

An Integrated Science Plan for the Lake Tahoe Basin: Conceptual Framework and Research Strategies

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Abstract

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An integrated science plan was developed to identify and refine contemporary science information needs for the Lake Tahoe basin ecosystem. The main objectives were to describe a conceptual framework for an integrated science program, and to develop research strategies addressing key uncertainties and information gaps that challenge government agencies in the theme areas of: 1) air quality, 2) water quality, 3) soil conservation, 4) ecology and biodiversity, and 5) social sciences. Each strategy concludes with a presentation of near-term research priorities. Several factors (e.g., changing agency priorities, funding levels, and the emergence of new issues, new information, or new technologies) can affect the applicability of near-term research priorities. Thus, this science plan is considered a living document. The research priorities are best reviewed and revised regularly to ensure they reflect the changing information needs and evolving priorities of agencies charged with the welfare of the Lake Tahoe basin.

Keywords: Lake Tahoe basin, air quality, water quality, soil conservation, ecology and biodiversity, social sciences.

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Chapter 1. Introduction

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It is clear that a complex suite of interrelated changes has occurred in and around the Lake Tahoe basin over the last 150 years. These changes have substantially affected the atmospheric, aquatic and terrestrial environments, and socioeconomic conditions in the basin (Elliott-Fisk et al. 1996, Lindström et al. 2000). Human responses to these changes have taken many forms; however, the overall trend shows a transition from policies favoring unrestricted use of habitats and living resources for development and economic benefit, to policies favoring limitations on development and increased habitat conservation and restoration (see Elliott-Fisk et al. 1996 for a review). This transition ultimately led to the policy declaration establishing the Tahoe Region Planning Compact (Public Law 96-551), which aims to ensure equilibrium between the region's natural endowment and its manmade environment, and to the subsequent State of California designation of Lake Tahoe as an Outstanding National Resource Water under the Federal Clean Water Act (LRWQCB 1995).

The known effects of past actions and the unique character of the Lake Tahoe basin have led to broad-based support for substantive conservation and restoration efforts. Active pursuit of these efforts has occurred over the last two decades (CTC 2006, Elliott-Fisk et al. 1996, Murphy et al. 2000, Public Law 106-506, TRPA 2001). Increased attention and funding over the past decade, in particular, have resulted in remarkable progress toward restoration goals, along with considerable information on the strengths and weaknesses of different approaches to addressing the substantial restoration challenges (Elliott-Fisk et al. 1996, Murphy et al. 2000, TRPA 2002, 2007). Restoration has focused not only on Lake Tahoe, but also on the entire watershed. Special attention has been given to the highly interdependent nature of terrestrial and aquatic habitats, and the multifaceted socioeconomic conditions that influence the Tahoe basin ecosystem (Elliott-Fisk et al. 1996, Murphy et al. 2000). The Lake Tahoe basin is recognized as a highly complex physical, biological and social environment, and the challenges posed by its restoration and continued management for multiple benefits are paralleled by few other locations.

Conservation and restoration of the Lake Tahoe basin ecosystem has required the sustained engagement of Federal, State and local governments, and the private sector. These entities have worked together to develop and implement a variety of programs and activities aimed at achieving common environmental and social goals (TRPA 2001, 2007). Yet determining how to proceed with conservation and restoration efforts in the face of limited information remains a central challenge to these efforts. Science (e.g., monitoring, research, and modeling), particularly applied science completed to inform an adaptive management system, provides a promising set of tools to address information limitations that affect our ability to select and implement effective management strategies. The coordination of scientific activities with management actions is at the core of an effective adaptive management approach (Manley et al. 2000). However, effort is required to organize and describe the science activities

needed to inform an adaptive management system focusing on the conservation and restoration of a complex system. This document presents the results of science community efforts to organize and describe the initial elements of an integrated science plan for the Lake Tahoe basin: a conceptual framework for science operating in an adaptive management system, and focused research strategies covering topic areas of relevance to Tahoe basin management and conservation. Separate, agency-led efforts are underway to develop other essential elements of an integrated science plan including, programs for status and trends and effectiveness monitoring, new data applications aimed at converting data into information and knowledge, and the integration of monitoring and applied research efforts.

1.1 Approach for Developing This Science Plan

This science plan was developed through a collaborative effort among agency, science community, and stakeholder representatives to identify and refine science information needs for the Lake Tahoe basin. The main purpose of this effort was to develop a set of research strategies addressing key uncertainties and information gaps that challenge resource management and regulatory agencies. The research needs identified in these strategies are based on assessments of the issues and information needs that currently confront government agencies and stakeholders working in the basin. The resulting strategies are intended to guide future research efforts and to help maximize the information gained from future science investments.

The plan begins by presenting an overview conceptual model and framework, which identify issues of concern in the Tahoe basin and describe how science can work to inform policies, management strategies, and actions within the context of a Lake Tahoe basin adaptive management system. Next, the plan presents five chapters describing focused research strategies for the theme areas of: 1) air quality, 2) water quality, 3) soil conservation, 4) ecology and biodiversity, and 5) social sciences. Each research strategy describes the knowledge gaps and research needs for relevant issues of concern (i.e., sub-themes). Scientists worked with resource management agency representatives and stakeholders to identify relevant sub-themes (e.g., fire regime is one sub-theme under the Biodiversity and Ecology theme area), and to identify the management issues and information needs associated with each sub-theme (e.g., minimizing adverse impacts to wildlife is one management issue under the fire regime sub-theme). For each sub-theme, the authors summarize the current state of knowledge, identify remaining uncertainties and knowledge gaps, and list science activities that address the uncertainties and knowledge gaps.

The research strategy theme areas were chosen based on an examination of resource areas considered in four management plans or planning processes: 1) the 1987 Lake Tahoe Basin Regional Plan, 2) the 2000 Lake Tahoe Watershed Assessment, 3) the Pathway planning process³, and 4) Phase II of the Environmental Improvement Program for the Lake Tahoe basin (table 1.1).

Three common needs drive the recommendations presented in each research strategy:

- Increasing our understanding of the factors and processes driving change.
- Developing the tools and understanding to predict future conditions in the Lake Tahoe basin and permit comparisons among alternative futures.
- Providing information to inform future management decisions aimed at conserving and restoring the natural and human environments of the Lake Tahoe basin.

Each research strategy concludes with a presentation of near-term research priorities. The selection of near-term research priorities is based on the input of agency and stakeholder representatives received during sub-theme identification, as well as the best professional judgment of the authors. Several factors (e.g., changing agency priorities, funding levels, the emergence of new issues or new information, and the availability of new technologies) can simultaneously affect the applicability of chosen research priorities. Thus, the selected priorities are best reviewed and revised regularly to ensure the current science needs and priorities reflect the changing information needs and evolving priorities of agencies charged with the welfare of the Lake Tahoe basin. For this reason, this science plan is considered a living document. The agency, stakeholder, and science community representatives active in the Lake Tahoe basin all share the continuing responsibility to revisit and update this document in the future.

1.2 A Review of Science Planning and Support in the Lake Tahoe basin

Over the last thirty years there have been several efforts to organize and describe the science needed to improve our understanding of the Lake Tahoe basin ecosystem and inform management actions. The most substantial efforts include the following:

- Research Needs for the Lake Tahoe Basin (LTARCB 1974). A National Science Foundation funded project, which aimed to “encourage research needed to achieve the planning and management objectives of public and private entities” and to “provide scientific expertise and data to support effective planning and management programs.” Information shortfalls that compromised management of the Tahoe basin’s air, water, vegetation, fish and wildlife, social sciences, and resource systems were identified. More than 80 separate research needs were proposed.
- Lake Tahoe Environmental Assessment (WFRCIRTF1979). The assessment and a compilation of information prepared in support of this assessment evaluated data for a number of resources, habitats, and socioeconomic factors. These were pivotal evaluations, formally introducing the concepts of carrying capacity and environmental thresholds, which were central to the scientific underpinnings of the 1987 Lake Tahoe Basin Regional Plan.
- Lake Tahoe Case Study (Elliott-Fisk et al. 1996). This document took a science-based approach to provide an ecosystem and policy assessment of the Lake Tahoe basin. The case study synthesized information from these assessments to inform the Sierra Nevada Ecosystem Project, and identified future science-based management needs for the Lake Tahoe basin.

- Environmental Improvement Program (EIP, TRPA 2001). The EIP described a series of program areas and projects, which if implemented, would advance the Lake Tahoe basin towards attainment of the environmental thresholds identified in the 1987 Lake Tahoe Basin Regional Plan. The science and research portion of the EIP (updated and expanded in 2001) identified threshold and EIP-related research and monitoring projects designed to: 1) advance scientific understanding of ecosystem processes and threshold attainment, 2) refine planning and restoration strategies, and 3) improve and quantify the effectiveness of capital improvement projects.
- Lake Tahoe Watershed Assessment (Murphy et al. 2000). This document provided a synthesis of 20 years of research publications and reports dealing with the atmospheric, aquatic, and terrestrial environments, the living resources associated with these environments, and socioeconomic conditions. Like the documents that precede it, this assessment included recommendations for research and monitoring. The assessment also presented an adaptive management strategy, describing a means of organizing current information, and linking management planning with essential science activities.
- Key Management Questions (SAG 2001). Scientists and agency representatives worked together to develop a list of Key Management Questions (KMQ) to direct new research and monitoring efforts in the Lake Tahoe basin. Some of the KMQ were periodically revised and updated (2002-2004) to reflect the most important questions that land managers, project implementers and regulators had about land use decisions and methods to improve ecosystem health in the Lake Tahoe basin. Tahoe basin agency executives went through a process to prioritize some of the KMQ. This information was used by Federal and State agencies to develop budgets for future science funding.

The documents described above range from lists of research needs and questions, to in-depth reviews and issue-specific analyses. In some cases, the documents also describe processes and approaches for obtaining new scientific information. To varying degrees, all of these efforts provided recommendations for the kinds of science activities, and in several cases the specific studies, needed to address existing uncertainties and information gaps.

In several cases, it was implicitly assumed that providing a description of the science needs for the Lake Tahoe basin would lead to establishment of a sustained program for addressing those needs. However, such a program has never been established and, with the exception of water quality, information gains for many critical issue areas generally lag behind the information needs of managers and policy-makers. In some cases these information gains are lacking because the necessary studies have not been initiated or completed. In other cases, these information gains have not been realized due to a lack of existing data synthesis and analysis.

With the exception of the Key Management Questions (KMQ), none of the science plans prepared for the Lake Tahoe basin have been supported by sustained science planning processes that provide a means for objective prioritization and regular revision.

Unfortunately, the KMQ planning process eventually fragmented with different issues areas receiving varying degrees of attention. Yet functional science planning processes are critical to ensuring a science program remains relevant and responsive to management information needs. To remain effective, it is recommended that support for science planning be provided to ensure that any funds available for new science address the highest priority information needs.

In addition to efforts to organize and describe science needs, efforts to improve the organization of science entities and implementation of science activities occurring in the Tahoe basin also have occurred over the last decade,. Two persistent challenges have provided the motivation to improve science organization and implementation:

1. For years the academic and management communities could not agree on a scientific agenda that would answer both key management and research questions.
2. Many times scientific work was not deemed pertinent to what the agencies wanted, and the management questions were not articulated in ways the science community could use.

Explicit efforts to address these challenges were formalized in 1999 with the signing of a memorandum of understanding (MOU) with a primary focus on priority research, monitoring, evaluation, and outreach supporting Tahoe basin management goals. The entities signing this MOU (Tahoe Regional Planning Agency (TRPA), University of Nevada, Reno (UNR), Desert Research Institute (DRI), University of California, Davis (UC Davis), United States Geological Survey (USGS) and the United States Forest Service (USFS)) committed to work collaboratively to:

1. Establish a joint steering committee to evaluate the Environmental Improvement Plan to determine what environmental issues may benefit from broader research inquiry.
2. Further develop and improve the communication and coordination among existing research groups working in the Tahoe basin to prevent duplication of efforts and provide the maximum interdisciplinary team work necessary to resolve the most important environmental issues.
3. Contribute to TRPA's development of a Research Master Plan and set of Guiding Principles for Research Inquiry in the Lake Tahoe Region related to priority preservation, restoration and enhancement needs.
4. Encourage the development of competitive research proposals based on the principle of peer review to achieve the highest caliber of scientific assessment of problems facing the Lake Tahoe region.
5. Identify monitoring tasks and evaluations that would be assured on a continuing basis to fully inform the research community evaluating the Lake Tahoe region.
6. Develop outreach plans to convey research results and recommendations to the public in general and specifically to the communities within the Lake Tahoe region.

In 2000, the TRPA requested the MOU participants convene a Lake Tahoe Science Advisory Group (SAG). The SAG also included representatives from numerous State, Federal, and local agencies. Key objectives of the SAG were to: 1) develop a scientific work plan that would dovetail with restoration efforts and management objectives, and 2) coordinate/facilitate the operating principles of a Tahoe Environmental Science System identified in a second MOU signed in February 2000. The SAG, in conjunction with a number of work-groups active in the Tahoe basin, identified critical information needs requiring attention for effective management decisions. This was intended to be an ongoing process that included two key components: 1) development of a series of Key Management Questions (KMQ), and 2) development of a science plan, produced by the research institutions, which addressed the KMQ. Although the SAG did prepare KMQ for a number of theme areas (table 1 and summarized above), funding and resource commitments to produce a science plan did not occur.

Over time, support and commitment to the SAG and its goals declined. Select agencies did pursue new funding initiatives to support scientific investigations related to specific agency needs (e.g., technical studies for the Lake Tahoe Total Maximum Daily Load, and the Lake Tahoe Air Deposition Study). However, with the exception of water quality, efforts to organize collaborative science efforts within and among issue areas continued to struggle.

In 2003, the Federal government began providing funding to support implementation of the Lake Tahoe Restoration Act (PL 106-506). Some of this funding was reserved for new science; however, the two persistent challenges identified above continued to compromise the processes for identifying science needs, and the objective selection of projects for funding. In addition, all parties recognized that the SAG had neither the charge nor the resources to develop a vision, structure, and program capable of supporting science and research as it applies to Lake Tahoe basin restoration (TRPA and USACOE 2005). Thus, discussions were initiated in December 2003 among members of the science community and staff from the TRPA, the U.S. Environmental Protection Agency, and the U.S. Army Corps of Engineers to evaluate and possibly re-structure SAG operations to better support allocation of Federal funding under the Lake Tahoe Restoration Act. These discussions led to a proposal for an enhanced science community group known as the Tahoe Science Consortium (TSC). In 2005, science community and agency representatives signed an MOU forming the TSC⁵, and establishing its primary objective: "To provide environmental managers and decision makers with comprehensive and well-synthesized scientific findings drawn from research, monitoring, and modeling." The TSC is a partnership among five research organizations: 1) University of Nevada, Reno; 2) University of California, Davis; 3) The Desert Research Institute; 4) The US Forest Service, Pacific Southwest Research Station, and 5) the US Geological Survey, Carson Science Center. The TSC operates independent of the management and regulatory agencies working in the Tahoe basin, and TSC efforts have focused on:

1. Science Planning: Working with Lake Tahoe basin agency representatives to develop regional monitoring approaches for specific issue areas, and developing a

science plan for the Lake Tahoe basin that identifies and priorities research needs. These efforts are intended to contribute to the primary objective of the TSC.

2. **Peer Review:** Administering or conducting the scientific peer review of research proposals, science products, or technical programs related to Lake Tahoe basin management and restoration. Independent peer review is intended to ensure that science activities conducted in the basin are scientifically sound, and that the results are technically credible.
3. **Technical Assistance:** Providing scientific input and technical advice to resource management and regulatory agencies that addresses management issues and concerns as they arise.

After nearly a decade of effort, agency and science community representatives have made progress in addressing the two persistent challenges affecting science organization and implementation. Formation of the TSC concurrent with increased investments and commitments by the TSC partners represent major efforts of the science community to better address Lake Tahoe basin science needs on a sustained basis. In addition, the establishment of two new working groups (the Tahoe Science Agency Coordination Committee, and the Science and Management Integration Team) has provided greater organizational capacity for agencies to communicate management issues and information needs to the science community, and to provide the ongoing support for science planning processes. Efforts now focus on sustaining the progress made.

1.3 Advancing an Applied Science Program in the Tahoe Basin

The Lake Tahoe Restoration Act (PL 106-506) sets forth the primary policy directive for providing and sustaining an effective science program in the Tahoe basin:

The Secretary [of Agriculture] shall provide for continuous scientific research on and monitoring of the implementation of projects on the priority list, including the status of the achievement and maintenance of environmental threshold carrying capacities.

This overarching policy directive is supported by several policies and goals within the Tahoe Regional Planning Agency (TRPA 1986) and through implementation of the Federal Vision for the Environmental Improvement Program (Lake Tahoe Basin Executives 2006). Clear policy direction and agency commitments are essential to advancing an effective science program.

Fundamentally, science is comprised of several practices and principles, which are applied in an integrated fashion to provide objective and verifiable approaches to acquiring new information that addresses uncertainties and knowledge gaps. To effectively support the ongoing information needs of resource management and regulatory agencies, it is recommended that these practices and principles be organized and implemented as an integrated science program that includes the means to provide timely information in formats useful to agency representatives and decision-makers.

Conceptually, the efforts and activities of an integrated science program can be divided among three basic elements: 1) monitoring, 2) empirical research, and 3) data application. To be effective, however, it is recommended that efforts be integrated across all three elements, and the allocation of resources among all elements is essential. This is the basis for the conceptual framework presented in Chapter 2.

The brief review of past science planning efforts presented in Section 1.2 shows that merely producing a science plan is not enough to ensure the establishment of a sustained science program that can deliver useful information covering a diversity of issues. Clear policy direction is essential, but a deeper level of commitment among all relevant parties would enhance progress from planning to implementation. An explicit assumption of this effort is that the agencies charged with responsibility for the welfare of the Lake Tahoe basin will work to establish the funding, resources, and infrastructure necessary for sustained implementation of an applied science program. The Tahoe Science Consortium is prepared to work with agency representatives to make a sustained science program for the Lake Tahoe basin a reality.

1.4 Geographic Scope and Environmental Setting⁶

Lake Tahoe and its tributary watersheds together comprise the Lake Tahoe basin (figure 1.1). In most cases, the Lake Tahoe basin encompasses the entire geographic scope of this science plan. Where appropriate, however, the scope is broadened to consider external factors (e.g., regional meteorology or climate change) that can substantially influence conditions or future management actions within the basin.

The Lake Tahoe basin lies in the east-central portion of the Sierra Nevada mountain range and on the western boundary of the Great Basin. It is a montane, lacustrine-dominated ecosystem with several physical characteristics that make it a unique attribute of the Sierra Nevada mountain ecosystem (table 1.2).

The broad elevation range of the basin (1,900 – 3,050 m; 6,200 – 10,000 ft. above sea level) and a topography that strongly controls precipitation and temperature combine to yield a wide diversity of montane vegetation types, ranging from coniferous forests and woodlands, riparian forests, subalpine to alpine meadows, various wetland communities, and Great Basin shrublands. Soils are thought to act as a secondary control (after climate) of vegetation patterns. Geology within the basin is dominated by granitic rocks and soils in the southern portions, with an overlay of volcanic rocks and soils in the northern portions. The diversity of plant communities and vegetation types creates a broad spectrum of wildlife habitats. Numerous fish and invertebrate species occupy the stream and lake habitats, but in many cases introduced species dominate (Chandra 2003).

Human activities have had and continue to have a dominant influence on the natural resources and environment of the Lake Tahoe basin. These activities include numerous past and present habitat and species modifications (e.g., logging, urban, commercial, road and infrastructure development, recreation, fire suppression, water diversion, species extirpations and introductions, habitat enrichment, and habitat

restoration). Most anthropogenic activities are considered stressors to the natural environment, so restoration projects generally aim to remove or reduce the effects of these stressors. Humans and human development will remain dominant components in the Lake Tahoe basin ecosystem, so ensuring the equilibrium between the basin's natural endowment and its manmade environment remains the primary directive.

1.5 Using This Document and Target Audience

This Science Plan is comprised of six chapters that present a conceptual framework and focused research strategies for five topics of importance to the Lake Tahoe basin ecosystem. Chapter Two presents the conceptual framework and overview conceptual model for this Science Plan. This chapter describes the foundational elements and approach for establishing an integrated science program as part of a Lake Tahoe basin adaptive management system. The overview conceptual model will orient readers to the important issues covered in this plan and the relationships among those issues. Five theme-specific research strategies comprise the core of this Science Plan. These chapters cover the topics of:

- **Air Quality:** Air quality in the Lake Tahoe Basin is known to affect lake water quality, forest health, and human health. To address these issues and develop a sound scientific approach for mitigating the impacts of atmospheric pollutants, this chapter provides an update and builds on recent work to understand how changes in air quality affect various aspects of the natural and human environment in the Lake Tahoe basin. This chapter also delineates current knowledge gaps and defines the research needs and strategies to close those gaps.
- **Water Quality:** Lake Tahoe is the most-studied feature of the Tahoe basin ecosystem with regard to water quality. While a substantial amount of research and monitoring has been accomplished, it has only been in recent years that the institutional commitment has occurred to focus this work on specific management issues, such as the Lake Tahoe Total Maximum Daily Load Program. Knowledge gaps and uncertainties still exist, however, particularly in understanding how watershed restoration efforts influence the long-term water quality of Lake Tahoe. Since water quality restoration efforts in the Tahoe basin are expected to exceed \$1 billion, it is critical that we continue to collect and deliver information in an organized fashion. The Water Quality chapter is intended to serve as a road map for discussions with resource managers. The chapter identifies those science projects necessary to help guide water quality restoration efforts and understand related ecosystem processes.
- **Soil Conservation:** Today soil conservation conveys a concept much broader than preventing soil erosion and reclaiming eroded lands. Soil conservation strategies go well beyond simply protecting soil from processes of physical erosion to now encompass the protection and enhancement of overall soil quality and ecology. The intent of the Soil Conservation chapter is to identify the most pressing management questions, uncertainties, and pertinent research needed to address a wide spectrum of plant, soil, and water related issues in the Lake Tahoe basin.

- **Ecology and Biodiversity:** The integrity of animal and plant communities serves as a critical measure of the effectiveness of implementation policies designed to protect and restore ecosystem processes in the Lake Tahoe basin. The conservation of plants and animals in the Tahoe basin is wholly dependent on the conservation of its terrestrial and aquatic ecosystems. Thus, the research agenda for biological diversity and ecological function is based on investigations that integrate data collection efforts across scientific disciplines to maximize the recovery and persistence of biological diversity. The Ecology and Biodiversity chapter highlights the interactions between native species and communities, and natural and human-caused stressors that present the greatest ecological and/or social risk, and for which research can reduce uncertainties that present barriers to more effective management.
- **Integrating the Social Sciences in Research Planning:** The evaluation of social science research needs was included in this Science Plan to explicitly recognize that the processes underlying environmental degradation, as well as their conservation and recovery, are fundamentally based on human decision-making. Effective conservation and restoration policies rely on a well-grounded understanding of human behavior, the interaction of social and natural processes, and linking information from the social sciences to decision-making. The goals of this chapter are to: 1) identify social science data and research needs for management objectives that are not directly environmental, 2) describe the research needs necessary to improve policy design and implementation for managing environmental conditions, and 3) develop a framework for prioritizing social science research needs in areas that focus on the interaction between the human and natural environments.

Those reading multiple chapters of this Science Plan will soon realize the research strategies differ in scope and breadth. These differences are due to the diversity of management issues that exist among the theme areas and to variations in the state of knowledge. Past efforts to obtain knowledge in each of the theme areas have not been equal (TRPA 2007). This means different levels of investment are recommended to progress from this point forward. For example, we now have an operating Lake Tahoe clarity model that can be used to predict future conditions and analyze the effects of alternative management strategies aimed at improving Lake Tahoe water clarity. Thus, some research needs identified in the Water Quality research strategy will include recommendations to improve the validity and predictive capabilities of this model. In contrast, we are struggling to obtain and aggregate basic regional socioeconomic data for the Lake Tahoe basin that can inform us about trends in the human environment. These differences in knowledge base compromise our ability to understand and quantify interactions among resources, habitats, processes, and stressors. Continued commitment of future resources and funding across all five theme areas is recommended as the best strategy to ensure the disparity in our knowledge base does not continue to grow.

Each research strategy is meant to serve as a stand-alone document. We think this organizational approach is most useful because government agency representatives and stakeholders often seek issue-specific information. This organizational approach also should aid those agencies dealing with multiple theme areas, because they are

internally organized across distinct programs that generally coincide with the different theme areas. However, this stand-alone approach affected the way cross-cutting issues are treated. Through the course of preparing this Science Plan several issues that cut across multiple theme areas were identified, including:

- Quantification of key environmental indicators
- Model application and development
- Adaptive management functionality and effectiveness,
- Research and policy implementation,
- Effects of climate change, and
- Effects of fire.

The stand-alone organization of the research strategies means information on cross-cutting issues is presented under multiple theme areas. For example, those wanting to learn about the research needed to improve our understanding of climate change effects will need to review the appropriate section in several chapters. Although this organizational approach means the reader will have to do more work to synthesize information on cross-cutting issues, this approach does allow for better integration of cross-cutting issues within each theme area.

The target audience for information presented in this document includes those individuals within government agencies and the stakeholder community that have a role in the protection and management of the Lake Tahoe basin ecosystem. We hope this document is of particular use to those individuals who find themselves responsible for deciding if and how new funding for science should be allocated.

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1.7 Footnotes

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2. Tahoe Science Consortium, Incline Village, Nevada 89451.
3. The Pathway planning process (formerly known as Pathway 2007) is a collaborative planning effort among four partner agencies, including the Tahoe Regional Planning Agency, USDA Forest Service, the California Lahontan Regional Water Quality Control Board, and the Nevada Division of Environmental Protection. These agencies are working together to update important resource management plans for the Lake Tahoe basin, which will guide land management, resource management, and environmental regulations over the next 20 years. This planning process is ongoing and is referred to as “Pathway” or “Pathway planning process” in this document. More information about the Pathway planning process is available at <http://www.pathway2007.org/>
4. Information on science planning is taken in part from Murphy (2000).
5. More information about the TSC and its member organizations is available at www.tahoescience.org.
6. Information on geographic scope and key physical characteristics is taken in part from Elliott-Fisk et al. (1996).

1.8 Tables

Table 1.1-- A comparison among theme areas considered in four Lake Tahoe Basin planning documents or processes and the Lake Tahoe Science Plan.

TRPA 1987 Regional Plan: Threshold Categories	2000 Lake Tahoe Watershed Assessment	Pathway planning process	Environmental Improvement Program – Phase II	Lake Tahoe Science Plan Theme Areas
*Air Quality	Air Quality	Air Quality	Improving Air Quality and Transportation	Air Quality
Soil Conservation/ Stream Environment Zone (SEZ)	Upland Water Quality/Sediment and Nutrient Discharge	Soil Conservation and SEZ habitats	Habitat and Vegetation	Soil Conservation
*Water Quality	Water Quality	Water Quality	Storm Water Management	Water Quality
*Vegetation	Biological Integrity and Aquatic Resources	Vegetation and Forest Fuels	1) Forest Health and Fuels Management; 2) Habitat & Vegetation	Ecology and Biodiversity
*Wildlife		Wildlife and Fisheries	1) Habitat and Vegetation; 2) Watershed Management 3) Threatened, Endangered, and Sensitive Species	
Fisheries				
--	Socioeconomics	Socioeconomics	--	Integrating the Social Sciences in Research Planning
Recreation		Recreation	Enhancing Recreation and Scenic Resources	
--	--	Transportation	Improving Air Quality and Transportation	
Scenic Resources	--	Scenic Quality and Resources	Enhancing Recreation and Scenic Resources	
Noise	--	Noise	--	
--	Adaptive Management Strategy	Lake Tahoe Adaptive Management System	“Working Together”, and Science and Reporting	Science Plan Framework and Overview Conceptual Model

*Theme areas considered in the June 6, 2001 Key Management Questions. See section 1.2 for more information about development of the Key Management Questions.

Table 1.2-- Key physical characteristics of the Lake Tahoe basin

Characteristic	Size	Comment
Basin surface area	1,300 km ² (500 mi ²)	
Land surface area	800 km ² (308 mi ²)	
Developed land surface area	83 km ² (32 mi ²)	The developed land area occupies ~10.5% of the total land area and includes residential, commercial, institutional, utilities, and transportation development.
Undeveloped land surface area	~717 km ² (276 mi ²)	The undeveloped land area occupies ~89.5% of the total land area. This area is dominated by undeveloped montane forest habitat.
Lake surface Area	500 km ² (192 mi ²)	The Lake surface area comprises ~38% of the basin surface area, yielding a watershed area to Lake area ratio of ~1.6:1.
Maximum Lake depth; Mean Lake depth	502 m (1,645 ft.); 313 m (1,027 ft.)	Lake Tahoe is the 11 th deepest lake in the world
Lake width and length	19 km (12 mi.) x 35 km (22 mi.)	
Lake volume	~156 km ³ (126 million acre ft.)	The top six feet of Lake Tahoe is operated as a draw-down reservoir with a nominal yield of 903 million m ³ (732,000 acre ft.)
Average water residence time	650 years	Average residence time of most pollutants of concern is on a decadal time scale or less
Number of watersheds draining into Lake Tahoe	63	Tributary inflow annually delivers about 430 million m ³ (350,000 acre ft.) to Lake Tahoe.
Number of drainages out of Lake Tahoe	1	The Truckee River flows north-east from Lake Tahoe to Pyramid Lake, Nevada.

1.9 Figures

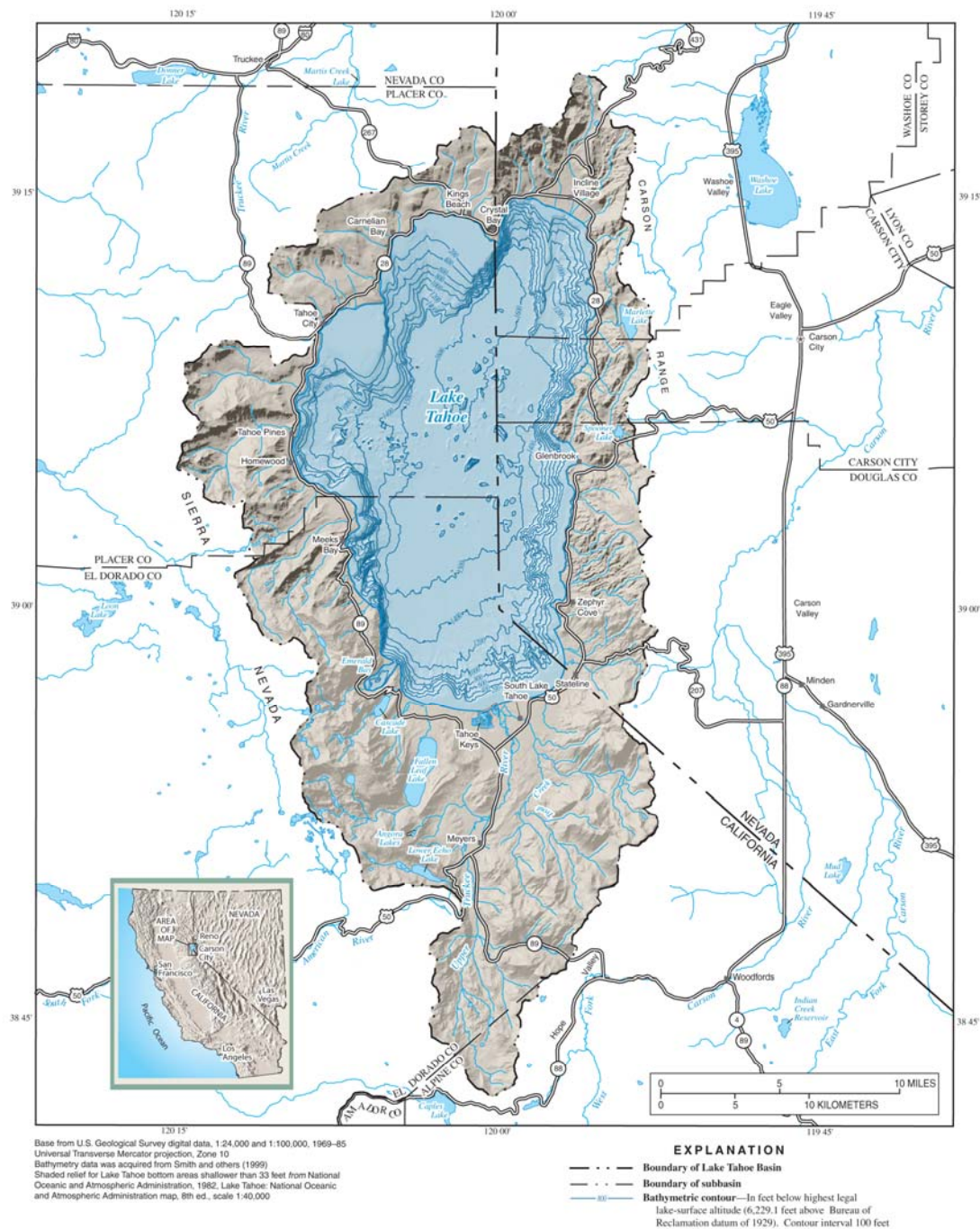


Figure 1-- Plan view of the Lake Tahoe basin illustrating select hydrologic and bathymetric features, major roadways, and political boundaries. The area of shaded relief indicates the watershed boundary. Figure courtesy of the US Geological Survey.