2004 Sediment Monitoring Report
Entiat River
Mad River

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Executive Summary

The Wenatchee National Forest Land and Resource Management Plan (WNF LRMP 1990) states that spawning gravel will consist of no more than 20 percent fine sediment ≤1.00 mm. Fine sediment is a natural component of streambeds; however, elevated levels of fines resulting from accelerated erosion (e.g., from roads, clear cuts, grazing, fire) can adversely affect salmonid spawning and rearing success. This was the twelfth consecutive year of evaluation of fine sediment conditions by the McNeil core sampling method in the Entiat River (RM 0.5-34) and the eleventh consecutive year for the lower Mad River.

This year, all four sampled Entiat River reaches and the Mad River were within the Forest Plan Standard for fine sediment. The results from four Entiat River reaches (48 samples) show sample mean percent fines ≤1.0 mm in salmonid spawning habitat were variable by reach with one reach decreasing and three reaches increasing from 2003. Results from the Mad River (12 samples) indicate sample mean percent fines ≤1.0 mm in salmonid spawning habitat increased compared to last year. The twelve-year trend of fine sediment levels in the Entiat and Mad Rivers has been variable and may be explained by annual precipitation and runoff. Higher flows of longer duration tend to favor fine sediment transport rather than deposition. Water-year 2004 was atypical as depicted in the 2003-04 hydrograph (Figure 2). Annual peak flow actually occurred during a short-duration rain-on-snow event in October 2003, and the spring runoff peak was about 300 cfs below average and occurred about two weeks earlier than average. This atypical hydrograph may partially explain the atypical sediment response in Reach 4 of the lower Entiat River.

It is recommended that sediment sampling be continued indefinitely in the Entiat River and Mad River drainages to (1) support future iterations of Watershed Analysis with time/trend data, (2) continue tracking the effects of a major wildfire in 1994, and (3) provide invaluable fine sediment data for Forest Plan revision, Biological Assessments for ESA-listed steelhead, spring chinook salmon, and bull trout. It is recommended that sediment monitoring projects continue to be performed by a Washington Conservation Corps (WCC) crew trained by experienced FS personnel to ensure sampling consistency.

Introduction

Fine sediment is a natural component of streambeds; however, elevated levels of fines resulting from accelerated erosion (e.g., from roads) can adversely affect salmonid spawning and rearing success. The deleterious effects of excessive sedimentation on egg-to-fry survival of salmonids are well-documented in the scientific literature. Deleterious effects include: suffocation and metabolic-waste-poisoning of eggs (Chapman 1988); decreased egg survival to emergence (Reiser and White 1988); and increased fry mortality due to entrapment and suffocation (Chapman and McCleod 1987). Accelerated sedimentation rates can lead to channel widening and loss of important pool habitat (Peterson et al. 1992).

The Entiat and Mad Rivers are WNF Class I (Washington State Class AA) waters that provide significant spawning and rearing habitat for spring and late-run chinook salmon (*Oncorhynchus tshawytscha*), sockeye salmon (*O. nerka*), summer steelhead (*O. mykiss*), and bull trout (*Salvelinus confluentus*). The WNF LRMP (1990) states the desired future condition for stream sediment as:

> *"Maintain <20% fines (<u><</u>1.0 mm) as the area weighted average in spawning habitat (pool tail-outs and glides)." The Plan also states; "It is known that present conditions in some subdrainages on the Forest do not meet one or more of the measurable standards." "If a subdrainage does not meet a standard due to man's activity, then a strategy and timeframe needs to be developed to achieve the standard. If man's activities have altered a subdrainage so that it is unlikely that a standard can ever be achieved, then a new standard needs to be developed for that area. If a standard cannot be achieved due to natural conditions, a new standard would need to be developed for that subdrainage."*

Sediment monitoring was initiated for the Entiat River in 1993 and Mad River in 1994 using an established methodology for Forest-wide consistency. This monitoring project addresses long-term trends in watershed condition as expressed by changes in water quality and fish habitat capability and is being conducted to determine if present sediment conditions in the Entiat and Mad Rivers meet measurable standards. Sediment monitoring results will determine the extent of future analysis, the adequacy of monitoring methods, and the appropriateness of the current sediment standard. Results will also be used to describe the range of variability of fine sediment in the Entiat and Mad Rivers and guide future watershed restoration activities aimed at reducing sources of accelerated fine sediment in spawning habitat.

Methods

The purpose, procedures, and limitations of the methodology are well-documented in the Northwest Indian Fisheries Commission Salmonid Spawning Gravel Composition Module (Schuett-Hames et al. 1993) and need not be repeated here. Samples were collected from four reaches in the Entiat River and one reach in the Mad River, according to the sampling methodology established by the Upper Yakima Resource Management Plan (RMP), Yakama Nation (YN), and Naches Ranger District. For statistical validity, this methodology specifies a minimum sample size of three reaches per stream, three riffles per reach, and four samples per riffle.

Reaches 1, 2, and 3 were chosen to coincide with the reach delineation of the 1991 WNF Stream Survey of the Entiat River. Sampling sites were selected based on their suitability for, or known occurrence of, spawning by chinook salmon, steelhead or bull trout. Sampling sites in Reaches 1 and 2, which overlap the WDFW/USFWS chinook spawning index reach on the Entiat River, were selected in consultation with WDFW fishery biologists L. LaVoy and B. Steele. Reach 3 contains known bull trout spawning habitat. Reach 4 on the lower river was sampled for comparison at the suggestion of Chelan County PUD fishery biologist S. Hays who expressed an interest in the spawning potential of the lower river. Late-run chinook, steelhead, and coho (2001) spawning is known to occur in the lower Entiat River (Mullan et al. 1992, Steele pers comm 1994, Carie 1996-2001, pers obs 1994-2004). Reach 4 sampling sites were in suitable spawning gravel just above the upper limit of fluctuation of the Rocky Reach Dam pool (Lake Entiat). The lower reach of Mad River, from mouth to Pine Flat Campground (RM 4.0), is known spawning habitat for steelhead and spring chinook.

A McNeil core sampler was used to collect the samples. Samples were collected by a WCC crew consisting of 4 individuals, one crew boss, and one Forest Service supervisor from 8/23 – 9/2/2004.

The core-collection procedure conformed to that described in Schuett-Hames et al. (1993). Bucketed samples were tightly covered and transferred to the Steliko Work Center for processing where they were wet-sieved through the following sequential series of 8-inch diameter, stainless steel, soil sieves: 75.0, 25.0, 19.0, 9.5, 6.3, 4.0, 2.36, 1.7, 1.0, 0.85, and 0.5 mm.

Silts (<0.5 mm) collected in a bucket beneath the sieves were poured into Imhoff cones where they settled out and were measured. In 1997, 0.85 mm was added to the sieve series and 0.25 mm deleted from the sieve series. The reasons for this change were to provide data on percent fines less than 0.85 mm, the value used by Washington State, the US Fish and Wildlife Service (1998), and the National Marine Fisheries Service (NMFS 1996). The data produced by the 0.25 mm sieve had no apparent application and fines less than 0.25 mm are now being collected with and reported as "silts". The sieving procedure conformed to that described in Schuett-Hames et al. (1993).

Data entry and summary statistic calculation were accomplished using an Excel spreadsheet program furnished by WNF Fisheries specialist P. Dawson. Excel-generated summary statistics include: mean percent fines $\leq$1.0mm per sample, riffle, and reach; mean percent fines $\leq$0.85mm per sample, riffle, and reach; standard deviation per riffle and reach; and geometric mean particle size per sample. Confidence intervals (95% CI and 80% CI) were calculated for each reach using the formula in Schuett-Hames et al. (1993) with the appropriate sample size (n=12) and t-values for reach statistics (Zar 1984):

$$t_{0.05(2),11} = 2.201 \quad \text{and} \quad t_{0.20(2),11} = 1.363$$

Results

Sediment sampling results from the Entiat and Mad Rivers are shown in Table 1. Sample mean percent fines $\leq$1.0 mm were 13.96 percent, 13.48 percent, 9.75 percent, and 12.31 percent in Entiat Reaches 1, 2, 3, and 4, respectively. Mad River Reach 1 sample mean percent fines $\leq$1.0 mm were 14.04 percent. Figure 1 shows 1993 through 2004 results for comparison. Sample mean percent fines $\leq$0.85 mm were 11.18 percent, 11.66 percent, 7.98 percent, and 9.76 percent in Entiat Reaches 1, 2, 3, and 4, respectively. Mad River sample mean percent fines $\leq$0.85 mm were 12.38 percent.

Zar (1984) cautions that although the sample mean is the best estimate of the population mean (μ), it is still only an estimate, and the calculation of the confidence interval for the population mean allows us to express the precision of the estimate. Therefore, we report the 95% and 80% confidence intervals for each reach and these results should be interpreted as follows:

1. Based on sample statistics for Reach 1, we are **95** percent confident that the population mean percent fines $\leq$1.0 mm lies within the interval between 12.84 percent and 15.07 percent, or $12.84\% < \mu < 15.07\%$. Also based on sample statistics for Reach 1, we are **80** percent confident that the population mean percent fines $\leq$1.0 mm lies within the interval between 13.27 percent and 14.64 percent, or $13.27\% < \mu < 14.64\%$.

2. Similarly, for Reach 2, we are **95** percent confident that $10.63\% < \mu < 16.33\%$ and **80** percent confident that $11.71\% < \mu < 15.24\%$.

3. For Reach 3, we are **95** percent confident that $7.93\% < \mu < 11.56\%$ and **80** percent confident that $8.62\% < \mu < 10.87\%$.

4. For Reach 4, we are **95** percent confident that 10.09%<μ<14.52% and **80** percent confident that 10.93%<μ<13.68%.

For Mad River Reach 1, we are **95** percent confident that 11.95%<μ<16.12% and **80** percent confident that 12.75%<μ<15.32%.

Table 1. Entiat River and Mad River sediment sampling statistical data, 2004.

Sample Sites	n	Mean % Fines < 1mm	Std. Dev.	95 % C.I. Lower	95% C.I. Upper	80% C.I. Lower	80% C.I. Upper	Mean % Fines < 0.85mm	Location
Entiat Reach 1									
site 1	4	13.80						10.90	RM 18.3 @ Stormy Cr.
site 2	4	12.85						10.12	RM 21.5 @ Dill Creek
site 3	4	15.22						12.51	RM 23.3 @ Brief
Reach 1 Average	**12**	**13.96**	**1.75**	**12.84**	**15.07**	**13.27**	**14.64**	**11.18**	**RM 18 to RM 25**
Entiat Reach 2									
site 1	4	11.47						10.13	RM 26 @ WNF Boundary
site 2	4	15.53						13.17	RM 26.5 @ Snow-Park
site 3	4	13.43						11.68	RM 27.5 @ Fox Cr spn chan
Reach 2 Average	**12**	**13.48**	**4.49**	**10.63**	**16.33**	**11.71**	**15.24**	**11.66**	**RM 25 to RM 29**
Entiat Reach 3									
site 1	4	7.99						6.22	RM 29.7 @ Box Canyon
site 2	4	8.87						7.15	RM 30.8 @ Silver Falls CG
site 3	4	12.38						10.56	RM 33.5 @ Entiat Falls
Reach 3 Average	**12**	**9.75**	**2.85**	**7.93**	**11.56**	**8.62**	**10.87**	**7.98**	**RM 29 to RM 34**
Entiat Reach 4									
site 1	4	16.04						12.78	RM 0.6 near mouth
site 2	4	10.02						7.83	RM 0.7 near mouth
site 3	4	10.86						8.67	RM 1.3 @ Keystone bridge
Reach 4 Average	**12**	**12.31**	**3.49**	**10.09**	**14.52**	**10.93**	**13.68**	**9.76**	**RM 0.6 TO RM 1.3**
Mad River									
site 1	4	14.12						12.15	RM 3.3
site 2	4	11.79						10.80	RM 1.3
site 3	4	16.19						14.18	RM 4.0 @ Pine Flat CG
Reach 1 Average	**12**	**14.04**	**3.28**	**11.95**	**16.12**	**12.75**	**15.32**	**12.38**	**RM 1.0 to RM 4.0**

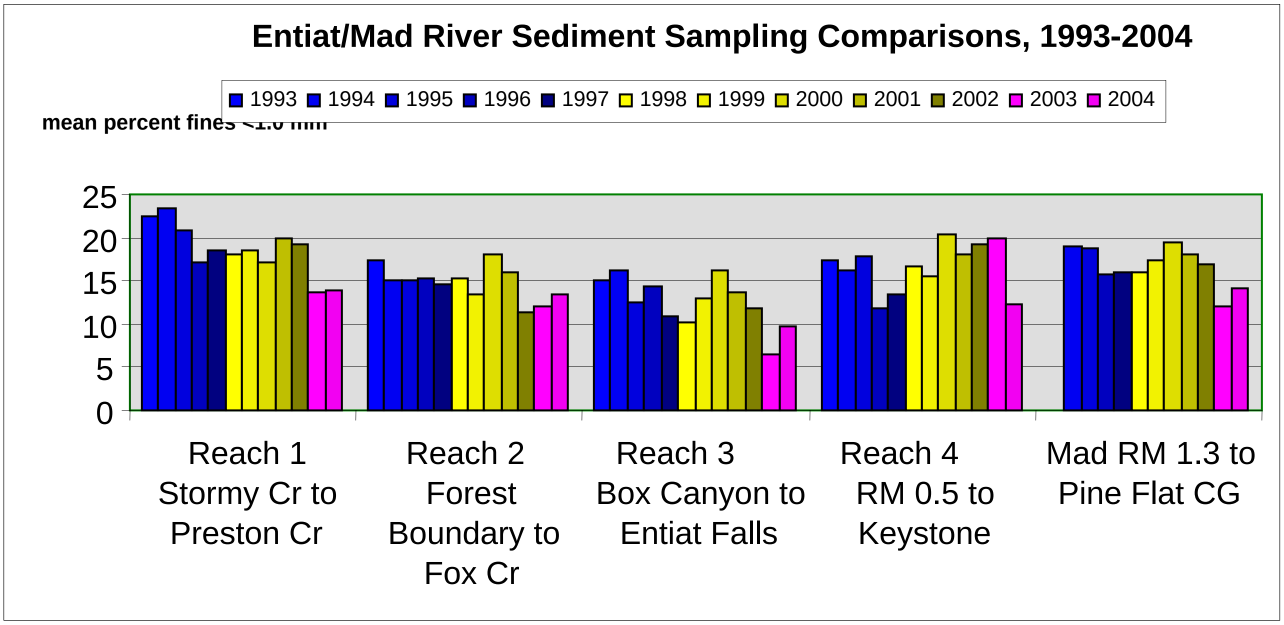

Figure1. Entiat and Mad Rivers Fine Sediment Sampling Comparisons, 1993-2004.

Conclusions and Discussion

Although variability exists in the mean percent fines ≤1.0 mm within reaches, between reaches, and from year to year, a certain amount of inherent natural variability is expected. Also, consistent precise methods need to be applied over a large sample size to reduce sampling error. In 2004, as in the previous ten years, sampling was performed by a WCC crew who were trained and supervised by a Forest Service project supervisor. We believe this consistent application of the sampling method and quality control has kept sampling errors at minimal levels. Statistical evaluation (ANOVA) of sediment levels to examine variability over time supported this conclusion (see Appendix A of the 1999 report).

This year's results compare reasonably well to the twelve-year reach grand means in the Entiat and Mad Rivers. The 2004 mean percent fines for Entiat River Reach 1 was 13.96 compared to a twelve-year grand mean of 18.56. The same comparison for Reach 2 was 13.48 versus 14.73, Reach 3 was 9.75 versus 12.52, Reach 4 was 12.31 versus 16.53, and Mad River was 14.04 versus 16.66. Three sampled reaches (2, 3, and Mad River) showed notable increases from last year. Reach 4 showed a fine sediment decrease (19% fines in 2003) to 14% fines in 2004. The 12-year trend for Reach 1 is unclear but can be interpreted as a long-term decrease. The 12-year trend for Reaches 2 and 3 appears to be a long-term decrease. The 12-year trend for Reach 4 appears to be a long-term increase. The 11-year trend for Mad River is apparently stable within a range of 12 to 19%.

The overall trend of fine sediment levels in the Entiat and Mad Rivers may be explained by annual weather patterns, precipitation and runoff. Below normal precipitation and streamflow in 1993 and 1994 led to accumulating fine sediment due to lack of flushing flows those years. Above average snowpacks and runoff during the years 1995-1997, and 1999 transported fine sediment out of the upper three Entiat reaches and the Mad River after the 1994 Tyee Fire. In 1999, Entiat River streamflow measured two-three times the 40-year average in August. In 2000, Entiat River streamflow was close to "normal" (40-year mean USGS Ardenvoir gage) except during the June peak period when fine sediment transport is expected to be greatest. The magnitude of peak streamflow during 2001 was 50 percent lower than the 43-year mean. The magnitude of peak streamflow during 2002 was well above the 44-year mean and the magnitude of peak streamflow during 2003 was nearly 800 cfs above the 46-year mean. Water-year 2004 was atypical as depicted in the 2003-04 hydrograph (Figure 2). Annual peak flow actually occurred during a short-duration rain-on-snow event in October 2003, and the spring runoff peak was about 300 cfs below average and occurred about two weeks earlier than average. This atypical hydrograph may partially explain the atypical sediment response in Reach 4 of the lower Entiat River. Our assumption that higher peak flows tend to produce fine sediment transport rather than deposition is supported in Figures 3, 4, 5, and 6.

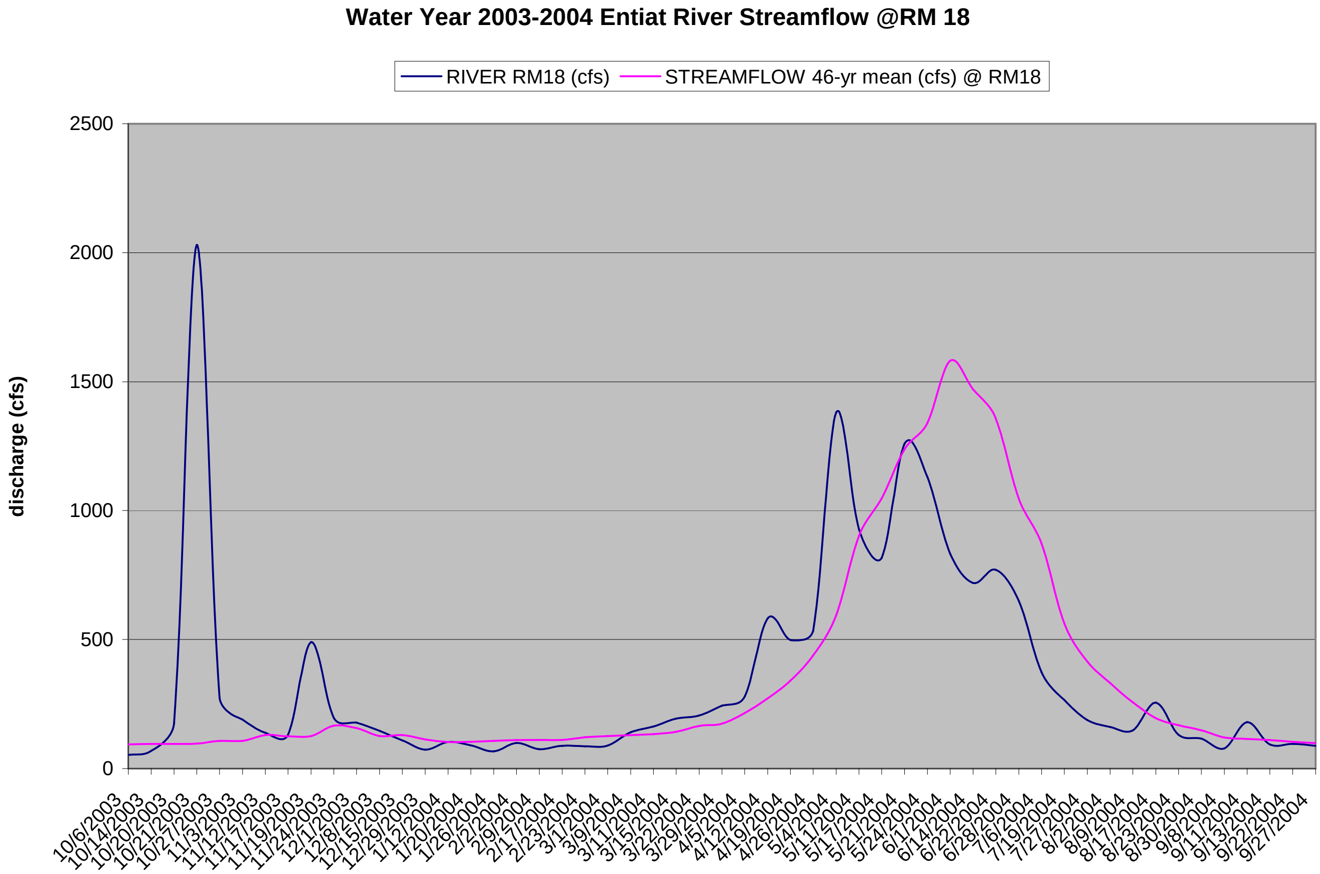

Figure 2. Water year 2003-2004 Entiat River streamflow versus the 46-year mean.

Reach 1 (Stormy Creek to Preston Creek): Reach 1 showed little change from 2003 (13.76 percent fines) to 2004 (13.96 percent fines). For the past ten years, fine sediment has decreased in Reach 1. This is encouraging because this reach contains most of the chinook salmon spawning habitat of the entire subbasin. This is the "stillwater" reach, a low gradient, low velocity depositional area for the system, with a relatively wide (>600 feet) floodplain. Given these features, Reach 1 is expected to have naturally elevated deposition and storage of fine sediment compared to other higher gradient reaches (i.e., Reaches 2 and 3). The effect of human activities on fine sediment both within the reach and in the upper watershed has yet to be determined.

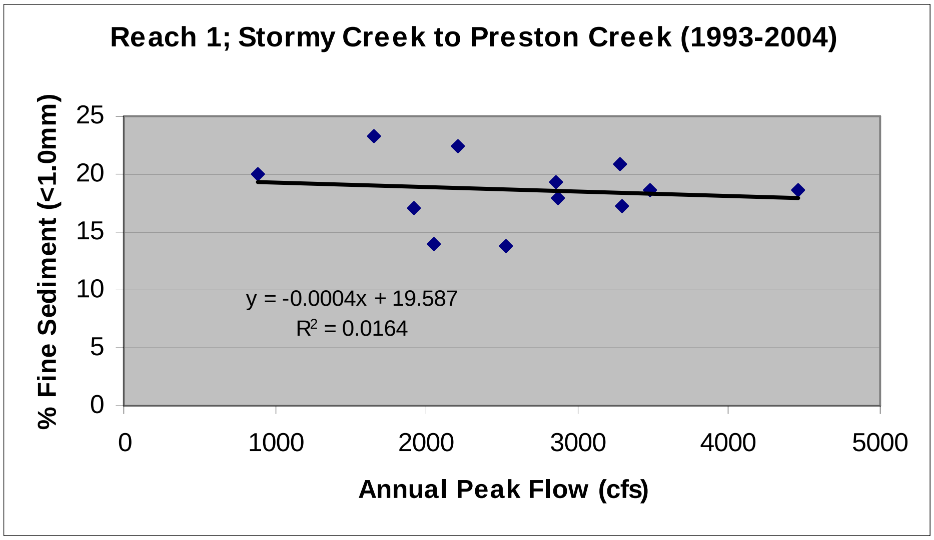

Figure 3. Percent fine sediment in Reach 1 vs annual peak flow.

The linear regressions presented in Figures 3 through 6 represent a simplistic analysis of annual peak flow at Entiat RM 18 versus percent fine sediment in spawning gravel in four reaches. These regressions do not account for annual duration of peak flows. In all four reaches, decreasing fine sediment is weakly positively correlated with increasing peak flows (R-squared values of 0.02, 0.13, 0.05, and 0.11).

Reach 2 (Burns Creek to Fox Creek): This reach was relatively constant from 1994 to 1999. Reach 2 fine sediment increased in 2000 to 18.07 percent, the highest value observed in that reach during the ten-year history of this monitoring project then decreased to 11.33 percent in 2002 and 11.94 percent in 2003, below the eleven-year grand mean of 14.85 percent.

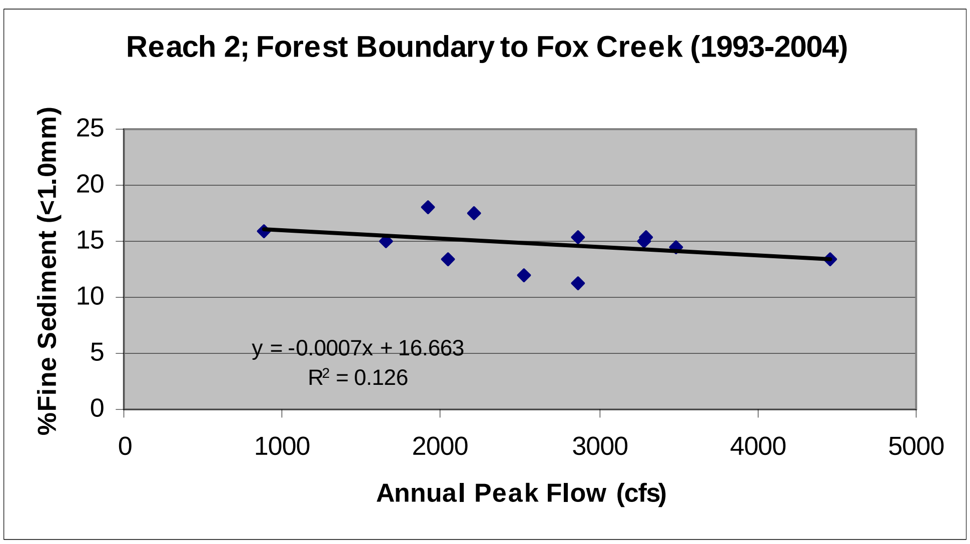

Figure 4. Percent fine sediment in Reach 2 vs annual peak flow.

Reach 3 (Box Canyon to Entiat Falls): Data from this reach indicated a slight (3%) increase in 2004 (9.75% fines) after the dramatic decrease in levels of fines from 16.21 percent in 2000 to 11.92 percent in 2002 to 6.58 percent in 2003 (eleven-year grand mean of 12.78 percent). This reach is currently and typically the lowest of all sampled reaches.

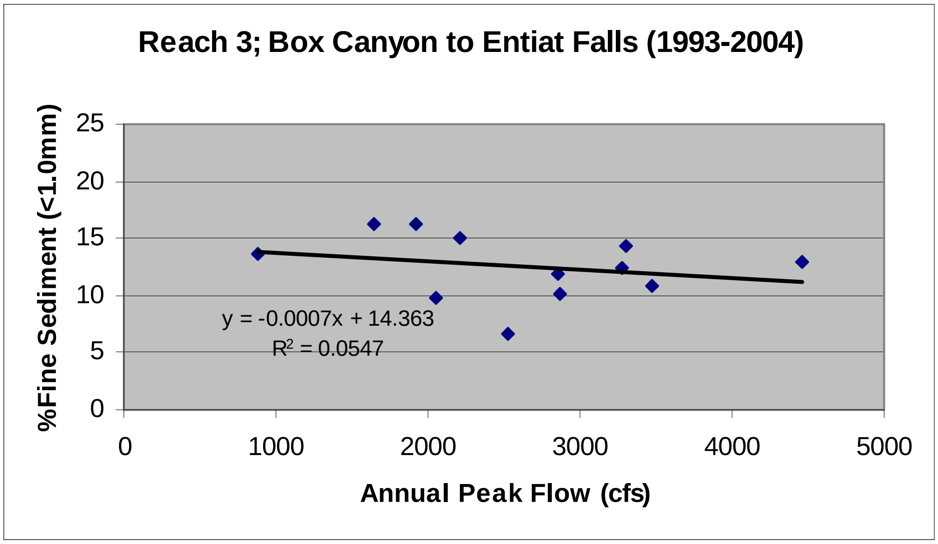

Figure 5. Percent fine sediment in Reach 3 vs annual peak flow.

Reach 4 (mouth to Keystone Bridge): Reach 4 is a response reach for the entire Entiat subbasin and is affected by all events upriver. Fine sediment levels in Reach 4 had increased to 16.64 percent in 1998, which was attributed to mud/debris torrents that issued from Potato and Stormy Creeks on August 26, 1997 after a high intensity thunderstorm hit portions of those drainages. The year 2000 was the first year that Reach 4 exceeded 20 percent fines in eight years. In 2001 the level of fines decreased to 18.15 percent then increased to 19.22 percent in 2002, 19.86 percent in 2003, and dropped dramatically to 12.31 percent in 2004 compared to the eleven-year grand mean of 16.92 percent.

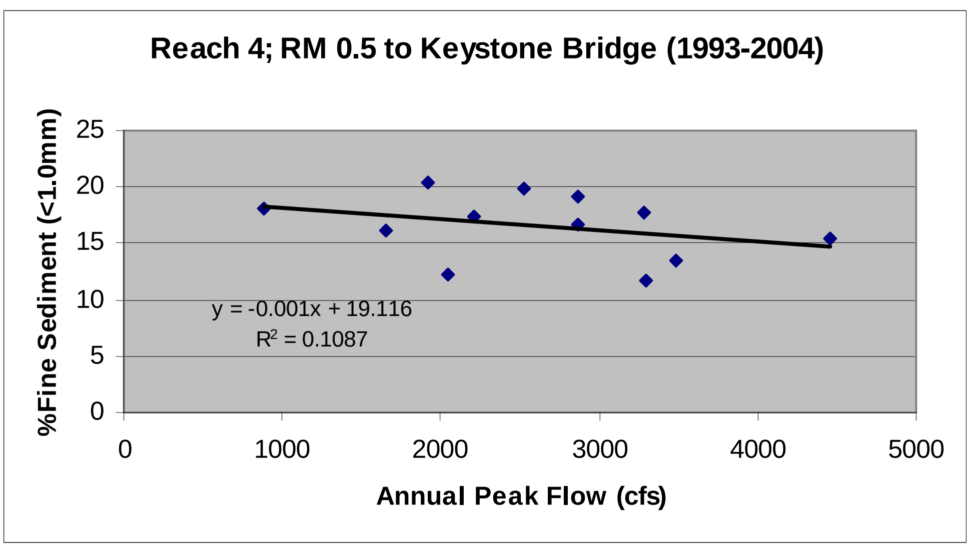

Figure 6. Percent fine sediment in Reach 4 vs annual peak flow.

Mad River: Data from this reach show that mean percent fines ≤1.0 mm was 14.04 percent in 2004 compared to 12.14 percent in 2003, down 28% from 16.80 percent in 2002, 18.15 percent in 2001 and 19.41 percent in 2000 and well below the ten-year grand mean of 16.93 percent. Mad River fine sediment levels appear to be returning to the relatively stable values observed during the years 1996-1998 (see Figure 1). The increased fine sediment level observed in 2000 was likely due to a large mud/debris torrent that entered the Mad River near rivermile 15 below Miners Creek confluence in the spring of 1999.

Recommendations

The most important recommendation is to exercise care in the interpretation of these results. Data limitations should be acknowledged when drawing conclusions based on these data. We recommend that Entiat River and Mad River sediment sampling be repeated indefinitely because of the usefulness of the results in watershed analysis and Biological Assessments for listed fish species.

The core-collection procedure requires considerable physical effort and can be arduous. The sample-sieving procedure requires a consistent level of attention to detail and repetitiveness of method. Since the District was not adequately staffed to assure consistent availability of personnel with the necessary preparation and physical attributes in 1993, it was recommended that subsequent sediment monitoring projects be contracted to qualified bidders. Although the project was not subsequently contracted, beginning in 1994 a WCC crew has performed the sediment sampling, sieving, measuring and data recording. It is recommended that future sampling be performed by a crew similar to the one performing the sampling this year.

This year, Entiat Ranger District watershed specialists continued to provide assistance to the Methow Valley Ranger District, Lake Wenatchee/Leavenworth Ranger District and the Cle Elum Ranger District (WCC crew scheduling/training and equipment repair/replacement). It is recommended that this type of assistance continue in the future to encourage continued sediment data collection.

Cost Analysis - The following costs were incurred on this monitoring project:

Sample collection, sieving & training - 9 WCC crew days @$650/day =	$5,850
GS-11 supervision, QC, analysis & reporting - 10 days @$298/day =	3,000
vehicle mileage - 700 miles @ .35/mile =	250
supplies (refurbish 3 samplers) =	700
Total =	$9,800

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