

Change Detection Analysis Using Serial Lidar Data Along a Portion of the Upper Sandy River, Oregon

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Change Detection Analysis Using Serial Lidar Data Along a Portion of the Upper Sandy River, Multnomah and Clackamas Counties, Oregon

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Locator map depicting map/study area in context of the Sandy River watershed. This area was chosen to examine the effects of the 2010 flood along the Sandy River above the former Marmot dam site.

Introduction

The Sandy River is a dynamic river subject to significant geomorphic change. The combination of fine sediment, large woody debris, and frequent effective flows from rain-on-snow events allows the river to change its bed composition and location regularly. The floodplain contains numerous abandoned channels that readily recapture flow during large flows, requiring residents within the floodplain to pay close attention to the river's movement. Although large flows sometimes inundate the overbank areas, mass wasting caused by bank erosion and changes to bed formation are a major concern to residents; significant property loss has occurred in recent years. The removal of Marmot dam on October 17, 2007, changed the river's sediment regime as approximately 730,000 cubic meters of stored sand and gravel were released downstream (Major and others, 2008). The Sandy River experienced two significant flow events greater than 25,000 cubic feet per second (cfs) since 2007 (based on peak flow results for Sandy River gauge 14142500; Figure 1). In January 2009 a large flow of 30,000 cfs occurred on the Sandy, causing significant channel change while destroying a several homes (Portland Tribune, 2011). In January 2011 another flood of 39,000 cfs occurred, wiping out several homes; again, the channel experienced significant erosion (Tomlinson, 2011). The upper Sandy River continues to experience channel change as it cuts through the sediment of the former upstream reservoir. Scientists continue to monitor the Sandy River to better understand the post dam removal sediment and flow regime (Podolak and Pittman, 2011).

Site Description

The upper Sandy River is a High Cascade stream characterized by a relatively steep gradient and pool-riffle bed formations (Figure 2). The flow regime of the Sandy consists of higher flows in winter and spring brought on by rain and rain-on-snow events; low flows occur in late summer months (Figure 3). The removal of the Marmot dam in 2007 has led to significant change in channel geometry along the Sandy (Major and others, 2008). The full effects of the dam removal are still being assessed, but it is likely that the sediment transport regime will change over the next several years. The riparian area is dominated by palustrine forest consisting of old and second growth Douglas fir, western hemlock, and red alder. The substrate of the Sandy River channel consists of fine sand, cobbles, and boulders with valley slopes consisting of basalt formations. Near-stream land use consists of forest and low-density residential development associated with the towns of Brightwood, Mt. Hood Village, Welches, Wenme, and Zigzag. Flooding and mass wasting are concerns for many residents as the active channel moves throughout the floodplain.

Methods

Lidar data were collected through the Puget Sound Lidar Consortium in March 2007. A second flight was collected through DOGAMI between August 30 and September 3, 2011. Lidar bare-earth digital elevation models (DEMs) extracted from lidar point data depict river channels and the fluvial conditions at time of flight with unprecedented accuracy and detail. This study attempts to quantify the change in the upper Sandy River fluvial environment between 2007 and 2011.

Change detection was evaluated by subtracting 2007 lidar bare-earth DEMs from 2011 lidar bare-earth DEMs to produce a difference raster. Both DEMs originally contained elevation values in meters (NAVD83) and had 1-m cell size. Resulting statistical and output data have been converted to English units for reporting. The historic migration zone (HMZ) delineated by English and others (2011) was used to identify the active channel extent and thus to define the study area. In some cases the study area was expanded to include areas of recent channel migration that took place after the work of English and others (2011).

It was immediately apparent that not all difference values between data sets were due to actual land elevation changes and that a threshold was necessary to remove values associated with internal lidar sensor noise and differences in lidar ground classifications. The threshold for removing noise was decided after testing various raster classifications, using continuity of change, geomorphic plausibility (i.e., erosion on cut banks), and area as criteria. It was found that difference values between -2.5 feet and 2.5 feet were unreliable. Values greater than ±2.5 feet were extracted from the difference raster and converted to polygons. Zonal statistics were calculated to provide the sum change and area for each polygon. These statistics allowed for the volume of change to be calculated for each contiguous polygon area. The result of this analysis produced a single shapefile with values of positive and negative volumes of change within the study area.

Some noise remained in the data and was found to be associated with building footprints and with differences in ground classification between DEMs. To remove this, an additional filter was used to remove polygons with area less than or equal to 4.8 cubic yards (4 cubic meters). Additionally, some data were removed from the areas far outside the active channel area as these data were deemed not to be riverine related. The final polygon shapefile represents areas where negative vertical change (sediment removal) and positive vertical change (deposited sediment) have taken place over the course of four years.

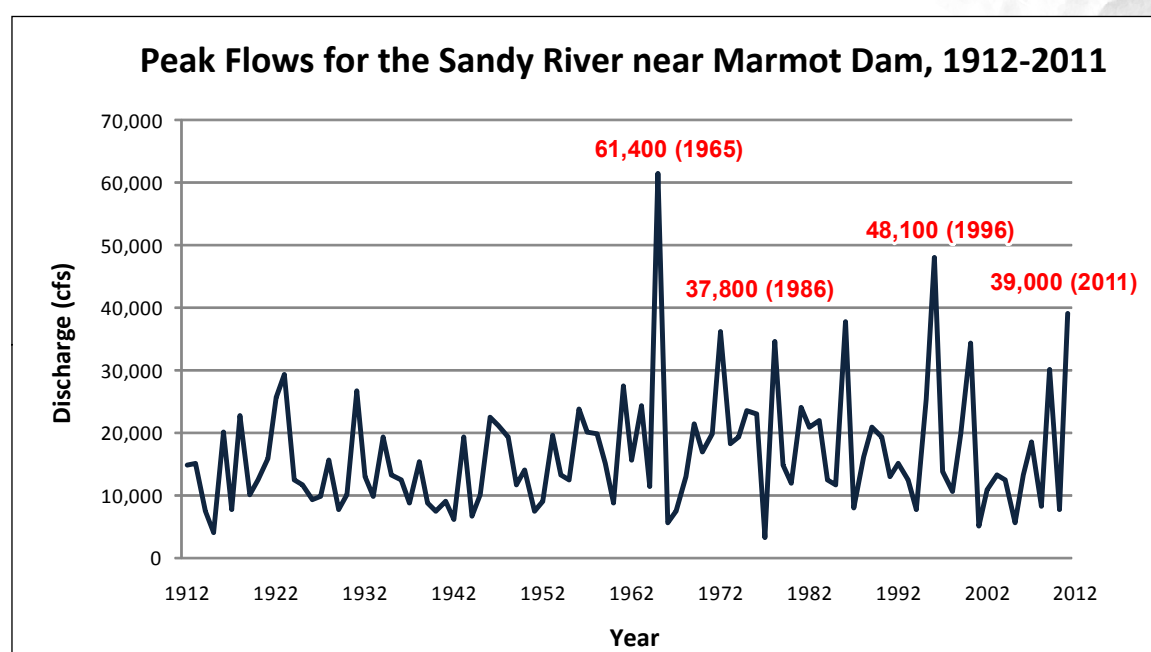


Figure 1. This figure shows historic peak flows along the Sandy River from 1912 through 2011. From the distribution shown, flows greater than or equal to 30,000 cubic feet per second are regular events. Two such flows occurred in 2009 and 2011.

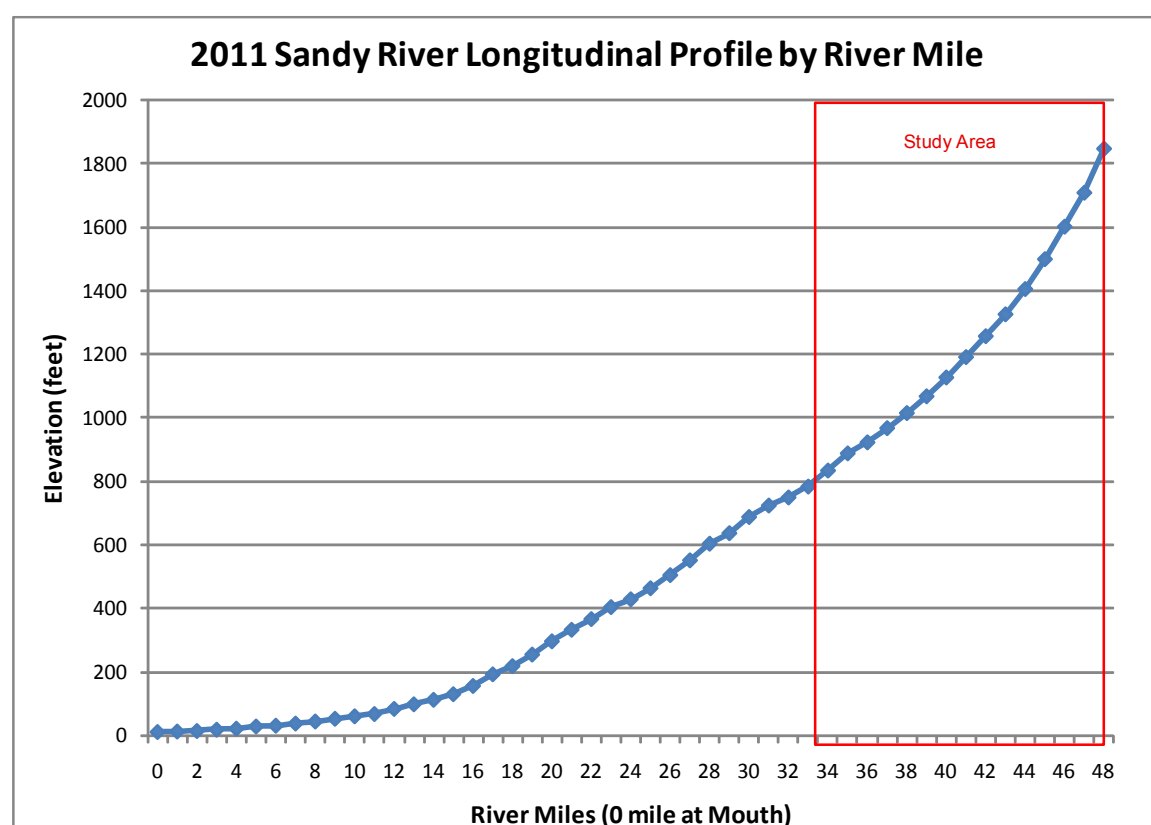


Figure 2. The 2011 longitudinal profile of the Sandy River from the mouth to river mile 48 is shown. The convex shape of the profile is typical of a mountain stream: a steep water surface slope in upper reaches changing to lower slopes near the mouth. Steep slopes of the upper reaches are areas where sediment is supplied, whereas downstream reaches with lower slope are areas of deposition. Upper reaches are characterized by lower amplitude and magnitude meanders and contain closely spaced pools and riffles. Lower slope reaches are characterized as response reaches in that when a large flow event occurs, these reaches experience significant change to bed form and lateral movement. These portions of channel have higher magnitude and amplitude meanders with widely spaced pools and riffles. Near the mouth, pools and riffles decrease and the river takes on a plane bed state.

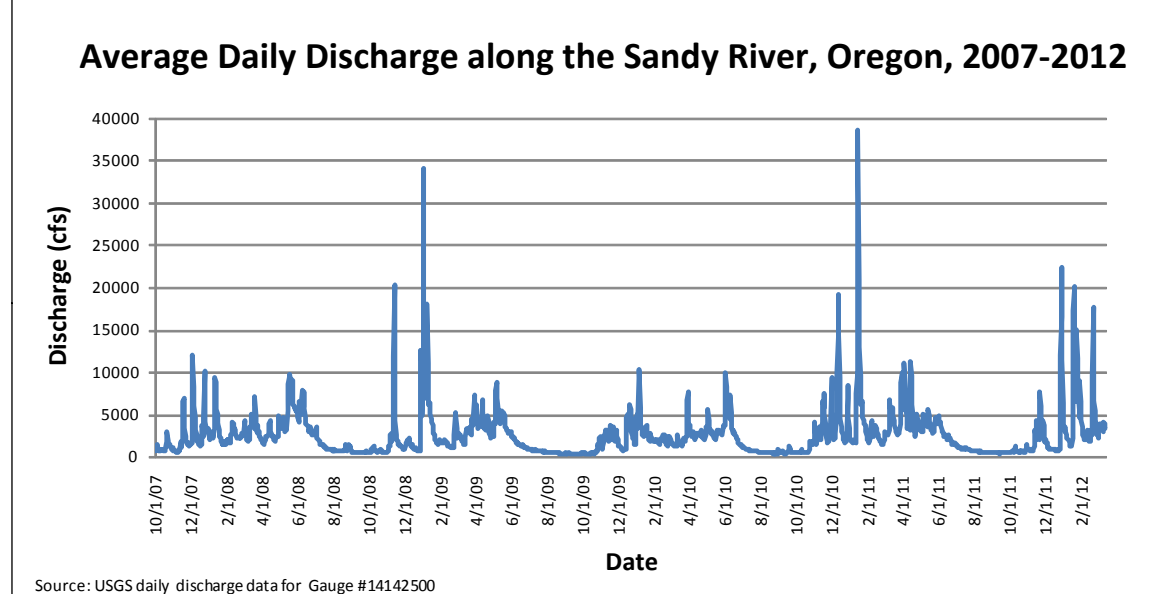


Figure 3. Between October 1, 2007, and February 1, 2012, there were two significant flows (Figure 1). Peak flow values were calculated using the U.S. Geological Survey PACTwin program. From the output of this model it was determined that the 50% chance (2-year flood) was 25,110 cubic feet per second. This flow value was used to represent an effective discharge. Effective discharges occurred January 2, 2009, with a flow of 34,000 cfs and January 16, 2011, with a flow of 38,600 cfs.

Results

The geometry of the Sandy River changed considerably between 2007 and 2011. Within the study area, five areas of channel experienced large amounts of erosion and deposition. Most of the change likely resulted from large flows occurring January 2, 2009, and January 16, 2011. The majority of erosion occurred along existing cut banks, and in several cases the river reoccupied or formed new channels. Volumetric measurements showed a net loss of sediment, suggesting some channel widening and degradation had occurred.

The upper Sandy River located above the confluence of the Zigzag River experienced massive change as the river avulsed and became semi-braided between river miles 46 and 49. Large amounts of deposition occurred along existing point bars and mid-channel bars. New point bars were formed as well. The largest amount of change for this study occurred between river mile 48 and 49, where the river experienced a net loss 123,043 cubic yards of sediment (Table 1).

The Zigzag River experienced large amounts of erosion. The majority of the erosion occurred upstream of river mile 1, where a total of 66,944 cubic yards were removed (Table 1). At its mouth the Zigzag River experienced significant change. While some erosion took place along cut banks, most erosion occurred within the channel, suggesting that the channel degraded.

Near Mt. Hood Village the Sandy River showed erosion on cut banks and deposition along point and mid-channel bars. Downstream of river mile 43 a large amount of erosion occurred along the north bank (~19,003 cubic yards removed). Just upstream of river mile 43 it appears the river temporarily occupied a lateral channel north of the main channel. The river cut into this lateral channel (~2,886 cubic yards removed), and it is highly probable the river will occupy this channel in the future.

Downstream of river mile 42 (south of Sandy River Road) a large amount of channel change took place (see Figure 4 profile). Severe erosion along two cut banks increased the amplitude and magnitude of the meanders. Both cut banks are adjacent to developments. The point bar located just north of Riverside Road experienced large amounts of deposition, extending the point bar north. This area experienced the greatest amount of change for reaches downstream of the Zigzag confluence with a total of 53,096 cubic yards removed and 16,841 cubic yards deposited (Table 1).

River	River Mile	Sum Removed (yd ³)	Sum Deposited (yd ³)	Net Change (yd ³)
Zigzag	0	37,541	6,232	-31,309
Zigzag	1	36,550	915	-35,635
Zigzag	2	1,416	64	-1,352
Sandy	34	12,349	10,567	-1,782
Sandy	35	7,185	1,558	-5,627
Sandy	36	15,803	2,383	-13,420
Sandy	37	14,551	2,684	-11,867
Sandy	38	5,427	1,179	-4,249
Sandy	39	17,390	3,887	-13,503
Sandy	40	18,325	4,004	-14,321
Sandy	41	53,096	16,841	-36,254
Sandy	42	33,856	3,535	-30,321
Sandy	43	19,003	8,691	-10,312
Sandy	44	11,973	1,525	-10,447
Sandy	45	28,219	9,750	-18,468
Sandy	46	72,747	22,224	-50,523
Sandy	47	72,092	13,119	-58,973
Sandy	48	143,830	20,786	-123,043
Sandy	49	35,037	745	-34,292
Totals		636,389	130,690	-505,699

Table 1. Total volume for areas of removal and deposition were compiled for each river mile using zonal statistics in ArcGIS. Net change was calculated by subtracting removal sums from deposited sums for each river mile reach.

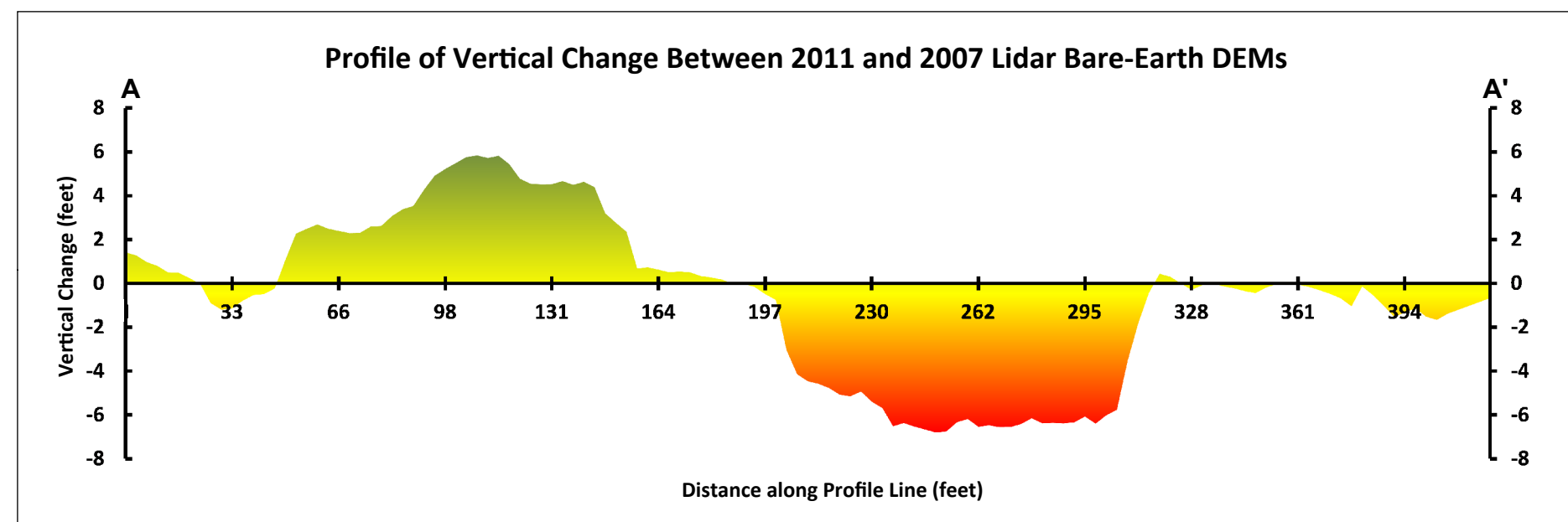
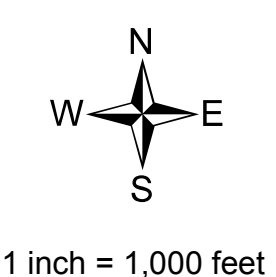


Figure 4. A profile showing change was constructed showing the elevation difference between 2011 and 2007 bare-earth models. The profile is located between river miles 41 and 42 just north of Riverside Road. The profile shows a large amount of removal (red) along the cut bank and deposition (green) along the point bar on the north side of the meander. This change in channel geometry is a typical example of how streams migrate across the flood plain.

Legend

- Sediment Deposited
- Sediment Removed
- 2011 River Channels
- River Mile Marker
- Building
- Road
- Vertical Change Profile



Data Sources

Lidar data used in this study were collected through the Puget Sound Lidar Consortium (2007) and the Oregon Department of Geology and Mineral Industries (2011). All other map layers were created by DOGAMI.

Data Projection

Universal Transverse Mercator (UTM), Zone 10, NAD83, meters.

Project Units

Map units and results have been converted from metric to English units.

Acknowledgments

Ian Madin, Chief Scientist, Oregon Department of Geology and Mineral Industries for assistance with study methods; Dan Coe, Cartographer, Oregon Department of Geology and Mineral Industries for review of map layout.

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Study Limitations

In-stream volume change calculations are estimated to be accurate to approximately two cubic yards, on the basis of accuracy of the lidar DEMs used to generate the change grid. No field verifications were attempted in this study. Deposition and removal values are not exclusively due to stream processes. In some cases deposition and removal values may result from mass wasting on stream banks. Special attention was given to these areas to remove values that were obvious artifacts due to differences in grid interpolation (e.g., deposition on top of the bank with no immediate upslope removal).



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