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The purpose of this peer review is to determine whether the scientific basis of the findings concerning water quality impacts of suction dredging for gold are both supported by the literature evaluated by the consultant team contracted by the Department of Fish and Game (DFG) and are based on sound scientific knowledge, methods, and practices. I have limited my comments to findings on the impact of resuspension of mercury and other toxic metals because those are the areas of research with which I am most familiar. These are both areas for which the impacts are considered potentially significant. I have addressed the two questions as they pertain to the findings on mercury and other toxic metals and have added my comments below in italics.

(a) In reading Chapter 4.2 of DFG's in the context of the entire Suction Dredging SEIR, are there any additional scientific issues that are part of the scientific basis not described above? If so, please comment with respect to the statute language given above in the first three paragraphs of Attachment 2.

2. Mercury. Pages 4.2-33 to 4.2-54. Available evidence suggests that suction dredging has the potential to contribute substantially to:

- **Watershed mercury loading (both elemental mercury and mercury-enriched suspended sediment) to downstream reaches within the same water body and to downstream water bodies.**
  I concur that the scientific evidence for this finding is scientifically sound.

- **Methylmercury formation in the downstream reaches of the same water body and in to downstream water bodies (e.g., the Bay-Delta) from dredging caused mercury loading.**
- *I concur that the scientific evidence for this finding is scientifically sound. The studies conducted by Marvin-DiPasquale (2011) are strong support for this finding.*

- **Mercury bioaccumulation and magnification in aquatic organisms in downstream reaches within the same water body and downstream /water bodies.**
  While the scientific data for Hg bioaccumulation downstream of gold dredging operations is minimal, I do strongly concur that mercury bioaccumulation and biomagnifications in downstream aquatic organisms could be substantially increased by the formation of methylmercury from dredging caused mercury loading. Not only would the total mercury burdens increase in biota but the percent of the total that is methylmercury could also increase as the inorganic mercury is transported to higher methylation systems such as reservoirs, floodplains, and wetlands.

- **Increased methylmercury body burdens in aquatic organisms which increase the health risks to wildlife (including fish) and humans consuming these organisms.**
- *I strongly concur that the scientific evidence for this finding is scientifically sound. Methylmercury is largely transferred to higher trophic levels via consumption of food and is preferentially assimilated in animal tissue relative to inorganic mercury. As a result, fish are almost 100% methylmercury. Thus, piscivorous wildlife and humans who consume fish can be exposed to levels of methylmercury that have reproductive, developmental, and neurological consequences.*

In California, suction dredging frequently occurs in streams that were contaminated with mercury beginning in the Gold Rush. Suction dredgers encounter mercury in the forms of elemental mercury, mercury alloyed with gold (amalgam), and mercury-enriched sediment. Both elemental and reactive mercury are adsorbed onto the sediments. Suction dredgers recover and process amalgam because it contains gold. Suction dredge sluices do not capture 100% of the mercury, amalgam, and gold in sediment that passes through them (losses are in the percent range). In addition, suction dredgers dredge fine grained sediment (i.e., 63 micron and smaller) in mercury contaminated streams is at least 10x higher in mercury that what would be considered background for an uncontaminated stream. Suction dredges do not recover sediment finer than 63 microns.

Suction dredges then release mercury and mercury enriched fine-grained sediment that was formerly buried. This mercury may then be transported to aquatic environments where it can be converted into bio-available methylmercury.

I concur with these statements and the potential for methylmercury exposure in aquatic environments downstream of suction dredging activity.

3. Other Trace Metals. Pages 4.2-54 to 4.2-59. Available evidence suggests that while suction dredging has the potential to remobilize trace elements (e.g., cadmium, zinc, copper, and arsenic), the levels of increase:

- **Would not be expected to exceed state or federal water quality criteria by frequency, magnitude, or geographic extent that would result in adverse effects on one or more beneficial uses.**
- *I do not concur with this statement since the spatial variation in toxic metal concentrations in stream sediments is great and dredging activities in toxic metal hotspots could result in mobilization of metals to the water column that would exceed state or federal criteria.*

- **Would not result in substantial, long-term degradation that would cause substantial adverse effects to one or more beneficial uses of a water body.**

While other trace metals do not have the same propensity to biomagnify as mercury, there is still the possibility of these other metals to be bioaccumulated by aquatic invertebrates and fish (Chapman 2003; and the many papers by NS Fisher and his colleagues). I disagree with the assessment in the SEIR that aquatic organisms do not take up metals bound to sediments or only a limited amount from water:

"….metals that are bound to sediment particles are not bioavailable to fish and benthic macroinvertebrates and thus are not in a form that can cause toxicity to aquatic life. Moreover, the dissolved fraction of metals measured is not all bioavailable for uptake by organisms".

Aquatic organisms can bioaccumulate metals from ingesting particles, both organic and sedimentary. They can also take up a great deal of metals from water particularly when the pH and dissolved organic matter conditions are both low (common in these mountain streams). The degree of toxicity from the exposure would entirely depend on the concentrations of metals and the chemistry of the water as the SEIR suggests. But these routes of exposure should not be underestimated since the extent of hotspots and the effects of gold dredging on mobilization of these metals are poorly known.

- **Would not substantially increase the health risks to wildlife (including fish) or humans consuming these organisms through bio-accumulative pathways.**
- *I do not agree with the statement which precedes this finding (p. 4.2-58, lines 29-33) and states that "because trace metals addressed in this assessment are not bioaccumulative constitutuents, the potential to mobilize the trace metals discussed herein would not substantially increase the health risks to wildlife or humans….". The metal contaminants other than mercury being considered here are certainly bioaccumulated by aquatic invertebrates and fish but are not biomagnified like mercury. There is an enormous literature about the exposures and and bioaccumulation of toxic metals by aquatic fauna that supports this but these studies are not included in this SEIR.*
- *"*

  As I have stated above, I do believe that aquatic organisms, e.g. fish, can take up metals from particle ingestion and via uptake from water. Thus, fish could be exposed to health risks from the mobilization and transport of metal contaminated sediments. By dredging up deeper contaminated sediments that may not have been in contact with biota prior to the disturbance of gold dredging, the operation could result in exposures to these metals in surface sediments downstream in which benthic infauna live and benthic feeding fish consume their prey. There is a broad literature that suggests that benthic infauna toxicity is related to porewater concentrations of metals (Besser et al. 2009; D. DiToro and his colleagues). There was no mention of these studies in the review and also no mention of porewater measurements of metals in the areas downstream of contaminated hotspots. Moreover, there are possible indirect effects of metals on fish due to the metal toxicity effects on invertebrate prey that then result in changes in the food *web and subsequent decreases in food availability for fish (Iwasaki et al. 2009). Finally, while chronic or acute effects of metals from disturbed sediments may not be a problem, the effect of metals in hotspot areas likely already have impacts on invertebrate communities (e.g. decreases in diversity) and disturbance from dredging would likely exacerbate that impact (Lefcort et al. 2010)*

- **Would not exceed CTR metals criteria by frequency, magnitude, and geographic extent that could result in adverse effects to one or more beneficial uses, relative to baseline conditions, unless suction dredging occurs at known trace metal hot-spots (e.g., caused by acid mine drainage caused trace metal contaminated sediment and pore water) where high metal concentrations and bio-available forms are present.**
  Until better identification of the geographic extent of hotspots is conducted for mercury or for other trace metals, I don't think that this finding is very useful. If there are extensive hotspots in these watersheds, it is likely that the CTR metals criteria could be exceeded and adverse effects could result.

In California, suction dredging frequently occurs in streams that were contaminated with trace metals beginning in the Gold Rush. Historic base metal mines align along the Sierra Nevada foothill copper belt, and are found in the Klamath-Trinity Mountains. Historic base metal and gold mines discharged their waste to steams if possible until the practice was prohibited in about 1910. In addition, many abandoned base metal mines still discharge metal-rich, acid mine water to streams in California. Although trace metal levels in Sierra Nevada streams have not been thoroughly evaluated (except for site specific data at form mine clean up projects), Regional Water Quality Control Boards have designated numerous stream segments as impaired because of trace metals. Suction dredges discharge trace metal contaminated sediment when operating in a trace metal-contaminated stream

Given that there are many trace metal contaminated streams in which suction dredging is likely to occur, the effects of metal bioaccumulation and toxicity to downstream fauna could be significant.

(b) Taken as a whole, is the scientific evaluation of the water quality effects of suction dredging presented in Chapter 4.2 of DFG's Suction Dredging SEIR based upon sound scientific knowledge, methods, and practices?

For the most part, the SEIR is based on sound scientific knowledge except for the points made above. However, the lack of information on the mercury and other toxic metal distributions in the watersheds is a very important and problematic: "not all locations of elemental mercury deposits (and other metal contamination) are known, the feasibility with which sites containing elemental mercury (or metal contaminated sites) could be identified at a level of certainty that is sufficient to develop appropriate closure areas or other restrictions for allowable dredging activities, is uncertain at this time." This *uncertainty makes the protection of aquatic resources throughout these watershed extremely difficult.*

I also feel that while the review of the Hg literature is extensive and up to date, the review of literature for other toxic metals is less extensive and possibly incomplete. There is an assumption made that metals will be entirely bound to sediments and not bioavailable to aquatic fauna. The references below are just an example of some of the information that would have been useful to this SEIR.

References:

Angelo, RT; Cringan, MS; Chamberlain, DL, et al. 2007. Residual effects of lead and zinc mining on freshwater mussels in the Spring River Bason (Kansas, Missouri, and Oklahoma, USA. Science of the Total Environment 384: 467-496.

Besser, JM; Brumbaugh, WG; Allert, AL, et al. 2009. Ecological impacts of lead mining on Ozark streams: toxicity of sediment and porewater. Ecotoxicology and Environmental Safety 72: 516-526.

Chapman, PM, Wang, F. Janssen, CR, Goulet, RR, Kamunde, CN. 2003. Conducting ecological risk assessments of inorganic metals and metalloids: Current status. Human and Ecological Risk Assessment 9:641-697.

Iwasaki, Y; Kagaya, T; Miyamoto, K, et al. 2009. Effect of heavy metals on riverine benthic macroinvertebrate assemblages with reference to potential food availability for drift feeding fishes. Environmental Toxicology and Chemistry 28: 354-363.

Lefcort, H; Vancura, J; Lider, EL. 2010. 75 years after mining ends stream insect diversity is still affected by heavy metals. Ecotoxicology 19: 1416-1425.