**Independent Multidisciplinary Science Team (IMST)**

**State of Oregon**

Neil Christensen
Michael J. Harte
Robert M. Hughes
Victor W. Kaczynski
Nancy Molina
Carl Schreck
Carlton Yee

c/o
Oregon State University
Department of Forest Science
321 Richardson Hall
Corvallis OR 97331-5752

July 27, 2007

Robert Baumgartner
Department of Environmental Quality
811 SW 6th Avenue
Portland, OR 97204-1390

Dear Bob,

At the request of the Oregon Department of Environmental Quality, the Independent Multidisciplinary Science Team (IMST) has reviewed the October 2005 draft document titled *Technical Basis for Revising Turbidity Criteria*. In your February 8, 2006 letter to the IMST, you listed two questions for the IMST to consider during its technical review of the document. As you know, IMST requested that DEQ staff technically review an earlier version of IMST's review for clarity and appropriate use of language related to proposed criteria and agency programs. DEQ comments were reviewed by the IMST and where appropriate the IMST clarified its meaning of specific statements or provided additional information to points made by the IMST. In the attached review, the IMST addresses these questions as well as general comments on the draft document.

We recognize that development of criteria that are user friendly yet appropriately protective of aquatic resources is a daunting task. We commend your agency staff for their scientific analyses and creativity in developing the draft criteria. Our comments are mostly directed at providing clarity and strengthening the rationale behind the criteria. We hope your staff finds these comments constructive, and helpful in crafting a more scientifically sound and defensible document. Feel free to contact us if you have questions about our review.

The review was adopted by the IMST at its July 26, 2006 public meeting. There were no dissenting opinions amongst the IMST regarding this review. One IMST member was absent from the final deliberations. As we mentioned to you yesterday at the meeting, the IMST does not normally release reviews to the public or post them to our web site for 30 days after sending the review to the requesting agency. If you would like IMST to post the review at an earlier time please let Kathy Maas-Hebner (541-737-6105) know and she will post it on IMST's web site.

Sincerely,

Carl B. Schreck
IMST Co-Chair
(541) 737-1961
carl.shreck@oregonstate.edu

Attachments

cc with attachments:
Tom Rosetta, DEQ
Sue Knapp, GNRO
Frank Shields, Senate Nat. Res. & Alt. Eng. Committee
Patti Smith, House Ag & Nat. Res. Committee
Tom Byler, OWEB
IMST

# IMST Review of Oregon Department of Environmental Quality's *Technical Basis for Revising Turbidity Criteria* (DEQ Water Quality Division, October 2005 draft)

The Independent Multidisciplinary Science Team (IMST) reviewed the document titled *Technical Basis for Revising Turbidity Criteria October 2005 Draft* at the request of the Oregon Department of Environmental Quality (DEQ; letter from Robert Baumgartner dated February 8, 2006). In particular, DEQ asked the IMST to review the document and public comment issues and evaluate these with respect to two questions:

1. Does the technical basis provide a reasonable and objective review of the body of the available information related to turbidity effects (not solids, toxics, or other parameters)?
2. Does the technical basis provide reasonable and objective inference on risk of impairment from the available literature regarding the protection of beneficial uses?

Public comment issues were presented to the IMST during briefings by Bob Baumgartner (DEQ) and Tom Rosetta (DEQ) at two IMST public meetings (February 23 and May 25, 2006). Both staff members were available at several other IMST meetings to answer questions and to provide clarification to the IMST as it reviewed the document. During the review , IMST requested that DEQ staff technically review an earlier version of IMST's review for clarity and appropriate use of language related to proposed criteria and agency programs. DEQ comments were reviewed by the IMST and where appropriate the IMST clarified its meaning of specific statements or provided additional information to points made by the IMST.

The IMST commends the DEQ for review of the technical basis for revised turbidity criteria, especially the use of data from fish behavioral studies. The IMST offers the following comments with the purpose of enhancing the final draft and improving the clarity and scientific basis of the proposed turbidity criteria. Our initial comments are oriented towards addressing general impressions of the document as a whole. These are followed by comments that address specific sections or topics within the document, references cited within this review and finally, editorial comments. We will address the two questions from DEQ within the framework of our review.

## GENERAL COMMENTS

IMST compliments DEQ on the excellent literature review it compiled for this document. We found that it had good depth and breadth, but some of the references used within the supporting figures were confusing or contradictory to the IMST, which are discussed below under specific comments.

IMST commends DEQ for seeking independent technical review of these proposed turbidity criteria. Independent peer review is especially important where agency funding

for works of this type comes from non-public sources and promotes transparency and quality assurance.

The document would benefit from an organizational restructuring so that a reader can find in one place the criteria and when each criterion is appropriate. In other words, it would help clarity if one could find a table or succinct recapitulation of the criteria without having to wade through a significant amount of biological justification. In addition, the document should provide clear guidelines for when it is appropriate to use each of the specific turbidity criteria options. As written, we find it nearly impossible to determine when certain "exemptions" can be expected[1]. Some of our comments likely stem from our confusion over precisely what the proposed criteria are, that is when and how they would be implemented and when waived.

IMST feels that the document would benefit from a careful editing. Frequent subject-verb disagreement, punctuation errors, font style/size changes, cumbersome wording, incorrect scientific and common names, inconsistent reference style, and misplaced words detract from the content. Also, some references in the document are incomplete or contain incorrect information and others are omitted from the reference section.

DEQ desired a simple, practical, and flexible approach for assessing and complying with turbidity criteria. While IMST recognizes that Oregon's proposed turbidity criterion of 5 Nephelometric Turbidity Units (NTUs) above ambient resembles those of other states, IMST feels that there are biological risks in using those approaches for two major reasons: (1) where multiple dischargers to large rivers choose reference/background sites immediately upriver with only the guidance provided in this document, and (2) where criteria for clear water fishes appear less protective than may be necessary if one objective were to be protective of biological function. Additional detail on both these matters is provided below. Furthermore, most turbidity research has been conducted at turbidities higher than those shown to have behavioral effects on salmonids. This adds risk to setting protective criteria for salmonids should those behavioral effects translate into ecological effects.

## SPECIFIC COMMENTS

Clear Water Fish Concerns

Table 4.1 needs to emphasize that the proposed criteria are not absolute levels; instead they are only allowances above background—which currently exceed the key 3 to 5 NTU effect level for clear water fishes (see Figures 3.2, 3.4, 3.5, 3.9, 3.10, 3.11 and Tables 3.3, 3.4, 3.5, 3.6) in 20-30% of low and high river flow periods, respectively (Table 3.6). Also, in Figure 3.12 (p. 30), the mean feeding rates increased for all three prey types for the largest fish when turbidity increased. Competing behavioral responses associated with predator prey relationships are hypothesized. However, laboratory studies of drift feeding

[1] IMST is aware of the DEQ document "Implementation Guidance for Turbidity Standard (Draft)" where much more detailed elaboration is given on intent, application and implementation of various portions of the proposed turbidity criteria. DEQ did not request that we incorporate this guidance document as part of our review and we have not done so.

rheophilic fish in static aquaria are less convincing than those in model streams with appropriate current velocities and prey densities. Additionally, it is unclear if the n=8 represent 8 individual fish or 8 treatments.

Like other states, DEQ's analysis of turbidity effects, while not explicitly stated, leaves the impression that biotic responses are linearly related to the amount of turbidity present. For example, one could surmise from the discussion that a 10 NTU change going from 5 to 15 NTU could have the same biotic impact as one going from 105 to 115 NTU.

Figures and discussion in section 3.2.3.1 indicate that behavioral responses were curvilinear, implying curvilinear, not linear, physiological effects. Berg (1982) reported that coho have more mis-strikes at 10 NTU than 0 NTU. Rainbow trout reaction distances at 15 NTU were 80% of those at 4–6 NTU (Barrett et al. 1992). McCabe and O'Brian (1983) found that 10 NTUs significantly reduced *Daphnia pulex* feeding, assimilation, and reproduction. Lloyd (1987) recommended a criterion of 7 NTU for a high level of protection for salmonids, noting that stricter limits would be needed for exceptionally clear waters because of dramatic initial effects of turbidity on light penetration. Vogel and Beauchamp (1999) found that reaction distance of lake trout occurred as a decaying power function of turbidity (80% of the decline occurred between 0 and 5 NTU). In other words, slight turbidity increases in low turbidity waters are associated with larger behavioral and ecological changes than the same turbidity change in high turbidity water. It would be helpful if DEQ described explicitly what they believe the response pattern to increasing turbidity is.

There may be threshold levels above which entirely different sets of models would be appropriate, such as implied by a switch from rest/strike feeding to actively searching for food. Long-term animal responses to a decrease in photic zone might be very different if photosynthesis were eliminated entirely, or if the surviving flora were less edible or of poorer nutrient quality. A slight increase in turbidity may reduce the visual perception in native fish species but substantially more turbid water often offers competitive or predatory advantage to sympatric alien fish species adapted to low light intensities (percids, centrarchids, and ictalurids). Conversely, salmonid juveniles could benefit from turbid water in certain instances if their predators are less successful in detecting and pursuing them. This effect is countered if adequate cover exists (Gregory and Levings 1996). Mazur and Beauchamp (2003) found that differences in reaction distance to prey by predators could alter predator–prey interactions under different visual conditions.

Biotic effects at low turbidities appear to increase exponentially with a linear increase in turbidity. Such effects would be lost in the noise of the proposed "increase above background" approach (see below). In addition, responses to turbidity may not even be curvilinear. Relative criteria based on upstream background turbidities lead to continued degradation, especially from diffuse sources, as indicated on p. 47 of DEQ's document. Bash et al. (2001) also concluded that these types of measurements may not be protective of salmonids, and suggested sampling minimally disturbed reference sites. Currently, it is difficult to identify natural conditions for mainstem rivers because observed downstream changes in turbidity covary naturally with changes in bed form, soil type, phytoplankton

growth, etc. However, Van Sickle et al. (2004) and Kilgour and Stanfield (2006) used best-subsets variable-selection regression and backward-stepwise multiple regression to hindcast stream conditions in the Willamette Valley and eastern Ontario, respectively. Such analyses would aid DEQ in modeling natural levels of turbidity. IMST would not expect natural lowland rivers to have the turbidities of forested mountain rivers, but the mean turbidities of lowland rivers shown in Appendix B of DEQ's draft document are not likely the result of differences in soil type and phytoplankton alone. For example, in the mainstem Willamette River, August 1983 background (upper river) turbidities were 2 NTUs, except near point sources at river kilometers (RKs) 283, 232, 137, and 93, then gradually rose in the lower river to 6 NTUs above Portland (Hughes and Gammon 1987). The peak NTUs collected near point sources did not appear to accumulate downstream until reaching the Newberg pool and Portland. What should background be for the Willamette River based on these data? One to two NTUs as occurs in the clearer reaches, 5–6 NTUs as occurs at and upriver of many of the point sources, or 5 NTUs above the upriver turbidities already at 5 NTUs, or something else? Which is most protective of adult and juvenile salmonids?

Unmeasured and more severe biotic consequences may occur at higher turbidity levels, such as fundamental shifts from sight-feeding (salmonid) to olfactory-feeding (ictalurid, barbeled cyprinid) fish. But there is a lack of published data on ecosystem-level effects of turbidity in the document, possibly because turbidity alone does not account for all the biological responses. Therefore, DEQ could, as one option, use field data from its own monitoring group showing the relationships between biological assemblages [e.g., index of biological integrity (IBI)] and increased turbidity, as well as their correlation coefficients. In addition, published data from Hughes and Gammon (1987) on the Willamette River could be added by plotting the turbidity data from their Figure 4 against IBI data from their Table 4 to indicate the possible cumulative effects of increased turbidity on a single river. Finally, turbidity vs. IBI data are also available from the US Environmental Protection Agency's (EPA's) Environmental Monitoring and Assessment Program (EMAP) database to which DEQ should have free access as part of the EMAP Western Pilot. The latter data could be used to amplify the DEQ data and the correlations. Unfortunately, ecological and biological effects of turbidity in natural systems are typically confounded by covarying changes in nutrients, dissolved oxygen, and temperature. However, in a national survey, Judy et al. (1984) found that turbidity adversely affected fish assemblages in 34% of the nation's waters. Analytical tools for separating effects of covariates when employing ambient ecological data include quantile regression (Mebane et al. 2003), covariance structure analysis (Zorn and Wiley 2006), and multiple linear regression (Kaufmann and Hughes 2006).

As Figures 3.2, 3.3, 3.4, 3.5, 3.6, 3.7, 3.9, 3.10, and 3.11 indicate, increases in turbidity from 0 to 10 NTUs are associated with substantial effects on various biological responses; however there have been few studies measuring the impact of turbidity at less than 10 NTUs. IMST's evaluation of the scientific literature indicates that clear water systems are most susceptible to detrimental impacts from low-level turbidity increases. For example, reduced feeding efficiency by clear water fishes (salmonids, cottids) as presented in the draft document places sight-feeding fish at increased risk. Reduced

feeding efficiency cascades into reduced growth. Reduced growth cascades into reduced fitness (i.e., reduced reproduction and reduced competitive ability). Reduced fitness of turbidity intolerant species cascades into fundamental alterations of fish assemblages (e.g. from salmonid/cottid to catostomid/cyprind/ictalurid or from clear water species to turbid water species (Tarzwell and Gaufin 1953; Larimore and Smith 1963; Warren 1971; Trautman 1981). However, responses to increases from 30 to 40 NTUs yield insignificant biological responses, and changes from 10 to 30 NTUs have intermediate effects. This suggests the need for a different approach, such as a tiered approach for example, to criteria, similar to those DEQ uses for temperature and dissolved oxygen. For example, different criteria might be employed to insure that Oregon's clearest waters (0–10 NTUs) are protected, naturally turbid waters (>30 NTUs) are commensurately protected, and waters of intermediate turbidity (10–30 NTUs) have intermediate criteria. USEPA (2005) also recommended tiered biological uses to protect high quality biological assemblages, and DEQ has tiered uses (salmon spawning, salmon rearing, salmon migration, aquatic life). For example, waters with salmonid spawning and rearing use designations might be better protected by a fixed turbidity criterion of something like 5 NTUs than a criterion of 5 NTUs above background. For example, waters with a salmon migration use designation could be protected with a turbidity criterion of a low NTU, like 5 NTUs, above background as indicated from regional reference sites or models. And non-salmonid waters might have a turbidity criterion of an NTU that is somewhat higher, like 10 NTUs, above background as determined from models or regional reference sites. Those non-salmonid waters are likely not only to have higher background turbidities, but higher peak turbidities as well, if they drain more erodible soils and channels. IMST is not proposing these criteria; it is simply providing an example of tiered turbidity criteria that DEQ could consider.

Turbidity effects are magnified for deeper water bodies like lakes and large rivers. See Figure 3.3 for the deeper water (0.5 m), which is still shallower than the mean nearshore and thalweg depths of most raftable Oregon rivers (Hughes et al. 2002). Figures 3.1 and 3.2 and Table 3.5 suggest that a high level of lake and stream protection appears to support a turbidity criterion of 5 NTUs, at least during base flow (non-storm flow) periods. On page 46, DEQ states that too high an absolute criterion would be under protective, and too low a criterion would be too restrictive. But the same is true of the proposed relative criteria.

Upstream Reference Sites

DEQ is proposing turbidity criteria based on an upstream-downstream approach for reference conditions, and as statewide criteria. Although upstream-downstream or near-field far-field monitoring sites are established sampling designs in aquatic assessments, a series of upstream reference sites means that all but the most upstream sites are downstream of point sources. It is important to recognize that cumulative downstream increases in "background" turbidity resulting from land uses, and the consequent degradation of biotic assemblages from clear water to turbid water species. DEQ defines background turbidity as that measured above cumulative sources or without discernable anthropogenic sources—but does not define those sources. For example, are logging, roads, and agriculture considered sources? If not, such criteria also accept considerable

increases in turbidity over those existing before widespread removal of natural vegetation. Also, in large rivers, the most upstream sites are typically altered by diffuse sources of turbidity (for example off-channel mining, channel erosion, logging, grazing, and agriculture).

An upstream–downstream approach has value in assessing a point source problem but may be inappropriate for providing statewide criteria (Bash et al. 2001). Statewide criteria ignore likely natural turbidity and biotic differences among eco-regions (e.g., the Owyhee in the High Desert vs. the Siletz in the Coast Range). For small wadeable streams, DEQ's estimate for background based on minimally-disturbed ecoregional reference sites is excellent (USEPA 2000; IMST 1999; Drake 2004), but recent research suggests that an upstream-downstream approach may not be as useful for large rivers (e.g., Riseng et al. 2006) and alternatives may need to be explored. Although it is very useful to have statewide ambient monitoring data from fixed sites, 20 large river sites, especially when not randomly selected, cannot be considered representative of Oregon waters and DEQ would be wise if it used these with caution. Also, if most field studies of turbidity effects are based on small, shallow streams, the effects of the same level of turbidity increases on large, deep rivers and lakes will likely be underestimated because of the additive effect of more turbid water above the bottom for light to penetrate (Figure 3.3).

Other options to the upstream-downstream approach include using anthropogenically least disturbed or minimally disturbed eco-regional reference sites (Human Disturbance Index (HDI) grade A and B sites in Table 2.3), a background turbidity of 0–1 NTUs, landscape based models (Van Sickle et al 2004; Wang et al 2006), together with turbidity constituent analyses and their probable sources. By comparing what is in the water of large rivers with what is in the water of minimally-disturbed reference sites feeding them, models can be generated for estimating sources (anthropogenic versus natural). Presumably such models are generated in the TMDL process. This is essential for establishing criteria protective of salmonid life histories and effectively regulating diffuse sources of turbidity.

<u>Miscellaneous</u>

*Water body types.* It is unclear if DEQ is proposing the same criteria for lakes as streams and DEQ should point out the rationale for establishing different background turbidities for maximum and monthly average criteria (i.e., why are they not both the same?).

*Newcombe's model*. While there is heavy reliance in the draft document on the Newcombe (2003) publication, it would be prudent in the draft document to state that while this publication is scholarly and scientifically based, it is neither a holistic review nor definitive in conclusions. Newcombe offers a model from which impacts of turbidity can be inferred. Although this model appears reasonable, to IMST's knowledge it has not been validated. However, the use of Newcombe's model was innovative and incorporated a newer scientific contribution to the field of turbidity effects. Similarly, we found that DEQ's emphasis on the effects of turbidity on fish behavior versus acute effects a useful approach. Beauchamp et al (1999) developed another visual foraging model for

piscivores that predicts search volume as a function of light and turbidity in three western U.S. lakes. Their approach appears useful for constructing temporally and spatially explicit trophic interaction models for examining mechanisms underlying predator and prey distributions or to predict the response of existing or introduced predators to changing environmental conditions, prey abundance, or distribution.

*Chronic assemblage effects*. IMST agrees with the DEQ focus on chronic, versus acute, effects of turbidity, species richness, process rates (respiration, photosynthesis, production, growth), and behaviors (reactive distance, avoidance, feeding) often have lower signal/noise ratios than assemblage structure. This is because more tolerant or cosmopolitan species can substitute for more intolerant species in field situations, and yield the same or increased species richness, process rate (photosynthesis, productivity, growth), and behaviors (reactive distance, feeding), or lower respiration and avoidance. This is why universal relationships do not exist for turbidity and productivity—unless the species are held constant. In other words, all species in an assemblage should not be viewed as interchangeable. As suggested above, DEQ could benefit from an evaluation of available DEQ and USEPA databases to examine correlative scatterplot relationships between turbidity and fish and benthos assemblage index and metric scores. Such an approach of course is only correlative, not causal. But by considering correlation and mechanism in comparison with co-occurring stressors, the role of turbidity in influencing assemblage changes can be assessed. In addition, common stressors that often co-occur with increased turbidity, such as increased sedimentation, nutrients, and temperature and decreased dissolved oxygen, are all influenced by increased turbidity in ways that are detrimental to salmonids. This is why various types of regression models are employed to tease out those relationships. Equating "clear water fish with fish presence and production under turbid conditions" (page 46) seems like a stretch, without specifying the species, their relative abundances, their relative levels of production, and the relative levels of turbidity.

IMST finds that the document is predominantly fish-centric, rather than oriented towards primary production (algal-centric), and more specifically, oriented toward clear-water fish and salmonids. IMST was unclear if DEQ's use of the word "fish" included warm-water, non-native fish. There is also little discussion on such animals as mussels or amphibians and the effect turbidity would have on these organisms. See Naymik et al. (2005), Biggs et al. (1998) for possible effects of increasing turbidity on diatoms.

*Sedimentation.* Much of this emphasis can be attributed to the use of turbidity as a surrogate for sediment in the water column. The use of turbidity as a surrogate measurement for sediment and other light transmission reducers in waters of the State to infer impacts on beneficial uses is a complex subject. Turbidity does not correlate well with settleable solids across the landscape and finer settleable solids (and mobile coarser solids) are what cause direct stream substrate problems for aquatic animal life (Lane and Sheridan 2002). In most cases, turbidity criteria have been developed to address concerns about sedimentation and possible adverse effects on plant photosynthetic responses, macro-invertebrate and fish habitats. However while there is considerable literature relating to sediment and sedimentation effects on community health and biological

effects in streams, there is not the same degree of correlation in the literature concerning turbidity and these same factors. There has been little success in establishing a correlation between specific turbidity amounts and corresponding amounts of sediment or sedimentation (pg. 12) except on a specific reach or stream. It may be unwise for DEQ to rely on examples of effects of sedimentation to support a turbidity criterion. If the objective is to protect aquatic life, then excess sediment must be addressed. Because of the great importance of the concentration of sand and fine sediments on stream, river bottoms and lakes, IMST suggests that a criterion for regulating bottom sediments makes scientific sense to protect beneficial uses.

*Diffuse turbidity sources.* This document appears to have an implicit point or discreet source focus, but is less clear on how it would apply to diffuse or nonpoint sources. But there are likely to be effects from diffuse sources of turbidity from reservoir releases, channel erosion, and numerous land use practices including roads and driveways, lawns, logging, grazing, mining, and agriculture. It is unclear how DEQ proposes to assess and enforce its turbidity criteria relative to those sources? In other words, how might entire basins be listed on 303(d) lists, and how might total maximum daily loads (TMDLs) be established for those basins?

A probability sampling design, with sufficient site densities and minimally-disturbed reference sites could distinguish eco-region level effects within a basin (e.g., the Willamette Valley vs. the Cascades eco-regions within the Willamette Basin). Such designs are more robust means of ascertaining background and typical turbidity levels than are 20 fixed sites (Appendix B of DEQ's draft document). Twenty sites for a state as diverse as Oregon seem suspect for establishing patterns, especially when those sites are hand picked.

*Mixing zones.* The proposed criteria provide for the establishment of a Regulatory Mixing Zone (RMZ) compliance monitoring point for activities not subjected to Oregon Administrative Rule (OAR) 340-041-0053 is a new requirement. It would be very helpful for clarity's sake and to be more defensible if DEQ were to more clearly lay out a full and well-documented reasoning as to why it feels that an expansion of the use of compliance monitoring points for turbidity sampling (at the end of a RMZ) is warranted. Providing a more complete discussion of scientific or management rationale for the extent of the mixing zone would be useful. Might the RMZ be based on a consistent multiplier of stream width?

*Seasonal criteria.* There are ample reasons to support statewide low flow and high flow criteria (see Appendix B of DEQ's draft document).

*Quality assurance.* DEQ acknowledges that the proposed turbidity criteria will be largely self-monitoring. National Pollution Discharge Elimination System (NPDES) self-monitoring has worked satisfactorily with quality assurance monitoring being done by the agency. Adequate quality assurance is a key component of rigorous monitoring programs, along with study design, indicators, and data analyses. It would be wise to incorporate quality assurance monitoring into the new criteria for the 401 permitting process. If not

already done so elsewhere, it would be useful if DEQ describes how it will assure quality for diffuse discharges from agriculture, livestock, logging, roads and driveways, and recreational mining?

*Vague terminology*. IMST finds that the document contains many imprecise and arbitrary terms in the proposed turbidity criteria (p. 8–10). Examples of this can be found in many places, but a few examples here should suffice for illustration. For example, in Table 1.1 (p. 10), section (e)(A) what does the term " cannot practically comply" mean? Or in the same table, subsection (e)(D), how will DEQ "coordinate with" Oregon Department of Fish and Wildlife before authorizing turbidity exceedance under this regulation? The proposed turbidity criteria also "may allow the default value of 1 NTU when background data are unavailable". Who makes this determination and how is this decided? Lastly, in subsection (g)(A), what is the definition of "all reasonable and practicable measures" and who decides this standard? Also, more explicit information is needed if readers are to understand how the visual criterion for monitoring without a turbidity meter is described (p. 51). This is a potentially very important source of monitoring information if it can be done accurately and precisely with minimal effort. There are other terms and standards that are vaguely or undefined (see editorial comments). IMST suggests that DEQ give more precise definition and standards to terms contained within the proposed turbidity criteria if it is to avoid imprecise interpretations amongst readers.

## REFERENCES


Barrett, J.C., Grossman, G., and Rosenfeld. 1992. Turbidity-induced changes in reactive distance of rainbow trout. Transactions of the American Fisheries Society. 121: 437–443.

Bash, J., Berman, C., and Bolton, S. 2001. Effects of turbidity and suspended solids on salmonids. Center for Streamside Studies, University of Washington, Seattle.

Beauchamp, D.A., Baldwin, C.M., Vogel, J.L., and Gubala, C.P. 1999. Estimating diel, depth-specific foraging opportunities with a visual encounter rate model for pelagic piscivores. Can. J. Fish. Aquat. Sci. Vol. 56 (Suppl. 1):128–139.

Berg, L.1982. The effect of exposure of short-term pulses of suspended sediment on the behavior of juvenile salmonids. Pages 177–196 in G. F. Hartman et al. editors. Proceedings of the Carnation Creek workshop: a ten year review. Department of Fisheries and Oceans, Nanaimo, BC.

Biggs, B.J., Stevenson, R.J., and Lowe, R.L. 1998. A habitat matrix conceptual model for stream periphyton. Archives fur Hydrobiologie 143:21–56.

Drake, D. 2004. Selecting reference condition sites: An approach for biological criteria and watershed assessment. Oregon Department of Environmental Quality. Technical Report WAS04-002.

Gregory, R.S., and Levings, C.D. 1996. The effects of turbidity and vegetation on the risk of juvenile salmonids, *Oncorhynchus* sp., to predation by adult cutthroat trout, *O. clarkii*. Environmental Biology of Fishes 46:279–288.

Hughes, R.M., and Gammon, J.R. 1987. Longitudinal changes in fish assemblages and water quality in the Willamette River, Oregon. Transactions of the American Fisheries Society 116:196–209.

Hughes, R.M., Kaufmann, P.R., Herlihy, A.T., Intelmann, S.S., Corbett,, S.C., Arbogast, M.C., and Hjort, R.C. 2002. Electrofishing distance needed to estimate fish species richness in raftable Oregon rivers. North American Journal of Fisheries Management 22:1229–1240.

Independent Multidisciplinary Science Team (IMST). 1999. Recovery of wild salmonids in western Oregon forests: Oregon Forest Practices Act rules and measures in the Oregon Plan for Salmon and Watersheds. Technical Report 1999-1 to the Oregon Plan for Salmon and Watersheds, Governor's Natural Resources Office, Salem, Oregon.

Judy, R.D., Seeley, P.N., Murray, T.M., Svirsky, S.C., Whitworth, M.R., and Ischinger, L.S. 1984. 1982 National fisheries survey, volume 1 technical report: initial findings. FWS/OBS-84/06. U.S. Fish and Wildlife Service. Washington, DC.

Kaufmann, P.R., and Hughes, R.M. 2006. Geomorphic and anthropogenic influences on fish and amphibians in Pacific Northwest coastal streams. Pages 429–455 in R.M. Hughes, L. Wang, and P.W. Seelbach, editors. Landscape influences on stream habitat and biological assemblages. American Fisheries Society, Symposium 48, Bethesda, Maryland..

Kilgour, B.W., and Stanfield, L.W. 2006. Hindcasting reference conditions in streams. Pages 623–639 in R.M. Hughes, L. Wang, and P.W. Seelbach, editors. Landscape influences on stream habitat and biological assemblages. American Fisheries Society, Symposium 48, Bethesda, Maryland.

Lane, P.N.J. and Sheridan, G.J. 2002. Impact of an unsealed forest road stream crossing: water quality and sediment sources. Hydrological Processes 16:2599–2612.

Larimore, R.W, and Smith, P.W.1963. The fishes of Champaign County, Illinois, as affected by 60 years of stream changes. Bulletin of the Illinois State Natural History Survey 28:299–382.

Lloyd, D.S. 1987. Turbidity as a water quality standard for salmonid habitats in Alaska. North American Journal of Fisheries Management. 7:34–45.

Mazur, M.M. and Beauchamp, D.A. 2003. A comparison of visual prey detection among species of piscivorous salmonids: effects of light and low turbidities. Environmental Biology of Fishes 67: 397–405.

McCabe, G.D., and O'Brien, W.J. 1983. The effects of suspended silt on feeding and reproduction of *Daphnia pulex*. American Midland Naturalist 110:324–337.

Mebane, C.A., Maret, T.R. and Hughes, R.M. 2003. An index of biological integrity (IBI) for Pacific Northwest rivers. Transactions of the American Fisheries Society 132:239–261.

Naymik, J., Pan, Y. and Ford, J. 2005. Diatom assemblages as indicators of timber harvest effects in coastal Oregon streams. Journal of the North American Benthological Society 24:569–584.

Newcombe, C.P. 2003. Impact assessment model for clear water fishes exposed to excessively cloudy water. Journal of the American Water Resources Association. 39(3): 529–544.

Riseng, C.M., Wiley, M.J., Stevenson, R.J., Zorn, T.G., and Seelbach, P.W. 2006. Comparison of coarse versus fine scale sampling on statistical modeling of landscape effects and assessment of fish assemblages of the Muskegon River, Michigan. Pages 557–576 in R.M. Hughes, L. Wang,

and P.W. Seelbach, editors. Landscape influences on stream habitats and biological assemblages. American Fisheries Society, Symposium 48, Bethesda, Maryland.

Tarzwell, C.M., and Gaufin, A.R. 1953. Some important biological effects of pollution often disregarded in stream surveys. Purdue University Engineering Bulletin 1953:295–316.

Trautman, M.B. 1981. The fishes of Ohio. Ohio State University Press. Columbus.

US Environmental Protection Agency (USEPA). 2000. Ambient water quality criteria recommendations: Information supporting the development of state and tribal nutrient criteria. Rivers and Streams in Nutrient Ecoregion II. EPA 822-B-00-015.

US Environmental Protection Agency (USEPA). 2005. Use of biological information to better define designated aquatic life uses in state and tribal water quality standards: tiered aquatic life uses. Office of Water, Washington, DC.

Van Sickle, J., Baker, J., Herlihy, A., Bayley, P., Gregory, S., Haggerty, P., Ashkenas, P., and Li, J.. 2004. Projecting the biological condition of streams under alternative scenarios of human land use. Ecological Applications 14:368–380.

Vogel, J.L., Beauchamp, D.A.. 1999. Effects of light, prey size, and turbidity on reaction distance of lake trout (*Salvelinus namaycush*) to salmonid prey. Canadian Journal of Fisheries and Aquatic Sciences 56:1293–1297.

Wang, L., Seelbach, P.W., and Hughes, R.M. 2006. Introduction to landscape influences on stream habitats and biological assemblages. Pages 1–23 in R.M. Hughes, L. Wang, and P.W. Seelbach, editors. Landscape influences on stream habitats and biological assemblages. American Fisheries Society, Symposium 48, Bethesda, Maryland.

Warren, C.E. 1971. Biology and water pollution control. W.B. Saunders. Philadelphia.

Zorn, T.G., and Wiley, M.J. 2006. Influence of landscape characteristics on local habitat and fish biomass in streams of Michigan's lower peninsula. Pages 375–393 in R.M. Hughes, L. Wang, and P.W. Seelbach, editors. Landscape influences on stream habitats and biological assemblages. American Fisheries Society, Symposium 48, Bethesda, Maryland.

**EDITORIAL COMMENTS**

Page 3, second square bullet – "..some point sources should not have limits"
What is the basis for this assumption?

Page 4, Section 1.1.2 – What is the meaning of "open-ended narrative"? It is not explicit to the reader.

Page 6, sub section (b) "Dredging, construction or ..." These should be better defined for the reader. What limitations and conditions would be included with such permits for certifications?

Page 6, Section 1.2.2.3 – Section title is incorrect and should include wording to denote the inclusion of British Columbia (perhaps insert "provinces"). Also, there are >52 states and territories (consider Puerto Rico, U.S. Virgin Islands, American Samoa, Guam, Marianas)

Page 6, Section 1.2.2.3, 2nd paragraph – Reword introduction to paragraph. It begins "No state other than..." but then includes British Columbia which in not a state.

Page 8, Section 1.2.3.2, 3rd paragraph—Algae are probably the most sensitive taxa to light, and little is discussed herein about them.

Page 8, Section 1.2.3.3, 2nd paragraph – How far is "up-stream" for calculating historical turbidity? How is it determined if it is not a set distance?

Page 10, (A) – What does "the source cannot practicably comply" mean?

Page 11, Table "Turbidity Criteria Points of Compliance" – Is this table a continuation of Table 1.1 or a new table? What are the bases for the numbers used in this table besides being in statute? How were the numbers chosen?

Page 11, 1st paragraph – What is this statement based on (i.e., data or an assumption) "...The 3 and 5 NTU allowances provide a high level of protection...". In the 4th line of the paragraph, what does "use protection" mean? How is "use" defined here (e.g., beneficial use, permitted use)?

Page 12, Section 2.1.1—Sediments are also important transporters of nutrients.

Page 15, Section 2.41, 2nd paragraph – "streams are typically relatively clear" Relative to what? Is there an NTU range that would be considered "relatively clear" or other metric?

Page 17, Table 2.3 – What is the basis for quality rankings of letter grades used in this table? How are they determined for a site (e.g., what separates an "A" site from a "B" site)?

Page 18, Figure 2.1 “non-outlier range” What is a non-outlier and how is the range determined?

Page 20, Section 3.12., 1st paragraph – “biological or behavior” behavior is biological. And not all endpoints in Table 3.1 fit into these categories especially the ones related to water supply, aesthetics, and recreation.

Page 21, Table 3.1 – under the category for fish and aquatic life should, egg mortality be included if turbidity becomes fine sediment? Assemblage structure could be included for biota. Also, fish are aquatic life.

Page 22, Section 3.2.1, 1st paragraph – why is 10% a significant change – based on data or an arbitrary number?

Page 24, 2nd paragraph, 2nd line – productivity is misspelled as proclivity

Page 26, Section 3.2.2 first line. Direct turbidity effects also include physical injury especially if turbidity is due to silt. Review literature effects on gills, including abrasion.

Page 28, Figure 3.8 – Why is the line linear and not curvilinear? Compare to Figure 3.7.

Page 30, Figure 3.12--How can the increases in feeding rate (mg/min) as NTU increases be explained?

Page 34, 1st paragraph – Northern pikeminnow is the correct name for *P. oregonensis* not squawfish.; “...probably due to olfaction” how is this known? Also, walleye is a better “darkness” predator than pikeminnow.

Page 35, middle of page – Under “severely impaired”, is “poor condition <u>of</u> habitat alienation” a typographical error?

Page 41, Section 3.2.5, 2nd paragraph – “Tolerance to suspended sediment <u>effects</u> at..” Does this need rewording or should “effects” be deleted?

Page 42, Section 3.2.5, 2nd paragraph – The IMST did not <u>recommend</u> a management and policy goal of emulating natural processes. The IMST report states “we conclude that the goal of management and policy should be to emulate (not duplicate) natural processes within their historic range.”

Page 42, Section 3.3.1, 4th paragraph – “required by EPA to protect for *Cryptosporidium*” replace “for” with “against”

Page 48, Section 4.1.3 – Why is 1 NTU used or “may be used” as the default value? Is this an arbitrary number or based on data? And if it “may be used” when can a higher value be use. Why isn’t “will be used”?

Page 48, Section 4.1.3, last two sentences are unclear regarding the default level and background turbidity data in larger systems. Also how are "larger systems" defined? Also replace "void of background data.." with "lacking data on background data". Void means empty, not inhabited, etc.

Page 49, 2nd paragraph beginning with "While measurable..." could be rewritten for clarity and readability.

Page 49, 3rd paragraph – Again, the IMST did not recommend a management and policy goal of emulating natural processes. The IMST report states "we conclude that the goal of management and policy should be to emulate (not duplicate) natural processes within their historic range."

Page 50, Section 4.2.1, 2nd paragraph - How must the model be used and how careful should one be? What is the scope of inference and limitations for the model, these should have been included in the Newcombe (2003) and DEQ may want to describe more limitations as they apply to Oregon.

Page 50, Section 4.2.2., 1st paragraph – What is a self-monitoring program and who is doing the self-monitoring and what quality assurances and controls are used?

Page 52, Section 4.2.4, 2nd paragraph – Why were three weeks chosen as a short period? Is this an arbitrary number?

Page 52, Section 4.2.4.1, 2nd paragraph – Why were 30 NTUs chosen as the cut off level? What is a designated compliance point and how is it designated?

Page 54, Figure 4.2 – There is no caption for this figure. The title should be deleted and a detailed caption inserted. What is the meaning of "in a severity of"? The regression line is driven by one point at roughly 250 days, why aren't there more points between 0 and 250 days?

Page 55, Section 4.2.4.2 – Where were the numbers listed in the recommendation derived from?

Page 62, Section 4.2.6, 2nd paragraph – What is the presumption regarding an observable plume based on?

Page 64, 3rd paragraph recommendation – If the visual observation is in doubt and no turbidity meter is available then what is the course of action?

Page 65 – What is the impact on aquatic biota before thorough mixing occurs?

Page 66, Figure 4.8 – Could the NTUs be put on a logarithmic scale to see if there are break points?

Page 66, Table 4.6 – Why and how were the ranges listed under the column "Proportion of full mix with receiving waters" chosen?

Page 72, USEPA references. It would be wise for the authors to check the accuracy of the USEPA reference titles and document numbers. For example the title used for USEPA (2001) document # EPA 822-B-00-12 does not match the actual document title found at: http://www.epa.gov/waterscience/criteria/nutrient/ecoregions/lakes/lakes_11.pdf

Page 122, Appendix H, 2nd paragraph, 9th line – Is "hierarchies" correct or should "categories" be used instead?