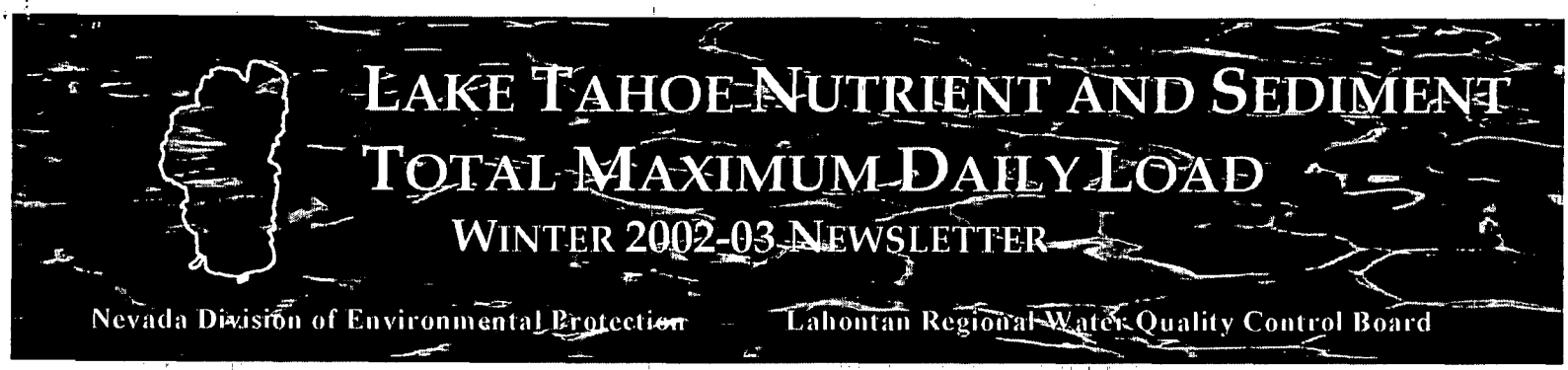

USE OF MATHEMATICAL WATER QUALITY MODELS FOR TMDL DEVELOPMENT

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❖ TWO MODELS HAVE LEADING ROLES

The Fall 2002 edition of the Lake Tahoe Nutrient and Sediment TMDL newsletter (available at http://www.swrcb.ca.gov/rwqcb6/TMDL/Tahoe/Fall02_Tahoe_TMDL_Newsletter.pdf) introduced the concept of Total Maximum Daily Loads (TMDLs) and the research and planning that the multi-agency team developing the TMDL is conducting. In this and subsequent editions, we explain how the use of mathematical models will aid in the restoration of water quality in the Lake Tahoe Basin by allowing us to better quantify nutrient and fine sediment loading and to calculate the lake's ability to assimilate these pollutants without exceeding its clarity standards. The centerpiece of, and basis for, the numeric Lake Tahoe TMDL is two separate but intimately linked mathematical representations of the ecological processes at work in the basin: one representing the watershed, or the terrestrial component of the system, and the other the response of the lake itself to land-, air-, and groundwater-based pollutant loads.

These tools for calculating the fate and transport of pollutants such as phosphorus, nitrogen and fine sediments from their origins within and outside the basin to their impact on Lake Tahoe clarity are called water quality models. This edition of the newsletter will focus on the Watershed Model and will introduce the scientists developing this crucial component of the TMDL, while details on the Lake Clarity Model will be presented in the next newsletter in Spring 2003.

❖ STRONG SUPPORTING CAST OF SIX OTHER MODELS

This edition also introduces other models being developed by the research team that are designed to provide nutrient and fine sediment inputs to the Watershed and Lake Clarity models. These models are listed in the box below and are described briefly later in this newsletter. Future newsletters will provide more details on these important components of the TMDL calculation.

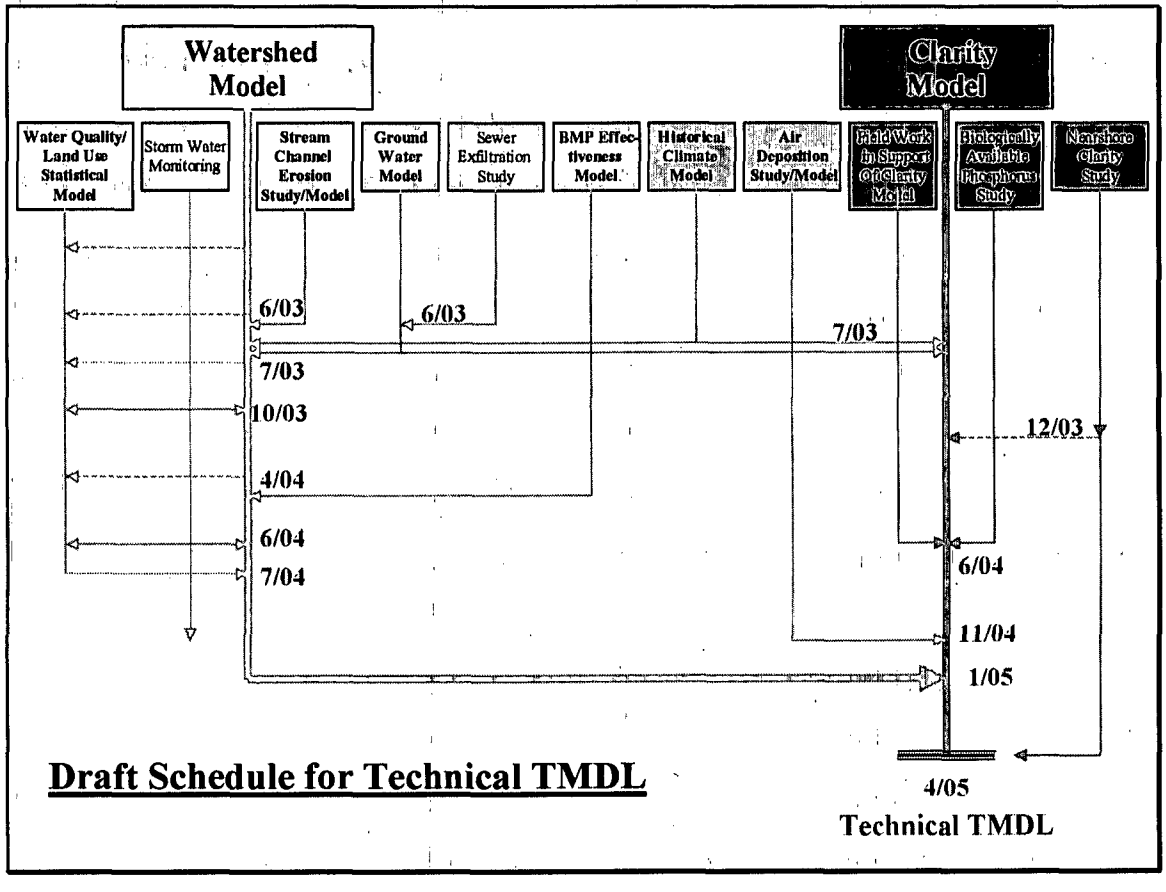
Additional Models Complementing the Watershed and Lake Clarity Models:

- **ground water model**
- **stream channel erosion model**
- **air pollutant deposition model**
- **land use runoff model**
- **Best Management Practices (BMPs) effectiveness model**
- **historic meteorology model.**

Together, these modeling efforts will provide Lake Tahoe Basin resource managers, for the first time, with (1) a quantitative estimate of pollutant reductions needed to achieve water quality

standards, and (2) the ability to predict the likelihood of success of a range of pollution reduction strategies intended to restore Lake Tahoe's clarity to its famed, historical levels.

Interactions between these water quality models, and the schedule for their development and integration into a final Technical TMDL, are portrayed in the diagram below. The modeling projects (as distinct from related, non-modeling studies) are highlighted in bold print, while other studies in support of the models or of the TMDL itself are in regular font. Studies and models of terrestrial processes are represented by brown boxes and lines (in the Internet version of this newsletter) or lighter shading (in the black and white hard copy version). Air quality and meteorological models are in light blue/medium shading, and the lake clarity model and studies supporting it are in darker blue/shades. Solid lines represent final or interim reports providing specific inputs from one project to another; dashed lines are more informal information exchanges.



IT'S ALL IN THE TIMING

It could take decades to show actual improvements in Lake Tahoe's clarity resulting from the TMDL's water quality restoration efforts. This is largely a result of the fact that (1) the flushing rate of the lake is extremely slow, (2) the lake is so deep that fine particles take a long time to settle down to the bottom, and (3) during this settling process, nutrients can be recycled many times. Ecological models apply the collective knowledge of scientific experience to develop simulations of environmental processes that allow natural resource managers to make decisions regarding future conditions.

❖ THE PURPOSE OF MODELING

The use of ecological models allows for a scientifically informed prediction of management scenarios without having to wait decades to see if a particular approach will result in the desired outcome. These models enable resource managers to answer "What if..?" questions about possible restoration strategies and future environmental conditions. For the model to be useful for making management decisions, it must correlate an ecological condition (such as lake clarity) with a controllable source (such as pollutant loading). The model must also be validated using data or other observations to confirm that the modeling results are reasonably similar to actual environmental conditions. Due to the extreme complexity of environmental systems, models are by necessity only simplified approximations of actual conditions. However, models are powerful and sophisticated tools that allow resource managers to make informed decisions and to track progress toward achieving their objectives.

❖ HOW MODELS ARE DEVELOPED AND APPLIED TO THE TMDL

Initially, a model is calibrated based on some past period of record for which good data are available. Once the model is calibrated or 'tuned up,' and is believed to represent actual conditions, it is then validated by comparing model results with another period of available data. Calibration and validation are iterative processes which, when complete, produce a model that conforms with our understanding of cause-and-effect relationships in the environment. The model may then be utilized to simulate future conditions (e.g., improved lake clarity), based on a scenario of potential management options (e.g., reduced pollutant loading). Again, applying an iterative computation process, a desired future condition such as the adopted water quality standards for lake clarity can be correlated to a level of pollutant loading necessary to achieve that clarity. This loading level may be considered the assimilative capacity of the water body, or the total maximum daily load that achieves the desired standard. In this manner, water quality models enable resource managers to predict future conditions that may take years, decades or centuries to realize, and to make decisions now that, based upon our current level of understanding, will achieve the desired outcome with a reasonable level of confidence.

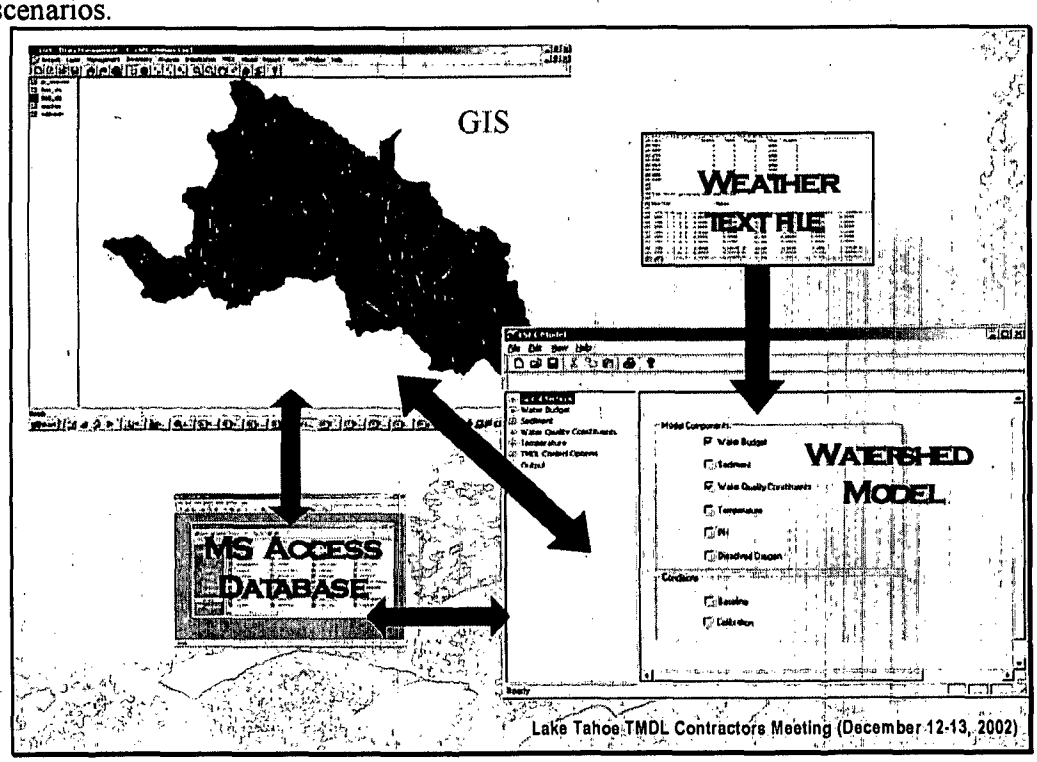
In order to determine a pollutant loading level that will achieve Lake Tahoe's desired clarity, the agencies and researchers developing the TMDL must correctly model the terrestrial and atmospheric pollutant loads to Lake Tahoe (such as ground water, stream and storm water inflows, and direct deposition of airborne pollutants). The rich history of monitoring in the Lake Tahoe Basin provides us with a very good data set for model calibration and verification. Simultaneously, the broad spectrum of scientific research in the basin has enabled us to better understand the environmental processes the model is trying to simulate. The model must also accurately represent source reduction measures (such as erosion and other sediment and nutrient control projects, air pollution abatement measures, etc.), such that a given level of pollution control can be correlated to a reduced level of pollutant loading into the lake. This effort is described in the following section.

To ensure that the watershed model corresponds as closely to reality as possible, existing data and studies are being coupled with new efforts that are being undertaken to monitor the quality of streams, storm water runoff, and air deposition of pollutants in the Lake Tahoe Basin, and with studies of pollution control measures and their effectiveness. Future editions of the newsletter will discuss these studies in depth.

LAKE TAHOE WATERSHED MODEL

To model the Lake Tahoe watershed, a highly-qualified team from the consulting firm Tetra Tech (see box on following page) will adapt and apply a comprehensive watershed modeling framework developed for the U.S. Environmental Protection Agency (EPA) called "Loading Simulation Program in C++" (LSPC). The watershed model will integrate research results from the numerous studies being conducted in support of the Lake Tahoe TMDL with the wealth of historical data currently available. The LSPC watershed modeling system includes algorithms for simulating watershed hydrology, erosion, and water quality processes, as well as in-stream transport processes. Key features of the system include a convenient, underlying Microsoft Access database for model input and output data storage, a simplified geographic information system (GIS) interface for visualization, and a TMDL calculation and source allocation tool, as shown in the diagram below.

LSPC is particularly well-suited to modeling the Lake Tahoe watershed, because it can be readily modified to represent Lake Tahoe Basin-specific issues. Data from a number of concurrent research efforts will be incorporated into Tetra Tech's LSPC modeling effort. The meteorological model described in later sections will provide necessary inputs to drive LSPC's hydrologic simulation. Specific statistical relationships between land cover, slope, and pollutant loading will be used to generate sediment and nutrient loading estimates. Data from the groundwater assessment, storm water monitoring, and stream channel erosion assessment and modeling efforts will be particularly useful for model testing. Information on (1) the effectiveness of Best Management Practices (BMPs) to reduce runoff and pollutant loading and (2) local and regional BMP planning scenarios will be incorporated into the model to evaluate strategies for achieving the TMDL. Ultimately, flow, sediment and nutrient loading estimates generated by the LSPC model will be linked to the Lake Tahoe Clarity Model. This will provide a sound basis for recreating historical conditions and testing hypothetical "what-if" scenarios.



WATERSHED MODELING TEAM

A team from Tetra Tech, Inc. will develop and apply the model of the Lake Tahoe Basin or watershed. This work will be conducted in close collaboration with the multi-agency Lake Tahoe TMDL Development Team (which is lead by the Lahontan Regional Water Quality Control Board and includes Nevada Division of Environmental Protection, Tahoe Regional Planning Agency, U.S. Forest Service, California Tahoe Conservancy and other interested agencies). Tetra Tech's Water Resources and TMDL Group has conducted hundreds of modeling studies; participated in over 1,000 approved TMDLs nation-wide; developed user-friendly model interfaces; peer-reviewed completed modeling studies; and provided technical assistance to federal, state, and local agencies throughout the country. Key members of Tetra Tech's team undertaking the Lake Tahoe Basin watershed model include Leslie Shoemaker, Andrew Parker, and John Riverson.

Dr. Shoemaker has been building models to support environmental management since the 1980s. Her master's thesis work involved building watershed models to evaluate management actions in the New York City Reservoirs. Since the early 1990s, Dr. Shoemaker has supported states and EPA in TMDL development, developing methods, applying models, writing guidance, and providing technical training. She has designed national and regional water quality modeling systems for EPA, and as EPA's lead instructor for TMDL development, has provided training to over 1,000 attendees in 20 states and all 10 EPA regions across the country.

Andrew Parker brings to the team experience in watershed modeling and development of over 1,000 approved TMDLs. Mr. Parker holds bachelors and masters degrees in civil and environmental engineering, respectively, from the University of Virginia. He has extensive experience providing technical and management support to federal, state, regional, municipal, and private clients in the areas of watershed and receiving water modeling, watershed and water quality assessment, water resource planning, and TMDL development. He has also been part of the team developing and maintaining national and regional water quality modeling systems, and has provided intensive modeling training to hundreds of practitioners.

John Riverson brings to the Lake Tahoe TMDL expertise in watershed modeling as well as key spreadsheet and database programming experience focused on managing, analyzing, and summarizing complex data sets. He holds bachelors and masters degrees in civil and environmental engineering, respectively, from the University of Virginia. Mr. Riverson has worked on and led a variety of modeling and environmental systems development projects for federal, state, and local agencies. In addition to model development and application aimed at TMDL development, Mr. Riverson has contributed to two engineering textbooks and various peer-reviewed technical papers.

Expert Modelers John Riverson, Leslie Shoemaker, and Andrew Parker of Tetra Tech, Inc.

ADDITIONAL MODELS SUPPORTING THE TMDL

Historical Meteorology

To run both the lake clarity and watershed models, a detailed, long-term account of weather in the Lake Tahoe Basin is needed. Therefore, the Lahontan RWQCB has contracted with the UC Davis Hydrologic Research Laboratory to re-create a record of the climate in the Lake Tahoe Basin over the period of 1958-2001. The database will provide meteorological information on an hourly basis and be able to characterize specific locations as small as 3 kilometer squares covering the entire basin. The Spring 2003 newsletter will describe this complex, state-of-the-art model in greater detail.

Groundwater and Stream Channel Erosion

Groundwater that transports pollutants either directly into Lake Tahoe or indirectly into a tributary stream may be out of sight, but it is not out of mind. Similarly, the magnitude of nutrient and sediment loading to the lake from stream bank erosion must be evaluated and quantified. The U.S. Army Corps of Engineers is lending invaluable assistance to the Lake Tahoe TMDL project by collecting additional data and modeling the pollutant loading contributions from both these processes. These models will enable us to determine the degree of pollutant loading from stream bed and stream bank erosion, as well as ground water movement, and to identify opportunities for load reduction projects.

Air Deposition

While scientists have monitored atmospheric deposition on a limited basis within Lake Tahoe Basin since the early 1980s, we need more information on direct pollutant loading to the whole lake from this source to more confidently calculate a TMDL. In addition, to propose appropriate emission controls, we need to determine whether airborne pollutants originate from inside or outside the basin. The importance of direct deposition of pollutants to Lake Tahoe has prompted the California Air Resources Board to undertake an extensive, approximately $1.5 million project to study air quality and atmospheric deposition in the Tahoe Basin. The approach will include direct measurement of important pollutant species and their sources and monitoring of relevant meteorological conditions. With this information, an inventory of air emission sources within the basin will be developed and a mechanistic model will be adapted to extrapolate those measurements into basin-wide deposition calculations. The air emissions inventory will provide us with focal points for future pollutant reduction strategies.

Statistical Relationships between Land Use and Runoff

An extensive, long-term database of stream flows and pollutant concentrations will be combined with results of an intensive storm water monitoring program to develop statistical relationships between land characteristics and runoff. Hydrokios Consulting, the Desert Research Institute, and the Tahoe Research Group are collaborating to determine these correlations, thereby enabling us to determine the impact of changing land management practices on lake clarity.

BMP Effectiveness

A final significant input to the watershed model is information regarding the effect of implementing control measures such as storm water Best Management Practices (BMPs) on pollutant loading. BMP effectiveness model outputs include, for a variety of BMPs (such as infiltration or detention basins, vegetated swales, street sweeping, etc.), the amount of runoff controlled by the BMPs and the effluent quality from areas where BMPs are installed. GeoSyntech Consulting is developing this important model.

TMDL TIDBITS

❖ CONTRACTORS CONVENE AND COORDINATE THEIR EFFORTS

On December 12 & 13, 2002, Lahontan RWQCB and Nevada Division of Environmental Protection hosted a meeting at the North Tahoe Conference Center in Kings Beach of all the researchers involved in development of the Lake Tahoe TMDL. The purpose of the meeting, which was attended by over 30 primary investigators and participating agency officials, was to share information on the status of each research project (see page 4 of previous newsletter for complete list), to review the TMDL development process and the current status of our efforts, and most importantly, to initiate the process of integrating the research projects into a coherent whole. Informal breakout sessions addressed specific subtopics such as statistical analysis of storm water and other pollutant source data, how to determine pollutant loads from vegetated areas in the Lake Tahoe Basin, and the application of exciting new research into the extent and sources of nearshore turbidity hotspots. But the primary emphasis of the meeting was on the structure and information needs of the two water quality models that will determine the TMDL: the Tetra Tech Watershed Model and the UCD Lake Clarity Model. In particular, researchers addressed how their individual projects contribute to those two unifying tools (which themselves must be seamlessly integrated), and what data sources would be utilized to populate the models. Researchers made brief presentations on their approaches and the status of their projects and Lahontan RWQCB provided an update on TMDL development. The visual aids for these presentations may be viewed at Lahontan's Lake Tahoe TMDL website, http://www.swrcb.ca.gov/rwqcb6/TMDL/Tahoe/Tahoe_Index.htm, under the title: "Presentations given at the Lake Tahoe TMDL Contractors Meeting on December 12-13, 2002." The website also contains general information and other work products of interest related to TMDL development. Check back often as information is added when it becomes available. Questions related to these presentations and additional project information may be directed to Dave Roberts and/or Jack Landy (see contact information below).

❖ IF YOU WANT TO BE PART OF TMDL DEVELOPMENT, CHECK OUT SNAPSHOT DAY!

The Lake Tahoe Environmental Education Coalition (LTEEC) has scheduled the third annual Snapshot Day in the Lake Tahoe watershed for May 10, 2003. This event mobilizes dozens of citizen-volunteers, working with water quality management agencies including Lahontan RWQCB, to gather valuable water quality information in the form of visual assessments, photos, and water quality data. This year, the intent is to gather water quality samples in all 63 tributary watersheds of Lake Tahoe. These data will be directly applied in calculating the TMDL. To join LTEEC's Clean Water Team for stream monitoring and to participate in TMDL research, please contact Heather Segale at (775) 832-4138.

❖ TAHOE RESEARCH GROUP REPORT ON 2002 CLARITY

U.C. Davis's Tahoe Research Group (TRG) recently issued its annual report on Lake Tahoe Clarity for 2002, which includes the encouraging information that average pelagic lake clarity improved to 78 feet last year, its clearest since 1992. The full news report may be seen at http://www.news.ucdavis.edu/search/printable_news.lasso?id=6281.

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