Curriculum Development Workshop

Model Exercise #2: Interdisciplinary Modeling Project Background Material

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Lake Tahoe and its Environmental History

Lake Tahoe is renowned for its optical clarity and deep blue color. It has been designated an "Outstanding National Water Resource" by the Environmental Protection Agency due to its ecological assets, scenic quality, and year-round recreational appeal. Unfortunately, the optical clarity of Lake Tahoe has decreased during the last four decades, the result of algal growth stimulated by nutrient input from atmospheric deposition, urban runoff, and transport of sediment into the lake. Currently, Lake Tahoe is listed on California's 303(d) list of the Clean Water Act (see http://www.swrcb.ca.gov/tmdl/303d_lists.html) of impaired water bodies, and several streams in the Tahoe Basin are listed on Nevada's 303(d) list (see http://ndep.nv.gov/bwqp/303dlist.htm).

The Lake Tahoe basin is comprised of 63 sub-watersheds in 506 square miles. About 95% of the terrestrial basin is comprised of second-growth mixed coniferous forests with about 12 to 15 percent developed for residential and commercial purposes. The lake itself is 192 square miles and has an average depth of 990 feet. The maximum depth is approximately 1,646 feet, making Lake Tahoe the tenth deepest lake in the world. The water level within the lake has been regulated since 1874, making it the largest reservoir in the Truckee River Basin that serves the cities of Reno and Sparks, Nevada.

Lake Tahoe's clarity has resulted from the historical scarcity of nitrogen (N), phosphorus (P), and other nutrients that support the algae that commonly cloud the water of other lakes. However, logging during the Comstock era (1858-1890), and the tremendous growth in population and tourism after 1960 have had an adverse effect on the capacity of the basin's watersheds to filter out nutrients and sediment prior to the discharge of tributaries into Lake Tahoe.

Timber from the Lake Tahoe Basin was used to shore up the underground workings of the mines in Virginia City, 15 miles to the east. Timber stands were nearly-clear cut with little regard for streamside areas. The mill at Incline, the second largest at Tahoe, averaged 40,000 to 75,000 board feet of lumber per day. Soil was disturbed by the cross-country skidding of the timber, and fires were also common, with blazes ravaging the sawdust and slash piles, and ran virtually unchecked. These factors contributed to degraded water quality, with estimates that sediment deposition to the lake increased 7 to 12-fold over the rates prior to logging. The associated nutrient input is thought to have increased primary productivity in the lake by about 6 times.

Urbanization pressures began affecting the basin in the early 1960s when the completion of Interstate 80 and Highway 50 coupled with the growth of casinos and ski areas made Lake Tahoe accessible and attractive for increased tourism. The number of full-time residents grew five-fold and the number of houses grew from 500 to 19,000 between 1960 and 1980 (Lindström 2000). Increased urbanization has increased non-point pollution of the streams and lake. Examples of other urban influences include destruction of the Tahoe Keys wetlands, MTBE inputs to Lake Tahoe by watercraft, and nutrient inputs from land disturbance and anthropogenic practices, such as fertilization. A cumulative result of these influences is the loss of about 1 to 1.5 feet of clarity per year over the last 30 years (Jassby et al. 2000). When first measured in 1968, the secchi depth was 168 feet compared to today's depth of approximately 70 feet. Detailed discussions of the impacts of human land use (Lindström 2000), the state of water (Reuter and Miller 2000) and air (Cliff and Cahill 2000) quality, biological integrity (Manley et al. 2000), and socio-economic factors (Nechodom et al. 2000) can be found in the Lake Tahoe Watershed Assessment (Murphy and Knopp 2000).

Environmental Monitoring and Research in North Lake Tahoe and Surrounding Watersheds

Today, much effort is being devoted to research and monitoring projects that are concerned with the water quality of Lake Tahoe. In order to increase lake clarity, the control of suspended sediment and nutrient loading from hydrologic, atmospheric, and anthropogenic sources must be controlled. The Tahoe Integrated Information Management System (see http://tiims.org/) is a good source for information pertaining to the restoration and planning efforts within the Lake Tahoe Basin. Some specific projects and research within the North Lake Tahoe area include:

The Lake Tahoe Interagency Monitoring Program (LTIMP) program (http://nevada.usgs.gov/activities/nv147.cfm): A joint effort of the Tahoe Regional Planning Agency (TRPA; see http://www.trpa.org), the University of California's Tahoe Research Group (TRG; see http://trg.ucdavis.edu), and the United States Geological Survey (USGS; see http://tahoe.usgs.gov) has collected and analyzed stream and ground water samples from up to 32 sites around the basin. The LTIMP program does routine and storm-based monitoring with emphasis on storm and snowmelt events that result in the greatest transport of sediment and nutrients. In 1990 the program expanded to include 32 ground water sampling sites. Sites in North Lake Tahoe include:

- Incline Creek at Tyrol Village (see http://waterdata.usgs.gov/nv/nwis/uv/?site_no=103366993)
- Incline Creek below Highway 28 (see http://waterdata.usgs.gov/nv/nwis/nwisman/?site_no=103366995&agency_cd=USGS)
- Incline Creek at Crystal Bay (at Aspen Grove Park; see http://waterdata.usgs.gov/nv/nwis/uv?site_no=10336700)
- Third Creek at Crystal Bay (see http://waterdata.usgs.gov/nv/nwis/uv?site_no=10336698).

The Lake Tahoe Nutrient and Sediment Total Maximum Daily Loads (TMDLs) (see http://www.waterboards.ca.gov/lahontan/TMDL/Tahoe/Tahoe_Index.htm): A joint effort spear-headed by California's Lahontan Regional Water Quality Control Board (LRWQCB; see http://www.waterboards.ca.gov/lahontan/) and the Nevada Division of Environmental Protection

(NDEP; see http://ndep.nv.gov) to form a comprehensive and collaborative lake clarity restoration plan using a science-based decision making process. Some pertinent projects funded by this effort include: 1) the Lake Tahoe Clarity Model, 2) the Lake Tahoe Watershed Model, 3) reconstruction of historic meteorology, 4) characterization of air quality emission sources and modeling of atmospheric deposition, 5) measurement and analysis of stream channel erosion, 6) loading of fine sediment by streams into Lake Tahoe, 7) stormwater runoff monitoring, 8) land-use effects on stream water quality, and 9) groundwater and sewer line exfiltration assessments (see http://www.waterboards.ca.gov/lahontan/TMDL/Tahoe/tahoe_symposium_12_04.html).

Water Clarity: The Tahoe Research Group (TRG; see http://trg.ucdavis.edu) at UC Davis was established to conduct research in limnology after UC Davis researchers became aware of the decline in the lake's water quality in 1959. Research topics of TRG faculty have included: lake clarity and limnology, the construction of predictive models of water quality, paleolimnology, sediment analysis, nutrient/sediment transport and treatment, aquatic ecology, air quality, and forest ecology. Real-time data from several monitoring platforms on Lake Tahoe is available (see http://remote.ucdavis.edu/tahoe_location.asp).

Impacts of Land Use on Water Quality in Lake Tahoe Watersheds: The goal of this study funded by NDEP (see http://ndep.nv.gov) is to conduct a source assessment of sediments and nutrients in the Third and Incline Creek Watersheds in support of the Lake Tahoe TMDL (see http://www.waterboards.ca.gov/lahontan/TMDL/Tahoe/Tahoe_Index.htm). The objectives of the study are to characterize sediment and nutrient loading from specific land uses (e.g. forested, golf course, ski area, commercial) and to understand N and P transport pathways.

Incline Creek Watershed Project (ICWP; http://inclinecreek.dri.edu/): A primary goal of the University of Nevada's ICWP was to provide baseline data encompassing a wide selection of watershed processes. Two biogeochemical study plots were established in a high elevation white fir (*Abies concolor*) stand and a mid-elevation forest stand dominated by Jeffery pine (*Pinus jeffreyi* Grev. and Balf.). Vegetation health, above- and belowground nutrient fluxes were monitored in these plots. Additionally, stream water quality was assessed at several locations within the Incline Creek watershed utilizing spatial and temporal approaches in order to better assess the stream transport of nutrients and sediments through upland forests and urbanized areas. The ICWP maintains a meteorological station within the watershed. The project was initially funded by the National Science Foundation and continues on-going monitoring with support by local, state, and federal agencies.

Rosewood Creek Restoration Project (2003): Rosewood Creek is a small, urban creek in the northeastern part of the Lake Tahoe basin. The Nevada Tahoe Conservation District (see http://www.ntcd.org) and the Nevada Division of State Lands (see http://lands.nv.gov) funded this restoration project in an effort to improve the sensitive environmental zone and mitigate suspended sediment delivery into Third Creek and ultimately into Lake Tahoe. Current monitoring of the project includes in-stream turbidity and discharge measurements above and below the restoration project to assess the impact of the project on the delivery of suspended sediment to Lake Tahoe. Recent funding will provide for an assessment of upstream sediment sources, including the development of a restoration plan.

Other Best Management Practice (BMP) Projects: The Wetlands Efficiency project (Village Green, Incline Village) was conducted to determine the effectiveness of natural and constructed wetlands in treating urban runoff. The Griff Creek Stream Environment Zone and Watershed Restoration Project (see http://www.ice.ucdavis.edu/nrpi/NRPIDescription.asp?ProjectPK=3349) was constructed to return the area back to native conditions after the abandonment of urban structures. The Snow Creek Stream and Wetland Restoration Project (see http://www.pubs.asce.org/WWWdisplay.cgi?0106399) involved the re-establishment of a pond, the construction of two seasonal wetlands, and 360 lineal meters of new wetland channels. A variety of local, state, and federal agencies funded these projects.

Incline Village Clean Water Team: This is a volunteer citizen's water monitoring group sponsored by the Incline Village General Improvement District and NDEP (http://ndep.nv.gov). Water samples are collected once a month at a variety of locations including from Rosewood, Third, and Incline creeks.

Nevada Division of Environmental Protection (NDEP) Routine Sampling: Until recently, NDEP has collected six water quality samples per year since the late 1960s. Sampling sites include several locations within the Third and Incline Creek watersheds (see http://ndep.nv.gov/bwqp/TruckeeRiverBasin.html).

Why the Incline Creek Watershed?

The Incline Creek watershed is one of the main watersheds draining into the northeastern portion of Lake Tahoe. The watershed is 18.1 km^2, with elevations ranging from 2,810 m to 1,900 m at the outlet of Incline Creek. The average annual discharge from Incline Creek was 8 cfs between 1988 and 2001, with snowmelt-dominated peak discharge typically above 30 cfs. Annual average air temperature is 6.1°C and annual precipitation averages 650 mm of which 65 to 70% occurs as snow Atmospheric dry deposition of N from both local and regional sources ranges from 1 to 9 kg N $ha^{-1}yr^{-1}$.

The Incline Creek watershed was chosen as a study watershed for Lake Tahoe for a number of reasons:

1) There is a rich body of existing data. In addition to the previously discussed research and monitoring efforts, additional studies have been conducted on infiltration, groundwater, and nutrient transport. The Incline Creek watershed (see http://inclinecreek.dri.edu) adjoins the Little Valley watershed (see http://www.cabnr.unr.edu/littlevalley/index.html), which has been the site of numerous forest, soil, and ecological studies.

2) The soils in the Incline Creek watershed are primarily decomposed granite derived from grandiorite, the dominant parent material within the Lake Tahoe basin. The availability of nutrients, such as P, is highly controlled by the type of soils and parent material, with granitic soils having higher levels of P availability relative to the andesite-derived soils found in north Lake Tahoe.

3) There are several discrete land-uses in the watershed, such as higher elevation forests, lower elevation residential and commercial uses (Incline Village, population of 10,000), and ski areas and golf courses.

4) Relative to the other LTIMP monitored streams in the basin, Incline and Third creeks have been shown to have among the highest combined yields for all nutrients and sediments per watershed area (Rowe et al. 2002).

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