Appendix B – Responses to Peer Reviews

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Linda S. Adams
Secretary for Environmental Protection

State Water Resources Control Board

Office of Research, Planning, and Performance
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Arnold Schwarzenegger
Governor

RECEIVED
APR 23 2009
By DFS

TO: Douglas F. Smith, Chief
TMDL/Basin Planning Unit
Lahontan Regional Water Quality Control Board

Gerald W. Bowes

FROM: Gerald W. Bowes, Ph.D.,
Manager, Cal/EPA Scientific Peer Review Program
Office of Research, Planning and Performance

DATE: April 21, 2009

SUBJECT: SCIENTIFIC PEER REVIEWERS FOR LAKE TAHOE NUTRIENT AND SEDIMENT TMDL

In response to your request for peer reviewers for the subject noted above, the University of California, through an Interagency Agreement with Cal/EPA, identified candidates it considered qualified to perform this assignment. Each candidate was required to complete and sign a Conflict of Interest Disclosure form.

After my review of the disclosure forms, I contacted selected candidates to provide clarification where necessary and confirmation they could perform an objective and independent review free of conflict of interest and bias. I forwarded to approved reviewers my latest (January 7, 2009) supplement to the Cal/EPA peer review guidelines, and am attaching it here. Please read it carefully. The approved reviewers are identified below.

1. Patrick L. Brezonik, Ph.D.
   Professor of Environmental Engineering
   Department of Civil Engineering
   University of Minesota
   Minneapolis, MN 55455

   Telephone: (612) 625-0866
   Email: brezonik@umn.edu

2. Menachem (Meny) Elimelech, Ph.D.
Roberto Goizueta Professor and Chair
Department of Chemical Engineering
Environmental Engineering Program
Yale University
New Haven, CT 06520-8286

Telephone: (203) 432-2789
Home Page: http://www.yale.edu/env/elimelech/bio.html
Email: menachem.elimelech@yale.edu

3. Thomas M. Holsen, Ph.D.
Professor
Department of Civil and Environmental Engineering
W.J. Rowley Laboratory, Box 5710
Clarkson University
Potsdam, N.Y. 13699-5710

Street Address: 8 Clarkson Avenue

Telephone: (315) 268-3851
Fax: (315) 268-7985
Email: tholsen@clarkson.edu

4. William M. Lewis, Jr., Ph.D.
Associate Director
Cooperative Institute for Research in Environmental Sciences
Professor and Director
Center for Limnology
216 UCB, CIRES
Boulder, CO 80309-0216

Telephone: (303) 492-6378
Fax: (303) 492-0928
Email: william.lewis@colorado.edu

5. John Melack, Ph.D.
Professor
Bren School of Environmental Science and Management
University of California
Santa Barbara, CA 93106

Telephone: (805) 893-7363
Fax: (805) 893-7612
Email: melack@lifesci.ucsb.edu

Biographical information for the approved reviewers is provided with this memorandum.

Please contact your reviewers right away. Tell them when you will transmit the material. They have accepted the assignment based on the date of availability given in your letter of request to me. If preparation of the material is delayed, ask them if the new date is acceptable, including me as a "cc." If subsequent delays occur, inform the reviewers and me as soon as possible. I am often contacted by reviewers and the University if delays occur and reviewers are not kept up to date.

If the number of pages you plan to send the reviewers is significant, I recommend you provide them a hard copy of this material. You can enquire if any would prefer an electronic copy as well. Ask them (1) if their preferred mailing address is the same as that given above; and (2) to provide whatever additional information is necessary for an overnight delivery service.

Provide a cover letter to initiate the review process. Include with it your request letter to me, which provides a concise synopsis for your intended actions, and its three attachments. **Please inform them that their review must follow the guidance provided in Attachment 2.**

When the reviews have been completed, please let me know and send me a copy of each review and cover letter to the reviewers for the review files I keep here.

If I can provide additional help, contact me at any time during the review process.

Attachments

cc: Sheila Vassey, Office of Chief Counsel (w/o biographical material)
Rik Rasmussen, Division of Water Quality (w/o biographical material)

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Doug Smith - Lake Tahoe TMDL Peer Review Request

From: Doug Smith
Subject: Lake Tahoe TMDL Peer Review Request

Sent via email on 6/4/2009:

Hello Professor,

The Draft Lake Tahoe TMDL is ready for your review! I will send the PDFs in separate email, shortly.

Please refer to the attached Lake Tahoe Peer Review Request & Attachments-REVISED 2009.pdf for details on the eight issues I am asking to be reviewed. I made some minor edits in Attachments 1 & 2 and marked those changed pages as "REVISED June 4, 2009"; all other pages remain unchanged. In Attachment 1, I changed the fine sediment particle number from < 20 micrometers to < 16 micrometers to be accurate and consistent with the research. In Attachment 2, I added a paragraph within each issue discussion to highlight where supporting information can be found in the TMDL documents.

As a courtesy to you, I am sending a hard copy of all the documents along with a CD of the documents to help your review. I will send the hard copies out on Monday June 8 to the address you provided, below, unless you direct me to send the documents to a different address. When I send the hard copies, I will email you the courier service information and tracking number.

The second attachment to this email is a two-page Word document summarizing the proposed policy changes to the Lahontan Regional Water Quality Control Plan. I am not asking you to review the proposed changes. Rather, the summary is intended to give context for potential policy changes based on the science supporting the Lake Tahoe TMDL, subject to the external peer review comments.

I am asking that your review address the issues in Attachment 2 in the sequence given. I would greatly appreciate you submitting your completed review to me between July 6, 2009 and July 20, 2009. Please do not hesitate to contact me if you have any questions or if you need help navigating through the mountain of documents. Thank you!!!

Doug

==
Douglas F. Smith, PG
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Chief, TMDL & Basin Planning Unit
Lahontan Water Board
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California Regional Water Quality Control Board
Lahontan Region

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Secretary for Environmental Protection

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Arnold Schwarzenegger
Governor

MEMORANDUM

TO: Dr. Gerald Bowes
State Water Resources Control Board
Division of Water Quality
P.O. Box 100
Sacramento, CA 95812

FROM: Douglas F. Smith
Chief of the TMDL/Basin Planning Unit

DATE: November 12, 2008

SUBJECT: REQUEST TO INITIATE SCIENTIFIC PEER REVIEW PROCESS FOR LAKE TAHOE WATERSHED TOTAL MAXIMUM DAILY LOAD (TMDL) FOR SEDIMENT AND NUTRIENTS

Lahontan Water Board staff request that you begin the process for selection of scientific peer reviewers for the draft Basin Plan Amendment for the Lake Tahoe TMDL. The TMDL is a joint effort between Lahontan and the Nevada Division of Environmental Protection (NDEP). Lake Tahoe, located in both California and Nevada, sits between the crest of the Sierra Nevada Mountains on the west and the Carson range on the east. Sixty-three streams flow into Lake Tahoe, and the Lake's one outlet, the Truckee River, drains into Pyramid Lake located in Nevada.

Lake Tahoe is listed pursuant to the federal Clean Water Act, Section 303(d), for impairment due to an excess loading of nutrients and fine sediment particles. Lahontan Water Board staff expects the draft amendment will be circulated for public review in 2009, and brought to the Water Board for consideration in late 2009. At least four peer reviewers are requested to cover four specific disciplines: 1) limnology, with expertise in estimating load capacity and lake response to pollutant input, 2) watershed water quality/hydrology, with expertise in source load estimates, 3) water quality resources management, with expertise in non-point source assessment and best management practices, and 4) atmospheric science, with expertise in the transport and deposition of nutrients and fine sediment particles. In addition to the four disciplines listed above, peer reviewers with expertise in non-point source pollution and biogeochemistry, as related to limnology and water quality, would be appropriate additions.

Peer reviewers are asked to determine whether the scientific portion of the Lake Tahoe TMDL Staff Report and proposed Basin Plan Amendment is based upon sound scientific knowledge, methods, and practices. These documents should be available for peer review by the week of February 2, 2009. Attachment 2 provides more information on the technical and scientific issues to be addressed by the peer reviewers. Supporting information used to develop the Lake Tahoe TMDL and Basin Plan Amendment will be provided for the peer reviewers' reference, including three specifically significant documents, the Lake Tahoe TMDL Technical Report (2008), the Pollutant Reduction Opportunity Report (March 2008), and the Integrated Water Quality Management Strategy Report (March 2008). These three documents are summarized in the Lake Tahoe TMDL Staff Report and will be sent to the peer reviewers as documents in PDF format on a disk.

I understand from the California Environmental Protection Agency's November 2006 guidance document that, after reviewing the attached summaries, you will contact the State Board's contractor to arrange for identification of potential peer reviewers. Once reviewers have been identified, communication with them will be Water Board staff's responsibility. Due to the timeline for public review and Board consideration, I request that the peer review process be completed within 30 days of receipt of the review materials.

Five Attachments are provided as part of this peer review request: (1) a summary of the Lake Tahoe TMDL, (2) a summary of the technical and scientific issues that may require peer review, (3) a list of scientists, engineers, and land-use planners external to the State or Water Board involved in previous studies related to the TMDL, (4) a list of peer reviewed publications relied on for the Lake Tahoe TMDL, and (5) a list of non-peer reviewed publications relied on for the Lake Tahoe TMDL.

Please contact me at our South Lake Tahoe office if you have any questions or need further information. You may reach me at (530) 542-5453; my email address is dfsmith@waterboards.ca.gov. Thank you.

cc: David Coupe, Office of Chief Counsel, SWRCB
Rik Rasmussen, Division of Water Quality, SWRCB
Joanne Cox, Division of Water Quality, SWRCB
Jason Kuchnicki, Nevada Division of Environmental Protection
Larry Benoit, Tahoe Regional Planning Agency

Attachments

Attachment 1

Background of the Lake Tahoe TMDL

The proposed amendment is a plan to control the fine sediment particle and nutrient inputs that are impacting Lake Tahoe's famed clarity. This plan, known as the Lake Tahoe Total Maximum Daily Load (TMDL), identifies the basin-wide budget of fine sediment particles less than 16 micrometers (µm) and nutrients (total nitrogen and total phosphorus) and estimates the total load reductions for these pollutants that are needed to restore clarity. The amendment will (1) describe the impacts of fine sediment particles and nutrients on relevant beneficial uses designated for the Lake, (2) propose numeric targets to interpret narrative sediment and nutrient-related water quality objectives, and (3) provide an estimate of pollutant source loads and load reductions needed to improve the transparency and clarity to meet the water quality objectives.

The maximum allowable pollutant loads, or TMDL, will be allocated to major source categories in the Lake Tahoe basin according to land use types and estimates of sediment/nutrient control efficiencies. For the urban source category the pollutant loads will be allocated to specific jurisdictions. The amendment will include a plan of implementation, describing the general nature of actions needed to control fine sediment particles and nutrients entering the lake, and an initial monitoring plan to determine the success of these measures.

To facilitate TMDL development, Water Board staff contracted with University of California-Davis and Tetra Tech, Inc., entities which in turn sub-contracted with various academic and consulting groups, to study sediment, nutrients (total nitrogen and total phosphorus) and turbidity conditions affecting the Lake Tahoe watershed. These studies helped develop a basin-wide budget of pollutant inputs associated with each significant source category (e.g., upland runoff, atmospheric deposition). Additionally, Water Board staff contracted with Tetra Tech, Inc. and Environmental Incentives Inc. to determine types of pollutant control measures that could be used to restore Lake Tahoe. The products from these studies will be provided to the peer reviewers for their reference.

The draft Lake Tahoe TMDL document prepared by Water Board and NDEP staff is based on our interpretation of data from these comprehensive research studies. Our interpretation is that Lake Tahoe is not capable of assimilating the current loads of fine sediment particle and nutrient inputs. This phenomenon is indicated by years of clarity measurements showing the Lake is not meeting the clarity and transparency standards developed by the Water Board. Additionally, 2007 Secchi disk measurements demonstrate the Lake has lost more than seven meters of annual average clarity depth since measurements began in 1968. TMDL research indicates that fine sediment particles (< 16 µm in diameter) are a leading cause impacting the Lake's clarity: However, the importance of nutrient reduction is also recognized.

Urban runoff, forest runoff, stream channel erosion, atmospheric deposition, and shoreline erosion are all contributing factors that deliver fine sediment particles to Lake Tahoe. The largest percent contribution of fine sediment particles is generated in urban areas from its associated commercial, residential, and roadway network.

The Lake Tahoe TMDL is a plan to restore Lake Tahoe's historic transparency and clarity.

Attachment 2

Description of the Scientific Basis of the TMDL and Issues to be Addressed

The statute mandate for external scientific peer review (Health and Safety Code Section 57004) states that the reviewer's responsibility is to determine whether the scientific portion of the proposed Basin Plan Amendment is based upon sound scientific knowledge, methods, and practices.

We request that you make this determination for each of the following issues that constitute the scientific basis of the proposed regulatory action. An explanatory statement is provided for each issue to focus the review.

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

Although Lake Tahoe is on the Clean Water Act 303d list as impaired due to sediment and nutrient inputs, the primary indicator of these impairments is the loss in transparency as measured by Secchi disk depth. The Lake Clarity Model, developed, calibrated, and validated by UC Davis, indicates clarity loss is primarily due to the number of fine sediment particles suspended in the water column. Specifically, the number of particles with a diameter of less than 16 µm is responsible for the majority of the clarity condition. Increased primary productivity driven by elevated nitrogen and phosphorus inputs is a lesser, but still important, factor in Lake Tahoe's clarity loss. Based on the model's predictive capability, the Lake Tahoe TMDL implementation plan emphasizes fine sediment particles as the target pollutant. Nutrient load reductions are also important but to a lesser degree as compared to fine sediment particle load reductions. All three pollutant loads will be allocated and load reductions will be tracked.

Your review for this issue should focus on the summary information in Chapters 3 and 8 in the Draft TMDL, and for detailed information, you should focus on Chapters 3.4, 5, and 6 in the TMDL Technical Report.

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.**

Staff, contracted researchers, and consultants created a pollutant loading budget for three forms of sediment (total suspended sediment mass, < 63 µm mass, and < 16 µm particle number), phosphorus and nitrogen. The loading budget identified six pollutant sources: urban uplands, forest uplands, atmospheric deposition, groundwater, shoreline erosion, and stream channel erosion. Of these sources, urban uplands was found to contribute more than 70% of the total fine sediment particle load as measured by the number of particles less than 16 µm in diameter. The reliability of these estimates was checked using a number of approaches including field monitoring, modeling and comparison to previously reported studies in the Tahoe basin.

Your review for this issue should focus on the summary information in Chapter 7 of the Draft TMDL and, for detailed information, you should focus on Chapter 4 of the TMDL Technical Report.

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

The Lahontan Water Board contracted with the University of California, Davis and Tetra Tech, Inc. to determine the magnitude of fine sediment and nutrient loads from upland sources (undeveloped and developed). Building on the EPA-approved Load Simulation Program in C++ (LSPC) watershed model, Tetra Tech developed the watershed-specific Lake Tahoe Watershed Model capable of estimating average annual loads from a variety of different land use conditions, including rural and urban areas. The model results indicate approximately 9% and 72% of the average annual fine sediment particle load is generated in the undeveloped and urban uplands, respectively.

Your review for this issue should focus on the summary information in Chapter 7.5 of the Draft TMDL and, for detailed information, you should focus on Chapter 4.3 in the TMDL Technical Report. For additional detail regarding the selection and development of the Lake Tahoe Watershed Model, please see the *Watershed Hydrologic Modeling and Sediment and Nutrient Loading Estimate for the Lake Tahoe Total Maximum Daily Load* report, dated February 2007.

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

The United States Army Corp of Engineers (USACE) completed an evaluation in 2003 to analyze available groundwater data and estimate groundwater nutrient inputs to Lake Tahoe and its tributary streams. By dividing the Lake Tahoe Basin into regional groundwater sub basins, the USACE 2003 evaluation refined previous groundwater loading estimates, evaluated ambient groundwater nutrient loading rates, and identified potential groundwater pollution sources. Based on this information, the Lake Tahoe TMDL program determined that groundwater contributes approximate 12% and 15% of the average annual nitrogen and phosphorus loads, respectively.

Your review for this issue should focus on the summary information in Chapter 7.2 of the Draft TMDL and, for detailed information, you should focus on Chapter 4.1 in the TMDL Technical Report.

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.**

Because the Lake's surface area (501 km^2) is large relative to its watershed drainage area (812 km^2), the Lake Tahoe TMDL team spent significant time and resources to quantify nutrient and particulate loading from direct atmospheric deposition. In cooperation with the California Air Resources Board (CARB), the TMDL team undertook a multi-year science program to quantify the contribution of dry atmospheric deposition. The 2006 *Lake Tahoe Atmospheric Deposition Study*, conducted by CARB, augmented long-term atmospheric data collected by the University of California, Davis. Based on these studies, the Lake Tahoe TMDL found that atmospheric deposition contributes 55% of the average annual nitrogen load directly to the lake.

Your review for this issue should focus on the summary information in Chapter 7.6 of the Draft TMDL and, for detailed information, you should focus on Chapter 4.5 of the TMDL Technical Report.

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 Water Board contracted with Tetra Tech, Inc. to conduct a thorough evaluation of pollutant load reduction opportunities for the major pollutant sources. The project was organized around four Source Category Groups, led by local and regional experts in their respective fields. These groups screened potential treatment options on (1) the ability to treat the pollutants of concern and (2) the ability to quantify load reduction effectiveness. The analysis results provide the basis for the Lake Tahoe TMDL implementation strategy. The PRO analysis found the largest, most cost effective opportunities for fine sediment particle load reductions are from the urban upland source.

Your review for this issue should focus on the summary information in Chapter 9 of the Draft TMDL. Details of each Source Category Group analysis approach are described in Chapters 2-5 of the Lake Tahoe TMDL Pollutant Reduction Opportunity Report v2.0 (March 2008). Combined results summarizing the basin-wide estimated load reductions and associated costs can be found in Chapter 6 of that report. Chapter 2 of the Integrated Water Quality Management Strategy Project Report outlines the Recommended Strategy for TMDL implementation, while Chapter 3 of that document describes how the Pollutant Load Reduction Opportunity analysis was used to develop the Recommended Strategy.

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

Researchers at the University of California at Davis developed the Lake Clarity Model to predict how Lake Tahoe's Secchi depth may respond to changing pollutant input over time. The Lake Tahoe TMDL program used the Lake Clarity Model to predict how the lake's transparency is expected to change in response to the proposed implementation approach.

Your review for this issue should focus on the summary information in Chapter 8 of the Draft TMDL and, for detailed information, you should focus on Chapter 6 of the TMDL Technical Report.

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

Fine sediment particle and nutrient loads were allocated based on the relative source loads and the ability to control fine sediment particles and nutrients from the primary contributing land uses. The efficacy of various pollutant control options was evaluated and provided the basis of the recommended implementation strategy. 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 bear the brunt of the reduction responsibility. Current programs to reduce fine sediment particle and nutrient loads from undeveloped forest areas and stream channel erosion are adequate and cost effective. Dust control measures offer further opportunities for fine particle reductions from atmospheric deposition and are included in the implementation approach.

Your review for this issue should focus on Chapter 10 of the Draft TMDL. Chapter 5 of the Integrated Water Quality Management Strategy Project Report describes the load allocation analysis methods for dividing allocations by responsible jurisdiction and summarizes the different load allocation approaches considered. Your attention should focus on Approach II, Load Source Weighted, as this was the chosen load allocation approach.

The Big Picture

Reviewers are not limited to addressing only the specific issues presented above, and are asked to consider the following questions:

(a) In reading the staff technical reports and proposed implementation language, are there any additional scientific issues that are part of the scientific basis of the proposed rule not described above?

(b) Taken as a whole, is the scientific portion of the proposed rule based upon sound scientific and technical knowledge, methods, and practices?

(c) Was the science program reasonably designed to fill in knowledge gaps: was historical data appropriately used.

Reviewers should also note that some proposed actions may rely significantly on professional judgment where available scientific data is not as extensive as desired to support the statute requirement for absolute scientific rigor. In these situations, the proposed course of action is favored over no action.

The preceding guidance will ensure that reviewers have an opportunity to comment on all aspects of the scientific basis of the proposed Board action. At the same time, reviewers also should recognize that the Board has a legal obligation to consider and respond to all feedback on the scientific portions of the proposed rule. Because of this obligation, reviewers are encouraged to focus feedback on the scientific issues that are relevant to the central regulatory elements being proposed.

Additional Materials Provided to the Peer Reviewers

The Lake Tahoe TMDL Technical Report references numerous projects that were funded as part of the Lake Tahoe TMDL. These numerous studies, which are listed below, are also provided for the peer reviewers since these studies were intended for direct use in the Lake Tahoe TMDL Technical Report. In some cases, the language from portions of those project reports was directly incorporated into the text of the Technical Report.

Groundwater

USACE (United States Army Corps of Engineers). 2003. *Lake Tahoe Basin Framework Study: Groundwater Evaluation*. U.S. Army Corps of Engineers, Sacramento District.

Stream Channel

Simon, A., E.J. Langendoen, R.L. Bingner, R. Wells, A. Heins, N. Jokay and I. Jaramillo. 2003. *Lake Tahoe Basin Framework Implementation Study: Sediment Loadings and Channel Erosion*. USDA-ARS National Sedimentation Laboratory Research Report. No. 39.

Simon, A. 2006. *Estimates of Fine-Sediment Loadings to Lake Tahoe from Channel and Watershed Sources*. USDA-Agricultural Research Service, National Sedimentation Laboratory. Oxford, MS.

Atmospheric

CARB (California Air Resources Board). 2006. *Lake Tahoe Atmospheric Deposition Study (LTADS)*. Final Report – August 2006. Atmospheric Processes Research Section, California EPA, Sacramento, CA.

Upland

Tetra Tech, Inc. 2007. *Watershed Hydrologic Modeling and Sediment and Nutrient Loading Estimation for the Lake Tahoe Total Maximum Daily Load.* Final modeling report. Prepared for the Lahontan Water Board and the University of California, Davis.

Shoreline Erosion
Adams, K.D. 2004. Shorezone erosion at Lake Tahoe: Historical aspects, processes, and stochastic modeling. Final report for the U.S. Bureau of Reclamation and the Tahoe Regional Planning Agency. Desert Research Institute, Reno, NV.

Adams, K.D. and T.B. Minor. 2001. *Historic Shoreline Change at Lake Tahoe from 1938 to 1998: Implications for Water Clarity.* Desert Research Institute, Reno, NV. Prepared for the Tahoe Regional Planning Agency.

Lake Clarity Modeling
Sahoo, G.B., S.G. Schladow and J.E. Reuter. 2007. *Linkage of Pollutant Loading to In-lake Effects.* University of California, Davis – Tahoe Environmental Research Center. Prepared for the Lahontan Water Board.

Water Quality Planning
Lake Tahoe TMDL Pollutant Reduction Opportunity Report. Environmental Incentives, LLC., prepared for the Lahontan Water Board and the Nevada Division of Environmental Protection. March 2008

Integrated Water Quality Management Strategy Project Report, Environmental Incentives LLC, prepared for the Lahontan Water Board and the Nevada Division of Environmental Protection. March 2008

Attachment 3

Scientists, Engineers, and Land Use Planners Involved in Studies Related to the Lake Tahoe Watershed Sediment and Nutrient TMDL

FEDERAL AGENCIES

1. ***U.S. Army Corps of Engineers***
   Meegan Nagy, Melissa Kieffer, Lewis Hunter, Timothy Crummett, Teresa Rodgers, John Baum, Elizabeth Caldwell, Scott Gregory, Suzettee Ramirez, Glenn Cox, Richard Meagher

2. ***U.S. Environmental Protection Agency***
   Jacques Landy, Jane Freeman

3. ***U.S. Geological Survey***
   Tim Rowe, Kip Allander

4. ***U.S. National Park Service***
   Lee Tarnay

5. ***U.S. Department of Agriculture (USDA), United States Forest Service – Lake Tahoe Basin Management Unit***
   Sue Norman, Denise Downey, German Whitley, Joey Keeley, Craig Oehrli

6. ***USDA – National Sedimentation Laboratory, Oxford, MS***
   Andrew Simon, Eddie Langendoen, Ron Bingner, Brian Bell, Loren Klimetz, Danny Klimetz, Mark Griffith, Charlie Dawson, Robert Wells, Amanda Heinz, Nick Jokay, Igor Jaramillo

STATE AGENCIES

1. ***California Air Resources Control Board***
   Earl Withycomb, Eileen McCauley, Leon Dolislager, Tony VanCuren, Jim Pederson, Ash Lasgari, Bart Croes, Richard Corey, Dongmin Luo, William Vance, Clinton Taylor, Steve Mara, Deborah Popejoy, Michael Fitzgibbon, Jerry Freeman, Pat Vaca

2. ***California Department of Transportation (Caltrans)***
   Jody Jones, Amarjeet Benipal, Joe Caputo, John Rodrigues, Katrina Pierce, Steve Kirkpatrick, John Webb, Douglas Coleman, Leslie Case, Bill Davis, Tom Brannon, Jody Brown, Scott McGowen, Joyce Brenner, Karl Dreher, Keith Jones, Daniela Guthrie, Mitch Mysliwiec, John Johnston

3. ***California Tahoe Conservancy (CTC)***

Judy Clot, Kim Carr

4. ***Tahoe Regional Planning Agency (Bi-state agency, California and Nevada)***
   Larry Benoit, Sean Dougan, John Stanley, Charles Emmett, Karen Fink

5. ***Nevada Department of Transportation (NDOT)***
   Steve Cooke

6. ***Nevada Division of Environmental Protection***
   Jason Kuchnicki

7. ***Nevada State Lands***
   Charlie Donohue, Elizabeth Harrison

8. ***Nevada Tahoe Conservation District***
   Matt Vitale, Doug Martin, Scott Brown

9. ***Tahoe Resource Conservation District***
   David Roberts – formerly with the California Regional Water Quality Control Board - Lead author of Draft Lake Tahoe Maximum Daily Load Technical Report, September 2007

UTILITY DISTRICT

1. ***South Tahoe Public Utility District***
   Ivo Bergsohn

STATE UNIVERSITIES

1. ***University of California, Davis – Tahoe Environmental Research Center***
   John Reuter, Geoff Schladow, Goloka Sahoo, Scott Hackley, Tom Cahill, Steve Cliff, Ted Swift, Joaquim Perez-Losada, Alan Jassby, Bob Richards, Charles Goldman, Jenny Coker, Alex Rabidoux, Mark Grismer, Andrea Parra, Colin Strasenburgh, Raph Townsend, Lev Kavvas, Michael Anderson, Patty Arneson, Mark Palmer, Tina Hammell, George Malyj, David Jassby, Brant Allen, Debbie Hunter

2. ***University of Nevada, Reno***
   Jerry Qualls, Joseph Ferguson, Anna Panorska, Wally Miller

3. ***University of Nevada, Reno - Desert Research Institute***
   Alan Heyvaert, Jim Thomas, Ken Adams, Ken Taylor, Todd Mihevc, Gayle Dana, Rick Susfalk, Melissa Gunter, Alan Gertler, Tim Minor, Paul Verburg, Mary Cablk, Erez Weinroth

ENVIRONMENTAL SCIENCE AND ENGINEERING CONSULTANTS

1. ***2NDNATURE, LLC***
   Nicole Beck, Maggie Mathias, Nick Handler

2. ***Countess Environmental***
   Richard Countess

3. ***Environmental Incentives***
   Jeremy Sokulsky, Chad Praul

4. ***Entrix***
   Steve Peck, Mike Rudd

5. ***GeoSyntec***
   Eric Strecker, Jim Howell, Andi Thayumanavan, Marc Leisenring

6. ***Hydroikos***
   Bob Coats, Matt Luck

7. ***Integrated Environmental Restoration Services***
   Michael Hogan, Kevin Drake

8. ***Kieser & Associates***

9. ***Northwest Hydraulic Consultants (nhc)***
   Ed Wallace, Brent Wolfe

10. ***Tetra Tech, Inc.***
    John Riverson, Leslie Shoemaker, Clary Barreto, Andrew Parker, John Craig, Will Anderson

11. ***Valley and Mountain Consulting***
    Virginia Mahacek

Attachment 4
Peer Reviewed Publications Cited in the Lake Tahoe TMDL Report

* Publications followed by and asterisk have been subjected to a peer review process different than that for publications in scientific journals.

Adams, K.D., and T.B. Minor. 2002. Historic shoreline change at Lake Tahoe from1938 to 1998: implications for sediment and nutrient delivery. Journal of Coastal Research, 18(4), 637-651.

Arhonditsis, G.B., M.T. Brett. 2005. Eutrophication Model for Lake Washington (USA) Part I. Model description and sensitivity analysis. Ecological Modelling, 187, 140-178.

Bates, B.C., Z.W. Kundzewicz, S. Wu and J.P. Palutikof, Eds. 2008. Climate Change and Water. Technical Paper of the Intergovernmental Panel on Climate Change, IPCC Secretariat, Geneva, 210 pp.*

Beauchamp, D.A., B.C. Allen, R.C. Richards, W.A. Wurtsbaugh, and C.R.Goldman. 1992. Lake Trout Spawning in Lake Tahoe: Egg Incubation in Deepwater Macrophyte Beds. North American Journal of Fisheries Management, 12, 442-449.

Bicknell, B.R., J.C. Imhoff, J.L. Kittle, A.S, Donigian, Jr. and R.C. Johanson. 1997. Hydrological Simulation Program - FORTRAN, User's manual for version 11. Athens: USEPA, EPA/600/R-97/080.*

Bowie, G.L., W.B. Mills, D.B. Porcella, C.L. Campbell, J.R. Pagenkopf, G.L. Rupp, K.M. Johnson, P.W.H. Chan, S.A. Gherini and C.E. Chamberlain. 1985. Rates, constants, and kinetics formulations in surface water quality modeling, Tetra Tech, Incorporated. Second ed. Athens, U.S. Environmental Protection Agency, EPA 600/3-85/040, 455 p.*

Bradu, D. and Y. Mundlak. 1970. "Estimation in Lognormal Linear Models." Journal of the American Statistical Association, 65(329), 198-211.

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PROPOSED AMENDMENTS TO THE WATER QUALITY CONTROL PLAN FOR THE LAHONTAN REGION TO ENSURE CONSISTENCY WITH RECENT SCIENTIFIC FINDINGS AND THE LAKE TAHOE TMDL IMPLEMENTATION PLAN

The Lake Tahoe TMDL program describes a restoration plan to halt Lake Tahoe's transparency decline and restore the lake's clarity over time. To affect this change, the Lahontan Water Board is amending the Water Quality Control Plan for the Lahontan Region (Basin Plan) to incorporate the Lake Tahoe TMDL and change portions of the Basin Plan to be consistent with recent scientific information and the Lake Tahoe TMDL implementation approach.

1. Lake Tahoe TMDL Summary

Water Board staff will add a sub-section to Basin Plan Chapter 5 - *Water Quality Standards and Control Measures for the Lake Tahoe Basin* summarizing the Lake Tahoe TMDL. The summary will include a brief overview of the TMDL research findings, a detailed synopsis of the TMDL implementation plan, and the pollutant load allocation tables.

2. Pollutants of Concern

Current Basin Plan text emphasizes the role nutrients (nitrogen and phosphorus) play in Lake Tahoe's clarity decline. The proposed amendment will add reference to fine sediment particles in all discussions of water quality impairment and pollutant reduction efforts to highlight the role this pollutant plays in transparency decline. Amendment language will emphasize fine sediment particles as a discreet pollutant independent of nutrients while maintaining existing references to nitrogen and phosphorus as additional pollutants affecting Lake Tahoe's transparency.

3. Replace Stormwater Effluent Limits with TMDL Load Allocations

The Basin Plan currently includes concentration-based numeric effluent limits for stormwater discharges to surface waters and for infiltration facilities discharging to ground water. According to the Basin Plan, these limits are to be applied on a site- or project-specific basis in response to identified erosion or runoff problems.

The proposed Basin Plan amendment replaces the existing nitrogen, phosphorus, and turbidity effluent limits with mass-based pollutant source load allocations for fine sediment particles, nitrogen, and phosphorus to protect beneficial uses related to Lake Tahoe's transparency.

Existing concentration-based receiving water standards for oil and grease, iron, turbidity and nutrients will remain in place.

4. Replace the 20-year Compliance Date ending in 2007 with the TMDL Implementation Plan Timeline

The Tahoe Regional Planning Agency (TRPA) developed the Water Quality Management Plan for the Lake Tahoe Basin (208 Plan) which was amended in 1988. In numerous instances, the Basin Plan references the 208 Plan and the associated 20-year compliance date ending in 2007 for implementing water quality control measures in the Tahoe watershed.

The proposed Basin Plan amendment will remove references to the 208 Plan compliance schedule and replace it with the timeline for the Lake Tahoe TMDL Implementation Plan.

5. Specify Stormwater Treatment Efficiencies for Small Scale Projects

The Basin Plan currently includes a requirement for facilities to be designed to treat the 20-year, 1-hour design storm for stormwater in the Lake Tahoe Hydrologic Unit. This design guidance requires project proponents to capture and/or treat approximately one inch of stormwater runoff from the project area.

Project proponents, particularly municipal jurisdictions and other entities planning stormwater treatment facilities at the catchment or sub-watershed scale (i.e. projects typically greater than one acre), need flexibility to consider a variety of design storms for planning sub-watershed or catchment scale water quality improvements. Resource managers also need established standards for determining whether smaller projects (on parcels less than one acre) effectively meet stormwater control requirements.

The proposed Basin Plan amendment removes strict references to compliance with the treatment design standard for a 20-year, 1-hour design storm for stormwater and establishes new stormwater treatment facility guidelines.

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Lake Tahoe Sediment and Nutrient TMDL

Response to Peer Review Comments

William M. Lewis, Jr.

Peer Review Received: July 9, 2009

Review of

The Lake Tahoe Watershed Total Maximum Daily Load (TMDL) for Sediment and Nutrients

Prepared for the California Regional Water Quality Control Board

TMDL/Lahontan Basin Planning Unit

Prepared by: William M. Lewis, Jr.

Date of Preparation: 9 July 2009

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Date of Preparation: 9 July 2009

This review is designed to meet the requirements described in a memorandum prepared by Doug Smith, Chief of the TMDL/Lahontan Basin Planning Unit, California Regional Water Quality Control Board, Lahontan Basin, dated 12 November 2008 and revised 4 June 2009. The purpose of the review, as given on page 3 of the memorandum, is to determine whether the scientific portion of the proposed basin plan amendment is based upon sound scientific knowledge, methods, and practices. The memorandum specifies eight issues that are to serve as the focus of the review, and directs the reviewers to specific sections of the draft TMDL report, the TMDL technical document, and supporting documents for information to be reviewed. This review is organized around the eight issues identified in the memorandum.

I) Fine sediment particles as the primary cause for impairment of clarity.

a. Draft TMDL report: comments.

1. The TMDL text of special interest here (Section 3) is poorly crafted in that it is awkwardly presented and in some places confusing or factually incorrect. This defect does not invalidate the section as a contribution to the TMDL, but it would be better if the text were revised so that it can be understood more easily and be free of misleading or incorrect statements (see below).

2. The opening statement, on page 3-1 contains a number of errors. Nutrients are not examples of particles, contrary to the text. The reference to "floating" algae is off the mark; the main concern for Lake Tahoe would be suspended algae (phytoplankton) in open water and attached algae (periphyton) near shore. Also, it is unlikely that leaves would be among the organic particles found in Lake Tahoe; breakdown products of leaves might appear in small amounts.

3. Conventions set by the regulatory agencies appear to distinguish between transparency

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3. Conventions set by the regulatory agencies appear to distinguish between transparency

1

WL-1: The text in Chapter 3 of the Final Report has been revised to clarify the points about nutrients, algae, and leaves.

and clarity. This distinction, however, is not common knowledge and should be explained in the text. The report should state that, for purposes of this TMDL, transparency will be understood to refer to the secchi depth measurement and clarity will be assumed to refer to the extinction coefficient, as estimated by measurements of irradiance in the water column. The two are quite closely related, but the effect of particles on transparency is somewhat more drastic than it is on extinction coefficient, in that particles cause a cloudiness in water that interferes with the perception of objects even where there is enough light for vision.

4. The text associated with Figure 3-1 is erroneous, as is the figure itself. The text states that water does not absorb light. This is patently incorrect (see TMDL technical report). Pure water absorbs light and also scatters light. The proportion of light absorbed or scattered depends on wavelength. Particles also both absorb and scatter light, and do so differentially with respect to wavelength. Although the diagram in Figure 3-1 comes from a reputable study (PhD dissertation), it apparently misled the author of the TMDL draft, and should be either corrected or eliminated.

5. The opening page of Section 3 identifies pure water and particulate matter as factors that explain the decline of light with depth in the lake (although the relative mechanisms of decline caused by scattering vs. absorption are not explained). A key omission here is the role of dissolved organic matter, which has an additional effect on the absorption of light in water. This effect is most pronounced where humic and fulvic acids are present in water. These materials are derived from watersheds (soils) primarily. They are highly chromatic in that they cause rapid light extinction when present. They are present in all waters, but obviously are not abundant in Lake Tahoe,

Response

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WL-2: Though clarity is measured by the vertical extinction coefficient while transparency is measured by the Secchi disk depth, the public commonly refers to Lake Tahoe's Secchi depth as the "clarity". Therefore this TMDL uses "clarity" in the general sense to refer to the Secchi depth unless specifically stated as the clarity measurement of vertical extinction coefficient. Changes were made throughout the Final Report, Chapters 1-8, where appropriate in light of this distinction.

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WL-3: The text was modified in the Final Report, Section 3.1; and the Technical Report, Section 3.4.1, to correct the discussion. The figure was removed from the Final Report (Figure 3-1) and the Technical Report (Figure 3-8).

5. The opening page of Section 3 identifies pure water and particulate matter as factors that explain the decline of light with depth in the lake (although the relative mechanisms of decline caused by scattering vs. absorption are not explained). A key omission here is the role of dissolved organic matter, which has an additional effect on the absorption of light in water. This effect is most pronounced where humic and fulvic acids are present in water. These materials are derived from watersheds (soils) primarily. They are highly chromatic in that they cause rapid light extinction when present. They are present in all waters, but obviously are not abundant in Lake Tahoe,

2

WL-4: The issue of colored dissolved organic matter (CDOM) has been added to the text in Section 3.1 of the Final Report and Section 3.4.1 of the Technical Report. Swift (2004) measured CDOM in the lab and CDOM is included as a specific parameter in the optical sub-model for the Lake Clarity Model. Because of the ultra-oligotrophic nature of Lake Tahoe's waters, Swift found light attenuation due to CDOM to be minor; however, CDOM was measured and is part of the Lake Clarity Model.

which otherwise would not have such high transparency (see TMDL technical report). Mention of this occurs as an aside later in the Section, but a reader who is unaware of the CDOM effect may be confused.

6. Figure 3.3 is difficult to interpret. What is the assumed abundance or mass per unit volume of particles upon which this graph is based? The graph is meaningless without a more complete explanation of the underlying assumptions or of the observations that are portrayed here.
7. Figure 3-4 also cannot be easily interpreted based on the labels (see also TMDL technical report). The scattering effect of pure water is not labeled on the graph. Inorganic particles are labeled “sediment” although sediment is the name for all particles and not just inorganic particles. Organic particles are termed “algae” although it has already been stated that organic particles include other items.
8. On page 3-4, a reference is made to phytoplankton primary production before 1850. The wording of the sentence suggests that researchers were studying primary production before 1850. The author means to say that researchers have estimated production that occurred prior to 1850, but without measuring it (see the TMDL technical document).
9. On page 3-4, the box explanation of primary production is not very clear. The organisms in question need to be capable of photosynthesis. The byproduct is organic matter (a better term than “food” in this context).
10. On page 3-7, the last sentence in paragraph two could be a bit misleading. “Mixing” is used in two ways here: with reference to the seasonal mixing, which does not always reach the bottom of the lake, and with reference to mixing of the entire water

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3

Response

WL-5: The text was modified to clarify this graph (Figure 3-2) in the Final Report in Sections 3.1 and 3.2 and in the Technical Report for Figure 3-8 in Section 3.4.1.

WL-6: The figure and captions have been revised in both the Final Report (Figure 3-4) and Technical Report (Figure 3-11).

WL-7: The text has been revised in the Final Report, Section 3.4.1 to state that researchers estimated phytoplankton primary productivity before 1850.

WL-8: The text inside this 'call-out' box in the Final Report, Section 3.4.1 has been revised with more details explaining primary production.

WL-9: The text in Section 3.5 of the Final Report has been revised to clarify the difference between annual deep mixing and mixing of the lake's entire volume. Additional text and a new figure (Figure 3-16) with the historic time series for annual depth of lake mixing has been added to the Technical Report in Section 3.4.2.

column, which occurs at multiyear intervals. The last sentence seems to say, but does not intend to say, that seasonal mixing occurs on an irregular basis. It would be better to state that Lake Tahoe shows an annual deep mixing that has seasonal regularity, but that mixing of the entire lake volume occurs on an irregular basis at multiyear intervals.

11. Page 3-8. At the bottom of page 3-8, periphyton is defined as "attached filamentous algae." Periphyton includes all attached algae, not just filamentous species. References to "excessive" algae and "extra" nitrogen or phosphorus are a bit difficult to interpret. It would be better to say that the amount of periphyton in a given environment may increase if concentrations of phosphorus and nitrogen increase.

12. Section 8 comes through more clearly than Section 3, although it does raise a number of questions, as explained below.

13. On page 8-1, the first of a number items refers to the simulation of "secchi depth clarity." Because Section 3 made a distinction between transparency (secchi depth) and clarity (extinction coefficient), the reversion to use of secchi depth as an index of clarity in this chapter is confusing and inconsistent.

14. In Figure 8-1, the output of the upper part of the flow diagram is shown as total pollutant load. Actually, this load is more correctly referred to as total load. Only a portion of this total is traceable to pollution. We cannot count every ounce of phosphorus, nitrogen, or suspended solids as pollution. Also, in the same diagram, there is a reference to CDOM, which comes in from the watershed mostly. It is good to have this component in the model, but the means of estimating it is not given in the text, nor is any information given on the treatment of CDOM in the model.

Response

column, which occurs at multiyear intervals. The last sentence seems to say, but does not intend to say, that seasonal mixing occurs on an irregular basis. It would be better to state that Lake Tahoe shows an annual deep mixing that has seasonal regularity, but that mixing of the entire lake volume occurs on an irregular basis at multiyear intervals.

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4

WL-10: The text in Section 3.6 of the Final Report was revised to clarify that periphyton amounts may increase if phosphorus and nitrogen concentrations increase.

WL-11: Changes have been made throughout the Final Report to be consistent in terminology between clarity and transparency and specifically, the word clarity has been deleted from Section 8.1 in the Final Report. (See response WL-2)

WL-12: Not all nutrient and fine sediment loading to Lake Tahoe (and to other waterbodies) is a pollutant. The word 'pollutant' was removed from Figure 8-1 in the Final Report and Figure 6-1 in the Technical Report. The term 'pollutant' is used in the TMDL to include both the nutrient and sediment material because the TMDL allows for reduction of these materials regardless of its ultimate source (i.e. surface runoff can include both anthropogenic and natural sources) and treatment/control applies to the combined load. The CDOM (colored dissolved organic matter) term in the conceptual model (Figure 8-1 Final Report)) is supported by laboratory experiments using water from Lake Tahoe. The value used in the model for absorption due to CDOM is given in Table 6-4 in the Technical Report along with a reference.

Presumably it is trivial, but some explanation is required.

15. Table 8-2 is given as proof of validation for the lake clarity model. The model predicts secchi depths within a very narrow range (23.1-23.9) whereas the observations fall in a considerably broader range (20.5-23.8). The model shows a consistent directional bias, which is problematic for any model. Furthermore, the observed and the modeled values are not significantly correlated with each other, i.e., the model is not capturing the causes of variation, which is its main purpose (Figure 1).

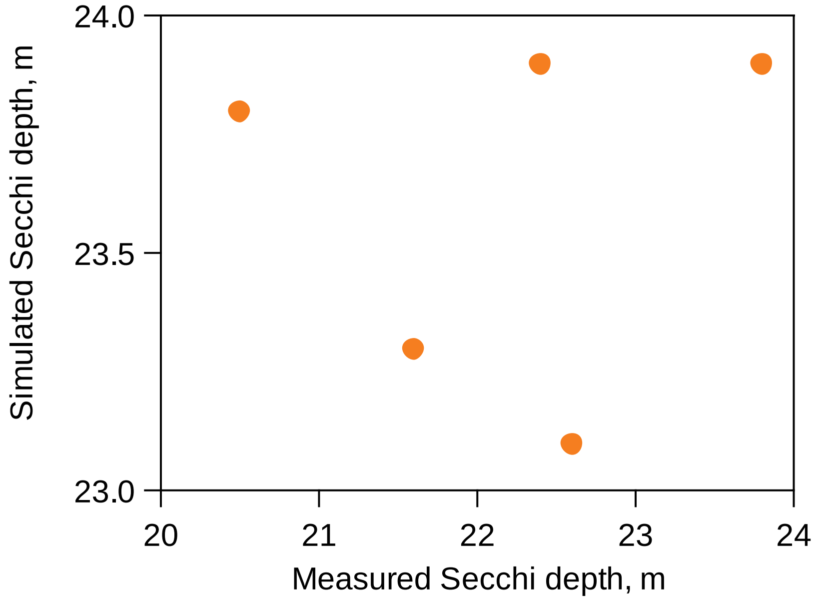

Figure 1. Plot of secchi depth measurements predicted from TMDL Report Section 8. R^2= 0.01; relationship not significant ($p >> 0.05$).

16. Figure 8.2 also poses some problems. Years 2000-2005 are reported to show good agreement, but there are some reasons to question this conclusion, as mentioned above. More troubling is the very wide variation of predicted secchi depths after 2005. The range of variation seen here for predictions is not found anywhere in the previous record of observed secchi depths. Certainly secchi depth observations must

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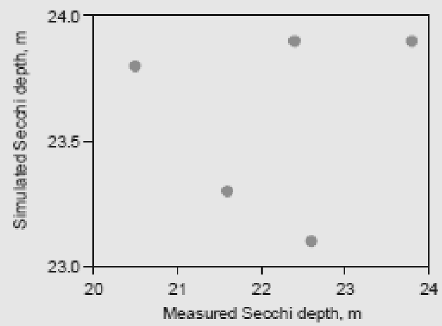

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WL-13: The period 2000-2004 included in Table 8-2 (Final Report) and Table 6-6 (Technical Report) was a period of relatively uniform Secchi depth when viewed in terms of both monitoring and modeling data. However, plots of simulation runs done to evaluate the resulting Secchi depth under conditions of sustained load reduction (see Section 6.4.2 in the Technical Report) show that the Lake Clarity Model (LCM) produces a much broader range of values, i.e. the LCM is capable of detecting a change in Secchi depth under changing conditions. We are also encouraged by the observations that (1) the change in particles needed to achieve the TMDL target was very similar based on LCM output and the empirical relationship between measured in-lake particles and measured Secchi depth (Technical Report, Figure 6-26) and (2) the LCM prediction that if all sources of urban particles were eliminated that the resulting Secchi depth would be near what is considered as the historic baseline (see Section 6.5 in the Technical Report). The LCM can detect changes in Secchi depth that are relevant to management needs; the period 2000-2004 was too similar (in Secchi depth) for the model to capture small differences.

WL-14: The modeled values after 2005 were based predominantly on the precipitation values used to populate the Lake Clarity Model. Since there is no way to know these values before the fact, the modelers based their selection on past trends and records. This is discussed in detail in Section 6.4.1 of the Technical Report and in the Lake Clarity Model technical report (Sahoo et al. 2006 and Sahoo et al. 2009). The recurrence interval of annual precipitation years was preserved for the simulation of future precipitation (i.e the same fraction of wet, average, dry, etc. years). However, the order of occurrence of these years was purely random. So a very wet year could be followed by a very dry year, which could be followed by another very wet year. In reality there are likely to be multi-year cycles (influenced by factors such as the Pacific Decadal Oscillation) that would act to constrain the year-to-year variability. However, we believe the longer term trends associated with implementing the TMDL will be captured. This was considered the least potentially biased approach. The results allow resource managers to initially establish the TMDL from a reasonable position. To the extent that future precipitation conditions do not turn out to be similar as the ones selected in this TMDL analysis, adjustments can be made during the TMDL adaptive management process in the future.

be available now for years 2006-2008. How do the predicted large variations over this span of years compare with the observations for these years?

17. On page 8.6, it is mentioned that phosphorus and nitrogen control are more effective than phosphorus control alone in eliminating phytoplankton biomass. Some explanation should be added, particularly since Section 3 makes the argument that the lake is under substantial phosphorus control at present due to an increase in atmospheric loading of nitrogen. In fact, the two nutrients are nearly co-limiting in that addition of phosphorus is predicted to cause a phytoplankton biomass response, but this response has substantial limits because of depletion of inorganic nitrogen when phytoplankton biomass is increased by increasing phosphorus.

b. TMDL Technical Support Document. A number of the comments given above on the TMDL apply also to the TMDL support document, and need not be repeated here.

1. It seems strange that particulate phosphorus, mentioned on page 3-13, shows a sedimentation rate 1/40 of the sedimentation rate for fine particulate matter, mentioned on page 3-14. Perhaps some explanation should be offered.

2. On page 3-16, first full paragraph, the text seems to say that phosphorus and nitrogen nutrient limitation can be diagnosed accurately form the ratio of total N to total P in the water column of a lake. This is patently untrue. Total nitrogen and total phosphorus consist of mixtures of particulate, dissolved organic, and dissolved inorganic forms of nitrogen and phosphorus. These forms vary greatly in their availability to phytoplankton, and the ratio of available nitrogen to available phosphorus does not follow the ratio of total nitrogen total phosphorus. Furthermore, the picture is complicated by the ability of algae to store phosphorus and nitrogen

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Response

WL-15: For management purposes the issue of nitrogen versus phosphorus limitation is not as important as it might appear. First, algal growth in Lake Tahoe appears to be co-limited, since the addition of nitrogen and phosphorus combined nearly always results in a larger stimulation than either nitrogen or phosphorus additions singly. Second, as shown in Table 8-4 of the Final Report, mitigation efforts to control nutrient loading will include both nitrogen and phosphorus. Third, as discussed in the Final Report the major emphasis will be placed on fine sediment reduction as this has such a large effect on transparency and phosphorus comes primarily from fine sediment.

WL-16: The settling rates cited for nitrogen and phosphorus represent the average residence time for nitrogen and phosphorus in the water column, and not the residence time of the particles with which they are associated. Many of the nutrients associated with particles are mineralized by bacteria and effectively recycled before settling to the bottom (Paerl 1973). Consequently, the residence time for nitrogen and phosphorus in the water column will be longer than that for the actual particle. The text was revised in the Technical Report in Section 3.4.1.

WL-17: While the Technical Report recognized and discussed bioavailability in Section 3.4.2 of the Technical Report, and factors were used in the Lake Clarity Model to account for this (values for nitrogen were taken from the literature and values for phosphorus were directly analyzed as part of the TMDL science program at Lake Tahoe), the text has been revised in the Technical Report in Section 3.4.2 based on a recent paper by the reviewer (Lewis and Wurtsbaugh 2008).

beyond their immediate needs. The text that follows the opening paragraph gives a more realistic view of the many qualifications that one must attach to the ratios of total nitrogen to total phosphorus.

3. Page 3-17 paragraph 4. There is a problem with the units that are given in this paragraph. The author seems to be equating chlorophyll a with carbon, which is incorrect. Chlorophyll makes up about one percent of algal dry mass, whereas carbon makes up about fifty percent of algal dry mass. This needs to be straightened out.
4. Page 3-24. Somewhat contrary to what one might expect from the text, there seems to have been no significant change in periphyton abundance between 1982 and 2003. There is a contrast here with phytoplankton.
5. Chapter 5, page 5-1, third paragraph. It is surprising that the TMDL technical support document relies here on pure speculation as to how much of the particle load is organic and how much is inorganic. There probably is some relevant literature on this matter, and certainly a few measurements would help.
6. Page 5-3 to 5-7. The method used for estimating the source strength for particles coming from the watershed follows a logical path but it mostly unpublished (partly because it is new) and therefore has not been as much scrutinized as the work on Lake Tahoe.

c. Summary of opinion on question 1: Fine sediment particles are the primary cause of clarity impairment.

The TMDL document and the parallel text of the technical support document summarize the evidence in support of the conclusion that fine sediment particles are the main cause for impairment of clarity in Lake Tahoe. The text of both documents contains

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WL-18: The text in the Technical Report, in Section 3.4.2 under the heading *Primary Productivity, Phytoplankton and Algal Growth Bioassays* has been corrected, the units are grams of carbon per meter squared per year.

WL-19: The increase in phytoplankton was as primary productivity and not as biomass. A new figure and text was added to the Technical Report (Section 3.4.2, Figure 3-14) showing no discernable trend in annual average chlorophyll *a* concentrations since 1984. This difference between productivity and biomass accumulation may be related to picoplankton community that is composed of very small, yet photosynthetically active cells (see recent paper by M. Winder, doi:10.1093/plankt/fbp074, available online at www.plankt.oxfordjournals.org). With regard to periphyton biomass, the historic data do not account for increases in the localized range of colonization or the biomass distribution outside the confines of the established monitoring station. Recently, the UC Davis monitoring program has been expanded to investigate these considerations; however, the data is limited at this time.

WL-20: Research to test this assumption is not yet completed; however, according to Alan Heyvaert (personal communication 2009) at the Desert Research Institute, preliminary and limited data suggest that on average organic matter constitutes only about 10-20 percent of the total sediment in the < 1,000 µm size class for urban runoff. Since organic matter is subject to pulverization by vehicular traffic in urban landscapes, the percent contribution by fine organic particles in streamflow should be smaller. The text in the Technical Report, Section 5.1.1 has been updated to include this preliminary information.

WL-21: The topic of fine sediment particles sources and the relationship to transparency is relatively new at Lake Tahoe. The science team has been working on academic papers and a number of them are in progress. A critical part of the external peer review of these TMDL documents was to allow for a high level of scrutinization.

a number of errors and misleading statements, which can be easily revised, but the underlying information is very sound scientifically. The key discovery, published by Jassby et al. in 1999, is that attenuation of light in the upper portion of Lake Tahoe by fine particles is more important than attenuation of light by phytoplankton biomass, which had earlier been considered the main cause for declining clarity of Lake Tahoe. The study was followed by additional studies of particle size distribution, seasonality, and proportionate contribution of other factors contributing to light attenuation. Publication of the Jassby paper and some of the other research in peer review outlets adds to the credibility of the analyses and interpretations.

A logical final step leading to the use of information on light attenuation factors as part of the TMDL is the development of a lake clarity model, as presented, by Swift and others. While there is no reason to doubt the predominant importance of particles in causing increased light attenuation through time in Lake Tahoe, as shown by empirical relationships derived from lake sampling, evidence for the soundness of the lake clarity model is still mixed. As indicated above, lake clarity model produces an accurate estimate of the mean clarity across years based on contributing factors, including fine particles, but fails to capture interannual variation. The concern here is that a secular change in mean might not be captured for the same reason that interannual variation is not captured by the model. The handicap for the modeler is that the range of variation is not very great, and the model simply may not be sensitive enough to depict interannual variation, but this matter needs attention.

Even if the model cannot be made to capture more variation interannually, there can be little doubt that measures taken through the TMDL process to reduce the loading of

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WL-22: When trying to model interannual variability it is critical that the timing of events is captured with some accuracy. As shown in both Jassby et al. (1999) and Swift et al. (2006) Secchi depth in Lake Tahoe is affected by both fine sediment particles and to a lesser extent phytoplankton that is brought into the surface waters from the deep chlorophyll maximum, as the thermocline begins to erode in the fall and early winter. Modeling of each antecedent condition in the lake over a more resolved time scale is difficult, especially when the lake may not respond immediately to pollutant loading. Since regulatory standards that guide this TMDL are based on annual averages, interannual patterns were not considered critical; the 29.7 meter target set by the State of California is based on a multi-year average. Documentation of the actual achievement of the desired TMDL target will not be based on model outcomes but rather on Secchi depth monitoring data, which shows significant intra- and interannual variation in lake response. Based on management needs the Lake Clarity Model's performance on an annual time scale (Table 6-6 in the Technical Report) meets the TMDL's objective. Finally, the observations that (1) the model simulation without fine sediment particle loading from urban areas is very similar to what is considered the historical baseline for Lake Tahoe Secchi depth (Technical Report, Section 6.5) and (2) model results for fine sediment reduction correspond to agree with the results of empirical observations of fine sediment particle levels and measured Secchi depth (Figure 6-26 in Technical Report) elevates our confidence that the Lake Clarity Model is functional at the appropriate time scale.

fine particles to Lake Tahoe would improve its clarity, provided that the presently substantial efforts to control nutrient loading are maintained.

II) Sources of Nutrients and Particles.

a. TMDL report.

Section 7 of the TMDL Report gives a clear overview of the results of studies contributing to quantitative partitioning of nutrients and particles for Lake Tahoe.

b. TMDL Technical Support Document.

1. Apparently no quantitative error estimates have been made.

c. Answer to question 2: Identification of the six sources of pollution affecting lake clarity.

The methods for estimation of sources of pollution (nitrogen, phosphorus, particles) as described in the TMDL Report reflect the state of the art, and incorporate both modeling and empirical analysis of sampling data. Although at least some of the modeling components were calibrated with empirical data, there is no clear presentation of the expected error for each of the estimates. Even so, the great observed difference between mean concentrations of particles emanating from upland urban areas and other areas insures that the final conclusion is quite secure qualitatively. Thus, for TMDL purposes, a strong focus on particle release from upland urban areas is warranted.

Overall, the partitioning work was done very conscientiously and should be viewed as reliable for TMDL purposes.

III) Lake Tahoe watershed model.

a. TMDL report.

1. The TMDL report contains only a sketch of the water quality modeling. The validity of the modeling must be judged entirely from the technical support document and

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WL-23: The Lake Tahoe Watershed Model analysis did not evaluate error associated with each of the model's components. Rather, load estimates were determined based on model calibration using empirical analysis and field data. Excepted error was evaluated based on a direct comparison of simulated versus monitored data. As stated in the Technical Report (Section 4.3.6 under the heading *Lake Tahoe Watershed Model versus Lake Tahoe Interagency Monitoring Program Loading Comparison*), while there was some difference between the LTIMP and Lake Tahoe Watershed Model (LSPC) values for certain tributaries and for certain nutrient species (e.g. Blackwood Creek dissolved inorganic nitrogen and Ward Creek soluble reactive phosphorus, there was very good agreement, especially when considering the combined sum for the 10 tributaries (Table 4-41). The relative percent difference (LSPC-LTIMP)/(mean of LSPC and LTIMP) was between 10 − 14 percent with the exception of soluble reactive phosphorus which was much higher at 60 percent.

modeling report.

b. TMDL Technical Report.

1. Tetra Tech, which did the modeling, chose LSPC, an EPA approved watershed model for application to the Lake Tahoe basin. Because this model is approved by USEPA for TMDL applications, it seems likely that the model is appropriate for use. As is the case for widely used models of this type, LSPC is quite flexible with respect to number of watershed components and other features that are specific to any given basin.

2. The LSPC model apparently was customized for the Lake Tahoe project because of the specific importance of particles less than 63 µm for Lake Tahoe. Apparently, as explained on page 4-25, the model is able to produce predictions of total suspended solids, and it was assumed that the observed fractionation of total suspended solids in the watershed, as shown by monitoring, could be applied to the predicted TSS. This seems reasonable, although it means that there are no mechanistic components of the model that specifically deal with fine particles. Similarly, nutrient species were not actually predicted by the model, but rather were assumed to reflect currently observed speciation in streams.

3. There was no allowance in the modeling for uptake or immobilization of nitrogen and phosphorus in transit. The modelers argue that the transit time and the velocity of flow indicate the insignificance of these processes. More secure would have been some empirical demonstration that this is a correct assumption, but it does seem reasonable.

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WL-24: There are no known watershed models that can directly predict the number of fine particles (0.5-16 µm diameter) in runoff from an area as large as the Lake Tahoe basin with the level of confidence needed for the Lake Clarity Model. Because appropriate values for mechanistic parameters are not available - especially from mountainous regions with complex terrain - it was decided to calibrate with empirical monitoring data. A significant monitoring effort was undertaken as part of this TMDL to collect fine particle data for both streamflow and urban runoff. This monitoring effort for fine particles was vital for the modeling approach taken. The LTIMP stream data is very extensive and comprehensive. Given the complexity of mountainous landscape and the fact that the Lake Tahoe basin consists of 63 independent watersheds it was decided that calibration to the high-quality LTIMP dataset was the best approach.

WL-25: The goal of the model was to obtain a good match at the mouth for the nutrient species. Because of the shape of the watershed and nature of its tributaries, most of the stream times of concentration were faster than the rates at which these transformations would likely occur. If the Lake Tahoe Interagency Monitoring Program data were not available from the stream mouth regions (i.e. near point of discharge to the lake), the uptake/immobilization of nitrogen and phosphorus would have required further consideration.

surprisingly large, as shown in Table 4-25. It would be reassuring have some explanation of these corrections based on monitoring.

5. The comparisons of modeled and observed concentrations show wild divergences on individual dates (often 1 order of magnitude). If hydrology is known, concentrations generally can be predicted fairly well for a given land use mixture. Perhaps the hydrologic modeling is introducing some unsuspected high degree of variation. Although the model is adjusted to produce means that reflect reality, predictions for individual dates show that the model does not understand the processes that control concentrations.

c. Answers to question 3: Lake Tahoe watershed model.

The choice of watershed model by Tetra Tech seems quite defensible. In addition, a great deal of monitoring information is available in support of modeling. Even so, the requirement for large adjustment factors and the large absolute value of deviations for concentrations between observations and predictions on specific dates shows that the model does not have a high degree of skill. The model is essentially forced by the adjustment factor process to produce means that correspond reasonably well with means for monitoring data. A lingering question is whether reliable predictions for changes in land use or control measures can be drawn from modeling, or whether they would be better drawn from direct use of data from monitored watersheds. I suspect the latter, although standard practice would be the former.

IV) Estimates of groundwater nutrient loading.

a. TMDL report.

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Response

WL-26: As stated in both the Technical Report and the companion watershed modeling report (Tetra Tech 2007), the Lake Tahoe Interagency Monitoring Program (LTIMP) stream dataset allowed the modelers to calibrate to actual field measurements. The scaling factors used to distinguish loading by the four watershed quadrants (Table 4-18) are based on actual stream monitoring data. The scaling factors are empirical, but were necessary to account for differences seen in loads from streams in different locations of the lake. These quadrant scaling factors came from the calibration process. The sensitivity of the Lake Tahoe Watershed Model and the nature of the stream monitoring data provided by LTIMP (10 monitored streams) was not sufficient to customize loading for each of the lake's 63 tributaries and assumptions were required. New text was added to the Technical Report in Section 4.3.5 under the headings *Model Parameterization by Land-use* and *Water Quality Calibration Process* to make this step in the analysis more clear. Scaling factors are difficult to avoid unless more individual streams were directly monitored.

WL-27: There is room for improvement in the watershed model and there can be a high degree of variation between modeled versus measured observations for individual dates. However, it is of the greatest importance to the TMDL that both the model seasonal and annual load estimates were similar to the values derived from the observed values (Tetra Tech 2007). Unlike BMP stormwater design where it is critical that individual storms and even peaks in loading within a single storm be identified (i.e. needed for project design), daily resolution of loading to Lake Tahoe is not critical for the Lake Clarity Model to simulate annual lake Secchi depth.

WL-28: The Lake Tahoe Watershed Model was selected for source analysis phase of the TMDL because the model had to apply to the entire drainage area of the Lake Tahoe basin, with its mountainous terrain, strong east to west rain shadow, geological differences, etc. For this large-scale approach, certain averaging assumptions were required. It was important to calibrate to the high-quality Lake Tahoe Interagency Monitoring Program data set that best reflects actual conditions. There is no intent to use the full basin-scale version of the Lake Tahoe Watershed Model to predict changes in loading based on changes in land-use or control measures. Modelers working for the Water Board and NDEP have recently developed a different model to specifically predict load reduction associated with individual urban stormwater control projects. The Pollutant Load Reduction Model (PLRM) is a customized interface to the EPA's Storm Water Management Model version 5 (SWMM5) and was created as part of the TMDL program for use at Lake Tahoe. Information related to PLRM is available at http://tiims.org/TIIMS-Sub-Sites/PLRM.aspx.

in detail to support a review. This review is focused on the technical support document.

b. Technical support document.

1. General agreement between two separate studies (Thodal's 1997 study and the USACE's 2003 study) increases confidence to the estimates for groundwater loading of nitrogen and phosphorus to Lake Tahoe.
2. On page 4-8, at the top of the page, the technical support document distinguishes between aquifer types. Shallow aquifers, which make contributions to streams, are assumed to be reflected in estimates of tributary loading to the lake, which seems quite reasonable and is standard. Groundwater, according to this paragraph, is treated as originating from deeper aquifers that enter the lake at rock faces well below the water surface. Unless something is missing in this description, it seems that a third component is not considered. While tributaries pick up shallow alluvial flow, some of the shallow alluvial flow is intercepted by the lake itself without reaching a tributary. Obviously, the importance of this source varies with topography, but it seems wrong not to mention it at all.
3. Table 4-4 and other parts of the text for the groundwater portion of the report are confusing in use of the term "ambient." Ambient means characteristic of a specific place and time. The word "background" means natural or without superimposed influences. In this case, the authors are using the word ambient to mean background.
4. The background concentrations for phosphorus in groundwater are surprisingly high. They align well with stream concentrations for undisturbed or minimally disturbed areas summarized by the Tetra Tech study, however.

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4. The background concentrations for phosphorus in groundwater are surprisingly high. They align well with stream concentrations for undisturbed or minimally disturbed areas summarized by the Tetra Tech study, however.

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WL-29: Section 4.1.1 of the Technical Report has been modified to mention the shallow and deeper groundwater contribution directly to the lake.

WL-30: The USACE (2003) *Groundwater Evaluation* report defined ambient nutrient loading as the amount of nutrients that would discharge into Lake Tahoe regardless of anthropogenic sources. "Background" is a more appropriate term, so the word "ambient" was changed to "background" in the Technical Report, Section 4.1.3 and in the Final Report, Section 7.2.

5. The modeling approach used by USACE is standard. A specialized model was used only for the south Tahoe Basin. The general modeling was done by application of Darcy's Law, with numerous adaptations to the characteristics of individual sub-watersheds, as determined by sampling. The underlying problem, which plagues all groundwater flow estimates, is the applicability of Darcy's Law. Preferred flow paths, such as bedrock layers or cracks, may facilitate much faster flow than would be estimated from sampling based on bore holes. There is no easy fix for this problem, but it introduces tremendous uncertainty in estimates that cannot be calibrated or validated with actual observations at the discharge point.

c. Conclusions about question 4: Groundwater nutrient loading rates.

Estimation of groundwater nutrient loading reaching the lake follows standard practice and is backed up by substantial sampling. The groundwater contribution is small as a proportion of the total load, which means that even substantial errors in this estimate, which might occur through some unavoidable problems in estimating groundwater flows, would not likely change the overall conclusion. Given the literature on nutrient partitioning, a relatively small contribution of groundwater sources directly to the lake would be expected.

V) Atmospheric deposition as a source of particles and nutrients for Lake Tahoe.

a. TMDL report.

1. The availability of two separate studies, which appear to provide mutually consistent results, is advantageous.

b. Technical support document.

1. Figure 4-51 and associated text do not match up very well. TSP does not seem to

Response

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b. Technical support document.

1. Figure 4-51 and associated text do not match up very well. TSP does not seem to

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WL-31: Estimating groundwater inflow and nutrient loading is complicated in mountainous terrain where the natural geology does not result in uniform flow paths. Since the discharge of groundwater into Lake Tahoe will most likely be diffuse, validation is difficult. The flow and nutrient loading estimates used in the TMDL source analysis are similar to other independent estimates as discussed in the Technical Report (Section 4.1). The uncertainties associated with these values are primarily at a moderate level.

WL-32: Figure 4-51 was removed and replaced with Table 4-45. The table is much easier to understand and according to CARB (2006) the data in the Table 4-45 was derived from data presented in Figure 4-51; therefore relevant information is not lost.

appear on Figure 4-51, nor are the axes explained. Too bad not to present more clearly what appears to be some very good work.

2. The procedure for allocating particles of a given size range to functional categories is not clear (page 4-121). For this reason, it is not easy to understand the basis for the third paragraph on page 4-121, which gives detailed information on the partitioning of particles within size classes. The apparent absence of any information on black carbon is unfortunate.
3. The good agreement mentioned on page 4-137 for CARB and TERC give confidence to the overall estimates, but only if CARB was fitted with deposition velocities that were developed completely in isolation of any information on the expected outcome based empirical data collection.
4. Estimates of loading from wet deposition for nutrients is accomplished in a rigorous manner with the benefit of a long term data record at one station. Although data for multiple stations are scarcer, they are sufficient to indicate relatively uniform deposition rates. This is somewhat surprising, given the potential for stagnation of polluted air in mountainous terrain, particularly during winter. However, comparison with NADP measurements in other states at locations of similar climatology is supportive. Absence of data collection on the lake's surface over extended periods of time is a disadvantage, especially in that precipitation over the lake might be cleaner than precipitation over terrestrial portions of the watershed, both the pollution sources and the natural terrestrial sources are associated with land. Altogether, however, the final estimate is responsibly made and is unlikely to be grossly erroneous.
5. The predominance of local sources of nutrients and fine particulate matter, as

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WL-33: The section of the Technical Report entitled *Estimated Particle Number and Deposited Fraction,* contained in Section 4.5.2, was revised and expanded. Investigating black carbon was not in the scope of LTADS. Ross Edwards at the Desert Research Institute has recently made some preliminary measurements of black carbon in Lake Tahoe, but only on particles < 0.5 μm. The distribution of black carbon in Lake Tahoe is still largely unknown and its potential impact on lake transparency has yet to be evaluated.

3. The good agreement mentioned on page 4-137 for CARB and TERC give confidence to the overall estimates, but only if CARB was fitted with deposition velocities that were developed completely in isolation of any information on the expected outcome based empirical data collection.

WL-34: CARB did not fit deposition velocities for nutrients using the empirical deposition data collected by UC Davis - TERC. As stressed in text on atmospheric deposition, these were independent approaches. Their close agreement in part lead to the high level of confidence associated with this component of the loading budget (see Table 4-67).

4. Estimates of loading from wet deposition for nutrients is accomplished in a rigorous manner with the benefit of a long term data record at one station. Although data for multiple stations are scarcer, they are sufficient to indicate relatively uniform deposition rates. This is somewhat surprising, given the potential for stagnation of polluted air in mountainous terrain, particularly during winter. However, comparison with NADP measurements in other states at locations of similar climatology is supportive. Absence of data collection on the lake's surface over extended periods of time is a disadvantage, especially in that precipitation over the lake might be cleaner than precipitation over terrestrial portions of the watershed, both the pollution sources and the natural terrestrial sources are associated with land. Altogether, however, the final estimate is responsibly made and is unlikely to be grossly erroneous.

WL-35: While the concentrations of nitrogen in wet deposition from a limited number of stations around the basin are similar, they are not identical. The levels of dissolved inorganic nitrogen (DIN) did vary by a factor of two. Section 4.5.4 of the Technical Report has been revised to include a comparison of nitrogen and phosphorus deposition and noted that the wet deposition rate of DIN at the Saghen Creek location (located just north of Lake Tahoe) was virtually identical. Though there were no actual measurements of wet deposition on the lake, there were measurements for dry and bulk deposition. The current monitoring program does not fund wet deposition measurements. The approach taken in the Technical Report was done based on previous synoptic (around-the-lake) measurements and on precipitation differences across the lake.

5. The predominance of local sources of nutrients and fine particulate matter, as

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discussed in section 4.5.5, is somewhat surprising. One would think that air movement across the Lake Tahoe basin from adjacent watersheds would have some influence on air quality. Certainly the results were arrived at in a careful way, but they are difficult to critique because the computations that are involved in producing the estimates cannot be followed. The validity of the is conclusion is rather important, as controls on loading that derived from the TMDL will be more or less effective according to the proportion of local sources in governing loading to the lake.

c. Answers to question 5: Atmospheric deposition of nutrients and particles.

The atmospheric component of the TMDL study was done at the state of the art for data collection and modeling and is backed up by a diversity of empirical studies. Inevitably, the dry deposition contribution to loading is more difficult to estimate than wet deposition, but the agreement between empirical and modeling studies is reasonably good, which offers some assurance that the overall conclusion is not severely flawed.

VI) Pollutant load reduction opportunities.

a. TMDL report.

1. Section 9.2.1 is confusing with respect to ground water. In the technical document, the term groundwater is used with reference to water that is pumped from wells bellow the surface alluvium. There is no indication in the results from the groundwater analysis, as presented in the technical document, that groundwater is universally polluted, as suggested in the text shown within section 9.2.1. There is some kind of terminology error or misunderstanding here.
2. Because the origin of fine particles in runoff is focused on urban uplands, it is unclear why it is cost effective to spend restoration dollars on forested upland or stream

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2. Because the origin of fine particles in runoff is focused on urban uplands, it is unclear why it is cost effective to spend restoration dollars on forested upland or stream

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WI-36: The text in Section 4.5.5 of the Technical Report was revised to provide more background on how the evaluation concerning locally-generated versus regionally-transported atmospheric sources was made. The LTADS Report, done by CARB (2006) provides a detailed explanation. Since the Recommended Strategy includes control of urban stormwater runoff and street sweeping to reduce the soil particle loading to both runoff and the atmosphere, this management strategy would not be significantly changed.

WL-37: The text in Chapter 9 of the Final Report has been revised and no longer notes that groundwater is universally polluted.

WL-38: There are a variety of land management and restoration programs that are currently in place within the Lake Tahoe basin. These programs and projects are undertaken for a variety of reasons, including but not limited to habitat restoration, vegetation management, riparian restoration, soils and wetland restoration, and trail and road rehabilitation. Many of these actions have ancillary water quality benefits. The Lake Tahoe TMDL implementation plan acknowledges that these actions will occur regardless of the TMDL effort and accounts for the pollutant load reductions expected from ongoing restoration and land management activities. Although the expected load reductions from stream channel restoration and forest management activities are relatively small at the basin-wide scale, the water quality benefits are very cost effective. The Lake Tahoe TMDL Pollutant Reduction Opportunity Report provides additional detail regarding the relative cost/benefit of various load reduction activities.

channels.

b. Appendix: Pollution control opportunities.

The pollution control opportunities appendix gives details of the rationale and estimation procedure for various pollution control opportunities. This is a methodical and thoughtful component of the TMDL. There are enormous uncertainties, through no fault of the estimators, but a number of the more important opportunities are among the most confidently predicted.

c. Question 6: Pollution control opportunities.

The methodological text on pollution control opportunities is difficult to evaluate item by item. Overall, the approach seems comprehensive and defensible, and makes good use of the available information. As noted in the text, however, the predictions are uncertain in some cases. Given that the cost of the pollution control program can only be described as shocking, it is important that that an adaptive management procedure (as mentioned in the text and diagrammed) be a consistent feature of this program. Adaptive management is used in many long term environmental activities managed by government, but it is seldom implemented successfully. It is critical that evidence of ineffectiveness of a specific pollution control protocol lead to a redesign of the protocol. Acting against this enlightened way of proceeding is a natural but harmful entrenchment of attitudes and practices along lines that are preconceived at the beginning of the process.

VII) Appropriateness of the lake clarity model.

a,b. Comments on the TMDL report and the TMDL support document relevant to this question are as given above in Section I.

c. Answer to Question 7, lake clarity model.

Response

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VII) Appropriateness of the lake clarity model.

a,b. Comments on the TMDL report and the TMDL support document relevant to this question are as given above in Section I.

c. Answer to Question 7, lake clarity model.

16

WL-39: Chapter 12 in the Final Report describes the adaptive management details, including the development of the Lake Tahoe TMDL Management System and how that system is critical to the TMDL Implementation Plan.

There is no question as to the appropriateness of using a model based on the absorbance of particulate and dissolved constituents of water for explaining observed light absorbance in the water column of Lake Tahoe. The conceptual basis for the Lake Tahoe water clarity model is sound, and there is a considerable amount of underlying empirical information. The usefulness of a model in anticipating future conditions, however, is measured by the degree to which the model captures year to year variation over a period of validation. As mentioned in Section I above, the Lake Tahoe water clarity model in its present form fails to capture a significant amount of year to year variation in transparency of Lake Tahoe. Some explanation is needed for this failure to capture variability. Adjustments to the model that allow it to capture variability better could be a second step in model development. If not, the limitations of the model in predicting future conditions must be acknowledged. The model is certainly on the right track conceptually, but there are signs of an unresolved problem.

VIII) Allocation of allowable fine sediment particle and nutrient loads.

a,b. Comments on the allocation system are as given above under VI.

c. Answer to Question 8: Suitability of approach 2, load source weighted allocation.

Approach 2 is rational and is a significant step toward optimizing results per unit of expenditure. It may fall short of maximum cost effectiveness, however, in allocating some resources to the capture of nutrients or fine particulate matter from sources that are diffuse, such as non-urban upland. Resources allocated to controlling these sources may not return significant results, in which case it would be better to allocate these resources to the more potent sources (e.g. urban areas). In context of the full budget, this is not a major issue because the proportionate allocation of dollars is certainly weighted toward

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Response

WL-40: Please refer to the Response WL-13. The year-to-year variation between 2000-2004 was relatively small compared to the > 9 meters improvement needed to meet the TMDL target of 29.7 meters. Section 6.4.1 of the Technical Report shows that the Lake Clarity Model is able to capture magnitude of Secchi depth changes needed for management purposes. Distinguishing between interannual monitored annual Secchi depth measurements with a high degree of certainty is unlikely because of the year-to-year differences in precipitation. This is why the TMDL milestones have been placed on a 5-year basis and not more frequently. The results of the simulated model runs based on fine sediment and nutrient reduction suggest that changes in lake transparency will be seen. This is further supported by the discussion in Section 6.5 of the Technical Report. The Secchi values in the period 2000-2004 were too small for the model to capture; however, a lake response much larger than that narrow range will be needed to meet the TMDL. Model results indicate those changes can be detected.

WL-41: Working within a framework where watershed protection benefits aquatic resources, the Lake Tahoe basin community considers a modest investment in non-urban upland restoration an overall benefit to riparian/wetland/stream channel function and consequently watershed health. Also, given the inherent complexity involved in a restoration program that virtually relies on the control of non-point sources, there is no reason to exclude non-urban uplands. As a result of the work done for the Lake Tahoe TMDL to date, agencies and stakeholders in the Lake Tahoe basin are very aware of the need to treat urban pollutant sources. It will take load reductions from all sources that receive an allocation to meet the long-term goals of the TMDL, while the focus will be on the urban sources.

the strongest sources, but the millions to be spent on weak sources may be wasted.

IX) Overall, the TMDL and its supporting documentation is a very impressive body of work. It is rare that such a strong fundamental scientific basis is combined with a detailed analysis of source control, prediction of outcomes, and allocation of resources. There are a few significant weaknesses, as mentioned above, but these can be investigated and perhaps mitigated. Modeling of clarity and loads is more problematic than other aspects of the TMDL.

My overall concern about the implementation phase of source control is its enormous cost. Given the financial realities of the current economy, it might be good to have a companion document, of small size, outlining the results that could be obtained for expenditures of 50 percent or 25 percent of the proposed expenditure. Thus, in the event of a financial hardship, source control could proceed, and still could be meaningful.

My final point is to reiterate what is explained in VI c concerning adaptive management. It is critical that the true success of the projected methods of source control be assessed in a realistic way as time goes by. It is further necessary that any evidence of failure in a specific control strategy lead to the cessation and reformulation of the control strategy, rather than inertial continuation of expenditures on an ineffective strategy. Projects such as this often founder on the inflexibility of the action plan once implementation begins.

Congratulations to the contributors to this work, who did overall a very impressive job in addressing a complicated problem.

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9 July 2009

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Congratulations to the contributors to this work, who did overall a very impressive job in addressing a complicated problem.

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9 July 2009

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WL-42: The Water Board and NDEP estimate that the resources necessary to achieve required load reductions from the urban uplands will be roughly $100 Million per year for the next fifteen years. While the Water Board and NDEP acknowledge the challenge of dedicating such resources in the current economic climate, the magnitude of the commitment is similar to the amount spent during the past ten years of erosion control, stormwater treatment, and restoration efforts in the Tahoe Basin. The TMDL Implementation Plan requires each implementer to assess its baseline load and devise its own pollutant load reduction strategy to meet the load reduction requirements. Therefore, each implementer can weigh cost as a factor when choosing its load reduction actions for each year.

WL-43: If the annual required monitoring shows that some of the assumptions are incorrect, and if projects and modeling assumptions are not as predicted, adjustments will be made as part of the adaptive management process in the TMDL Management System. The adaptive management component is to evaluate new information and create annual recommendations for adjustments and changes where needed. New text was added to Chapter 12 of the Final Report.

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Lake Tahoe Sediment and Nutrient TMDL

Response to Peer Review Comments

Thomas M. Holsen

Peer Review Received: July 24, 2009

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.

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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).

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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

Response

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

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3

TH-1: Characterizing fine particle loading to lakes and reservoirs, for the purpose of understanding light scattering and modeling light attenuation and Secchi depth transparency, has not been widely reported with the notable exception of Steven Effler, Feng Peng (i.e. Peng and Effler (2007) and Peng et al. (2007)) and their colleagues at the Upstate Freshwater Institute in Syracuse, New York. Studies related to understanding fine sediment particle size in urban runoff at Lake Tahoe will be continuing under the Lake Tahoe Regional Stormwater Monitoring Program and research on this topic is currently underway with funding from the Southern Nevada Public Lands Management Act.

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.

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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.
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Response

TH-2: Literature was consulted to address this comment and new text was placed in the Technical Report (Section 4.5.4) to acknowledge that the rates of atmospheric deposition of both nitrogen and phosphorus to Lake Tahoe were very similar to values measured in California, the western United States and other places in the world. This comparison with other studies provided high confidence in these findings. As noted in the Technical Report (Section 4.6.2), there is less confidence in the fine sediment particle deposition rates, which led to CARB addressing deposition rates through the LTADS study.

TH-3: Although these quantities are not explicitly quantified, atmospheric deposition to the land is implicitly included in the runoff event mean concentrations (EMCs). It was beyond the scope of the source category analysis to distinguish between atmospheric sources and land-based sources when considering loading from surface runoff. In particular, the sediment and nutrient content in runoff depends on the nature of atmospheric deposition, and changes dramatically as rain or snowmelt travel over the landscape and accumulates pollutants from soil erosion and urbanized land-uses. Furthermore, pollutants that either (1) enter the surface runoff by atmospheric deposition or (2) are entrained into the atmosphere from the terrestrial environment require land-based controls.

TH-4: Based on decades of monitoring and research it was determined that urban and vegetated uplands, atmospheric deposition and groundwater dominate nutrient and sediment input. As part of the new TMDL research stream channel and shoreline erosion were considered for the first time. Inputs such as leaves, pollen, bird droppings, etc. typically will travel through the upland environment (i.e. transported in surface flows) before entering the lake. These should be captured to the extent possible by stream and urban runoff sampling. Colored dissolved organic matter is very, very low in Lake Tahoe (Swift 2004). In smaller lakes where shoreline vegetation is more dominant, these could have a large affect. Because of its great depth and near oval shape (not a dendritic shoreline) and the fact that the subalpine vegetation does not extend to the lakeshore, these "natural sources" were not considered to be critical. Forest fires could have an effect and they have been evaluated during development of the land-use layer for Veg-burned, see Section 4.3.5 under the heading *Model Parameterization by Land-use*. There have only been two large wildfires that have been monitored in the Tahoe basin and wildfires are not only infrequent but largely unpredictable. Finally, the watershed modeling team considered pollutant loading from areas that have been subject to controlled burns and/or wildfires during the 1996 – 2004 modeling time period. A six-year linear recession curve to zero-impact is used to compute the diminishing effects of the burn over time.

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Response

TH-5: Fugitive dust from vehicular traffic was not studied directly, however analysis was conducted in the Pollutant Reduction Opportunities Report for certain control measures, the load reductions that are potentially achievable and the cost associated with those control measures. Text was added in the Technical Report, Section 4.5.1 to include discussion of why the source category did not distinguish between atmospheris sources and land-based sources when considering loading from surface runoff.

TH-6: The CARB (2006) report acknowledged that a complete characterization of in-basin versus out-of-basin sources of atmospheric contaminants could not be done as part of LTADS. However, the data presented in Chapter 4 of the Technical Report does not depend on the source since the data was intended to estimate atmospheric deposition in comparison with other major sources. The LTADS report gives a good initial estimate of locally generated and regionally transported sources, and this work strongly suggests in-basin sources. It was considered most pragmatic to focus on those air pollutant sources in the basin that could be locally addressed through the TMDL, EIP and TRPA Regional Plan. Since the majority of fine sediment particles come from urbanized sources within the Lake Tahoe basin, it is logical to focus controls in the urban areas.

TH-7: Section 4.5.2 (Page 4-120) of the Technical Report, as well as in other sections (e.g. Section 4.6) emphasized that the estimate of fine soil particles coming from atmospheric deposition contains uncertainty. The phrase "adequate first estimates" was used to signify that while this contains uncertainty, and that replication of these estimates would add to overall confidence, field data was actually collected at Lake Tahoe to look at this very issue. The LTADS data, while a first estimate, was based on site specific data and not theoretical considerations.

TH-8: Results from the DRI dry nitrogen deposition modeling are presented in Section 4.5.2 under the heading entitled, *Comparison to Other Studies*, and as stated, - could not be used in the annual estimates. The DRI data in the Technical Report supports the findings for dry nitrogen deposition made by CARB and UC Davis - TERC. At least for the summer months when there was temporal overlap, the three separate estimates of CARB, UC Davis - TERC and DRI were comparable. This agreement increased the level of confidence in the CARB and UC Davis - TERC estimates of nitrogen deposition used in the Technical Report to calculate whole-lake deposition. In the Technical Report, Section 4.5.2 under the heading *Overview of Dry Deposition Estimation Methodologies*, the units for Equation 3 have been corrected and more information is provided.

TH-9: Text was modified in Section 4.5.2 under heading *Results of Dry Deposition* to present the findings of Liu (2002) and related those to LTADS results.

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.

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Response

TH-10: The data is contained in Hackley et al. (2004, 2005) and the text in Section 4.5.4 of the Technical Report has been updated. These data are part of the Lake Tahoe Interagency Monitoring Program (refer to Chapter 1 for a brief description of this program).

TH-11: The text in Section 4.5.5 of the Technical Report has been modified to include a discussion of locally-generated and regional-transportation of atmospheric pollutants, based on the LTADS report (CARB 2006).

TH-12: The word 'also' has been deleted in Section 4.5.5 of the Technical Report under the heading *Summary of LTADS Conclusions Regarding Atmospheric Sources*.

TH-13: Section 4.5.5 of the Technical Report was revised and unsupported statements were deleted from the text.

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.)

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TH-14: The modeled values for nitrogen, phosphorus, and nitrogen plus phosphorus in Table 8-3 in the Final Report, Section 8.3.2 are not significantly different from each other. Therefore, no difference in effectiveness is implied in the table. However, these three modeled values are significantly less than fine sediment alone and much less than the combination of fine sediment and nutrient load reductions together. The number of significant figures has been corrected in Table 8-3 of the Final Report.

TH-15: Considering the variability in street sweeping technologies, the Lake Tahoe Total Maximum Daily Load report has been edited to replace references to capture of a specific particle size with references to "PM10-efficient street sweepers."

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Lake Tahoe Sediment and Nutrient TMDL

Response to Peer Review Comments

Patrick L. Brezonik

Peer Review Received: July 25, 2009

Lake Tahoe Total Maximum Daily Load Review

Patrick L. Brezonik

Overview

The Lake Tahoe TMDL study and its reports associated are evidence for the highly complicated and extensive efforts underway to protect and restore water clarity in a lake that is a national treasure. The technical efforts have involved hundreds of scientists, engineers, and other professionals in studies encompassing most of the present decade. The analysis leading to the recommended goal and strategy to achieve it relied on collection of new data, analysis of old and new data, and especially an extensive modeling component. Overall, my conclusion is that the work was performed carefully with considerable amount of oversight and review. State of the art techniques were employed in data collection and analysis and in the various modeling efforts. The reputations of the leading participants are sound, and many of the individuals, firms and institutions involved are well known internationally and highly respected in their fields. The study has involved considerable public input and stakeholder involvement, and much attention has been paid to developing a long-term strategy for the implementation plan that appropriately involves a sophisticated adaptive management strategy.

The watershed and in-lake modeling efforts used current modeling techniques and are impressive in their attention to detail. Although I describe some technical issues and concerns about the methods and results of these modeling efforts later in this review, I want to emphasize here that I recognize the huge amount of work that went into these components of the TMDL study and believe they constitute a "state-of-the science" effort.

This review first addresses some important technical issues and concerns I found in reading the TMDL document and associated technical report. Next, based on my reading of the documents and in reference to the technical issues mentioned above, I address the eight issues posed to reviewers in the June 4, 2009 revision of Attachment 2 to the memorandum from Douglas Smith, Chief of the TMDL/Basin Planning Unit to Gerald Bowes, State Water Resources Control Board (dated November 12, 2008). Finally, I list some smaller technical issues, wording problems and typographical/formatting issues I found in the TMDL documents. I want to emphasize that I did not view my responsibilities as a reviewer to focus on the latter problems, and the list is not intended to be a comprehensive enumeration of such errors in the report.

Important Technical Issues

1. ***Is the goal really reasonable given climate change is occurring?*** Given the scenario painted on pages 12-7 and 8 of the TMDL, I wonder whether it is reasonable to have a clarity standard based on historical climatic conditions. Would it not be more realistic to accept that the described changes in climate—e.g., on the mix of snow/rain in precipitation, on increasing erosion from the greater proportion of precipitation falling as rainfall, and the other climate change impacts described in this section—would cause Lake Tahoe to have a different transparency even if there were no people living in the basin? I believe the TMDL should be written explicitly to account for this likelihood. Perhaps the initial target value does not need to be changed, but the documented climate changes in the region over the past 20-40 years (mentioned in the second paragraph on p. 12-8 of the TMDL) suggests that perhaps this should be considered. At the least the TMDL should acknowledge that the target should be a "climate-normalized" nondegradation standard.

Response

Lake Tahoe Total Maximum Daily Load
Review

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PB-1: Scientific investigations regarding the potential impact of climate change on Lake Tahoe water quality have only recently started. There is a strong dataset on historic lake temperature (Coats et al. 2006) to show a statistically significant change since measurements began in 1970. The science community - while working on this issue - is currently not in a position to predict the actual limnological impacts of climate change on Lake Tahoe with an acceptable degree of certainty. The concern of how the TMDL will operate within an environment where climate change can affect lake processes led to the climate change section in the Final Report. The transparency target will be 'climate normalized' and will be evaluated within the adaptive management process. As discussed in the Final Report the intent is to establish 5-year milestones for transparency. These milestones will be supported by estimates of pollutant load reduction (based on modeling and field data). If the predicted Secchi depth is different from the measured values during those five years, the adaptive management process will consider possible reasons for the difference (e.g. model refinement needed, estimates of pollutant load reduction need refinement). Another possible reason for a difference could be an affect from climate change. The lake monitoring program is sufficiently robust to identify changes in lake mixing resulting from temperature changes. Lake Tahoe has a rich history of research and monitoring which is expected to continue well into the future. However, it is understood that an alteration to lake may not be evident for 20+ years. Instead of trying to use a prediction of climate change to develop the TMDL, science and monitoring data will be relied on to inform the adaptive management framework for the TMDL.

2. ***Optical modeling in Lake Tahoe.*** Because the TMDL is based on a loss of water clarity (or transparency) in the lake, work related to predicting the effects of various lake conditions and concentrations of substances affecting Secchi depth are of critical importance to the credibility of the conclusions and goals stated in the TMDL document. The optical model thus is a critically important aspect of TMDL development for Lake Tahoe, and it needs to be described in much greater detail than it is in the TMDL document (hereafter referred to as "the TMDL"), where it is mentioned only in passing on page 8-2, or in the Technical Report (hereafter referred to as TMDL-TR), where it is described in one short sentence on page 3-14, paragraph 3. Readers (and reviewers) should not have to go to the original literature for such an important component of the study. The TMDL-TR gives a table of parameters used in the optical model in section 6, which helps a little to give an understanding of what is involved in the model, but this still is not sufficient to be able to evaluate the model.

3. ***Accuracy of predicted Secchi depth values and effects of stratification***. I consider the difference between measured and simulated in 2000 in Table 8-X (TMDL, p. 8-4) to be quite large, in spite of the fact that the table heading states the numbers are in good agreement. Overall, comparing the differences as percentages of the measured values is not very useful because the measured values (the denominator term) are high, leading to seemingly small percentage differences that actually are large (> 1 m, on average) in an absolute sense. A more appropriate analysis would indicate that the simulated values consistently overestimate SD, and the average overestimation is 1.4 m over the five years. Giving a standard deviation for the difference also would be useful. This difference is fairly large relative to the overall change in SD over the period of record and even larger relative to the hoped-for improvement in transparency over the next 20 years.

The effects of thermal stratification on lake transparency and timeframe of particle settling in relation to stratification are discussed in several places in the TMDL and TMDL-TR, but the statements are not always in agreement. For example, the last statement in the second paragraph on page 3-14 of the TMDL-TR seems to contradict the statement on the previous page about a decadal time frame for particle settling. It would seem to me that settling should be even more rapid in the quiescent waters below the thermocline than in the upper (mixed) layer. It is important that the discrepancy between these two statements on settling times be resolved. Similarly, the statement on page 3-20 (third line from bottom) seems to contradict earlier arguments about the slow settling of particles and about the negative impacts that deep waters have on transparency.

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Response

PB-2: Text has been added to the Technical Report in the beginning of Chapter 6 indicating where more detailed information can be found on the Lake Clarity Model. Readers who are interested in a detailed description of the actual development of the Lake Clarity Model, including model structure, algorithm development, selection of rate coefficients and model parameters are encouraged to read Sahoo et al. (2006). Sahoo et al. (2006) built upon Perez-Losada (2001), the original source that documented the development and structure of the Lake Clarity Model. Sahoo et al. (2006) was provided to the external peer reviewers as a supplement document.

PB-3: Given that the seasonal swing in Lake Tahoe's Secchi depth can be as much as 15 meters and that the annual average value is sensitive to annual precipitation conditions, the agreement between the annual modeled and measured Secchi depth in four of the five years analyzed was considered very good. The mean percent difference during those four years (2001-2004) was less than five percent. This corresponded to a value of just less than one meter (0.98±0.71 meters) in terms of an absolute difference. While one meter of Secchi depth is very large for most lakes, it is not necessarily the case for Lake Tahoe with its mean annual value of 20-25 meters. Jassby et al. (1999) compared two independent viewers recording Secchi depth simultaneously based on 217 sampling dates. Based on visual observations, the difference in Secchi depth reading could be on the order of 0.32-0.40 meters. The year 2000 appeared to be an anomalous year when the relative difference between modeled and measured average annual Secchi depth was 16 percent of 3.25 meters. The text in Section 6.2.2 of the Technical Report discusses possible factors leading to the difference seen in 2000. As part of the TMDL management strategy this model will not be used to predict Secchi depth; rather, the detailed field measurements will continue to be taken and the actual field data will be used to monitor progress towards meeting TMDL goals whether they are the 20 year Clarity Challenge or the effort to return transparency to its existing water quality standard of nearly 30 meters. Consequently, the goal of the Lake Clarity Model is to help guide a reasonable control strategy. As discussed in the Final Report, the ability of the Lake Clarity Model to predict transparency based on actual, implemented pollutant controls will be evaluated within an adaptive management framework.

PB-4: There is a distinction between the estimated settling time of a few months for particles and the longer settling velocities for nitrogen and phosphorus. As noted, nutrients are mineralized from particulate organic matter and recycled as they settle in the water column. As a result there is a longer residence time for these nutrients in the water column. The transport of particles as reported by Sunman (2001) refers only to the particle matrix itself and not the associated nutrients. Jassby (2006) modeled particle deposition for Lake Tahoe and found that particle aggregation increased the rate at which particles themselves settled. Text was added to the Technical Report in Section 3.4.1 to clarify this issue.

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PB-5: A new scientific paper came out (Sahoo and Schladow 2008) since this section was written that models the expected future lake mixing patterns in Lake Tahoe under climate change conditions, new information has been added to the text in Section 12.2 of the Final Report. While there has yet to be research on the topic of whether or not the bottom waters of Lake Tahoe will go anoxic over a 20 year period of no mixing, the purpose of this section is to identify areas that might require attention under an adaptive management framework.

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PB-6: Text has been added to the Technical Report, Section 4.1.5 to indicate that all sewage (solid and liquid) is exported out of the basin, so the exported materials were not counted as a source. The municipal water purveyors do not add ammonium as part of chlorination but at <1.0 parts per million (ppm) sodium hypochlorite for disinfection into their water delivery system. Most water purveyors do not add phosphate for corrosion protection, except about 10% or less of all water lines have zinc orthophosphate added, usually at concentrations <1ppm. USACE (2003) concluded that exfiltration is not a significant source of nutrients to Lake Tahoe. Adding low concentrations of zinc orthophosphate to <10% of all water delivery pipes is considered an insignificant potential source of phosphorus.

4-2 and associated text of the TMDL-TR at least should mention these potential sources and also should note that wastewater wasn't considered because it is exported from the basin.

Second, the EMC multiplying factor used to calibrate fine sediment loads (pages 4-62 and 63 of the TMDL-TR) seems rather arbitrary and empirical, and no explanation is provided for its basis (other than that it seemed to work). Some effort to explain the need for this empirical factor would seem to be appropriate. I note that the factor has a large range (> 6) and so it has a large effect on predicted loads. The same criticisms apply to the scaling factor based on quadrant.

Third, I always find graphs like Figures 4-27 to 4-29 of the TMDL-TR troublesome, especially when they are presented to illustrate "how well" the simulations fit to measured data. It is difficult to tell from the figures, especially in any quantitative sense, how good or poor the fit actually is, but it appears that the fit is not good in terms of simulating either the timing of events or the variability in the data. This is especially the case for 2000-2001 for all three modeled constituents. About the best one can say from these figures is that the simulated values are in the "same ballpark" as the measured values. Perhaps that is sufficient for the purposes of the TMDL study, but if that is the case, I doubt that the time and effort that went into developing such a comprehensive and detailed modeling approach can be justified. Simpler approaches that didn't try to model and portray short-term variability would have been sufficient. If the authors want to show how well (or poorly) the model simulates reality, they should present plots of simulated versus measured concentrations (scatter plots) and show the statistics (r^2 values) that quantify the degree to which the simulations explain the variance in the measured data. I suspect such plots would show poor fit of individual simulated values to measured values. I accept the arguments made in various places in the TMDL-TR that the goal was not to simulate individual measurements and that it is very difficult to achieve that, but some larger-scale statistics could and should be produced to show whether the simulations capture key features of the measured values at the time scale of a year (e.g., annual means and ranges, and annual variance).

Finally, the regressions of Rabidoux (2005), described on p. 5-5 of the TMDL-TR, to predict particle fluxes as a linear function of stream flow involve a self-correlation. Particle flux (P) is a product of particle concentration, C_P, (in stream water) and stream flow, Q; i.e.:

$$P = C_P{*}Q \text{ (number/m}^3\text{)*(m}^3\text{/sec) = (number/sec)}$$

The regressions thus implicitly are C_P*Q versus Q, which is a correlation of a variable with a function of the same variable. Depending on the ranges of C_P and Q this could lead to spurious self-correlations. The authors need to examine whether in fact this occurred in Rabidoux's analyses. There are straightforward statistical techniques for deciding whether this is a serious problem or not.

5. ***Atmospheric loading issues.*** I have two separate concerns about the work on atmospheric loadings. First, the issue of local versus regional sources for atmospheric particles and nutrients has very important implications in terms of implementing a control strategy, and the subject deserves more attention and description in the text than it is given. The text associated with Table 4-64 (p. 4-150 of the TMDL-TR) at least should provide a summary of the basis by which CARB concluded that most of the particulate matter, TN and TP in wet deposition is locally generated. This is a very important finding. I also note that the proportions of regional versus local contributions for fine particulate matter are reversed in winter-spring versus summer-fall, and that regional sources dominate in the latter seasons. This suggests that regional sources may be more important in affecting lake transparency during the critical summer period than implied by using the aggregated annual values of regional versus local contributions. The authors should address this issue.

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Response

PB-7: The reasoning behind these multiplication factors was empirical and based on the observation that the behavior of granitic and volcanic soils are different. In a series of papers by Grismer and Hogan (2004, 2005a,b) who studied soil erosion in the Lake Tahoe basin using a portable rainfall simulator, they reported that runoff rates, sediment concentrations and sediment yields were greater from volcanic soils as compared to that from granitic soils for nearly all vegetated cover conditions tested. The first set of multipliers was therefore related to the soil composition, to account for areas with volcanic soils having larger unit area loads than areas with granitic soils. Given that Grismer and Hogan (2004) found that sediment yield from bare volcanic soils ranged from 2-12 g $m^{-2}mm^{-1}$ as compared to 0.3-3 g $m^{-2}mm^{-1}$ for granitic soils, the range of multipliers determined in Figure 4-26 appears reasonable. The second set of multiples, by quadrant, is empirical, but was necessary to account for differences seen in loads from streams in different locations of the lake. These quadrant multiplication factors came from the calibration process. The sensitivity of the Lake Tahoe Watershed Model and the nature of the stream monitoring data provided by the Lake Tahoe Interagency Monitoring Program (10 monitored streams) was not sufficient to customize loading for each of the lake's 63 tributaries and assumptions were required. New text was added to the Technical Report in Section 4.3.5 under the headings *Model Parameterization by Land-use* and *Water Quality Calibration Process* with the above information.

PB-8: There is agreement that papers/reports on water quality modeling often show plots of observed and simulated results without further analysis. This is often unsatisfactory to readers and reviewers and it is why a more direct comparison of the output from the Lake Tahoe Watershed Model versus the measured data from the Lake Tahoe Interagency Monitoring Program (LTIMP) was developed and presented in Table 4-41. The goal was not to simulate individual measurements. Given the changes measured in Lake Tahoe and the high interannual variability in precipitation and hydrology, an annual comparison was chosen considering the monthly-seasonal values were realistic. As stated in the Technical Report (Section 4.3.6 under the heading *Lake Tahoe Watershed Model versus Lake Tahoe Interagency Monitoring Program Loading Comparison*), while there was some difference between the LTIMP and Lake Tahoe Watershed Model (LSPC) values for certain tributaries and for certain nutrient species (e.g. Blackwood Creek dissolved inorganic nitrogen (DIN) and Ward Creek soluble reactive phosphorus(SRP)), there was very good agreement, especially when considering the combined sum for the 10 tributaries (Table 4-41). The relative percent difference (LSPC-LTIMP)/(mean of LSPC and LTIMP) was between 10 − 14 percent with the exception of SRP which was much higher at 60 percent. The difference between LTIMP field data and LSPC modeled output for SRP was greatest for the Upper Truckee River, Ward Creek and Blackwood Creek. While these differences require further investigation, the Lake Clarity Model considers biologically available phosphorus which is derived from both SRP and a fraction of total phosphorus. Assuming all SRP is bioavailable and that approximately 20 percent of the remaining phosphorus is bioavailable (Ferguson 2005), an approximation of bioavailable-phosphorus from the10 monitored streams shows the relative percent difference between LTIMP and LSPC was reduced to 25 percent.

4-2 and associated text of the TMDL-TR at least should mention these potential sources and also should note that wastewater wasn't considered because it is exported from the basin.

Second, the EMC multiplying factor used to calibrate fine sediment loads (pages 4-62 and 63 of the TMDL-TR) seems rather arbitrary and empirical, and no explanation is provided for its basis (other than that it seemed to work). Some effort to explain the need for this empirical factor would seem to be appropriate. I note that the factor has a large range (> 6) and so it has a large effect on predicted loads. The same criticisms apply to the scaling factor based on quadrant.

Third, I always find graphs like Figures 4-27 to 4-29 of the TMDL-TR troublesome, especially when they are presented to illustrate "how well" the simulations fit to measured data. It is difficult to tell from the figures, especially in any quantitative sense, how good or poor the fit actually is, but it appears that the fit is not good in terms of simulating either the timing of events or the variability in the data. This is especially the case for 2000-2001 for all three modeled constituents. About the best one can say from these figures is that the simulated values are in the "same ballpark" as the measured values. Perhaps that is sufficient for the purposes of the TMDL study, but if that is the case, I doubt that the time and effort that went into developing such a comprehensive and detailed modeling approach can be justified. Simpler approaches that didn't try to model and portray short-term variability would have been sufficient. If the authors want to show how well (or poorly) the model simulates reality, they should present plots of simulated versus measured concentrations (scatter plots) and show the statistics (r^2 values) that quantify the degree to which the simulations explain the variance in the measured data. I suspect such plots would show poor fit of individual simulated values to measured values. I accept the arguments made in various places in the TMDL-TR that the goal was not to simulate individual measurements and that it is very difficult to achieve that, but some larger-scale statistics could and should be produced to show whether the simulations capture key features of the measured values at the time scale of a year (e.g., annual means and ranges, and annual variance).

Finally, the regressions of Rabidoux (2005), described on p. 5-5 of the TMDL-TR, to predict particle fluxes as a linear function of stream flow involve a self-correlation. Particle flux (P) is a product of particle concentration, C_P, (in stream water) and stream flow, Q; i.e.:

$$P = C_P * Q \text{ (number/m}^3\text{)*(m}^3\text{/sec) = (number/sec)}$$

The regressions thus implicitly are C_P*Q versus Q, which is a correlation of a variable with a function of the same variable. Depending on the ranges of C_P and Q this could lead to spurious self-correlations. The authors need to examine whether in fact this occurred in Rabidoux's analyses. There are straightforward statistical techniques for deciding whether this is a serious problem or not.

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Response

PB-9: Rating curves were constructed with measured particle size data and the corresponding instantaneous streamflows using the Bradu-Mundlak Estimator, which is a statistically unbiased rating curve method (Cohn et al. 1989). Rabidoux (2005) considered this issue of self-correlation. Initially particle concentrations (C) were regressed against instantaneous flow (Q); however, the R^2 values were very low ranging from 0.00 - 0.74 (mean±sd = 0.24±0.22) and this range is not unlike what is seen in other systems (e.g. Braun et al. 2000; Schoellhamer and Wright 2003). Instead, particle flux (#/sec) was regressed against Q yielding higher R^2 values. As noted, this may in part be due to auto-correlation since Q is considered as part of particle flux. There is a large amount of natural variability in sediment transport measurements compared with the transport of dissolved constituents. This is exacerbated since the LTIMP monitoring program deliberately attempts to capture high flow events when variability in sediment transport is the largest. The impact of hysteresis, which can never be adequately resolved by episodic measurements (as opposed to continuous measurements), results in a large degree of scatter in the data (the same flow rate yielding different concentrations during different events). Consequently, a straight regression of C vs Q, while strictly correct, does not necessarily add much meaning in this particular circumstance. Considerable variability has been seen by others when comparing streamflow total suspended sediment concentration. The finest fraction (<16 microns) is considered and little is known about the variation in that range.

An approach explored by Rabidoux was to use the correlations of C vs. Q and then simply multiply by Q to get the flux. This yielded essentially the same fluxes as when CQ vs. Q correlations were used (with their seemingly higher correlation coefficients). Therefore, for ease of use, this second approach was adopted.

PB-10: A brief overview of methodology used to distinguish between local and regional sources for wet deposition has been added to Section 4.5.5 of the Technical Report. The Lake Tahoe Atmospheric Deposition Study (CARB 2006) provides the detailed analysis used to distinguish between local and regional sources for wet deposition. While particulate matter shows a large increase in the relative contribution (i.e. percent of total deposition) from regional sources in the summer and fall (Table 4-64), the absolute amount of each of the particulate matter size classes during this period was only 15-20 percent the total annual load from wet deposition (Table 4-61). Given that the minimum, long-term, Secchi depth typically occurs in Nov-Dec and again in May-June regional particulate matter deposition in the summer-fall is having an important affect on lake transparency.

Second, it is not entirely clear to me what the basis is for the expectation that watershed management will be sufficient to meet atmospheric load reductions, as is stated in the TMDL on page 11-13. The text notes that the majority of fine particles from the atmosphere are generated by urban roadways. As a minimum, the effectiveness of controls on particle loads from these roadways in decreasing atmospheric loadings will depend on the nature of the controls on stormwater from the urban roadways. If the controls primarily involve treatment of roadway runoff in detention/retention ponds, this will have no effect on the extent to which the roadways generate fine particles that are swept into the atmosphere during periods when it is not raining. Increased frequency of street sweeping could help decrease atmospheric loadings of fine particles derived from roadways, but it would have been useful to see a more thorough analysis of this.

6. ***Feasibility of adjusting the management plan in response to wildfires and climate change*.** Just because wildfires are sporadic does not to me seem adequate justification for excluding them from consideration in loading targets and management plans, as the TMDL states on page 12-11, first paragraph. It seems likely, given what the report describes concerning the consequences of climate warming, that wildfires will be more prevalent in the future than they have been in the past. At least the TMDL should acknowledge this and indicate that it will be considered as a part of the adaptive management program.

It will be very difficult to adjust the management plan to changing climate over the 20-year timeframe of the clarity challenge because of inherent noise in climate data. For example, five years of above average temperatures and below average precipitation could be followed by five years of below average temperatures and/or above average precipitation. The signal of increasing global CO_2 is apparent at near annual resolution from the long-term record in Hawaii, but the signal of climate change is not apparent anywhere near this level of resolution, especially for specific geographic areas. At best, I think the managers might be able to see a change in climate at the end of the 20-year challenge period and adjust their goals and management plans for the next 20 years accordingly. However, even this is not a certainty. The text should be modified to reflect the strong likelihood that we will not be able to see long-term climate changes within the timeframe of the initial implementation period (really the first 15 years of the challenge period).

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Response

PB-11: Although the Water Board and NDEP cannot specify how responsible parties will achieve needed load reduction within the urban areas, greater street sweeping frequency with efficient vacuum sweepers is expected. Unpaved parking areas, construction projects, and unpaved forest roadways have also been identified as significant sources of fine sediment particles that reach the lake through atmospheric deposition. Existing regulations that require best management practices for construction activities and for commercial properties are expected to reduce the atmospheric fine sediment particle load. Similarly, the U.S. Forest Service LTBMU and other forest management agencies have active programs to reduce the number of unpaved forest roadways in the Lake Tahoe basin. The Lake Tahoe TMDL Implementation Plan relies on these existing plans and polices to achieve needed atmospheric deposition pollutant load reductions.

PB-12: Since the early 1900s, the occurrence of large wildfires in the Lake Tahoe basin has been significantly reduced due to an effective fire control program (Heyvaert 1998). Consequently, (1) there are very few instances where the affect of wildfire on water quality has been documented and (2) our confidence in knowing how a future wildfire would affect sediment and nutrient loading to Lake Tahoe is limited. As discussed in Section 12.3 of the Final Report, only the Gondola Fire (2002) and most recently the Angora Fire (2007) have been monitored. The water quality studies associated with these two events are much too limited to allow us to predict pollutant loading at any location in the Tahoe basin. As is the case for climate change, that there was too much uncertainty to directly incorporate wildfire into loading targets. Most importantly, wildfires are stochastic events and not predictable. In light of this there would be no basis for including the timing, duration, coverage, severity, or location of a wildfire in simulations of future conditions. Instead, it was the intention of the Final Report to convey that wildfires will be considered as part of the 5-year milestones within the adaptive management program. Data collection from the Angora Fire is only two years old at this point; however, should another wildfire occur the Gondola Fire and Angora Fire data along with site-specific monitoring data and an updated fire component to the Lake Tahoe Watershed Model will all be used to evaluate potential ramifications to load allocations within the TMDL.

Second, it is not entirely clear to me what the basis is for the expectation that watershed management will be sufficient to meet atmospheric load reductions, as is stated in the TMDL on page 11-13. The text notes that the majority of fine particles from the atmosphere are generated by urban roadways. As a minimum, the effectiveness of controls on particle loads from these roadways in decreasing atmospheric loadings will depend on the nature of the controls on stormwater from the urban roadways. If the controls primarily involve treatment of roadway runoff in detention/retention ponds, this will have no effect on the extent to which the roadways generate fine particles that are swept into the atmosphere during periods when it is not raining. Increased frequency of street sweeping could help decrease atmospheric loadings of fine particles derived from roadways, but it would have been useful to see a more thorough analysis of this.

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Response

PB-13: The natural variability in precipitation could create multiple years of wet or dry conditions and this could mask the more subtle year-to-year changes caused by climate change. It is difficult to incorporate climate change directly into the formulation of a clarity standard-TMDL target. The 20-year time table for the Clarity Challenge is based on what has been determined to be a reasonable goal to confirm a noticeable improvement in lake transparency. Actions to require additional pollutant reduction will extend beyond that 20-year period until the water quality standard of 29.7 meters is reached. Consequently, the time frame for considering the impact of climate change on Lake Tahoe will extend well beyond the initial 15-20 year implementation period. Continued long-term monitoring as well as using the existing Lake Clarity Model to predict the possible magnitude and timing of a climate change induced impact to Lake Tahoe will be important to support. The Lake Clarity Model is currently being used for this purpose as part of a research grant funded by the Southern Nevada Public Land Management Act (SNPLMA). When complete, this work will inform us as to what might be expected and over what time frame. All this type of information will be incorporated in the TMDL Management System (adaptive management program) and if needed in the future, adjustments to the program will be made based on new knowledge.

PB-14: Regarding limnological methods such as primary productivity and Secchi depth measurements, the protocols have largely remained consistent over the period of record. Programs with long-term data collection must face the fact that as technology improves and improved approaches for making field and lab measurements are developed, a switch in methods can possibly affect trends if the new and old data sets are not comparable. The UC Davis Lake Tahoe limnology program is very aware of this and has been careful to eliminate these types of uncertainties to the extent possible. Additional text has been added to the Final Report in Section 3.4.1 regarding consistent data collection methodologies for the long-term data. It is difficult to know if fertilizer application was under or over estimated in either the 1972 or the 2003 studies. The calculations for fertilizer application are relatively straightforward, i.e. loading estimates in both studies were primary based on the land-use specific recommended application rates, the nutrient content of the fertilizer in use, and the amount of land receiving fertilizer. The availability of GIS allows the estimation of the amount of land that could receive fertilizer to be more accurate. While the USACE (2003) Groundwater Evaluation report liberally assigned fertilizer use to a portion of the land area of all single-family homeowners in the Lake Tahoe basin, the values from the remaining land-use areas were considered by USACE (2003) to be based on realistic rates. This is discussed in Section 4.1.5 of the Technical Report. The USACE report stated that "the method for determining the percent fertilized land area for each category was based on historical reports (Mitchell 1972) and sound judgment." Furthermore, it is important to note that the current TMDL analysis does not depend on an increase in fertilizer use over time, but rather on the current use. The goal of the TMDL, in part, is to develop an approach for reducing existing pollutant loading.

Second, it is not entirely clear to me what the basis is for the expectation that watershed management will be sufficient to meet atmospheric load reductions, as is stated in the TMDL on page 11-13. The text notes that the majority of fine particles from the atmosphere are generated by urban roadways. As a minimum, the effectiveness of controls on particle loads from these roadways in decreasing atmospheric loadings will depend on the nature of the controls on stormwater from the urban roadways. If the controls primarily involve treatment of roadway runoff in detention/retention ponds, this will have no effect on the extent to which the roadways generate fine particles that are swept into the atmosphere during periods when it is not raining. Increased frequency of street sweeping could help decrease atmospheric loadings of fine particles derived from roadways, but it would have been useful to see a more thorough analysis of this.

6. ***Feasibility of adjusting the management plan in response to wildfires and climate change.*** Just because wildfires are sporadic does not to me seem adequate justification for excluding them from consideration in loading targets and management plans, as the TMDL states on page 12-11, first paragraph. It seems likely, given what the report describes concerning the consequences of climate warming, that wildfires will be more prevalent in the future than they have been in the past. At least the TMDL should acknowledge this and indicate that it will be considered as a part of the adaptive management program.

It will be very difficult to adjust the management plan to changing climate over the 20-year timeframe of the clarity challenge because of inherent noise in climate data. For example, five years of above average temperatures and below average precipitation could be followed by five years of below average temperatures and/or above average precipitation. The signal of increasing global CO_2 is apparent at near annual resolution from the long-term record in Hawaii, but the signal of climate change is not apparent anywhere near this level of resolution, especially for specific geographic areas. At best, I think the managers might be able to see a change in climate at the end of the 20-year challenge period and adjust their goals and management plans for the next 20 years accordingly. However, even this is not a certainty. The text should be modified to reflect the strong likelihood that we will not be able to see long-term climate changes within the timeframe of the initial implementation period (really the first 15 years of the challenge period).

7. ***Consistency in methods for long-term data.*** The report uses some of the valuable long-term data collected on Lake Tahoe, but it does not indicate whether consistent methods were used to obtain the results over the entire period of record. For example, in discussing trends in primary production, the report indicates a significant increase over time since Goldman's original measurements in the 1959 (TMDL, page 3-4, line 2 from bottom; Figure 3-5). I wonder whether the same measurement methods were used throughout this time period. Are the earlier results really comparable with the later ones? The text should comment on this. Similarly, the TMDL-TR (page 4-18, first paragraph) compares fertilizer use in the basin in 1972 with current or recent rates. One wonders whether the 1972 data were underestimates. If so, perhaps fertilization rates have not increased so markedly in the basin. Some attention to this possibility seems in order.

8. ***Monitoring issues.*** Future monitoring activities on Lake Tahoe are described in the TMDL in the second paragraph on page 13-8. I recommend that the monitoring program add pH, specific conductance, and DOC/TOC as routine measurements and annual measurements of major ions (including alkalinity), iron and manganese. None of these is expensive to measure, and they will add greatly to the usefulness of the long-term database. Specific conductance and pH are very basic limnological parameters measured in nearly all chemical studies. DOC is related to transparency, at least indirectly.

Given the huge budget problems facing the state of California, one wonders how certain the authors of the document are (or can be) that the LTIMP tributary monitoring described on page 13-9 of the TMDL

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Response

PB-15: An investigation by Swift (2004) showed that CDOM had very little influence on Secchi depth and other lake optical properties in the open-water pelagic zone. Consequently, sampling for DOC/DOM has not been done in that region. However, depth profiles for particulate carbon and nitrogen are routinely taken as part of the UC Davis/Lake Tahoe Interagency Monitoring Program (lake sampling). In addition, it is possible that DOM/DOC may affect lake clarity in the nearshore region as urban stormwater and wetland flow drain into Lake Tahoe. Resource agencies and researchers in the Lake Tahoe basin are currently (2010-2011) designing a more detailed nearshore monitoring plan that should include this constituent. Furthermore, a UC Davis graduate student is currently measuring DOC/TOC in the lake and its water sources as part of a research project. Data from that study will help to determine if the current monitoring program requires revision. *In situ*, specific conductance is also measured routinely by UC Davis limnologists using and submersible sensor (Seahbird). However, pH is not routinely measured and the lake is well-buffered compared to other regional lakes.

PB-16: Monitoring and research in the Lake Tahoe basin has been funded and highly supported for decades at the local, state and federal levels. Resource agencies, in partnership with the Tahoe basin scientists and the Tahoe Science Consortium (http://www.tahoescience.org/) are currently involved with an extensive re-evaluation of the resources available for funding monitoring as compared to agency/science needs. The Regional Stormwater Monitoring Program (RSWMP – as discussed in Section 13.2.2 in the Final Report) is also considered a very high priority. The details associated with any need to modify monitoring programs will be discussed among implementing partners and stakeholders to ensure the data is providing for loading (or load reduction) evaluations.

will continue to provide data that can be used to assess the effects of load reduction measures. I think this issue needs to be addressed explicitly in the report.

9. ***Need for more specificity and examples in citing shifts and trends.*** In several places the reports the report describes shifts that apparently have occurred in certain characteristics in the lake but the text is vague on the magnitude of the shift. Inclusion of some numbers would be useful to put the comments into perspective. An example related to thermal stratification is on page 3-8, line 3 of the TMDL. Similarly on line 9 of the same page, the text is vague about the shift in the deep chlorophyll maximum. Some vertical profiles illustrating the change would be useful (or referencing where they may be found in an accompanying document would help).

Review Issues Requested by California Regional Water Control Board—Lahontan Region

The request to review the Lake Tahoe TMDL and associated documents requested responses regarding eight issues of primary concern. In each case the reviewer was requested to determine whether the scientific portion of the proposed Basin Plan Amendment (related to the stated issue) is based upon sound scientific knowledge, methods, and practices. The eight issues are listed in bold below followed by my analysis and conclusions.

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

The reports provide sufficient evidence based on field studies and analysis of historical data that fine particles (< 16 µm in diameter) are the primary cause of clarity impairment in Lake Tahoe. Actually, the reports provide evidence that clarity is affected primarily by particles $\leq$ 5 µm in diameter. The reports also demonstrate that the clarity reduction is caused by fine (mostly inorganic) particles exported from the watershed and also deposited directly onto the lake surface by atmospheric wet and dry deposition, as well as by in-lake generated particles produced by phytoplankton growth. To some extent, the study relies on the seminal findings of Jassby et al. 1999 to make the case for the importance of inorganic particles of watershed and atmospheric origin, but I think sufficient data are presented in the TMDL documents to make the case. By use of the Lake Clarity Model, the researchers were able to make predictions of what would happen to lake clarity under a range of scenarios of nutrient and fine particle loadings to the lake. The work related to this issue is based on sound science and widely accepted scientific methods.

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.

Based upon my review of the TMDL and TMDL-TR, I conclude that the study adequately and appropriately identified the six main sources of pollution affecting Lake Tahoe water clarity and was correct in assessing urban upland areas as the most important of these sources. The work described in the reports was based on sound and currently accepted scientific methods, as described elsewhere in this review. I agree that the reliability of the estimates was checked, where possible, by using several independent methods of analysis or calculation. Of course, there is a stronger database and much longer historical record available to assess the contributions of nutrients than fine sediment particles, but my assessment is that the study was adequate to address this specific issue.

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

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

Response

PB-17: New text and figures were added to the Technical Report, Section 3.4.2 to include information on annual Chlorophyll *a* concentrations (or phytoplankton) (Figure 3-14), the annual deep chlorophyll maximum data and trends (Figure 3-15), the annual depth of mixing (Figure 3-16), and the volume averaged temperature with trendline.

PB-18: As highlighted in the Technical Report in Section 3.4.1, it was the optical model developed by Swift et al. (2006) that created the supportive documentation that (1) validated the hypothesis in Jassby et al. (1999) that fine sediment particles were important with respect to Lake Tahoe transparency and (2) developed the optical submodel that was incorporated into the larger Lake Clarity Model.

The Lake Tahoe Watershed Model is based on several existing components that have been accepted and used by others and were adapted and further developed for application to the drainage basin of Lake Tahoe. As indicated elsewhere in this review, the reports describe in considerable detail the work done to develop and use this model. Although I have a few specific concerns about the way the model was used (e.g., see item 4 of the previous section), I do not have any concern that the model was inappropriate or represents a less than "state-of-the-art" approach to modeling pollutant export from watersheds. The university and firm that conducted much of the watershed modeling work are well respected institutions, and based on evidence provided in the text, I conclude that the model development was carefully done.

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

I preface my conclusions on this issue with two initial remarks. First, I do not consider myself to be an expert on ground-water modeling. Second, the TMDL and TMDL-TR documents rely heavily on the U.S. Army Corps of Engineers study (USACE 2003) and mostly summarize what is reported in that document. The TMDL documents do not provide the level of detail on ground-water loading estimates provided on watershed modeling. Consequently, I was not able to perform a thorough, independent review and analysis of the technical details on ground-water nutrient loadings. Nonetheless, the descriptions provided in the reports indicate that the USACE work was competently and carefully performed, with attention to issues of heterogeneity in the ground-water aquifers of the basin. The concentrations of nutrients reported for the aquifers and the nutrient loading rates appear to be reasonable. It also was reasonable for the study to assume that ground water is not a source of fine particles to Lake Tahoe.

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.

The studies undertaken to quantify nutrient (N and P) and fine particle loadings to Lake Tahoe from atmospheric deposition directly to the lake's surface were extensive, and they appear to have been competently done. Both historical and new data were used to make the assessment. In my opinion, the conclusions related to rates of N and P deposition and the fraction of annual fine particle load contributed by direct deposition of dust are based on sound scientific knowledge, methods, and practices.

I am unable to make the same statement about the conclusion that in-basin sources were found to be the dominant source of nitrogen and fine particles. As noted in item 5 of the previous section, I found the report deficient in its description of how CARB reached this conclusion. This is not to say that the wrong conclusion was reached or that the work was scientifically unsound or based on unsound methods. I simply am unable to evaluate these issues on this topic because the report lacks sufficient detail. Additional documentation should be added to the TMDL-TR to describe how this was done. In addition, the high variability in local versus regional contributions across the seasons suggests that merely looking at the annual loadings may not be adequate. The data in Table 4-64 of the TMDL-TR indicate that most of the atmospheric loadings in summer are from regional rather than local sources, and this could impact water clarity negatively during this period, which is critical from lake-user perspective.

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.

Much of the work done on this issue was not highly technical (at least not of the nature of the analyses and modeling efforts that led to the loading estimates, targets, and allocations), and a somewhat different

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Response

PB-19: The methodology used by the US Army Corps of Engineers for the Lake Tahoe groundwater investigation was specifically defined in their *Groundwater Evaluation* report (USACE 2003). This report is available through the Lahontan Water Board and provides the technical details for their estimates of groundwater loading. It is highly recommended that those interested in the methodology refer to that document. There are a number of studies that were used to inform the Technical Report; however the details of particular studies do not appear in the report, just the important findings are summarized.

A summary of the approach taken to estimate nutrient loading is provided below. The loading estimates were separated into five regions based on political boundaries and major aquifer limits. The five regions included South Lake Tahoe/Stateline, East Shore, Incline Village, Tahoe Vista/Kings Beach and Tahoe City/West Shore. Depending on the amount and type of groundwater data available, discharge estimates were developed using one or a combination of three methods; groundwater flow modeling, Darcy's Law and/or seepage studies. The South Lake Tahoe/Stateline aquifer discharge was based on existing data of sufficient quality and quantity to develop a groundwater flow model. The remaining four regional aquifer seepage estimates were developed using either Darcy's Law or existing seepage data. Once the groundwater discharge estimates were calculated, nutrient concentrations were applied to determine annual loading to Lake Tahoe.

The nutrient concentrations used to determine the loading estimates were based on either average nutrient concentrations for a region, measured down gradient concentrations for a region or land-use weighted concentrations. The land-use weighted concentrations were used in areas with little monitoring data available or areas that did not have meaningful placement of wells in relation to land-use.

PB-20: The Technical Report text in Section 4.5.5 has been modified to provide additional information about in-basin sources of nitrogen and fine sediment particles.

basis is appropriate to address its adequacy. The PRO analysis and related IWMS involved a wide range of experts from many stakeholder groups and extensive amounts of review of preliminary findings. I am not an expert on the processes whereby pollutant reduction options have been analyzed in other TMDL studies, but I found the approach used in this study to be thorough, objective, and open. The results presented in the PRO appear reasonable to me, although I also am not an expert on many of the load reduction technologies. The costs associated with the implementation efforts needed to achieve the clarity challenge are truly daunting in this day of (many) billion dollar state deficits and trillion dollar national deficits.

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

Insofar as the Lake Clarity Model (LCM) was developed specifically for Lake Tahoe, which is a highly unusual lake with respect to water clarity, I agree that this is the most appropriate model for predicting responses of the lake to changes in pollutant loads. The LCM is based on a hydrodynamic sub-model that has been tested internationally and is widely accepted as appropriate. This sub-model produced reasonable simulations of thermal stratification and related patterns in the lake. The LCM takes a comprehensive approach to simulating the behavior (and formation) of light scattering and light absorbing particles in Lake Tahoe. The component dealing with phytoplankton growth is explained thoroughly in the report and appears to use appropriate mathematical formulations.

In some respects, however, the core of the LCM is the optical model that was developed by Swift and coworkers. Unfortunately, as indicated in item 2 of the previous section, the reports do not provide sufficient information for a technical review of this critically important component.

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.

Although limitations in the field data cause a fair amount of uncertainty to remain in the estimates of particle contributions from specific sources, the study did a creditable job of estimating these contributions for each pollutant source. This was a very difficult task, and the researchers recognized the limitations in the data and compensated as best they could by using (where feasible) independent methods of analysis and calculation to reach their conclusions. Overall, I conclude that the work on this issue was based on state-of-the-art techniques and involved extensive review and oversight. Based on my review of the reports, I conclude that allocations of allowable loads were done objectively based on the relative magnitude of source contributions with proper attention to technological and economic constraints in the ability to reduce loads from various sources. Nonetheless, some issues should be addressed, as noted in items 1, 5, and 6, and the last paragraph of item 4 in the previous section.

Smaller Technical Concerns and Editorial Issues

(Note: "fb" in the column for "line" denotes "from bottom" of the page; ¶ denotes paragraph number)

Page	**¶/Line**	**Comment**
ES-2	4fb	It would be clearer if the values were given as percentages of the required reduction (e.g., 24.5*100/32 = 76.5% of the reduction should come from urban uplands.)
2-1		The map (Figure 2-1) is not very helpful. It is unclear where the line between CA and NV is. It is not clear that the unnamed area on the NW end of the lake is a part of

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PB-21: The location map, Figure 2-1 in the Final Report has been replaced with a more accurate figure.

		Placer County. The middle county in NV is labeled Ormsby, but the text (p. 11-7) refers to it as Carson City Rural.
2-2	11fb	There should be no spaces between the dash connecting a range of numbers and no apostrophe for pluralizing numbers (should read: 1900s-1950s). This is a consistent problem in the text and should be corrected in the final report.
2-3	3-4	The text does not agree with what the map shows. Much of the west shore is developed; only the SW end appears undeveloped. Similarly, much of the east shore appears to be developed except for a few stretches on the northern third of the east shore.
2-4	Fig. 3-2	Box indicates the line of best fit is a linear fit but the line clearly is curved. The best fit equation should be provided in the box.
	6fb	This is an understatement. The figure shows that ~70% of the scattering is due to particles < 5 µm in diameter.
3-4	5	I doubt that we can know this increase with the accuracy implied by the text (725%).
	10	Use of double slashes is incorrect and a mathematically ambiguous way to display areal rates. The report should use either $g\ C/m^2 \cdot yr$ or $g\ C\ m^{-2}\ yr^{-1}$.
7-7	6	"Data" is a plural word; text should read "water quality data were collected.…" This error occurs in a number of places in the TMDL and accompanying technical document and should be corrected in the final versions.
	1,2fb	"provide" and "estimate" should be written in the past tense.
7-8	13fb	One wonders how inorganic versus organic particles were determined.
8-5	Figure	The slope of the "Projected trend" does not appear to fit the data in the graph.
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10-4	15fb	Should be Tables 10.2 through 10.4
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2-2	11fb	There should be no spaces between the dash connecting a range of numbers and no apostrophe for pluralizing numbers (should read: 1900s-1950s). This is a consistent problem in the text and should be corrected in the final report.
2-3	3-4	The text does not agree with what the map shows. Much of the west shore is developed; only the SW end appears undeveloped. Similarly, much of the east shore appears to be developed except for a few stretches on the northern third of the east shore.
2-4	Fig. 3-2	Box indicates the line of best fit is a linear fit but the line clearly is curved. The best fit equation should be provided in the box.
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3-4	5	I doubt that we can know this increase with the accuracy implied by the text (725%).
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7-7	6	"Data" is a plural word; text should read "water quality data were collected…." This error occurs in a number of places in the TMDL and accompanying technical document and should be corrected in the final versions.
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PB-22: The spaces between the dash connecting a range of numbers and the apostrophe for pluralizing numbers have been removed throughout the document.

PB-23: Figure 3-2 in the Final Report has been updated and the R^2 and p-value has been added to the caption.

PB-24: The text refers to Figure 3-4 and not Figure 3-3 in the Final Report

PB-25: The text in Section 3.4.1 of the Final Report has been updated and the new percent value given is more general.

PB-26: The text has been corrected, the use of double slashes was incorrect, the units are correctly displayed in the Final Report (Section 3.4.1).

PB-27: The term data is plural, the text has been updated in Section 7.5 of the Final Report and throughout both the Final Report and Technical Report.

PB-28: The text has been updated in the Final Report (Section 7.5), the terms are now "provided" and "estimated".

PB-29: The text in the Final Report, Section 7.6 has been updated, and the statement regarding organic verses inorganic source origin has been deleted.

PB-30: The text has been removed and/or corrected for Chapters 9-11.

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PB-31: The Figure 2-1 has been replaced, the text is correct, it is Carson City Rural County.

PB-32: The text has been removed and/or corrected for Chapters 9-11.

PB-33: New text was added to the Final Report, Section 12.2.

PB-34: A new figure was added to the Technical Report (Figure 3-16) that displays the annual depth of mixing from 1973 – 2008. New text was also added to the Final Report (Section 12.2) to include additional information on an analysis conducted on the possible impacts of climate change on lake mixing and stratification.

PB-35: The stormwater samples will be collected as specified in the Regional Stormwater Monitoring Program. Both composite (event-integrated) samples and grab samples will be analyzed in the monitoring program. The text has been corrected in the Final Report, "unionized" has been changed to "un-ionized".

PB-36: The text in the Final Report (Section 13.3.2), has been updated to include how far the index station is located from shore (2 kilometers).

PB-37: The text has been updated, and the reference to $10 Million dollars being spent on research has been deleted in the Final Report (Section 14.2.1).

PB-38: The uncertainty was not determined explicitly; rather it was evaluated relatively amongst the different source category estimates and not for any specific models.

PB-39: The text has been updated in the Final Report (Section 14.3) to include the word "conservative" in the sentence.

assumptions in the two areas are described in subsequent paragraphs (although there is not a lot of information provided) or are described in detail in the technical report).

Lake Tahoe Total Maximum Daily Load Technical Report

Page	**¶/Line**	**Comment**
3-1	¶ 2	There is no "typical value" of watershed/lake ratio. I will grant that the watershed/lake ratio for Lake Tahoe is small, but the value of the ratio ranges widely, and it is misleading to imply that there is such a thing as a typical watershed that has a watershed/lake ratio of 10.
3-4	Fig. 3-2	This is a better map than Fig. 2-1 in the TMDL report. The authors should consider replacing Figure 2-1 with this or a similar figure.
3-11	Fig. 3-9	Authors should give the r^2 and equation for the line of best fit. One wonders what a linear fit would look like. The data are sufficiently scattered that it is dubious whether a curvilinear fit is really appropriate.
3-13	¶ 1	One wonders at what depths the sediment traps were deployed and whether the settling velocities are representative of the entire water column. Given the fact that N- and P-containing particles are undergoing continual degradation on their downward journey, the point made in the last sentence (about mineralization and recycling) is especially pertinent.
3-15	1	Figure 3-13 does *not* show that lake clarity increased. One can infer that it likely increased from the trends in mass sedimentation rates, biogenic silica fluxes, and inferred primary production, but the figure itself does not have any transparency parameters on it. The authors need to be careful in how they phrase the text on such an important and sensitive issue.
	¶ 2	The decline in transparency has *not* been caused primarily by the gradual accumulation of pollutants over time, but is caused by *continuing* inputs of the specific pollutants. Again, this is a matter of being precise in the use of language. As written, this paragraph implies that pollutants accumulate in the lake for long periods of time. I don't want to get into arguments about the meaning of "long," but as the text in paragraph 1 on this page indicates, reductions in loadings of sediment and nutrients likely leads to increased transparency in relatively short periods of time.
3-16	3	Saying that algae "require" N:P in a ratio of 7:1 is at best simplistic. This should be restated after consultation with a limnologist who understands the nuances of nutrient ratios.
	9	The text should replace total Kjeldahl nitrogen (TKN) with total organic nitrogen (TON). I doubt that laboratories analyzing Lake Tahoe samples actually use the Kjeldahl method anymore; most limnologists and environmental laboratories converted to a more sensitive alkaline persulfate oxidation method 10-20 years ago, which gives accurate results for total N (from which TON is calculated by subtracting separately measured values for nitrate-N and ammonium-N).
	¶ 4	"Bioavailability" depends on the method used to determine it. The text should give some indication of how bioavailable P was determined.
	4fb	The range 16-56% is so large that it is not very meaningful to say that the value of 40% found by Hackley et al. agrees with the results of Dillon and Reid.
4-1	¶ 3	It would be more appropriate and accurate to state that Reuter et al. developed the first nutrient budgets for Lake Tahoe. Nutrients (N and P) are not pollutants per se, although there is widespread agreement that excess nutrient inputs are a type of pollution. Even pristine Lake Tahoe requires some nutrient input to survive as an ecosystem. In addition, I think it would be more accurate to use the term fine particles rather than fine grained sediment because not all the particles are (or have been) sediment; atmospheric particles certainly fall in this category. I think the terminology used in this paragraph is a

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PB-40: The text in the Technical Report, Section 3.1 has been updated to reflect that the watershed/lake surface area ratio of Lake Tahoe is small but that there may not be a 'typical' value.

PB-41: Figure 3-1 in the Technical Report has been replaced with a more accurate figure.

PB-42: The Figure 3-9 has been replaced with a more accurate figure in the Technical Report (Figure 3-8), the R^2 and p-value have been added in the caption.

PB-43: There were three sediment traps placed in the water column at depths of approximately 175 meters, 290 meters and 400 meters with the lake bottom at 435 meters. This provides good vertical coverage throughout the water column. The text has been updated in the Technical Report (Section 3.4.1) to include these values.

PB-44: The text was updated in the Technical Report (Section 3.4.1) to correctly express what Figure 3-13 demonstrates.

PB-45: The text was updated in the Technical Report (Section 3.4.2) to specify that the decline in transparency is not from gradual accumulation of pollutants, rather continued loading of the pollutants.

PB-46: The text stating that algae require a N:P ratio of 7:1 was a simplification, however this discussion was to explain that nitrogen and phosphorus are required at different amounts for algae growth. The text in the Technical Report (Section 3.4.2) was updated and a new citation was added that cautions the reader that using the stoichiometric ratio of 7:1 (by weight) to assess nutrient limitation can be problematic.

PB-47: The TERC labs still conduct the total Kjeldahl nitrogen method. The total Kjeldahl nitrogen equals total organic nitrogen plus ammonium.

PB-48: Ferguson and Qualls (2005) employed an approach where both chemical phosphorus-fractionation and algal bioassays were used to estimate bioavailable phosphorus. In the bioassays, particulate phosphorus was trapped on a filter and separated by a membrane that allowed the passage of dissolved phosphorus but not particulate phosphorus into the algal culture. New text has been added to the Technical Report (Section 3.4.2) with this information.

PB-49: While the range from Dillon and Reid is large, this citation was put in to provide perspective and not to justify the Hackley et al. value. The text was revised in the Technical Report in Section 3.4.2 to remove the reference that the two studies results are in agreement.

		little careless. Also, if the budgets were developed in 1998 and revised in 2000, why were they not published until 2003? Given that Jassby et al. noted the concern about fine particles as a pollution source for the lake in 1999, the argument that the budgets focused on nutrients because they were thought to be the principal cause of clarity loss are a little strained.
4-4	3fb	Actually, it is 72%, which is closer to three-fourths.
4-7	1	It would be helpful if the report would show results demonstrating that ground water in fact is “nutrient-rich,” as this line states. Alternatively, it would be fine if the text would refer the reader to any table or figure elsewhere in the report where such documentation is given.
4-11		“principals” should be “principles.”
4-12	¶ 2fb	Missing word “have” in line 2?
4-13	¶ 2	The word “ambient” is misused here and in Table 4-4. Why not say what you mean—undisturbed? Also, it is not clear what the difference is between vegetated and forested undeveloped and undisturbed areas (last line of paragraph).
4-90	5	I think the authors mean “latter” not “later.” Nonetheless (line 8) is one word, not three.
4-109		One wonders why the streambed samples that were analyzed for TP were not analyzed for TN at the same time. The same digestion procedure can be used for both N and P, and the amount of additional labor would have been minor.
4-121	¶ 1	The reasoning in this paragraph to ignore organic particles is questionable. Certainly the authors would agree that phytoplankton and detritus produced from phytoplankton and other microbial activity in the water does have an important effect on water clarity even though the particles are nearly entirely organic. I cannot see any reason why organic particles from the atmosphere would not affect lake transparency.
5-13		The standard deviations for most sites exceed the mean values for both particle sizes, in some cases substantially so. This indicates that the data are highly skewed. The text should acknowledge this and describe what was done to overcome this problem.
5-14	¶ 2	Use of four-place precision (318.3) for the multiplication factor is a rather extreme example of going overboard in creating a false sense of precision in the analysis. There is no way that the authors can imply that the factor is known to that level of precision and accuracy. Rounding to one place (300) would describe better the accuracy with which they can estimate the factor.

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PB-50: All waterbodies need some amount of nitrogen and phosphorus loading to sustain production. If this level is exceeded it can be considered a pollutant. No attempt was made here to imply that all nutrient loads are pollutants. Language regarding fine sediment was modified for consistency in the Technical Report in the beginning of Chapter 4. As stated the nutrient budgets were developed in 1998-2000 at the same time that Jassby et al. (1999) hypothesized that the role of fine particles could be significant. It was not until Swift's work in 2004 that this was actually substantiated.

PB-51: The text has been changed in the Technical Report to give reference that the urban uplands contribution is close to three fourths of all the fine sediment particles to Lake Tahoe in the beginning of Chapter 4.

PB-52: The text was modified in the Technical Report (Section 4.1) to remove the term "nutrient-rich" for the groundwater and reference to Table 4-4 was given where the data is located.

PB-53: The word "principals" has been replaced with "principles" in the Technical Report (Section 4.1.3).

PB-54: The word "have" has been inserted into the text in the Technical Report (Section 4.1.3).

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4-121	¶ 1	The reasoning in this paragraph to ignore organic particles is questionable. Certainly the authors would agree that phytoplankton and detritus produced from phytoplankton and other microbial activity in the water does have an important effect on water clarity even though the particles are nearly entirely organic. I cannot see any reason why organic particles from the atmosphere would not affect lake transparency.
5-13		The standard deviations for most sites exceed the mean values for both particle sizes, in some cases substantially so. This indicates that the data are highly skewed. The text should acknowledge this and describe what was done to overcome this problem.
5-14	¶ 2	Use of four-place precision (318.3) for the multiplication factor is a rather extreme example of going overboard in creating a false sense of precision in the analysis. There is no way that the authors can imply that the factor is known to that level of precision and accuracy. Rounding to one place (300) would describe better the accuracy with which they can estimate the factor.

Response

		little careless. Also, if the budgets were developed in 1998 and revised in 2000, why were they not published until 2003? Given that Jassby et al. noted the concern about fine particles as a pollution source for the lake in 1999, the argument that the budgets focused on nutrients because they were thought to be the principal cause of clarity loss are a little strained.
4-4	3fb	Actually, it is 72%, which is closer to three-fourths.
4-7	1	It would be helpful if the report would show results demonstrating that ground water in fact is "nutrient-rich," as this line states. Alternatively, it would be fine if the text would refer the reader to any table or figure elsewhere in the report where such documentation is given.
4-11		"principals" should be "principles."
4-12	¶ 2fb	Missing word "have" in line 2?
4-13	¶ 2	The word "ambient" is misused here and in Table 4-4. Why not say what you mean—undisturbed? Also, it is not clear what the difference is between vegetated and forested undeveloped and undisturbed areas (last line of paragraph).
4-90	5	I think the authors mean "latter" not "later." Nonetheless (line 8) is one word, not three.
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PB-55: The word "ambient" was misused; the word has been replaced with "background" in the Technical Report, Section 4.1.3 and in Table 4-4.

PB-56: The word "later" was changed to "latter" and "none the less" has been changed to "nonetheless" in the Technical Report (Section 4.3.6).

PB-57: Prior to the samples being analyzed for total nitrogen, there was a problem with the QA/QC protocol (specifically the holding times). At that point there was uncertainty regarding the appropriateness of conducting the total nitrogen analysis, and thus is was not conducted. The uncertainty regarding the estimate for stream channel total nitrogen was discussed in the Technical Report, Section 4.4.3 under the heading - Estimates of Nutrient Loading Associated with Streambank Erosion.

PB-58: Based on the work of Swift (2004) and Swift et al. (2006) organic particles influence lake transparency but to a much less extent than fine sediment particles. This is also supported by modeling runs that suggest that annual average Secchi depth would be close to 31 meters if all urban fine sediment particles were removed (including atmospheric deposition). This, in concert with the lower level of confidence in our atmospheric particle deposition of organic particles to the whole lake, a conservative approach was taken. More research could help clarify this point. The text has been updated in the Technical Report, Section 4.5.2 to address this comment.

PB-59: As the urban particle concentration data demonstrates there is considerable variability both between locations and during the year at a single location. This latter variability is evident by the elevated standard deviations at each site; the standard deviation frequently exceeds the annual mean. This is not necessarily a sign of sampling or statistical uncertainty as it is a reflection of the degree of seasonal changes in concentration for stormwater samples. Particle concentrations in urban runoff vary significantly, especially in an environment where precipitation type (summer thunderstorm, snow melt, rain on ground, etc.) and amount (drizzle to ~1 inch in a few hours) also vary significantly over the year. This is the first time this type of data (particle size in urban runoff) was collected at Lake Tahoe – the objective was to evaluate annual loading and not event loading. New text has been added to the Technical Report (Section 5.1.4) to address this comment.

PB-60: The number of significant figures associated with this multiplication factor was not intended to be a reflection of the level of confidence in this value. Given that the objective was to estimate a basin-wide loading value, the location-to-location variability was accounted for by using the average value of all stations with data. Ongoing stormwater monitoring will provide additional information on this topic. Text was added to the Technical Report (Section 5.1.4) in response to this comment.

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Lake Tahoe Sediment and Nutrient TMDL

Response to Peer Review Comments

Menachem Elimelech

Peer Review Received: August 5, 2009

Review of

Lake Tahoe Total Maximum Daily Load Report

Menachem Elimelech
Department of Chemical Engineering
Yale University
New Haven, CT 06520-8286
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The Lake Tahoe Total Maximum Daily Load (TMDL) Report is a comprehensive document that identifies the contaminants responsible for the deterioration in transparency and clarity of the lake, the sources of these contaminants, and the plan to reduce the input of these contaminants to the lake in order to attain the water quality objectives and restore the lake clarity. It is concluded that the culprit for the deterioration in lake clarity is mainly the presence of suspended inorganic particles and, to a lesser extent, nutrients in the form of nitrogen and phosphorus.

The TMDL report has benefited tremendously from extensive research and monitoring data for Lake Tahoe that started nearly 40 years ago. Research associated with the development of the Lake Tahoe TMDL was designed to build on the extensive information available on the lake and its watershed. The components of the model used to develop the plan to restore the lake clarity are based on completed research projects from the past 10-20 years, most of which have been published in peer-reviewed journals. The published research adds to the credibility of the methodology used and the developed plan. Further, there are additional ongoing research projects that support the next phases of the Lake Tahoe TMDL.

The Lake Tahoe TMDL report is well presented. It clearly states the problem and objectives, provides the necessary background, presents the methodology used to arrive at the plan to attain the TMDL Clarity Challenge, and outlines the implementation steps that need to be taken. The Final Report also refers to the relevant reports and documents when needed. Overall, I find the report to be technically sound and of high quality.

Below are a few comments and suggestions that may help in refining the report at this stage as well as in the next phases of the Lake Tahoe TMDL. Furthermore, replies to the 8 specific issues that the reviewers were requested to address will follow.

Inverse Modeling

The Lake Clarity Model is a mathematical model comprising several sub-models and algorithms. The model can simulate the water quality in the lake (concentrations of particles and nutrients)

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Lake Tahoe Total Maximum Daily Load Report

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Response

and link it to water clarity (or Secchi depths), which is essential to achieving the Clarity Challenge. This approach is termed forward modeling. The model has been used to determine the total maximum daily loads of particles and nutrients to the lake and the necessary reductions in the loadings of particles and nutrients from the various sources to attain the Clarity Challenge.

However, there is also a need for an inverse problem modeling as well as a parameter identification algorithm. A robust inverse problem model can be used to optimize performance and minimize costs in the TMDL management system as well as the monitoring program. Currently, the management and monitoring plans/models are conceptual and qualitative in nature, and thus will not yield the most cost-effective outcomes. The inverse problem approach has been used extensively in water quality management covering a wide range of problems. See for example the book by Ne-Zhen Sun (Inverse Problems in Groundwater Modeling, 1994, Kluwer Academic Publishers). Lastly, the inverse problem coupled with a robust parameter identification algorithm can help in finding the unknown physical parameters for the model based on limited experimental data.

Other recent references highlighting the inverse problem modeling with applications to water quality can be found in:

> Zou, R., Lung, W.S., Wu, J. "An adaptive neural network embedded genetic algorithm approach for inverse water quality modeling", *Water Resources Research*, 43 (2007, W08427.
>
> Shen, J., Jia, J.J., Sisson, G.M., "Inverse estimation of nonpoint sources of fecal coliform for establishing allowable load for Wye River, Maryland", *Water Research*, 40 (2006) 3333-3342.

<u>Role of Particle Aggregation</u>

One of the key steps in the Lake Clarity Model is to link the loadings of particulates and chemicals (nutrients) into Lake Tahoe to the Secchi depth and light attenuation which are measures of lake clarity. Since inorganic suspended particles govern the light attenuation behavior, it is imperative to be able to predict the number concentration and size distribution of particles at various water depths. Thus, even if the other modeling efforts can estimate adequately the inorganic particle loading to Lake Tahoe, the ability to predict the Secchi depth remains the key to the Lake Tahoe TMDL Clarity Challenge.

An important process governing the number and size distribution of particles in lakes (as well as marine environments) is particle aggregation. Examples for the important role of particle aggregation in aquatic systems can be found in the following references (and references therein):

> Weilenmann, U., O'Melia, CR, and Stumm, W. "Particle-Transport in Lakes - Models and Measurements", *Limnology and Oceanography*, 34 (2009) 1-18.

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Weilenmann, U., O'Melia, CR, and Stumm, W. "Particle-Transport in Lakes - Models and Measurements", *Limnology and Oceanography*, 34 (2009) 1-18.

2

Response

ME-1: The level of sophistication needed to analyze this using an inverse problem modeling approach and a parameter identification algorithm was outside the scope of this project. As part of the ongoing research at Lake Tahoe, the intent is that a quantitative linkage between management, monitoring, cost-effectiveness and environmental response will be developed and continually improved upon as new information becomes available. The Lake Tahoe TMDL Management System is being developed to ensure that milestones will be evaluated for all sources (quantitatively, not qualitatively) and if recommendations arise that result in a need to adapt and make changes to the TMDL implementation program, this will occur within the adaptive management framework.

Burd A.B., Jackson G.A., "Particle Aggregation", *Annual Review of Marine Science*, 1 (2009) 65-90.

It is not clear from the Lake Tahoe TMDL report (and related reports) if and how the process of particle aggregation has been incorporated in the Lake Clarity Model. It is likely that the impact of aggregation may not be as significant if the number concentration of particles is relatively low and if the collision (sticking) efficiency is low. The latter is dependent on the water chemistry, namely the total ionic strength, concentration of divalent cations (mostly calcium), and dissolved natural organic matter (NOM). The collision efficiency cannot be predicted from theory but must be determined from experimental measurements Note also that particle aggregation results in fractal aggregates having settling behavior that cannot predicted by the simple Stokes Law.

Beneficial Health Effects to Beaches

The largest source of inorganic particles to Lake Tahoe comes from storm water runoff from urban areas. To achieve the Clarity Challenge, significant reductions in particle loading from urban areas are proposed. This measure will not only improve the lake clarity but will also have beneficial health effects by minimizing potential microbial pathogen loads to recreational beaches along Lake Tahoe. In recent years it has been recognized that microbial contamination of beaches form urban and agricultural runoff is responsible for numerous illnesses. This may be a potential problem for Lake Tahoe and, as such, funding and research programs tackling both lake clarity and microbial contamination of beaches should be promoted. This will lead to more effective use of state and federal funds. Recent papers highlighting the problem of microbial contamination of recreational water include:

Heaney, C.D. et al. "Contact with Beach Sand among Beach Goers and Risk of Illness", *American Journal of Epidemiology*, 170 (2009) 164-172.

Wong, M. et al. "Evaluation of public health risks at recreational beaches in Lake Michigan via detection of enteric viruses and a human-specific bacteriological marker", *Water Research*, 43 (2009) 1137-1149.

Boehm, A.B. et al. "A sea change ahead for recreational water quality criteria", *Journal of Water and Health*, 7 (2009) 9-20.

Potential Detrimental Effects on Lake Water Quality

Suspended particles in lakes play an important role in the transport of heavy and trace metals to the sediments. Heavy and trace metals adsorb to suspended particles which aggregate and settle to the sediment. Thus, lakes with greater concentrations of suspended particles may have lower concentration of dissolved metals in the water. Examples of references describing this phenomenon include:

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Response

ME-2: Particle aggregation is an important consideration in Lake Tahoe and was included in the Lake Clarity Model (see technical support document on model structure, development and algorithms by Sahoo et al. (2006 and 2009). Particle settling rate was tested in the sensitivity analysis (Technical Report Section 6.3.1) and was found to affect Secchi depth. Sahoo et al. (2006) discussed that particle aggregation depends on (1) particle concentration, (2) collision rate, and (3) sticking efficiency (coagulation rate). The Lake Clarity Model used the algorithms reported by O'Melia (1985) and supported by Casamitjana and Schaldow (1993). As noted in Table 6-5 of the Technical Report, coagulation rates found in the literature typically range from 0.001-0.1. A value of 0.015 was used in the Lake Clarity Model. Since the model showed a higher degree of sensitivity to this parameter, it was considered most appropriate to determine its value by direct calibration based on the actual measured and predicted Secchi depth values. It was outside the scope of this work to conduct collision efficiency and coagulation research. Since 'sticking efficiency' in aqueous solutions, and especially under low concentrations, is very complex, we considered the calibration approach (based within the literature values) to be a reasonable approach.

Sigg, L., Sturm, M., Kistler, D. "Vertical Transport of Heavy-Metals by Settling Particles in Lake Zurich", *Limnology and Oceanography*, 32 (1987) 112-130.

Sigg, L. et al. Cycles of Trace-Elements (Copper and Zinc) in a Eutrophic Lake - Role of Speciation and Sedimentation, In: Aquatic Chemistry - Interfacial and Interspecies Processes. Advances in Chemistry Series, Vol. 244, pages 177-194, 1995.

I wonder if the concentration of heavy and trace metals in Lake Tahoe has ever been correlated to the concentration of suspended particles in the water column. This will give an indication if the proposed reduction in the particle loading will have an effect on the concentration of metals in the lake water.

Finally, it was also requested to determine whether the following eight specific issues are based on sound scientific knowledge, methods, and practices.

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.

I concur with the analysis and scientific methods leading to this conclusion. This has also been published in the peer-reviewed literature as outlined in the report.

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.

I concur with the analysis and scientific methods leading to this conclusion. This conclusion was based on extensive data collected over the past 40 years. Some of this data has also been published in the peer-reviewed literature as outlined in the report.

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

I am not familiar with this model and thus I cannot provide an assessment of this question. For this question you should rely on a reviewer with expertise in watershed modeling.

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

I cannot provide an assessment of this question. For this question you should rely on a reviewer with expertise in groundwater hydrology, more specifically someone with knowledge on groundwater – surface water interactions.

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

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Response

ME-3: While heavy and trace metals can be correlated with suspended particles as suggested, heavy and trace metals have not been linked to water quality problems that interfere with the beneficial uses of Lake Tahoe (i.e. Lake Tahoe is not 303 (d) listed for metals). This TMDL focuses on deep water transparency, or Secchi depth. No scientific studies have been conducted to correlate suspended sediment concentration to heavy or trace metals in Lake Tahoe.

particulate matter. Direct deposition of dust accounts for approximately 15% of the average annual fine sediment particle load.

> I concur with the conclusion that atmospheric deposition directly to the lake is the dominant source of nitrogen; this was also documented in the peer-reviewed literature. Atmospheric deposition is not the main source of fine suspended particles; the main source of fine particles is the urban upland.

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.

> It is a reasonable conclusion that the largest, most cost effective opportunities for fine sediment particle load reductions are from the urban upland source. The PRO analysis is interesting and appears to be reasonable; however, the approach used was semi-quantitative in nature. Hence, it may not represent the most optimal solution to the problem in terms of cost and effectiveness. Perhaps the use of more quantitative approaches involving optimization techniques and control theories that are common in the chemical engineering process industry would have resulted in a more optimal solution.

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

> I concur that the Lake Clarity Model was appropriate to predict how Lake Tahoe's Secchi depths will respond to changing particle loading. The major components of the model have been published in the peer-reviewed literature as outlined in the report. However, as indicated in my general comments above, it is not clear if and how the aggregation of particles was incorporated in the model.

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

> This statement seems reasonable, but see my reservation indicated in item (6) above.

particulate matter. Direct deposition of dust accounts for approximately 15% of the average annual fine sediment particle load.

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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

This statement seems reasonable, but see my reservation indicated in item (6) above.

5

Response

ME-4: The Pollutant Reduction Opportunity project represents the most quantitative analysis of basin-wide load reduction potential performed to date. The project only analyzed quantifiable load reduction options and used available performance and cost effectiveness data to evaluate site-scale load reduction and cost estimates. A meta-heuristic optimization technique was applied to evaluate the benefits, costs, and selection trade-offs among basin-wide pollutant sources. This technique was applied in a Microsoft Excel environment and was developed by Tetra Tech to facilitate aggregation of pollutant controls, load reductions, and costs. The tool uses a lookup table and linear scaling to adjust estimated load reductions and costs of applying differing levels of implementation measures on the landscape. This tool provided the TMDL team the opportunity to compare different options across pollutant source categories and objectively evaluate a number of implementation scenarios to determine the most efficient and cost effective approach to achieving needed load reductions. The analysis included an optimization effort to identify the most cost effective load reduction opportunities and develop implementation options for stakeholder review. The TMDL implementation plan reflects a quantitative, optimized approach for reducing fine sediment particle and nutrient loads at Lake Tahoe.

ME-5: Same as response ME-2 above.

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Lake Tahoe Sediment and Nutrient TMDL

Response to Peer Review Comments

John M. Melack

Peer Review Received: August 15, 2009

Review of Lake Tahoe Total Maximum Daily Load

John M. Melack
Acting Dean and Professor
Bren School of Environmental Science and Management
University of California, Santa Barbara

The following material was read as the basis of the review of the Lake Tahoe Total Maximum Daily Load:

- Draft (June 2009) Lake Tahoe Total Maximum Daily Load
- Technical Report (June 2009) Lake Tahoe Total Maximum Daily Load
- Lake Tahoe TMDL Pollutant Reduction Opportunity Report (March 2008)
- Integrated Water Quality Management Strategy Project Report (March 2008)
- Appendices:
  - Urban and Groundwater Appendix A: PSC Performance Review
  - Forest Uplands Appendix B: Fire Literature Review
  - Appendix A: Stream Channel Erosion Nutrient Framework Analysis
  - Appendix B: Stream Channel Erosion Pollutant Control Options
  - Appendix C: Stream Channel Erosion Bank Stability Modeling
  - Appendix D: Stream Channel Erosion Load Reduction Analysis
- Appendix A: Packaging and Assessment Tool Description
- Appendix B: Information Supporting Chapter 3
- Appendix C: Supporting Tables and Figures
- CARB (2006)
- Tetra Tech (2007)

NB: Over the years I have read many of the papers published on Lake Tahoe, have heard numerous presentations at professional meetings by researchers from the area, and have visited the Lake Tahoe basin in all seasons.
In addition, several key journal articles were examined as part of the TMDL review; if specific publications are cited, they were read.
Supporting material was read less intently than primary TMDL text, in part, because the text was less focused on the key issues and many of the tables and figures were not sufficiently well described or were difficult to read given their size.

General comments

The process of developing the Lake Tahoe TMDL and the product is scientifically sound and credible. By building on a long period of research with many peer-reviewed publications and by conducting focused studies to augment and synthesize prior information, the TMDL is well supported. Modeling plays a significant part in the determination of the TMDL and is based on established approaches; the models are examined with appropriate sensitivity analyses.

One weakness in the Draft TMDL report is the lack of convincing evidence for the criteria used as the basis for the TMDL. Though Swift's thesis may contain the necessary

Response

Review of Lake Tahoe Total Maximum Daily Load

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  - Forest Uplands Appendix B: Fire Literature Review
  - Appendix A: Stream Channel Erosion Nutrient Framework Analysis
  - Appendix B: Stream Channel Erosion Pollutant Control Options
  - Appendix C: Stream Channel Erosion Bank Stability Modeling
  - Appendix D: Stream Channel Erosion Load Reduction Analysis
- Appendix A: Packaging and Assessment Tool Description
- Appendix B: Information Supporting Chapter 3
- Appendix C: Supporting Tables and Figures
- CARB (2006)
- Tetra Tech (2007)

NB: Over the years I have read many of the papers published on Lake Tahoe, have heard numerous presentations at professional meetings by researchers from the area, and have visited the Lake Tahoe basin in all seasons.

In addition, several key journal articles were examined as part of the TMDL review; if specific publications are cited, they were read.

Supporting material was read less intently than primary TMDL text, in part, because the text was less focused on the key issues and many of the tables and figures were not sufficiently well described or were difficult to read given their size.

General comments

The process of developing the Lake Tahoe TMDL and the product is scientifically sound and credible. By building on a long period of research with many peer-reviewed publications and by conducting focused studies to augment and synthesize prior information, the TMDL is well supported. Modeling plays a significant part in the determination of the TMDL and is based on established approaches; the models are examined with appropriate sensitivity analyses.

One weakness in the Draft TMDL report is the lack of convincing evidence for the criteria used as the basis for the TMDL. Though Swift's thesis may contain the necessary level of analysis of underwater optical conditions and their relation to Secchi transparency, particles and phytoplankton, the Draft TMDL does not. Similarly, the case that N and P are the key nutrients influencing changes in phytoplankton abundance is not well documented.

The inclusion of the nearshore waters and bottom in the scope of a follow-on TMDL is recommended given the documented reductions in habitat quality nearshore, the region that most people experience.

Specific issues

Were sound scientific knowledge, methods and practices applied to the following determinations and actions in the TMDL?

1. Determination of fine sediment particles (<20 micrometers) as the primary cause of clarity impairment based on interpretation of scientific studies, available data, and the Lake Clarity Model.

The Ph.D. thesis by Swift (2004) as published in Swift et al. (2006) provides a theoretically and empirically sound basis for the 'determination of fine sediment particles (<20 micrometers) as the primary cause of clarity impairment'. More precisely, Swift's results demonstrate that most of the light scattering occurs because of inorganic particles less than 10 micrometers in size and with a significant contribution to light attenuation by algal cells. Swift developed an additive semi-analytic model of water clarity to calculate apparent optical properties of diffuse attenuation and Secchi depth from inherent optical properties due to water, algal cells, suspended inorganic sediments and colored dissolved organic matter. His modeling approach is based on recognized optical theory and uses measured properties of particles and algae in Lake Tahoe. Though the TMDL cites several additional sources of supporting information in support of the determination, this evidence is in Master's theses that were not provided for review.

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 six sources areas considered include urban areas, forested areas, groundwater, stream channel erosion, atmospheric deposition and shoreline erosion. Each was evaluated with detailed measurements and extrapolated to the whole lake using GIS techniques and/or modeling (see following sections for evaluation of these models). In each case, the approach used, the analyses done and the conclusions reached are well supported and scientifically sound. A critical aspect of such calculations is that the uncertainty in the estimates be discussed, and this was done reasonably well. The results from these analyses clearly identify urban uplands as the dominant source of fine particles.

3. Determination that the Lake Tahoe Watershed Model was an appropriate

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Response

JM-1: Additional text has been added to the Technical Report, Section 3.4.2 on the optical conditions and information about phytoplankton (new Figure 3-14), changes in the deep chlorophyll maximum (new Figure 3-15), and the depth of mixing (Figure 3-16).

JM-2: For a TMDL to be conducted on a water body, it must first be listed on the 303(d) list as impaired, and then the TMDL will address the pollutants that have caused the impairment. Though the existing nearshore standards are not listed as being impaired, these standards do not address the changing nearshore conditions and are not appropriate indicators. The nearshore region of Lake Tahoe currently has research projects underway to assist in determining new and appropriate standards that will allow for assessing the condition and if impairments are occurring.

model to estimate upland pollutant source loads.

Several models are available with which to calculate inputs of pollutants for uplands, and the selection of the USEPA's LSPC modeling system as the basis for the Lake Tahoe Watershed Model is a reasonable choice. This modeling system includes simulations of watershed hydrology, erosion and processes influencing water quality and in-stream transport processes. The material available in the Technical Report (June 2009; Lake Tahoe Total Maximum Daily Load) is sufficient to judge the veracity of the model. To fully evaluate the version of LSPC being applied to Lake Tahoe required examining Tetra Tech (2007).

The estimation of sediment loads and parameterization of nutrient and TSS by land use, including an intensive stormwater study, represent a substantial effort with mixed results as illustrated in Tables 4-26 to 4-28 and Figures 4-27 to 4-29. While typical of comparisons between modeled and measured values for variables such as TSS, TN or TP, the scatter indicates the difficulty in modeling these items. The mean annual loading of TSS and N and P fractions calculated by LSPC falls within the standard deviations of the measured values in most of the 10 streams monitored. Based on the Lake Clarity Model inorganic particles less than 10 micrometer in size have the most influence on clarity, yet the fine sediment calculated by the Watershed Model is material less than 63 micrometers in size. This issue is dealt with in Chapter 5.

A few questions about the application of the model arise:

1. No in-stream transformations or biological interactions were simulated. While appropriate during maximum snow melt or major runoff events, during baseflow conditions it may not be appropriate.
2. What resolution DEM was used to delineate watersheds, subwatersheds and slopes?
3. How well validated is the National Hydrology Dataset for stream lengths in the Tahoe basin?
4. How were the rainfall and snowfall amounts distributed spatially from the eight SNOTEL sites?
5. Riverson et al. (2005) is cited as the basis for the selection of an evapotranspiration (ET) calculation, but this appears to be a presentation at a conference and is not available. ET and sublimation from snow are important aspects of the hydrological balance, and it would strengthen the report to provide more information about how these processes were determined.
6. Land –use is a key component of a watershed model, and several data sets apparently vetted by knowledgeable personnel were used. It would be helpful to have an overall assessment of the veracity of the land-use classification and the areas assigned to each class. When remote sensed data are used, such as the IKONOS data, formal procedures are usually applied to evaluate the validity of the product; however, Minor and Cabik (2004) is not available for review.
7. Metrics, such as the Sutcliff-Nash metric, are usually applied to evaluate model predictions, but these metrics are provided. Offering plots (e.g., Figures 4-18 and 4-19) with measured and predicted lines is not sufficient. The 'error statistics' in Table 4-15

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JM-3: LSPC is set-up to model in-stream transformations, but given the relatively fast time of concentration (i.e. time of travel from headwaters to mouth is only on the order of hours) the additional effort - and required assumptions - to represent these transformations was not considered to be significant during periods of elevated flow. While the statement is correct that biological interactions could be of consideration during the summer period of very low baseflow, loading during that period is minor. Nutrient fractions were determined using observed data at the mouth and upstream transformations had been made by that location in the channel. Additional text was added to the Technical Report, Section 4.3.5 under the heading *Water Quality* with the information above.

JM-4: Initially, more delineated watersheds were provided by Lahontan and TRPA (597 subwatersheds) - these were hydrologically merged into the fewer modeled subbasins. The merging process aimed to preserve important orographic changes in the delineation (i.e. merge areas with similar slope and elevations) while trying to minimize the number of subwatersheds. A 10-meter resolution Digital Elevation Model (DEM) was used to estimate average subwatershed elevations and to derive the average slope by land-use. Further details on land-use representation and watershed delineation are provided in Section 3.4 of Tetra Tech (2007).

JM-5: For stream segment delineation, the Lake Tahoe Watershed Model used the stream polylines, and calculated the lengths using the appropriate GIS layer(s). The main channel of each subwatershed was used to represent the primary water pathway. The National Hydrology Dataset was not used for this analysis.

JM-6: Precipitation and temperature were assigned to subwatersheds based on spatial proximity to the meteorology (MET) station. High-temporal-resolution weather observations for a long period of record are rarely available at a small enough scale to completely reflect the degree of spatial variability seen on mountainous landscapes. However, with the exception of the NRCS SNOTEL and NCDC weather stations, other MET sites in the Lake Tahoe Basin did not provide the level of resolution needed for the Lake Tahoe Watershed Model. Given the low percent error in total volume when the model output was validated using the LTIMP stream discharge data and the high level of agreement between the modeled annual water budget and those estimated over many years, the spatial distribution of precipitation based on the SNOTEL data appears reliable. The model's snow simulation module internally determines when precipitation is snowfall based on temperature. To distribute the rainfall and snowfall amounts spatially from the eight SNOTEL sites, a temperature lapse rate is applied to correct for elevation changes between the observed gage and the average watershed elevation of each subwatershed.

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JM-7: Evapotranspiration and sublimation are important aspects of the hydrological balance. This was recognized in both the Technical Report and in Tetra Tech (2007). This was considered important enough by the modeling team that three approaches were taken to test which was most appropriate for conditions in the Lake Tahoe basin. These included Penman (1945), Hamon (1961) and Jensen-Haise (1963). The Penman method (1948) was deemed most suitable for Lake Tahoe (Riverson et al. 2005). Riverson et al. (2005) found that the annual observed evapotranspiration at Tahoe City was between 35.5 and 42.5 inches per year for reference crop (crop factor of 1.0) and evergreen forest (crop factor of 1.2), respectively. Total modeled evapotranspiration at Ward Creek is within the expected range at 37.5 inches per year. New text was added to the Technical Report, Section 4.3.3 under the heading *Evapotranspiration Calculations*.

JM-8: The land-use layer is a composite dataset based on the individual datasets that were known to have undergone their own quality assurance process. The additional effort to build this composite layer provided a more accurate spatial characterization of land-use than any other data source previously available. Spatial comparisons between the composite layer and an alternative UC Davis land-use layer are presented in Tetra Tech (2007). From a large set of GIS layers that varied in resolution and quality, a plan of action evolved through the data review process. A number of the most critical GIS layers became available only after this project had already begun. With input from staff at land-use management agencies (US Forest Service, TRPA, California Tahoe Conservancy, and Nevada Division of State Lands), the Water Board and NDEP determined a manageable and representative set of land-use categories and identified relevant spatial information available for representing each category. Over the course of this development process, certain categories and layers were included or excluded on the basis of ground-truth comparisons, data duplication/exclusion, and site-specific information about the significance of the impact. For example, the initial list of land-uses was modified to exclude grazing (a practice that has almost disappeared from the basin and whose historical or legacy impacts are not currently significant for water quality) and further refined the open space recreational category into turf and non-turf vegetated areas (e.g., golf courses versus campgrounds). New layers were developed when existing data was inadequate (e.g. zones of forest fires, forest harvest, ski runs). A detailed one-square-meter resolution Hard Impervious Cover (HIC) layer was developed using remote sensing techniques from IKONOS™ satellite imagery (Minor and Cablk 2004). Text was added to the Technical Report in Section 4.3.4 under the heading *Land-use Representation*.

JM-9: The Sutcliff-Nash metric was not used; however, this particular metric will be added to the validation work currently in process for the period 2004-2008 (Note - this updated validation is being done as part of a Southern Nevada Public Lands Management Act science grant that was funded after the TMDL modeling analysis was completed). The modeling report (Tetra Tech 2007) has more information on hydrology and water quality validation (Tables 4-2, 4-3, 4-4, 4-10 and 4-11). In addition, Table 4-41 in the Technical Report directly compares simulated loads versus loads estimated using LTIMP monitoring data. Confidence in the watershed model to simulate loads was based on these validation comparisons and not based on plots showing predicted and measured lines (data points). As stated in the Technical Report, the goal of the load modeling was not to simulate individual measurements.

help (though it is not clear if they are percentages or volumes), but are not really evaluated in the text.

8. Given the large amount of climate variability in the Tahoe basin, a four year calibration period seems short, especially since the model will be used to forecast conditions in the future as part of the overall TMDL.

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

Groundwater movement and transport of materials is complex. It enters streams, where its influence is combined with other sources of runoff, and enters the lake directly. The USACE (2003) study (only summarized in the TMDL Technical Report) done as part of the TMDL work complements earlier investigations and used recognized, standard procedures, and provided spatially distributed estimates, which are relevant to mitigation options. The assumption of homogeneous aquifers and application of Darcy's Law is acknowledged as a simplification, and is asserted to provide reasonable estimates of groundwater flow. Since much more sophisticated, but data intensive, models, such as MODFLOW, exist and have been applied in other places, it would be valuable to have evidence offered to allow evaluation of the assertion. An indication of the considerable uncertainty in the estimates is noted in Table 4-5 where order of magnitude ranges from maximum to minimum values are listed. Given the acknowledged uncertainties, single values for basin-wide groundwater nutrient loading, as in Table 4-6, should not be listed. On page 4-15 under the subheading 'Ambient nutrient loading to Lake Tahoe from groundwater', it is stated that ambient groundwater represents approximately 46% and 34% of the P and N loading, while in Figures 4-1 and 4-2 groundwater is assigned 15% and 12.5% of the P and N loading. This apparent discrepancy should be clarified.

Estimates of groundwater nutrient loading should be described as reasonable estimates with wide error bars, hence the word accurate does not seem appropriate.

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.

Considerable effort was expended to quantify both wet and dry atmospheric deposition to the lake using established methods of measurement and calculation. The data on P deposition were quite difficult to obtain and special care was taken with the analytical methods. Dry deposition is a problematic measurement, and the two approaches used are complementary and have different sources of error. LTADS collected material from the air and then calculated deposition based on meteorological data and deposition velocities. LTIMP deployed bulk and wet/dry collectors; these bucket collectors are known to not represent true particle deposition. Snow sampling is also subject to errors if collected in buckets; this issue is not addressed. The transport models based on meteorological and

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JM-10: The calibration and validation periods used for the Lake Tahoe Watershed Model spanned the eight most recent years from WY1997 through WY2004 (10/1/1996 - 9/30/2004). Figure 4-19 in the Technical Report shows an example of four of the eight years calibrated and is not meant to imply that only four years was the calibration period. This eight year period of record included a wide range of annual precipitation values including the second highest (very wet) since measurements began in 1910 and two in the bottom 10 percent of all the values collected since 1910 (very dry).

JM-11: The accuracy of the groundwater discharge and nutrient loading estimates is a function of the input parameter data quality. The available data for parameters related to groundwater flow were considered sufficient enough for Fenske (ACOE 2003) to apply MODFLOW to the south shore region of Lake Tahoe. His report appears as Appendix B in the ACOE *Groundwater Evaluation Report* that was done for the TMDL. However, data to support a more sophisticated model, such as MODFLOW, does not exist for the entire Lake Tahoe basin. As a result, the groundwater scientists with the ACOE decided to rely on the simplicity of using Darcy's Law, i.e. when data is lacking the approach taken was not to rely on complex models. There was a wide range between the minimum and maximum values, which is why the ACOE provided a 'most reasonable' estimate. The high degree of similarity between the ACOE study and a previous study done by the USGS (Thodal 1997) for the entire Lake Tahoe basin increased confidence in these estimates. The single values given in Table 4-6 are intended for the sole purpose of comparing the Thodal (1997) and ACOE (2003) results based on mean estimated values. Table 4-5 includes the specific values for minimum, maximum and actual estimated loading for each nutrient constituent and flow for each of the modeled regions (i.e. Table 4-5 is intended to provide the reader with an estimate of variability). The ACOE used the term ambient to describe background conditions. The change in nomenclature has been made from ambient to background in the text in Section 4.1.4 of the Technical Report. The 46 percent and 34 percent values represent the relative contribution of background groundwater sources of phosphorus and nitrogen, respectively, to the total groundwater load (including background and urban sources). The values in Figures 4-1 and 4-2 represent the relative contribution of groundwater nitrogen and phosphorus to all the input sources (including atmospheric deposition, upland runoff, shoreline erosion and groundwater).

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8. Given the large amount of climate variability in the Tahoe basin, a four year calibration period seems short, especially since the model will be used to forecast conditions in the future as part of the overall TMDL.

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

Groundwater movement and transport of materials is complex. It enters streams, where its influence is combined with other sources of runoff, and enters the lake directly. The USACE (2003) study (only summarized in the TMDL Technical Report) done as part of the TMDL work complements earlier investigations and used recognized, standard procedures, and provided spatially distributed estimates, which are relevant to mitigation options. The assumption of homogeneous aquifers and application of Darcy's Law is acknowledged as a simplification, and is asserted to provide reasonable estimates of groundwater flow. Since much more sophisticated, but data intensive, models, such as MODFLOW, exist and have been applied in other places, it would be valuable to have evidence offered to allow evaluation of the assertion. An indication of the considerable uncertainty in the estimates is noted in Table 4-5 where order of magnitude ranges from maximum to minimum values are listed. Given the acknowledged uncertainties, single values for basin-wide groundwater nutrient loading, as in Table 4-6, should not be listed. On page 4-15 under the subheading 'Ambient nutrient loading to Lake Tahoe from groundwater', it is stated that ambient groundwater represents approximately 46% and 34% of the P and N loading, while in Figures 4-1 and 4-2 groundwater is assigned 15% and 12.5% of the P and N loading. This apparent discrepancy should be clarified.

Estimates of groundwater nutrient loading should be described as reasonable estimates with wide error bars, hence the word accurate does not seem appropriate.

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.

Considerable effort was expended to quantify both wet and dry atmospheric deposition to the lake using established methods of measurement and calculation. The data on P deposition were quite difficult to obtain and special care was taken with the analytical methods. Dry deposition is a problematic measurement, and the two approaches used are complementary and have different sources of error. LTADS collected material from the air and then calculated deposition based on meteorological data and deposition velocities. LTIMP deployed bulk and wet/dry collectors; these bucket collectors are known to not represent true particle deposition. Snow sampling is also subject to errors if collected in buckets; this issue is not addressed. The transport models based on meteorological and

JM-12: Direct measurement of ambient air concentrations of phosphorus were problematic in the original LTADS monitoring. This was readily acknowledged by CARB, and as a consequence they solicited the assistance of Dr. Thomas Cahill and Dr. Steve Cliff at UC Davis. Cahill is an acknowledged international expert in air quality measurements. After considerable effort these researchers provided revised air phosphorus concentrations that were used to estimate phosphorus deposition. As discussed in the Technical Report (Section 4.5.4), two completely different approaches were taken to estimate nitrogen and phosphorus deposition to Lake Tahoe from the atmosphere. For nitrogen, only the deposition of the inorganic fraction had sufficient data for a direct comparison. The deposition rates for modeled versus direct measurement approaches for this component were remarkably similar at 116 metric tons per year and 76 to 101 metric tons per year. Phosphorus deposition as modeled by CARB, Cahill and Cliff, and directly measured using deposition buckets (UC Davis) were 3, 6 to 8 and 5 to 6 metric tons per year, respectively. Assuming the relative accuracy of the other phosphorus sources (see Table 4-66 in the Technical Report) the percent contribution from atmospheric deposition were 7, 15 and 12, respectively. Based on the difficultly that LTADS had with phosphorus deposition, the Technical Report reported the values estimated by Cahill; however, both the modeled and direct measurement approaches yielded a very similar relative contribution for phosphorus at 12 to 15 percent of all sources. Regardless of which of the three values are used, phosphorus loading from atmospheric deposition does not exceed approximately 15 percent. The 15 percent value for fine sediment particle load is acknowledged to have high uncertainty (see Section 4.6 of the Technical Report).

compositional measurements were used to account for atmospheric deposition in the basin that originated outside. It is surprising that error bars are not shown for results since the text notes uncertainty. However, the considerable sources of fine particles and N identified within the basin support the conclusion that in-basin sources dominant. The overall percentage of fine particle load from atmospheric deposition depends on the values of all the other sources, all of which have uncertainties; hence it is difficult to assign a level of certainty to the approximation that direct deposition of dust accounts for approximately 15% of the average annual fine sediment particle load.

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 material presented in the PRO analysis appears to thoroughly consider options and provide abundant documentation of costs for many options. The reduction options and costs evaluated are not sufficiently well known to this reviewer to allow critical appraisal.

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

The 'Lake Clarity Model' combined an optical model (Swift et al. 2006) with a hydrodynamic model derived from the widely used DYRESM model (Imberger and Patterson 1981), an ecological model related to a model described in Schladow and Hamilton (1997) and particle fate model. As such it includes the key processes and has algorithms verified by use in other systems as well as Lake Tahoe. However, to argue that it is the 'most appropriate' model is not possible unless it is compared to alternative models. In particular, while the optical and hydrodynamic components are grounded in optics and hydrodynamics, the ecological model includes many simplified expressions and numerical values selected from the literature. Hence, application of the ecological model requires very careful sensitivity analysis and has considerable uncertainty.

The validity and accuracy of model output depends on inputs, and the hydrodynamic model is being driven by readily available data. Though considerable information on nutrients and plankton exist for Lake Tahoe, the inherent complexity of the biological system leads to missing information required for the ecological model, a further source of uncertainty. These differences are evident in Figures 6-2 to 6-6 in which the close match between modeled and measured temperature profiles contrasts with the less good matches for chlorophyll, nitrate and bioavailable phosphorus. While simulated and observed annual average Secchi depths are close (Table 6-6), seasonal variations of simulated and observed values diverge considerably (Figure 6-7) and reflect the difficulty of modeling the dynamic processes the combine to influence transparency.

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

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Response

JM-13: A review of the Technical Report and the Final Report reveals no suggestions that the Lake Clarity Model was the "most" appropriate model. The Lahontan website for the Lake Tahoe TMDL contains a list of selected peer reviewed journal articles where the full model has been used. Given the complexity of the lake biology/ecology, including a number of unknowns related to the microbial food web, trophic dynamics, bacteria and nutrient cycling, there is always room for improvement in the ecological portion of the model; this is largely true for nearly all lake models. Given the dependence of lake transparency on fide sediment particles, it is not believed that management decisions are being hindered by the ecological sub-model.

The ecological sub-model was simplified for two main reasons: (1) insufficient data existed to use in the model; and (2) nutrient cycling as it related to the physiological ecology of plankton and the aquatic food web is quite complex. Typically, most water quality models have difficulty in modeling these bio-ecological processes. Additionally, concentrations of chlorophyll and nutrients are very low in Lake Tahoe and small numeric deviations can appear large. For example, the total range of measured biologically available phosphorus in the water column typically occurs within the very narrow boundary of < 1 – 2.7 µ/L. The range of simulated concentrations was in a very similar range of < 1 – 2 µ/L. This is at the analytical limit of detection. Consequently, in a system with such low orthophosphate concentrations, it may be asking too much of this type of model to accurately simulate the very small and rapid changes in concentration. Also, the modeled nitrate values were able to demonstrate the typical nitricline. Chlorophyll concentrations like orthophosphate are very low in Lake Tahoe. The Lake Clarity Model simply can not distinguish between values that are close to detection limits. One aspect of the "inherent complexity" is that biological and chemical constituents generally exhibit spatial variability (or patchiness). Neither the sampling program nor the use of a one-dimensional model can capture this. However, since the model's intended use was to determine trends in lakewide annual averages, these shortcomings are negligible.

estimated ability to reduce fine sediment particle and nutrient loads.

The logic of this statement is correct, and the information supporting it is discussed elsewhere. However, a general concern is that allocations are not stated as ranges or as estimates with uncertainty specified.

Comments on text of Lake Tahoe Total Maximum Daily Load – June 2009 Draft

Executive Summary

Page ES-1 Lake Tahoe is a subalpine lake not an alpine lake, as is stated elsewhere in the material.

The basis for the transparency standard of a Secchi depth of 29.7m as the annual average for the period 1967 to 1971 seems overly precise and the selection of years for this standard is not well supported.

The percentage reductions assigned to particular sources are too precise and do not include uncertainties.

The 'adaptive management' to be used to address issues such as climate change or wildfires is not formally described and seems difficult to implement in the context of the TMDL process.

1. Introduction

The possibility that nutrients other than N and P may influence the growth of algae is not mentioned. In ultra-oligotrophic waters, such as those in Lake Tahoe, trace elements can be important.

2. Basin and Lake Characteristics

Since Lake Tahoe does not mix thoroughly each year, it would seem appropriate to calculate a residence time for the water that considered differing volumes.

Optical Properties

The introduction and conceptual model of underwater light should note the dissolved organic matter is a constituent contributing to underwater light attenuation.

What are the sizes of the particles represented in Figure 3-2?

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JM-14: The load allocations are enforceable requirements and states as minimum values. The uncertainties involved in determining the absolute load reduction allocation, as discussed throughout the Technical Report and in the Margin of Safety (Section 14.3 of the Final Report), are not appropriate as enforceable regulatory targets.

JM-15: No change to the existing transparency standard is proposed. Rather, 29.7 meters is being specified as the annual average for the period of record stated in the standard.

JM-16: The percentages that describe expected pollutant load reductions within the Executive Summary do not explicitly describe the relative uncertainty associated with those values. There are a number of uncertainties associated with the load reduction percentage estimates, including but not limited to the uncertainty in baseline load calculations, unknown variability in best management practice effectiveness, and uncertainties in the relationship between loading rates and Lake Tahoe's transparency response. These uncertainties (and others) are addressed in the Margin of Safety portion of the TMDL (Chapter 14 of the Final Report). In response to the reviewer's position that the numbers, as presented, suggest a degree of accuracy that does not adequately reflect the reality of the uncertainty, the Final Report has been edited to round load reduction percentages to the nearest whole number.

JM-17: Chapter 12 in the Final Report has details on the adaptive management process that will be formally developed for this TMDL with funding allocated for the TMDL Management System.

JM-18: This TMDL addresses the three pollutants (nitrogen, phosphorus, and sediment) that resulted in Lake Tahoe being placed on the 303(d) list as an impaired water body. The trace metal iron has been found to stimulate algal growth in Lake Tahoe, presumably because of its importance to enzymes associated with nitrogen cycling. Since iron is inexorably linked to soils and watershed sediment, the control strategy is expected to reduce the potential impacts from iron inputs to Lake Tahoe as well.

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JM-19: Hydraulic residence time was calculated using a textbook definition - time require for all the water in a lake to theoretically pass through its outflow. In the context of Chapter 2 of the Final Report and Chapter 3 of the Technical Report, the very long hydraulic residence time has significance in that pollutants that enter the lake will generally not be readily flushed from the lake. This means that loss of pollutants from Lake Tahoe will typically depend on in-lake physical, chemical and/or biological process and that loss from the outlet is not large. Because the lake does not mix to the bottom each year, the volume could be 'isolated'. However, given a 650-year hydraulic residence time, year-to-year differences resulting from the lack of assured complete mixing is not critical for the sections of the document where this is presented. It is important to note that the Lake Clarity Model takes the depth of mixing into account when simulating annual Secchi depth.

JM-20: The text was changed in the Technical Report, Section 3.4.1 and the Final Report, Section 3.1 to note that while absorption of light by colored dissolved organic matter (e.g. tannins and humic substances) was measurable in Lake Tahoe, it was a small contributor in comparison to the fine sediment particles for lake transparency decline.

JM-21: The size of particles represented in Figure 3-2 of the Final Report (and Figure 3-8 of the Technical Report) were particles <16 µm in diameter. This information was added to the appropriate figure captions.

Section 3.4.1: Primary productivity by phytoplankton does not directly cause transparency decline. It is the resulting accumulation of phytoplankton, not their rate of photosynthesis, that leads to less transparency.

4. Problem Statement

Since Secchi transparency is the key criterion, more information should be provided about the nature of the measurement and its relation to instrumental measurements of underwater light attenuation.

What is the definition of the euphotic zone used as the basis of the statement that light penetrates as deep as 100 m?

How many measurements per year are represented in Table 4.1? Though the annual average may be calculated to mm precision, the accuracy of the Secchi transparency measurement is at the cm level. The values in the Table should be rounded to the nearest cm.

5. Water Quality Standards

Page 5-6: To interpret the vertical extinction coefficient (VEC; which should be called the vertical attenuation coefficient), the wavelength range of the sensor used for the measurements must be specified.

6. Numeric Target

Pages 6-1 and 6-2: VEC is not properly defined, and it is a concern that there appears to be no trend in VEC from 1971 to 2002 while Secchi transparency has a declining trend.

Page 6-3: If the numeric target is based on the annual average Secchi transparency, the number of measurements and their seasonal distribution must be stated.

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Page 6-3: If the numeric target is based on the annual average Secchi transparency, the number of measurements and their seasonal distribution must be stated.

Response

JM-22: A graph for chlorophyll biomass and accompanying text were added to both the Final Report (Figure 3-5, Section 3.4.1) and the Technical Report (Figure 3-14, Section 3.4.2). Additional text was added to these sections mentioned above to more accurately define primary productivity.

JM-23: Text was added to the Final Report, Section 4.1 to help explain the nature of the Secchi depth measurement. Section 6.1.1 of the Final Report contains an explanation of the vertical extinction coefficient - made by taking instrumental measurements of underwater light attenuation. It was concluded that with regard to the water body impairment, transparency was the focus of this TMDL since Secchi depth was more protective.

JM-24: The euphotic zone was taken as the approximate depth where algal photosynthesis and respiration are equal and primary productivity goes to zero. Text was added to the Final Report (Section 4.1) and the Technical Report (Section 1.4).

JM-25: Changes made as suggested to Table 4-1 and text was added to Section 4.1 on Secchi measurements in the Final Report (Table 1-3, Section 1.4.1 of the Technical Report).

JM-26: Language was added that specifies the wavelength range of the sensor (PAR, 400-700 nm) in Section 5.2 in the Final Report and Section 2.1.2 in the Technical Report. The term vertical extinction coefficient is used in limnology and is the language used in the Lahontan Basin Plan.

JM-27: While the pattern for the long-term VEC data is not as well defined as that for Secchi depth, some larger scale trends were seen. For example, during the period 1967-1976 the VEC was about 0.06 per meter. The average annual values were just less than 0.08 per meter during the ten year period from 1985-1995 and increased to 0.08-0.09 per meter between 1997 and 2002. The submersible sensor used to make measurement was considered questionable during 1977-1983, making it difficult to define the long-term trend with certainty. Since VEC also includes changes in water clarity below the Secchi depth - and is influenced by Lake Tahoe's deep chlorophyll maximum, a direct, side-by-side comparison between these two parameters may not occur. Text has been added to Section 6.1.1 of the Final Report and Section 2.2.1 of the Technical Report with the above information.

JM-28: Text was added to the Final Report, Section 6.2, and Section 1.4.1 of the Technical Report regarding the number of Secchi depth measurements taken during the period of 1967 – 1971 and during the entire period of record.