Thomas M. Holsen
Professor
Clarkson University
holsen@clarkson.edu

TO: Douglas F. Smith

FROM: Thomas M. Holsen

SUBJECT: Lake Tahoe TMDL

DATE: Friday, July 24, 2009

Attached is my review of the scientific portion of the Lake Tahoe TMDL. Please let me know if you have any questions or would like any additional information.

The *Draft Lake Tahoe Total Maximum Daily Load (June 2009)* is a well-written document that explains, synthesizes and summarizes an extremely large and complex group of studies. Leading up to this report separate, extensive investigations of many aspects of the Lake Tahoe ecosystem with regards to water clarity were carried out. Portions of this prior work have undergone extensive peer-review (for example the Lake Tahoe Atmospheric Deposition Study). Clearly there are still many unanswered questions however, taken as a whole, I believe the scientific portion of the proposed rule is based upon sound, state-of-the-art, scientific and technical knowledge, methods, and practices. Given the amount of money available the science program was reasonably used to fill in knowledge gaps and when available, historical data was appropriately used. One criticism of this report is that data from the peer-reviewed published literature was rarely compared to the measurements and modeling results presented (see specific comments below). Never-the-less, the proposed course of action is reasonable and will likely improve the clarity of Lake Tahoe in a cost-effective manner.

Answers to the questions posed to the reviewers are detailed below however it should be noted that my expertise, as it pertains to this study, is in atmospheric deposition. It is that portion of the report that I read the most critically and that generated the most comments.

1. Determination of fine sediment particles (<16 micrometers) as the primary cause of clarity impairment based on interpretation of scientific studies, available data, and the Lake Clarity Model.

The Lake Clarity Model which indicates that clarity loss is primarily due to the number of fine sediment particles suspended in the water column is reasonable based on the data presented. In other lakes inorganic, or minerogenic particles have also been found to make substantial, and in some cases dominant, contributions to light scattering (Davies-Colley et al., 2003; Kirk, 1985; Peng and Effler, 2005, 2007). In a very recent paper nonspherical clay mineral particles in the 1–10 mm size range were found to be the dominant form of light scattering and turbidity in interconnected reservoirs and the intervening creeks in New York (Peng et al, 2009).

References

Davies-Colley, R.J., Vant, W.N., Smith, D.G., 2003. Colour and Clarity of Natural Waters: Science and Management of Optical
Water Quality. Blackburn Press, Caldwell, NJ.

Kirk, J.T.O., 1994. Light and Photosynthesis in Aquatic Ecosystems. Cambridge University Press, UK.

Peng, F., Effler, S.W., 2005. Inorganic tripton in the Finger Lakes of New York: importance to optical characteristics. Hydrobiologia 543, 259–277.

Peng, F., Effler, S.W., 2007. Suspended minerogenic particles in a reservoir: Light-scattering features from individual particle analysis. Limnol. Oceanogr 52 (1), 204–216.

Peng, F., Effler, S.W., Pierson, D.C., Smith, D.G. Light-scattering features of turbidity-causing particles in interconnected reservoir basins and a connecting stream Water Research 43 (2009) 2280 – 2292

2. Identification of the six sources of pollution affecting lake clarity of which urban upland areas was found to be the primary source of fine sediment particles causing Lake Tahoe's clarity loss.

The finding that urban upland areas are the primary source of the fine sediment particles causing Lake Tahoe's clarity loss is justified based on the data and analysis presented. Since this region is relatively remote with limited amounts of traffic and industry this finding makes sense. One shortcoming noted in the discussion of this finding is the lack of comparison to other similar studies in other locations.

3. Determination that the Lake Tahoe Watershed Model was an appropriate model to estimate upland pollutant source loads.

The Lake Tahoe Watershed model is based on an EPA-approved watershed model. It contains a complex system of sub-models including hydrodynamic, ecological, water quality, particle and optical. As with any of these types of models that attempts to simulate complex environmental systems, the underlying physical processes are approximated using mathematical descriptions. A large number of variables are needed to characterize the physical processes, many of which are unknown or poorly constrained. In addition there are usually missing or poorly known input data which also contains errors. To overcome these challenges the error (direct and cumulative) produced in the model prediction is minimized by calibration and the calibrated model is validated using an independent data set. Typically values in the literature are used for variables not known.

Based on the description of the model development, calibration, variables used and validation using an independent data set I believe the model is appropriate for estimating upland pollutant source loads. The model was able to simulate most of the seasonal trends over the five-year period and the results of the sensitivity analysis were reasonable.

4. Determination that estimates of groundwater nutrient loading rates are reasonable and accurate.

Given the fact that two different approaches (USACE and Thodal (1997)) generated loadings estimates that were very similar gives confidence that the loadings estimates are reasonable.

5. Pollutant loading rates from atmospheric deposition directly to the lake surface were quantified and in-basin sources were found to be the dominant source of both nitrogen and fine particulate matter. Direct deposition of dust accounts for approximately 15% of the average annual fine sediment particle load.

Accurately quantifying particle and nutrient deposition, and particularly dry deposition, is extremely difficult. Overall the work summarized and synthesized in this section is a credible effort to quantify these loadings. The shortcomings and uncertainties in the approaches used are generally adequately discussed. However often there are too many significant figures used (up to five in Table 4-56 for example) which conveys a sense of certainty that is clearly not justified. Since there is no generally accepted method to measure or model deposition it would be very useful to compare the deposition estimates with the wealth of similar information that is available in peer reviewed literature and also as part of U.S. EPA sponsored networks. For example there are NADP wet deposition data for several sites relatively near Lake Tahoe. A quick review of the NADP CA50 site suggests wet deposition ammonia fluxes are very similar at that site as estimated for Lake Tahoe. There are also CASTNET sites in Yosemite and at high elevations in the Rockies that estimate dry N deposition (although not to water surfaces so they would have to be adjusted accordingly). Both NADP and CASTNET data are available on the web and easily accessible. As another example Ahn and James (Water Air & Soil Pollution, 126,1-2, 2001) discussed P deposition measurements made in S. Florida since 1974. The average mean and standard deviation of the estimated P deposition rates for 13 sites were 41±33 mg P m^{-2} yr^{-1} – virtually the same as estimated for Lake Tahoe. Given the inherent uncertainties in the estimates used in this work comparing them to other measurements would increase the confidence in the results presented.

Other specific comments:

The importance of indirect atmospheric deposition is not clearly addressed. Page 4-111 indicates that pollutants that fall on the land are included in the evaluation of groundwater and upland loading however this topic is not clearly addressed in those sections either.

For completeness there should be more discussion on the importance of what might be called “natural sources” (forest fires, pollen, leaves, pine needles, bird droppings etc) on loadings to the lakes. These sources may be important, although difficult to quantify and control.

Loadings from fugitive dust from vehicular traffic on both paved and unpaved roads may be important. Although this source is discussed in other sections there is limited or no discussion of this source in the atmospheric deposition section.

There was no real source apportionment work done to characterize in-basin vs. out-of-basin sources of atmospheric contaminants. I find this to be a fairly serious short-coming of this work since it could directly address important questions about locations of sources and source-apportionment of atmospheric sources is a fairly well developed science. However the conclusions that most of the dust, N and P is probably from in-basin sources is reasonable given Lake Tahoe’s geography and meteorology.

P 4-120 last paragraph. How was it determined that the values are “adequate first estimates”?
P 4-130-131. This section should include results or be linked to a table. Currently it is not clear if the DRI data were actually used. The units for deposition velocity in the equation and the paragraph immediately following the equation are different which is confusing. The units for flux should be mass/area time not mass/area/time.
P 4-137 2nd para. A mention of work by Liu (2002) is made but the results are not presented or discussed. This work seems relevant so results should be included. The last

two sentences of this paragraph are very important and deserve their own paragraph (and probably should be expanded on).
P4-147 last para. I do not believe including unpublished data (Hackey) without a description of how it was collected and a critical evaluation of its accuracy is warranted in a report of this type.
P4-150 bottom. The discussion of only the Lake Tahoe emission inventory is not germane to the section topic of "regionally transported vs local sources." To be useful the total emissions in the basin would need to be compared to regionally emissions.
P4-151 2nd para. "…LTADS also concluded….. It is not clear what "also" is refereeing to. It implies that ammonia deposition it primarily of local origin which is in conflict with the preceding sentence.

P4-152. The statement that constituents of road dust are less soluble than fine particles from wood smoke or other combustion sources needs a reference.

6. Pollutant Reduction Opportunity (PRO) analysis identifies fine sediment particle and nutrient reduction options that can be quantified. The PRO findings offer basin-wide pollutant load reduction estimates and costs for a range of implementation alternatives for reduction loads from urban uplands, forest uplands, stream channel erosion, and atmospheric deposition sources.

The evaluation of pollutant load reduction opportunities for the major pollutant sources is well documented and thorough. The project organization around the four Source Category Groups, led by local and regional experts in their respective fields is well conceived and lends credence to the results obtained. The finding that the largest, most cost effective opportunities for fine sediment particle load reductions are from the urban upland source is a reasonable, well justified conclusion.

7. Lake Clarity Model was the most appropriate for predicting the lake response to changes in pollutant loads.

The Lake Clarity Model, used for estimating Secchi depth in Lake Tahoe, accounts for a number of variables, including algal concentration, suspended inorganic sediment concentration, particle size distribution, and colored dissolved organic matter. The model is a complex system of sub-models including hydrodynamic, ecological, water quality, particle and optical. Some (but not all) of these sub-models have been published in the peer-reviewed literature. Similar to the Lake Tahoe Watershed model the model was calibrated and then validated using an independent data set.

Based on the description of the model development, calibration, variables used and validation using an independent data set I believe this model is appropriate for predicting the lake response to changes in pollutant loads. The model was able to simulate historical Secchi depths and the predicted responses to changes in loads are reasonable. The discussion on pages 6-42 through 6-44 that substantiate the reasonableness of the model are convincing.

8. Allocation of allowable fine sediment particle and nutrient loads is based on the relative magnitude of each pollutant source's contribution and the estimated ability to reduce fine sediment particle and nutrient loads.

The Recommended Strategy for achieving load reductions builds on the Pollutant Reduction Opportunity analysis and incorporates detailed scientific investigation and extensive stakeholder input. Because the urban landscape contributes the largest percentage of the fine sediment particle load and because urban stormwater controls represent the greatest control opportunity, urban stormwater dischargers rightly bear the brunt of the reduction responsibility (approx 25% of the 32% total reduction or approx 75%). Forest upland, stream channel erosion and atmospheric deposition load reductions make up the remaining 25%. Overall the findings are well documented and reasonable.

Other minor comments:

The 3rd paragraph on page 3-7 (vertical mixing increases transparency) contradicts the last paragraph on page 6-3 (mixing decreases transparency). This should be rectified.

Page 8-5. There are several typos in the 1st paragraph

Table 8-3 page 8-6. Why are N+P controls less effective than N and P controls by themselves? (Maybe there are too many significant figures used in this table.)

Page 9-5 and elsewhere. It is indicated that street sweeping will be used to capture 10 µm particles – don't you mean particles <10 µms?