Peer Review –
Machado Lake Eutrophic, Algae, Ammonia, and Odors (Nutrient) TMDL

Report Prepared by

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Summary

The Machado Lake TMDL report is reviewed. The report is well-written, and organized according to the elements of a TMDL analysis. The data, modeling analyses, and the pollutant allocation have been presented in a scientifically credible manner. The two areas of concern are: (i) model validation, and (ii) lack of ammonia data. The model needs to be tested against a dataset that was not used in the calibration. If no data are available, the model calibration-validation sections (Section 5.1.1 and 5.1.2) of the report should be combined and called as model application. Since the report is about a TMDL analysis for ammonia, ammonia data must be presented even if ammonia levels in the lake are less than the presumed toxicity levels.

The detailed comments are as follows:

Machado Lake

The Regional Board Staff should mention that Machado Lake is a rapidly flushing lake. The hydraulic retention time (τ) on a completely mixed, annual average flow basis can be estimated from

$$\tau = V/Q = 0.114 \times 10^6 \text{ m}^3/8.45 \times 10^6 \text{ m}^3/\text{yr} = 5 \text{ days}$$

The implication of the low retention time on the water quality in the lake is that it will attain a new steady-state very quickly (~ 3 τ) although, the sediment will respond more gradually and the chlorophyll will show any reduction only after phosphorus limitation is reached in the lake.

Water Quality Data

The report adequately describes the available in-lake total phosphorus (TP), total nitrogen (TN), chlorophyll, dissolved oxygen (DO) and Secchi disk (SD) data to determine the trophic status of the lake.

Can a timeseries of total ammonia levels in the lake be included since TMDL analysis for ammonia is required? Also, DO depth-profiles should be shown to illustrate that the lake is polymictic with periods of stratification and destratification. Further, it will help the reader understand the severity of the DO problem in the lake and provide a basis for explaining the dynamics of internal sediment release of nutrients and reduced chemical species.

Development of targets

Selection of chlorophyll *a* is an appropriate target to address the eutrophication issue in Machado Lake. A numeric target of 20 µg/L chlorophyll *a* on a seasonal average basis is consistent with EPA guidance (U.S. EPA 2000) and is attainable according to the modeling analysis presented in the report. Total phosphorus and total nitrogen targets of 100 µg/L and 1000 µg/L, respectively, are generally consistent with the eutrophy observed in other lakes and reservoirs (Bartsch and Gakstatter 1978 as cited in Chapra 1997).

Ammonia: Ammonia is an important component of the nitrogen cycle of freshwater bodies. It is toxic to aquatic life at low concentrations (U.S. EPA 1985, 1999). The TMDL Report states that ammonia was found to be at levels below the toxicity standards. However, no quantitative details were provided regarding the evaluation of ammonia toxicity criteria in the lake. The Regional Board Staff should consider adding a section on ammonia toxicity criteria in the TMDL Report where the following details could be provided:

(i) review of available total ammonia (sum of ionized and un-ionized forms of ammonia) data
(ii) review of pH and temperature data to compute the allowable concentrations – the criterion continuous concentration (CCC) that is intended to protect aquatic life against chronic toxicity effects (U.S. EPA 1991)
(iii) a comparison of the in-lake total ammonia levels with the computed CCC values

The Basin Plan objective for ammonia for chronic exposure of 2.2 mg/L is based upon *median* values of pH and temperature data. This appears to be not protective enough of aquatic life for ammonia toxicity (e.g., Gelda and Effler 2003). Although, the total nitrogen target of 1 mg/L is conservative, the implementation of it on a water-column, monthly average basis is not consistent with that of the ammonia target. For example, an ammonia exceedance can occur whenever the instantaneous concentration is above the CCC, and an ammonia excursion can occur whenever the average concentration over the specified duration of the averaging period (4 days; U.S. EPA 1985) is above the CCC (U.S. EPA 1991). Presenting the detailed ammonia data in the report will be helpful even if ammonia levels in the lake are less than the presumed toxicity levels.

Source Assessment

Internal nutrient loading: The nutrient release rates were determined from sediment cores collected from a single location in the lake. Are there data available (e.g., from sediment surveys) to support the assumption of spatial homogeneity of sediment characteristics?

Table 10: Instead of using "Summer" and "Winter", specify actual months considered in the computation (e.g., May-October).

The estimated total annual loads of TP and TN entering Machado Lake are generally consistent with the observed in-lake concentrations. As shown below, a simplified mass balance analysis of TP and TN can independently corroborate the estimated loads.

TN mass balance:
Assuming that (i) Machado Lake is a completely mixed system, (ii) TN in the lake is conservative, i.e., net loss of N from the system via denitrification or through burial is insignificant; the following mass balance equation can be written:

$$V\frac{dc}{dt} = W_{ext} + W_{\text{int}} - Qc \qquad \text{Eq. 1}$$

where, V = lake volume, W_{ext} = external loading of TN, W_{int} = internal loading of TN, Q = outflow, and c = in-lake TN concentration.
Under steady-state conditions, $dc/dt = 0$, therefore, $c = (W_{ext} + W_{int})/Q$.

Substituting in the above equation the annual total load of TN and assuming that outflow is the same as inflow, the in-lake TN concentration can be obtained from

c = (24327 kg/yr) / (8.45 x 10^6 m^3/yr) = 2.88 mg/L

which matches closely the observed average concentration of 2.7 mg/L for 2006-07 interval.

Linkage Analysis – Modeling

The Regional Board Staff have chosen to use BATHTUB, a steady-state empirical water quality model, for the linkage analysis. BATHTUB is an example of hybrid class of models that uses mass balance and multiple segments to characterize transport, but to quantify kinetics, it uses empirically derived relationships. In the diagnostic mode, it can be used to formulate water and nutrient balances, including identification and ranking of potential sources of prediction error. In the predictive mode, it can be used to assess impacts of changes in nutrient loadings. BATHTUB can also estimate nutrient loadings consistent with given water quality management objectives.

Although, empirical water quality models are rarely used to make water quality management decisions, BATHTUB is an adequate tool to perform TMDL analysis for Machado Lake because the lake is shallow, small and rapidly flushing without any complex morphometric and hydrodynamic features. Further, the temporal and spatial extent of the data available for this lake is extremely limited and does not support the development and testing of a dynamic, fully mechanistic mass balance model.

The Regional Board Staff used 2006-07 data to calibrate the model but it was not clear what data were used to validate the model. It appears that the validation was performed by simply using the average values observed in 2006-07. This cannot be called as the model validation because the underlying dataset is the same as used in the calibration. To validate or confirm the calibrated model, it should be tested with a new data set, preferably which reflects entirely different forcing conditions. Can the Staff use 1992-93 data for validation? If no data are available, the model calibration-validation sections (Section 5.1.1 and 5.1.2) of the report should be combined and called as "model application".

Can BATHTUB predict typical DO concentrations for the current and future nutrient loading conditions of Machado Lake? Some qualitative description on how the DO target will be achieved should be included in the report. If oxic hypolimnion is achieved round-the-year, it would stop the release of odor causing sulfides from the sediments.

What will be the typical Secchi disk transparency for the future nutrient loading conditions? How will the increased Secchi disk transparency affect the macrophyte population in the lake? Macrophytes in Machado Lake may result in a more stable and diverse ecosystem but too much of it may have undesirable effects as well. The Staff should consider adding some discussion on this topic as the macrophytes play a role in nutrient recycling, reduce wind-induced resuspension of sediment, and alter the aesthetics of the lake.

Wasteload and Load Allocations

Concentration based allocations are appropriate for this lake for the reasons mentioned in the report.

The Staff should discuss the implications of interim WLA in the report, particularly of TP. As mentioned in the report, an interim WLA value of TP of 0.41 mg/L ($= 0.41 \times 8.45 \times 10^3 = 3465$ kg/yr) will not result in any substantial improvement in the lake with regard to chlorophyll because this level of phosphorus is still in the saturated region of phytoplankton growth curve (Figure 12 of the report). This is important from the point of view of managing expectations of the public and stakeholders. The lake will respond very rapidly once the TP load is reduced to less than 2000 kg/yr (Figure 12 of the report). Further, the Staff should discuss that the reduction in deposition of particulate organic matter will take place associated with reduction in the phytoplankton growth in the water-column after the implementation of the final WLA. As a result, the internal release rates of phosphorus and nitrogen will also be lower in the future. A sediment model may be needed to predict how long will it take for the sediment to come to a new steady-state and what would be the magnitude of the future release rates.

Margin of Safety and Critical Conditions

The load capacity was based on dry weather conditions. What was the return frequency of these dry weather conditions? Any records of the water surface elevation in the lake can also be presented, if available. These data will establish a quantitative basis for the selection of critical conditions.

For this system, it is appropriate to consider the margin of safety implicitly by making conservative assumptions about the loads, the targets, and the critical conditions.

Monitoring Program

Monitoring of total sulfides (in the absence of oxygen) in the hypolimnion of the lake may be included in the program as it is related to the odor problem in the lake.

Also, monitoring of the lake level (i.e., water surface elevation) may be included in the program.

Lake Management Implementation Options

The selection of specific implementation option(s) may depend upon factors such as cost, technical, and engineering feasibility. A critical review of pros and cons of specific alternatives is outside the domain of expertise of this reviewer. But it is worth reiterating that the lake sediment will begin to respond naturally after the final WLA has been implemented. The lake sediment will receive particulate organic matter that is significantly less than the current levels. The previously and newly deposited organic matter will continue to undergo aerobic/anaerobic decomposition and will come into a new equilibrium state eventually. A sediment model could help determine the magnitude and the timing of new steady-state release rates of phosphorus and nitrogen, and could decide the requirements of LA.

References

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