# Sediment Effects on Macroinvertebrates
# Implications for the Indian Creek Sediment Target

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The following table summarizes the literature cited on the Indian Creek Watershed Advisory Group (WAG) website (http://www.deq.idaho.gov/about/regions/indian_creek_wag/index.cfm).

**EXHIBIT 1. SEDIMENT EFFECTS SUMMARY**

| Study | Author(s) and Date | Location | Primary Species, if applicable | Recommended SS Target | Conclusions | Other Notes |
|---|---|---|---|---|---|---|
| Effect of Silt, Water and Periphyton Quality on Survival and Growth of the Mayfly, *Heptagenia sulphurea* | Peeters et al., 2006 | Common Meuse River, Netherlands | Mayfly (*Heptagenia sulphurea*) | No suggestion | Laboratory experiment found presence of silt layer on periphyton limited mayfly growth, and suspended sediment (SS) in river may need to be reduced to reestablish mayfly populations. | River has an armored gravel bed and velocities up to 4 m/s. SS of 25-30 mg/L in 1990s considered possible impediment to benthic macroinvertebrates (observations by others). |
| Understanding the Influence of Suspended Solids on Water Quality and Aquatic Biota | Bilotta and Brazier, 2008 | a) New Zealand<br>b) United States<br>c) England<br>d) United States<br>e) United States<br>f) United States<br>g) New Zealand<br>h) Canada<br>i) England | a) Invertebrates<br>b) Benthic invertebrates<br>c) Stream invertebrates<br>d) Cladocera<br>e) Chironomids<br>f) Benthic invertebrates<br>g) Mayfly<br>h) Rainbow trout<br>i) Brown trout | No single suggestion because potential impacts are complex.<br><br>Current standards range from increases beyond background (Canada), impact on photosynthetic activity (U.S. EPA), absolute values (EU), and regional/environment-specific values (Australia).<br><br>Recommendations for developing standards include environment-specific considerations, high resolution (frequent) monitoring, SS characterized according to geochemical composition and particle size distribution, and concurrent SS and ecological status monitoring. | a) 8 – 177 mg/L SS for 1344 hours reduced density by 26%<br>b) 62 mg/L SS for 2400 hours reduced population by 77%<br>c) 130 mg/L SS for 8760 hours reduced species diversity by 40%<br>d) 82 – 392 mg/L SS for 72 hours harmed survival and reproduction<br>e) 300 mg/L SS for 2016 hours reduced population by 90%<br>f) 743 mg/L SS for 2400 hours reduced population by 85%<br>g) 1,000 nephelometric turbidity units (NTU) for 336 hours and 20,000 NTU for 24 hours did not increase mortality<br>h) 47 mg/L SS for 1152 hours caused 100% mortality in incubating eggs<br>i) 5,838 mg/L SS for 8,670 hours reduced population by 85% | These values were observed by others and reported in Tables 2 and 3 of this study.<br><br>Factors other than concentration, including duration of exposure, chemical composition, and particle size distribution, also contribute to the effect of SS on aquatic biota.<br><br>Turbidity should not be used as a sole, direct surrogate for SS because factors other than SS affect turbidity measurements. |

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| Protecting Sediment-Sensitive Aquatic Species in Mountain Streams Through the Application of Biologically Based Streambed Sediment Criteria | Bryce et al., 2010 | Western U.S. mountain streams | a) Vertebrates<br>b) Macroinvertebrates | No suggestion | Minimum-effect levels for reach-wide wetted streambed material:<br>a) Fines (<0.06 mm) = 5%, Sand and fines (<2 mm) = 13%<br>b) Fines (<0.06 mm) = 3%, Sand and fines (<2 mm) = 10% | Study focused on bed sediment composition, not SS. |
| An Experimental Test of the Effects of Inorganic Sediment Addition on Benthic Macroinvertebrates of a Subtropical Stream | Vasconcelos and Melo, 2008 | Forqueta River, Brazil | Ephemeroptera, coleoptera, and trichoptera | No suggestion | Macroinvertebrate abundance and species richness were significantly reduced by sediment addition, and coarse sand had more of an effect than fine sand. Reductions in these parameters was likely due to abrasion. | Experiment featured addition of sediment (fine and coarse sand) to a stream. |
| Literature Review: Biotic and Abiotic Factors Affecting the Distribution of Freshwater Macroinvertebrates | Vanessa, 2010 | N/A | N/A | No suggestion | Identified biotic (e.g., predation) and abiotic (including suspended sediment) factors affecting macroinvertebrates. | Brief review of other studies. |
| Effects of Sedimentation and Turbidity on Lotic Food Webs: A Concise Review for Natural Resource Managers | Henley et al., 2010 | N/A | Varied | No suggestion | Turbidity (NTU) and suspended sediment concentrations cannot always be correlated across different measurement techniques/units and watersheds.<br>Methods such as riparian buffers may limit introduction of sediment to river systems. | Literature review:<br>- Shifts toward silt-tolerant genera (e.g., mayflies of Tricorythodes) occurred at as low as 53 mg/L SS<br>- 600 – 750 mg/L SS led to reduced clearance rates and nitrogen excretion for mussels.<br>- Turbidity of 6 NTU reduced *Daphnia pulex* feeding efficiency by 25%,60 NTU caused decreased feeding rate in bluegills, and increases of 25 NTU decreased primary production up to 50%. |
| The Biological Effects of Suspended and Bedded Sediment (SABS) in Aquatic Systems: A Review | Berry et al., 2003 | N/A | Varied | At the time of writing, U.S. SS criteria values ranged from 30 mg/L up to 158 mg/L, depending on stream, substrate, and organisms present. | Elevated levels of SABS have been shown to have wide ranging effects on both pelagic and benthic invertebrates (Cordone and Kelly 1961; Maurer et al., 1986; Peddicord,1980; Waters, 1995; Wilber and Clarke, 2001). Effects can be classified as having a direct impact on the organism due to abrasion, clogging of filtration mechanisms thereby interfering with ingestion and respiration, and in extreme cases smothering and burial resulting in mortality. Indirect effects stem primarily from light attenuation leading to changes in feeding efficiency and behavior (i.e., drift and avoidance) and alteration of habitat stemming from changes in substrate composition, affecting the distribution of infaunal and epibenthic species (Donahue and Irvine, 2003; Waters, 1995; Zweig and Rabeni, 2001).<br>Some useful models for the biological effects of SABS exist and others are under development. Generalizations are difficult because biological response to both increased suspended sediment and increased bedded sediment varies with species and sediment characteristics. | Increased SS (~120 mg/L) can result in increased drift of benthic invertebrates.<br>*Idaho's Guide to Selection of Targets for Use in Idaho TMDLs* (Idaho DEQ, 2003) referenced as a good example of a document outlining criteria with explicit biological justification.<br>Copepods displayed reduced feeding at SS concentrations as low as 95 mg/L, while daphnids showed reduced feeding at between 50 and 100 mg/L. Copepod population grow was reduced at SS concentrations exceeding 350 mg/L.<br>SS effects on fish are varied over different studies. For rainbow trout, eggs experienced 100% mortality at as low as 46.6 mg/L SS, juveniles experienced mortality of 0-15% at 90 mg/L SS, and adults showed reduced abundance at 18 mg/L SS in one study buy no mortality at 80,000 mg/L SS in another. |

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| Landscapes and Riverscapes: The Influence of Land Use on Stream Ecosystems | Allan, 2004 | N/A | N/A | No suggestion | Sedimentation identified as a factor that influences stream ecosystems by increasing turbidity, scour, and abrasion, impairing substrate suitability for periphyton and biofilm production, decreasing primary production and food quality, in-filling interstitial habitat harming crevice-occupying invertebrates and gravel-spawning fish, coating gills and respiratory surfaces, and reducing stream depth heterogeneity. | Study reviews and identifies pathways and mechanisms through which land use influences stream conditions. |
| Environmental Effects of Sediment on New Zealand Streams: A Review | Ryan, 1991 | New Zealand and elsewhere | Varied | At background levels up to10 NTU (10 g/m$^3$), allow an increase above background of up to 1 NTU (1 g/m$^3$). At background levels exceeding 10 NTU, allow an increase of up to 10% beyond background. | Noted that suspended sediment loadings on streams affect fauna in many ways, and that relatively unimpacted streams may be more sensitive to anthropogenic increases of suspended sediment. | An increase of 40 g/m$^3$ SS above background increased drift by 25%, and an increase of 80 g/m$^3$ SS increased drift by 90%.<br><br>A 12-17% increase in interstitial fine sediment of a low sediment substrate resulted in a 16-40% decrease in total invertebrate abundance, and a 27-55% decrease in abundance of the ephemeropteran *Deleatidium*. |
| Direct and Indirect Effects of Sediment Pulse Duration on Stream Invertebrate Assemblages and Rainbow Trout (*Oncorhynchus mykiss*) Growth and Survival | Shaw and Richardson, 2001 | Moffat Creek, British Columbia | 31 families of invertebrates, with Chironomidae being most abundant, followed by Baetidae and Limnephilidae. | No suggestion | Duration of a sediment pulse, given a constant concentration, had a negative effect on the richness and abundance of benthic invertebrates and the richness of drifting invertebrates. However, the total abundance of drifting invertebrates increased over the duration of the experiment. | Mean sediment pulse was 704 mg/L SS. |
| Fine-Grained Sediment in River Systems: Environmental Significance and Management Issues | Owens et al, 2005 | Case studies in New Zealand, British Columbia, and the U.S. | N/A | No suggestion | Article focused on management of fine-grained sediment in river systems. Recommended developed integrated management strategies to address sediment quantity and quality issues. | Not focused on specific dose-effects. |
| Mayflies (Insecta: Ephemeroptera) and the Assessment of Ecological Integrity : a Methodological Approach | Bauernfeind and Moog, 2000 | Europe | Mayfly | No suggestion | Mayfly abundance and diversity can be used to assess ecological integrity if a proper monitoring program is implemented. | This article is focused on using mayflies as an indicator of ecological integrity, rather than SS concentrations affecting mayflies. |
| Stream Insects as Bioindicators of Fine Sediment | Relyea et al., 2000 | Idaho, Oregon, Washington, and Wyoming | 83 widely-occurring aquatic macroinvertebrates | No suggestion | The fine sediment bioassessment index (FSBI) was developed from a large dataset consisting of 562 stream segments and 661 taxa, which was refined to the 83 most common taxa. The presence/absence of these 83 macroinvertebrates was compared to percent fine sediment in each stream's substrate. | Declines in density as a response to increased fine sediment input may be more prominent with Plecoptera (stoneflies) than other orders, and examining density changes of those specific taxa may be more important than total aquatic invertebrate density during development of a biomonitoring index.<br><br>Study not focused on SS concentrations. |
| Biological Effects of Fine Sediment in the Lotic Environment | Wood and Armitage, 1997 | N/A | N/A | No suggestion | Numerous impacts to macroinvertebrates, such as impaired filter-feeding, reduced density, reduced abundance, reduced diversity, increased drift, and change in community structure, were attributed to SS and sedimentation. Specific SS concentrations resulting in impacts were not identified. | Article focused on sediment sources and effects, but did not attempt to identify specific dose-effects. |
| Effects of Sediment Addition on Macrobenthic Invertebrates in a Northern Canadian River | Rosenberg and Wiens, 1978 | Harris River, Northwest Territories | Oligochaeta, plecoptera, | No suggestion | Sediment was added to the test channel. The mass of sediment added was intended to generate 30 mg/L SS. | Experiment compared invertebrate drift in a control channel and a channel received |

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| | | | ephemeroptera, simulidae, chironomidae, hydracarina | | Actual observed SS concentrations in the control channel ranged from 0.76 to 1.52 mg/L, and SS concentrations in the sediment addition channel ranged from 0.72 to 20.94 mg/L. Mean SS concentration in sediment addition channel during the August experiment was 7.76 mg/L, and mean concentration during the September experiment was 7.42 mg/L. Significantly more macrobentho drift occurred in the sediment addition channel than in the control channel. Settled sediment likely creates most changes to macrobenthic communites in rivers, and isolated measurements of SS concentrations are not directly correlated with the amount of sediment that settles.<br><br>From another study (Gammon, 1970), SS addition achieving concentrations approximately two times normal (15 – 40 mg/L during summer) did not allow for easy detection of reduction in standing crops. However, when SS increased to four times normal, standing crop decreases were easily detected. | sediment input. The channels were side by side and partitioned with plywood. |
| Water Quality Criteria for Freshwater Fish, Chapter 1: Finely Divided Solids | Alabaster and Lloyd (editors), 1982 | N/A | Varied, mostly fish | *Less than 25 mg/l - no evidence of harmful effects on fisheries<br>*25 – 80 mg/l – it should usually be possible to maintain good or moderate fisheries<br>*80 – 400 mg/l – unlikely to support good freshwater fisheries<br>*Greater than 400 mg/l – only poor fisheries are likely to be found | Note that these EIFAC guidelines were developed in 1964, and no specific duration was identified in the Alabaster and Lloyd chapter. Further clarification regarding duration has since been provided : "The working party of EIFAC (European Inland Fisheries Advisory Committee) investigated the effect of water pollution, including suspended solids, during the development of Water Quality Criteria for European Freshwater Fish. The studies used to determine the criteria have subsequently been summarised by Alabaster and Lloyd (1980) in which a series of ***tentative annual mean values*** for chemically inert solids in suspension were given for the maintenance of freshwater fisheries…" (emphasis added). From "Review of UKTAG Proposed Standard for Suspended Solids," APEM Scientific Report 410242, August 2007. | The M.P. Vivier personal communication text in this chapter of Alabaster and Lloyd does not support the conclusion that "Populations of Ephemeroptera disappeared when exposed to greater than 29 mg/L of suspended sediment for 30 days" as cited in the pre-draft TMDL. This stream in France was subjected to discharge of 29,900 mg/L of SS in a wastewater, of which 19,750 mg/L was settleable. A variety of fauna existed upstream of the discharge, and had disappeared immediately downstream. At 4 km (2.5 miles) downstream, all fauna except for Ephemeroptera had reappeared. The SS concentration at this downstream location was reported to be 29 mg/L. The author did not attribute the lack of Ephemeroptera to the residual SS. There are a number of possible explanations, including effects of the very high levels of settleable solids in the discharged water. Moreover, the durations associated with the discharge and the downstream 30 mg/L concentration were not indicated in this text, nor were any of the sampling methods. |

Note: Several other studies were briefly reviewed but did not include sufficient information regarding specific suspended sediment dose responses to warrant detailed description in this exhibit. Those studies included *Effects of Sediment on the Aquatic Environment: Potential NRCS Actions to Improve Aquatic Habitat* (Castro and Reckendorf, 1995), *Influence of Fine Sediment on Macroinvertebrate Colonization of Surface and Hyporheic Stream Substrates* (Richards and Bacon, 1994), *The Influences of Inorganic Sediment on the Aquatic Life of Streams* (Cordone and Kelley, 1961), and *Water Purity Standards for Freshwater Fishes* (Ellis, 1944).

## Brief Synopsis

The articles posted on the DEQ website represent some of the available literature on sediment effects on aquatic biota. Because DEQ is proposing a suspended sediment concentration target for Indian Creek based in part on potential impacts to macroinvertebrates, the summary presented in Exhibit 1 primarily focuses on macroinvertebrates. This body of literature generally agrees that anthropogenic sediment inputs from agricultural practices, mining, construction, and other sources can result in an increase in suspended solids and sedimentation in rivers and streams, degrading habitat quality. The literature also agrees that excess fine sediment (suspended and in the substrate) can have deleterious effects on macroinvertebrates. However, much of the literature is focused on fines content of sediment at rest within the river channel. There does not seem to be consensus among the articles regarding a suspended sediment concentration that is protective of macroinvertebrates. Following on our initial review of the literature, it does not appear that there is strong scientific basis for a suspended solids/sediments target for Indian Creek based on effects on macroinvertebrates. There does appear to be ample scientific documentation that the duration of exposure to suspended sediment is important for both macroinvertebrates and fish.