Data article

Title: ***Discharge and suspended sediment a paired watershed study examining the effects of contemporary forest harvesting in the Oregon Coast Range: Alsea Watershed Study Revisited***

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Abstract

Forest harvesting practices can expose mineral soils, decrease infiltration capacities of soils, disturb the stream bank and channel, and increase erosion and fine sediment supply to stream channels. To reduce nonpoint source sediment pollution associated with forest management activities and to maintain the high water quality typically provided from forests, best management practices (BMPs) were developed and implemented. The Alsea Watershed Study was an important early research site that lead to the development of contemporary forest management practices to protect water quality and fish habitat in Oregon and elsewhere. By returning to the same watersheds that were harvested in 1966, this is one of the few times that a watershed-scale study is able to directly compare and contrast the effects of historical practices with contemporary practices. The Alsea Watershed Study Revisited includes the same three watersheds as the original study. Flynn Creek (FCG, 219 ha) is an old-growth dominated reference watershed. Deer Creek (DCG, 315 ha) is an extensively managed watershed that was patch-cut during the original study. Needle Branch (NBLG, 94 ha) was clearcut harvested in the original study and again in the recent study, but with contemporary BMPs, including riparian buffers. The upper portion of Needle Branch was harvested in 2009 (Phase I), while the lower

portion of the watershed was harvested in 2015 (Phase II). This data set suspended sediments and discharge from WY 2006–2016.

Specifications Table

Subject area	*Hydrology*
More specific subject area	*Forestry*
Type of data	*Table*
How data was acquired	*Stream gages for stage and laboratory analysis for suspended sediment*
Data format	*Suspended sediments are raw, discharge is modeled from stage*
Experimental factors	*Harvesting and water year*
Experimental features	*Treatments include and uncut reference watershed (FCG) and a watershed harvested using contemporary harvesting practices (NBG)*
Data source location	*Alsea Watershed Study Revisited (located at approximately 44.5°N, 123.9°W), near Toledo, Oregon, USA*
Data accessibility	*Freely accessible*

Value of the data

- **Unique study that revisited a site with suspended sediment data from the 1960s**
- **Examined the effects of contemporary harvesting effects on suspended sediment**
- **Oregon Coast Range is one of the most productive timber producing regions in the world**

Data

Data are from 3 watersheds in the Oregon Coast Range ("WS" = FCG: never harvested; DCG: patch cut in the 1960s, little management since; NBLG: harvested in the 1960s and 2009-2014). Data include: "Phase" which the phase of the treatments (Pre- treatment, Phase I – post phase I treatment, Phase II – post phase II treatment); "Date" which includes data and time of data collection; "UnitQ10.mm" which is the unit discharge collected at a 10 minute interval in units of mm, "SSC.mgL" which is the suspended sediment concentration in mg L^{-1} collected using a turbidity discharge threshold method, and "Precip.mm" which is precipitation in mm. ***Missing values are denoted by "NA".***

Experimental Design, Materials and Methods

Site description and history

The Alsea Watershed Study (AWS) Revisited (located at approximately 44.5°N, 123.9°W) was a paired-watershed study consisting of a reference watershed (Flynn Creek, 219 ha; measured at the Flynn Creek Gage or FCG) and a nearby treatment watershed (Needle Branch, 94 ha; measured at the Needle Branch Lower Gage or NBLG). Current harvesting practice rules stipulate that harvests be less than 48.5 ha (120 acres) and replanted trees must be "free-to-grow" before nearby harvests are conducted; therefore, the upper half of the treatment watershed, (35 ha; measured at the Needle Branch Upper Gage) was harvested in 2009 (Phase I) and the lower half was harvested in the fall of 2014 and mid-summer 2015 (Phase II). Harvests were logged using hand felling and cable yarding systems with no yarding through stream channels. Unlike the original AWS, there was no wood removal from stream channels—any woody material that fell into unbuffered reaches during the operation was left within the

stream channel. No new roads were built during the AWS Revisited and most of the roads were along the ridgetop. Existing roads received a fresh application of gravel, any blocked ditches were cleaned, and any needed ditch relief culverts were installed. No riparian buffers were retained on non-fish bearing stream segments of Needle Branch. This included ~969 m of stream segments during the Phase I harvest and an additional ~588 m of stream segments during the Phase II harvest. These non-buffered segments still had machine exclusion protections (total = 1,557 m). Riparian management areas (RMAs) of ~15 m widths were retained on fish-bearing stream reaches of Needle Branch. This included ~987 m during the Phase I harvest and an additional ~833 m of stream reaches during the Phase II harvests (total = 1,820 m). Unlike the original AWS there was no broadcast burning—harvest --residuals were piled and burned. A third watershed, Deer Creek (315 ha; measured at the Deer Creek Gage or DCG) was used as a treatment watershed in the original Alsea Watershed Study (roads were built and patch-cut in 1965–1966), and serves as a secondary control for the current study and is used to compare contemporary and historical sediment yields in the discussion section.

The study area is located in the central Oregon Coast Range, a highly-dissected mountainous region characterized by short, steep, soil-mantled hillslopes. In general, the soil textures of these watersheds are loams and gravelly loams on the hillslopes and valley bottoms and clay loams on the ridges. Geology consists primarily of Eocene Tyee Formation sandstone and siltstone. The region has a Mediterranean-like climate with dry summers and wet winters. The mean annual precipitation (1981–2010) of the study region is ~2192 mm (PRISM Climate Group, 2004). Precipitation primarily occurs from October to April in "long-duration, low-to-moderate intensity frontal storms" (Harr, 1976). Snow, while occurring occasionally, does not usually accumulate and is therefore a negligible portion of the precipitation record (Moring and Lantz, 1974).

Flynn Creek is a 2nd-order stream with a mean watershed elevation of 280 m, mean watershed gradient of 33°, and mean channel gradient of 0.025 m m^{-1}. The catchment, having never received silvicultural treatments or other human perturbations relevant at the watershed scale, was designated a Research Natural Area in 1975 by the USDA Forest Service. At the time of the original Alsea Watershed Study canopy vegetation consists of 75–115 yr-old red alder (*Alnus rubra*) along with a mix of 75–95 yr-old and 115–155 yr-old Douglas-fir (*Pseudotsuga menziesii*) based on information provided in Moring and Lantz (1974). At the time of the original Alsea Watershed Study Brown *et al.* (1973) estimated the red alder component to be 68% of the forest cover. The channel substrate in FCG primarily consisted of gravels (42.6% ± 0.08 SD) and fines (< 1 mm; 19.1% ± 0.04 SD) with lesser amounts of cobbles, boulders, and bedrock (unpublished data).

Needle Branch is a 2nd-order stream with a mean watershed elevation of 222 m, a mean watershed gradient of 39°, and average stream gradient of 0.014 m m^{-1}. The catchment was composed of 44 yr-old Douglas-fir occurring primarily on the hillslopes with red alder of the same age-class inhabiting both riparian and upslope areas (80% conifer per stand inventory documented Belt (1997)). The catchment was treated with a mid-rotation pre-commercial thinning in 1981 and a commercial thin in 1997, and fertilized in 1998 with 224 kg N ha^{-1} as urea (Stednick and Kern, 1992). Substrate in the mainstem channel of NBLG is primarily gravels (45.0% ± 0.10 SD) and fines (< 1 mm; 28.9% ± 0.08 SD) with occasional cobbles, boulders, and bedrock (unpublished data).

The upper portion of NBLG was clearcut harvested (35 ha) in summer 2009 using contemporary harvesting practices and BMPs. In fall of 2014, most of the lower NBLG watershed was harvested

employing the same standards. A final 2.4 ha patch of timber in the lowermost portion of the drainage was harvested in July 2015. In both entries, ground-based equipment was used where topography allowed, while cable-based equipment was used on steeper slopes. In non-fish-bearing reaches, there was no requirement for overstory retention so stream-adjacent trees were harvested. On the fish-bearing portion of the stream, a ~15 m wide RMA was retained on each side of the stream in accordance with the Oregon Forest Practices Act and Rules. Limited harvesting was allowed in RMAs according to tree and basal area retention requirements and further restrictions on near-stream disturbance from roads, yarding, and site-preparation. These rules have recently undergone changes that can increase the width and restriction of management activities within the RMA. NBLG was replanted within 2 years after harvest.

Deer Creek is a 2nd-order stream with a mean watershed elevation of 311 m, a mean watershed gradient of 43°, and a mean channel gradient of 0.018 m m^{-1} . Current canopy vegetation consists of Douglas-fir stands of various age-classes. Red alder is present in the riparian areas and on some hillsides and, as of 1992, represented only 36% of the forest composition (Belt, 1997). The original Alsea Watershed Study treatment for Deer Creek consisted of three small patch-cuts with retention of vegetated stream buffers. Additional (post-AWS) timber harvesting includes three small patch-cuts and commercial thinning in two of the three original patch-cuts. Silvicultural activity since the original study is considered to be relatively minor and inconsequential to sediment yield; therefore, the watershed is used here as a secondary control.

Instrumentation and data collection

Suspended sediment concentrations (SSC), discharge (Q), and daily precipitation were collected in all three of the study watersheds from October 2005 (WY2006) to June 2016 (WY2016), with the latest measurements taken August 2016 for Needle Branch and Flynn Creek. Discharge and suspended sediment were measured at compound broad-crested concrete weirs located at the watershed outlets of Flynn Creek (FCG), Needle Branch (NBLG), and Deer Creek (DCG). Precipitation was measured in tipping buckets (Davis Rain Gages, Texas Electronics, or Onset depending on availability with Onset event loggers) at four locations near the outlets of each watershed. We averaged precipitation across all three watersheds because of gaps in the record and the close proximity of the gages.

Water samples for suspended sediment analysis were collected in auto samplers (ISCO 3700, Teledyne ISCO, Inc., Lincoln, NE). The auto samplers were triggered based on both a turbidity and minimum stage threshold (Lewis and Eads, 2009). Turbidity was measured using OBS-3-L turbidity sensors (D&A Instrument Co., Port Townsend, WA), which use an optical backscatter method to measure turbidity in the range of 0 to 4000 Formazin Turbidity Units (FTU). All stage and turbidity data were recorded with a CR-10(X) datalogger at 10 minute intervals (Campbell Scientific, Inc., Logan, UT). Over the 11 water years of this study a total of 4,405 water samples were collected with automatic samplers, including total annual samples of 89–355 at FCG, 0–327 at DCG, and 2–226 at NBLG. The majority of samples were collected during relatively high flow conditions above 0.2 m^3 s^{-1} for FCG and DCG and above 0.07 m^3 s^{-1} for NBLG. These thresholds correspond to unit discharges between 0.02–0.03 mm s^{-1}.

All water samples were analyzed for suspended sediment concentration at the Oregon State University Department of Forest Engineering, Resources & Management Forest Hydrology Lab. The

samples were vacuum filtered using a 1.5 μm glass fiber filter paper (Whatman 934-AH), dried at 105°C, and weighed following standard protocols.

Stage was recorded every 10 minutes between 2005 and 2016 with a CS420-L Druck pressure transducer (Druck Inc., New Fairfield, CT). We developed rating curves for each watershed from 40–59 manual measurements of stage and discharge primarily collected between 2006 and 2016 (3–6 pairs per year). The stage-discharge relationships were best described by a 3rd order polynomial for FCG, 2nd order polynomial for NBLG, and a power relation for DCG.

Uncertainty in the rating curve was assessed by conducting 1 x 10^6 Monte Carlo simulations randomly varying the parameters of the rating curve fits. The uncertainty in the stage data varied between 4–8% among the 3 sites and was assessed by comparing the electronic and reference stage values collected over a wide range of flows. The overall uncertainty in the 10-minute discharge data, combining both sources of error, varied between 11–18% for FCG, 11–23% for NBLG, and 10–18% for DCG.

Except for WY2016, most years had almost complete coverage (> 95%) of Q data. Personnel and technical difficulties resulted in partial years of data in water years 2011 and 2012 across all watersheds.

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