# Local and Longitudinal Patterns of Woody Debris Accumulation

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## Abstract

Woody debris (WD) in rivers is recognized for its influence on channel form and function. A large body of literature describes the patterns of WD accumulation and the associated effect on channel morphology but very little data address the factors that determine wood mobility and retention. These factors are important for describing the overall wood regime or wood load in a given system. Most of existing log jam research has been conducted on large, low gradient rivers or small headwater tributaries. Few studies have described the patterns and processes of wood accumulation and transport in steep mountain channels. In order to address these gaps, we focus on Big Creek, a high gradient tributary to the Middle Fork Salmon River, located in the semi-arid Frank Church River of No Return Wilderness in central Idaho. Avalanches in spring, 2014 delivered thousands of logs to the channel, most of which remains as a single log raft in the upper reaches of Big Creek. The objective of this project was to define the current patterns of wood character and recruitment along Big Creek. Secondly, we compare the character of wood delivered by avalanche to wood delivered by deadfall in riparian areas. It is hypothesized that the length and root wad structure of avalanche debris will differ from riparian wood. Downstream jams, composed of wood largely recruited from riparian areas, were found to have a wider distributions of sizes than the wood delivered by avalanche. Neither the avalanche wood nor the riparian wood contained many root wads. The relationship between drainage area and log size was found to be insignificant. Differences between the two data sets were minor and suggest a similar method of delivery to the channel. Further investigation is needed to find if the majority of WD in Big Creek is delivered from the surrounding hillslopes rather than the riparian flood plain.

## Introduction

In a forested watershed, the role and influence of woody debris (WD) is fundamental to understanding all other geomorphic processes related to rivers. The geomorphic influence of WD has been observed to affect the following physical characteristics: channel roughness and bed surface character, sediment storage and routing (Gurnell et al., 2002), the formation of valley bottom land forms, and in stream habitat (Collins et al., 2012). Notably, wood can be of equal importance to channel morphology as sediment and discharge patterns (Montgomery, et al. 2003). Wood accumulation causes varying bedforms like bars, pools, and log steps depending on the type of accumulation and location in the channel (Abbe and Montgomery, 2002). The influence of WD is a function of the volume of wood within a channel reach and wood stability (Abbe & Montgomery, 2002).

The removal of WD can have drastic effects on a river. Channel incision, elevated turbidity and bank erosion can be consequences of the loss of WD (Montgomery et al. 2003). River managers are often asked to assess the wood load for the study reach or river. Impaired streams are often those that have bank erosion problems or water quality issues like elevated turbidity levels. However, it remains unclear as to whether the practice of re- introducing WD to an impaired stream is an effective means to restore natural channels.

One method to define wood load is a longitudinal census or survey of WD accumulations and individual piece characteristics within a jam. Length and diameter of individual logs has been observed to influence piece mobility (Wohl and Beckman, 2014). Investigating the pattern and distribution of woody debris in natural or unaltered riparian environments is important such that they may serve as a baseline to inform restoration efforts (Wohl, 2008). Some research suggests, wood recruitment mechanisms and forest age are important predictors of wood load and jam formation (Wohl and Cadol, 2010). Wood recruitment refers to the transport mechanisms that deliver WD to the active channel. The primary goal of this project is to compare the character of wood that was delivered to Big Creek by (A) the avalanches of 2014 (B) bank fall and in-stream transport.

## Setting

Big Creek is a steep mountain channel that is tributary to the Middle Fork of the Salmon River. The majority of its length flows through the Frank Church- River of No Return Wilderness. The forests surrounding Big Creek have experienced fire in the early 2000s and late 1990s. There were several avalanches to occur in March of 2014 just downstream of the Big Creek trailhead near the confluence of Smith Creek. These deposited large amounts of WD to the channel. Only the first and the last of the four avalanche debris deposits, remain as channel spanning accumulations. They are named jam A and jam D. Jam D is about 200m in length and spans the width of the channel for that entire length. Some wood remains on the adjacent hill slope from the avalanche. It is likely that jam D contains wood from the upstream avalanches A, B and C as well.

## Methods

The main goal our initial survey was to characterize the wood found within jam D. The secondary goal of the survey was to provide an accurate assessment of the spatial orientation of the wood within the channel. This allows for future assessment of compression or break up of the wood within the jam. A Leica total station was used. Initially, an arbitrary Cartesian coordinate system of easting, northing and elevation was set. The coordinate system unit was meters. A total of six control points were set up around the perimeter of jam D. Each one consists of a piece of rebar; driven into the ground about 30cm, and capped with an aluminum head stamped with a number. Having control points allowed for the use of the resection method during total station set up. No fewer than four control point locations were used for each set up. A Leica 360-degree reflector on a 2m tall survey pole was the total station’s target.

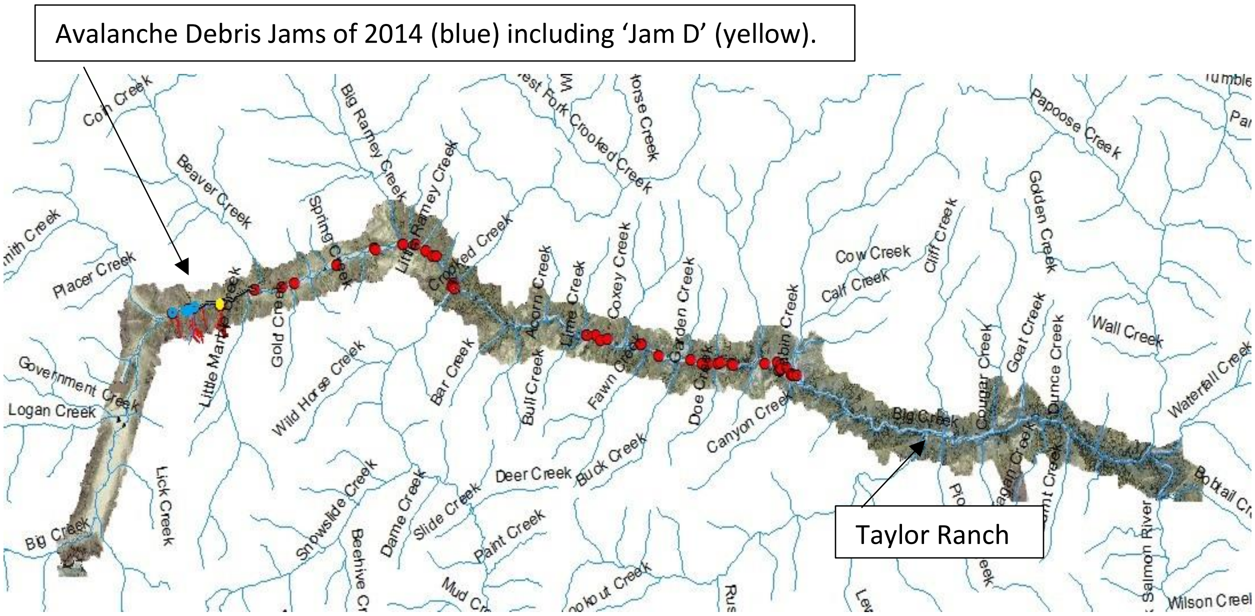
Key variables measured were piece length, diameter, and root code. Root code was defined by three numerical categories; 1: snapped end, 2: presence of root bole, and 3: presence of roots and or root wad. Individual logs were surveyed by positioning the reflector at both ends. Every effort was made to position the reflector over the end of the log, however if the log was partially buried within the jam or within sediment the reflector was held above the last visible position. The difference between point pairs was used to find length using the distance formula: $\sqrt{((x_2-x_1)^2+(y_2-y_1)^2+(z_2-z_1)^2)}$. Diameter was measured by wrapping around the log with a metric diameter tape. To aid future monitoring of movement within the jam, special points were shot throughout the jam. These points were shot as individual points usually in the middle of a key piece within the jam. The points were marked with a hand saw as an “x”, and then were numbered and circled with permanent marker. Twenty of these points were marked.

The second half of the project involved a longitudinal study of the WD accumulations found downstream of jam D. Similarly, piece length, diameter and root code were measured for pieces at least 1 m long and 10 cm in diameter. The longitudinal survey also served as a means to map the current distribution of WD within Big Creek. A laser rangefinder was utilized to measure the character and orientation of the downstream jams. The range finder was mounted onto a camera tripod. A single vantage point was used for each of the jams surveyed. The location of the vantage point was recorded with a handheld GPS for each site. The reflector used in this situation was made of an adjustable pole of PVC, with a red bike reflector attached to the top. The reflector height was set to match the height of the rangefinder’s laser at each site. To ensure accurate targeting of the reflector, the rangefinder was set to only accept points from highly reflective surfaces. The surveying procedure followed the same procedure as jam D for measuring length, diameter, and root code. Points from the rangefinder were reported in spherical coordinates, relative to the setup position, as azimuth, sight distance and inclination. These coordinates were recorded for each log by hand in a field notebook and then entered by hand into a spreadsheet. A spherical to Cartesian transformation allowed the metrics such as piece length to be calculated.

The location of each jam was marked on the existing LiDAR dataset. Upstream drainage area was calculated, for each jam, within a GIS using a 10 m USGS NED derived flow accumulation model. The longitudinal survey continued downstream from jam D until reaching the Cabin Creek valley; about 6 miles upstream from The University of Idaho's Taylor Ranch research facility. Photos and a written field description were also taken at each jam, including jam D.

## Results

The map view of the surveyed jams is shown in Figure 1. The cluster of jams at the western side of the image represents the Cabin Creek area. This area is a wide fluvial valley with a braided channel network. Most of Big Creek was a narrow bedrock channel up to this point. The Cabin Creek valley had the greatest concentration of jams throughout Big Creek. Root code distributions were nearly identical for both data sets (Figure 2). Length and diameter differed slightly between jam D and the downstream jams. Figures 3 and 4 show that the downstream jams have more variance in size than the wood in Jam D. Both data sets have similar mean diameters of 30cm. There is not a clear trend in piece size as a function of with drainage area (Figure 5). A weak trend of diameter decreasing with drainage area is present.



Avalanche Debris Jams of 2014 (blue) including 'Jam D' (yellow).

Taylor Ranch

**Figure 1**: Map view of the LiDAR coverage extending down the Big Creek's mainstem corridor. Red lines in the western portion of the image are the avalanche paths while red dots are the locations of visited logjams. The yellow dot marks jam D and the blue dots mark the location of the other avalanche deposits.

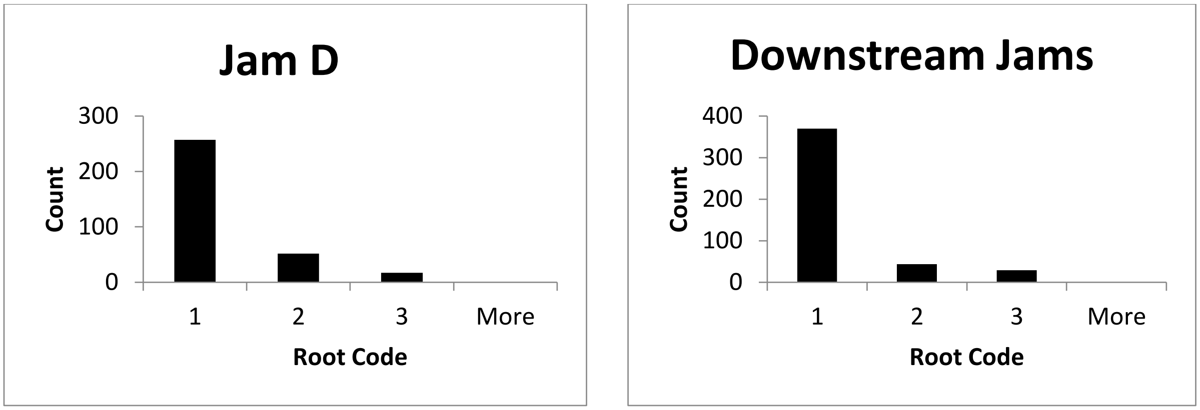


**Figure 2**. Histograms of the distribution of root codes within Jam D (top) and the surveyed logjams along Big Creek (bottom). . Root code is defined as three numerical categories; 1: base of tree snapped off, 2: presence of root bole, and 3: presence of roots and/or root wad. These histograms illustrate the similarity between the avalanche delivered wood at Jam D and the bank input debris of the downstream jams.

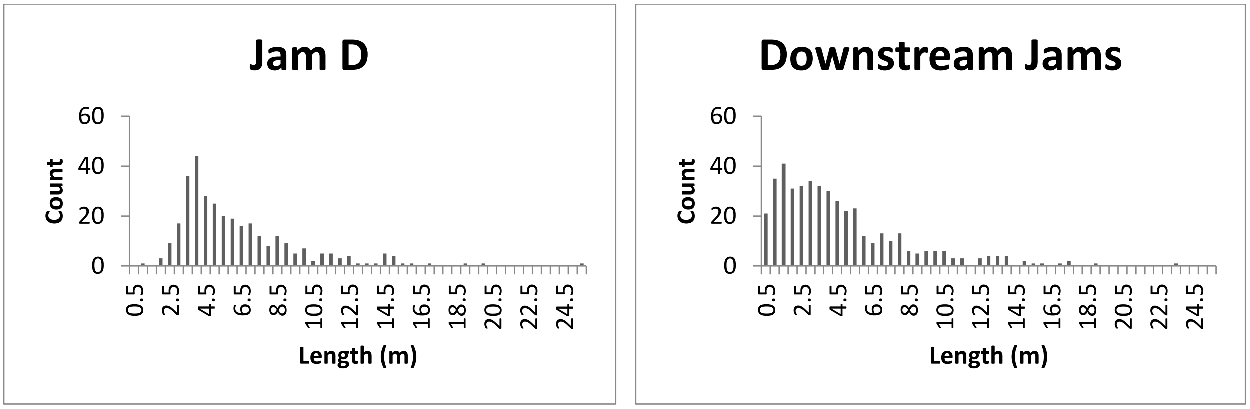


**Figure 3**. Histograms showing the distribution of piece lengths. Jam D has a more normal distribution of lengths and longer median length than the downstream jams. The downstream jams have more long and short pieces than jam D.

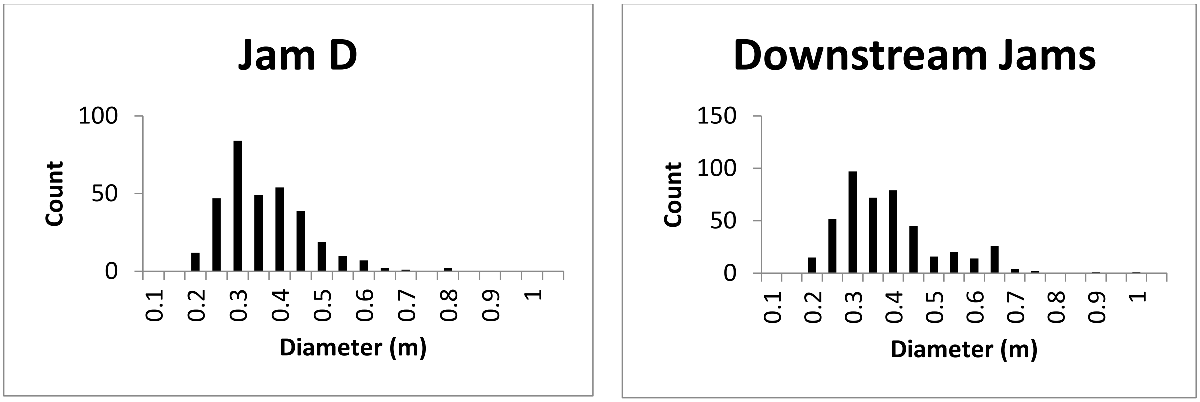


**Figure 4**. Histograms showing the distribution of diameters. The downstream jams exhibit more variance in log diameter and have more logs with large diameters than jam D. Large diameter logs may act as key members in the downstream jams.

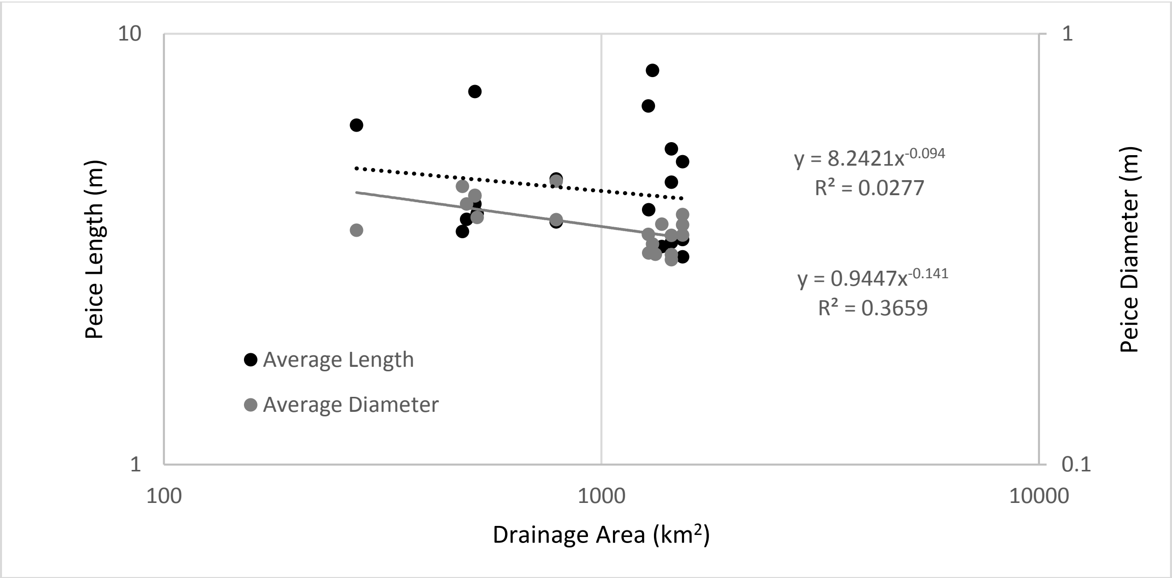


**Figure 5**. The average piece length and diameter from each of the surveyed jams, are plotted against the upstream drainage area of each jam location. Log axes are used. Power law regression equations and $R^2$ are shown on the graph; diameter equation at top and length below. The correlation between these piece size characteristics and drainage area is weak. There is a slight trend toward logs with smaller diameter as upstream drainage area increases.

## Discussion

Overall the downstream jams had larger pieces than Jam D. Some of the jams downstream seem very old by the degree of rot. The downstream jams may reflect different generations of forest growth and wood delivery. In nearly all of the jams surveyed, logs with burn scars from fire were found. It may be possible that after fires large quantities of wood are delivered to Big Creek. It remains unclear what the dominant transport or wood recruitment mechanism is.

The size characteristics of jam D followed a more normal distribution. This may suggest that pieces within the avalanche debris are more homogeneous. The avalanche wood had less travel to reach the channel and may not have received many opportunities to break during transport.  Root code distributions were similar for wood in jam D and the downstream jams (Figure 1). It was expected that the avalanche debris would not include many pieces with intact root wads. The avalanche debris existed as standing dead before the transport event. Due to the speed and force with an avalanche travels; it was expected that the trees caught up in the debris flow would preferentially snap at the base, rather than pull root wads along with them in transport. Contrary to that expectation, wood in the downstream jams was expected to contain more pieces with root wads (root code 3) but did not.  It is possible that the root wads were snapped off during downstream transport. The prevalence of standing dead wood on floodplains continued as the survey moved downstream.  It is possible that most of the bank input WD snaps at the base from wind and does not include a root wad. In systems unaffected by fire or beetle kill, most riparian inputs to the channel are due to bank erosion undercutting trees, thus delivering live trees into the river, along with their full root wads.  In areas where the majority of delivered wood is standing dead, snapped trees leave root wads in the ground, which may shorten the retention time of individual logs in the system and diminishing their capacity to snag and alter stream form.

As a consequence of increasing transport capacity of a larger river, piece length and diameter were expected to increase in the downstream direction. As the river progresses downstream drainage area and in general channel width is also expected to increase. These factors lend toward a higher transport capacity. The results shown in Figure 5 do not show any significant correlation between size and drainage area or between size and distance from the confluence point.  Drainage area and downstream distance may not be suitable for predicting piece length within jams. In future studies the relationship between jam frequency and upstream drainage area should be examined. Likewise, the relationships between overall jam volume and upstream drainage area should be considered. Similar relationships may exist with distance from the confluence point.

## Conclusion

There were only minor differences between wood derived from avalanche and wood derived for bank input in the riparian zones of Big Creek. The overall similarities between the two data sets may suggest that the dominant recruitment mechanism for in stream wood might be avalanche or debris flow from the surrounding hillslopes. It is possible that in similar rivers with narrow flood plains and steep canyons that this is also the case. The avalanches of 2014 are thought to be caused by rain on snow storms during the spring. These events may continue if current climate trends persist. Since most of the surrounding forests have been disturbed by fire, ongoing wood recruitment patterns in Big Creek will be affected in the years to come. Continued monitoring of WD recruitment and movement is needed to further define the wood load for Big Creek. It is important to consider forest health and the dominant transport mechanism by which WD enters the river; all of which can influence were and how jams form (Wohl and Cadol 2010). The stability of a jam has much to do with the character of the wood involved and thus the jam's geomorphic role within the river (Montgomery et al, 2003). A better understanding of current patterns of wood mobility, retention, and recruitment along Big Creek and its resilience following natural disturbances is needed.

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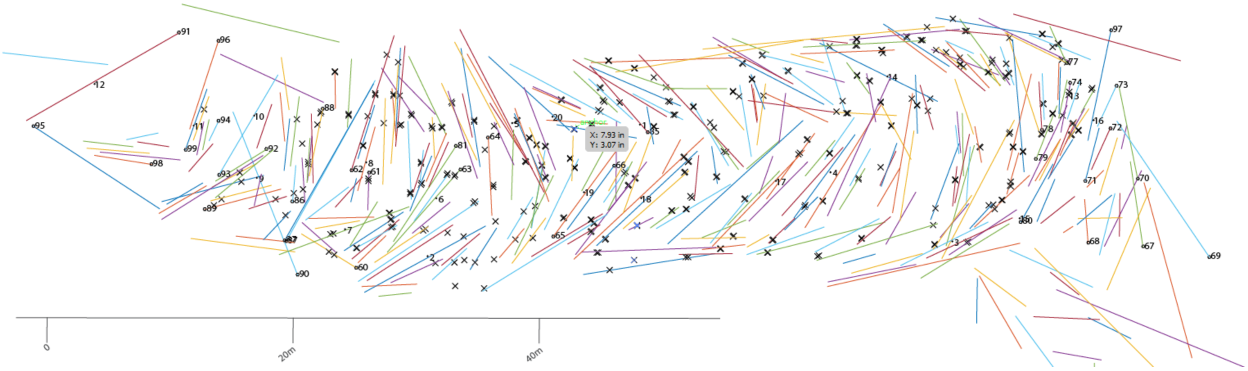
## Additional Images

Logjam D, ~6 months after initial avalanche delivery of wood. Most white wood in this image was delivered from upstream jams A, B and C.



Matlab rendering of surveyed logs from Logjam D. Colored lines represent logs measured from tip-to-tip in July, 2015. X's mark surveyed points visited in October, 2015. Note the concave-upstream deformation of the jam, suggesting that the most shearing/deformation occurs in the center of the channel where the water is the deepest and the bank-drag is minimized. Note, we have measured only a small fraction of the total logs in Logjam D.

Emmy at work surveying the logjam with a RTK GPS that returns positions with a precision of <1 cm.  This was used to set initial control points.  Jam D surveys were completed using a total station with a precision of ~1mm.

Emmy taking notes at jam C.  This jam had all its in-stream debris blown out to downstream.

Large mid-channel jam formed on an island bar downstream from jam D.