative bank | LWD embedded in the vegetative bank along part of its length |
| | Fully embedded in river bed | LWD embedded in the streambed along its entire length |
| | Fully embedded in bank | LWD embedded in the vegetative bank along its entire length |
| **Bank location** | River Left | Left bank looking down river |
| | Main Channel | LWD in the main channel, not associated with either bank |
| | River Right | Right bank looking down river |
| **NA** | | Data was either not applicable or missing |

# Appendix B: 2015 Survey Data Sheet

Data sheet: **Single Piece**
Date:
Surveyors:
Reach:
Piece #:

**Type of Substrate:**
Sandy
Pebbles
Cobble
Boulders

**Rootball present:**
Yes/ No

**Part of Channel:**
Yes/ No
<50% active channel

**Length (m):**
1.5-3.0
3.0-4.5
4.5-6.0
6.0-7.5
>7.5

**Width (cm):**
15-30
30-45
45-60
60-75
>75

**Condition:**
<5% decomposed
Partially decomposed
>75% decomposed

**Embedment:**
No embedment
Partially in bed
Partially in veg bank
Fully embedded in bed
Fully embedded in veg bank

**Bank location:**
River left
Main Channel
River Right

Data sheet: **Multiple Pieces**
Date:
Surveyors:
Reach:
Piece #:

**Type of Substrate:**
Sandy
Pebbles
Cobble
Boulders

**Rootball present:**
Yes/ No

**Part of Channel:**
Yes/ No
<50% active channel

**Average Length of LWD (m):**
1.5-3.0
3.0-4.5
4.5-6.0
6.0-7.5
>7.5

**Average Width of LWD (cm):**
15-30
30-45
45-60
60-75
>75

**Length of Accumulation (m):**
**Width of Accumulation (cm):**
**# LWD in Accumulation:**

**Condition:**
<5% decomposed
Partially decomposed
>75% decomposed

**Embedment:**
No embedment
Partially in bed
Partially in veg bank
Fully embedded in bed
Fully embedded in veg bank

**Bank location:**
River left/ Main Channel/ River right

Data sheet: **Rootball Only**
Date:
Surveyors:
Reach:
Piece #:

**Type of Substrate:**
Sandy
Pebbles
Cobble
Boulders

**Part of Channel:**
Yes/ No
<50% active channel

**Length (m):**
1.5-3.0
3.0-4.5
4.5-6.0
6.0-7.5
>7.5

**Width (cm):**
15-30
30-45
45-60
60-75
>75

**Condition:**
<5% decomposed
Partially decomposed
>75% decomposed

**Embedment:**
No embedment
Partially in bed
Partially in veg bank
Fully embedded in bed
Fully embedded in veg bank

**Bank location:**
River left
Main Channel
River Right

# Appendix C: 2015 Photo Documentation

Figure 11. LWD Rootball located in the Camp Steffani to Rosie's Bridge reach.

Figure 12. Multiple piece accumulation composed of nine pieces with an average length of 3.0-4.5. Dominant substrate type cobble.

Figure 13. Single piece observance in the main channel reach between Via Mallorca to Rancho Canada. LWD occurrences were documented as multiple pieces occurrences only when two or more qualifying pieces touched.

Figure 14. Single piece with rootball located in the main channel in Garland Park.

Figure 15. Single Piece observance partially embedded in the vegetated bank. Recorded as <=50% of the active channel and partially decomposed. Observed in the Borronda to Garland Park Stables reach.

Figure 16. Irrigation pipeline installed by the MPWMD as part of the RHP in the Quail to Via Mallorca survey area. The LWD on the right was outside the active channel, but recorded due to its high recruitment potential during a high flow event.

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