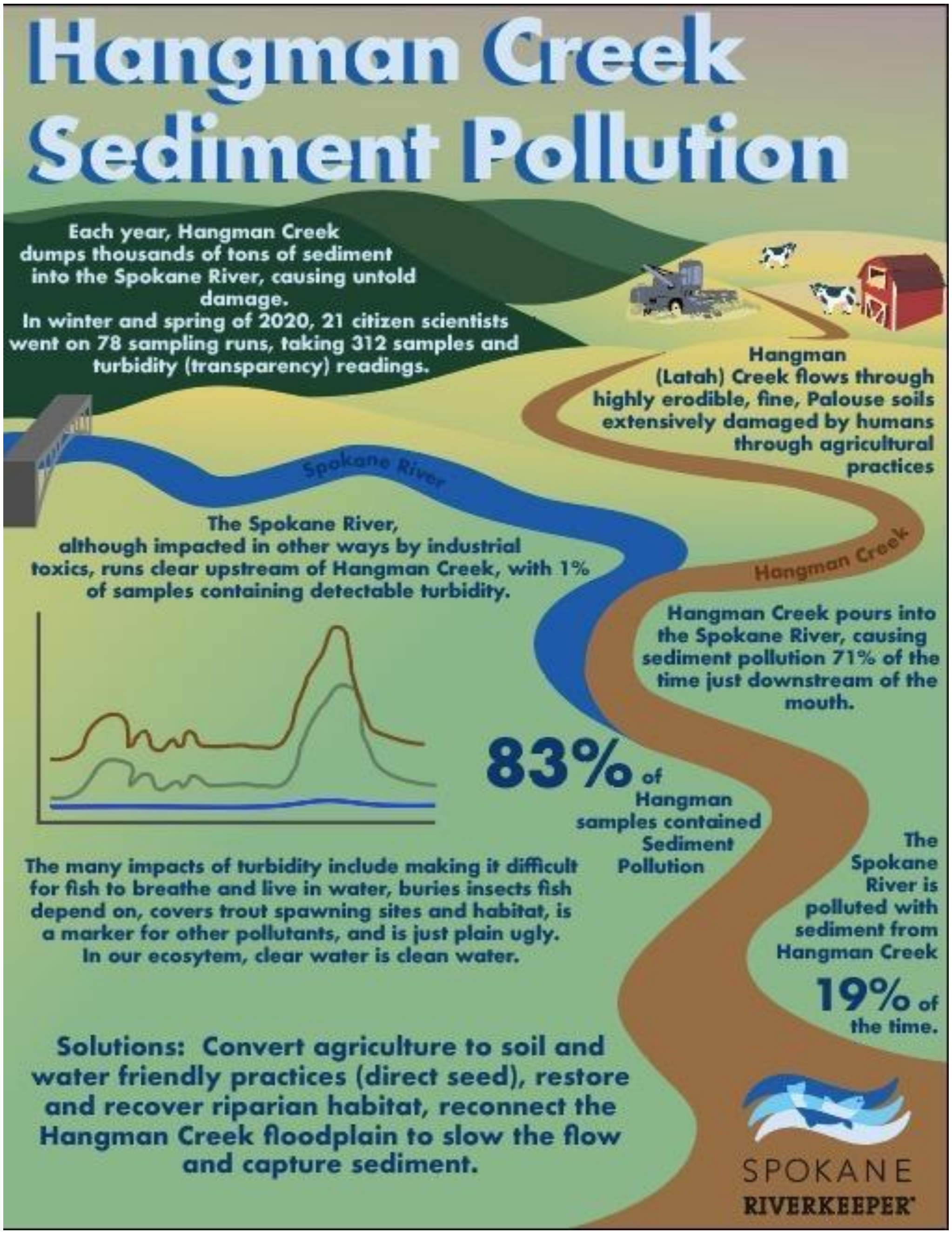
The Effect of Turbidity from Hangman Creek on the Spokane River

Jule Schultz
Spokane Riverkeeper



Infographic courtesy Dominic Arce

Note: This study was made possible by the incredible support of community scientists in Spokane Washington. Approximately 19 volunteers, plus 7 secondary students from the Salish School of Spokane, went on 78 sampling runs, collecting 325 samples, and over 60 photos. Data was stored on study partner Spokane Falls Trout Unlimited's (SFTU) website, and many of the volunteers were members of SFTU. Lastly, much of the study would not have been possible without help from interns Dominc Arce and Stacy Lee King.

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Abstract:
Volunteer citizen scientists took 316 turbidity samples from the Spokane River and Hangman Creek during the winter and spring of 2020-2021. Results showed that Hangman Creek causes the Spokane River to exceed Washington State Water Quality Standards (WQS) for turbidity 14% of the time. These turbidity results, caused by an estimated 33,000 tons of excess sediment in the Spokane River water over the course of the study, are assumed to negatively affect native redband trout behavior in the Spokane River as well as degrade their habitat. Results should be evaluated by the Washington State Department of Ecology for inclusion on the 303d list of waters impaired for turbidity and sediment pollution.

Introduction:
Sediment pollution in Hangman Creek, also known as Latah Creek, is a well-known and studied occurrence (Joy, 2009). Monitoring throughout the basin shows high levels of sediment and turbidity in the water (See River and Stream Flow Monitoring, WRIA 56), with almost 200,000 tons of sediment pollution exiting the system in a high water year (SCCD, 2002). The Washington State Department of Ecology (Ecology) lists the creek "impaired" for sediment (Joy, 2009), citing sediment loads that violate the designated uses of "salmon spawning, rearing, and migration" and increased by land use practices in WRIA 56 (Hangman Creek). Due to this, Hangman Creek has a "cleanup plan" called under the Clean Water Act, a TMDL (Total Maximum Daily Load) for turbidity (Joy, 2009). However, the Spokane River does not contain a TMDL for turbidity, despite frequent pollution loads entering the River from Hangman Creek and muddying it's waters for miles downstream. However, it has been established that the effects of sediment pollution on the Spokane River are wide ranging and profound, In their 1994 study the Spokane Conservation District stated, *"Hangman Creek is one of the largest contributors of bedload and suspended sediments into the Spokane River. Bedload and suspended sediments originating from Hangman Creek are transported to and deposited behind Nine Mile Dam and eventually settle out in Lake Spokane. Soletero et al. (1992) estimated Hangman Creek contributes 77 percent of the total annual sediment load to Lake Spokane. The annual suspended sediment load from Hangman Creek was estimated to be 52,000 tons in 1998 and 211,000 tons in 1999 (SCCD 2000). The increased sediment load has also more locally resulted in embedded substrate and unsuitable spawning habitat for salmonids. The principal source of suspended solids comes from nonpoint sources (roads, annual cropland, eroding streambanks (SCCD 1994)*."

Sediment pollution occurs in pulses or "events" that are correlated with higher precipitation and flows in Hangman Creek. These turbidity events negatively impact both fish health and behavior as well as their food base and habitats. Turbidity pollution impacts populations of aquatic insects called macroinvertebrates, with the effect of this pollution compounding with both time and intensity of the sediment pollution events in the Spokane River (Berry et al., 2003). Impacts of sediment pollution in Hangman Creek in Idaho show lethal and sub-lethal effects to trout (Peters, Kinkead, and Stanger, 2003). Not surprisingly, most of the Hangman Creek watershed does not contain native redband trout, although records suggest they once thrived there (Joy, 2009). The Spokane River still contains a "fishable" population of native, wild redband trout, although populations of these fish are lower than that of similar rivers in Idaho

Figure 1. Redband Trout in the Spokane River are sensitive to sediment pollution such as that from Hangman Creek.

and Montana (Lee, 2017). The primary populations occur I the main stem of the Spokane River and isolated headwaters of Hangman Creek tributaries. (Ashbrook, et al, WDFW 2012).

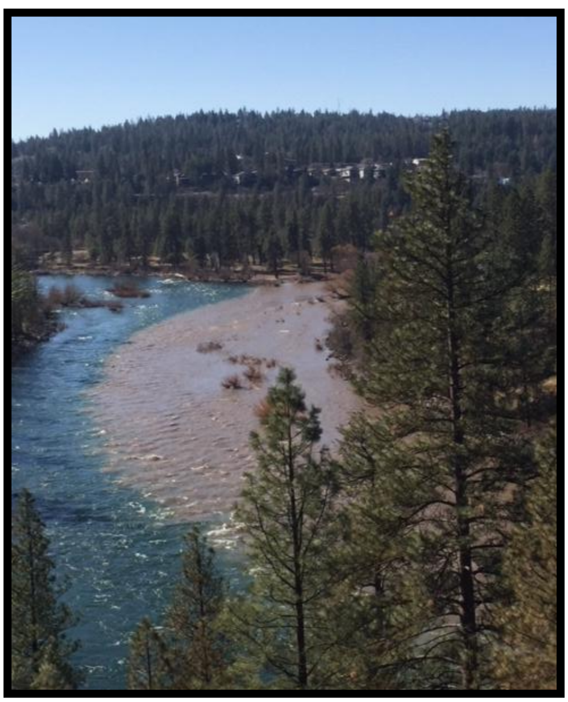
Few studies have been conducted on the effects of Hangman Creek sediment on the ecology of the Spokane River. The sediment is largely a result of agricultural practices and land use in the Hangman Creek Watershed. In a study looking at sediment bed-load from bank erosion contributions versus agricultural tillage and field, sediment runoff, it was established that,

> *".... the majority of the sediment suspended at both the Rock Creek and Bradshaw Road sites was runoff from agricultural fields and not 18 large-scale bank erosion. If the same daily-suspended sediment amount (23,800 tons) was assumed to erode uniformly off only 20 percent of the watershed, this would be approximately 0.002 inches of erosion. This would suggest that agricultural fields can supply large amounts of sediment without significant visual impacts. Although a majority of the sediment probably erodes off fields at varying rates, the suspended sediment in Hangman Creek is probably the result of a combination of bank erosion, field erosion, and the resuspension of previously eroded sediments".* (Spokane Conservation District, 2000)

Ecology currently conducts ambient monthly sampling at the mouth of Hangman Creek and downstream of the Hangman mouth at the Spokane River, on the main stem of the Spokane River at Riverside State Park and at the Nine Mile Bridge. This data, from monthly sampling events, suggest that turbidity from Hangman Creek influences the Spokane River. However, Hangman Creek flows can be "flashy" or fluctuate wildly, sometimes rising and falling thousands of cubic feet per second in a day, bringing with it the associated sediment. Monthly ambient sampling is not frequent enough to capture these flashy events. A sampling strategy that includes more frequent sampling will more accurately record the intensity and duration of Hangman Creek's sediment plume in the Spokane River. Hangman Creek flows into the Spokane River at the confluence of Hangman Creek and the Spokane River is at People's Park, downstream from downtown Spokane. At the confluence during periods of high, turbid flow, the contrast between the muddy waters of Hangman Creek and clear water of the Spokane River is visually stark (see Figure 3). The unmixed turbid waters of Hangman Creek flow over prime spawning habitat for redband trout in the Spokane River (Addley and Peterson, 2011).

Figure 2: Erosion of top soil to surface water from upper Hangman Creek Basin.

The duration and intensity of sediment and the resulting turbidity pollution in the Spokane River may cause adverse impacts to native redband trout, their populations and their habitat, but little is actually known about these pollution events. High concentrations of sediment coupled with high flows of Hangman Creek can cause high turbidity levels in the Spokane River. These events typically occur during the late winter and spring snowmelt season, which coincides with redband trout spawning and rearing. Hangman Creek may also display high sediment concentrations during low flow seasons in late spring due to thunderstorms or heavy precipitation. These events may not pollute the entirety of the Spokane River with sediment due to the high flow of the Spokane River and low flow of Hangman Creek, but they will produce measurable turbidity immediately downstream of the confluence in the Spokane River.



This study measures turbidity of Hangman Creek and the resulting turbidity in the Spokane River using both easy to measure transparency data as well as collecting the more technical and legally defensible, turbidity data. This data will be evaluated against state standards (see methods) for recommendations of incorporation into a TMDL on the Spokane River, the potential effect on fish, and a calculation of sediment loading to the river.

Figure 3. The confluence of Hangman Creek (right) with the Spokane River (left) showing the impacts of sediment to the river.

Methods:

This study of water turbidity in Hangman Creek and Spokane River was conducted from December 2019 through June 2020 by volunteers collecting samples twice per week (or more) at 3 locations. Samples were taken in Hangman Creek at the 11th Street Bridge, in the Spokane River at Sandifur Bridge, and below the TJ Meenach Bridge.

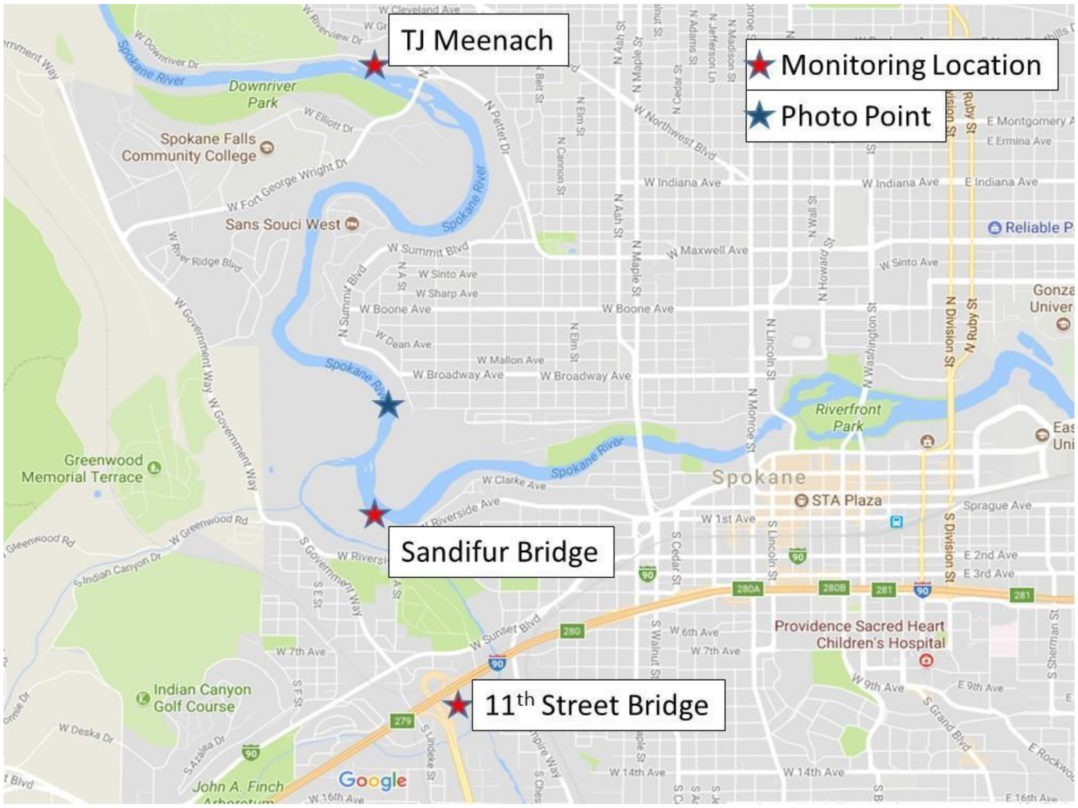


Figure 4. Sampling locations for the study.

All volunteer samplers were trained in all aspects of the study, including sampling, sample location and safety. Quality control of data was addressed through duplicate measurements, field staff training and observing samplers, and weekly review of data. Sample measurements were duplicated in the field to analyze variability in readings. Approximately 10% or 10 samples were duplicated. Any data identified as incorrectly collected is discarded and not used in the analysis.

Most samples were pulled directly from the river at the shoreline. The sediment in Hangman Creek tends not to settle out of the water column due to the fine nature of the particles, so pulling samples from the shoreline is representative of the entire river. In locations where the river/creek was not accessible from the shoreline, a jar/bucket was lowered into the water with a rope off of a bridge. Water was hauled up in the jar/bucket and analyzed for turbidity. The sample site downstream from Hangman Creek in the Spokane River below TJ Meenach Bridge is located sufficiently downstream to ensure complete mixing. The sampling strategy required volunteers to sign up in advance, assuring that no storm events were targeted.

In the field, samplers determined and recorded water turbidity using a transparency tube. The transparency tube functions as a modified secchi disk, with a black and white disk located at the bottom of a clear tube. The sampler fills the 60 cm tube (marked in 0.2 cm increments) with water, looks into the opening of the tube from above, lets out water by releasing the stopcock until the disk is visible, and records the height of water remaining in the tube in centimeters to the nearest 0.2. Measurements were taken in the shade to reduce glare off the sample. Dahlgren et al. concluded that transparency significantly correlates with turbidity. No specific calibration of the transparency tube is possible. In general, bias will be held to a 3-5% acceptable error. From an upland vantage point at the corner of Summit and College Streets (photo point on Figure 4), samplers photographed the mouth of Hangman Creek to record visual evidence of sediment pollution. Location, time, date, weather conditions, and USGS streamflow information was recorded for each sample on a paper field data sheet with permanent ink as well as in an online field form (https://spokanefallstu.org/spokane-river-sediment-study/).

Samples for lab analysis of turbidity were taken alongside the transparency tube readings. Samplers labeled Whirl-Pak bags with location, date and time. They filled the Whirl-Pak bags with sample water from each location and dropped them off in a cooler kept below 4°C. Each weekday, Spokane Riverkeeper staff picked up the samples for processing. Samples taken on the weekend were processed Monday morning, within 48 hours of sampling. Whirl-Pak samples were analyzed with the Hach 2100P mobile turbidimeter and recorded in NTU to the nearest 0.01. The turbidimeter was calibrated once following Hach manual instructions at the beginning of the sampling period using premixed calibration solutions. The turbidimeter unit has a stated accuracy of +/- 2%.

Readings from Sandifur Bridge samples are compared to readings from the TJ Meenach samples to determine the effect of Hangman Creek on the Spokane River.

https://www.hach.com/2100p-portable-turbidimeter/product-downloads?id=7640450099

To acquire an estimate of tons of suspended sediment we began with finding the correlation of suspended sediment (TSS) to turbidity (NTU), and based on past 20 years of data available from the Washington State Department of Ecology Hangman Mouth monitoring station found the ratio to be 1.54mg/L TSS to 1 NTU. By applying this ratio to each replicant sample NTU of the water year 2020 Spokane Riverkeeper Turbidity Study at discharge (cfs), we found the estimated mg/L TSS per cubic feet per second (cfs) at the point of sampling. Through dimensional analysis from the point of sampling we converted to tons TSS per day of suspended sediment. We applied this daily estimate of tons per day divided by 89 replicants to surmise a daily average and multiplied by 180 days to estimate the total tons of suspended sediment entering the Spokane River from the mouth of Hangman Creek for the duration of the study.

<u>Results:</u>

Turbidity in Hangman Creek and the Spokane River show turbidity peaks in late January. Hangman Creek contained turbidity of up to 300 NTU, as did the mouth of Hangman Creek at the Spokane River (Greenwood Cemetery site). These peaks affect the Spokane River at TJ Meenach, with turbidity of approximately 100 NTU (Table 1). Other bumps in turbidity in Hangman Creek do not affect the Spokane River nearly as much, most likely due to high flows in the Spokane River. Data was not recorded for the May and June turbidity samples due to exceeding the holding time requirements.

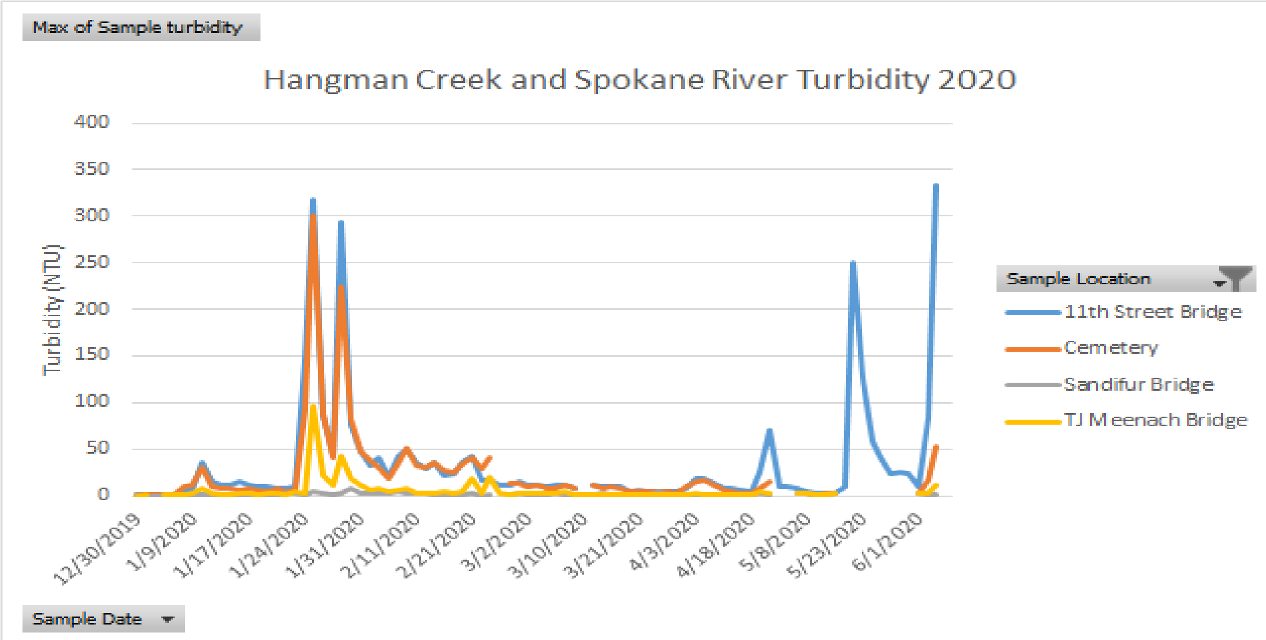


Figure 5. Turbidity measurements from the study. High turbidity measurements in Hangman Creek in late January led to high turbidity in the Spokane River.

Our study shows the Spokane River at TJ Meenach Bridge, the mouth of Hangman Creek at the cemetery, and in Hangman Creek 11th street bridge exceed the Washington State turbidity standard of 5 NTU above background clarity about 89%, 77%, and 19%, (Table 1, TJ). Hangman Creek causes the Spokane River to exceed state turbidity standard 14% of the samples. When the data from Sandifur Bridge (upstream of the mouth of Hangman Creek in the Spokane River) is subtracted from TJ Meenach (downstream of the mouth), this number represents the addition of turbidity from Hangman Creek. Figure 3 shows the raw data from these two sites.

Table 1: Turbidity (NTU) in Hangman Creek and the Spokane River					
Location	**Sandifur Bridge**	**11th Street Bridge**	**Cemetery**	**TJ Meenach Bridge**	**TJ - Sandifur**
max	8	334	301	97	
min	0	1	1	0	
average	1	35	25	5	
median	1	12	10	2	
% Exceeding State Standard	1.3	89.4	77.6	19.5	14.0

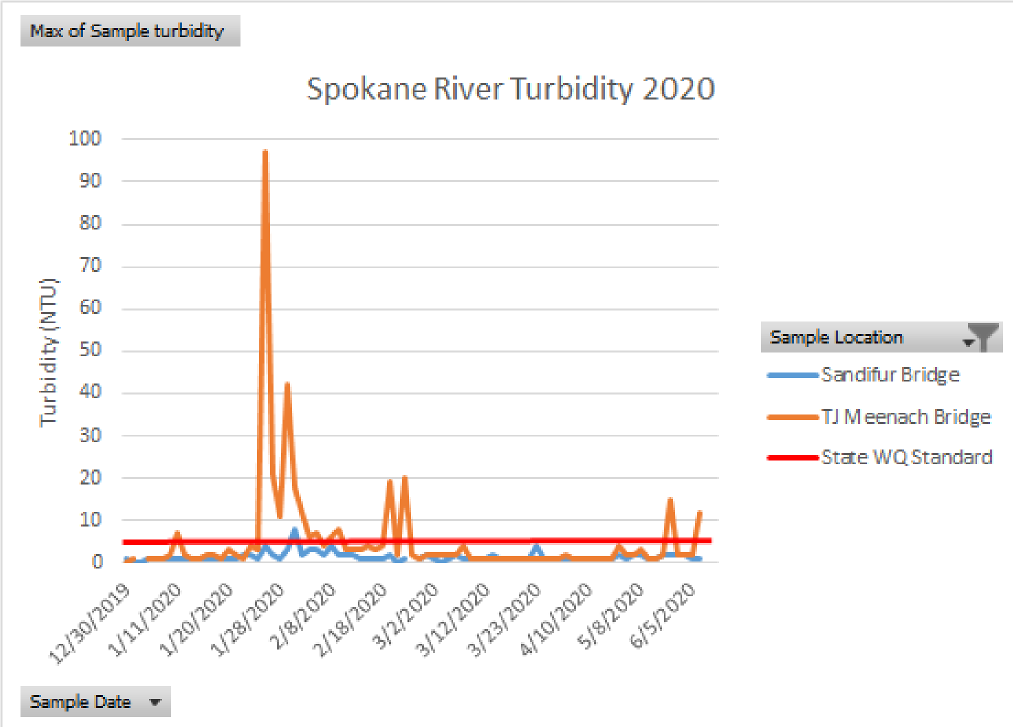


Figure 6. Turbidity in the Spokane River. Sandifur Bridge is upstream and TJ Meenach is downstream of Hangman Creek. The higher turbidity values in at TJ Meenach Bridge clearly show the impact of Hangman Creek on the Spokane River.

Using turbidity data from this study we attempted to extrapolate the total suspended sediment. In the Hangman Creek drainage, turbid water is the result of suspended sediment in the water. We used the equation, based on a correlation of the last 20 years of Total Suspended Solids (TSS) to Turbidity, taken by Ecology at the mouth of the Hangman Creek, to estimate the TSS loading based on the turbidity readings of our study.

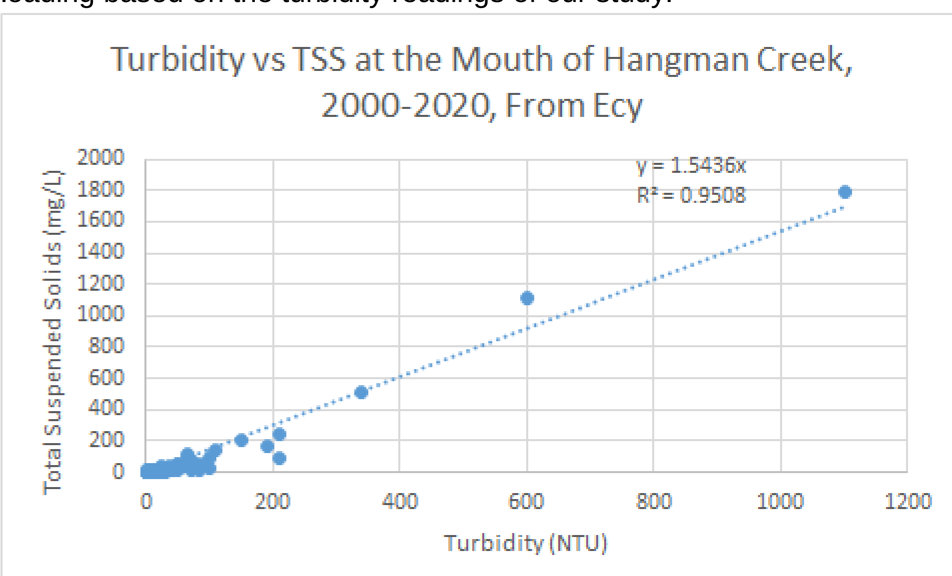


Figure 7. Data from Ecology ambient sampling on the mouth of Hangman Creek for TSS and turbidity. This correlation was used to

estimate sediment loading from our data.

Based on this correlation, we found that in 2020, approximately 33,000 tons of sediment entered the Spokane River (Table 2) during our study period. This is based on a lower than average annual flow of 153 cfs. (https://waterdata.usgs.gov/nwis/wys_rpt/?site_no=12424000&agency_cd=USGS).

Table 2: Estimated Total Sediment Load, 2020	
Average tons per day	185.8
Annual tons	33,400
ANNUAL ACRE FEET (1 acre-foot of soil = 2,000 tons (USDA))	16.7

Discussion: The Spokane River contains naturally reproducing populations of wild, Columbia Basin Interior redband trout, with approximately 300 fish/mile (Lee, 2007). The river has a designated use of spawning, rearing, and migration. Our data shows that turbidity in the Spokane River downstream of Hangman Creek exceeds aquatic life turbidity criteria (Table 3). It does this in approximately 14% of the samples taken in December-June. On the basis of Hangman Creek sediment pollution impacts to the Spokane River, we believe that Hangman Creek should be listed as "impaired" and included as a Category 5 listing under the CWA (https://ecology.wa.gov/Water-Shorelines/Water-quality/Water-improvement/Assessment-of-state-waters-303d). If it is designated as a Category 5 it will be listed as impaired on the 303d list and a clean-up plan (TMDL) developed and implemented. We believe that a TMDL would help focus resources on cleaning up the Hangman Creek watershed and recognize the pollution impacts that Hangman Creek pollution is having on the designated uses of native trout, and the water quality of the Spokane River.

Table 3: Table 200 (1)(e) from WAC 173-201A-200	
Aquatic Life Turbidity Criteria in Fresh Water	
Category	**NTUs**
Non-anadromous Interior Redband Trout	**Turbidity shall not exceed:** **• 5 NTU over background when the background is 50 NTU or less; or**
	• A 10 percent increase in turbidity when the background turbidity is more than 50 NTU.

Turbidity can be used to roughly calculate the total suspended solids in the river. Based on our turbidity readings, we estimate that 33,000 tons of sediment entered the Spokane River from Hangman Creek during the 6-month study period. This sediment loading is roughly inline with previous estimations of sediment from Hangman Creek. The "Hangman Creek Sediment Discharge Report for Water Years 1998 and 1999" (SCCD, 2000) states that in 1998 with an average yearly flow of 166 cfs, 35,000 tons of sediment were discharged from Hangman Creek. In 2020 Hangman Creek had an average flow of 153 cfs and our estimations show 33,000 tons of sediment entered the river in 6 months from Hangman Creek. Other ways of estimating suspended sediment show similar results. Calculating the suspended sediment in Hangman Creek in 2020 using the sediment rating curve and an average flow of 153 of the TMDL (Joy, 2009) shows a sediment discharge of 21,064 tons (Page 138, figure 38).

More importantly, suspended sediment can calculate the impact to native trout. Using the equation and table from Newcomb and Jenson (1996):

$$\text{Severity score} = 1.0642 + 0.6068(\log_e \text{Hours of exposure}) + 0.7384(\log_e \text{TSS mg/L})$$

Table 4: Severity Scale Description of Effect (Newcomb and Jenson (1996)):	
No Effect	
0	No behavioral effects
Behavioral Effects	
1	Alarm reaction
2	Abandonment of cover
3	Avoidance response
Sub-lethal Effects	
4	Short-term reduction in feeding rates or feeding success
5	Minor physiological stress; increased coughing, increased respiration rate
6	Moderate physiological stress
7	Moderate habitat degradation; impaired homing
8	Indications of major physiological stress; long-term
Lethal and Paralethal Effects	
9	Reduced growth rate; delayed hatching; reduced fish density
10	0 – 20% mortality; increased predation; moderate to severe habitat degradation
11	>20 – 40% mortality
12	>40 – 60% mortality
13	>60 – 80% mortality
14	>80 – 100% mortality

Using the extrapolated TSS data from our turbidity data, we find that the Spokane River at TJ Meenach Bridge contains sediment levels that impact trout in the “sub-lethal effects” range. The highest effects seen were approximately a score of five over a 24 hour period, showing “minor physiologic stress” on trout. This suggests that trout populations in the Spokane River downstream of Hangman Creek are affected by the sediment load polluting the Spokane River. This effect, during this below average flow year, is concerning. High flow years on Hangman Creek may deposit six times as much sediment in the river (SCCD, 2000), increasing the harm to native trout.

Figure 8. The mouth of Hangman Creek entering into the Spokane River in late January, 2020.

There is wide agreement on the sources of the sediment which pollute Hangman Creek. The Hangman Creek TMDL states "*Conventional agricultural practices and streambank erosion are the largest sediment sources in most areas of the watershed"* and suggests *"Conversions of conventional agricultural practices to conservation practices is needed to meet the load allocations in this TMDL as this action will have the biggest impact in reducing TSS in the watershed. ".* On average, in the neighboring Palouse watershed, soil erodes on average at a rate 14 tons/acre per year on cultivated farmland (Ebbert and Roe, 1998). Converting to direct seed/no till agricultural tillage practices reduces this erosion by up to 90% (https://www.directseed.org/about-us). The Spokane County Conservation District agrees, stating that "*Although a majority of the sediment probably erodes off fields at varying rates, the suspended sediment in Hangman Creek is probably the result of a combination of bank erosion, field erosion, and the resuspension of previously eroded sediments* (SCCD, 2000)."

Conversion of conventional agriculture to direct seed and no till practices will have a large impact on the watershed, especially sediment pollution in Hangman Creek. Other projects in the Hangman Creek watershed serve to significantly reduce soil erosion and improve water quality. The Coeur d' Alene Tribal Fisheries program has repaired the incised mainstem channel and reconnected a large part of Upper Hangman Creek and tributaries to the floodplain, significantly improving water temperatures in the creek, reducing flow rates through the use of beaver dams, planting riparian vegetation and moving sediment to the floodplain (Biladeu and Kinkaed, 2020).

Figure 9. Restoration of Hangman Creek on the Coeur d'Alene Reservation. The ditched portion of the creek has been filled and the creek allowed to fill its historic channel on the flood plain.

Figure 10. The old, incised channel of Hangman Creek that was filled.

The Washington State Department of Ecology recently made Hangman Creek a “priority Watershed”. They have committed to:

- Completing a full analysis of the creek’s health including streamside vegetation and in-stream conditions.
- Identifying, prioritizing, and fixing pollution problems with the installation of Agricultural Best Management Practices (BMPs).
- Monitoring the creek’s health and tracking progress of improvements/BMP installation.
- Developing an education and outreach program with partners.

This work will ensure improvements in water quality and trout habitat for years to come.

Summary:

Based on turbidity readings and extrapolated suspended sediment loads over the course of this 180 day study, both water quality and trout habitat are at risk in the Spokane River. The designated uses of trout and salmon habitat are compromised to suspended sediment inputs from Hangman Creek to the Spokane River. Further evaluation from Washington State Department of Ecology for turbidity and suspended sediment inclusion in Spokane River’s 303d listing and a Spokane River TMDL cleanup plan are warranted. Trends show a greater than 5-point increase in turbidity (NTU) below the Hangman Creek confluence from the upstream base reading of >50 NTU which exceeds water quality standards. Sediment levels in the Spokane River below the Hangman Creek confluence indicate a sub-lethal effect for trout that are living in the main stem of the Spokane River, as well as a degradation of fish and macro invertebrate habitat. As planned in the Hangman Creek TMDL, implementation of agricultural Best Management Practices, reconnection of the floodplain, and the enhancement and improvement of riparian health could serve to reduce turbidity, suspended solids in the water and the erosion of soil off of the surrounding landscape. Preventing these excesses of sediment pollution in the Hangman Creek watershed would have an immediate and marked improvement on the water quality and habitat for trout in the main stem of the Spokane River.

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