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The Role of Large Woody Debris in Inhibiting the Dispersion of a Post-Fire Sediment Pulse

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THE ROLE OF LARGE WOODY DEBRIS IN INHIBITING THE DISPERSION OF A POST-FIRE SEDIMENT PULSE

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ABSTRACT

THE ROLE OF LARGE WOODY DEBRIS IN INHIBITING THE DISPERSION OF A POST-FIRE SEDIMENT PULSE

by Lauren E. Short

To further the understanding of how rivers process an instantaneous increase in sediment supply, a study was conducted on a gravel bed channel affected by post-fire debris flows. Sleeping Child Creek (SCC), a tributary to the Bitterroot River, is located in the Sapphire Mountains of west central Montana. In the summer of 2000, 1500 acres of Sleeping Child Creek's watershed were burned with 65% of the area classified as a high severity burn. The following summer, intense rainfall triggered debris flows originating from tributaries of SCC with headwaters toward the north. Along a 7-km study reach, cross sections, longitudinal profiles, and pebble counts were taken near six debris flow fans in the summer of 2012. In addition, a survey of large woody debris was conducted throughout the study reach. Comparing the cross sections with previous measurements taken in 2005 demonstrated that the river has aggraded throughout most of the site. Moreover, the bed material has become finer and the amount of large woody debris has doubled in seven years. The aggradation and the finer bed material can be attributed to the increase in large woody debris in the channel. In 2005, the large woody debris in the channel was from the debris flows. Since then, the large woody debris has come from the severely burned slopes adjacent to the channel. The response documented in Sleeping Child Creek demonstrates that, in burned mountainous landscapes, the large woody debris can be instrumental in modulating the storage and release of the post-fire sediment pulse.

ACKNOWLEDGEMENTS

The field work for this project could not have been done without the help of Heidi Simon and Nick Sylva. Thank you to Dan Hoffman for the help locating the 2005 monuments. Thank you to Dave Andersen and Paula Messina for the thoughtful comments that polished the rough edges of this manuscript. This project was completed under the mentorship and guidance of Manny Gabet.

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INTRODUCTION

Landscape evolution relating to river incision is theorized but lacks detailed observations in a variety of channels. When a river starts to incise, the hillslopes adjacent to the channel begin to steepen until the slope fails. Landslides and debris flows add an instantaneous increase of sediment into the river. The river starts to aggrade due to the influx of sediment and it selectively transports the finer particles (Madej and Ozaki, 1996). When the finer particles are gone, the coarser material deposited from the debris flow or landslide protects preexisting finer sediment. The degree of channel armoring affects how the river recovers from the sediment pulse (Lisle et al., 1997). If the channel armoring is minimal, the river channel will recover to a state similar to the state before the hillslope failure (Madej and Ozaki, 1996). Otherwise, a large degree of channel armoring leads to the establishment of a new balance of transport capacity for the river channel (Brummer and Montgomery, 2006). The goal of this project was to determine the timing of the pulse dispersion.

Between 1950 and 1970, the population growth in the western United States increased the demand for dams to provide hydroelectric power, mitigate flood hazards, and store water for irrigation and urban supply (Doyle et al., 2003). As the dams age, reservoir sedimentation becomes a concern that was not addressed 60 years ago (Doyle et al., 2003). By the year 2020, 85% of the dams in the United States will reach the end of their lifetime and will need to be decommissioned (Doyle et al., 2003). Two possible solutions for releasing the sediment are (1) discharging the sediment in small increments before final dam removal, or (2) releasing all of the sediment down the channel at once.

The effects of natural sediment pulses (e.g., debris flows) on river channels could potentially be analogs to predict the potential effects of releasing the impounded sediment.

The study of the impacts of large sediment pulses on river systems began with Gilbert's (1917) research on the effects of hydraulic mining on the American and Sacramento River systems in northern California. Gilbert observed that the rivers aggraded with an increase in the sediment supply. Over time, the sediment pulse migrated through the American and Sacramento River systems and was deposited on the shores of the San Francisco Bay. Gilbert hypothesized that a sediment pulse traveled as a wave through a river system.

Long-term studies of the effects of sediment pulses show that the channel initially aggrades and becomes a sediment sink (Madej and Ozaki, 1996; Sutherland et al., 2002). Later, the channel degrades and becomes a sediment source. As the sediment pulse disperses, channel widths remain unchanged, contrary to Gilbert's original translating pulse hypothesis (Madej and Ozaki, 1996). If the sediment pulse translated, the channel would have widened as the wave traveled downstream (Madej and Ozaki, 1996). Possible sources of sediment pulses include debris flows and landslides. High-volume debris flows create knickpoints, step-pools, log jams, and boulder and gravel deposits (Benda and Dunne, 1997a, 1997b). Conclusions from flume studies were that extensive deposition occurs when sediment supply exceeds the transport capacity of the channel (Podolak and Wilcock, 2013; Lisle et al., 1997). The extensive deposition acts as a sediment trap to the approaching sediment from upstream, causing the channel to become a larger sediment sink (Lisle et al., 1997). To accommodate the increase in bed load, the slope of the channel increases until the sediment transport rate of the stream is fast enough that the finer particles are transported away (Podolak and Wilcock, 2013). Incision ceases when the bed surface is made of large, immobile particles (Brummer and Montgomery, 2006).

Debris flows are common in post-fire watersheds due to the loss of surface vegetation and the reduced infiltration capacity of soil (Hyde et al., 2007). The debris flows may incorporate burned trees as they travel downslope and deposit the burned trees as large woody debris in river channels (Hoffman, 2005). Hoffman and Gabet (2007) studied the effects of the sediment pulses in Sleeping Child Creek, a gravel-bed river, from debris flows three years after they were triggered. Hoffman and Gabet found a recurring pattern of morphological channel changes. The channel reaches above each debris flow fan were single-thread and aggrading, with gentle slopes and fine bed sediments. Where the channel passed through the fan, it incised, creating an entrenched single-thread channel with steep banks and bouldery bed material. Below the fan, the channel was braided with gravel bed material. The distribution of sediment throughout the channel was characterized by size-selective transport. Gravel was eroded from the fan and deposited a short distance away as the finer material continued downstream until it was deposited along the channel margins and behind large woody debris.

The study area of Sleeping Child Creek was revisited seven years after the initial measurements of Hoffman and Gabet (2007) to study how the sediment pulse had moved through the fluvial system. The methods outlined in the previous study were duplicated for this project. The overall goal of this study was to observe the long-term effects of post-fire debris flows in a mountain fluvial system.

MATERIALS AND METHODS

Study Site

Sleeping Child Creek, a tributary of the Bitterroot River, is located in the Sapphire Mountains of west central Montana (Fig. 1). The Sapphire Mountains are in the continental climate transition zone between the Pacific Northwest and the Rocky Mountains (Hyde et al., 2007). Summers are moderately warm with intense short-duration storms. Winters are mild with snowfall. The mean annual precipitation, measured at the nearest station 17 km away from Sleeping Child Creek, is 70 cm (Hyde, 2003). The Sleeping Child Creek basin is 169 km^2 with a mean elevation of 1900 m (Hoffman and Gabet, 2007). The upper part of the basin has average slopes of ~25° with a mixed conifer forest of pines and firs (Hyde, 2003). The lower part of the basin has slopes of approximately 0° to 10° with agricultural lands along the Bitterroot floodplain (Hoffman and Gabet, 2007). The lithology of the study site is Proterozoic gneiss, granite, and schist. The soils are geologically young and they have a gravelly and sandy texture (Hyde, et al., 2006). Anthropogenic impacts on the area are minimal. There are two rarely used recreational hiking/equestrian trails, and a paved US Forest Service road that ends near the trailhead. No logging has been performed in the area since 2000.

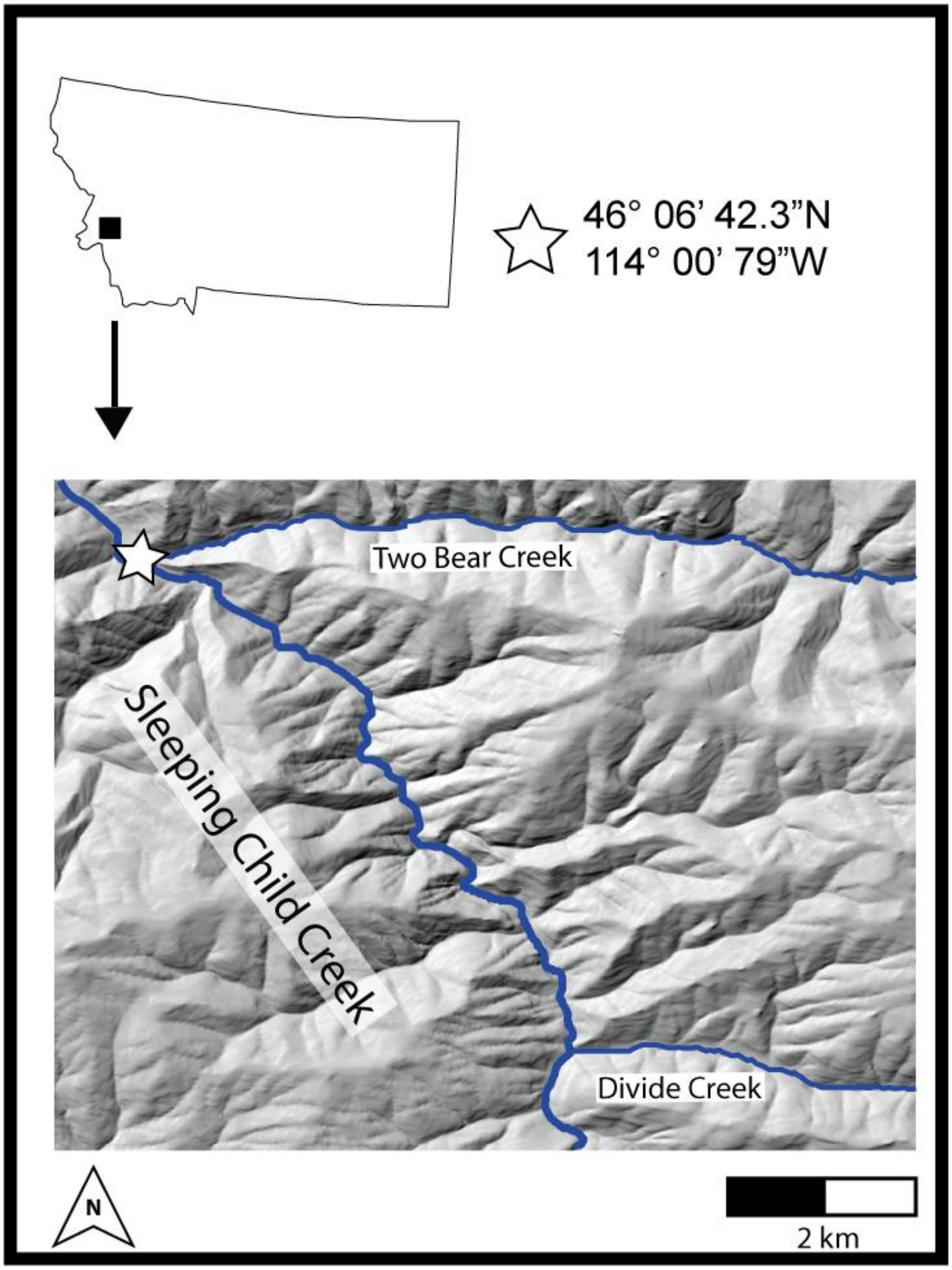

Figure 1. Location of the study site in Montana. The studied reach of Sleeping Child Creek is between the major tributaries: Two Bear Creek and Divide Creek.

In 2000, high summer temperatures, combined with half of the normal precipitation, created ideal wildfire conditions (Parrett et al., 2004). The Sleeping Child Creek watershed was burned in a series of small wildfires that eventually merged into a large fire complex (Parret et al., 2004). About 1500 acres of the Sleeping Child Creek watershed were burned with 65% classified as a high severity burn by the normalized burn ratio method (Hyde et al., 2006). In July 2001, thunderstorms brought intense rainfall to the area, triggering a series of debris flows. The debris flows originated from tributaries with headwaters toward the northeast (Parret et al., 2004) and within watersheds with high burn classifications (Hyde et al., 2006). The debris flow volumes ranged from 500 m^3 to 3400 m^3 (Parrett et al., 2004; Hoffman and Gabet, 2007; Gabet and Bookter, 2008). The debris flow fans, deposited at the junctions of the tributaries and Sleeping Child Creek, were composed of coarse sand, pebbles, cobbles, boulders, ash, and large woody debris (Hoffman and Gabet, 2007).

The debris flows changed the morphology of Sleeping Child Creek. In the channel reaches affected by debris flows, the channel was pinned to the southwestern valley wall (Parrett et al., 2004; Hoffman and Gabet, 2007). The channel reaches through the fans aggraded with particles ranging from fine gravel to coarse sand 1 - 2 m deep. Coarse sand was eroded from the fans, transported as suspended load, and then deposited along channel margins or behind obstacles (Hoffman and Gabet, 2007).

Field Methods

To quantify the morphological changes of Sleeping Child Creek since the previous survey in 2005 (Hoffman and Gabet, 2007), the same debris flow fans were studied according to the following methods. A longitudinal profile and three cross sections were surveyed for six debris flow fans (Fig. 2) using a hand level, stadia rod, and measuring tape. In 2005, Hoffman and Gabet monumented each of their measured cross sections with rebar and cairns. These monuments were reoccupied in the summer of 2012 for this study. The locations of each cross section were 10–30 m upstream of each fan, through the middle of the reach cutting through each fan, and 10–30 m downstream of each fan (Fig. 3). Longitudinal profiles for each debris flow fan started 0–10 m upstream of the up-fan cross section and ended 0 – 10 m beyond the down-fan cross section. Due to large log jams in the channels, some of the 2012 cross sectional profiles were shorter than their counterpart measurements. The shorter cross sectional profiles were interpolated between the last 2012 measurement and the last point of the 2005 survey. A longitudinal profile of Sleeping Child Creek was constructed from the 2011 1:24,000 USGS Bald Top Mountain and Deer Mountain topographic maps.

The plots of the cross sections and longitudinal profiles measured in the field were aligned with the 2005 measurements. The area between the 2005 and 2012 profiles represents how much the channel has aggraded or eroded. The area between the two cross sections was calculated using ImageJ (Rasband, 2012). The areas of cross sectional change were added together to determine net change for each debris flow study reach. This method of quantifying changes in morphology has two sources of error.

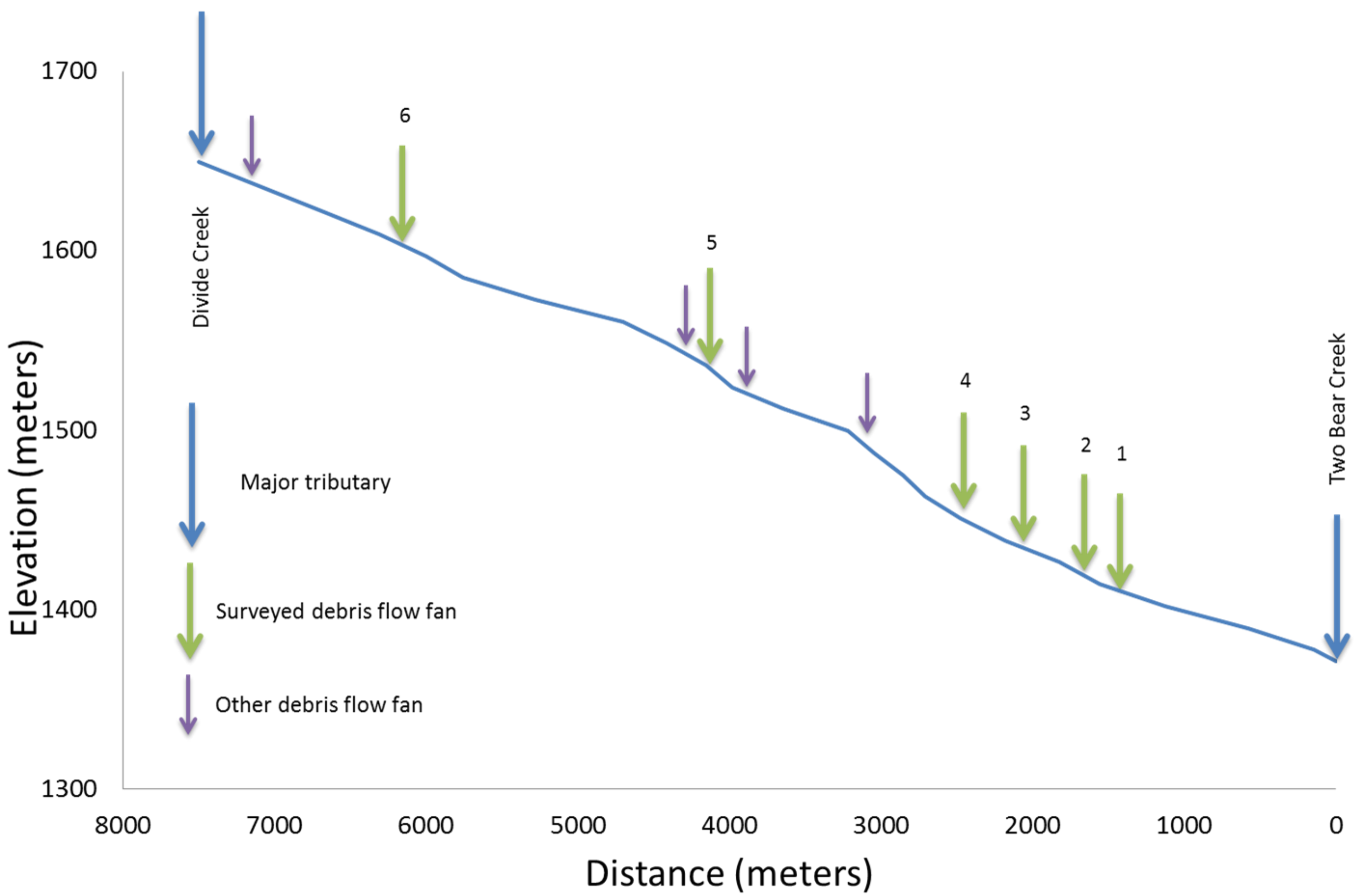

Figure 2. Longitudinal profile of the studied reach of Sleeping Child Creek with locations of surveyed debris flow fans (USGS topographic map quadrangles Deer Mountain and Bald Top Mountain, 2011).

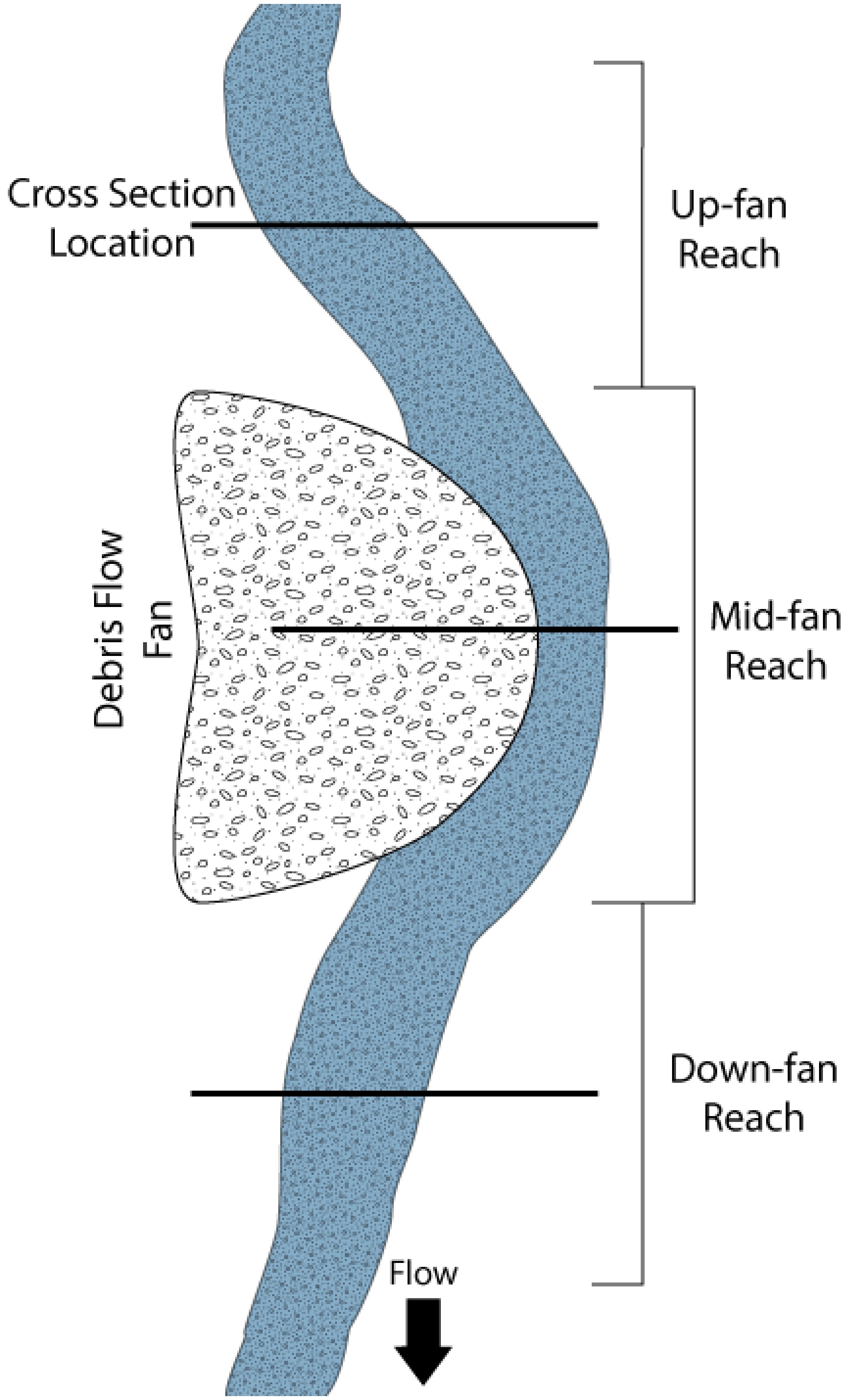

Figure 3. Cross section locations relative to a debris flow fan (map view).

First, the shorter cross sectional profiles were extended to the length of the longer profile for data analysis. Second, there were horizontal distance differences between vertical measurements of the 2005 and 2012 surveys (e.g., taking a vertical measurement with the stadia rod every meter versus every three meters). Therefore, some sub-meter changes in bed topography were not adequately captured when the cross sections were compared.

Pebble counts (Wolman, 1954) were conducted to measure the grain size distribution of the bed material at each cross section. Clasts smaller than 2 mm were individually counted and assigned a value of 1.9 mm. Clasts larger than 520 mm were individually counted and given a value of 521 mm.

A survey of large woody debris was taken between the Sleeping Child Creek tributary junctions of Two Bear Creek and Divide Creek using a hip chain. As in the study by Hoffman and Gabet (2007), large woody debris was defined as logs with a minimum diameter of 25 cm, a length greater than the channel width, and a location within the channel of SCC. The length of the study reach was divided into 10-m sections and the number of pieces of large woody debris within the channel reach was recorded in each section.

RESULTS

Spatial Distribution of Large Woody Debris

The total amount of wood in the study reach has increased since 2005 (Fig. 4A). The survey of large woody debris from 2005 and 2012 is provided in Appendix A. In 2005, the amount of large woody debris peaked with proximity to debris flows. In the past seven years, some areas not directly affected by debris flows have gained large woody debris. A running average was taken on both sets of data to reveal the general trends (Fig. 4B). The amount of wood decreased downstream of debris flow fan (DF) 4 from 2005 to 2012. Upstream of DF4, the amount of large woody debris rose by ~50% since 2005. The adjacent slopes upstream of DF4 had many leaning dead trees and large woody debris. The leaning dead trees would fall over whenever there was a strong breeze or a thunderstorm.

Based on Google Earth™ satellite imagery, sometime between 2010 and 2012 at least one beaver built a dam between the up-fan and mid-fan cross sections of DF6 (Fig. 5). This created a marshy environment that is about 50 m wide and continues 200 m upstream. The slight decrease in the amount of wood at this site (Fig. 4A) was attributed to the burial of some of logs and the beaver(s) moving the preexisting ones to create the dam.

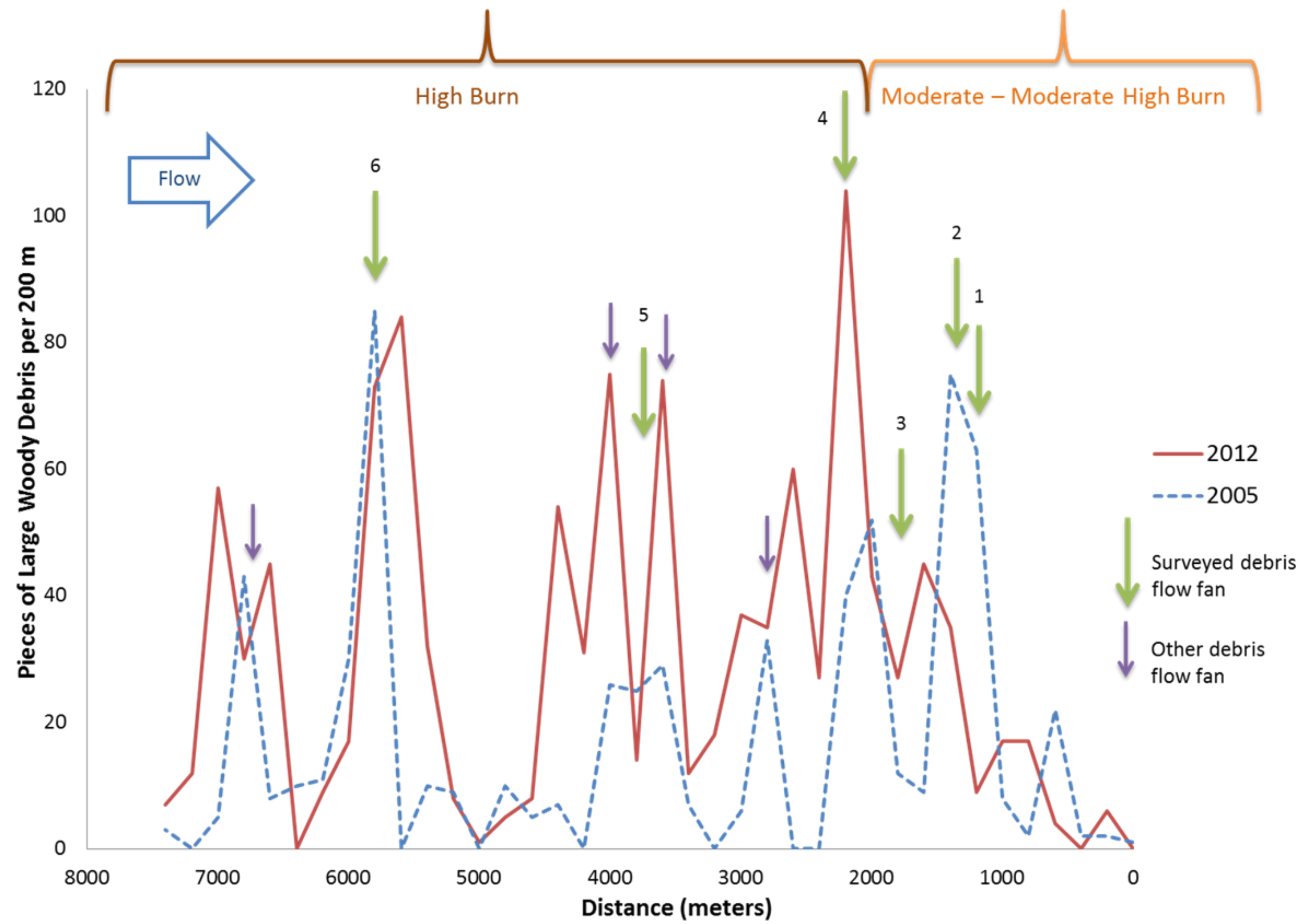

Figure 4A. Spatial distribution of large woody debris (2005 LWD data from Hoffman, 2005; 2000 burn data from Hyde, 2003).

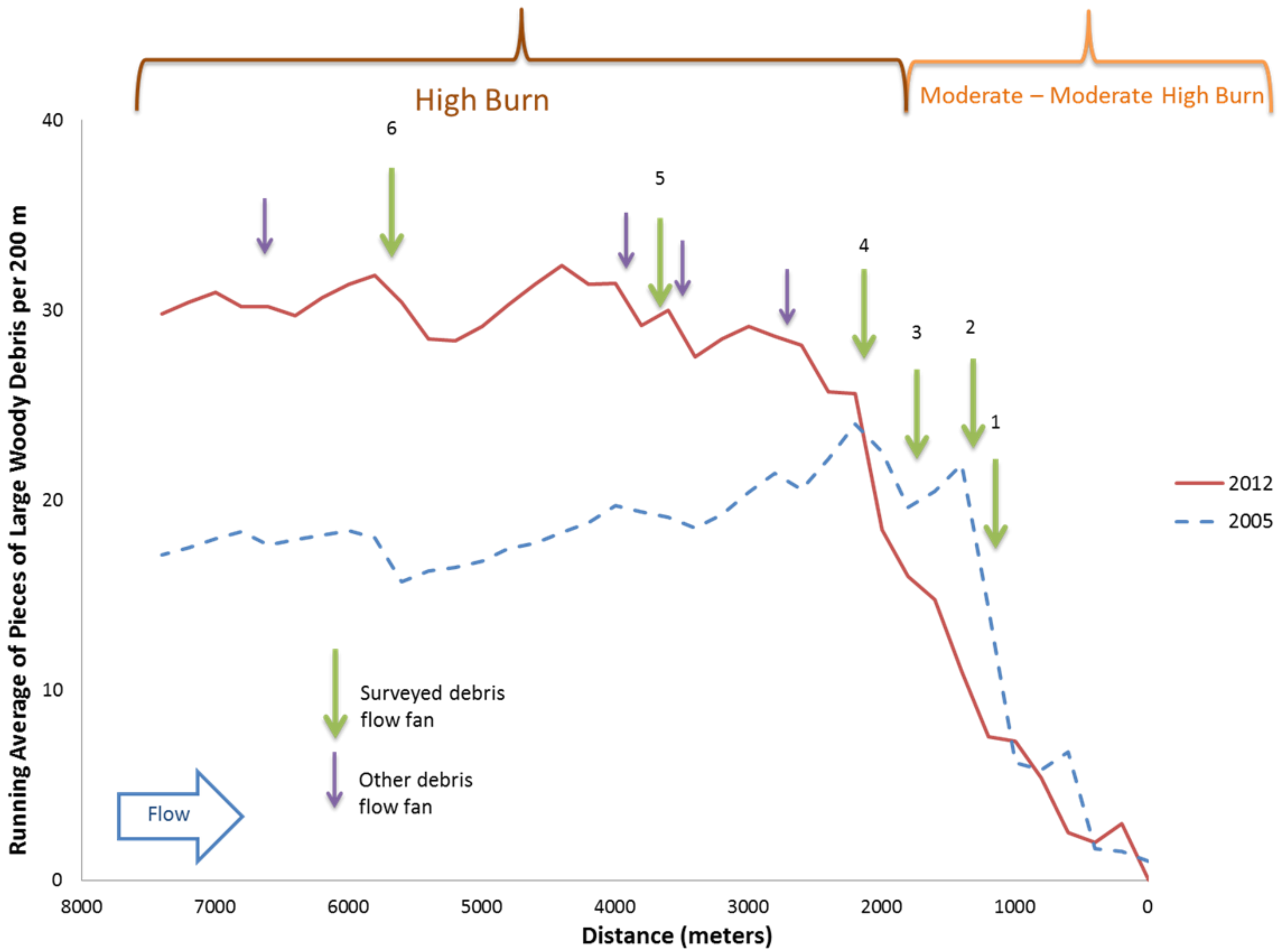

Figure 4B. Running average of the spatial distribution of LWD (2005 LWD data from Hoffman, 2005; 2000 burn data from Hyde, 2003). A run for each average value is the number of pieces of LWD per 200 m from distance 0 m to its respective distance upstream.

Figure 5. Google Earth™ imagery of debris flow fan 6. Flow direction is to the north. The image on the left is from 9/27/2010 and the one of the right was taken 8/6/2013. In the late summer of 2010, the upstream reach of DF 6 was a braided channel with visible sand bars. In the imagery on the right, the channel has widened and the sand bars are now submerged. The beaver dam (arrow) is the thick pile of wood. Source: "Sleeping Child Creek -DF6" 46° 4’ 36.23”N 113° 58’ 20.86”W. Google Earth v. 7.1.2.2041. 8/6/2013. 11/15/2013. "Sleeping Child Creek -DF6" 46° 4’ 36.23”N 113° 58’ 20.86”W. Google Earth v. 7.1.2.2041. 9/27/2010. 11/15/2013.

Bed Material Size

Since 2005, the range of bed material at the up-fan, mid-fan, and down-fan reaches decreased and the minimum and maximum values are finer (Fig. 6). The pebble counts from 2005 and 2012 are provided in Appendix B and C. Generally, the up-fan reaches still had the smallest median bed material (D_{50}) of the three reaches. In 2005, the down-fan reaches typically had the coarsest bed sediment. In 2012, the mid-fan reaches of DF 1, 2, and 5 had the coarsest bed material while DF 3, 4, and 6 continued to have the coarsest bed material in the down-fan reach. On average, the D_{50} at each cross section became 61% finer (Fig. 7). The two exceptions are the upstream and downstream cross sections of DF6. The D_{50} of the up-fan cross section did not change because it was already at the measured minimum at both times. The down-fan section of DF6 was the only section where the D_{50} became coarser.

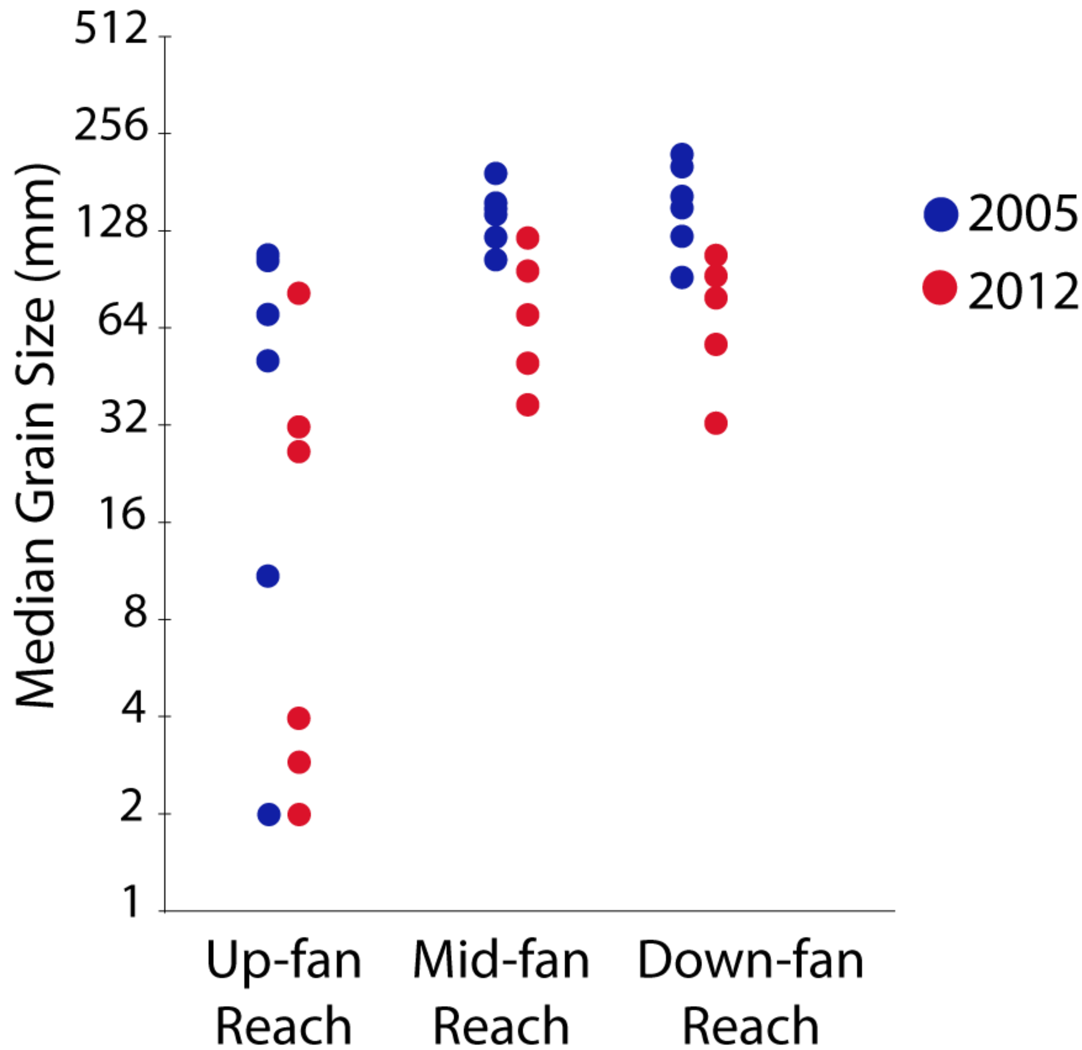

Figure 6. The combined median size bed material from each fan. The sizes of the median bed material were smaller in 2012 than in 2005 (2005 D_{50} data from Hoffman, 2005). Note the $\log_2$ scale of the y-axis.

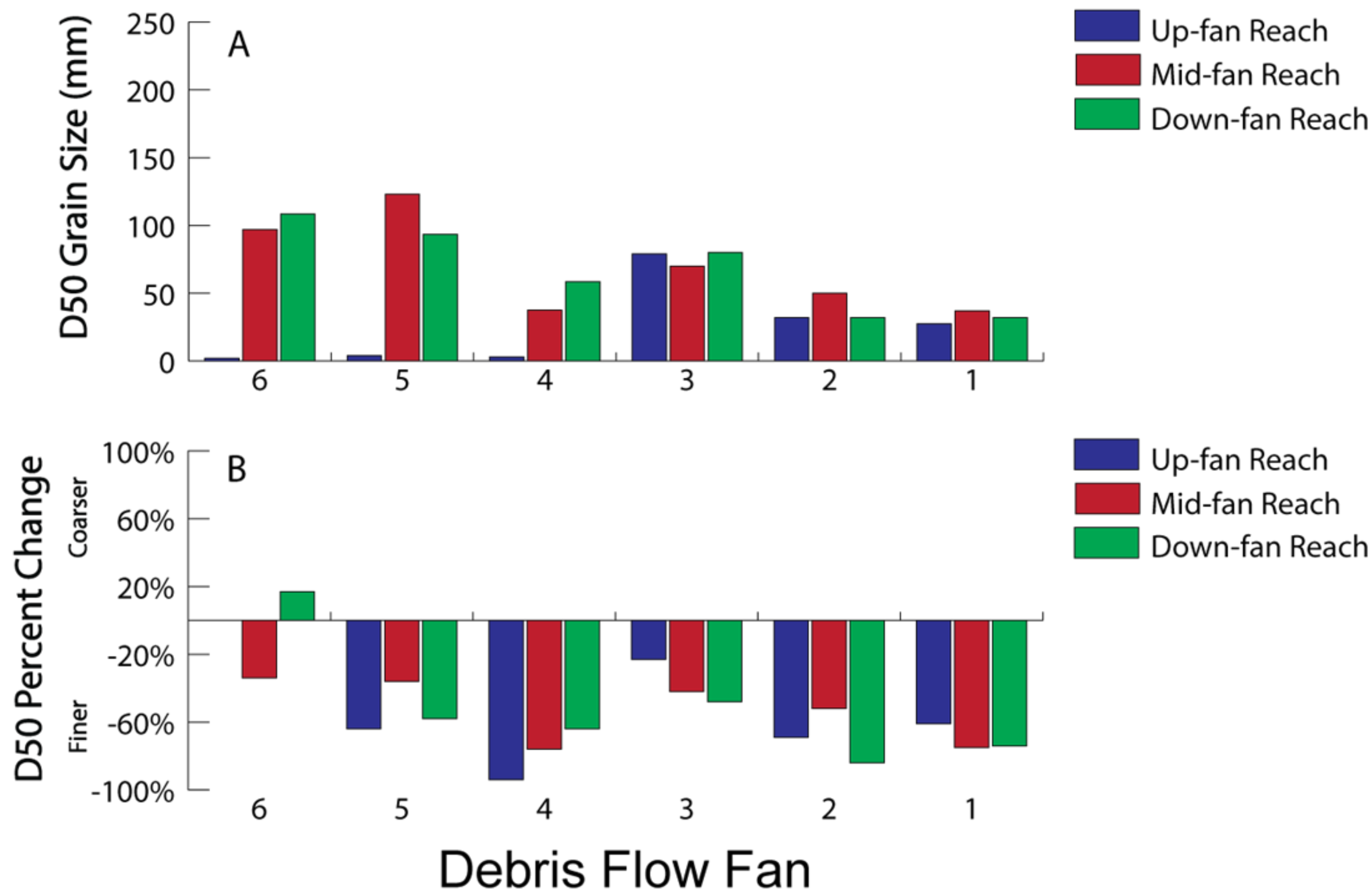

Figure 7. A) The D_{50} from each cross section measured in 2012. B) The D_{50} change from 2005 (2005 D_{50} data from Hoffman, 2005).

Changes in Channel Morphology

All the cross sections had changed in some manner since 2005 (Fig. 8A). All cross sections are provided in Appendix D. A majority of the cross sections had aggraded. The downstream cross sections had the largest range of change of cross-section area and the mid-fan cross sections had the least range of change. The aggraded reaches had laterally extensive fine bed material creating a marshy environment. The incised reaches had coarse bed material with coalescing pockets of fine material trapped behind large woody debris. These pockets were not laterally extensive but large enough to bury the smaller cobble bars. All studied areas affected by debris flows have aggraded, with one exception, as is evident by adding the net area change of the three cross sections from each individual debris flow fan (Fig. 8B).

The repeating pattern of channel gradients observed in 2005 was no longer present in 2012 (Table 1). All slope profiles are provided in Appendix E. In 2005, there was typically a rapid increase in channel gradient from the up-fan reach through the debris flow fan (Hoffman, 2005). DF6 had a slope change of a factor of 7 (0.009 to 0.067) while other slope changes ranged from a factor of 0.6 to 5 (Hoffman, 2005). The abrupt transition was caused by the channel selectively transporting away the finer sediment from the fan (Hoffman, 2005). The channel gradients have since changed by +/- 2% (Table 1). However, the cause of the variety of slope changes throughout the studied reaches is unclear. It was expected that the slopes would approach a single value as SCC approached a new sediment transport equilibrium. Based on the recent observations, that did not occur.

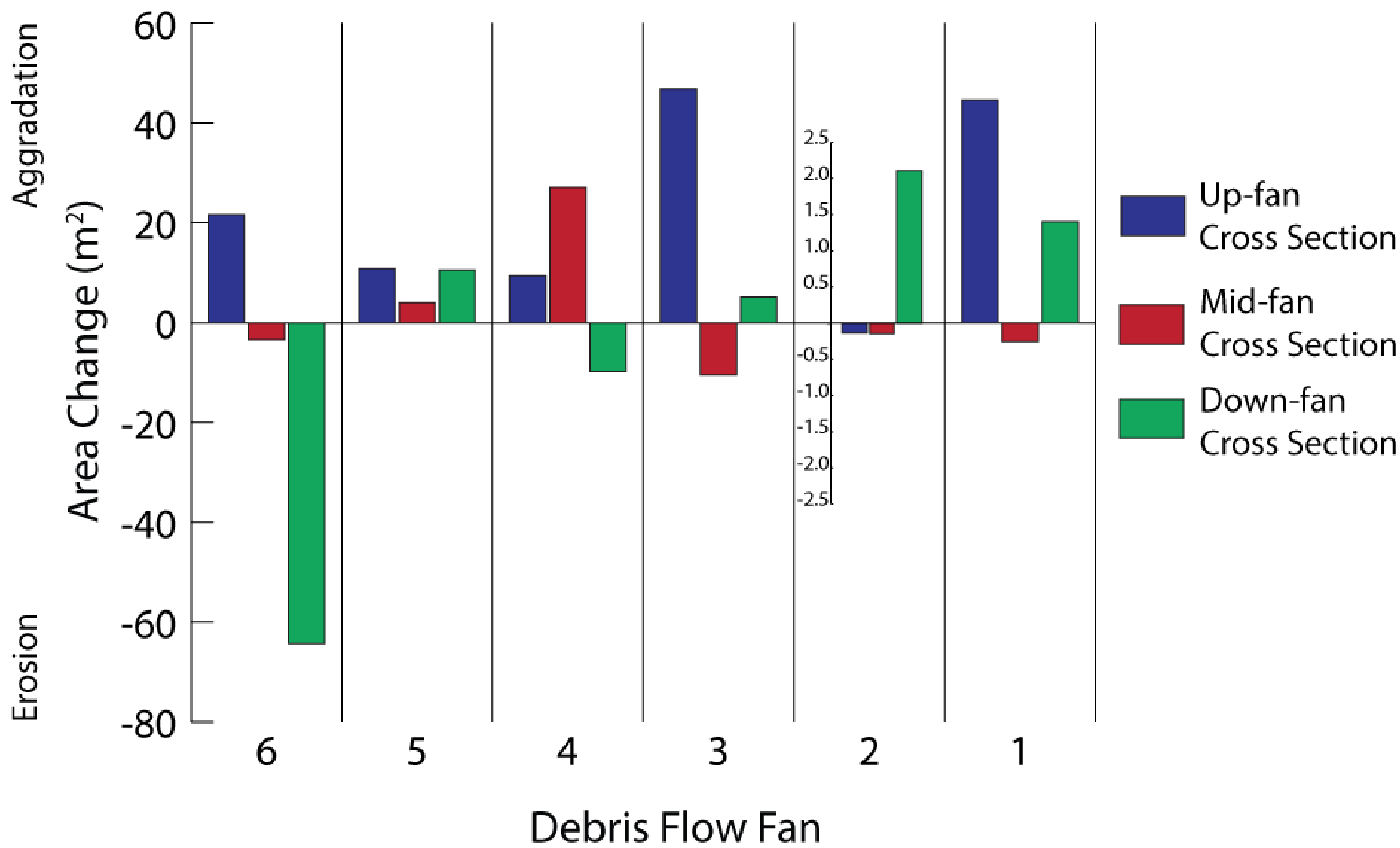

Figure 8A. Area change per cross section from 2005 to 2012. The degree of change of DF 2 was so small, it required its own y-axis.

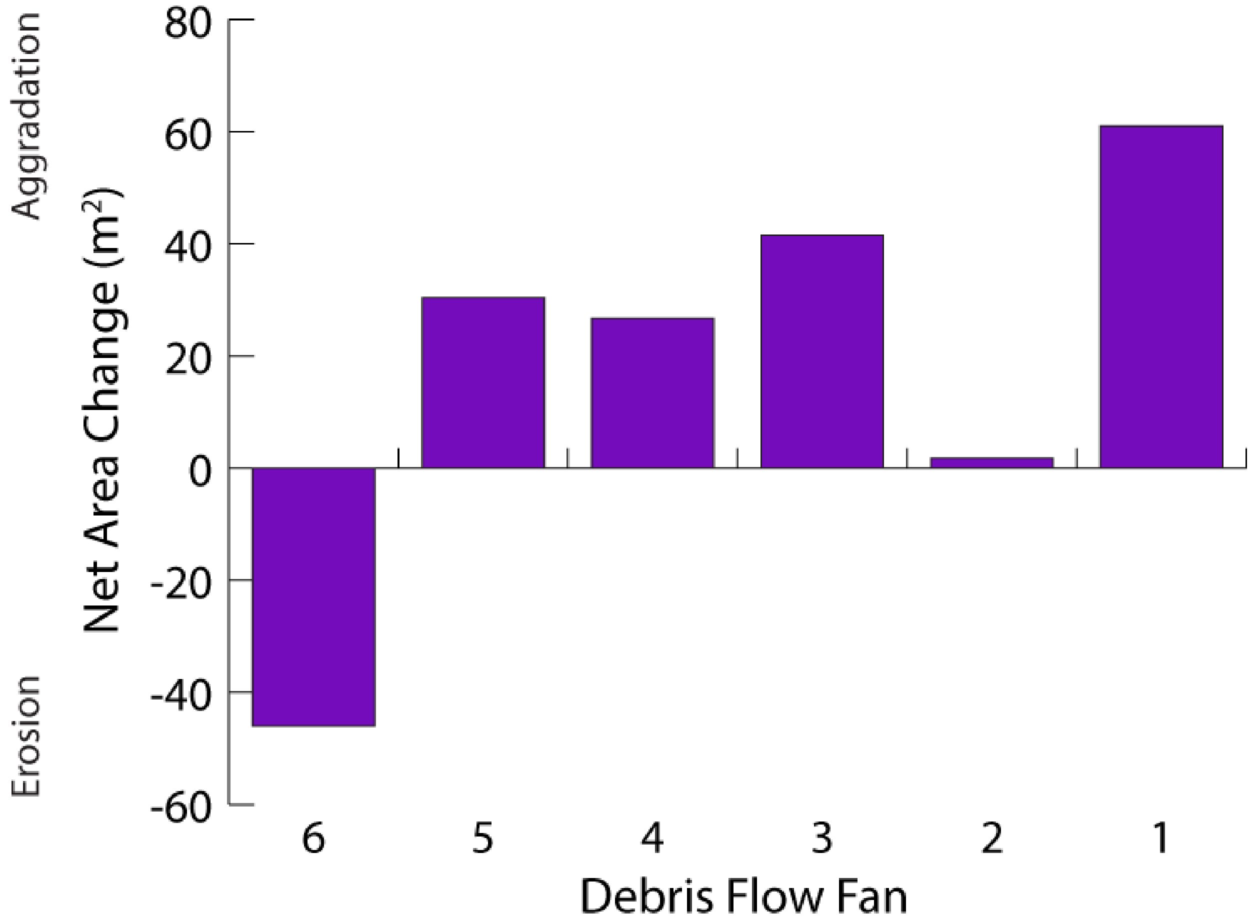

Figure 8B. Net area change per debris flow fan.

TABLE 1. SLOPES FOR EACH REACH OF EVERY DEBRIS FLOW FAN MEASURED IN 2005 AND 2012

	DF 6	DF 5	DF 4	DF 3	DF 2	DF 1	Average
2005 *							
Upstream Reach	0.009	0.019	0.011	0.019	0.007	0.038	0.017
Fan Reach	0.067	0.038	0.042	0.072	0.036	0.021	0.046
Downstream Reach	0.037	0.041	0.043	0.028	0.047	0.037	0.039
2012							
Upstream Reach	0.020	N.D. #	0.003	0.010	0.161	0.034	0.046
Fan Reach	0.075	0.036	0.057	0.042	0.036	0.029	0.046
Downstream Reach	0.066	N.D. #	0.057	0.063	0.025	0.050	0.052

Note: The upstream reaches and downstream reaches of DF 5 could not be measured in 2012 due to the large log jams in the reaches.

* 2005 slope data from Hoffman (2005).

N.D. = not determined

DISCUSSION

Sediment Transport and the Effects of Channel Morphology

Three kinds of responses of sediment transport have occurred in SCC since 2005. First, 11 cross sections experienced burial of the 2005 channel, and the relative channel bed elevation increased (Fig. 9A). The fine bed material in these reaches was laterally extensive throughout the reach creating a marshy environment. This occurred in five up-fan reaches of the debris flow fans, two mid-fan reaches, and four down-fan reaches. In 2012, the D_{50} was finer in these sections and there was a decrease of coarser bed material with an overall increase of finer material. The coarser bed load from 2005 appears to have been buried or not replenished from upstream reaches. The influx of large woody debris since 2005 has trapped sediment and driven aggradation.

The second response was the beginning of incision of the channel mostly into the fan or downstream of the fan (Fig. 9B). This occurred in one up-fan reach of the debris flow fans, four mid-fan reaches, and one down-fan reach. These reaches were typically braided. In parts of the channel between the braids, there were pockets of fine sediment trapped behind large woody debris. Many of these pockets coalesced and buried the smaller cobble bars. These reaches had a lower bed elevation than the one measured in 2005, but the D_{50} was finer (Fig. 7B). The 2012 sediment distributions were similar to that of the first response (Fig. 9A). There was a decrease of coarser material and a sharp increase in fine material. The fining of the bed sediment suggests that these reaches were no longer incising, despite the decrease in the bed elevation since 2005. The initial incisional response appears to have been interrupted when enough wood fell into the channel and the channel began to aggrade.

The third response applies only to the down-fan reach of DF6 (Fig. 9C). The reach was a wide gravel braided channel with no obvious pockets of fine sediment trapped behind large woody debris. The channel response of the down-fan reach of DF6 is controlled by the beaver dam upstream. Beaver dams are highly organized log dams maintained by the destruction of nearby trees by the beavers. Due to an increase of shear stress on the bed from the knickpoint created by the beaver dam in the mid-fan reach of DF6, the channel downstream of the dam experienced channel scour and the median bed material size increased to at least the gravel range (see also Levine and Meyer, 2014). The dam created a velocity shelter in the up-fan reach of DF6 that trapped large amounts of fine sediment. Typically, upstream reaches of active dams have low slopes and median grain sizes can be < 1 mm (Butler and Malanson, 2005; Levine and Meyer, 2014). This pool of fine sediment can extend several meters upstream (Levine and Meyer, 2014).

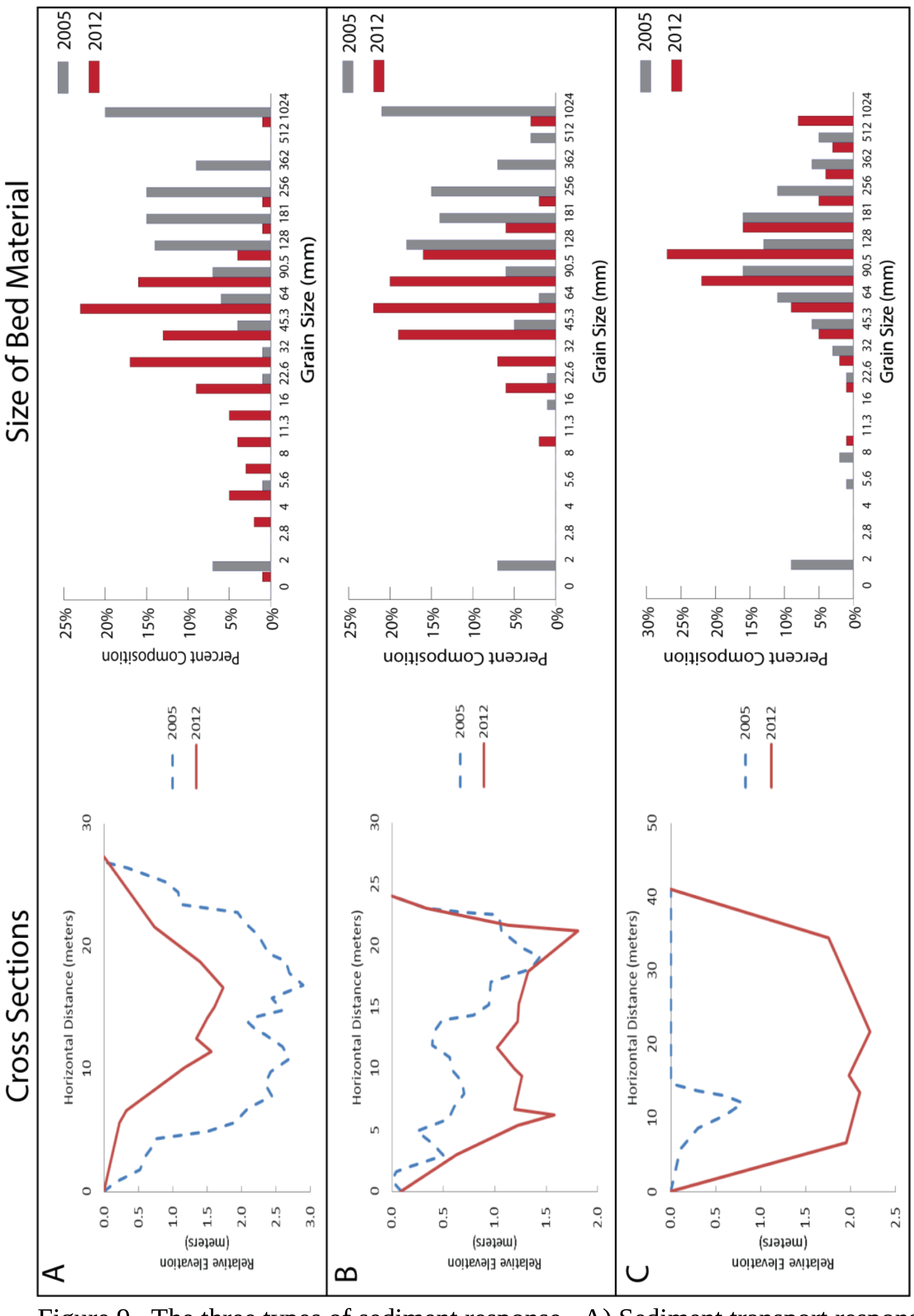

Figure 9. The three types of sediment response. A) Sediment transport response 1 represented by the mid-fan cross section of DF 4. B) Sediment transport response 2 represented by the downstream cross section of DF4. C) Sediment transport response 3 represented by the downstream cross section of DF 6 (2005 sediment data and cross sections from Hoffman, 2005).

Model of Response

After the 2005 surveys, Hoffman and Gabet (2007) proposed two hypotheses of future channel response of the studied reach of Sleeping Child Creek. The first one was that SCC would continue to aggrade until the sediment traps were full or until incision was triggered. Incision would cease when a local base level, due to channel armoring, was reached. The second hypothesis was that the deposition and transport rates would reach equilibrium with much of the finer bed material from the sediment pulse remaining. Neither response was observed. The large woody debris in SCC created sediment traps, leading to only localized redistribution of sediment (Fig. 10). Soon after the debris flows in 2001, Sleeping Child Creek began to incise down through the fans leaving behind a coarse lag. Had this continued, the channel bed would have become armored in the mid-fan reaches. However, enough wood has fallen into the channel since 2005 to promote aggradation and halt incision. In areas of aggradation, the 2005 channel has been buried. In some areas, this aggradation did not reach the original channel elevation measured in 2005.

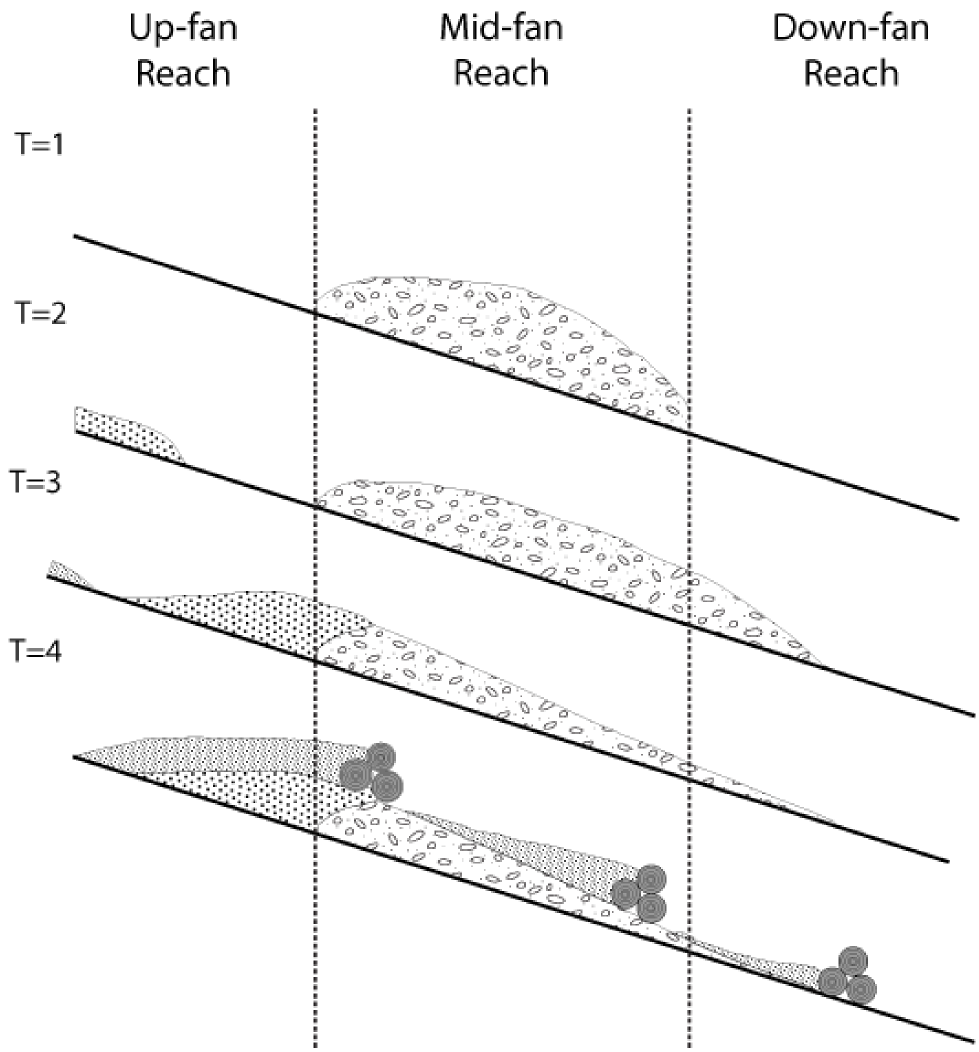

Figure 10: Conceptual model of response. Time units are arbitrary.

T=1: The debris flow is deposited in the channel.

T=2: The fine sediment added from upstream to the up-fan reach.

T=3: The fine sediment is trapped upstream of the fan.

T=4: More LWD falls in, creating sediment traps for more fine sediment.

The source of large woody debris has changed over the past decade. In 2005, it was observed that the large woody debris was deposited by the debris flows (Hoffman and Gabet, 2007). In 2012, the source was the highly burned slopes of the watershed. The boundary between moderately burned and highly burned areas near the channel is between DF3 and DF4 (Fig. 4). The moderately burned sections had less wood in 2012 than in 2005. However, there was still enough large woody debris to create the sediment traps that buried the coarse material. The large woody debris in these areas had decomposed enough to be flushed downstream and this was happening faster than the input of 'fresh' large woody debris. The highly burned slopes continued to provide a supply of large woody debris. It has been 12 years since the fire and trees were still falling throughout the watershed. This is evident when, during field work, trees would fall over whenever there was a strong breeze or a thunderstorm.

Large woody debris affects the sediment transport capacity of river channels by creating sediment traps and velocity shelters (Eaton et al., 2012). In unconfined channels, large woody debris and small log jams cause the channel to aggrade, incise, or laterally migrate across its floodplain (Brummer and Montgomery, 2006). There are two primary mechanisms for the input of large woody debris in channels: natural tree mortality and debris flows (Andreoli et al., 2007). Secondary mechanisms of large woody debris input include bank erosion and landslides (Andreoli et al., 2007). Tree mortality rates rise after a wildfire and can continue to be elevated for several decades (Jones and Daniels, 2008). Large woody debris can aggregate to form log jams. Models of log jams and field measurements have shown that the interaction of large woody debris creates variability in channel morphology, sediment transport, and sediment storage (Eaton et al., 2012). The variability persists as long as there is a steady input of large woody debris into the channel by random tree fall (Eaton et al., 2012). After the trees have fallen into the channel, it can take more than a decade for the large woody debris to decay or erode (Jones and Daniels, 2008; King et al., 2013). Large woody debris is depleted by the breakage and decay of the logs into sizes that can be transported downstream (Merten et al., 2013).

The response of the sediment pulse in Sleeping Child Creek is similar to results found in other mountain fluvial systems. An initial aggradation of the studied reaches of the channel from the 2001 debris flows was observed by Hoffman in 2005. Between then and the most recent observations, the large woody debris has created velocity shelters and sediment traps as expected from other research (Andreoli et al., 2007; Jones and Daniels, 2008; King et al., 2013) which leads to another cycle of aggradation. Tree mortality was not measured in the field, but the amount of fallen trees observed throughout the site and in the channel indicated that tree mortality was elevated from the fire in 2000. The initial large woody debris measurements showed that most of the large woody debris was deposited with the debris flow fans. Along debris flow fans 1 through 3, the amount of wood has decreased (Fig. 4). After 12 years, the wood has started to decay in the channel reaches downstream of DF3. These observations agree with previous observations of woody decay by Jones and Daniels (2008) and King et al. (2013).

Beaver Colonization

The beaver colony at DF6 was not there before 2010 (Fig. 5). The Sleeping Child Creek watershed is within the historical extent of the North American beaver (*Castor canadensis)* population (Jenkins and Busher, 1979). Increases of beaver population have been documented in post-fire watersheds in Michigan (Lawrence, 1954). Lawrence (1954) concluded the population increase was caused by the secondary succession of aspen after a wildfire. However, aspen was not present before or after the 2001 fire at SCC (Hyde, 2003), and Lawrence's study was done as many beaver hunting restrictions went into effect (Lawrence, 1954). Beavers are considered choosey generalists and will feed on leaves, twigs, and bark of woody plants that grow near water (Jenkins and Busher, 1979). As supported by other ecology and population studies, beaver colonies can succeed without aspen as a food source (Jenkins and Busher, 1979). Beavers migrate within a watershed or among watersheds when their food sources have been depleted (Jenkins and Busher, 1979; Allen, 1983). If there is an available food source in a potential beaver habitat, a beaver will reoccupy an abandoned lodge or dam instead of building a new structure (Allen, 1983). In 2005, there was a log jam upstream of the mid-fan cross section of DF6 that was large enough to slow the flow and create a large marshier environment compared to the reaches upstream of the other debris flow fans. The simplest explanation for the new beaver colony is that the beaver migrated into the watershed and interpreted the log jam an as old dam and fortified it. There have been no extensive studies of the potential beaver colonization in post-fire watersheds. Future work at SCC should include a small-scale study of long-term beaver colonization of the post-fire watershed.

Scenario of Future Response

The new hypothesis for continued response is that the areas of Sleeping Child Creek affected by debris flows with highly burned adjacent slopes will continue to aggrade until the sediment traps are at capacity or the log jams fail after there is no more input of large woody debris. In the moderate burn areas adjacent to the channel, the large woody debris will continue to decompose and finer material will be selectively transported until the bed load is too coarse to transport. Aggradation will cease in the highly burned reaches and incision will begin when the wood decomposes enough to break and to be flushed downstream. Conclusions from previous studies (Jones and Daniels, 2008; King et al., 2013) have shown that large woody debris takes at least a decade to break down enough to be moved downstream. Downstream of DF4 (the moderately burned section), the wood has started to decay as evident by the decrease of large woody debris since the 2005 survey. Over the next decade, the amount of large woody debris downstream of DF4 will continue to decrease and fine material in the previous sediment traps will be transported away. As of 2012, there were still many leaning dead trees and much large woody debris on the adjacent slopes upstream of DF4. Over the next several years, the amount of large woody debris will continue to increase upstream of DF4, creating more sediment traps and forcing continued aggradation.

It is expected that the beaver colony will remain at DF6 until the food source is depleted or protection from predators is no longer adequate. If the beaver colony maintains a dam similar in size to, or broader than, the one observed in 2012, the down-fan reach will continue to incise until there are no more fine particles to remove. The up-fan reach will continue to be an extensive beaver pond with a fine sediment bed. DF6 may not be the only suitable channel reach for a beaver colony. The mid-fan reaches of DF4 and DF5 also have large log jams. Potentially, more beaver colonies could be established in these reaches of SCC. If a beaver colony is established in these reaches, incision will be triggered downstream of the dam while deposition continues upstream. In the case of beaver dam construction in the mid-fan reach of DF4, the incision of the down-fan reach will be reactivated. The transported sediment of the down-fan reaches would be trapped again by the large woody debris and the debris flows of DF1, 2, and 3. Although the decrease of large woody debris in these reaches will lead to incision of the sediment pulses, incision may be thwarted by the incoming sediment. If the beaver colony abandons the dam of DF6, the dam will eventually fail, discharging all the sediment trapped in the up-fan reach. The sediment pulse will bury the channel of the down-fan reach.

CONCLUSION

Debris flows and landslides provide sporadic, large increases to the sediment supply in mountain fluvial systems. These sediment pulses disperse downstream through the channel over time. However, in watersheds that have experienced high intensity wildfires, the sediment pulse may not disperse as expected. The trees in the highly burned areas fall over and become large woody debris in the channel. When enough large woody debris accumulates, it creates a system of sediment traps that increase bed elevation as they are filled. Sleeping Child Creek was revisited 12 years after a wildfire, and seven years after initial measurements were taken to determine the channel's response to an increased input of large woody debris and sediment supply. The study was executed by cross sections surveys, longitudinal profiles, pebble counts, and a large woody debris survey. Results have shown that the debris flows are the initial supply of sediment, but the large woody debris kept the sediment pulse from being dispersed and transformed the study reach into a large sediment sink. The large woody debris pulse is just as important as the sediment pulse from debris flows. In highly burned watersheds, most of the trees are so severely burned that they cannot recover. The channel will continue to aggrade in the highly burned areas until the source of potential large woody debris is depleted. In the moderately burned areas, the amount of large woody debris has decreased since 2005. Even though most of the sections had aggraded, the channel will start to incise into the finer material as the large woody debris is broken down and transported downstream. In post-fire watersheds that experience debris flows, it is important to consider and measure the impact of large woody debris on the response of the fluvial system to the increase of sediment supply.

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APPENDIX A

Large Woody Debris Survey

Processed Data: LWD/200 m

Upstream	2005			Upstream	2012	
Distance (m)	LWD*	Comments		Distance (m)	LWD*	Comments
0	1			0	0	
200	2			200	6	
400	2			400	0	
600	22			600	4	
800	2			800	17	
1000	8			1000	17	
1200	63	DF 1		1200	9	DF 1
1400	75	DF 2		1400	35	DF 2
1600	9			1600	45	
1800	12	DF 3		1800	27	DF 3
2000	52			2000	43	
2200	40	DF 4		2200	104	DF 4
2400	0			2400	27	
2600	0			2600	60	
2800	33	DF		2800	35	DF
3000	6			3000	37	
3200	0			3200	18	
3400	7			3400	12	
3600	29	DF		3600	74	DF
3800	25	DF 5		3800	14	DF 5
4000	26	DF		4000	75	DF
4200	0			4200	31	
4400	7			4400	54	
4600	5			4600	8	
4800	10			4800	5	
5000	0			5000	1	
5200	9			5200	8	
5400	10			5400	32	
5600	0			5600	84	
5800	85	DF 6		5800	73	DF 6
6000	30			6000	17	
6200	11			6200	9	
6400	10			6400	0	
6600	8			6600	45	
6800	43	DF		6800	30	DF
7000	5			7000	57	
7200	0			7200	12	
7400	3			7400	7	

* # of pieces of large woody debris (logs >25 cm in diameter, longer than channel width and located within the channel)

Raw Data from the LWD Surveys

Upstream Distance (m)	2005 LWD*	2005 Comments	Upstream Distance (m)	2012 LWD*	2012 Comments
0			0	0	
6			11.5	0	
34			21.7	0	
39			31.5	0	
48			41.7	0	
58			51.7	0	
73			61.9	0	
86			72	0	
95			81.2	0	
106			92.2	0	
128			102.4	0	
134			112.9	0	
140			122.9	0	
152	1		133.5	0	
165			143.9	0	
171			153.9	0	
175	1		166.2	0	
224			171	6	
246			177.4	0	
300			187.6	0	
316			197.5	0	
344			207.8	0	
355	1		217.8	0	
442			227.7	0	
448			238	0	
532			258.8	0	
543			268.9	0	
564	2		278.9	0	
584			289.9	0	
605			299.4	0	
745	15		309.6	0	
765	6		319.7	0	
777	2		329.1	0	
895			340.1	0	
910			350.7	0	
1006	4		360.7	0	
1009			370.7	0	
1029			380.8	0	
1043	3		390.9	0	

Upstream Distance (m)	2005 LWD*	2005 Comments	Upstream Distance (m)	2012 LWD*	2012 Comments
1074			401.3	0	
1097	1		411.5	0	
1181	31		421.6	0	
1186	8		431.8	0	
1246	5		441.8	0	
1261	4		451.7	0	
1358	14		461.7	0	
1374	2		472	0	
1403	40		480.5	1	
1407	1		481.6	0	
1433	3		492.1	0	
1458	7		503.4	2	
1472			515.1	0	
1479	4		252.7	1	
1490	2		535.7	0	
1499			545.7	0	
1514	15		55.7	0	
1533			565.8	0	
1538			576	0	
1548			586	0	
1570			596.1	0	
1584	1		606.1	0	
1589	2		616	0	
1592	1		633.5	0	
1597			643.6	0	
1600	1		653.9	0	
1606			664.2	0	
1612			674.3	0	
1618			684.9	0	
1631			695	0	
1635			705.3	0	
1652			714.2	7	
1664			720.9	0	
1669	1		725.2	0	
1679	1		730.4	3	
1694	2		743.5	3	
1716			756.1	0	
1725			766.2	3	
1747			776.4	0	
1761	1		786.7	1	

Upstream Distance (m)	2005			Upstream Distance (m)	2012	
	LWD*	Comments			LWD*	Comments
1769				796.7	0	
1773				806.8	0	
1780				817.1	0	
1887	4			827.4	0	
1896	1			837.7	0	
1909				847.8	0	
1916				857.8	0	
1928	2			867.8	0	
1939	5			877.9	0	
1947	4			888.2	0	
1955	25			898.3	0	
2008	9			908.6	1	
2018	1			919.3	0	
2028	2			929.7	0	
2038	1			931.6	7	
2047				941.9	3	
2107	3			952.3	4	
2111				962.3	0	
2124	2			972.7	0	
2130	4			982.7	1	
2140	3			992.9	1	
2150				1003	1	
2158				1013.2	2	
2164	1			1023.8	0	
2179	8			1034.3	1	
2182	2			1045.2	0	
2210	30			1059.9	0	
2226				1066.4	0	
2415				1076.4	1	
2441				1087.4	1	
2484				1098.5	3	
2499				1108.8	0	
2773				1119.3	0	
2863	8			1129.6	0	
2879	12			1139.8	0	
2941	10			1150.1	0	
2964				1160.7	0	
3060	7			1212	0	
3069				1224.3	0	
3180				1233.7	7	

Upstream Distance (m)	2005 LWD*	2005 Comments	Upstream Distance (m)	2012 LWD*	2012 Comments
3203			1243.9	1	
3212			154.4	3	
3227			1264.4	0	
3392	4		1274.8	0	
3415	2		1295.6	0	
3454			1305.8	0	
3467	2		1316.3	0	
3637	12		1327.7	0	
3668			1327.7	1	
3699			1338.8	1	
3750	8		1350.1	6	
3761			1360.5	1	
3769			1370.5	0	
3789	5		1384.8	2	
3799			1385	0	
3806			1385.7	9	
3812			1395.7	4	
3950	5		1405.7	5	
3962	3		1415.8	0	
3971	3		1426	6	
3976	1		1436.1	3	
4032	5		1446.3	0	
4039	1		1456.6	2	
4066	3		1466.9	1	
4118	7		1477.6	2	
4144	1		1487.6	3	
4152			1497.7	4	
4352			1507.9	2	
4357			1518.1	6	
4380	4		128.3	2	
4388			1538.4	1	
4411			1548.6	1	
4425			1559.1	3	
4434	2		1564.8	4	
4478			1596.2	0	
4496			1606.4	0	
4519	2		1616.5	1	
4570			1626.4	4	
4586			1637.6	0	
4623			1648.5	0	

Upstream	2005			Upstream	2012	
Distance (m)	LWD*	Comments		Distance (m)	LWD*	Comments
4689				1658.8	3	
4699				1672.4	0	
4724	5			1682.4	0	
4759				1682.4	3	
4810				1693.6	4	
4824	2			1710.7	1	
4857	4			1721.3	1	
4891				1732.3	1	
4913				1744.3	0	
4949	5			1754.5	1	
4968				1765.2	4	
4976				1776.6	2	
5016				1787.5	2	
5030				1797.9	0	
5044				1808.4	1	
5080				1819.2	4	
5097				1842.5	3	
5119				1855.7	8	
5178	5			1869.5	2	
5195	2			1879.8	3	
5216				1894.7	5	
5255				1909.8	4	
5259	2			1922.5	0	
5309				1934	1	
5317				1945.2	3	
5379	5			1955.5	3	
5384				1966.7	0	
5394				1977.7	0	
5424				1988.8	6	
5434				2013.8	11	
5451				2041.4	18	
5465	2			2110.8	24	
5527	3			2132.1	3	
5550				2136.3	0	
5799	30			2151.3	6	
5822				2166.4	6	
5923	45			2181.5	8	
5941	10			2196.8	3	
6103	30			2212	5	
6125	1			2228.1	5	

Upstream	2005	
Distance (m)	LWD*	Comments
6167	1	
6221	1	
6263	10	
6286		
6301		
6320		
6332		
6360		
6389		
6475	7	
6493	4	
6628	4	
6645	1	
6695		
6703		
6717	3	
6897	40	
6940	3	
7012	6	
7021		
7163		
7175		
7239		
7267		
7275		
7318		
7325		
7337		
7360		
7451	3	
7469		
7549		
7555		
7571		

Upstream	2012	
Distance (m)	LWD*	Comments
2243.2	0	
2258.4	2	
2275.3	10	
2291.3	3	
2307.2	3	
2322.8	16	
2338	4	
2354	0	
2369.1	3	
2384.6	1	
2438.8	0	
2439.5	5	
2467	14	
2482.2	5	
2497.4	10	
2514	4	
2529	5	
2545.1	11	
2561.1	1	
2576.5	3	
2591.8	2	
2607.3	5	
2623.1	2	
2638	0	
2653.2	1	
2688.4	1	
2704.1	1	
2723	6	
2738.3	2	
2757	2	
2773.1	11	
2790.1	3	
2799.7	1	
548.4	8	
2831.1	2	
2847.2	5	
2863.1	14	
2883	1	
2898.7	0	
2915	0	

Upstream Distance (m)	2012	
	LWD*	Comments
2932.1	0	
2941.4	0	
2960	3	
2976.6	0	
2992.4	4	
3009	4	
3021.4	5	
3037.1	2	
3053	1	
3068.6	1	
3088.3	2	
3175.2	3	
3193	0	
3227.2	0	
3247	1	
3270.1	0	
3278.6	6	
3311.3	3	
3326.7	1	
3356.5	1	
3371.9	0	
3405.2	4	
3425.2	4	
3462	7	
3534	6	
3544	17	
3572.9	28	
3583	7	
3593.4	1	
3605	1	
3615	1	
3630.2	3	
3645.4	1	
3669	0	
3684.2	2	
3732.6	1	
3755.1	2	
3798.7	3	
3813.8	5	
3828.8	1	

Upstream Distance (m)	2012	
	LWD*	Comments
3848.2	3	
3871.3	4	
3888	27	
3906.4	17	
3921.5	8	
3938.2	2	
3955.6	5	
3971	3	
4005.3	1	
4022	0	
4040	2	
4059.1	2	
4090.8	2	
4106.2	0	
4122.6	0	
4165	20	
4184.5	4	
4204.2	0	
4222.2	9	
4248.8	1	
4271.2	0	
4289.7	0	
4308	3	
4327.9	1	
4344.3	0	
4360.8	1	
4380.1	2	
4397.2	1	
4414	3	
4429.3	4	
4449.6	4	
4468.4	3	
4488.6	2	
4519	2	
4534.7	1	
4551.2	4	
4569	9	
4569.6	4	
4588.8	0	
4607.2	0	

Upstream	2012	
Distance (m)	LWD*	Comments
4626.1	0	
4641.3	0	
4657.2	1	
4711.2	3	
4726.8	1	
4745.5	1	
4761.9	0	
4777.6	1	
4793.3	1	
4808.9	1	
4826.6	1	
4851.9	0	
4868.6	2	
4884.8	1	
4902	0	
4918.1	0	
4933.9	0	
4949.6	0	
4966.2	0	
4981.2	1	
5000.1	0	
5029.9	0	
5045.6	0	
5099.2	1	
5121.2	4	
5139.2	0	
5157	0	
5185.1	3	
5203.9	1	
5222.4	0	
5249.6	2	
5268.4	2	
5289.6	0	
5309.8	1	
5328.3	0	
5350.1	0	
5365.6	3	
5381.5	8	
5399.8	15	
5416.7	6	

Upstream Distance (m)	2012	
	LWD*	Comments
5438	6	
5455.9	7	
5471.7	2	
5488.3	10	
5507.7	8	
5525.3	2	
5542.1	25	
5557.7	3	
5575.1	3	
5591.4	12	
5603.8	4	
5614.9	6	
5625.1	6	
5635.6	17	
5645.7	7	
5655.7	10	
5665.7	4	
5676.2	1	
5686.2	5	
5696.2	0	
5704.4	1	
5715	1	
5725.8	1	
5736	0	
5756.9	0	
5767	5	
5780.5	5	
5792.1	0	
5806.2	0	
5817.5	0	
5828.4	0	
5843.6	2	
5853.7	0	
5853.7	1	
5865.8	1	
5877.9	0	
5878.1	0	
5893.4	3	
5909.2	4	
5924.6	4	

Upstream Distance (m)	2012	
	LWD*	Comments
5940	0	
5955.4	0	
5970.7	0	
5993.4	2	
6008.8	3	
6024.1	2	
6038.3	4	
6387.2	0	
6402.2	1	
6417.2	3	
6432.2	1	
6447.2	0	
6462.2	7	
6477.2	12	
6492.2	0	
6507.2	0	
6522.2	0	
6537.2	8	
6552.2	10	
6567.2	0	
6582.2	3	
6597.2	0	
6612.2	1	
6627.2	1	
6642.2	0	
6657.2	0	
6672.2	5	
6687.2	4	
6702.2	3	
6717.2	2	
6732.2	0	
6749.2	6	
6766.2	5	
6781.2	0	
6796.2	3	
6811.2	1	
6827.2	4	
6843.2	9	
6858.2	16	
6873.2	8	

Upstream Distance (m)	2012	
	LWD*	Comments
6888.2	11	
6903.2	1	
6919.2	0	
6934.2	1	
6949.2	2	
6964.2	2	
6979.2	1	
6995.2	1	
7010.2	3	
7025.2	0	
7040.2	0	
7050.8	2	
7065.8	0	
7073.8	0	
7088.8	4	
7103.8	0	
7118.8	1	
7133.8	0	
7148.8	0	
7163.8	2	
7178.8	0	
7193.8	0	
7208.8	0	
7223.8	0	
7238.4	0	
7253.5	0	
7268.5	0	
7286.5	1	
7301.5	0	
7316.5	0	
7331.5	0	
7346.5	1	
7362.5	0	
7378.5	1	
7393.5	4	
7408.5	0	
7423.5	1	
7438.5	0	
7453.5	1	
7468.5	1	

Upstream Distance (m)	2012	
	LWD*	Comments
7483.5	2	
7498.5	1	
7507.2	4	
7516.4	0	
7531.6	0	
7546.5	0	
7562.0	0	
7575.2	0	

APPENDIX B

Pebble Counts

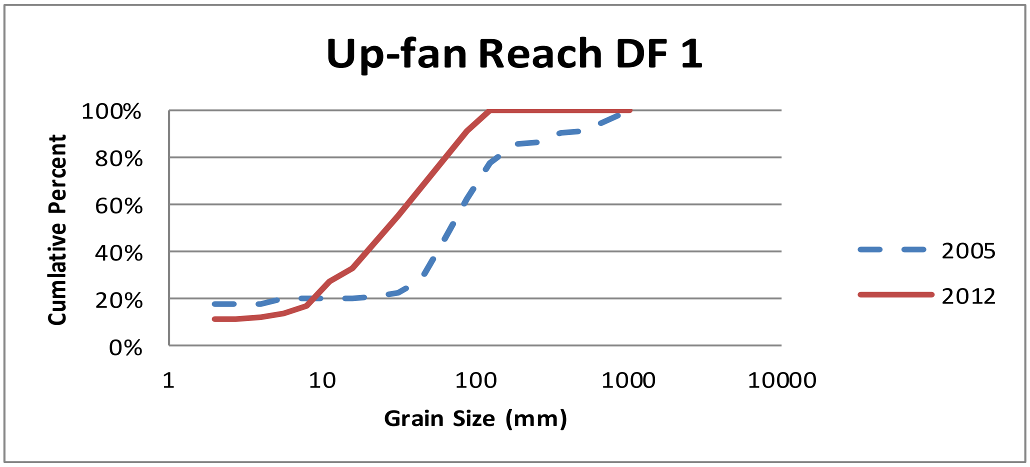
Location	Up-fan Reach of Debris Flow Fan 1			
Stream	Sleeping Child Creek			
Date	August-05		Date	July-12
Observer	Hoffman		Observer	Short

D50 (mm)	71

D50 (mm)	27.5

Grain Size (mm)	Percent Finer Than Size
2	18%
2.8	18%
4	18%
5.6	20%
8	20%
11.3	20%
16	20%
22.6	21%
32	22%
45.3	28%
64	45%
90.5	62%
128	77%
181	85%
256	86%
362	90%
512	91%
1024	100%

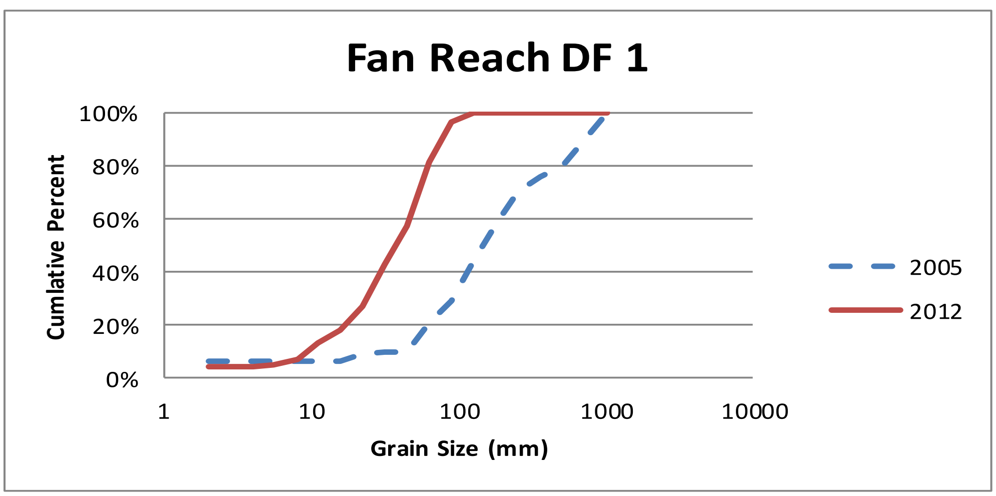
Grain Size (mm)	Percent Finer Than Size
2	11%
2.8	11%
4	12%
5.6	14%
8	17%
11.3	27%
16	33%
22.6	44%
32	55%
45.3	67%
64	79%
90.5	91%
128	100%
181	100%
256	100%
362	100%
512	100%
1024	100%



Location	Fan Reach of Debris Flow Fan 1			
Stream	Sleeping Child Creek			
Date	August-05		Date	July-12
Observer	Hoffman		Observer	Short

D50 (mm)	148		D50 (mm)	37

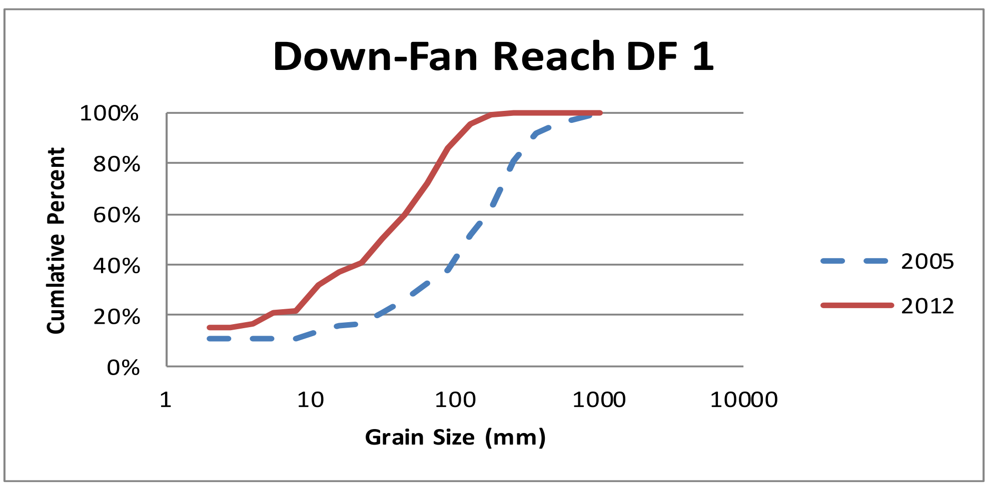
Grain Size (mm)	Percent Finer Than Size		Grain Size (mm)	Percent Finer Than Size
2	6%		2	4%
2.8	6%		2.8	4%
4	6%		4	4%
5.6	6%		5.6	5%
8	6%		8	7%
11.3	6%		11.3	13%
16	6%		16	18%
22.6	9%		22.6	27%
32	10%		32	43%
45.3	10%		45.3	57%
64	21%		64	81%
90.5	29%		90.5	96%
128	44%		128	100%
181	58%		181	100%
256	70%		256	100%
362	76%		362	100%
512	80%		512	100%
1024	100%		1024	100%



Location	Down-Fan Reach of Debris Flow Fan 1			
Stream	Sleeping Child Creek			
Date	August-05		Date	July-12
Observer	Hoffman		Observer	Short

D50 (mm)	122		D50 (mm)	32

Grain Size (mm)	Percent Finer Than Size		Grain Size (mm)	Percent Finer Than Size
2	11%		2	15%
2.8	11%		2.8	15%
4	11%		4	17%
5.6	11%		5.6	21%
8	11%		8	22%
11.3	14%		11.3	32%
16	16%		16	37%
22.6	17%		22.6	41%
32	21%		32	50%
45.3	26%		45.3	60%
64	33%		64	72%
90.5	38%		90.5	86%
128	52%		128	95%
181	62%		181	99%
256	81%		256	100%
362	92%		362	100%
512	95%		512	100%
1024	100%		1024	100%



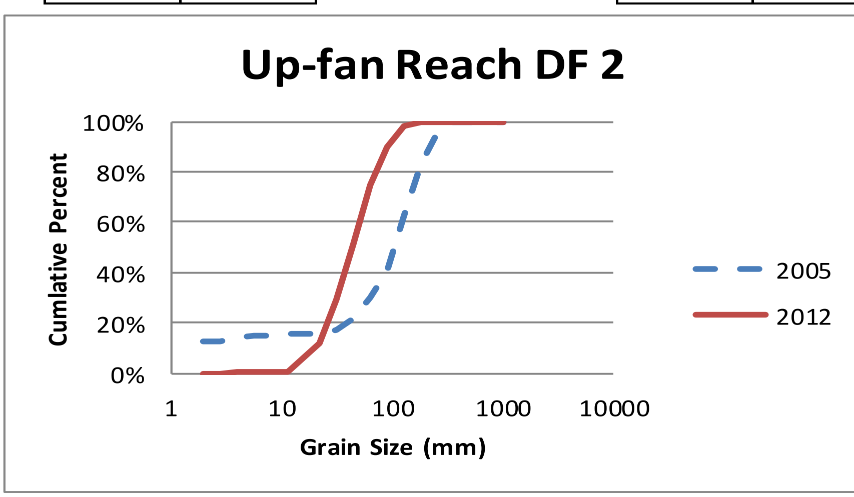
Location	Up-fan Reach of Debris Flow Fan 2		
Stream	Sleeping Child Creek		
Date	August-05	Date	July-12
Observer	Hoffman	Observer	Short

D50 (mm)	104

D50 (mm)	32

Grain Size (mm)	Percent Finer Than Size
2	13%
2.8	13%
4	14%
5.6	15%
8	15%
11.3	16%
16	16%
22.6	16%
32	17%
45.3	22%
64	30%
90.5	41%
128	63%
181	83%
256	96%
362	100%
512	100%
1024	100%

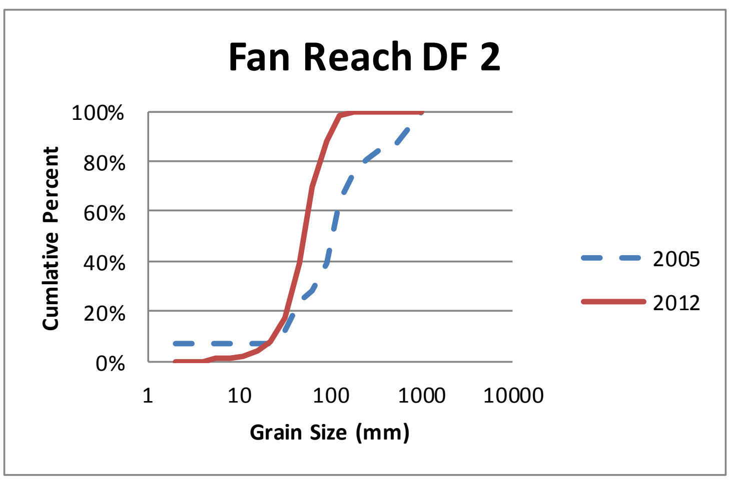
Grain Size (mm)	Percent Finer Than Size
2	0%
2.8	0%
4	1%
5.6	1%
8	1%
11.3	1%
16	7%
22.6	12%
32	29%
45.3	51%
64	75%
90.5	90%
128	98%
181	100%
256	100%
362	100%
512	100%
1024	100%



Location	Fan Reach of Debris Flow Fan 2			
Stream	Sleeping Child Creek			
Date	August-05		Date	July-12
Observer	Hoffman		Observer	Short

D50 (mm)	105		D50 (mm)	50

Grain Size (mm)	Percent Finer Than Size		Grain Size (mm)	Percent Finer Than Size
2	7%		2	0%
2.8	7%		2.8	0%
4	7%		4	0%
5.6	7%		5.6	1%
8	7%		8	1%
11.3	7%		11.3	2%
16	7%		16	4%
22.6	7%		22.6	8%
32	12%		32	17%
45.3	24%		45.3	39%
64	28%		64	70%
90.5	39%		90.5	88%
128	64%		128	98%
181	76%		181	100%
256	81%		256	100%
362	85%		362	100%
512	86%		512	100%
1024	100%		1024	100%



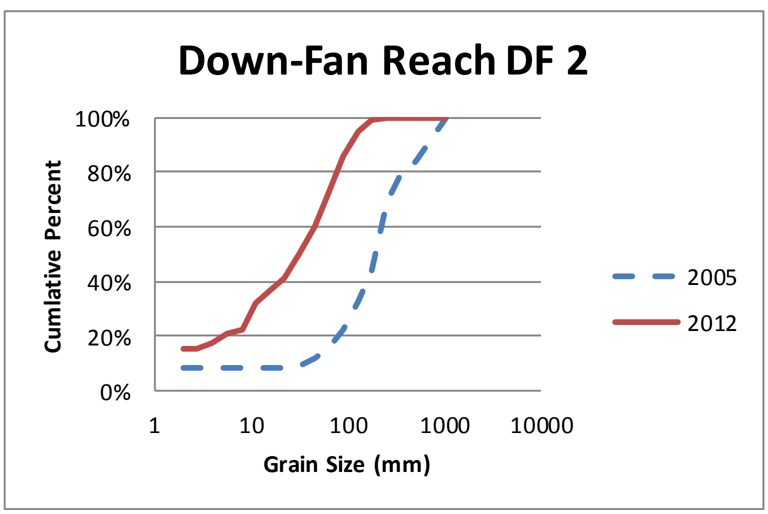
Location	Down-Fan Reach of Debris Flow Fan 2				
Stream	Sleeping Child Creek				
Date	August-05			Date	July-12
Observer	Hoffman			Observer	Short

D50 (mm)	197

D50 (mm)	32

Grain Size (mm)	Percent Finer Than Size
2	8%
2.8	8%
4	8%
5.6	8%
8	8%
11.3	8%
16	8%
22.6	8%
32	9%
45.3	12%
64	15%
90.5	22%
128	33%
181	44%
256	69%
362	80%
512	84%
1024	100%

Grain Size (mm)	Percent Finer Than Size
2	15%
2.8	15%
4	17%
5.6	21%
8	22%
11.3	32%
16	37%
22.6	41%
32	50%
45.3	60%
64	72%
90.5	86%
128	95%
181	99%
256	100%
362	100%
512	100%
1024	100%



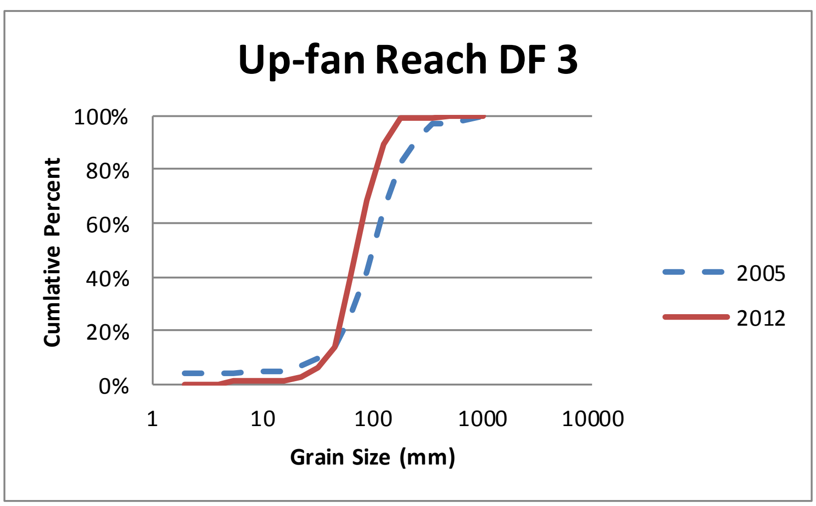
Location	Up-fan Reach of Debris Flow Fan 3				
Stream	Sleeping Child Creek				
Date	August-05			Date	July-12
Observer	Hoffman			Observer	Short

D50 (mm)	102

D50 (mm)	79

Grain Size (mm)	Percent Finer Than Size
2	4%
2.8	4%
4	4%
5.6	4%
8	5%
11.3	5%
16	5%
22.6	7%
32	10%
45.3	14%
64	25%
90.5	42%
128	65%
181	82%
256	91%
362	97%
512	97%
1024	100%

Grain Size (mm)	Percent Finer Than Size
2	0%
2.8	0%
4	0%
5.6	1%
8	1%
11.3	1%
16	1%
22.6	3%
32	6%
45.3	14%
64	39%
90.5	68%
128	89%
181	99%
256	99%
362	99%
512	100%
1024	100%



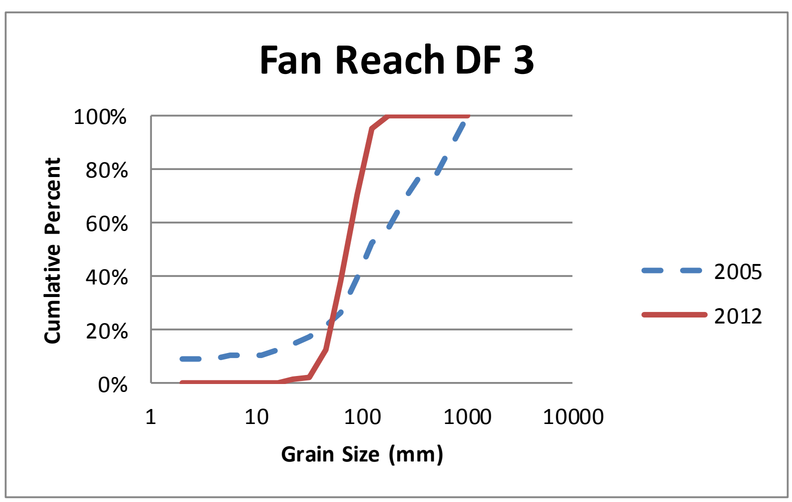
Location	Fan Reach of Debris Flow Fan 3				
Stream	Sleeping Child Creek				
Date	August-05			Date	July-12
Observer	Hoffman			Observer	Short

D50 (mm)	121

D50 (mm)	70

Grain Size (mm)	Percent Finer Than Size
2	9%
2.8	9%
4	9%
5.6	10%
8	10%
11.3	10%
16	12%
22.6	14%
32	17%
45.3	21%
64	26%
90.5	39%
128	52%
181	58%
256	69%
362	77%
512	78%
1024	100%

Grain Size (mm)	Percent Finer Than Size
2	0%
2.8	0%
4	0%
5.6	0%
8	0%
11.3	0%
16	0%
22.6	1%
32	2%
45.3	12%
64	38%
90.5	70%
128	95%
181	100%
256	100%
362	100%
512	100%
1024	100%



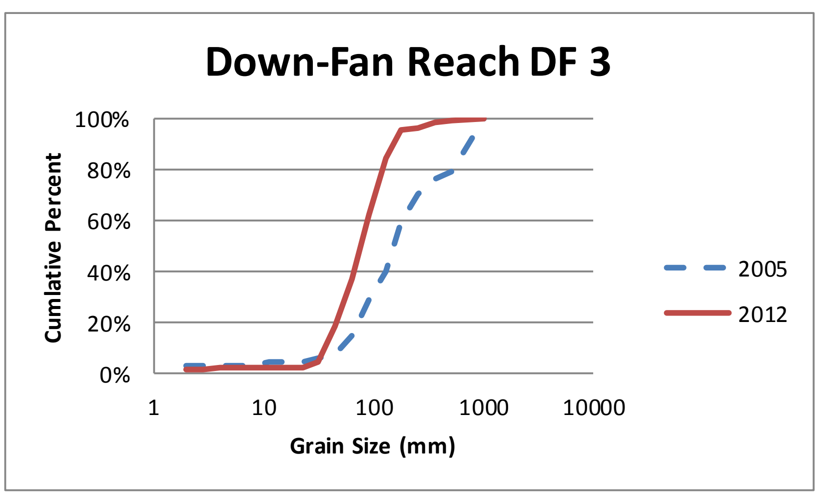
Location	Down-Fan Reach of Debris Flow Fan 3		
Stream	Sleeping Child Creek		
Date	August-05	Date	July-12
Observer	Hoffman	Observer	Short

D50 (mm)	154

D50 (mm)	80

Grain Size (mm)	Percent Finer Than Size
2	3%
2.8	3%
4	3%
5.6	3%
8	3%
11.3	4%
16	4%
22.6	4%
32	6%
45.3	7%
64	15%
90.5	29%
128	40%
181	59%
256	70%
362	76%
512	79%
1024	100%

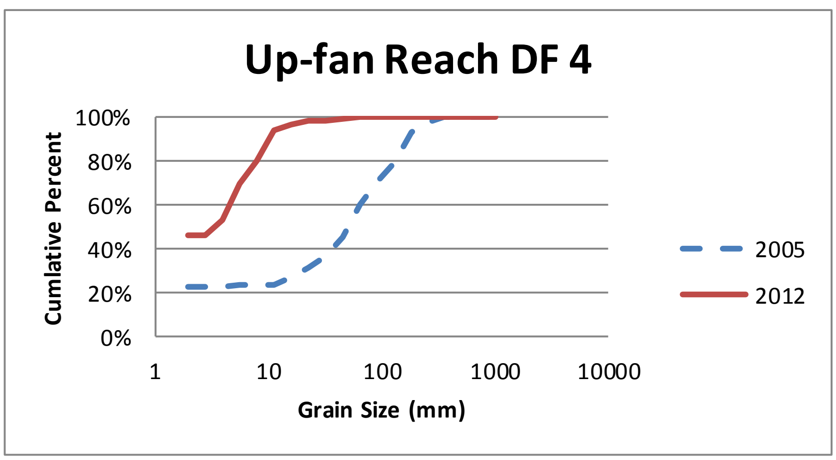
Grain Size (mm)	Percent Finer Than Size
2	1%
2.8	1%
4	2%
5.6	2%
8	2%
11.3	2%
16	2%
22.6	2%
32	4%
45.3	18%
64	37%
90.5	62%
128	84%
181	95%
256	96%
362	98%
512	99%
1024	100%



Location	Up-fan Reach of Debris Flow Fan 4				
Stream	Sleeping Child Creek				
Date	August-05			Date	July-12
Observer	Hoffman			Observer	Short

D50 (mm)	51	D50	3

Grain Size (mm)	Percent Finer Than Size	Grain Size (mm)	Percent Finer Than Size
2	22%	2	46%
2.8	22%	2.8	46%
4	22%	4	53%
5.6	23%	5.6	69%
8	23%	8	80%
11.3	23%	11.3	94%
16	27%	16	96%
22.6	31%	22.6	98%
32	36%	32	98%
45.3	45%	45.3	99%
64	60%	64	100%
90.5	70%	90.5	100%
128	79%	128	100%
181	93%	181	100%
256	97%	256	100%
362	100%	362	100%
512	100%	512	100%
1024	100%	1024	100%



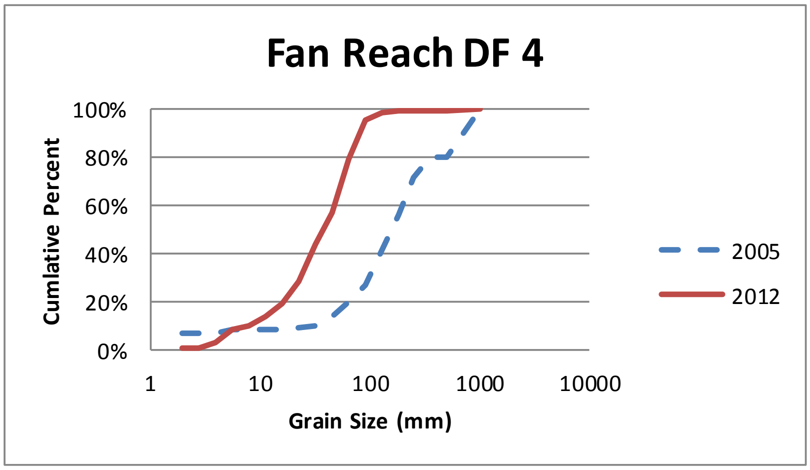
Location	Fan Reach of Debris Flow Fan 4			
Stream	Sleeping Child Creek			
Date	August-05		Date	July-12
Observer	Hoffman		Observer	Short

D50 (mm)	157

Grain Size (mm)	Percent Finer Than Size
2	7%
2.8	7%
4	7%
5.6	8%
8	8%
11.3	8%
16	8%
22.6	9%
32	10%
45.3	14%
64	20%
90.5	27%
128	41%
181	56%
256	71%
362	80%
512	80%
1024	100%

D50 (mm)	37.5

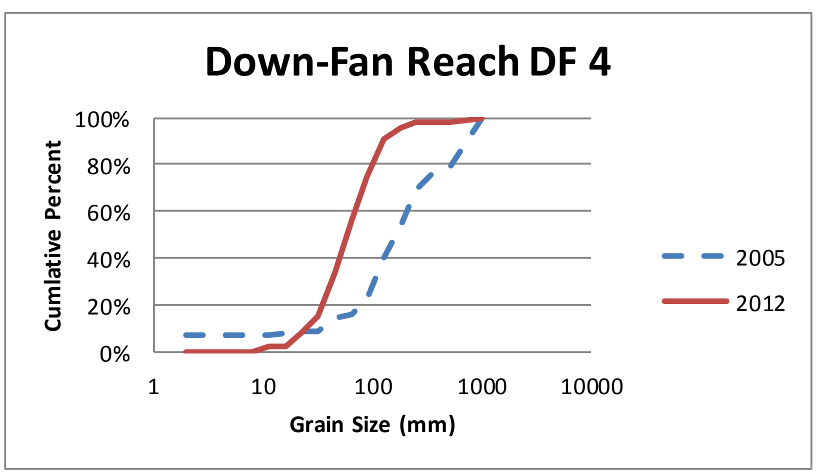
Grain Size (mm)	Percent Finer Than Size
2	1%
2.8	1%
4	3%
5.6	8%
8	10%
11.3	14%
16	19%
22.6	28%
32	44%
45.3	57%
64	79%
90.5	95%
128	98%
181	99%
256	99%
362	99%
512	99%
1024	100%



Location	Down-Fan Reach of Debris Flow Fan 4		
Stream	Sleeping Child Creek		
Date	August-05	Date	July-12
Observer	Hoffman	Observer	Short

D50 (mm)	164	D50 (mm)	58.5

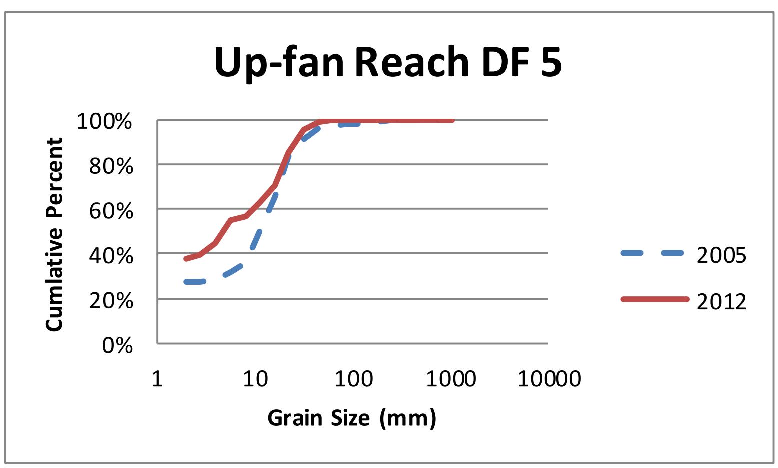
Grain Size (mm)	Percent Finer Than Size	Grain Size (mm)	Percent Finer Than Size
2	7%	2	0%
2.8	7%	2.8	0%
4	7%	4	0%
5.6	7%	5.6	0%
8	7%	8	0%
11.3	7%	11.3	2%
16	8%	16	2%
22.6	9%	22.6	8%
32	9%	32	15%
45.3	14%	45.3	34%
64	16%	64	56%
90.5	22%	90.5	75%
128	40%	128	91%
181	54%	181	96%
256	69%	256	98%
362	76%	362	98%
512	79%	512	98%
1024	100%	1024	100%



Location	Up-fan Reach of Debris Flow Fan 5		
Stream	Sleeping Child Creek		
Date	August-05	Date	July-12
Observer	Hoffman	Observer	Short

D50 (mm)	11	D50 (mm)	4

Grain Size (mm)	Percent Finer Than Size	Grain Size (mm)	Percent Finer Than Size
2	27%	2	38%
2.8	27%	2.8	39%
4	28%	4	45%
5.6	32%	5.6	55%
8	36%	8	57%
11.3	50%	11.3	63%
16	65%	16	70%
22.6	83%	22.6	85%
32	91%	32	95%
45.3	96%	45.3	99%
64	97%	64	100%
90.5	98%	90.5	100%
128	98%	128	100%
181	99%	181	100%
256	100%	256	100%
362	100%	362	100%
512	100%	512	100%
1024	100%	1024	100%



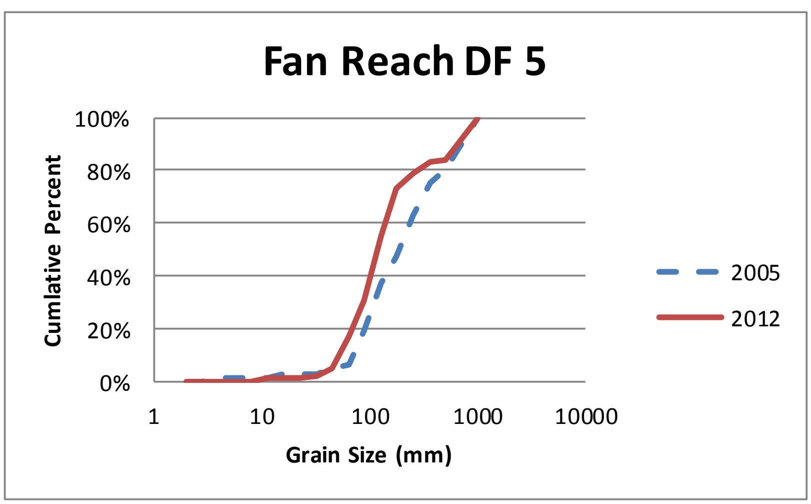
Location	Fan Reach of Debris Flow Fan 5		
Stream	Sleeping Child Creek		
Date	August-05	Date	July-12
Observer	Hoffman	Observer	Short

D50 (mm)	192

D50 (mm)	123

Grain Size (mm)	Percent Finer Than Size
2	0%
2.8	0%
4	1%
5.6	1%
8	1%
11.3	1%
16	3%
22.6	3%
32	3%
45.3	5%
64	6%
90.5	19%
128	37%
181	47%
256	63%
362	75%
512	80%
1024	100%

Grain Size (mm)	Percent Finer Than Size
2	0%
2.8	0%
4	0%
5.6	0%
8	0%
11.3	1%
16	1%
22.6	1%
32	2%
45.3	5%
64	17%
90.5	31%
128	55%
181	73%
256	79%
362	83%
512	84%
1024	100%



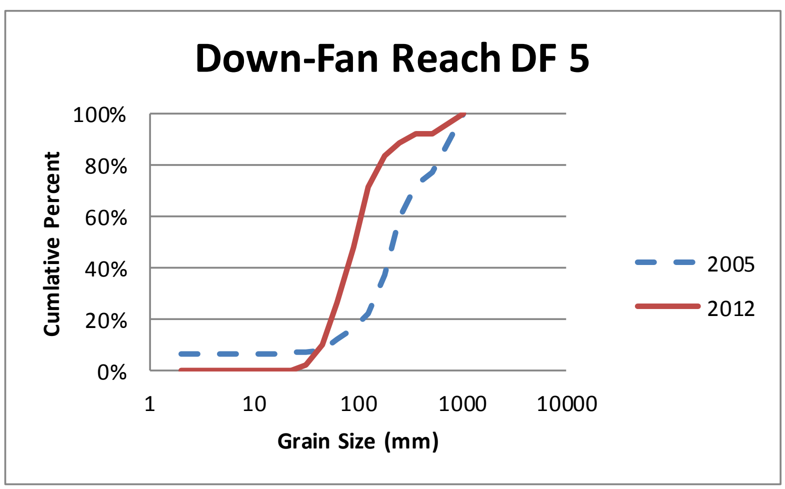
Location	Down-Fan Reach of Debris Flow Fan 5				
Stream	Sleeping Child Creek				
Date	August-05			Date	July-12
Observer	Hoffman			Observer	Short

D50 (mm)	222

D50 (mm)	93.5

Grain Size (mm)	Percent Finer Than Size
2	6%
2.8	6%
4	6%
5.6	6%
8	6%
11.3	6%
16	6%
22.6	7%
32	7%
45.3	8%
64	12%
90.5	16%
128	22%
181	37%
256	59%
362	72%
512	77%
1024	100%

Grain Size (mm)	Percent Finer Than Size
2	0%
2.8	0%
4	0%
5.6	0%
8	0%
11.3	0%
16	0%
22.6	0%
32	2%
45.3	10%
64	26%
90.5	48%
128	71%
181	83%
256	88%
362	92%
512	92%
1024	100%



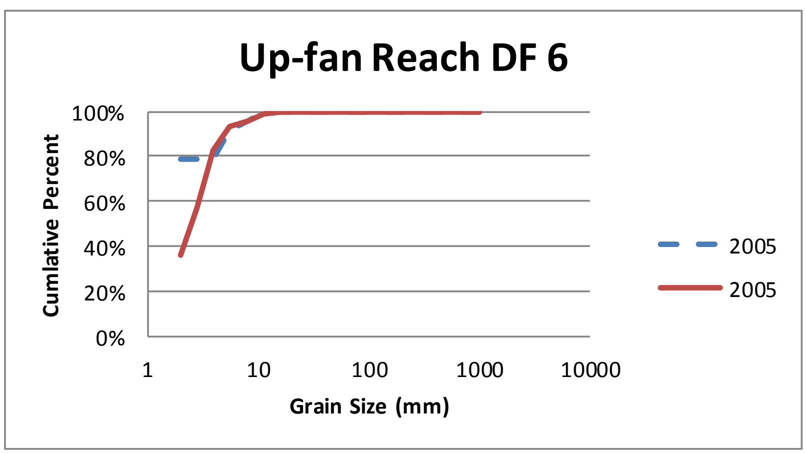
Location	Up-fan Reach of Debris Flow Fan 6		
Stream	Sleeping Child Creek		
Date	August-05	Date	July-12
Observer	Hoffman	Observer	Short

D50 (mm)	2

D50 (mm)	2

Grain Size (mm)	Percent Finer Than Size
2	79%
2.8	79%
4	79%
5.6	92%
8	96%
11.3	100%
16	100%
22.6	100%
32	100%
45.3	100%
64	100%
90.5	100%
128	100%
181	100%
256	100%
362	100%
512	100%
1024	100%

Grain Size (mm)	Percent Finer Than Size
2	36%
2.8	57%
4	83%
5.6	93%
8	96%
11.3	99%
16	100%
22.6	100%
32	100%
45.3	100%
64	100%
90.5	100%
128	100%
181	100%
256	100%
362	100%
512	100%
1024	100%



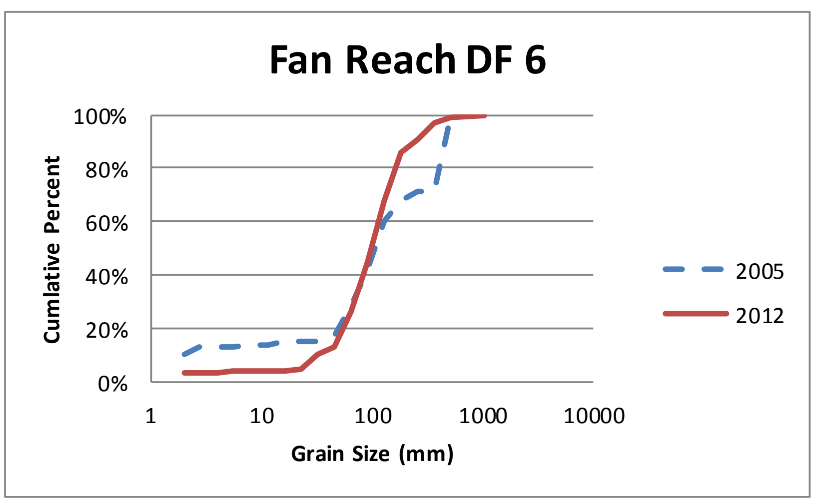
Location	Fan Reach of Debris Flow Fan 6			
Stream	Sleeping Child Creek			
Date	August-05		Date	July-12
Observer	Hoffman		Observer	Short

D50 (mm)	146

D50 (mm)	97

Grain Size (mm)	Percent Finer Than Size
2	10%
2.8	13%
4	13%
5.6	13%
8	14%
11.3	14%
16	15%
22.6	15%
32	15%
45.3	17%
64	28%
90.5	42%
128	60%
181	68%
256	71%
362	71%
512	100%
1024	100%

Grain Size (mm)	Percent Finer Than Size
2	3%
2.8	3%
4	3%
5.6	4%
8	4%
11.3	4%
16	4%
22.6	5%
32	10%
45.3	13%
64	26%
90.5	45%
128	68%
181	86%
256	91%
362	97%
512	99%
1024	100%



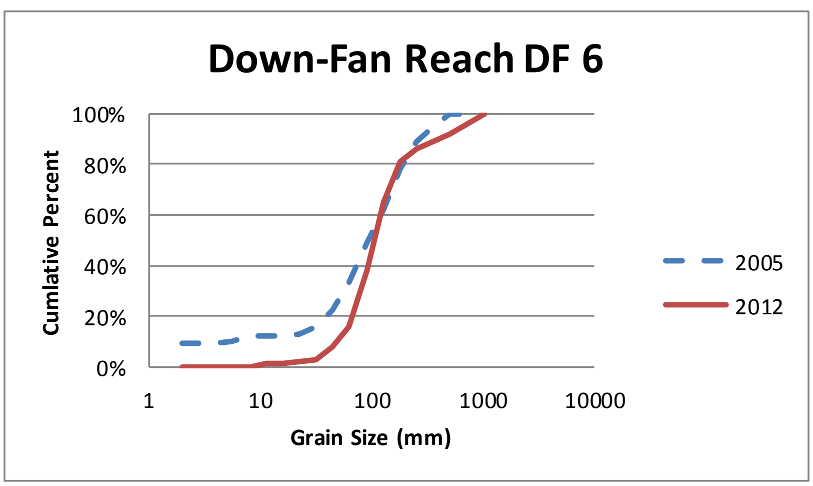
Location	Down-Fan Reach of Debris Flow Fan 6		
Stream	Sleeping Child Creek		
Date	August-05	Date	July-12
Observer	Hoffman	Observer	Short

D50 (mm)	93

D50 (mm)	108.5

Grain Size (mm)	Percent Finer Than Size
2	9%
2.8	9%
4	9%
5.6	10%
8	12%
11.3	12%
16	12%
22.6	13%
32	16%
45.3	22%
64	33%
90.5	49%
128	62%
181	78%
256	89%
362	95%
512	100%
1024	100%

Grain Size (mm)	Percent Finer Than Size
2	0%
2.8	0%
4	0%
5.6	0%
8	0%
11.3	1%
16	1%
22.6	2%
32	3%
45.3	8%
64	16%
90.5	38%
128	65%
181	81%
256	86%
362	89%
512	92%
1024	100%



APPENDIX C

Raw Pebble Counts 2012

Location	Up-fan Reach of DF 1					
Stream	Sleeping Child Creek					
Date	July-12					
Observer	Short					
Each cell is the grain size (mm) of 1 particle						
	1.9	8	16	27	40	69
	1.9	8	17	28	43	69
	1.9	8	17	28	44	70
	1.9	8	17	28	45	73
	1.9	8	17	29	46	73
	1.9	9	17	29	46	74
	1.9	9	18	29	47	74
	1.9	9	18	30	48	76
	1.9	9	18	31	48	79
	1.9	10	18	31	48	79
	1.9	10	19	32	48	81
	1.9	10	19	32	48	83
	1.9	10	19	33	49	86
	1.9	11	19	33	50	86
	1.9	11	20	33	50	87
	1.9	11	20	34	51	89
	1.9	11	21	34	51	92
	1.9	11	22	34	51	93
	1.9	11	22	34	52	93
	1.9	11	22	34	54	94
	1.9	11	22	34	55	97
	1.9	12	22	34	56	99
	3	12	23	34	56	101
	4	12	23	35	61	102
	4	13	23	36	62	105
	4	13	23	37	63	106
	4	14	23	38	64	106
	5	14	24	38	64	111
	6	14	24	39	66	113
	6	15	24	39	66	114
	6	15	24	39	68	114
	7	15	25	39	68	122
	7	16	27	40	68	126
						127
						146

Location	Fan Reach of DF 1					
Stream	Sleeping Child Creek					
Date	July-12					
Observer	Short					
Each cell is the grain size (mm) of 1 particle						
	1.9	15	26	37	49	68
	1.9	15	26	37	49	69
	1.9	15	27	37	50	69
	1.9	16	27	38	51	70
	1.9	17	28	38	51	71
	1.9	18	28	38	52	72
	1.9	18	28	38	52	74
	1.9	18	28	38	52	74
	4	19	28	38	53	75
	4	19	28	39	53	75
	6	20	29	40	54	80
	6	20	29	41	55	80
	7	20	30	41	56	80
	8	20	30	41	56	80
	8	20	30	41	57	80
	8	21	30	44	58	81
	9	21	30	44	58	81
	9	21	31	44	59	83
	10	22	31	45	59	84
	10	22	32	45	60	84
	10	23	32	46	60	85
	10	23	32	46	60	85
	11	23	33	46	60	85
	11	23	33	46	61	86
	11	23	33	47	62	86
	12	23	34	48	63	89
	12	23	34	48	63	91
	12	24	35	48	63	97
	12	24	35	48	63	100
	12	24	36	48	64	112
	14	24	36	48	64	117
	14	24	36	49	64	118
	15	26	36	49	67	121
						124
						130

Location	Down-fan Reach of DF 1					
Stream	Sleeping Child Creek					
Date	July-12					
Observer	Short					
Each cell is the grain size (mm) of 1 particle						
	1.9	4	14	32	52	84
	1.9	4	14	32	52	85
	1.9	4	15	32	52	85
	1.9	4	15	34	53	87
	1.9	4	15	36	54	87
	1.9	4	15	36	55	88
	1.9	5	15	36	55	90
	1.9	5	16	37	58	94
	1.9	6	16	37	58	95
	1.9	6	18	37	63	98
	1.9	7	18	39	63	100
	1.9	8	18	40	64	106
	1.9	8	21	40	64	106
	1.9	8	22	41	64	108
	1.9	8	22	41	65	108
	1.9	8	22	41	66	109
	1.9	9	23	42	66	114
	1.9	9	23	42	66	115
	1.9	9	24	43	67	116
	1.9	9	24	43	67	117
	1.9	9	25	44	69	117
	1.9	10	26	45	70	119
	1.9	10	26	45	72	119
	1.9	10	27	45	74	126
	1.9	10	28	45	76	136
	1.9	10	28	47	77	139
	1.9	11	28	48	78	139
	1.9	11	28	48	78	150
	1.9	11	29	49	79	154
	1.9	11	29	49	80	157
	3	12	30	49	82	163
	3	12	31	50	83	167
	3	14	31	51	83	186
						230
						300

Location	Up-fan Reach of DF 2					
Stream	Sleeping Child Creek					
Date	July-12					
Observer	Short					
Each cell is the grain size (mm) of 1 particle						
	3	25	36	43	56	78
	11	25	36	43	56	79
	12	25	36	43	56	79
	12	26	36	44	56	80
	13	26	36	44	57	80
	13	26	36	44	57	81
	14	26	37	44	58	81
	14	26	37	44	58	82
	14	27	37	45	59	83
	14	27	37	45	59	83
	15	27	37	46	59	84
	15	27	37	46	60	84
	15	28	37	47	60	86
	16	28	37	47	61	86
	16	28	38	47	61	91
	17	28	39	47	62	92
	18	30	39	48	63	92
	19	30	39	48	64	94
	21	30	39	48	65	94
	21	30	39	49	66	95
	21	30	40	49	67	95
	21	30	40	50	67	99
	22	31	40	50	68	99
	22	31	40	50	68	100
	23	33	40	51	68	105
	23	33	41	51	69	109
	23	33	42	51	70	112
	23	33	42	52	70	114
	24	33	42	52	71	116
	24	34	42	54	71	121
	24	34	42	54	73	127
	24	34	42	55	73	131
	25	35	43	55	76	147
						152
						220

Location	Fan Reach of DF 2					
Stream	Sleeping Child Creek					
Date	July-12					
Observer	Short					
Each cell is the grain size (mm) of 1 particle						
	5	32	41	50	61	80
	7	32	41	50	62	81
	8	32	41	50	62	84
	9	33	41	51	62	85
	12	34	42	51	62	85
	14	34	43	51	63	85
	15	34	43	51	63	86
	17	35	43	51	63	86
	19	35	43	51	65	86
	20	35	43	51	66	87
	21	35	43	52	67	87
	21	35	44	53	67	92
	21	36	44	53	69	93
	22	36	44	54	69	95
	22	36	44	54	69	95
	24	36	45	54	70	98
	24	36	45	54	70	99
	25	37	45	54	70	99
	25	38	46	55	70	102
	26	38	46	55	71	107
	26	38	47	56	73	107
	27	38	47	56	73	108
	27	38	47	56	74	109
	28	39	47	56	74	117
	28	39	48	56	77	118
	28	39	48	57	77	119
	29	39	48	57	77	123
	29	39	48	58	78	124
	30	40	49	58	78	125
	30	40	49	60	79	127
	31	40	49	61	80	143
	31	40	49	61	80	146
	31	41	50	61	80	168
						179
						298

Location	Down-fan Reach of DF 2					
Stream	Sleeping Child Creek					
Date	July-12					
Observer	Short					
Each cell is the grain size (mm) of 1 particle						
	1.9	4	14	32	52	84
	1.9	4	14	32	52	85
	1.9	4	15	32	52	85
	1.9	4	15	34	53	87
	1.9	4	15	36	54	87
	1.9	4	15	36	55	88
	1.9	5	15	36	55	90
	1.9	5	16	37	58	94
	1.9	6	16	37	58	95
	1.9	6	18	37	63	98
	1.9	7	18	39	63	100
	1.9	8	18	40	64	106
	1.9	8	21	40	64	106
	1.9	8	22	41	64	108
	1.9	8	22	41	65	108
	1.9	8	22	41	66	109
	1.9	9	23	42	66	114
	1.9	9	23	42	66	115
	1.9	9	24	43	67	116
	1.9	9	24	43	67	117
	1.9	9	25	44	69	117
	1.9	10	26	45	70	119
	1.9	10	26	45	72	119
	1.9	10	27	45	74	126
	1.9	10	28	45	76	136
	1.9	10	28	47	77	139
	1.9	11	28	48	78	139
	1.9	11	28	48	78	150
	1.9	11	29	49	79	154
	1.9	11	29	49	80	157
	3	12	30	49	82	163
	3	12	31	50	83	167
	3	14	31	51	83	186
						230
						300

Location	Up-fan Reach of DF 3					
Stream	Sleeping Child Creek					
Date	July-12					
Observer	Short					
Each cell is the grain size (mm) of 1 particle						
	5	46	58	79	90	114
	12	46	58	80	90	114
	18	46	59	80	90	116
	19	46	59	80	90	117
	20	46	60	80	91	118
	22	46	60	80	91	118
	23	46	62	80	91	120
	26	47	62	81	92	123
	26	48	62	82	95	123
	29	48	62	82	95	125
	30	48	63	83	96	126
	31	48	63	83	97	127
	32	49	65	83	98	131
	33	49	65	83	98	131
	34	50	65	83	99	133
	35	51	66	84	100	133
	35	52	66	84	101	136
	35	52	67	85	101	137
	36	52	67	85	101	137
	40	52	67	85	103	138
	41	53	67	85	103	138
	41	53	67	86	104	143
	41	53	68	86	107	144
	41	54	68	87	107	146
	43	54	69	87	107	148
	43	56	70	87	108	153
	43	57	71	88	108	157
	44	57	71	88	108	157
	44	57	72	88	111	159
	44	58	73	88	111	161
	45	58	75	88	112	172
	45	58	76	88	113	173
	46	58	77	89	114	184
						402
						521

Location	Fan Reach of DF 3					
Stream	Sleeping Child Creek					
Date	July-12					
Observer	Short					
Each cell is the grain size (mm) of 1 particle						
	22	49	60	70	85	107
	22	50	60	70	85	108
	27	50	61	70	85	109
	30	50	61	71	86	109
	33	50	61	71	86	111
	34	50	62	72	87	112
	34	50	63	72	89	112
	38	51	63	73	89	112
	38	51	63	74	91	112
	39	51	63	74	92	113
	39	51	64	76	92	113
	40	52	64	76	93	115
	41	52	64	77	94	118
	41	53	65	77	94	119
	42	53	65	77	95	119
	42	54	65	77	95	119
	42	54	65	77	96	120
	42	54	65	78	96	120
	43	54	66	79	96	121
	43	55	66	79	97	123
	43	55	66	80	97	125
	43	55	66	80	97	127
	43	55	66	80	98	127
	43	55	67	80	100	127
	44	57	67	81	100	129
	44	57	68	81	101	132
	45	58	68	81	102	144
	45	58	68	82	102	146
	46	58	69	82	104	148
	47	59	69	82	105	154
	47	59	69	83	105	163
	48	59	69	83	106	166
	48	59	69	84	107	167
						174
						242

Location	Down-fan Reach of DF 3					
Stream	Sleeping Child Creek					
Date	July-12					
Observer	Short					
Each cell is the grain size (mm) of 1 particle						
	1.9	43	58	80	97	125
	1.9	43	59	80	97	127
	3	44	60	80	99	129
	10	44	61	80	99	131
	29	44	61	81	102	133
	29	45	62	81	102	134
	30	45	62	82	102	136
	31	45	64	82	102	137
	32	46	65	83	103	140
	32	46	65	83	104	143
	33	46	66	84	105	143
	34	47	66	84	106	145
	35	48	66	85	107	146
	35	48	67	85	107	148
	35	49	67	85	108	151
	36	49	68	85	108	155
	37	50	68	86	108	163
	37	52	69	86	109	163
	38	53	69	87	109	164
	38	53	69	88	113	165
	39	54	69	88	113	168
	39	54	71	88	114	173
	39	54	71	89	116	173
	40	54	72	90	116	173
	40	54	72	90	118	178
	40	55	73	92	118	203
	40	55	73	92	119	212
	42	55	74	92	122	267
	42	55	75	93	122	272
	42	55	76	93	122	296
	43	56	77	95	124	303
	43	57	77	96	125	403
	43	58	78	96	125	480
						521
						524

Location	Up-fan Reach of DF 4					
Stream	Sleeping Child Creek					
Date	July-12					
Observer	Short					
Each cell is the grain size (mm) of 1 particle						
	1.9	1.9	1.9	3	5	8
	1.9	1.9	1.9	3	5	8
	1.9	1.9	1.9	3	5	8
	1.9	1.9	1.9	3	5	8
	1.9	1.9	1.9	3	5	9
	1.9	1.9	1.9	3	6	9
	1.9	1.9	1.9	3	6	9
	1.9	1.9	1.9	4	6	9
	1.9	1.9	1.9	4	6	9
	1.9	1.9	1.9	4	6	9
	1.9	1.9	1.9	4	6	9
	1.9	1.9	1.9	4	6	9
	1.9	1.9	1.9	4	6	9
	1.9	1.9	1.9	4	6	10
	1.9	1.9	1.9	4	6	10
	1.9	1.9	1.9	4	6	10
	1.9	1.9	1.9	4	6	10
	1.9	1.9	1.9	4	6	10
	1.9	1.9	1.9	4	6	11
	1.9	1.9	1.9	4	6	11
	1.9	1.9	1.9	4	6	11
	1.9	1.9	1.9	4	6	11
	1.9	1.9	1.9	4	6	12
	1.9	1.9	1.9	4	6	12
	1.9	1.9	1.9	4	7	12
	1.9	1.9	3	4	7	12
	1.9	1.9	3	4	7	14
	1.9	1.9	3	4	7	17
	1.9	1.9	3	5	8	17
	1.9	1.9	3	5	8	19
	1.9	1.9	3	5	8	34
	1.9	1.9	3	5	8	37
	1.9	1.9	3	5	8	50
						59
						61

Location	Fan Reach of DF 4					
Stream	Sleeping Child Creek					
Date	July-12					
Observer	Short					
Each cell is the grain size (mm) of 1 particle						
	1.9	14	25	37	53	69
	1.9	14	25	38	53	70
	3	14	25	38	54	70
	3	15	26	38	54	71
	3	16	26	38	55	71
	4	16	27	39	55	73
	4	16	27	39	55	75
	4	17	27	40	56	75
	4	17	27	41	56	76
	4	18	28	42	57	77
	4	18	28	42	57	78
	5	19	28	43	58	78
	5	19	29	43	58	78
	5	19	29	43	59	78
	5	19	29	44	59	80
	6	20	29	44	60	82
	6	20	29	44	60	84
	6	20	29	45	60	85
	7	20	30	45	60	85
	7	20	30	45	61	87
	8	20	31	45	63	88
	9	21	31	45	63	88
	9	23	32	46	63	88
	9	23	32	47	63	90
	9	23	32	48	63	93
	9	23	34	48	63	106
	10	23	34	48	64	107
	10	24	35	50	65	108
	12	24	35	50	65	108
	12	24	36	50	66	119
	12	24	36	51	66	122
	13	24	37	51	69	176
	13	25	37	53	69	208
						521
						521

Location	Down-fan Reach of DF 4					
Stream	Sleeping Child Creek					
Date	July-12					
Observer	Short					
Each cell is the grain size (mm) of 1 particle						
	10	33	43	58	79	108
	10	34	44	59	80	109
	11	34	44	60	80	109
	17	34	45	60	81	111
	19	34	45	60	81	112
	19	35	45	61	82	115
	19	35	45	61	82	116
	20	35	46	62	84	117
	20	35	46	62	84	122
	20	35	46	63	85	123
	20	35	46	63	86	124
	21	35	47	63	87	124
	22	35	47	64	87	125
	22	36	47	65	88	126
	22	36	47	65	88	126
	25	37	48	65	89	127
	26	38	48	65	89	134
	26	38	50	66	89	135
	27	38	51	67	91	136
	27	39	51	68	93	142
	27	39	52	69	94	143
	28	39	52	69	97	145
	28	39	54	70	97	147
	28	39	54	70	99	148
	29	40	54	70	100	149
	29	41	54	70	101	151
	30	41	55	71	101	152
	30	41	55	73	102	194
	30	41	55	73	103	209
	32	41	56	74	103	240
	32	42	57	75	105	521
	32	43	57	77	105	521
	33	43	58	78	106	521
						521
						521

Location	Up-fan Reach of DF 5					
Stream	Sleeping Child Creek					
Date	July-12					
Observer	Short					
Each cell is the grain size (mm) of 1 particle						
	1.9	1.9	1.9	4	13	21
	1.9	1.9	1.9	4	13	21
	1.9	1.9	1.9	4	13	21
	1.9	1.9	1.9	5	14	22
	1.9	1.9	1.9	5	14	22
	1.9	1.9	1.9	5	14	23
	1.9	1.9	1.9	5	15	23
	1.9	1.9	1.9	5	16	23
	1.9	1.9	1.9	5	16	23
	1.9	1.9	1.9	5	16	24
	1.9	1.9	2	6	17	24
	1.9	1.9	3	6	17	25
	1.9	1.9	3	7	17	25
	1.9	1.9	3	7	17	25
	1.9	1.9	3	8	17	26
	1.9	1.9	3	8	18	26
	1.9	1.9	3	8	18	26
	1.9	1.9	3	8	18	27
	1.9	1.9	3	8	18	27
	1.9	1.9	3	8	19	28
	1.9	1.9	3	8	19	28
	1.9	1.9	3	8	19	28
	1.9	1.9	3	9	19	28
	1.9	1.9	3	10	19	28
	1.9	1.9	4	10	19	32
	1.9	1.9	4	11	19	32
	1.9	1.9	4	11	19	34
	1.9	1.9	4	12	20	35
	1.9	1.9	4	12	20	35
	1.9	1.9	4	12	20	35
	1.9	1.9	4	12	20	37
	1.9	1.9	4	13	20	38
	1.9	1.9	4	13	21	38
						47
						51

Location	Fan Reach of DF 5					
Stream	Sleeping Child Creek					
Date	July-12					
Observer	Short					
Each cell is the grain size (mm) of 1 particle						
	11	63	95	123	162	350
	12	64	96	123	162	400
	24	64	97	124	163	521
	29	65	97	124	163	521
	32	65	98	125	165	521
	40	66	98	125	165	521
	40	66	98	125	165	521
	41	68	103	126	167	521
	42	69	104	126	170	521
	42	69	104	127	170	521
	44	70	104	127	173	521
	44	70	105	131	177	521
	45	72	105	132	177	521
	45	72	107	133	180	521
	49	73	107	134	190	521
	49	73	108	134	195	521
	49	74	110	135	197	521
	51	78	112	135	212	521
	51	80	112	135	217	521
	52	81	113	135	225	521
	53	82	113	136	228	521
	53	83	114	144	230	521
	55	84	115	144	238	521
	56	84	115	144	240	521
	56	85	116	146	240	521
	56	86	118	148	246	521
	58	86	119	150	260	521
	61	88	120	151	271	521
	61	89	121	151	300	521
	61	91	122	153	300	521
	61	91	122	159	307	521
	62	92	122	159	328	521
	62	94	122	161	335	521
						521
						521

Location	Down-fan Reach of DF 5					
Stream	Sleeping Child Creek					
Date	July-12					
Observer	Short					
Each cell is the grain size (mm) of 1 particle						
	27	57	70	93	119	182
	29	58	71	94	119	187
	30	58	71	94	120	189
	31	59	72	95	123	190
	32	59	74	95	124	190
	33	59	75	96	124	194
	34	60	76	97	125	197
	34	60	77	97	125	210
	35	60	78	97	127	219
	35	61	78	99	127	220
	35	61	79	99	128	230
	36	61	79	101	133	260
	38	61	80	102	133	262
	38	61	80	103	134	273
	39	61	81	103	140	300
	40	62	81	108	140	300
	40	63	81	108	141	318
	41	63	81	109	143	350
	42	63	82	109	144	400
	44	64	82	109	145	521
	44	65	82	110	148	521
	45	65	83	110	151	521
	45	65	84	110	152	521
	46	65	84	112	153	521
	48	66	85	113	155	521
	48	66	86	114	157	521
	52	66	87	115	159	521
	53	66	87	116	170	521
	55	66	88	116	172	521
	55	69	90	117	175	521
	55	69	91	117	176	521
	55	69	92	117	178	521
	56	69	93	118	180	521
						521
						521

Location	Up-fan Reach of DF 6					
Stream	Sleeping Child Creek					
Date	July-12					
Observer	Short					
Each cell is the grain size (mm) of 1 particle						
	1.9	1.9	1.9	2	3	4
	1.9	1.9	1.9	2	3	4
	1.9	1.9	1.9	2	3	4
	1.9	1.9	1.9	2	3	4
	1.9	1.9	1.9	2	3	4
	1.9	1.9	1.9	2	3	4
	1.9	1.9	2	2	3	4
	1.9	1.9	2	2	3	4
	1.9	1.9	2	2	3	4
	1.9	1.9	2	2	3	4
	1.9	1.9	2	2	3	4
	1.9	1.9	2	2	3	4
	1.9	1.9	2	2	3	4
	1.9	1.9	2	2	3	4
	1.9	1.9	2	3	3	5
	1.9	1.9	2	3	3	5
	1.9	1.9	2	3	3	5
	1.9	1.9	2	3	3	5
	1.9	1.9	2	3	3	5
	1.9	1.9	2	3	3	5
	1.9	1.9	2	3	3	5
	1.9	1.9	2	3	3	6
	1.9	1.9	2	3	3	6
	1.9	1.9	2	3	3	6
	1.9	1.9	2	3	3	6
	1.9	1.9	2	3	3	6
	1.9	1.9	2	3	3	6
	1.9	1.9	2	3	3	8
	1.9	1.9	2	3	3	8
	1.9	1.9	2	3	3	8
	1.9	1.9	2	3	3	10
	1.9	1.9	2	3	3	11
	1.9	1.9	2	3	3	12
						12
						12

Location	Fan Reach of DF 6					
Stream	Sleeping Child Creek					
Date	July-12					
Observer	Short					
Each cell is the grain size (mm) of 1 particle						
	1.9	50	77	97	125	163
	1.9	52	79	97	125	164
	1.9	52	79	97	127	164
	1.9	52	81	98	127	173
	1.9	53	82	99	128	174
	5	54	82	99	128	175
	5	55	82	100	128	176
	18	56	83	101	129	183
	19	56	83	102	130	194
	22	57	84	102	130	196
	23	58	84	102	130	203
	24	59	84	102	131	206
	26	59	85	104	132	206
	26	62	85	104	134	212
	27	62	85	104	135	218
	27	63	85	109	135	226
	28	63	86	110	135	238
	28	63	86	111	136	261
	29	64	87	112	137	264
	29	66	89	112	137	275
	33	66	89	113	138	280
	34	66	90	114	138	281
	35	67	90	114	138	290
	38	69	90	115	141	293
	41	69	92	115	145	318
	42	70	92	115	145	321
	44	70	93	117	147	323
	45	70	93	118	148	340
	45	71	93	120	151	372
	48	72	94	121	151	397
	48	73	94	122	154	420
	48	76	96	124	156	423
	49	76	97	124	163	521
						521
						521

Location	Down-fan Reach of DF 6					
Stream	Sleeping Child Creek					
Date	July-12					
Observer	Short					
Each cell is the grain size (mm) of 1 particle						
	8	64	86	108	129	213
	9	65	86	109	130	218
	18	65	87	109	132	220
	24	66	89	110	132	228
	28	67	89	110	132	237
	30	69	89	110	135	250
	35	71	90	113	135	275
	35	71	90	114	138	291
	36	71	90	114	140	300
	38	73	91	116	140	306
	38	73	92	116	140	307
	42	74	93	117	140	341
	42	75	93	118	142	350
	43	75	94	119	145	366
	43	76	94	119	145	387
	44	77	94	120	146	390
	45	77	95	120	150	390
	45	78	96	120	152	394
	45	79	96	122	154	470
	46	80	97	122	156	521
	49	80	98	123	160	521
	51	80	98	123	160	521
	53	81	98	123	161	521
	53	82	99	124	162	521
	53	82	102	125	164	521
	55	82	103	125	171	521
	56	82	104	125	173	521
	60	82	105	125	175	521
	60	83	105	127	175	521
	61	83	105	127	183	521
	61	84	105	128	184	521
	62	84	107	128	210	521
	64	86	107	128	212	521
						521
						521

APPENDIX D

Cross Sections

Location	Up-fan Reach of DF 1
Stream	Sleeping Child Creek

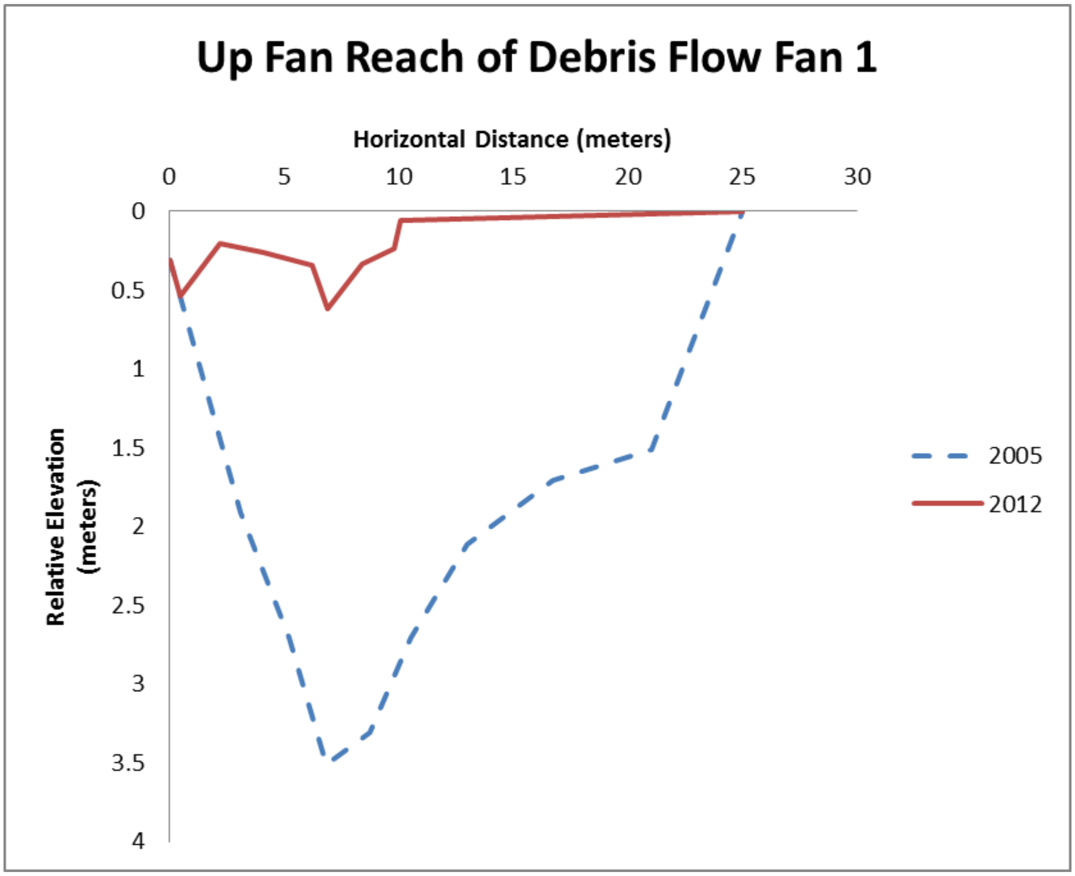
Date	August-05	Date	July-12
Observer	Hoffman	Observer	Short

	x (m) Horizontal Distance	z (m) Depth
	0	0.31
	3.1	1.91
	5.2	2.71
	6.8	3.51
	8.7	3.31
	10.5	2.71
	13	2.11
	16.7	1.71
	21	1.51
Projection	25	0

	x (m) Horizontal Distance	z Depth
	0	0.31
	0.45	0.54
	2.2	0.2
	4.07	0.26
	6.2	0.34
	6.86	0.62
	8.38	0.33
	9.8	0.24
	10.05	0.06
Extension	25	0

Projection = an addition to the 2005 measurements to create an endpoint of similar elevation to monument.

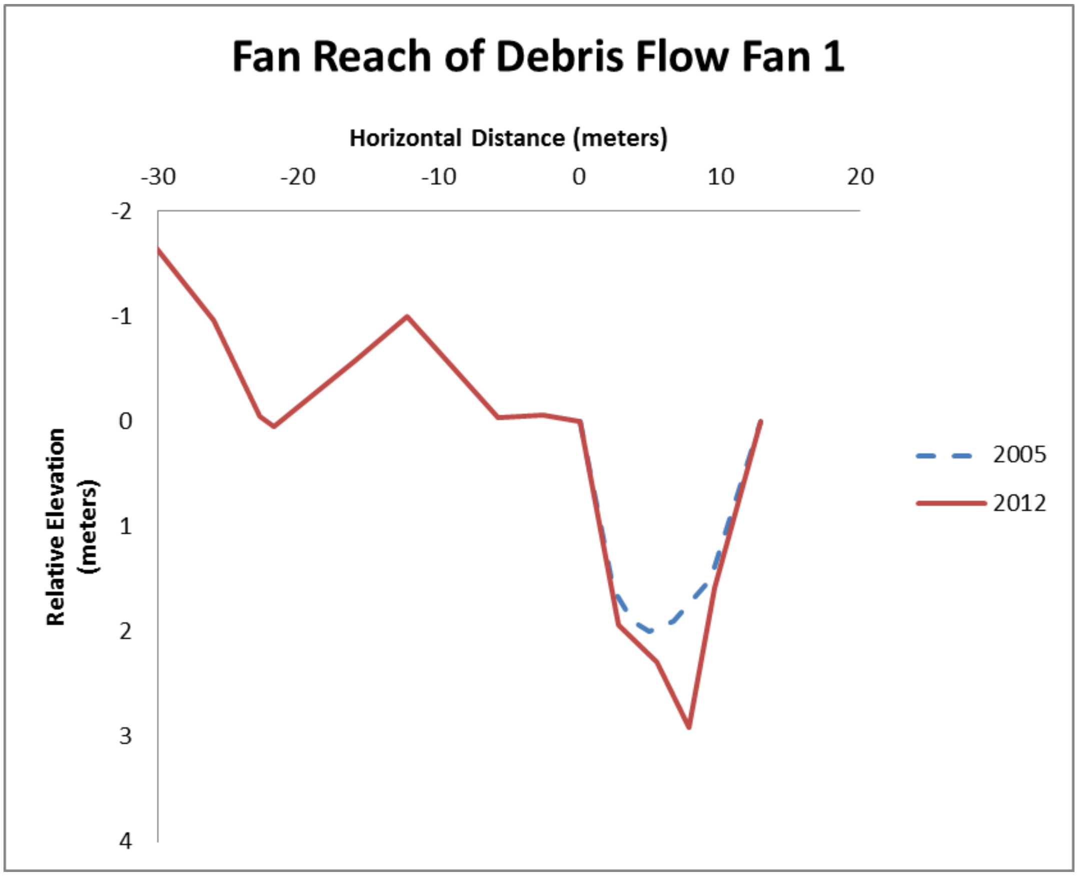
Extension = interpolation between the last 2012 measurement and the last 2005 point of the


Up Fan Reach of Debris Flow Fan 1
Horizontal Distance (meters)
0
5
10
15
20
25
30
Relative Elevation (meters)
0
0.5
1
1.5
2
2.5
3
3.5
4
2005
2012

Location	Fan Reach of DF 1			
Stream	Sleeping Child Creek			
Date	August-05		Date	July-12
Observer	Hoffman		Observer	Short

x (m)	z (m)
Horizontal Distance	Depth
0	0
2.4	1.6
3.8	1.9
5	2
6.7	1.9
9.3	1.5
12.9	0

x (m)	z (m)
Horizontal Distance	Depth
-30.2	-1.67
-26	-0.96
-22.77	-0.05
-21.7	0.05
-15.9	-0.59
-12.3	-1
-5.8	-0.04
-2.6	-0.06
0	0
2.77	1.94
5.5	2.29
7.83	2.92
9.65	1.58
12.9	0

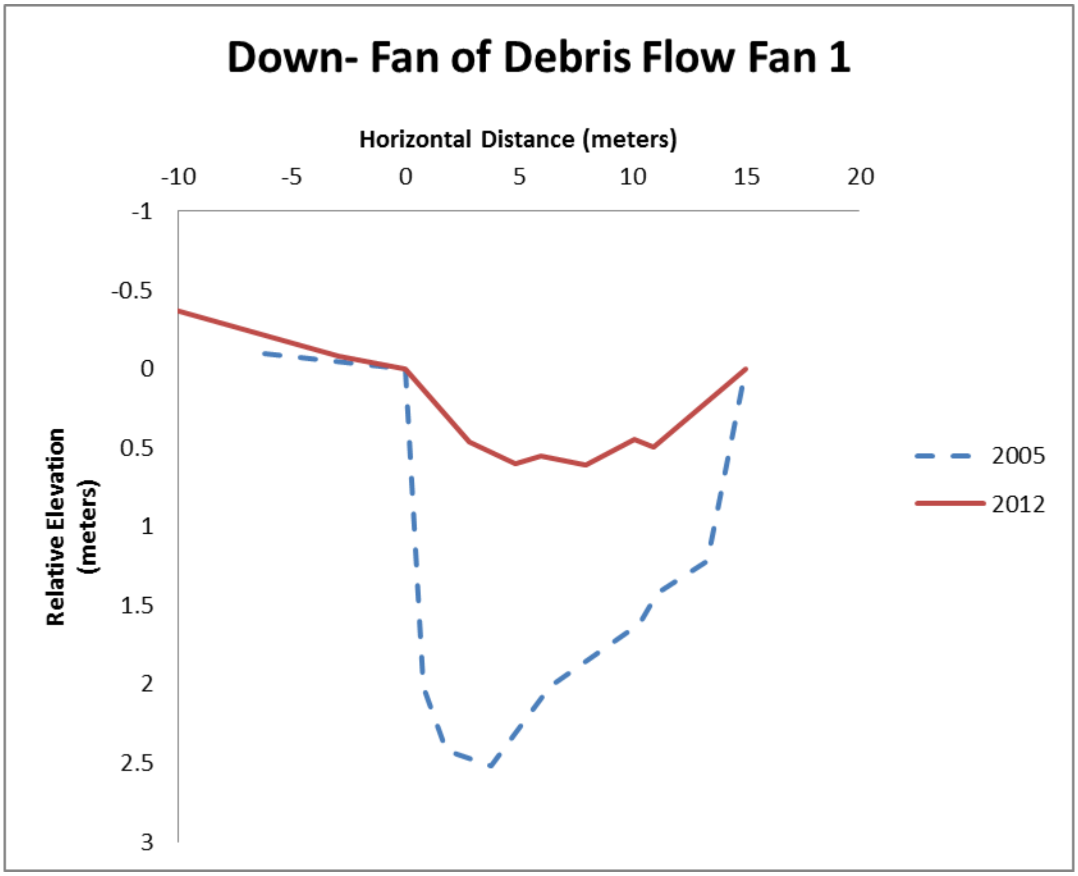


Fan Reach of Debris Flow Fan 1
Horizontal Distance (meters)
-30
-20
-10
0
10
20
-2
-1
0
1
2
3
4
Relative Elevation (meters)
2005
2012

Location	Down-Fan Reach of DF 1			
Stream	Sleeping Child Creek			
Date	August-05		Date	July-12
Observer	Hoffman		Observer	Short

	x (m)	z (m)
	Horizontal Distance	Depth
	-6.2	-0.1
	0	0
	0.8	2.02
	1.8	2.42
	3.8	2.52
	6.4	2.02
	10.3	1.62
	11.1	1.42
	13.3	1.22
Projection	15	0

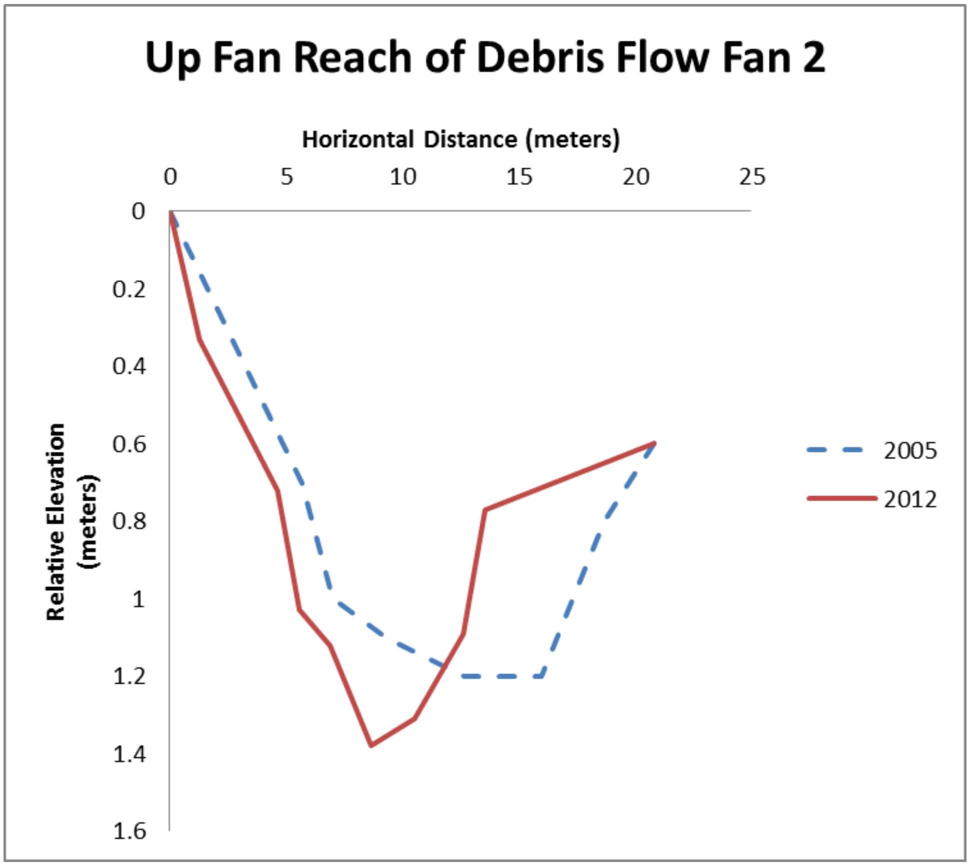
	x (m)	z (m)
	Horizontal Distance	Depth
	-10.5	-0.39
	-2.9	-0.08
	0	0
	2.85	0.46
	4.83	0.6
	6	0.55
	7.93	0.61
	10.11	0.45
	10.92	0.5
Extension	15	0


Down- Fan of Debris Flow Fan 1
Horizontal Distance (meters)
-10
-5
0
5
10
15
20
Relative Elevation (meters)
-1
-0.5
0
0.5
1
1.5
2
2.5
3
2005
2012

Location	Up-fan Reach of DF 2			
Stream	Sleeping Child Creek			
Date	August-05		Date	July-12
Observer	Hoffman		Observer	Short

x (m)	z (m)
Horizontal Distance	Depth
0	0
5.7	0.7
7	1
9.3	1.1
12.7	1.2
16	1.2
18.7	0.8
20.8	0.6

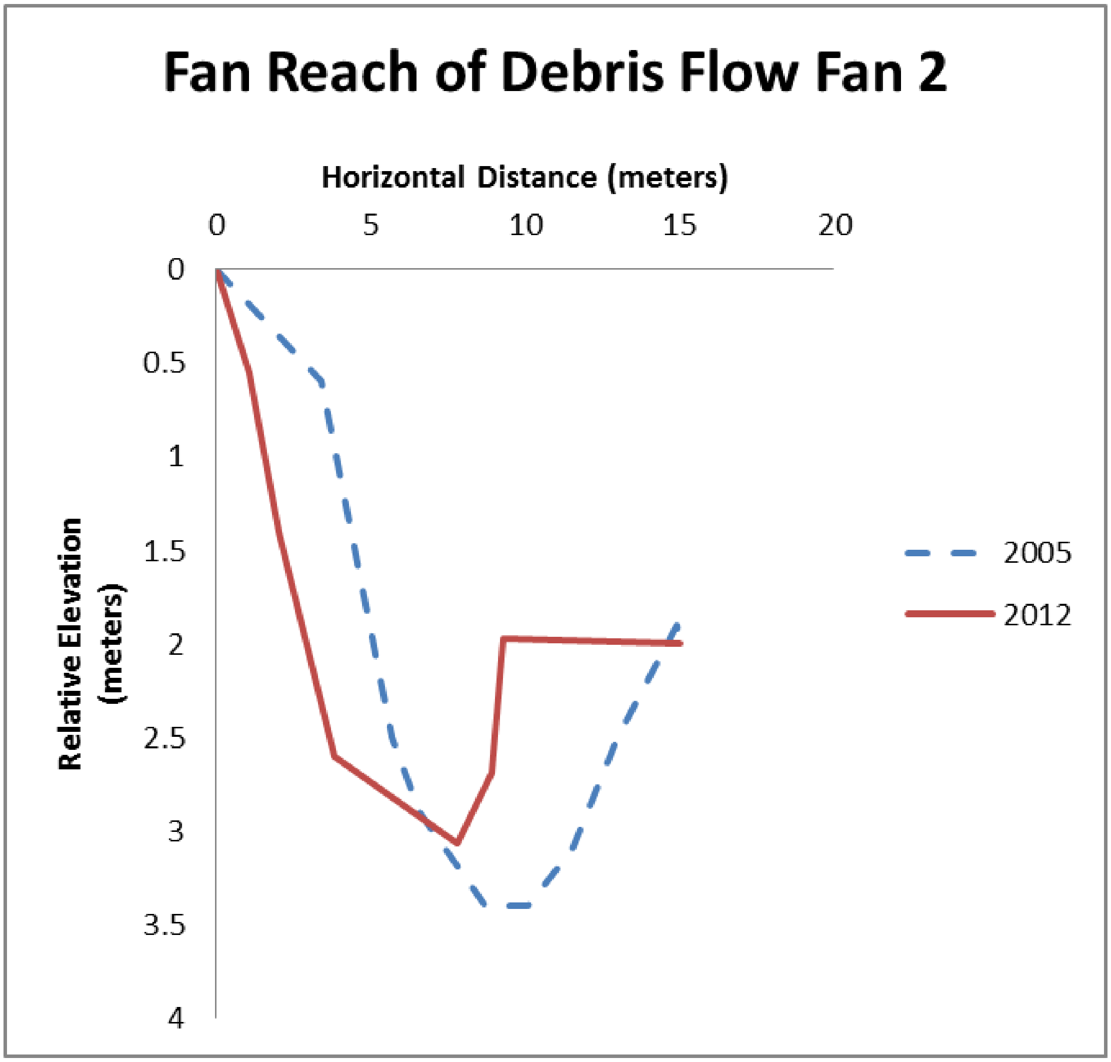
	x (m)	z (m)
	Horizontal Distance	Depth
	0	0
	1.3	0.33
	4.63	0.72
	5.57	1.03
	6.89	1.12
	8.66	1.38
	10.5	1.31
	12.64	1.09
	13.56	0.77
Extension	20.8	0.6


Up Fan Reach of Debris Flow Fan 2
Horizontal Distance (meters)
0
5
10
15
20
25
Relative Elevation (meters)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
2005
2012

Location	Fan Reach of DF 2			
Stream	Sleeping Child Creek			
Date	August-05		Date	July-12
Observer	Hoffman		Observer	Short

	x (m)	z (m)
	Horizontal Distance	Depth
	0	0
	3.4	0.6
	5.7	2.5
	6.6	2.9
	8.7	3.4
	10.1	3.4
	11.5	3.1
	13	2.5
	14.9	1.9
Projection	15	2

	x (m)	z (m)
	Horizontal Distance	Depth
	0	0
	1.05	0.55
	2	1.4
	3.85	2.6
	7.83	3.07
	8.9	2.69
	9.3	1.97
Extension	15	2

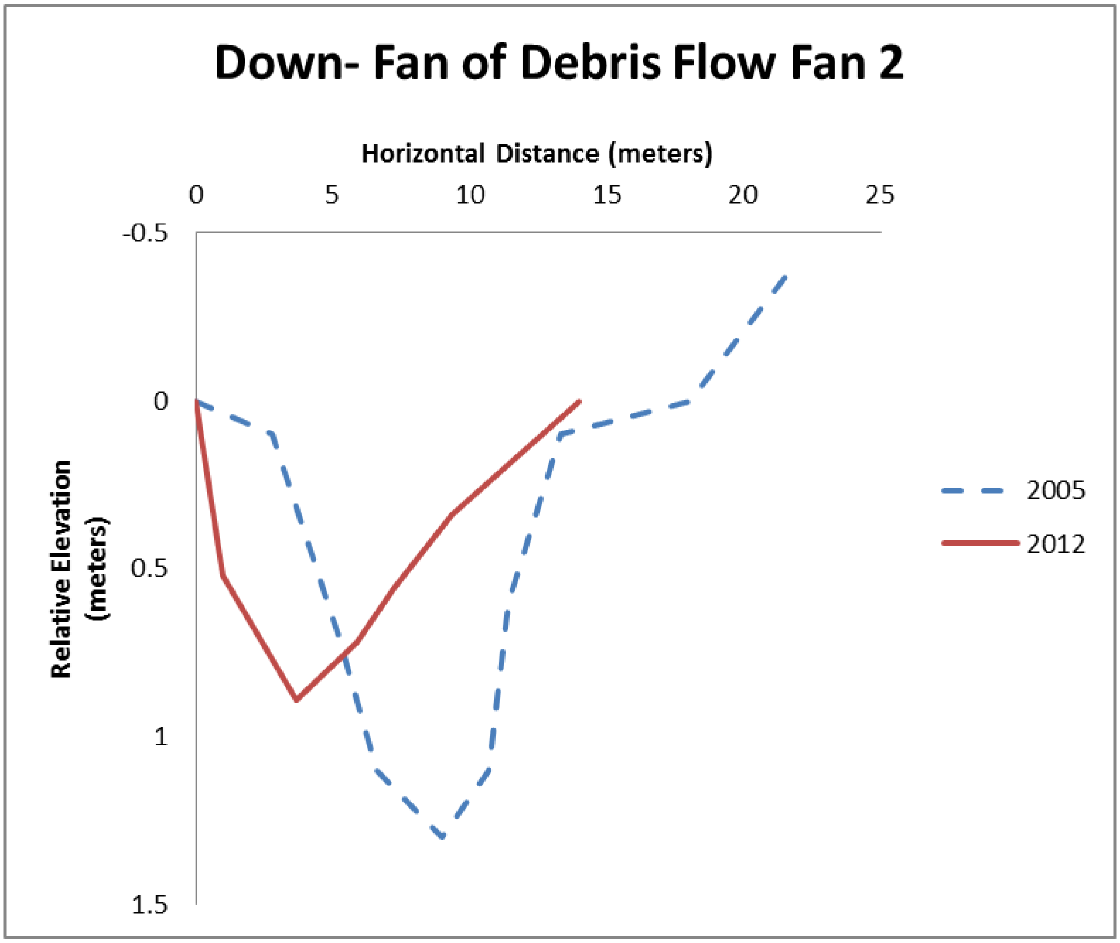


Fan Reach of Debris Flow Fan 2
Horizontal Distance (meters)
0
5
10
15
20
0
0.5
1
1.5
2
2.5
3
3.5
4
Relative Elevation (meters)
2005
2012

Location	Down-Fan Reach of DF 2		
Stream	Sleeping Child Creek		
Date	August-05	Date	July-12
Observer	Hoffman	Observer	Short

x (m) Horizontal Distance	z (m) Depth
0	0
2.8	0.1
5.2	0.7
6.6	1.1
9	1.3
10.7	1.1
11.4	0.6
13.3	0.1
18	0
21.8	-0.4

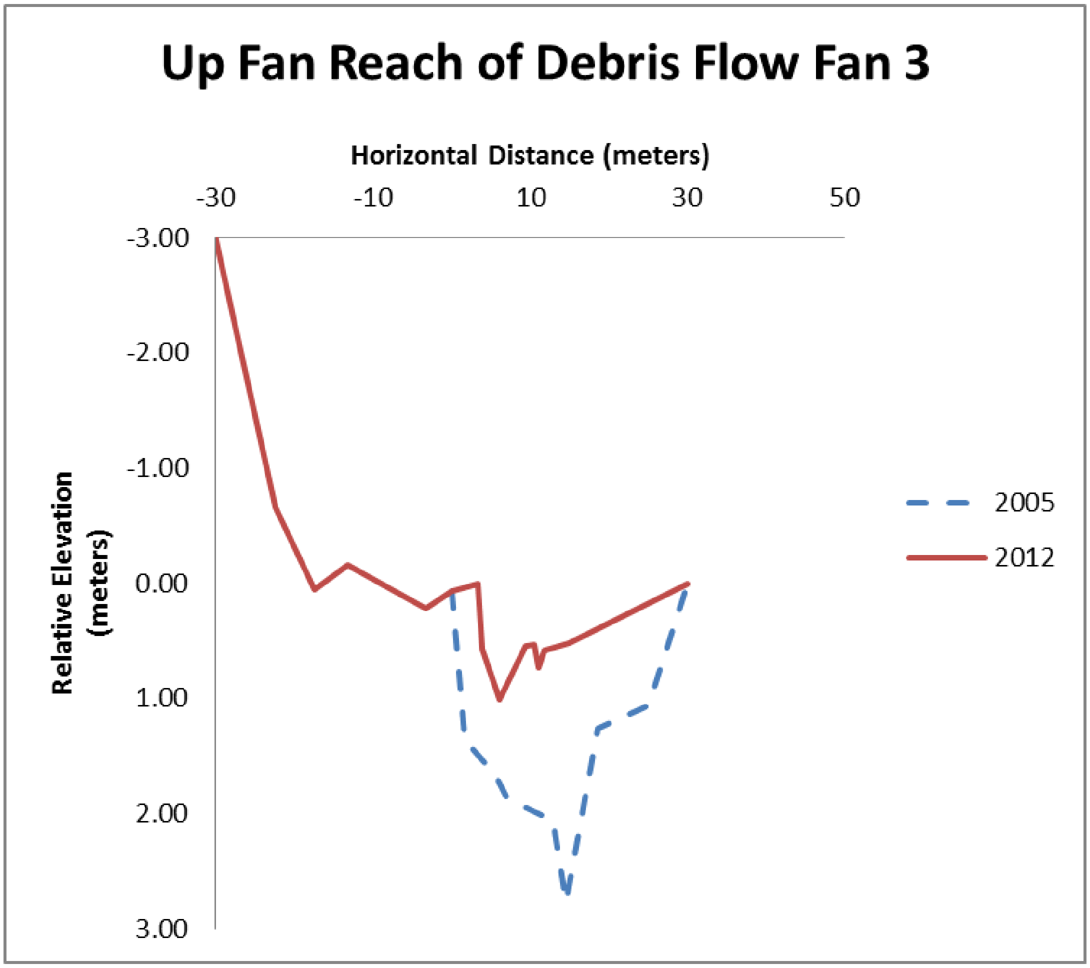
	x (m) Horizontal Distance	z (m) Depth
	0	0
	0.96	0.52
	3.66	0.89
	5.88	0.72
	7.2	0.56
	9.33	0.34
Extension	14	0


Down- Fan of Debris Flow Fan 2
Horizontal Distance (meters)
0
5
10
15
20
25
-0.5
0
0.5
1
1.5
Relative Elevation (meters)
2005
2012

Location	Up-fan Reach of DF 3			
Stream	Sleeping Child Creek			
Date	August-05		Date	July-12
Observer	Hoffman		Observ	Short

x (m)	z (m)
Horizontal Distance	Depth
0.00	0.06
1.70	1.36
5.50	1.66
7.10	1.86
13.00	2.06
14.60	2.76
18.60	1.26
25.00	1.06
30.00	0.00

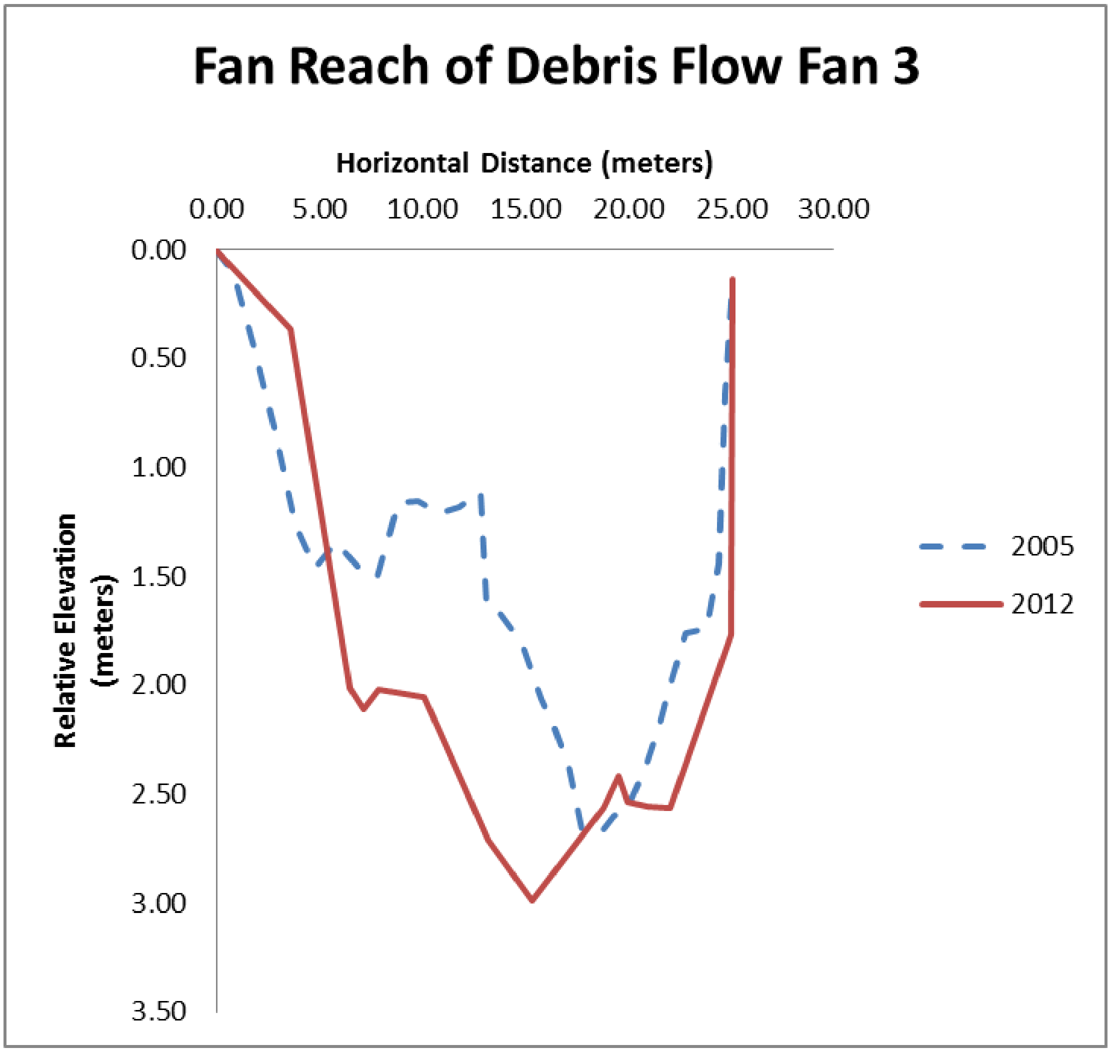
	x (m)	z (m)
	Horizontal Distance	Depth
	-30.20	-3.04
	-22.37	-0.67
	-17.45	0.05
	-13.20	-0.16
	-3.20	0.22
	0.00	0.06
	3.40	0.00
	3.91	0.57
	6.10	1.00
	9.40	0.54
	10.55	0.53
	11.10	0.73
	11.80	0.58
	15.03	0.51
Extension	30.00	0.00


Up Fan Reach of Debris Flow Fan 3
Horizontal Distance (meters)
-30
-10
10
30
50
-3.00
-2.00
-1.00
0.00
1.00
2.00
3.00
Relative Elevation (meters)
2005
2012

Location	Fan Reach of DF 3		
Stream	Sleeping Child Creek		
Date	August-05	Date	July-12
Observer	Hoffman	Observer	Short

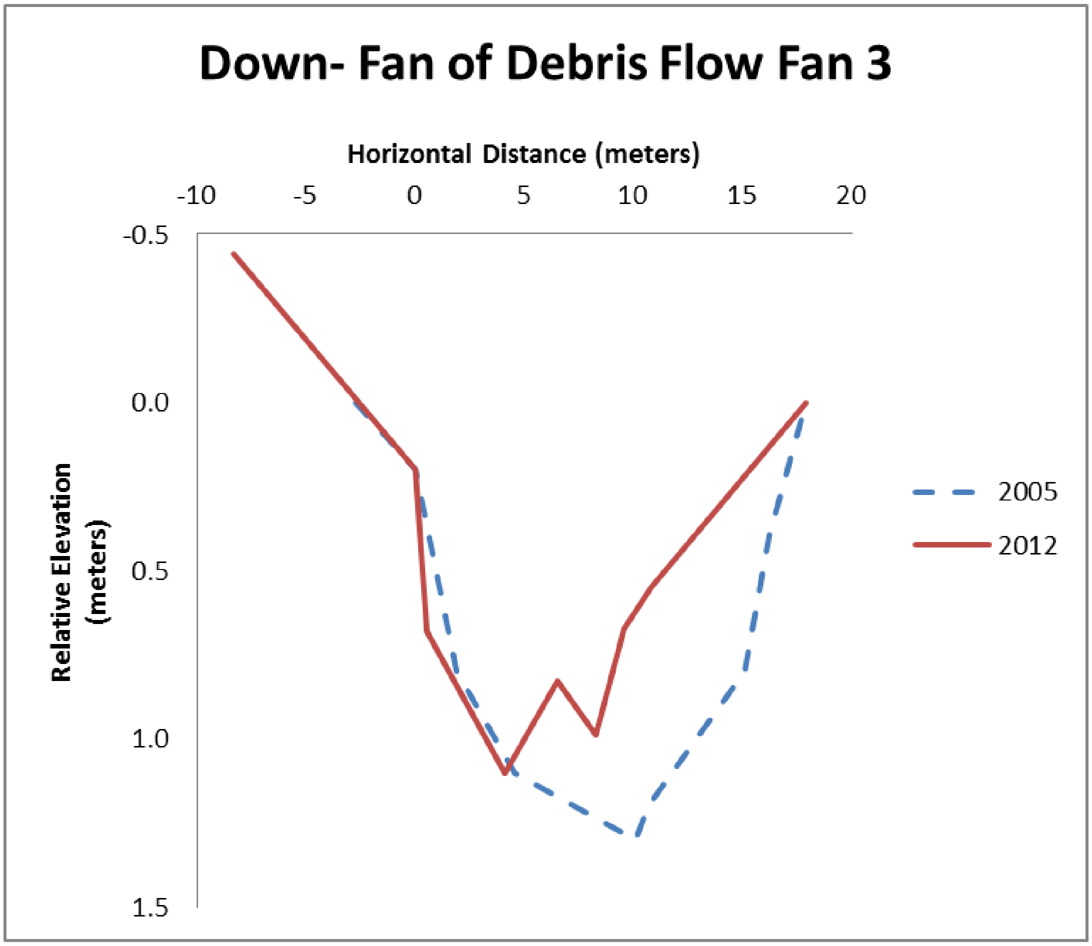
x (m) Horizontal Distance	z (m) Depth
0.00	0.00
0.80	0.10
1.80	0.45
2.80	0.81
3.80	1.26
4.80	1.46
5.80	1.34
6.80	1.45
7.80	1.50
8.80	1.16
9.80	1.15
10.80	1.21
11.80	1.18
12.80	1.11
13.10	1.64
13.80	1.67
14.80	1.80
15.80	2.06
16.40	2.20
17.10	2.37
17.80	2.67
18.80	2.66
19.30	2.60
19.80	2.59
20.80	2.39
21.50	2.18
21.80	2.07
22.80	1.76
23.80	1.74
24.40	1.44
24.70	0.66
25.10	0.13

	x (m) Horizontal Distance	z (m) Depth
	0.00	0.00
	3.60	0.37
	6.47	2.01
	7.14	2.11
	7.90	2.02
	10.10	2.06
	13.17	2.71
	15.30	2.99
	18.78	2.57
	19.55	2.42
	19.97	2.54
	20.95	2.56
	22.07	2.57
	25.00	1.77
Extension	25.10	0.13


Fan Reach of Debris Flow Fan 3
Horizontal Distance (meters)
0.00
5.00
10.00
15.00
20.00
25.00
30.00
0.00
0.50
1.00
1.50
2.00
2.50
3.00
3.50
Relative Elevation (meters)
2005
2012

Location	Down-Fan Reach of DF 3				
Stream	Sleeping Child Creek				
Date	August-05			Date	July-12
Observer	Hoffman			Observer	Short

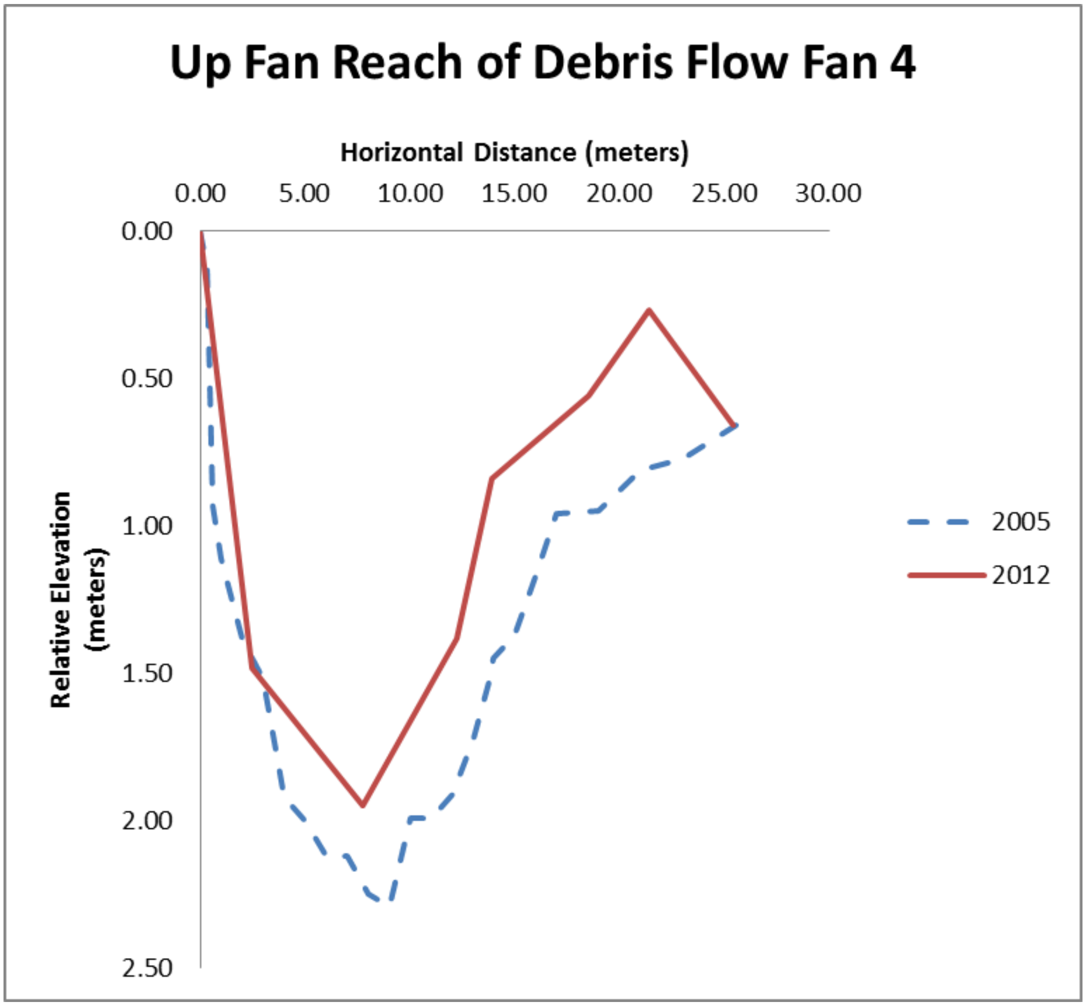
x (m)	z (m)		x (m)	z (m)
Horizontal Distance	Depth		Horizontal Distance	Depth
-2.7	0		-8.33	-0.44
0	0.2		0	0.2
1.9	0.8		0.53	0.68
4.6	1.1		4.12	1.1
10.1	1.3		6.55	0.83
10.7	1.2		8.27	0.99
15.1	0.8		9.6	0.67
16.2	0.4		10.83	0.55
17.9	0	Extension	17.9	0


Down- Fan of Debris Flow Fan 3
Horizontal Distance (meters)
-10
-5
0
5
10
15
20
-0.5
0.0
0.5
1.0
1.5
Relative Elevation (meters)
2005
2012

Location	Up-fan Reach of DF 4		
Stream	Sleeping Child Creek		
Date	August-05	Date	July-12
Observer	Hoffman	Observer	Short

x (m) Horizontal Distance	z (m) Depth
0.00	0.00
0.30	0.12
0.60	0.93
1.00	1.11
2.00	1.38
3.00	1.52
4.00	1.92
5.00	2.00
6.00	2.12
7.00	2.12
8.00	2.25
9.00	2.29
10.00	1.99
11.00	1.99
12.00	1.91
13.00	1.72
13.85	1.51
14.00	1.45
15.00	1.37
16.00	1.17
17.00	0.96
19.00	0.95
21.00	0.81
23.00	0.77
25.54	0.66

x (m) Horizontal Distance	z (m) Depth
0.00	0.00
2.42	1.48
7.76	1.95
12.21	1.38
13.90	0.84
18.55	0.56
21.40	0.27
25.40	0.66

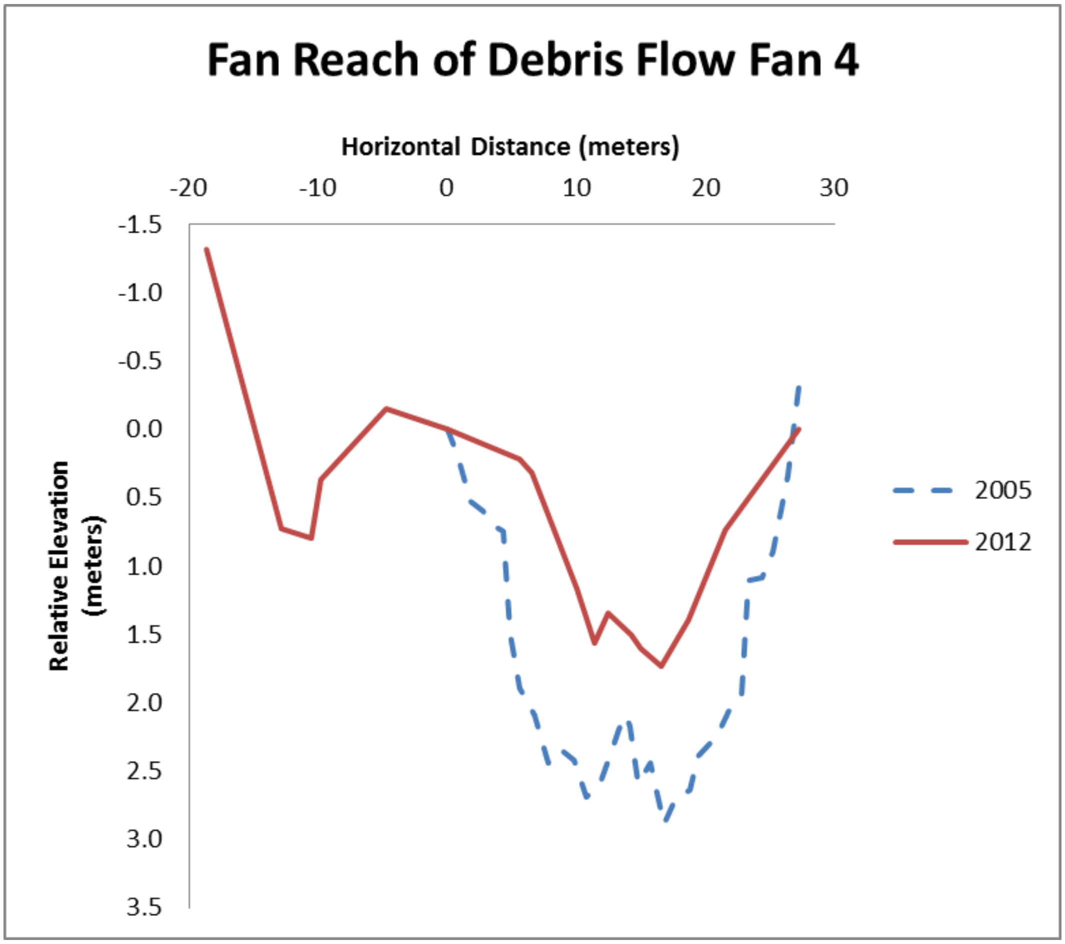


Up Fan Reach of Debris Flow Fan 4
Horizontal Distance (meters)
0.00
5.00
10.00
15.00
20.00
25.00
30.00
Relative Elevation (meters)
0.00
0.50
1.00
1.50
2.00
2.50
2005
2012

Location	Fan Reach of DF 4			
Stream	Sleeping Child Creek			
Date	August-05		Date	July-12
Observer	Hoffman		Observer	Short

x (m) Horizontal Distance	z (m) Depth
0.00	0.00
0.80	0.18
1.40	0.39
1.80	0.52
2.80	0.59
3.80	0.71
4.30	0.74
4.90	1.49
5.60	1.89
6.80	2.09
7.80	2.44
8.80	2.34
9.80	2.42
10.80	2.69
11.80	2.59
12.80	2.34
13.30	2.19
13.80	2.09
14.20	2.17
14.80	2.59
15.80	2.44
16.80	2.89
17.80	2.69
18.80	2.64
19.40	2.39
20.90	2.24
21.90	2.05
22.80	1.94
23.40	1.10
24.40	1.08
25.30	0.89
26.40	0.34
27.30	-0.31

	x (m) Horizontal Distance	z (m) Depth
	-18.70	-1.32
	-12.80	0.72
	-10.50	0.79
	-9.80	0.37
	-4.70	-0.15
	0.00	0.00
	5.60	0.22
	6.60	0.32
	10.09	1.17
	11.41	1.56
	12.45	1.34
	14.22	1.50
	15.05	1.60
	16.62	1.73
	18.75	1.39
	21.60	0.73
Extension	27.3	0

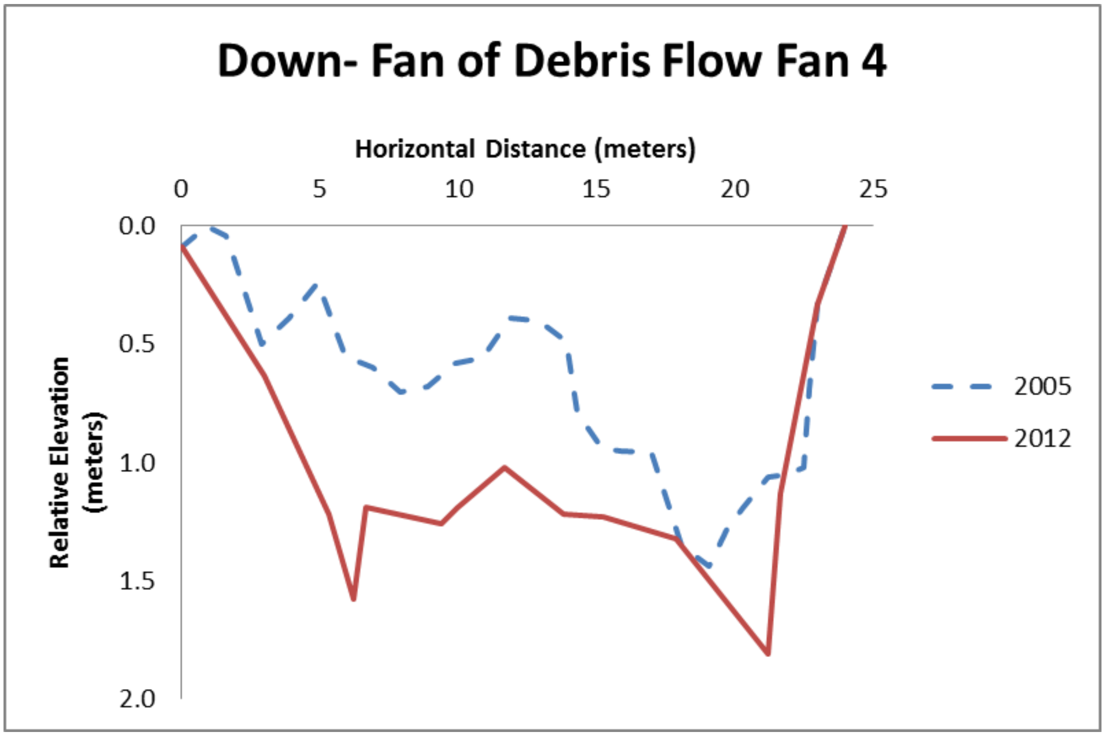


Fan Reach of Debris Flow Fan 4
Horizontal Distance (meters)
-20
-10
0
10
20
30
-1.5
-1.0
-0.5
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
Relative Elevation (meters)
2005
2012

Location	Down-Fan Reach of DF 4			
Stream	Sleeping Child Creek			
Date	August-05		Date	July-12
Observer	Hoffman		Observer	Short

x (m)	z (m)
Horizontal Distance	Depth
0.00	0.09
0.90	0.00
1.60	0.04
1.90	0.14
2.90	0.50
3.90	0.39
4.90	0.24
5.90	0.55
6.90	0.60
7.90	0.70
8.90	0.68
9.90	0.58
10.90	0.56
11.90	0.39
12.90	0.40
13.90	0.49
14.30	0.79
15.20	0.94
15.90	0.95
17.00	0.96
18.10	1.35
19.10	1.44
19.70	1.28
20.30	1.19
21.20	1.06
21.90	1.05
22.50	1.02
22.70	0.69
23.00	0.33
24.00	0.00

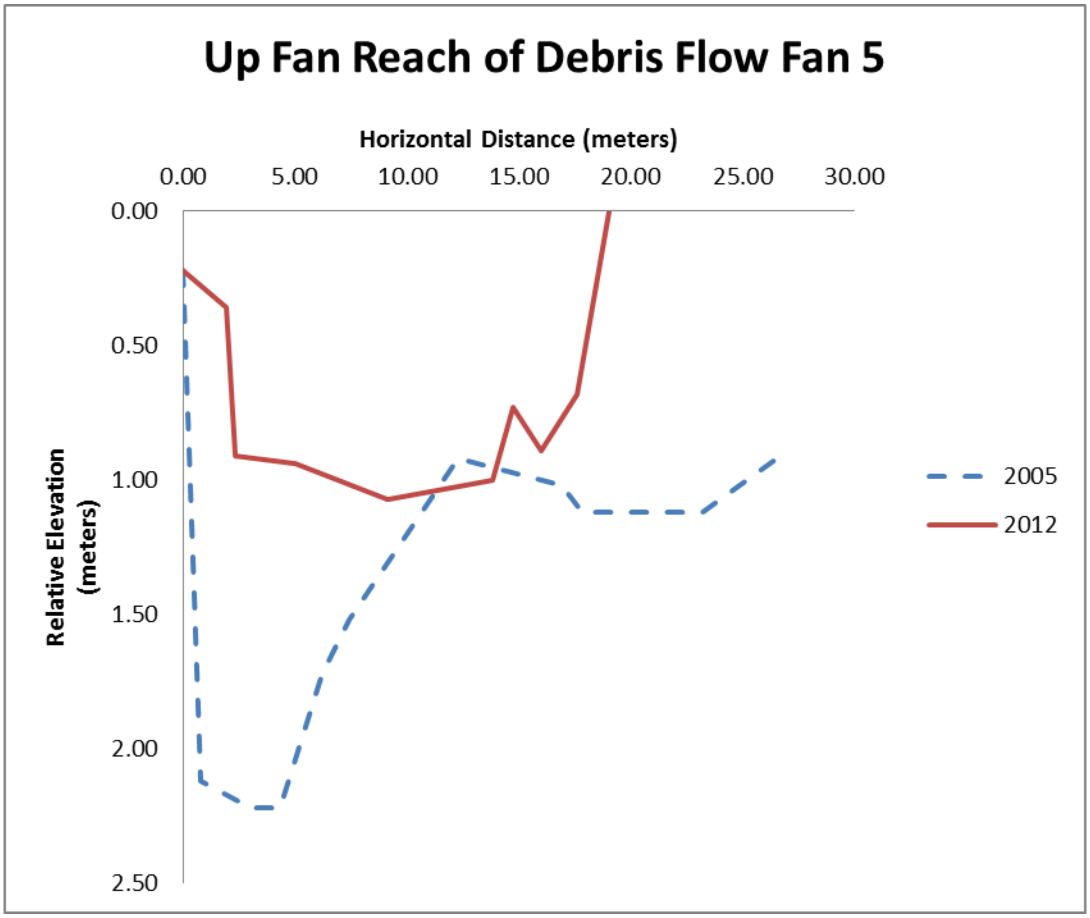
x (m)	z (m)
Horizontal Distance	Depth
0.00	0.09
3.00	0.63
5.32	1.22
6.20	1.58
6.65	1.19
9.40	1.26
10.00	1.19
11.70	1.02
13.81	1.22
15.26	1.23
17.91	1.33
21.20	1.81
21.65	1.13
23.00	0.33
24.00	0.00


Down- Fan of Debris Flow Fan 4
Horizontal Distance (meters)
0
5
10
15
20
25
0.0
0.5
1.0
1.5
2.0
Relative Elevation (meters)
2005
2012

Location	Up-fan Reach of DF 5			
Stream	Sleeping Child Creek			
Date	August-05		Date	July-12
Observer	Hoffman		Observer	Short

x (m)	z (m)
Horizontal Distance	Depth
0.00	0.22
0.80	2.12
3.00	2.22
4.30	2.22
6.20	1.72
7.40	1.52
12.30	0.92
16.90	1.02
17.80	1.12
23.20	1.12
26.50	0.92

x (m)	z (m)
Horizontal Distance	Depth
0.00	0.22
1.91	0.36
2.32	0.91
5.00	0.94
9.15	1.07
13.80	1.00
14.75	0.73
16.00	0.89
17.60	0.68
19.00	0.00

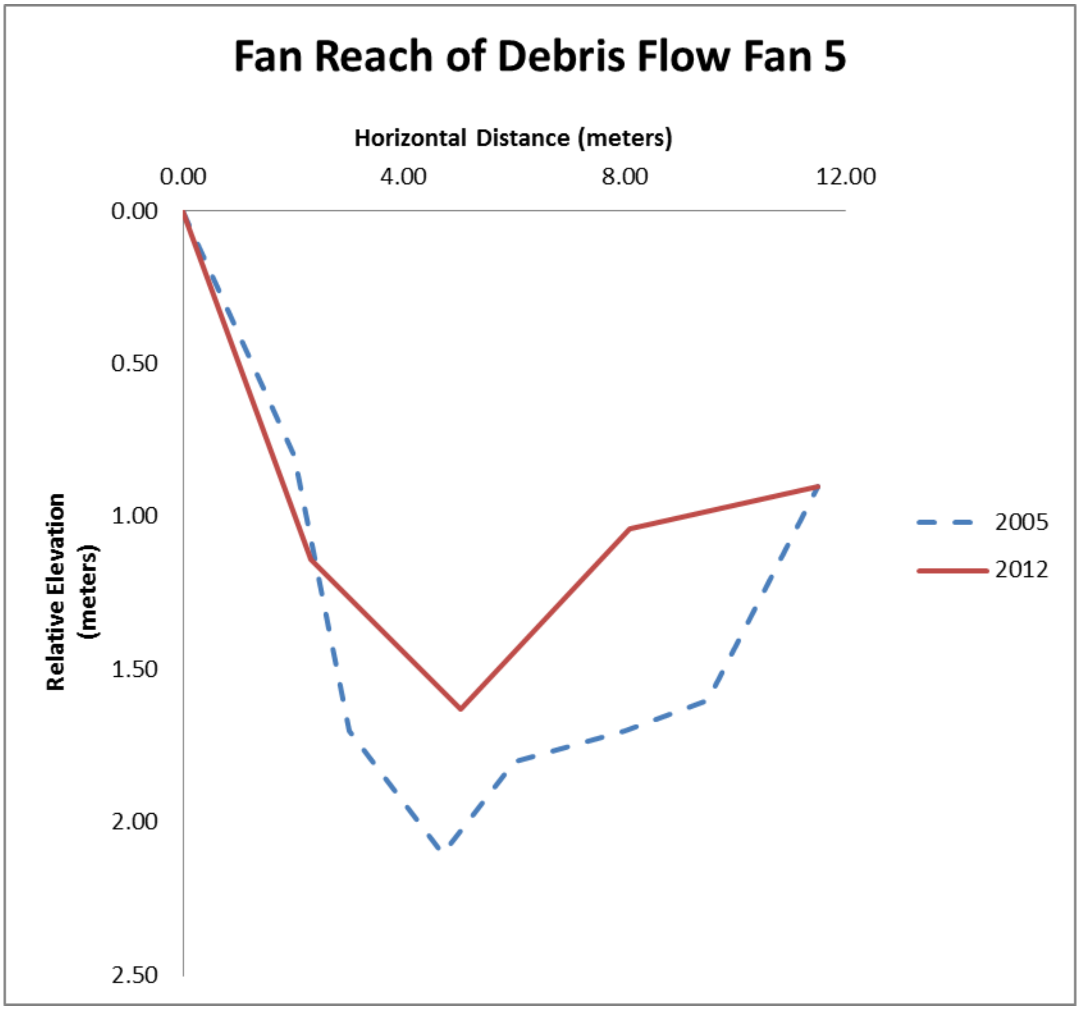


Up Fan Reach of Debris Flow Fan 5
Horizontal Distance (meters)
0.00
5.00
10.00
15.00
20.00
25.00
30.00
Relative Elevation (meters)
0.00
0.50
1.00
1.50
2.00
2.50
2005
2012

Location	Fan Reach of DF 5		
Stream	Sleeping Child Creek		
Date	August-05	Date	July-12
Observer	Hoffman	Observer	Short

x (m) Horizontal Distance	z (m) Depth
0.00	0.00
2.00	0.80
3.00	1.70
4.70	2.10
6.00	1.80
8.00	1.70
9.50	1.60
11.50	0.90

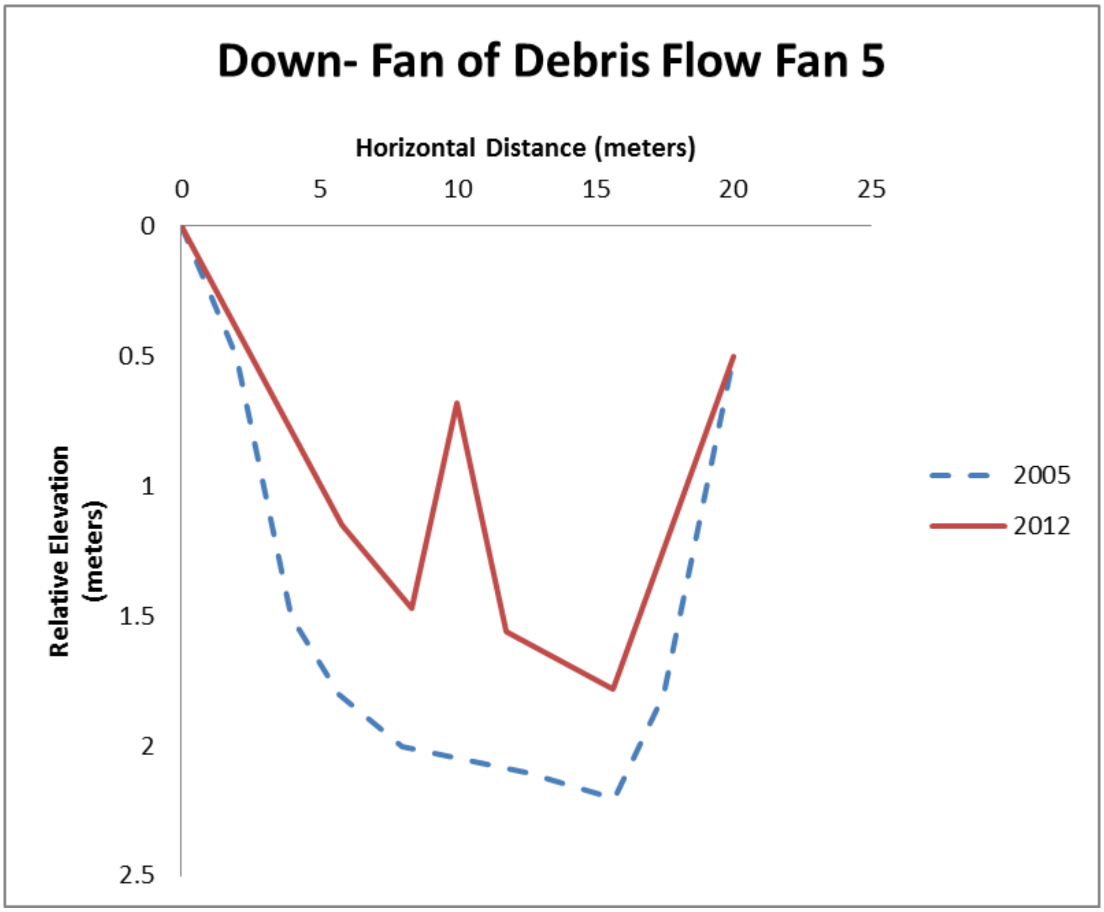
	x (m) Horizontal Distance	z (m) Depth
	0.00	0.00
	2.31	1.14
	5.03	1.63
	8.10	1.04
Extension	11.50	0.90


Fan Reach of Debris Flow Fan 5
Horizontal Distance (meters)
0.00
4.00
8.00
12.00
0.00
0.50
1.00
1.50
2.00
2.50
Relative Elevation (meters)
2005
2012

Location	Down-Fan Reach of DF 5			
Stream	Sleeping Child Creek			
Date	August-05		Date	July-12
Observer	Hoffman		Observer	Short

x (m)	z (m)
Horizontal Distance	Depth
0	0
2	0.5
4	1.5
5.7	1.8
8	2
12.5	2.1
15.7	2.2
17.5	1.8
20	0.5

	x (m)	z (m)
	Horizontal Distance	Depth
	0	0
	5.82	1.15
	8.34	1.47
	9.98	0.68
	11.79	1.56
	15.63	1.78
Extension	20	0.5

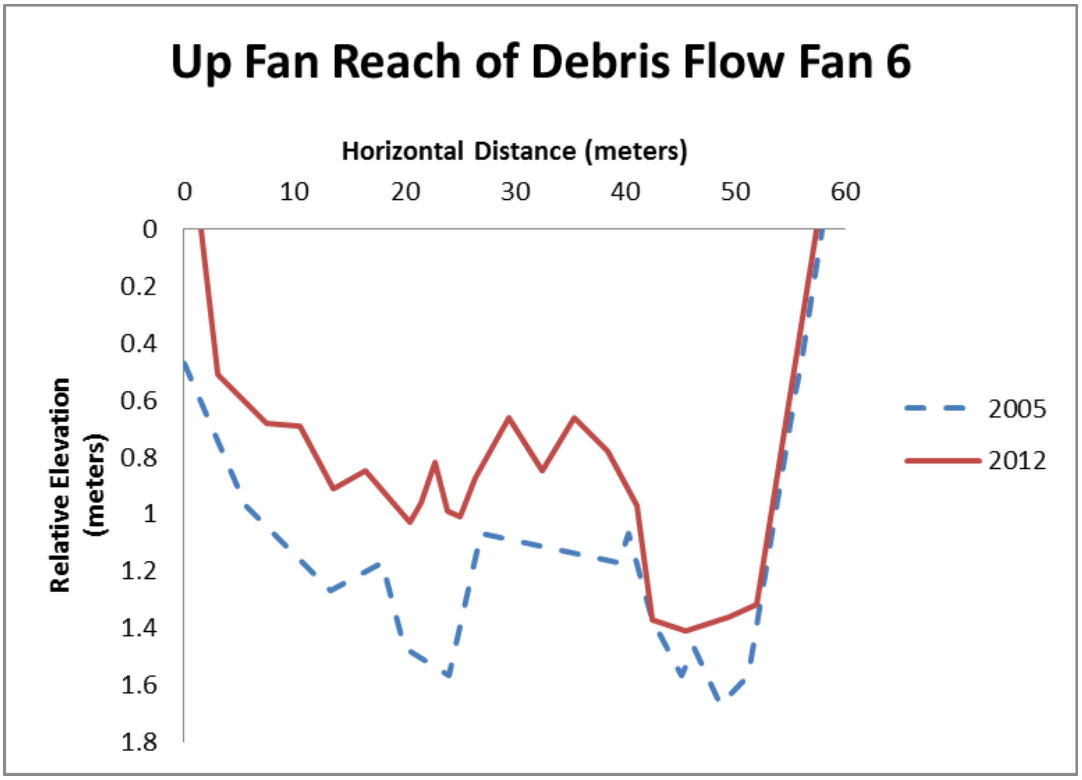


Down- Fan of Debris Flow Fan 5
Horizontal Distance (meters)
0
5
10
15
20
25
0
0.5
1
1.5
2
2.5
Relative Elevation (meters)
2005
2012

Location	Up-fan Reach of DF 6		
Stream	Sleeping Child Creek		
Date	August-05	Date	July-12
Observer	Hoffman	Observer	Short

	x (m)	z (m)
	Horizontal Distance	Depth
	0	0.47
	5.6	0.97
	13.3	1.27
	18	1.17
	20	1.47
	24	1.57
	27	1.07
	39.5	1.17
	40.4	1.07
	42.5	1.37
	45.2	1.57
	46.3	1.47
	48.7	1.67
	51.3	1.57
	55.5	0.57
	56	0.47
Projection	58	0

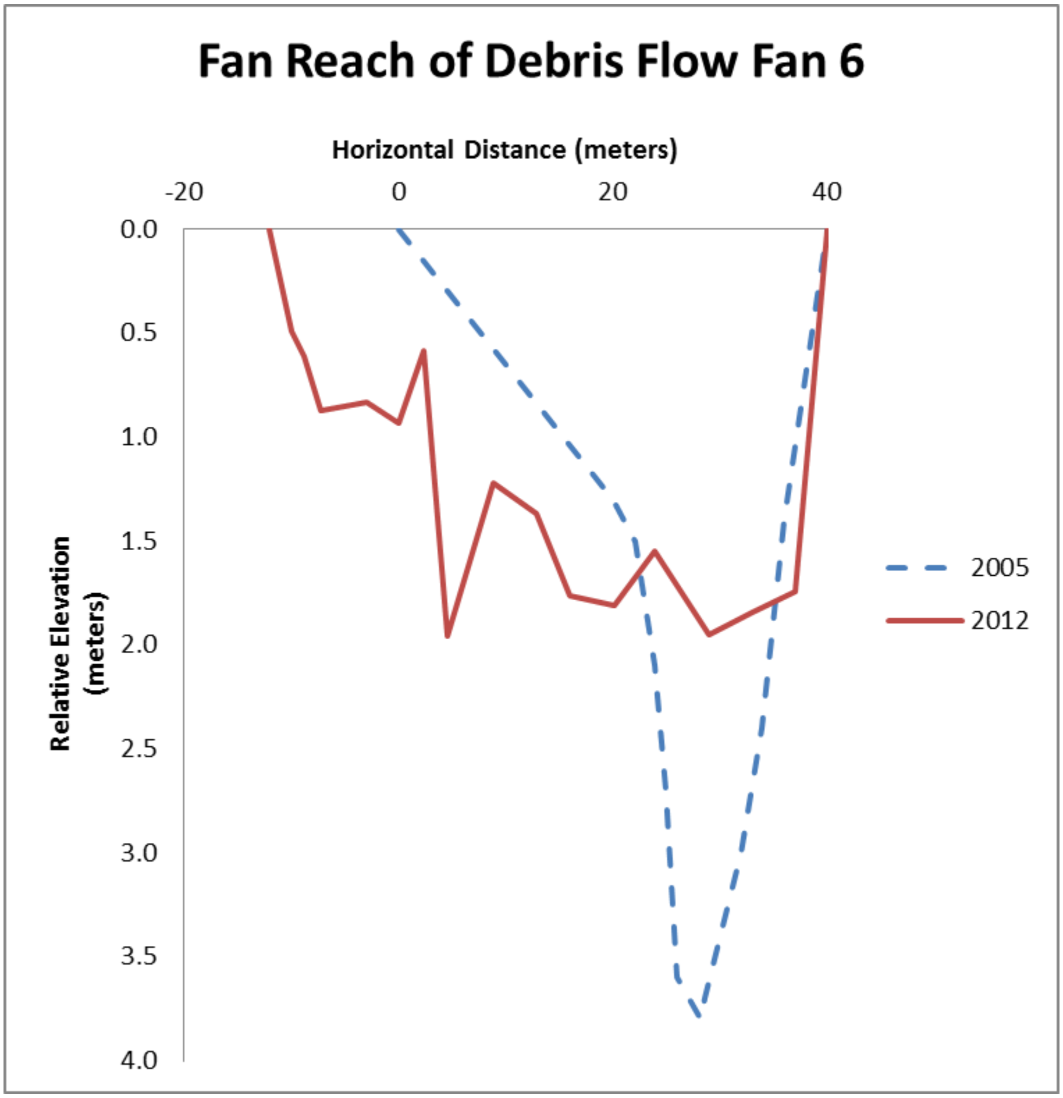
	x (m)	z (m)
	Horizontal Distance	Depth
	1.5	0
	3.05	0.51
	7.5	0.68
	10.5	0.69
	13.5	0.91
	16.5	0.85
	20.5	1.03
	21.5	0.96
	22.75	0.82
	23.9	0.99
	25.1	1.01
	26.5	0.87
	29.5	0.66
	32.5	0.85
	35.5	0.66
	38.5	0.78
	41.1	0.97
	42.5	1.37
	45.5	1.41
	49.5	1.36
	52	1.32
Extension	57.5	0


Up Fan Reach of Debris Flow Fan 6
Horizontal Distance (meters)
0
10
20
30
40
50
60
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
Relative Elevation (meters)
2005
2012

Location	Fan Reach of DF 6		
Stream	Sleeping Child Creek		
Date	August-05	Date	July-12
Observer	Hoffman	Observer	Short

x (m) Horizontal Distance	z (m) Depth
0.00	0.00
20.00	1.30
22.10	1.50
24.00	2.10
25.00	2.70
26.00	3.60
28.20	3.80
28.60	3.70
32.00	3.00
34.00	2.40
36.00	1.40
40.00	0.00

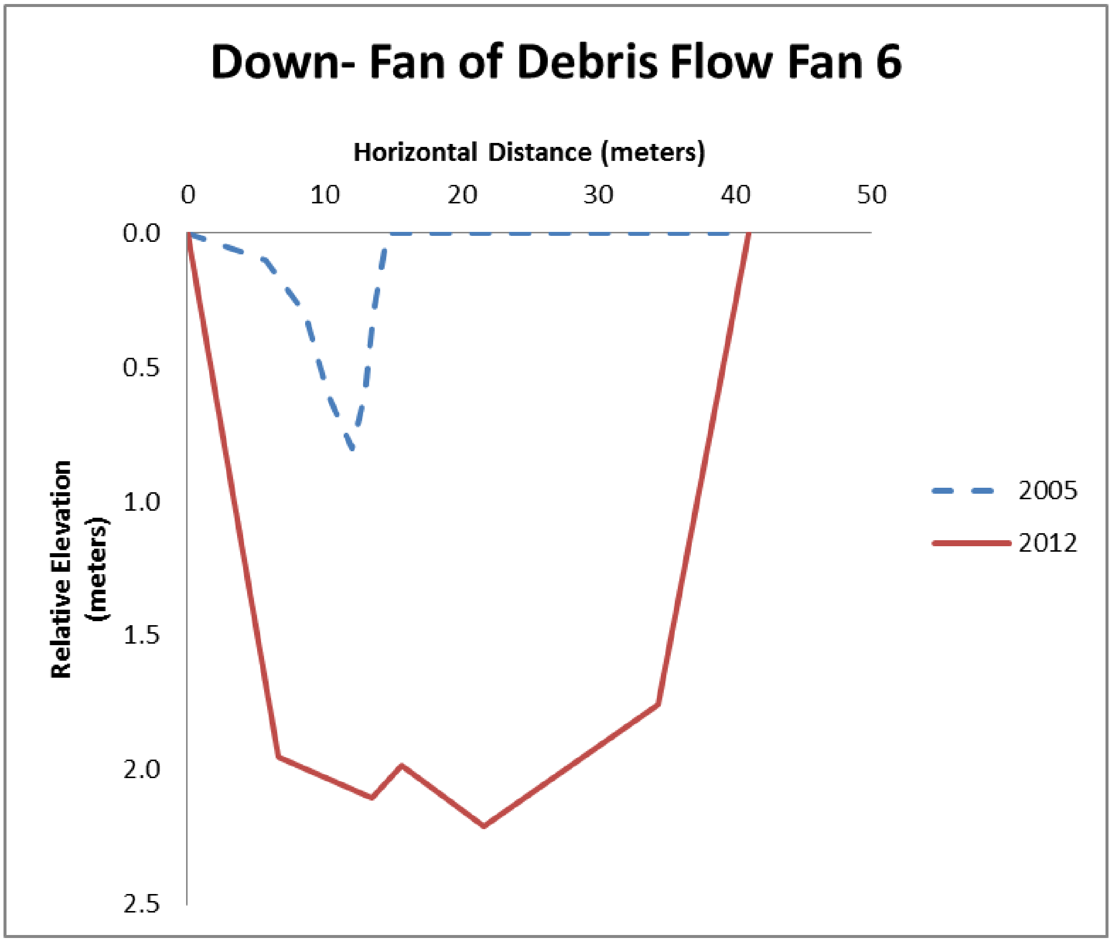
	x (m) Horizontal Distance	z (m) Depth
	-12.00	0.00
	-10.00	0.49
	-8.85	0.61
	-7.20	0.87
	-3.00	0.83
	0.00	0.93
	2.40	0.59
	4.60	1.96
	8.90	1.22
	12.90	1.37
	16.05	1.76
	20.20	1.81
	24.00	1.55
	29.00	1.95
	33.00	1.84
	37.00	1.74
Extension	40.00	0.00


Fan Reach of Debris Flow Fan 6
Horizontal Distance (meters)
-20
0
20
40
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
Relative Elevation (meters)
2005
2012

Location	Down-Fan Reach of DF 6		
Stream	Sleeping Child Creek		
Date	August-05	Date	July-12
Observer	Hoffman	Observer	Short

	x (m)	z (m)
	Horizontal Distance	Depth
	0.00	0.00
	5.70	0.10
	8.60	0.30
	10.30	0.60
	12.00	0.80
	13.00	0.60
	13.60	0.30
	14.60	0.00
	15.80	0.00
Projection	41.00	0.00

x (m)	z (m)
Horizontal Distance	Depth
0.00	0.00
6.60	1.95
13.43	2.10
15.70	1.98
21.64	2.21
34.40	1.76
41.00	0.00


Down- Fan of Debris Flow Fan 6
Horizontal Distance (meters)
0
10
20
30
40
50
0.0
0.5
1.0
1.5
2.0
2.5
Relative Elevation (meters)
2005
2012

APPENDIX E

Slope Profiles

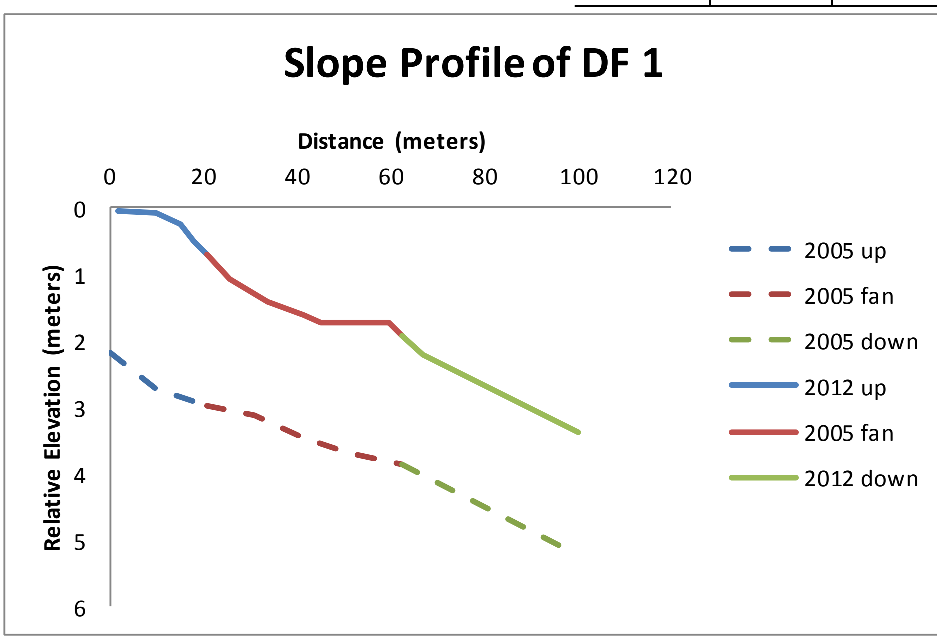
Location	Debris Flow Fan 1		
Stream	Sleeping Child Creek		
Date	August-05	Date	July-12
Observer	Hoffman	Observer	Short

Channel Slopes

0.04	**Up-Fan Reach**	0.03
0.02	Fan Reach	0.03
0.04	**Down-Fan Reach**	0.05

	y (m)	z (m)
Up-Fan Reach	**0.00**	**2.18**
	10.00	**2.71**
	21.00	**2.97**
Fan Reach	31.00	3.12
	41.40	3.46
	51.00	3.69
Down-Fan Reach	**62.60**	**3.86**
	100.00	**5.23**

	y (m)	z (m)
Up-Fan Reach	**1.68**	**0.04**
	10.00	**0.06**
	15.21	**0.24**
	18.13	**0.49**
	21.00	**0.71**
Fan Reach	25.83	1.07
	33.94	1.40
	41.58	1.62
	45.00	1.71
	59.68	1.73
Down-Fan Reach	**62.60**	**1.93**
	66.98	**2.22**
	71.88	**2.39**
	100.00	**3.37**



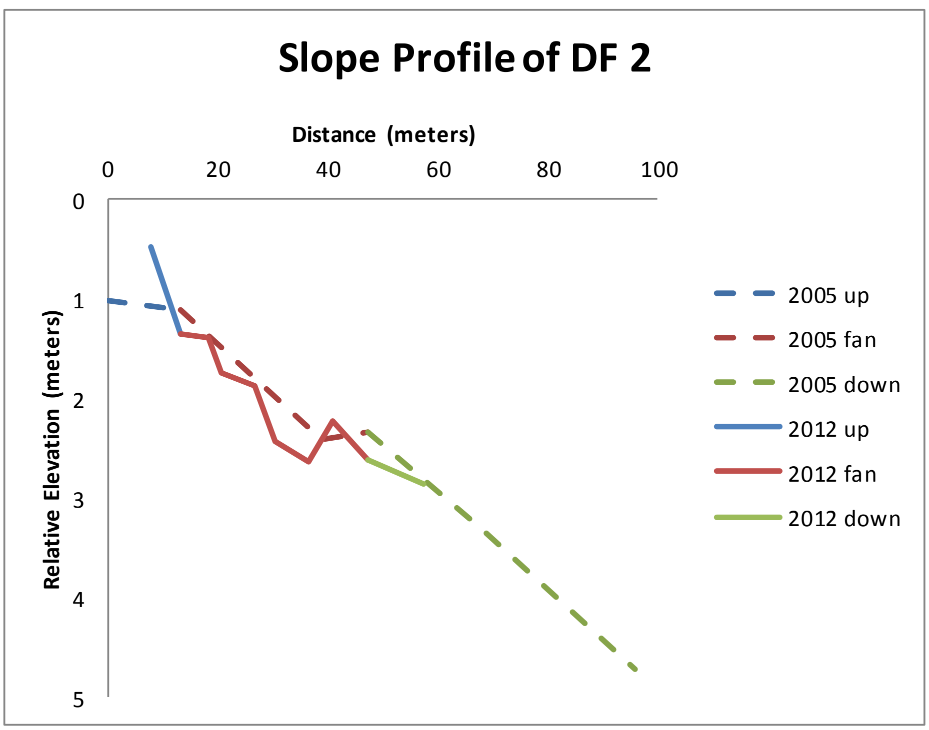
Location	Debris Flow Fan 2				
Stream	Sleeping Child Creek				
Date	August-05			Date	July-12
Observer	Hoffman			Observer	Short

Channel Slopes

0.01	**Up-Fan Reach**	0.16
0.04	Fan Reach	0.04
0.05	**Down-Fan Reach**	0.03

	y (m)	z (m)
Up-Fan Reach	**0**	**1.01**
	13.2	**1.1**
Fan Reach	39	2.41
Down-Fan Reach	**47.5**	**2.34**
	68	**3.3**
	96	**4.73**

	y (m)	z (m)
Up-Fan Reach	**7.75**	**0.48**
	13.2	**1.36**
Fan Reach	18.42	1.38
	20.57	1.75
	26.93	1.87
	30.51	2.43
	36.57	2.64
	40.87	2.22
Down-Fan Reach	**47.5**	**2.61**
	57.46	**2.86**



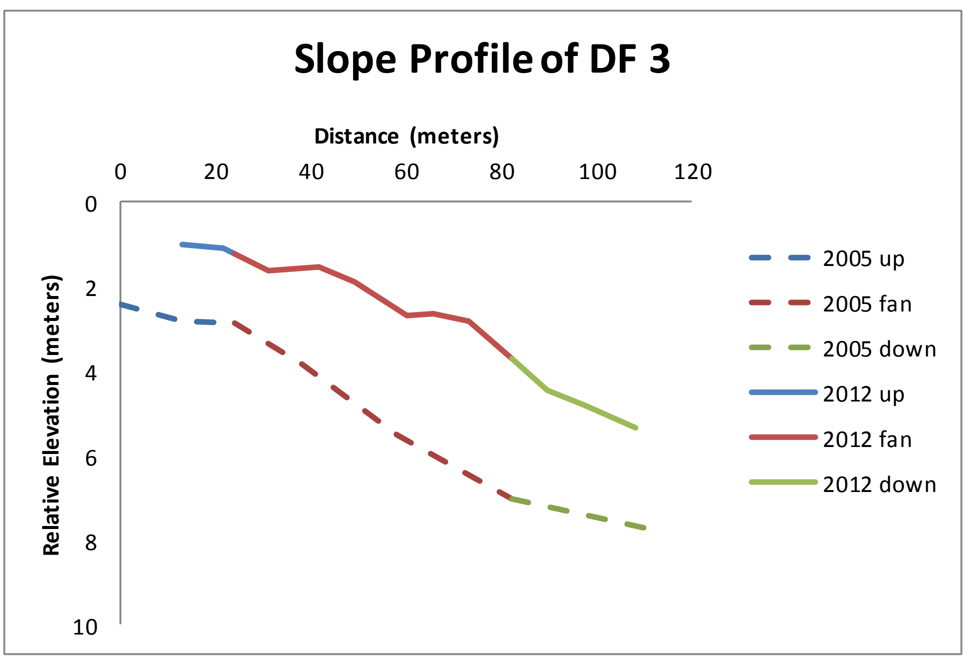
Location	Debris Flow Fan 3				
Stream	Sleeping Child Creek				
Date	August-05			Date	July-12
Observer	Hoffman			Observer	Short

Channel Slopes

0.02	**Up-Fan Reach**	0.01
0.07	Fan Reach	0.04
0.03	**Down-Fan Reach**	0.06

	y (m)	z (m)
Up-Fan Reach	**0.00**	**2.42**
	13.00	**2.80**
	24.00	**2.87**
Fan Reach	38.00	3.81
	58.00	5.52
Down-Fan Reach	**82.00**	**7.03**
	111.00	**7.71**

	y (m)	z (m)
Up-Fan Reach	**13.00**	**1.00**
	21.50	**1.10**
	24.00	**1.20**
Fan Reach	31.16	1.60
	41.70	1.51
	49.02	1.89
	60.13	2.69
	65.75	2.63
	73.10	2.80
Down-Fan Reach	**82.00**	**3.69**
	89.75	**4.47**
	97.68	**4.79**
	108.00	**5.34**



Location	Debris Flow Fan 4		
Stream	Sleeping Child Creek		
Date	August-05	Date	July-12
Observer	Hoffman	Observer	Short

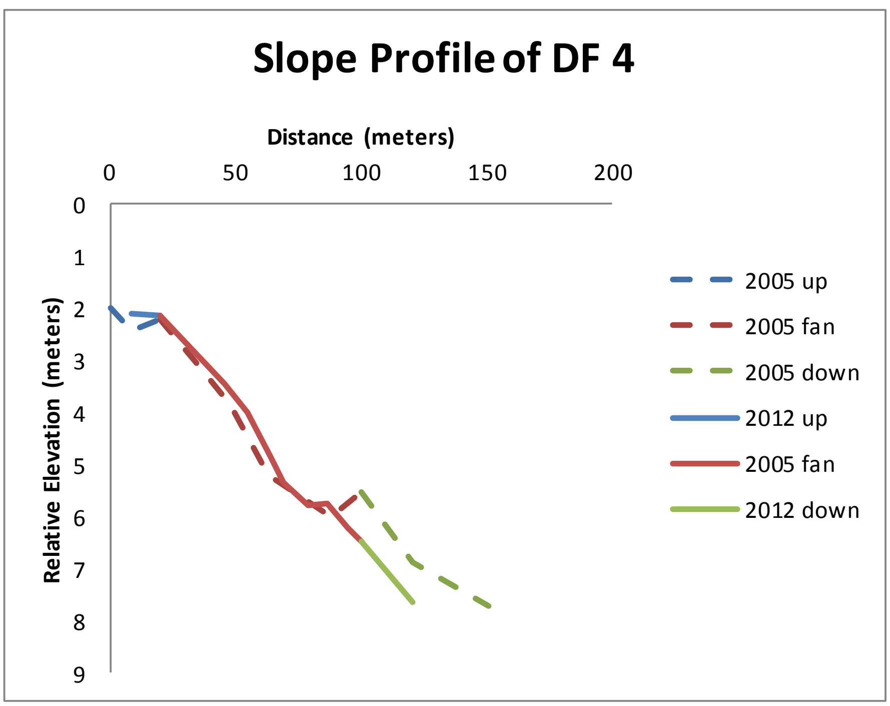
Channel Slopes

0.01	Up-Fan Reach	0.00
0.04	Fan Reach	0.06
0.04	Down-Fan Reach	0.06 * extrapolated

	y (m)	z (m)
Up-Fan Reach	**0.00**	**2.00**
	9.00	**2.43**
	20.00	**2.21**
Fan Reach	35.00	3.09
	48.00	3.84
	63.00	5.20
	88.00	5.98
Down-Fan Reach	**100.00**	**5.54**
	120.50	**6.89**
	150.70	**7.71**

	y (m)	z (m)
Up-Fan Reach	**9.00**	**2.09**
	19.69	**2.12**
Fan Reach	46.02	3.43
	54.82	3.99
	63.49	4.82
	69.17	5.35
	78.97	5.78
	86.88	5.74
	95.00	6.20
Down-Fan Reach	**100.00**	**6.48**
*	**120.50**	**7.64**

* extrapolated



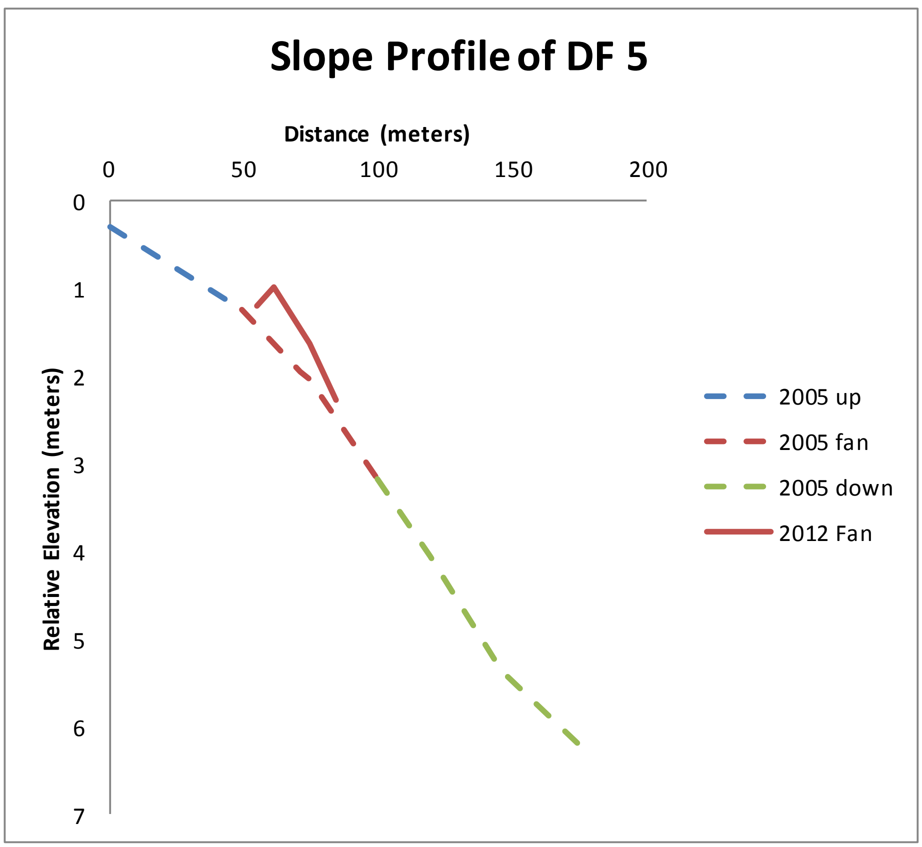
Location	Debris Flow Fan 5		
Stream	Sleeping Child Creek		
Date	August-05	Date	July-12
Observer	Hoffman	Observer	Short

Channel Slopes

0.02	**Up-Fan Reach**	N/A
0.04	Fan Reach	0.04
0.04	**Down-Fan Reach**	N/A

	y (m)	z (m)
Up-Fan Reach	**0.00**	**0.29**
	49.30	**1.23**
Fan Reach	71.00	1.95
	74.65	2.02
Down-Fan Reach	**100.00**	**3.16**
	119.00	**4.05**
	146.00	**5.35**
	175.00	**6.22**

	y (m)	z (m)
Fan Reach	54.75	1.19
	61.05	0.97
	74.65	1.63
	84.55	2.26



Location	Debris Flow Fan 6			
Stream	Sleeping Child Creek			
Date	August-05		Date	July-12
Observer	Hoffman		Observer	Short

Channel Slopes

0.01	**Up-Fan Reach**	0.02
0.07	Fan Reach	0.08
0.04	**Down-Fan Reach**	0.07

	y (m)	z (m)
Up-Fan Reach	**0.00**	**0.27**
	16.40	**0.31**
	36.50	**0.24**
	50.30	**0.7**
Fan Reach	57.00	0.82
	70.00	2.74
	81.00	3.8
	102.20	4.98
Down-Fan Reach	**115.10**	**5.07**
	122.50	**5.61**
	132.50	**6.35**
	151.10	**6.35**
	181.00	**7.52**

	y (m)	z (m)
Up-Fan Reach	**26.97**	**0.1**
	29.97	**0.05**
	34.97	**0.07**
	44.22	**0.48**
	46.97	**0.56**
	50.3	**0.57**
Fan Reach	51.57	0.57
	55.82	1.17
	62.15	1.19
	71.27	1.85
	81	1.95
Down-Fan Reach	**115.1**	**5.46**
	122.5	**6.22**
	127.15	**6.30**
	138.55	**7.04**
	181	**9.79**