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Effects of Road Obliteration on Stream Water Quality

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Abstract

The Nez Perce National Forest and the Rocky Mountain Research Station are conducting a long-term study of road obliteration that includes measurements of sediment generated during obliteration activities. Three culvert locations in the Horse Creek drainage of Idaho were monitored during road obliteration activity. Sediment yields varied from 2 to 170 kg. Yields decreased rapidly downstream and at the mouth of each watershed sediment concentrations did not exceed 150 mg/L except during a precipitation event. Turbidity values exceeded the Idaho Department of Environmental Quality limit of 50 NTU above background immediately below the culvert, but not at the watershed mouth.

Introduction

Between 1950 and 1990, increasing numbers of United States Forest Service (USFS) roads were built for timber harvesting and forest management activities. In 2000 the inventoried road length was 623,000 km. Less than 20 percent of USFS roads are currently maintained according to originally specified safety and environmental standards (USDA Forest Service, 2002).

One solution to this maintenance backlog is to remove roads with low priority. Removal from service, or "decommissioning," involves blocking the entrance and restoring the former road prism to a more natural state (USDA Forest Service, 2000). Road obliteration is the most comprehensive degree of decommissioning and involves decompacting the road surface and ditch, pulling the fill material onto the running surface and reshaping the roadbed to match the hillside contour. Culverts are removed and stream channels are restablished. Ground cover in the form of transplanted bushes or placement of branches from nearby vegetation. Grass and forb seeds are typically applied to the bare soil.

Although more than 23,700 km of roads have been decommissioned (Bosworth, 2003), little data is available to quantify how road removal activities affect stream water quality. U.S. Forest Service specialists typically assume sediment from road obliteration is less damaging than the long term environmental consequences of unmaintained roads. Brown (2002) measured the sediment generated during road obliteration at five stream crossings on the Clearwater National Forest in Idaho. Peak downstream concentrations ranged from 2.9 to 68,400 mg/L depending largely on the number of straw bales placed in the stream and on flow diversion.

The Rocky Mountain Research Station and the Nez Perce National Forest conducted a study to measure stream responses to road obliteration activities. The long-term goal is to deliver quantitative information to those making road management decisions in sensitive forested watersheds. The purpose of this case study was to measure the effects of culvert removal on stream water quality.

Methodology

Site Description. The research site was located in the Horse Creek drainage on the Nez Perce National Forest in Idaho. Horse Creek is a tributary to Meadow Creek in the Selway River drainage which is a critical habitat area for anadromous fish. The Horse Creek drainage was an Administrative Research Study area from 1965 to 1988. This study was summarized in King (1994). Research and monitoring efforts have spanned a variety of successive activities including road installation, harvesting, and now road removal. This wealth of data available for comparison of pre- and post-obliteration conditions made Horse Creek an ideal site selection.

The Horse Creek drainage consists of the Main Fork (Figure 1) and the East Fork. The Main Fork of Horse Creek, where the study occurred, is a third order stream with a drainage area of 1,690 ha. First and second order tributary watersheds range in size from 25 to 150 ha. Average annual precipitation ranges from 100 to 115 cm, and elevations range from 1,240 to 1,840 m. The majority of runoff is in the form of spring snowmelt. Hillside slopes are typically 31 to 36 percent, with some exceeding 65 percent. The predomininant geologic parent material is gneiss and schist derived from the Idaho Batholith Border Zone. Soils are moderately deep, well drained, loam to sandy loam with surface layers containing loessal silt. The dominant habitat type is western red cedar/*clintonia uniflora*, with subalpine fir and grand fir habitat types also present.

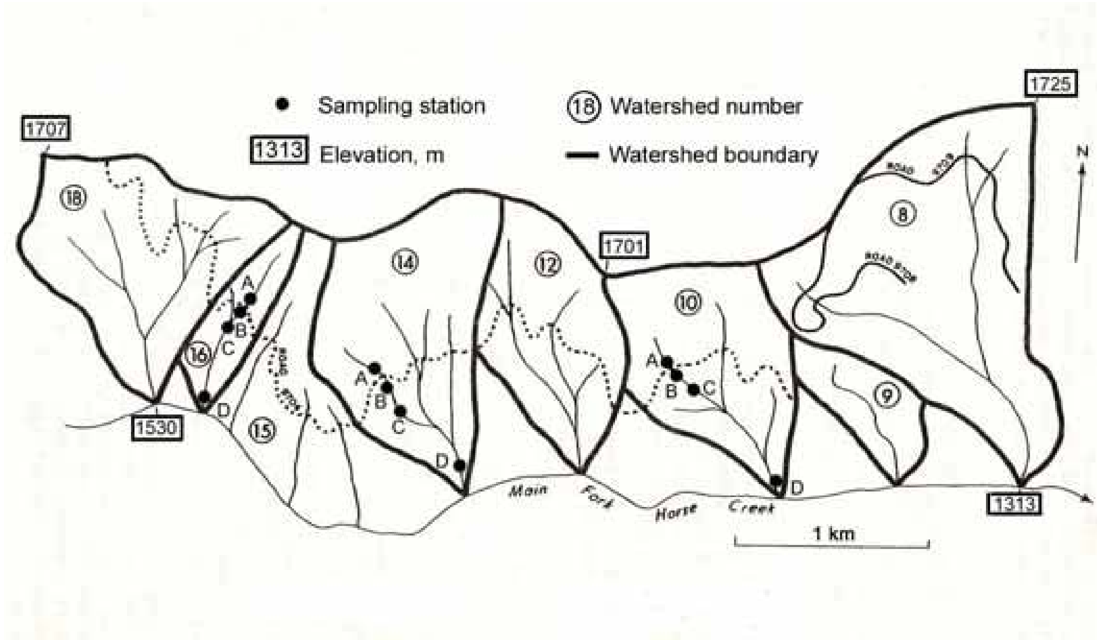

Figure 1 – A portion of the Horse Creek drainage in the Nez Perce NF. Sediment sampling stations A, B, C, and D are shown in each watershed monitored in this study.

A 7.2-km mid-slope road was removed to study the impact of road obliteration. The road crossed six watersheds ranging from 16 to 86 ha in size. Three of the six watersheds (10, 14, and 16) along this road were monitored to observe the impact of the road obliteration.

Areas of watersheds 10, 14, and 16 were 56, 62, and 16 ha, respectively. The volume of fill over the culverts of interest was largest at WS14 with 890 m^3 and smallest at WS10 at 180 m^3. WS16 had 220 m^3 of fill. All culverts were 0.61 m diameter CMP. Rosgen channel types (Rosgen and Silvey, 1998) above and below each culvert were A4a+. Aspects and elevations of all three watersheds were similar.

Mechanical Road Obliteration Technique. Obliteration work was performed using a 110,000-Newton (N) hydraulic excavator and a 10-m^3 dump truck. Culverts consisted of three sections bolted together and laid on a bedding material of coarse sand. The stream was not diverted around the culvert during road obliteration. Road fill material atop the culvert was removed and the culvert sections were pulled up one at a time with the most downstream section removed first. After lifting and removing culvert sections, water flowed on the compacted sand bedding material. Straw and riprap were placed in the streambed between the removal of each culvert section. No motorized vehicles or machinery traversed the stream channel once fresh soil was exposed. Grass seed and additional straw were placed on the stream banks within a few days following the culvert removal.

Stream Sampling Methods. Four stream sampling locations were established in each watershed. The sampling locations relative to the culvert were: A - 15 m upstream, B – 20 m downstream (as close to the culvert outlet as safety considerations allowed), C – 100 m downstream, and D – 800 m downstream at the mouth of the watershed. Stations A and C had permanent 2-inch, 45 degree WSC trapezoidal flumes. Flow rates were continuously monitored. A temporary flume was placed at Station B for taking grab samples.

During obliteration, grab samples were taken in 500-ml bottles from flumes at the A, B, and C stations. Grab samples were taken from a free overfall and included the entire width of the stream and, therefore, consisted of both suspended and bedload sediments. Samples were taken with an ISCO 3700 sampler at station D for the entire sampling period and at station C during nighttime hours. The sampler inlet was located above the streambed, thereby, sampling only suspended sediment. Sampling began one day prior to the culvert removal and continued throughout the obliteration activity.

Laboratory Analysis. Turbidity and total suspended sediment were measured according to standard methods (American Public Health Association, 1998). Turbidity was determined using a Hach Model 2100N Turbidity Meter.

Results and Discussion

The entire 7.2 km of road could not be obliterated in a single season due to a fire in an adjacent watershed and subsequent work restrictions in the Horse Creek drainage. The culvert in WS10 was removed September 10, 2003. Road obliteration work ceased for the season prior to reaching watersheds 14 or 16 then resumed in July 2004. The culvert in WS14 was removed August 24 and 25, 2004 in the midst of an unseasonal rainstorm. A total of 104 mm of rain fell between August 18 and 26. The culvert in WS16 was removed September 29, 2004. No precipitation occurred during culvert removals in WS10 or WS16.

A common maxim among road obliteration specialists is that each crossing is unique. The culverts in this study were no exception. In the years prior to obliteration, watershed 10 had accumulated sediment at the mouth of the culvert and caused the stream to flow laterally for about half a meter before entering the culvert. When the last section of culvert was removed, the stream began eroding this accumulated mass of sediment. The culvert in WS14 was removed during the typically dry season but had 104 mm of rainfall prior, during, and immediately afterwards. Watershed 16 had a sediment trap at the outlet of the culvert that had been in place for more than 15 years. Additionally, watershed 16 had a large permanently wet area below the culvert outlet decreasing surface flow at the downstream C station. Such differences between watersheds make a rigorous research comparison difficult.

Figure 2 shows sediment concentrations from three hours prior to culvert removal to 54 hours afterwards. Time of first culvert section removal was considered to be when

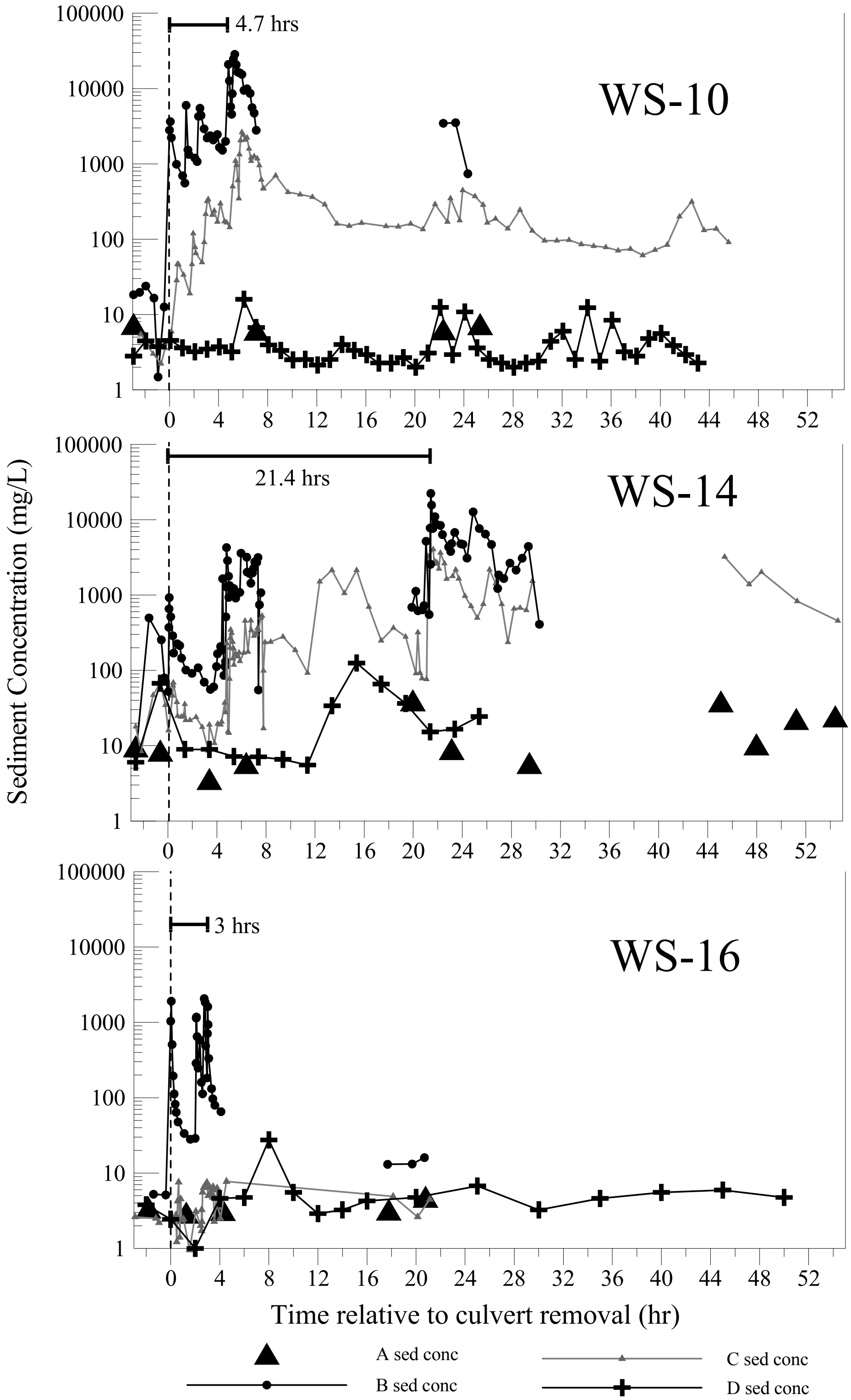

Figure 2 : Sediment concentrations for each watershed. Station A is above the road; B is at the culvert outlet, C is 100 m downstream, and D is at the watershed mouth. Horizontal bars show culvert removal duration.

the contractor pulled the first culvert section from the stream. The gap in each graph from about eight hours to about 20 hours corresponds to night hours when there was no road obliteration activity. The horizontal bars indicate the duration of culvert removal activities.

Responses Typical of All Horse Creek Culvert Removals. Although each culvert removal was unique, several common responses are evident. Short duration sediment concentration peaks corresponded to each culvert section removal. The first removal is evident in sediment concentration peaks among each of the three culvert removals. Additional peaks occurred between one and two hours later. These culvert section removal peaks are especially evident in WS16. Ironically, the highest concentration peak of 28,400 mg/L occurred when riprap was placed in the stream to help reestablish stream structure and reduce erosive flow.

The duration of the sediment concentration peaks caused by the stream disturbing activities were short. The concentration typically decreased by an order of magnitude in two hours. Generally, subsequent peak sediment concentrations due to additional culvert section removals were higher as more bedding material was exposed to the stream.

Decreases in sediment concentration between stations B and C occurred in each of the three watersheds (Figure 2). Sediment concentration reductions in each watershed were typically one order of magnitude, an indication of large amounts of bedload deposition between stations B and C. When higher streamflows occur during spring runoff this sediment will be available to the stream. Although both bedload and suspended load were combined in the grab samples, separate lab analyses were not done. Future studies should distinguish between the two.

Sediment concentrations elevated during obliteration activity did not return to background levels overnight. In WS10 the sediment concentration at station B measured the following morning was essentially the same as the end of the previous day. In WS16, samples taken the day after culvert removal had decreased from 60 to 20 mg/L overnight, a more rapid decline than in WS10.

Generally, the response at the watershed mouth (station D) was an increase in sediment concentrations of less than one order of magnitude for a duration of two hours. In WS10 the sediment concentration of 3 mg/L increased to a single peak of 16 mg/L and returned in three hours. In WS14 there was no apparent sediment concentration increase 12 hours after the first culvert removal. At that time the stream flow increased due to a storm. In WS16 the sediment concentration of 4 mg/L increased to 28 mg/L and returned in one hour. In the absence of increased storm runoff, an observer at the mouth of each of the streams would have seen little evidence of the road obliteration activity.

Sediment Yields. Table 1 presents the sediment yields for each of the watersheds in this study. The time period of 21 to 30 hours was chosen to reflect the amount of time that obliteration activities were having a direct impact on sediment generation. This time frame does not include the extended and unknown length of time the stream transported the freshly exposed material. Station A represents the background sediment yield while station B is the best estimate of the quantity of sediment generated by the obliteration activity. Sediment yields ranged from 2 to 170 kg. Neither volume of fill nor stream gradient appeared to be correlated to sediment yield.

Table 1 – Sediment Loads from Road Building and Road Obliteration Activities

Watershed	Time (hr)	Average Stream Flow (L/s)	Sediment Load (kg)		
			A	B	C
Removal					
HC10	25	0.58	0.31	170	19
HC14	30	0.13	0.23	33	10
HC16	21	0.12	0.10	2.23	0.05
W1*	44	0.35	0.75	95.4	ND
W2*	29	0.35	0.13	34.9	ND
W3*	31	0.35	0.12	0.84	ND
W4*	46	0.35	0.24	2.07	ND
W5*	20	0.40	0.11	3.56	ND
Construction					
HC14 (I)#	26	0.57	0.13	12.8	84.3
HC16 (I)#	12.2	1.13	0.86	9.4	ND
HC14 (P)#	23	1.13	0.31	ND	96.9

Time duration is from removal of first culvert section.
* Brown (2002) Wendover Creek, Clearwater National Forest
# USDA (1981) Horse Creek. Pioneering (P) and culvert installation (I)

Road Obliteration During Precipitation Events in WS14. Although unplanned, the culvert removal in watershed 14 was performed during a period of 104 mm of rainfall. The 7-day cumulative rainfall up to the day of the first culvert removal, was 60 mm. There was 32 mm of rainfall during the two days of culvert removal and 12 mm of rainfall the following day. These precipitation events provided a unique opportunity to observe the impact of the storm on road obliteration activities.

The only precipitation to have a noticeable impact on streamflow during the obliteration activities in WS14 was an event that began 11 hours after the first culvert section was removed (see Figure 3). The event lasted 5 ½ hours, had a depth of 30 mm, and a 30-minute intensity of 7.6 mm/hr. Streamflows at the A and C stations were 0.14 L/s prior to the event and peaked at 0.51 L/s at station A and at 2.2 L/s at station C. The return to base flow occurred in six hours, 30 minutes after the end of the storm.

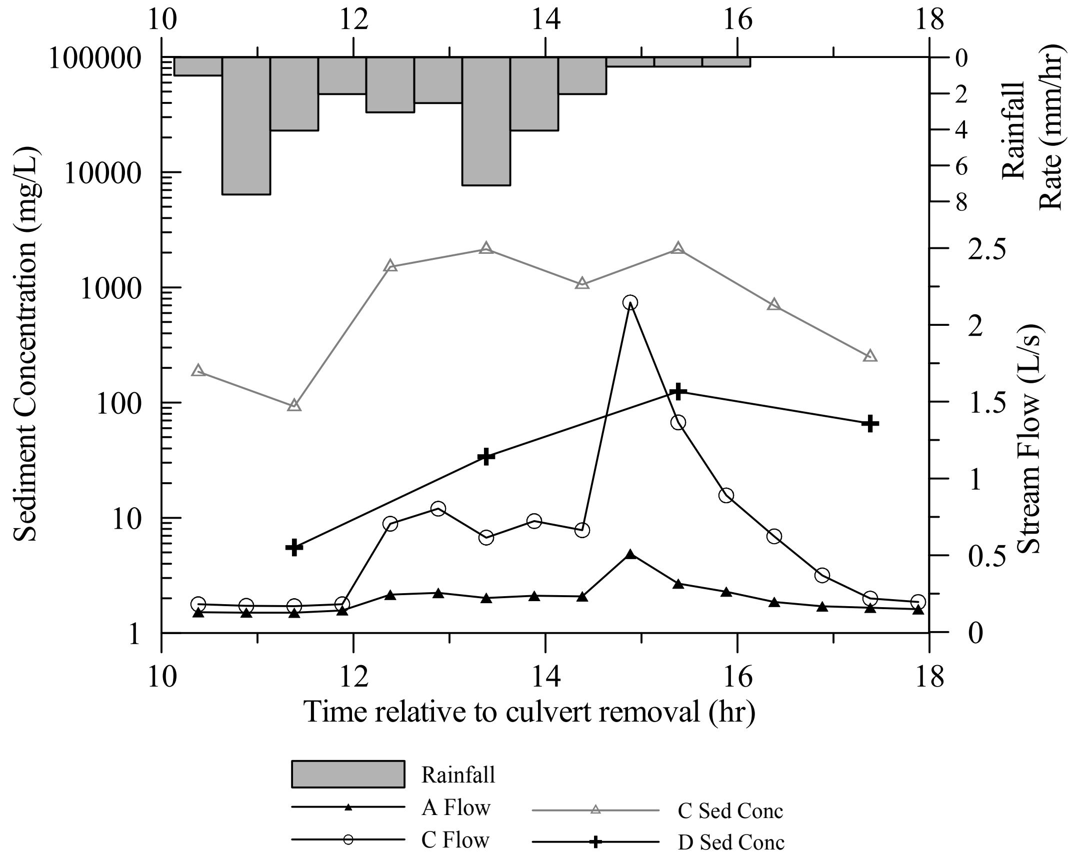

Figure 3 – Watershed 14 response to precipitation of 30 mm.

Sediment concentrations at station C increased by an order of magnitude from 100 to 2000 mg/L in response to the storm. Within an hour of the end of the precipitation event, sediment concentrations were again near 100 mg/L. This was a direct and immediate response from the precipitation on the newly exposed bare soil.

At the mouth of WS14 (Station D), the sediment concentrations increased from the background of 4 mg/L to a peak of 100 mg/L. They remained elevated at 20 mg/L for at least five hours after the precipitation event ended. These concentrations were the largest measured at any of the watershed mouths in this study. The combination of newly exposed bare former roadbed and sediment deposited in the stream caused the highest observed concentration at the stream outlets in WS14. Halting the road obliteration activities during the storm might have reduced this flush of sediment from the storm.

Turbidity. Idaho state water quality rules state that turbidity must not exceed the background level by more than 50 NTU instantaneously (Idaho Department of Environmental Quality, 2003). Immediately below the culvert outlet (Station B in Figure 4) this limit was exceeded in WS10 and WS14 starting when the first culvert section was removed and remained above the limit for the entire manual sampling period (up to 48 hours later). Turbidity levels were notably less, but still greater than

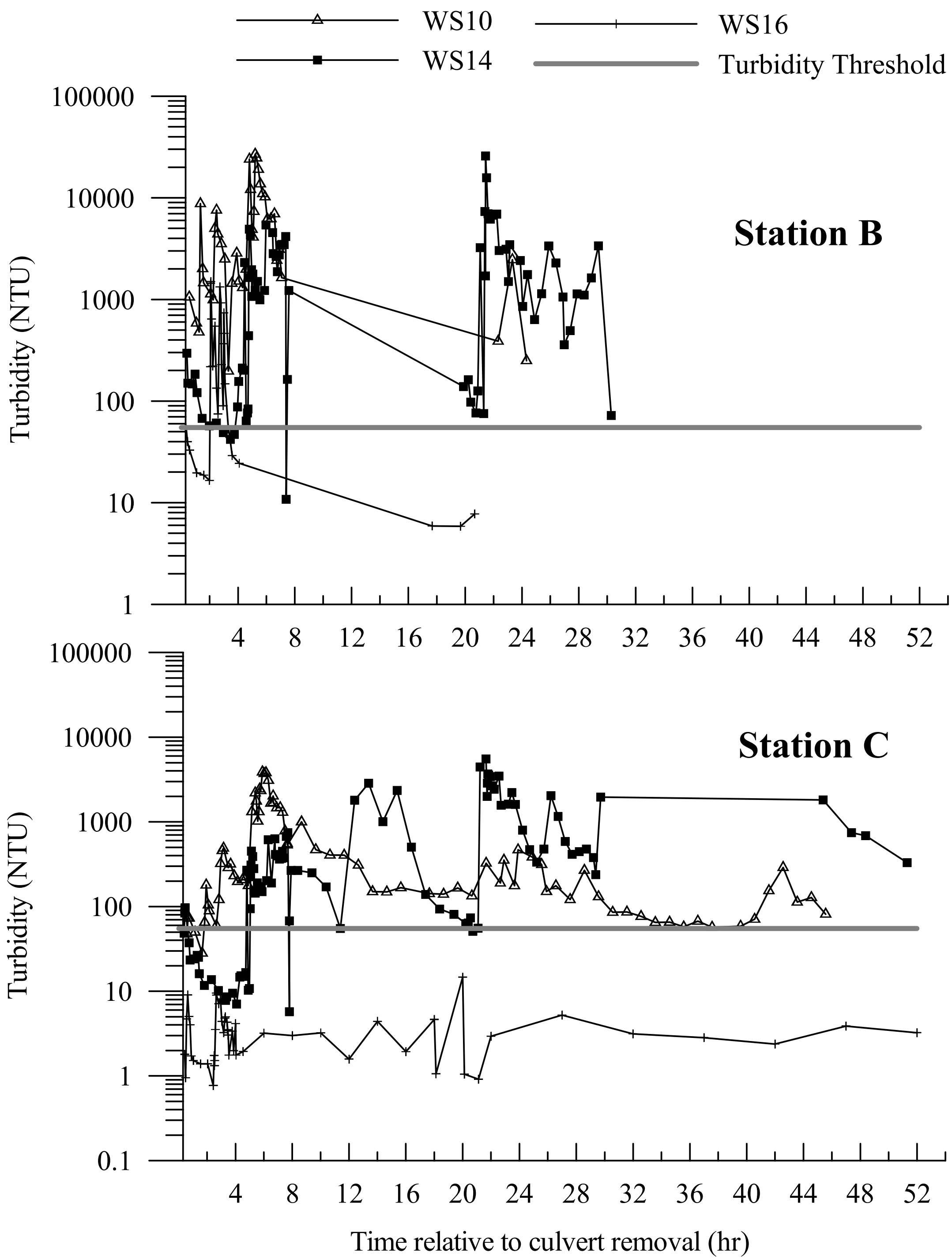

Figure 4 – Turbidity Values 20 m below the culvert outlet (Station B) and 100 m below the culvert outlet (Station C). Turbidity threshold is 50 NTU above background.

the limit, 100 m downstream (Station C in Figure 4). In WS16 turbidity levels exceeded the limit for only 30 minutes immediately below the culvert outlet. At a distance of 100 m downstream of the culvert outlet, the limit was never exceeded in

WS16. At the mouth of the streams, the turbidity limit was not exceeded in any of the watersheds.

Comparison of Sediment Yield from Road Building to Road Obliteration. Table 1 contains data from USDA (1981) that reported the amount of sediment generated from road pioneering and building activities at the same culvert crossings discussed in this report. Less sediment was generated from the obliteration activities than either the pioneering or installation work at both WS14 and WS16.

Comparison of Horse Creek to Wendover Creek. Each of the study sites in Wendover Creek reported by Brown (2002) had varying degrees of mitigation. Site W1 had no mitigation. Site W2 had one straw bale while W3 added an erosion mat to the straw bale. Sites W4 and W5 each had two straw bales without erosion mats. All sites had stream diversion.

The W1 site (Table 1) most closely resembled conditions at Horse Creek, i.e., no straw bales in the stream as a sediment trap. The range of Horse Creek sediment yields at the culvert outlet were 2 to 170 kg. The range of sediment yields at Wendover Creek was 0.84 to 95 kg. The 0.84 kg value from W3 suggests that an erosion blanket may be an effective means of reducing sediment loss during road obliteration. Such an erosion blanket at WS14 could have reduced the sediment peaks during the precipitation event.

Further Research. The study of sediment generated during removal of the culverts is a portion of an on-going study of road obliteration impacts at Horse Creek. Flow measurements will be taken for three to five years after culvert removals. At Horse Creek one of the primary impacts of roads was increased stream flows. These data will permit determining whether road removal will allow streams to return to their pre-development flows. Sediment deposition measurements behind dams will continue to be taken at the confluence of the Main and East Forks to observe changes due to road removal.

Sediment concentrations and flows from this study will be used to develop model parameters for sediment prediction models such as GeoWEPP. The Water Erosion Prediction Project model is a continuous simulation, process-based model that allows simulation of small watersheds. The Geo-spatial interface for WEPP (GeoWEPP) utilizes digital geo-referenced information such as digital elevation models and topographical maps to derive and prepare valid model input parameters.

Conclusions

The sediment yields resulting from culvert removals in the Horse Creek drainage ranged from 2 to 170 kg. There did not appear to be a correlation between either fill volume or stream gradient. Idaho Department of Environmental Quality water quality rule of 50 NTU above background turbidity was exceeded immediately below the culvert outlet during the removal operations, but was not exceeded 800 m downstream. Because a large fraction of the sediment was bedload and dropped out in less than 100 m, the streams will have fresh soil available for transport until vegetation can re-establish ground cover. Each mechanical activity in the stream, such as culvert section removal and riprap placement, was reflected as an increase in sediment concentration. These high sediment concentration peaks typically decreased by an order of magnitude within two hours. Minimization of stream disturbing activities will minimize sediment yields. In two of the three culvert removals there was less sediment generated by the culvert removals than was generated by the initial road construction. A rainfall event on the newly exposed soil in the former road prism caused a flush of sediment to reach the watershed outlet. The mechanisms were both sediment from the exposed soil and an increase in stream flow.

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