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Implementation of a System Structuring Approach for Water Quality Threshold Standards

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Executive Summary

The Tahoe Science Advisory Council (Council) has been working with the Tahoe Regional Planning Agency (TRPA) to develop specific recommendations for threshold standards and associated performance measures to ensure they formally link to appropriate metrics for the Environmental Improvement Program (EIP) and for thresholds progress reporting. This report summarizes progress toward that goal through diverse efforts over the last few years, including an updated set of recommendations for implementation of a system structuring approach, focused here on water quality threshold standards to serve as a model for similar reviews in other threshold categories. System structure in this context represents general organization of threshold standards and the reporting framework that supports decision-making on actions to promote standards attainment and maintenance.

Recommendations for structuring the threshold standards system comprise three key elements: first, to articulate program goals in clear language that communicates a collective purpose to a general audience; second, each goal statement should be supported by one or more specific objectives that explicitly define success, which are the threshold standards; third, objectives should be supported by result chains that link management actions (strategies and individual tactics) to objectives and clearly identify how implementation will be tracked and how the effectiveness of management actions will be evaluated.

Expanding on these key features, recommendations for structuring threshold standards include:

1) Ensuring that each threshold standard fits under a broad aspirational goal statement for its threshold category;
2) Clarifying that threshold standards are framed as objectives, and that each objective conforms to SMART criteria (specific, measurable, attainable, relevant and time-framed);
3) Where current threshold standards articulate a goal instead of an objective, a specific objective should be defined as the threshold standard for that goal;
4) Continue to reduce or eliminate sources of overlap between standards;
5) Develop result chains that link management actions (strategies and individual tactics) to expected results and final outcomes (threshold standards). Optimally, these result chains are based on a conceptual model representing system function and objectives;
6) Identify performance measures that track implementation and assess the effectiveness of strategies and tactics. Where current threshold standards identify strategies or tactics they should be recast as performance measures;

7) Conduct monitoring needed to assess progress for the EIP at both implementation and outcome levels to improve threshold evaluation reporting.
8) Implement and maintain an adaptive management approach to inform management decisions and adjust actions or strategies as necessary to achieve desired outcomes.

Adopting a *Goals, Objectives, Strategies, and Tactics (GOST)* framework to identify appropriate roles for threshold standard statements is well-suited for structuring the threshold standards system. In this approach the goal statements represent high-level collective visions for each of the nine threshold categories, and each goal is directly linked to one or more detailed objectives that describe the specifics of desired conditions (using SMART criteria). Strategies are then developed to address each objective, presenting high level descriptions for how to achieve the desired results, while tactics are the detailed set of actions that will be taken to execute that strategy.

Notably, within this framework the appropriate role for a threshold standard is to serve as an objective. Review of the existing water quality threshold standards, however, showed that many instead represent strategies or goals. Revising the existing threshold system to better correspond with this framework will enhance implementation, assessment of progress and communication of results. It will also help guide the development of conceptual models, the corresponding result chains, and more efficient monitoring programs that track the results of management actions and the influence of natural variables.

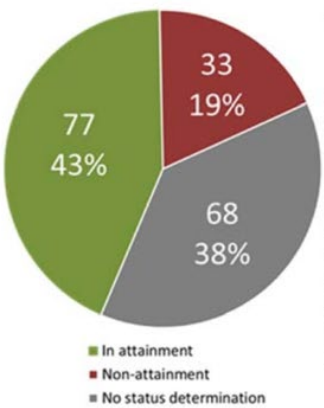
Result chains link across the GOST roles, showing distinct management actions (tactics) based on a particular strategy developed to achieve a specific objective in support of the collective goal. Streamlined result chains communicate the management investments made (e.g. funding and staff time) and the actions implemented (e.g. projects and best management practices) to achieve an ultimate outcome (for the threshold standard). Monitoring metrics and indicators of change are tied directly to these outcomes, as well as to essential intermediate outcomes represented in the more detailed result chains or conceptual models, where additional information is often needed to inform adaptive management models and to track near-term progress toward longer-term objectives.

The characteristics of good monitoring indicators are different from the characteristics for SMART objectives. Specifically, an indicator should be consistent, sensitive, timely, feasible, efficient, informative, attributable and cost-effective (as well as SMART, where attributable substitutes for attainable). System structure for the threshold standards must identify appropriate outcome indicators for each objective, and for critical intermediate outcomes. Successful resource management programs, however, usually report out on only a subset of these, which at Tahoe should be the threshold standards cast in their appropriate role as objectives.

Application of the recommended approach for structuring the threshold standard system will streamline program development and application, reduce redundancies among existing threshold standards, improve timely adaptive management evaluations, and contribute to communication of results and progress.

Introduction

The TRPA identified a set of threshold standards across nine broad categories of importance to the Lake Tahoe Basin in 1982. These nine threshold categories represent air quality, water quality, soil conservation, scenic resources, wildlife, fisheries, vegetation, recreation and noise. In their 2015 Threshold Evaluation Report the TRPA assessed status and/or implementation progress for 110 of the existing 178 individual threshold standards (Figure 1) and indicated that the number of standards for which no status could be determined was a cause for concern (TRPA 2016).



Category	Standards (#)	Status		
		Attainment	Non-attainment	No status determination
Air Quality	20	16	2	2
Water Quality	54	5	4	45
Soil Conservation	13	9	3	1
Vegetation	28	11	12	5
Fisheries	7	5	2	0
Wildlife	16	13	1	2
Scenic Resources	6	6	0	0
Noise	32	10	9	13
Recreation	2	2	0	0
Total	178	77	33	68

Figure 1. Status determination summary by threshold category for the 178 threshold standards addressed in the Threshold Evaluation Report (from TRPA 2016). A determination of "no status" indicates where ambiguity in the definition of a standard, reference to an unknown historic baseline, or insufficient data precluded determination of status.

In response to this concern, the Tahoe Science Advisory Council (Council) has been working with the TRPA to develop assessment strategies and system structuring approaches that will effectively streamline the evaluation process, avoid unnecessary overlap or duplication between standards, and will clarify the appropriate roles that standard thresholds and associated indicators should adopt for tracking and reporting on progress.

Background

TRPA initiated a Threshold Update Initiative process in 2016, recognizing that threshold standards adopted in 1982 were based on concerns from an earlier time, as well as 30-year old science, and that the cost of full and consistent monitoring for all 178 threshold standards would be unsustainable. One of the early steps for this update initiative was development of a threshold assessment methodology to review existing threshold standards. The Council reviewed draft documents and provided recommendations to improve the TRPA threshold assessment methods (TSAC 2017a, 2017b). When TRPA ultimately applied the Threshold Assessment Methodology (TRPA 2017a), they identified 46 threshold standards that were considered redundant in terms of content or application (TRPA 2017b). The results also identified the water quality threshold category as having more overlapping standards than any other threshold category. Subsequent work by the Council aided the TRPA in identifying and addressing sources of overlap and redundancy in their threshold standards system (TSAC 2018a), which facilitated two actions taken by the TRPA governing board: first, a set of technical corrections and reorganization of the threshold standards; and then second, the removal of six narrative policy statements.

In April 2019 TRPA adopted a new adaptive management system for managing information related to the threshold standards. The adaptive management structure lays out a vision for evidence-based management in the Tahoe Region to improve decision-making and to increase accountability and transparency at all levels of the system. It also provides a framework to guide reviews and updating of threshold standards, and the Environmental Improvement Program, as part of a periodic indicator review process. The Council played an integral role in development of this adaptive management structure. In 2017 the Council reviewed ten large natural resource evaluation systems from around the country, synthesized best practices and provided broad recommendations for improving information management at Tahoe (TSAC 2017c). Further work in 2018 built on the broad guidance gleaned from that review and from additional literature reviews to provide targeted recommendations for the implementation of data structuring at Tahoe (TSAC 2018b). That guidance provided a conceptual foundation for TRPA's newly adopted adaptive management structure.

Subsequently, TRPA requested Council assistance implementing and refining a system structure for the water quality threshold category. Our work summarized below includes an assessment of the existing water quality threshold standards, the identification of appropriate roles for threshold standards within a system structure, discussion of linkages to results chains, and reporting on progress through monitoring in support of the Environmental Improvement Program (EIP), which is the Region's capital improvement program implemented to advance threshold attainment. This work also provides recommendations on how to move forward with re-organizing the standards so that, ultimately, tracking and monitoring data are more directly linked to outcome assessments for the water quality threshold standards.

Elements of System Structuring for Threshold Standards

Council recommendations for structuring threshold standards include application of SMART criteria, reducing or eliminating sources of overlap between standards, and adopting a goals, objectives, strategies, actions perspective to identify appropriate roles for threshold standard statements. Each of these are discussed below in brief, then we apply that approach to the existing water quality threshold standards, followed by commentary on the use of result chains to link management actions with expected results and final outcomes in an adaptive management framework.

SMART Criteria Evaluation of Threshold Standards

Based on a review of ten large natural resource management systems from around the country, the Council identified use of "SMART" criteria as an essential element for achieving outcome-based goals and objectives (TSAC 2017c). SMART is a management acronym representing desirable characteristics for explicit outcomes that are Specific, Measurable, Attainable, Relevant and Time-framed (or time-bound). As part of their threshold assessment the TRPA assigned a ranking score from 1–5 to each SMART criterion for each existing threshold standard, with five being best (TRPA 2017b). Specific and measurable were identified as particularly important for program management, with a score of four considered the minimum. Only 39% of all 178 threshold standards scored values of four or above for both specificity and measurability, while only 22% of the 54 water quality threshold standards met these minimum criteria.

Identifying Sources of Overlap

The Council previously identified five common types of overlap in threshold standards (TSAC 2018a). These can be summarized as 1) complete overlap, when two different standards regulate the same constituent with the same numerical target; 2) wholly encompassing standards, when the achievement of one standard necessarily entails the achievement of another; 3) competing targets, when two or more standards address the same constituent in different ways; 4) indirect overlap, when one standard regulates an overarching category and additional standards regulate constituents of that category; and 5) policy or management statements used as standards, when the statements simply call out other standards to be achieved. (See Attachment 1 for additional information about overlap found in TRPA threshold standards.)

Distinguishing between Goals, Objectives, Strategies and Tactics

Managers often contend with unstructured problems characterized by uncertain knowledge, diverse perspectives and vague objectives. To structure reasoning and assessment under these conditions, many resource management programs could benefit from a *Goals, Objectives, Strategies, and Tactics* framework, which would induce a more action-oriented approach familiar to managers and policy makers. We recommend adopting this approach for review and application of threshold standards in the Lake Tahoe Basin, with clear differentiation and use of these four terms.

Goals should be developed and applied as a broad description of desired conditions. They represent a formal collective vision for long-term achievement (e.g., to restore and protect lake clarity). The Council previously recommended developing goal statements of long-term vision for beneficial uses and desired states (TSAC 2017c). Goals thus serve as the high-level representation of **what** we are attempting to accomplish.

Objectives are focused on concrete statements that identify tangible results linked to particular strategies. In contrast to a goal statement, objectives should always follow SMART criteria. Thus, objectives represent the measurable outcomes expected from implementation of a strategy. They detail **what** will be achieved to realize the goal. When goals conform to SMART criteria, they function essentially as final outcome objectives. This is how goals and objectives sometimes overlap in their roles; they both describe what outcome is desired, but at different levels of detail.

A strategy defines the overall approach or actionable plan to achieve a particular objective or goal. It serves as the high-level description of **how** a goal will be achieved. Strategies examine existing constraints and resources to delineate the most efficient path forward. There may be multiple ways to arrive at the same final destination, but the purpose of a strategy is to identify the most efficient approach. More than one strategy could be developed and implemented for a particular objective or goal, depending on available resources and opportunities.

Tactics are the discrete set of actions and tasks implemented to execute a strategy. It represents the details of **how** the strategy is pursued, once it has been selected. Multiple tactics are generally applied in execution of any particular strategy (Figure 2). Distinguishing between tactics and strategies can be particularly confusing, but is perhaps best summarized by the aphorism often attributed to Sun Tzu that *"Strategy without tactics is the slowest route to victory. Tactics without strategy is the noise before defeat."*

Figure 2. Illustration of relationships between goals, objectives, strategies and tactics (from USFS 2019).

To illustrate a simple application of this terminology, consider the goal of a New Year's resolution to eat healthy and lose weight. In this case, there may be two objectives, one for eating healthy and another for losing weight. If we set a SMART objective for losing weight by a healthy but slightly overweight adult, it could be to lose ten pounds by the end of year – an objective that is specific, measurable, attainable, relevant and time-framed. One selected strategy could be to exercise more regularly. Tactics to implement that strategy may include joining a gym, hiring a physical trainer, or finding a partner to exercise with.

In some cases, identifying goals, objectives, strategies and tactics can be a relatively straightforward exercise, but should always be done intentionally, perhaps as part of strategic planning at the beginning of a program or project. The role descriptions shown in Table 1 summarize Council recommended definitions for each, and provide examples drawn from Tahoe programs.

Table 1. Functional relationships between goals, objectives, strategies and tactics. Note the difference in detail levels and whether they address "what" is desired or "how" the desired outcomes will be achieved.

Role	Description	Purpose	Water Quality Example	Link to EIP Program
Goal	High-level "what"	Broad, high-level ultimate outcome that supports a collective vision.	Restore the historic clarity and exceptional water quality of Lake Tahoe.	EIP focus area goals
Objective	Detailed "what"	Specific (SMART) result representing desired conditions for a goal or an intermediate outcome.	Restore lake clarity to a depth of 97.4 feet by 2076 (Lake Tahoe Clarity Commitment).	Threshold standard
Strategy	High-level "how"	An overall approach or actionable plan taken to achieve the objectives linked to primary goals.	Reduce urban fine sediment particle loading. The TMDL jurisdictional pollutant load reduction plan.	EIP Action Priority (output performance measure, FSP load reduced)
Tactic	Detailed "how"	A discrete set of actions taken to execute the strategy.	Street sweeping.	EIP action performance measure (miles of street swept)

As will become evident below, these goals, objectives, strategies, and tactics categories map easily onto, and compliment, the results chain typology. Goals and objectives describe the desired outcomes and endpoints. Strategies map the tactics needed to guide a suite of actions toward the goal.

System Structuring for Water Quality Threshold Standards

The TRPA threshold assessment in 2017 characterized existing standards on whether they were considered outcomes, intermediate results, or activities and inputs. It also assigned a numeric evaluation from 1–5 (with 5 being most favorable) for each of the SMART criteria and for strength of the causal relationship associated with each threshold standard. Threshold standards in the water quality category represented 54 of the total 178 existing standards, more than any other threshold category (2017b), and showed a fair amount of overlap with other standards in that category. Most of the water quality standards were focused on intermediate results, rather than on final outcomes (Figure 3), and none of the intermediate result standards passed minimum criteria for specificity and measurability, which is not ideal when intermediate results are intended to provide timely feedback on adaptive management decisions and policy implementation.

The TRPA reviewed sources of overlap in their water quality threshold standards, as recommended by the Council (2018a), and then sorted these into 41 encompassing standards that address both the pelagic (deep) and the littoral (shallow) zones of Lake Tahoe, as well as aquatic invasive species, tributary and surface runoff to the lake, groundwater infiltration and load reductions (TRPA 2019). This set of 41 water quality standards (Appendix A) formed the basis of our analysis and demonstration of threshold structuring recommendations.

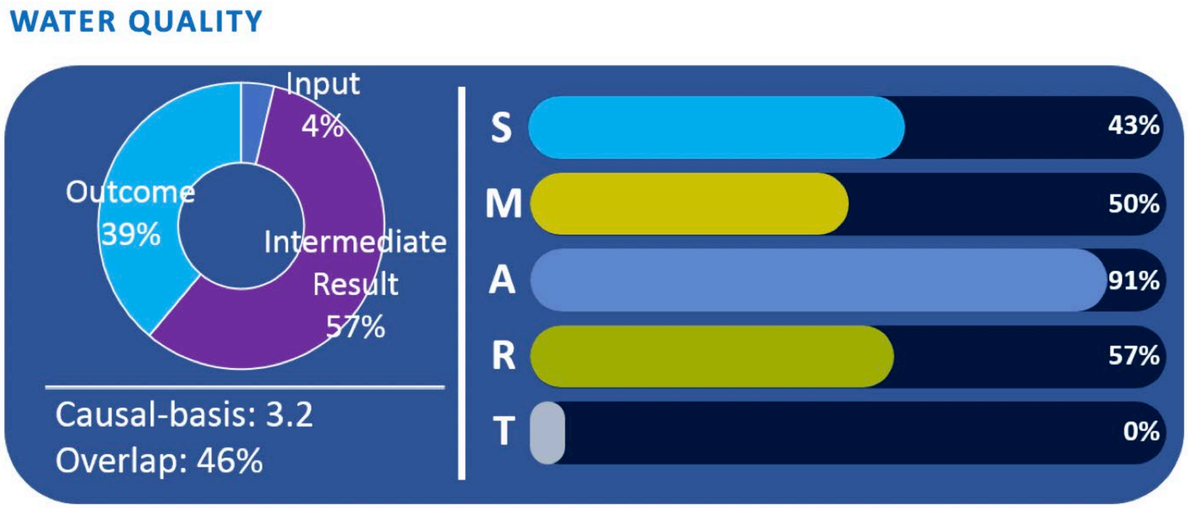


Figure 3. Water quality category consisted of 54 threshold standards evaluated by the TRPA in their initial threshold assessment (from TRPA 2017b).

After removing overlap from existing standards, the next step in application of the system structure was to identify for each standard whether it functions primarily as a goal, an objective, a strategy or a tactic. The results from our assessment are shown in Table 2, which should be cross-referenced to the full narrative language shown in Appendix A for each standard.

Applying the Goals, Objectives, Strategies and Tactics (GOST) framework, we identified eight water quality threshold standards that function as goals, eight standards that represent objectives, sixteen that serve as strategies (or tactics), and ten that do not fit any of these classifications within the context of the system structuring approach. Further, of the eight goals identified none link functionally to the eight objectives.

We recommend that goals (broad, high-level descriptions of desired conditions) be developed for each reporting category. Some of these may already exist in programmatic descriptions. One example, for the deep water (pelagic) category, would be to "restore, and then maintain, the waters of Lake Tahoe for the purposes of human enjoyment and preservation of its ecological status as one of the few large, deep-water, ultra-oligotrophic lakes in the world with unique transparency, color and clarity" (TRPA 2007) or simply, borrowing from the League to Save Lake Tahoe, to "Keep Tahoe Blue." This represents a high-level vision for the pelagic zone of Lake Tahoe onto which specific water quality threshold objectives (WQ-01 Secchi disk and WQ-02 phytoplankton primary productivity) can link, with each objective representing the details of a SMART specification for desired conditions that represent that goal.

Broad-scale aspirational goals communicate a collective purpose and commitment. A goal statement should be provided for each of the water quality reporting categories (pelagic, nearshore, AIS, tributaries, and other lakes), but they must also link to SMART objectives that are supported by selected strategies designed to achieve those goals and the associated tactics intended to implement those strategies.

Most of the existing water quality threshold standards are strategies. For example, WQ-34 through WQ-41 represent load reductions of various pollutants as an approach to achieve the objectives articulated in WQ-01 through WQ-06. These load reductions are descriptions for "how" the objectives and goals will be achieved. For example, WQ-34, calls for a reduction of the fine sediment particle load to achieve long-term pelagic water quality standards. It does not specify "what" the SMART criteria are for the objective(s), only an approach to be taken. A completely different approach, food web manipulation for example, would be considered a separate strategy. Each strategy should represent a distinct approach for achieving the objective. We recommend combining some of the individual strategy statements from WQ-15 through WQ-22 and WQ-34 through WQ-41 into one or more statements on load reduction strategy, linked to specific objectives, and to continue reporting on these as part of existing implementer effectiveness documentation required for the Lake Tahoe Total Maximum Daily Load (TMDL) program or as required to meet other state standards.

Tactics are the actions taken to implement a strategy and thus achieve the objective or goal. It is through the tactics developed for implementing water quality threshold strategies, for example, that distinctions can be made between characteristics of the different pollutants affecting clarity. Actions taken to reduce phosphorus loads may be different from those taken to reduce nitrogen loads. Review of WQ-23 through WQ-32 initially considered these as tactics for a load reduction strategy, but are more accurately described as land use guidelines, or performance criteria for tactics. Because they are not tactics themselves, they were not assigned a role within the recommended structure. Existing threshold standards that are not objectives should be moved to their appropriate place or program, such as to an EIP performance measure or to the TRPA code of ordinances.

Goals can be broad, collective and aspirational, or they can be more specific representations of the purpose toward which resources are directed. SMART objectives, however, must always represent the essential characteristics of outcomes necessary to achieve the goal. Strategies map the route selected to achieve an objective or goal, and tactics are the actions that implement the strategy. Threshold standards should be objectives articulated in conformance with the SMART criteria: they must be specific, measurable, attainable and relevant, usually within a time-frame as well. The objectives identified in Table 2 conform relatively well to these criteria, scoring from 15 to 19, out of a maximum of 25 in the TRPA threshold assessment (2017b), but there is still room for improvement to achieve scoring closer to 20 (ignoring time-bound), primarily by increasing specificity and documenting attainability.

Table 2. Role identification for WQ threshold standards. All are TRPA threshold standards at present, with VEC added as an existing state standard. N/A indicates a role was not identified within the system structure. See Appendix A for narrative definitions associated with each threshold standard.

ID No.	Reporting Category	Name of Standard	Role
State Standard	Deep Water (Pelagic) Lake Tahoe	Vertical Extinction Coefficient (VEC)	Objective
WQ-01	Deep Water (Pelagic) Lake Tahoe	Secchi Disk	Objective
WQ-02	Deep Water (Pelagic) Lake Tahoe	Phytoplankton Primary Productivity	Objective
WQ-03	Nearshore (Littoral) Lake Tahoe	Nearshore Turbidity (Stream Influence)	Objective
WQ-04	Nearshore (Littoral) Lake Tahoe	Nearshore Turbidity (No Stream Influence)	Objective
WQ-05	Nearshore (Littoral) Lake Tahoe	Nearshore Phytoplankton Primary Productivity	Objective
WQ-06	Nearshore (Littoral) Lake Tahoe	Nearshore Periphyton Biomass	Objective
WQ-07	Nearshore (Littoral) Lake Tahoe	Nearshore Attached Algae	Goal
WQ-08	Aquatic Invasive Species (AIS)	Aquatic Invasive Species Prevention	Goal
WQ-09	Aquatic Invasive Species (AIS)	Aquatic Invasive Species Abundance	Goal
WQ-10	Aquatic Invasive Species (AIS)	Aquatic Invasive Species Distribution	Goal
WQ-11	Aquatic Invasive Species (AIS)	Aquatic Invasive Species Ecological Impacts	Goal
WQ-12	Aquatic Invasive Species (AIS)	Aquatic Invasive Species Social Impacts	Goal
WQ-13	Aquatic Invasive Species (AIS)	Aquatic Invasive Species Economic Impacts	Goal
WQ-14	Aquatic Invasive Species (AIS)	Aquatic Invasive Species Public Health Impacts	Goal
WQ-15	Tributaries	Nitrogen Concentration (Tributaries)	Strategy
WQ-16	Tributaries	Phosphorus Concentration (Tributaries)	Strategy
WQ-17	Tributaries	Iron Concentration (Tributaries)	Strategy
WQ-18	Tributaries	Suspended Sediment Concentration (Tributaries)	Strategy
WQ-19	Surface Runoff	Nitrogen Concentration (Surface Runoff)	Strategy
WQ-20	Surface Runoff	Phosphorus Concentration (Surface Runoff)	Strategy
WQ-21	Surface Runoff	Iron Concentration (Surface Runoff)	Strategy
WQ-22	Surface Runoff	Suspended Sediment Concentration (Surface Runoff)	Strategy
WQ-23	Groundwater	Surface Discharge – Total Nitrogen	N/A
WQ-24	Groundwater	Surface Discharge – Total Phosphate	N/A
WQ-25	Groundwater	Surface Discharge – Iron	N/A
WQ-26	Groundwater	Surface Discharge – Turbidity	N/A
WQ-27	Groundwater	Surface Discharge – Grease And Oil	N/A
WQ-28	Groundwater	Discharge To Groundwater – Total Nitrogen	N/A
WQ-29	Groundwater	Discharge To Groundwater – Total Phosphate	N/A
WQ-30	Groundwater	Discharge To Groundwater – Iron	N/A
WQ-31	Groundwater	Discharge To Groundwater - Turbidity	N/A
WQ-32	Groundwater	Discharge To Groundwater - Grease And Oil	N/A
WQ-33	Other Lakes	Other Lakes	Objective
WQ-34	Load Reductions	FSP Load	Strategy

ID No.	Reporting Category	Name of Standard	Role
WQ-35	Load Reductions	Phosphorus Load	Strategy
WQ-36	Load Reductions	Nitrogen Load	Strategy
WQ-37	Load Reductions	Suspended Sediment Load	Strategy
WQ-38	Load Reductions	Dissolved Phosphorus Load	Strategy
WQ-39	Load Reductions	Iron Load	Strategy
WQ-40	Load Reductions	Other Algal Nutrient Load	Strategy
WQ-41	Load Reductions	Dissolved Inorganic Nitrogen Load	Strategy

Monitoring Progress and Communicating Results

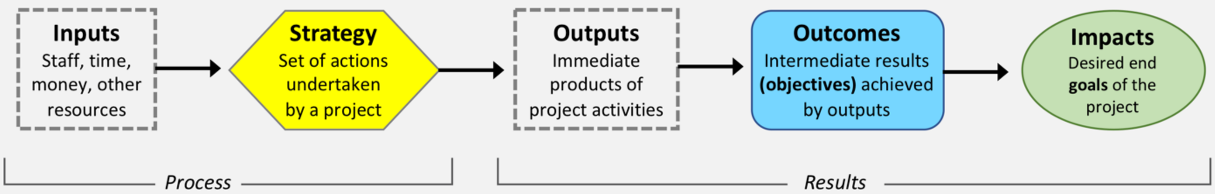
Once the SMART structure for threshold standards has been developed and appropriate GOST roles have been assigned to relevant elements within that structure, it is vital to assess progress within an adaptive management framework. Progress can be measured at multiple levels, including resources invested, the specific management or policy actions taken (potentially tracked at different implementation scales), the direct changes effected by implementation, and status of essential intermediate and final outcomes. Ultimately, the purpose of monitoring within an adaptive management system is to provide timely feedback on the progress and impacts of management actions.

Choosing what, where, and how to monitor for reliable assessment of progress is an exercise in long-term vision and judicious use of resources. While many factors can be tracked or measured, the costs associated with data collection, analysis and reporting usually set limits on the scope of a monitoring program. Further, not everything that is tracked or monitored will be elevated to the level of executive summary reports, although these high-level assessments must all link back to available data sources. Developing result chains from established conceptual models help to identify essential data requirements when deciding what to monitor and report. Most importantly, however, a result chain serves as a communication tool delineating the distinct GOST approach formulated to achieve a specific desired outcome (and goal).

Application of Result Chains to Achieve Objectives

Result chains, sometimes referred to as a results framework (or results chains), link management investments and actions to expected outcomes and desired impacts or goals. Typically considered a type of logic model, the results framework maps out known interactions and assumptions from conceptual models into a series of causal ("if – then") statements that link actions with expected short-term or intermediate outcomes to long-term goals (TSAC 2017c). Result chains are used to document the explicit steps required to achieve objectives and targeted goals, and they communicate why specific outcomes are anticipated from management actions (TSAC 2018b). The results chain shown in Figure 4 is the generic representation of a strategy directed toward a final desired outcome (goal), with progress toward that goal monitored from the point of tangible resources invested (inputs) to generate the necessary products and benefits (outputs) needed to achieve measurable results (intermediate outcomes) required to attain a desired end goal (final outcome for end objective). These types of result chains also help differentiate the implementation tracking metrics (on projects completed) from the effectiveness metrics (which indicate changes in state or condition resulting from tactics and strategy implementation).

There is a great deal of confusion over the different terms used to describe the results of a project or program. What one person calls an "outcome," another calls a "result," and yet a third person calls an "impact." The following figure shows the terms as they are most commonly used by evaluation experts in different fields such as development and public health.



Based on the above figure, the following terms can be defined for use in results chains:

- **Strategy** – An approach that represents how a set of actions or intervention will achieve desired outcomes.
- **Outcome** – The desired future state of a threat or opportunity factor. An **objective** is a formal (SMART) statement of the desired outcome.
- **Impact** – The desired future state or intended target of the project or program. A **goal** is a formal statement of the desired impact (linked to final objectives).
- **Result** – A generic term used to describe the desired future state of a target or factor. Impacts, outcomes, and outputs are all results.

The above terms refer primarily to a sequence of results in a logical sense. There is also a sequence of results in a temporal sense:

- **Intermediate result** – One or more outcomes along the way to a desired final result (final outcome).
- **Final result** – The ultimate desired impact over time (represented by outcomes for final objectives).

(Modified from Margoluis, 2013)

Figure 4. Basic components of a generic results chain (from Margoluis 2013). Not shown here are the associated metrics (performance measures) used to track inputs, outputs and outcomes.

Ideally, these result chains are extracted from a conceptual model that shows interactions and linkages among dominant factors influencing desired conditions. The conceptual model represents contemporary understanding of system function, condensed into a diagram and associated narrative that identify and organize the key attributes of complex system structure and dynamics (e.g. Appendix B). The results chain format shows anticipated cause and effect relationships among inputs and actions for a particular strategy, through intermediate results to the desired outcome. It should also show where monitoring is needed to track progress toward desired outcomes, as demonstrated in Appendix C.

Tracking progress toward an ultimate outcome associated with the desired end objective is clearly essential. Since the threshold standards at Tahoe should represent endpoint objectives (impacts), the outcomes for these must be monitored. Additional monitoring is often needed, however, to understand observed outcomes and to appropriately attribute results to management actions or natural drivers. Using the restoration of lake clarity as an example (objective WQ-01), one must acknowledge that ecosystem-level changes are far more complicated than just a response to management. Lake clarity also varies in response to timing and amount of precipitation, streamflow, internal lake processes, and ecological communities within the lake. Information about all these factors and more may be necessary to inform the interpretation of results when describing progress toward desired final outcome for Secchi clarity. Conceptual models help distinguish these interacting factors and identify the most important nodes or loci where monitoring would efficiently support the partitioning of relative influence from the various natural forces and management actions contributing to observed changes. Result chains, on the other hand, focus on the monitoring and reporting of management-related criteria. Progress on investment of resources is represented by input performance measures, while progress on implementation is represented by output performance measures. Taken together, conceptual models and result chains organized according to a goals, objectives, strategies and tactics framework will help winnow the universe of potential monitoring metrics down to a smaller manageable number of priority measurements that exhibit optimal characteristics for indicators (Appendix D).

Recent work on linking the threshold standards system to EIP performance measures has recommended using three metric categories for reporting progress toward achieving desired outcomes by Tahoe Basin managers (Environmental Incentives 2020). These three categories comprise in series 1) input performance measures that represent the resources applied and the quantity of work done, 2) output performance measures that represent the benefits and values produced through strategies and actions of project implementation, and 3) threshold standards that represent the quantifiable end goals as long-term indicators of program success. Building on this approach two types of results chains are identified: a detailed results chain that links multiple actions or strategies and includes several metrics in each of the three categories; and a streamlined results chain that summarizes one action or strategy (with its relevant input performance measures), shows the intermediate result (with its output performance measures), and the associated desired outcome (with threshold standard). The advantage of the streamlined results chain is that it includes only the most relevant information needed to concisely report to policy makers and funders on program investments, accomplishments and progress toward a desired goal (Figure 5).

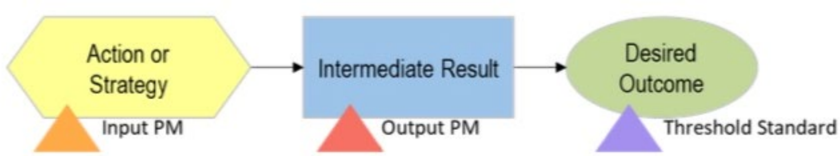


Figure 5. A streamlined results chain summarizes one action or strategy with relevant input performance measures (PMs), one intermediate result with relevant output performance measures, and one desired outcome with relevant threshold standard metrics (from Environmental Incentives 2020).

Detailed understanding of contributing factors is important when monitoring for adaptive management, but managers will rightly gravitate toward the streamlined results chains rather than detailed conceptual models when communicating on program progress and results. As noted recently by Environmental Incentives (2020), resource management programs that communicate a limited number of metrics in each category, and narratively explain the logical linkages between categories, have been successful in achieving desired outcomes, demonstrating return on investment, and enhancing their funding levels.

Reassembling the Tahoe Threshold Standards System

Setting up system structure at the beginning of a resource management program is much easier than making large-scale adjustments later. Indeed, the original Tahoe threshold standards reflect a structure suited to the needs of the time (TRPA 82-11), and that overall approach has served the Basin well for many decades. But these approaches must continually evolve to accommodate new insights, along with the longer-term goal of implementing a structuring approach that guides the process without being overly prescriptive. It should also inform a selection of informative metrics and indicators for monitoring progress associated with adaptive management. The TRPA has adopted a continuous improvement "plan–do–check–adjust" cycle. The goals, objectives, strategy and tactics approach recommended here for guiding review and reorganization of threshold standards provides structure along with flexibility to assign appropriate roles for each existing threshold standard without diminishing intended protections, while also accommodating the introduction of new or revised supporting metrics and indicators. It assembles a threshold standards system within an adaptive management framework that is structured to enhance coherence, assessment and communication (Figure 6).

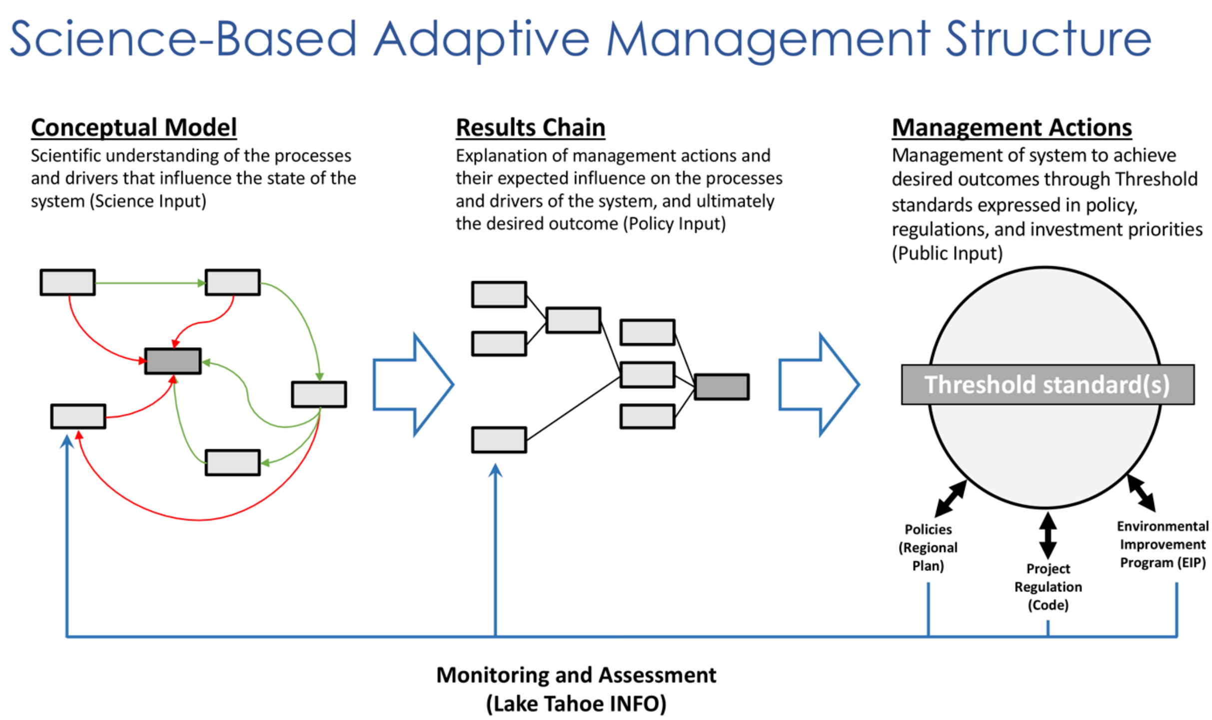


Figure 6. Representation of components organized to develop an adaptive management "plan–do–check–adjust" cycle for the Tahoe Basin thresholds system (TRPA draft).

Application of the recommended approach for structuring the existing threshold standards system will streamline program development and application, help reduce redundancies among existing threshold standards, improve timely adaptive management evaluations, and contribute to communication of results and progress. We see this as one step in the continuing evolution of an effective and responsive system for managing environmental resources in the Lake Tahoe Basin, and expect the structure and typology described herein will be flexible enough to accommodate new insights and improved approaches over time.

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Appendix A. Role assessment by this project for water quality threshold standards. Items in red text indicate where the authors recommend changes or increased specificity. Existing TRPA threshold standard names, reporting category and narrative text were taken from the TRPA Threshold Standards and Regional Plan: Amended, 04-24-2019. Vertical extinction coefficient is an existing state standard for California and Nevada, not included in TRPA threshold standards.

ID No.	Reporting Category	Name of Standard	Role	Standard Text
State Standard	Deep Water (Pelagic) Lake Tahoe	Vertical Extinction Coefficient	Objective	No TRPA Adopted Standard - State standard (CA-NV): vertical extinction coefficient must be less than 0.08 per meter when measured at any depth below the first meter.
WQ-01	Deep Water (Pelagic) Lake Tahoe	Secchi Disk	Objective	The annual average deep-water transparency as measured by Secchi disk shall not be decreased below 29.7 meters (97.4 feet), the average levels recorded between 1967 and 1971 by the University of California, Davis.
WQ-02	Deep Water (Pelagic) Lake Tahoe	Phytoplankton Primary Productivity	Objective	Maintain annual mean phytoplankton primary productivity at or below 52gmC/m2/yr.
WQ-03	Nearshore (Littoral) Lake Tahoe	Nearshore Turbidity (Stream Influence)	Objective	Attain turbidity values not to exceed three NTU.
WQ-04	Nearshore (Littoral) Lake Tahoe	Nearshore Turbidity (No Stream Influence)	Objective	Turbidity shall not exceed one NTU in shallow waters of the Lake not directly influenced by stream discharges.
WQ-05	Nearshore (Littoral) Lake Tahoe	Nearshore Phytoplankton Primary Productivity	Objective	Attain 1967-71 mean values for phytoplankton primary productivity in the littoral zone.
WQ-06	Nearshore (Littoral) Lake Tahoe	Nearshore Periphyton Biomass	Objective	Attain 1967-71 mean values for periphyton biomass in the littoral zone.
WQ-07	Nearshore (Littoral) Lake Tahoe	Nearshore Attached Algae	Goal	~~Support actions to~~ reduce the extent and distribution of excessive periphyton (attached) algae in the nearshore (littoral zone) of Lake Tahoe.
WQ-08	Aquatic Invasive Species (AIS)	Aquatic Invasive Species Prevention	Goal	Prevent the introduction of new aquatic invasive species into the region’s waters.
WQ-09	Aquatic Invasive Species (AIS)	Aquatic Invasive Species Abundance	Goal	Reduce the abundance of known aquatic invasive species.
WQ-10	Aquatic Invasive Species (AIS)	Aquatic Invasive Species Distribution	Goal	Reduce the distribution of known aquatic invasive species.

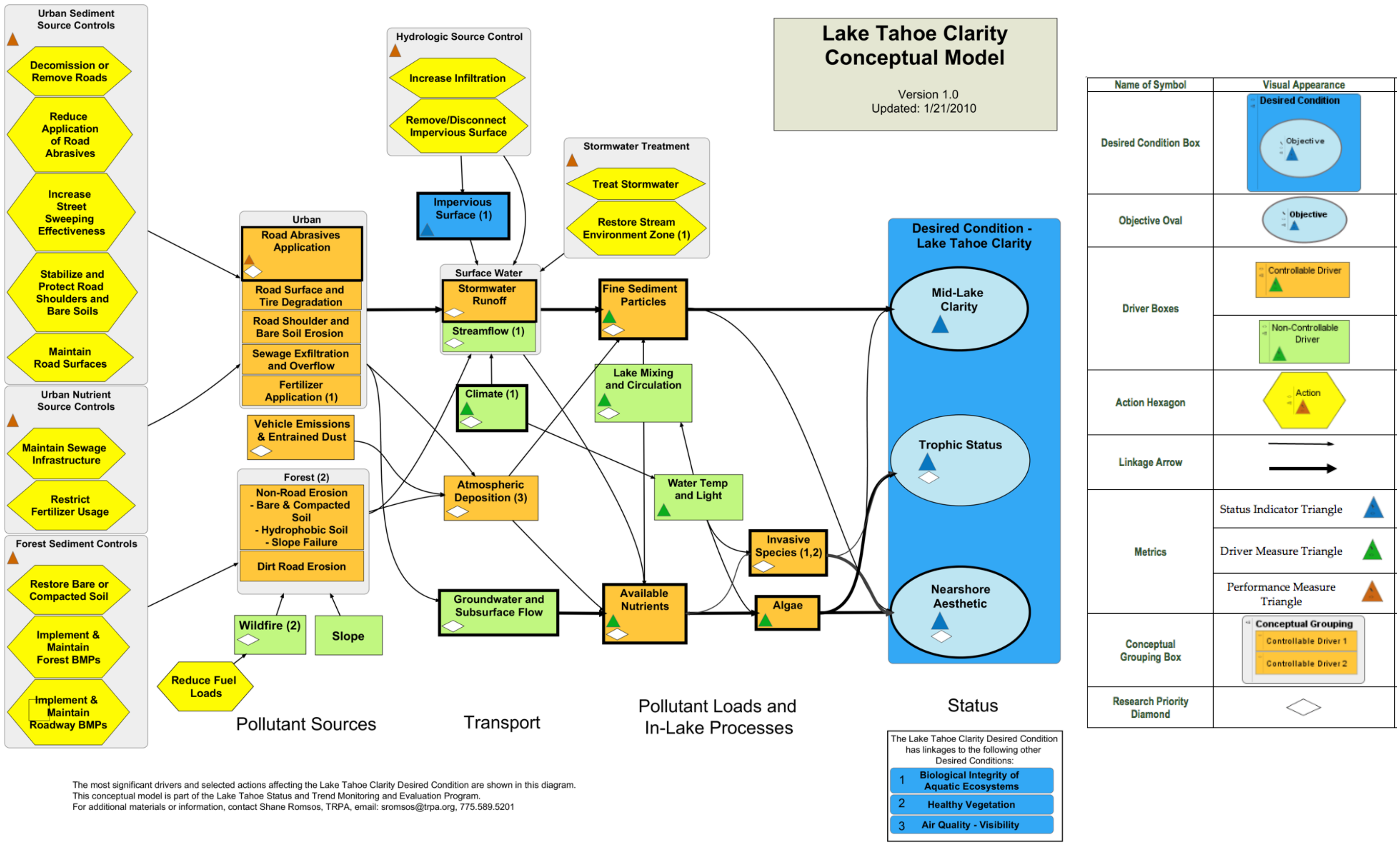
ID No.	Reporting Category	Name of Standard	Role	Standard Text
WQ-11	Aquatic Invasive Species (AIS)	Aquatic Invasive Species Ecological Impacts	Goal	Abate harmful ecological impacts resulting from aquatic invasive species.
WQ-12	Aquatic Invasive Species (AIS)	Aquatic Invasive Species Social Impacts	Goal	Abate harmful economic impacts resulting from aquatic invasive species.
WQ-13	Aquatic Invasive Species (AIS)	Aquatic Invasive Species Economic Impacts	Goal	Abate harmful social impacts resulting from aquatic invasive species.
WQ-14	Aquatic Invasive Species (AIS)	Aquatic Invasive Species Public Health Impacts	Goal	Abate harmful public health impacts resulting from aquatic invasive species.
WQ-15	Tributaries	Nitrogen Concentration (Tributaries)	Strategy	Attain applicable state standards for concentrations of dissolved inorganic nitrogen.
WQ-16	Tributaries	Phosphorus Concentration (Tributaries)	Strategy	Attain applicable state standards for concentrations of dissolved phosphorus.
WQ-17	Tributaries	Iron Concentration (Tributaries)	Strategy	Attain applicable state standards for concentrations of dissolved iron.
WQ-18	Tributaries	Suspended Sediment Concentration (Tributaries)	Strategy	Attain a 90 percentile value for suspended sediment concentration of 60 mg/L.
WQ-19	Surface Runoff	Nitrogen Concentration (Surface Runoff)	Strategy	Achieve a 90 percentile concentration value for dissolved inorganic nitrogen of 0.5 mg/L in surface runoff directly discharged to a surface water body in the Basin.
WQ-20	Surface Runoff	Phosphorus Concentration (Surface Runoff)	Strategy	Achieve a 90 percentile concentration value for dissolved phosphorus of 0.1 mg/L in surface runoff directly discharged to a surface water body in the Basin.
WQ-21	Surface Runoff	Iron Concentration (Surface Runoff)	Strategy	Achieve a 90 percentile concentration value for dissolved iron of 0.5 mg/L in surface runoff directly discharged to a surface water body in the Basin.
WQ-22	Surface Runoff	Suspended Sediment Concentration (Surface Runoff)	Strategy	Achieve a 90 percentile concentration value for suspended sediment of 250 mg/L in surface runoff directly discharged to a surface water body in the Basin.
WQ-23	Groundwater	Surface Discharge – Total Nitrogen	N/A	Surface runoff infiltration into the groundwater shall comply with... (see note 1): Surface Discharge: Total Nitrogen Maximum concentration 0.5 mg/L
WQ-24	Groundwater	Surface Discharge – Total Phosphate	N/A	Surface runoff infiltration into the groundwater shall comply with... (see note 1): Surface Discharge: Total Phosphate Maximum concentration 0.1 mg/L
WQ-25	Groundwater	Surface Discharge – Iron	N/A	Surface runoff infiltration into the groundwater shall comply with... (see note 1): Surface Discharge: Total Iron Maximum concentration 0.5 mg/L
WQ-26	Groundwater	Surface Discharge – Turbidity	N/A	Surface runoff infiltration into the groundwater shall comply with... (see note 1): Surface Discharge: Turbidity Maximum concentration 20 JTU
WQ-27	Groundwater	Surface Discharge – Grease And Oil	N/A	Surface runoff infiltration into the groundwater shall comply with... (see note 1): Surface Discharge: Grease And Oil Maximum concentration 2.0 mg/L

ID No.	Reporting Category	Name of Standard	Role	Standard Text
WQ-28	Groundwater	Discharge To Groundwater – Total Nitrogen	N/A	Surface runoff infiltration into the groundwater shall comply with... (see note 1): Runoff Discharged to Groundwater: Total Nitrogen Maximum concentration 0.5 mg/L
WQ-29	Groundwater	Discharge To Groundwater – Total Phosphate	N/A	Surface runoff infiltration into the groundwater shall comply with... (see note 1): Runoff Discharged to Groundwater: Total Phosphate Maximum concentration 1 mg/L
WQ-30	Groundwater	Discharge To Groundwater – Iron	N/A	Surface runoff infiltration into the groundwater shall comply with... (see note 1): Runoff Discharged to Groundwater: Total Iron Maximum concentration 4.0 mg/L
WQ-31	Groundwater	Discharge To Groundwater - Turbidity	N/A	Surface runoff infiltration into the groundwater shall comply with... (see note 1): Runoff Discharged to Groundwater: Turbidity Maximum concentration 200 JTU
WQ-32	Groundwater	Discharge To Groundwater - Grease And Oil	N/A	Surface runoff infiltration into the groundwater shall comply with... (see note 1): Runoff Discharged to Groundwater: Grease And Oil Maximum concentration 40.0 mg/L
WQ-33	Other Lakes	Other Lakes	Objective	Attain existing water quality standards (e.g. California standards exist for TN, TP, Fe and Secchi at Fallen Leaf Lake).
WQ-34	Load Reductions	Fine Sediment Particle Load	Strategy	Reduce fine sediment particle (inorganic particle size < 16 micrometers in diameter) load to achieve long-term pelagic water quality standards (WQ1 and WQ2).
WQ-35	Load Reductions	Phosphorus Load	Strategy	Reduce total annual phosphorus load to achieve long-term pelagic water quality standards (WQ1 and WQ2) and littoral quality standards (WQ5 and WQ6).
WQ-36	Load Reductions	Nitrogen Load	Strategy	Reduce total annual nitrogen load to achieve long-term pelagic water quality standards (WQ1 and WQ2) and littoral quality standards (WQ5 and WQ6).
WQ-37	Load Reductions	Suspended Sediment Load	Strategy	Decrease total annual suspended sediment load to achieve littoral turbidity standards (WQ3 and WQ4).
WQ-38	Load Reductions	Dissolved Phosphorus Load	Strategy	Reduce the loading of dissolved phosphorus to achieve pelagic water standards (WQ1 and WQ2) and littoral quality standards (WQ5 and WQ6).
WQ-39	Load Reductions	Iron Load	Strategy	Reduce the loading of iron to achieve pelagic water standards (WQ1 and WQ2) and littoral quality standards (WQ5 and WQ6).
WQ-40	Load Reductions	Other Algal Nutrient Load	Strategy	Reduce the loading of other algal nutrients to achieve pelagic water standards (WQ1 and WQ2) and littoral quality standards (WQ5 and WQ6).
WQ-41	Load Reductions	Dissolved Inorganic Nitrogen Load	Strategy	The most stringent of the three dissolved inorganic nitrogen load reduction targets shall apply: i. Reduce dissolved inorganic nitrogen loads to pelagic and littoral Lake Tahoe from: a) surface runoff by approximately 50 percent of the 1973-81 annual average, b) groundwater approximately 30 percent of the 1973-81 annual average, and c) atmospheric sources approximately 20 percent of the 1973-81 annual average. ii. Reduce dissolved inorganic nitrogen loading to Lake Tahoe from all sources by 25 percent of the 1973-81 annual average. iii. To achieve littoral water quality standards (WQ5 and WQ6).

Note: Surface runoff infiltration into the groundwater shall comply with the uniform Regional Runoff Quality Guidelines as set forth in Table 4-12 of the Draft Environmental Threshold Carrying Capacity Study Report, May, 1982. Where there is a direct and immediate hydraulic connection between ground and surface waters, discharges to groundwater shall meet the guidelines for surface discharges, and the Uniform Regional Runoff Quality Guide lines shall be amended accordingly.

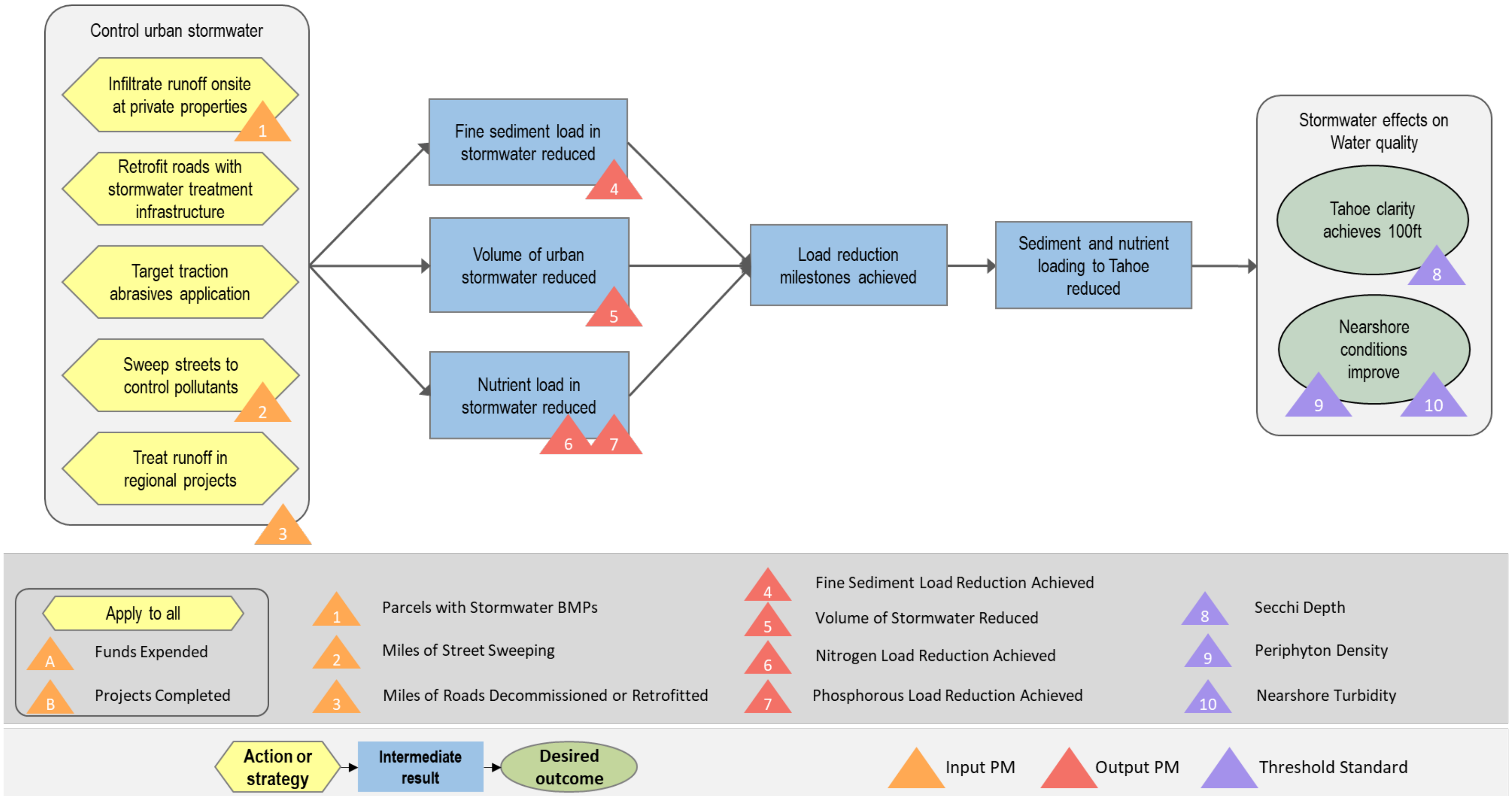
Note on Appendix A: In the interest of cleaning up legacy terminology we draw attention to certain words and phrasing observed in the existing threshold standards. These are highlighted with red text in Appendix A. For example, the Jackson Turbidity Unit (JTU) is an historical unit of measurement no longer in use for turbidity, having been replaced by NTU (and there is no direct one-to-one relationship between these two different measurement systems). Also, while text for standards associated with nutrients generally refer to nitrogen or phosphorus, a few refer to phosphate instead. This creates confusion because 0.1 mg/L of phosphorus is not the same as 0.1 mg/L of phosphate.

Appendix B. An example conceptual model developed for status and trends assessment of Lake Tahoe clarity (2010).



Appendix C. An example results chain proposed for Lake Tahoe clarity and nearshore conditions (EI 2020).

This program focuses on reducing urban stormwater pollution to improve Tahoe clarity and nearshore conditions. It excludes strategies, desired outcomes, and metrics related to other potential benefits like flood management.



Appendix D. Measurements, Metrics, Indicators and Performance Measures.

Deciding which of the myriad potential outcome and informational metrics are essential is one of the most difficult tasks in development of a monitoring program. It is a necessary exercise, however, since tracking progress toward intermediate and ultimate outcomes is generally more expensive than tracking the input (resources invested) and output (implementation) metrics. A determination of critical nodes in conceptual models and the data needed to inform management decisions must ameliorate the natural inclination to collect as much data as possible. In this context it is advantageous to distinguish measurements from metrics and performance measures from indicators when setting up the monitoring program.

Environmental Improvement Program (EIP) performance measures are specific indicators used by managers in the Tahoe Basin to show progress toward goals and objectives at both input and output levels. Some examples include dollars spent (input), or miles of street sweeping and acres treated for invasive species (outputs), or phosphorus load reduction achieved (outcome). In this context a metric is the general term for any useful quantifiable value. Measurements, on the other hand, are the base data collected in support of metric representation. A metric can represent direct environmental measurements, indices derived from measurements, modeled values, or something calculated from other sources (Environmental Incentives 2020).

Indicators are part of a more general assessment universe than are the EIP performance measures (PMs). Indicators serve a variety of purposes in science and management, not all of which are linked to assessing specific performance aspects of management actions. In this sense, performance measures (PMs) comprise a subset of all available indicators (Figure D-1). Different types of metrics and indicators are developed for specific audiences, depending upon who will be using the information. Typical audiences may comprise technical experts and science advisors, or policy makers and resource managers, or the general public and media. The detail and complexity of a particular indicator will usually reflect the needs of its respective audience.

Good indicators have different characteristics from goals and objectives (Table D-1). Specifically, optimal indicators should be consistent, sensitive, timely, feasible, efficient, informative, attributable and cost-effective at appropriate scales of application (as well as SMART, where attributable substitutes for attainable). Furthermore, measurements and metrics tracked in support of indicator quantification must be comparable, repeatable and scientifically defensible. Ideally, the indicator is constructed from variables that are easy to measure, easy to understand and simple to apply. Generally, the more complex an indicator the less useful it will be, particularly for communication to public audiences. Also, having too many indicators can confound assessment and communication of progress toward management objectives.

Since the number of potentially useful metrics and indicators typically exceed available resources, decisions must be made on how best to detect changes and track the condition of important variables. Appropriate indicators are usually identified during a strategic planning phase or during adjustments to existing programs, and consider the conceptual representation of system behavior, the ultimate programmatic goals, and the optimal indictor characteristics listed above (TSAC 2018b). Even after initial winnowing, however, the number of metrics and indicators needed for scientific purposes and for program accounting will likely exceed efficient communication of progress toward final outcomes. For that reason, many environmental management programs around the country emphasize and organize communication around a few key indicators, with names such as vital signs, apex indicators, the elegant few, or ultimate outcomes (TSAC 2017c). Threshold standards serve this purpose at Tahoe, when organized according to the structure described in this document for goals, objectives, strategies and tactics, and where threshold standards represent the ultimate outcomes expected from Tahoe Basin resource management actions.

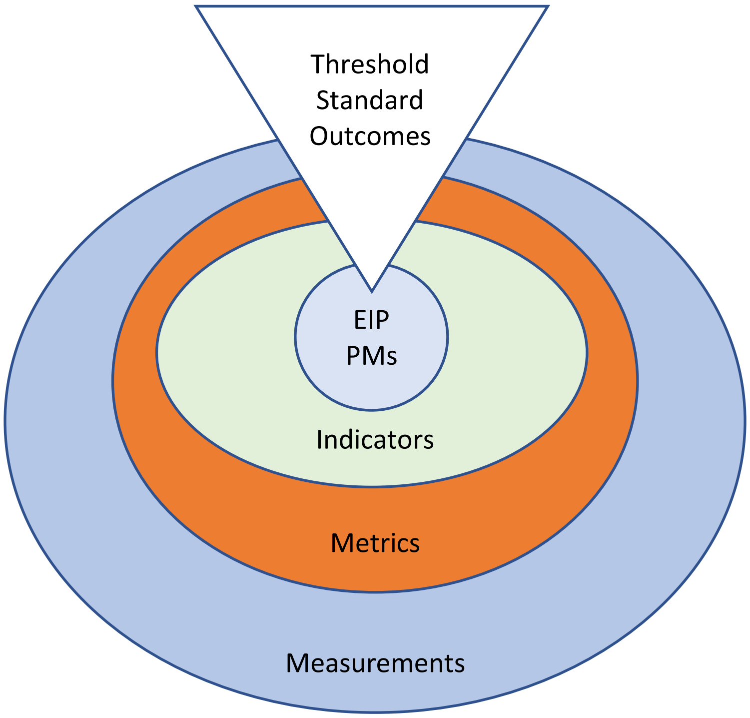


Figure D-1. Representation of logical relationships between measurements, metrics, indicators and the Tahoe Environmental Improvement Program (EIP) performance measures. Since each threshold standard is a high-level objective (or goal) they also must be associated with a final outcome indicator that is easy to represent and communicate.

Ancillary metrics and indicators are added as needed to adequately represent the execution and progress of restoration and maintenance of environmental resources at Tahoe. The recommended system structuring approach would define core indicators associated directly with threshold standards. An expanded set of indicators and metrics would track intermediate points of progress and account for system complexity related to the long-term objectives. Lake Tahoe clarity, for example, is expected to respond to nutrient and fine sediment particle load reductions, but changes in watershed and lake processes associated with climate change could confound the interpretation of results and progress. Additional metrics that track key variables linked to pollutant loading, lake hydrodynamics and within lake processing would contribute important information on progress from selected strategies and specific actions over time scales relevant to adaptive management. As an example of this approach, the bi-national Great Lakes Water Quality Agreement (GLWQA) and the Puget Sound Partnership have both identified high level indicators called Vital Signs that represent recovery goals (TSAC 2017c). The GLWQA recognizes nine Vital Signs linked to nine GLWQA objectives, with 44 sub-indicators and 56 or more corresponding metrics. This illustrates the concept for a core set of indicators that communicate progress toward long-term objectives, along with an expanded set of metrics and indicators as needed to enhance the interpretation of results, document progress over shorter timeframes and help explain interactions for complex systems.

Table D-1. Comparison of important characteristics for indicators, objectives and goals.

Indicators	Objectives	Goals
consistent	specific	aspirational
sensitive	measurable	expansive
timely	attainable	consensus-based
feasible	relevant	(may be SMART)
efficient	time-framed	
informative		
attributable		
cost-effective		

Metrics and indicators are what we manage toward. They inform our evaluation of progress and communicate distance from ultimately achieving the program goals or objectives. The approach recommended in this document allows sorting of indicators and metrics to ensure they are consistent with the system structure. Goals and objectives are outcome-based, so these require outcome indicators linked directly to the core objectives (threshold standards) or to critical intermediate objectives (interim results). Strategy and tactics are intent-based, so these use input metrics that track the scale of investment and output metrics that track implementation activities. Each of these indicators must be formally defined in strategic planning, and changes are only introduced after documented calibration with existing longer-term data sets. Additional metrics or indicators may arise and fade over time as required for special studies, to support the interpretation of emerging results, or as input data to models and analytic tools. Intermediate indicators often are essential for evaluating near-term results of management actions. When properly chosen and applied they tighten the adaptive management loop, and may indeed be interim in the long-term once sufficient progress is linked from these actions to ultimate desired outcomes. Indicators and metrics for intermediate results do not rise to the level of threshold standards that are the long-term expectations for desired outcomes to be achieved and maintained.

One additional observation from our review of system structure for threshold standards is the existence of some confusion over use of the term “standard.” This is a legacy term from when Congress defined environmental threshold carrying capacities for the Tahoe Basin (TRPA 1982). In this sense it represents a Congressionally mandated target for restoration, and so it fits well with our recommendation that threshold standards should be formulated as SMART objectives (with corresponding outcome indicators).

Attachment 1. TSAC. 2018a. Guidance on Technical Cleanup of Existing Threshold Standards memo. Tahoe Science Advisory Council work order memo, Incline Village, NV. April 25, 2018.

T S A C
TAHOE SCIENCE ADVISORY COUNCIL

April 25, 2018

To: Dan Segan, Tahoe Regional Planning Agency (TRPA)

From: Tahoe Science Advisory Council (TSAC)

RE: Work Order #007
Guidance on Technical Clean Up of Existing Threshold Standards

The Tahoe Science Advisory Council (TSAC) was tasked (March 2018) with attending a stakeholder meeting organized by TRPA to present the guidance document, answer questions about it, and collect feedback. Based on TSAC member comments and stakeholder feedback, the TSAC was then tasked with revising the document *Guidance Document on the Administrative/Technical Clean Up of Existing Thresholds Standards* (developed under Work Order #003, November 2017).

This document is the deliverable revised Guidance Document for that work order.

Contents

Executive Summary

The TRPA 2017 Assessment of 173 existing threshold standards identified 46 standards as overlapping with other standards in the threshold system (TRPA, 2017). In addition to the 46 previously identified overlapping standards, further sources of overlap may exist that were not specifically noted by the Assessment as redundant. Redundancy in threshold standards has the potential to increase the cost of enforcement and monitoring, to confuse the process of implementing standards, and to add uncertainty around the intent of threshold standards and how they contribute to meeting the overall goals of the regulations. Through examination of the existing threshold standards, the Tahoe Science Advisory Council (TSAC) identified five types of overlap: (1) complete overlap, (2) wholly encompassing standards, (3) competing targets, (4), indirect overlap, and (5) policy and management statements that overlap existing standards. This document provides a description those identified types of overlap, and for each one discusses the sources of each, the relative harm caused by the various types, and potential strategies to avoid or resolve that type of overlap.

Overlap can be caused by imprecisely written standards, unclear numerical targets or baselines, efforts to regulate the same process from different standpoints, or the adoption of more generalized policy statements as standards. In many cases, the overlap is relatively harmless – resulting in duplicative oversight or documentation, with few other problems – but in some instances, overlapping standards have the potential to cause confusion or even conflict during implementation of the regulatory system. The development and application of objective strategies to avoid and eliminate overlap among threshold standards will help TRPA achieve two of its stated goals for the Threshold Update Initiative: (1) [to identify] relevant and scientifically rigorous threshold standards, and (2) [to develop] a cost-efficient, feasible, and informative monitoring and evaluation plan. These strategies can be applied to both the existing threshold standards and proposed standards considered for implementation in the future.

It is important to understand that interconnected processes make the appearance of overlap unavoidable, even when standards are not overlapping. The same management action may be required to meet multiple standards, or a particular process may be regulated for its impact on different aspects of the basin's health. The mere appearance of overlap does not necessarily cause problems if it contributes to a holistic approach that furthers the goals of the Threshold Update Initiative.

This assessment provides a comprehensive catalogue of the characteristics of existing threshold overlap within the set of 46 thresholds previously identified as overlapping. Ultimately, the full set of 173 standards will need to be evaluated similarly to identify and categorize any additional sources of overlap that were not considered in this initial assessment. The typology presented in this assessment can be used to iteratively work through the review and updating process for all threshold standards.

The TSAC provides this typology and these potential strategies to better describe different types of overlap with the aim of improving the clarity, intent, and effectiveness of threshold standards. This document does not make recommendations about adopting, eliminating or revising any specific TRPA threshold standards from a regulatory perspective.

Introduction

The TRPA 2017 Assessment of 173 existing threshold standards identified 46 standards as overlapping with other standards in the threshold system. Additional standards were noted as partially overlapping other standards but were not included in the above tally. Overlap in standards can cause confusion about intent and can increase monitoring costs. Overlap within the standards appears to originate from a number of sources (e.g. multiple benefits of an individual standard, lack of information). A critical evaluation of areas and sources of overlap, and options for addressing overlap and redundancy in the existing standard system is recommended as a useful exercise in the overall threshold update initiative.

The purpose of this evaluation is to develop and enumerate a set of criteria, or typology, that can be applied to categorize the various types of overlap between standards, the potential impacts of those different types, and potential solutions for those types of overlap. The 46 standards previously identified by the TRPA were used as an example set to establish the framework for evaluating overlap. It is expected that the approach represented by this framework will contribute to the TRPA's administrative clean-up of all existing standards, as well as to review of proposed modifications to ensure that any modifications do not introduce unnecessary overlap or confusion.

Background

Following adoption of Public Law 96-551, the TRPA established nine environmental threshold carrying capacities (thresholds) that set environmental standards for the Lake Tahoe basin in 1982. These thresholds were defined at that time given the best available science to protect environmental degradation in nine categories: air quality, water quality, soil conservation, vegetation, fisheries, wildlife, scenic resources, noise, and recreation. The thresholds contain a mix of numerical, management, and policy statements that reflect the varying degrees of quantification used in describing the standard. Whereas numerical standards are quantifiable to avoid exceedances, management standards are non-quantifiable statements that typically target a given level of environmental quality. Policy statements are specific statements committing to a chosen course of action to achieve TRPAs management goals. As more information becomes available, policy statements may become management standards, and management standards may be quantified to become numerical standards.

Environmental thresholds were loosely defined to accommodate direct interactions between atmospheric, landscape, hydrological, and biological processes. The interrelationships among thresholds were tabulated in the 1982 threshold report to outline the importance relative to other environmental thresholds. The interconnected processes that contribute to threshold impacts must be recognized during evaluations or proposed modifications to individual standards so as to maintain the protections of existing standards that may result in environmental degradation. TRPA Resolution 82-11 directs that threshold standards shall be reviewed to insure that Regional Plan and environmental threshold carrying capacities are consistent.

A threshold evaluation is completed as part of the Agency's adaptive management cycle every four years. The re-evaluation ensures that the regional plan and projects of the Environmental Improvement Program (EIP) partners are sufficient to attain and maintain threshold standards. In the 2015 threshold evaluation, overlap was identified in 46 standards. Threshold overlap is broadly defined as functional equivalence from a regulatory perspective, where the protection conferred by one standard is also conferred by another standard. The functional equivalence is created by the type of overlap, and may result from:

- the same numerical target specified by multiple standards
- standards written such that the achievement of one standard ensures the achievement of another
- standards that call for different numerical targets to be applied to the same constituent,
- standards that regulate the same process differently in different locations, or
- policy statements that are adopted as standards.

Thresholds that overlap with non-numeric (management and policy) goals pose the greatest challenge in this typology and were not directly tabulated in the 2015 threshold evaluation. The objectives of this threshold overlap evaluation are to describe a generalized typology for the different types of overlap, provide examples of how overlap was defined, assess the relative harm that may arise from each type of overlap, and propose potential strategies to reduce or eliminate each type of overlap.

The TSAC provides this typology to better describe different types of overlap and to improve the clarity and intent of threshold standards. The TSAC does not make any recommendations about the TRPA Threshold Standards.

Approach

Following the 2015 Threshold Evaluation Report (TRPA 2016), the TRPA developed a Threshold Assessment Methodology (TAM) as part of its Threshold Update Initiative (TRPA 2017 draft document). The objective of the TAM was stated as (TRPA 2017):

> *Compare each of the existing threshold standards against best practice for the formulation of goals and standards, to highlight the aspects of the current system that are well designed and identify where improvements may be considered.*

As part of that process, TRPA examined the existing standards for redundancy and generated a list of 46 standards that were, in part or in whole, redundant. Those standards and the specific incidences of overlap identified by the 2017 Standards Assessment were used as the basis for the typology of overlap described here.

Here we describe five different types of overlap that are encountered in the TRPA standards. Any redundancy in threshold standards will result in duplicative effort in oversight, but some types of overlap create further issues. For each identified type of overlap, we present:

1. a description of the overlap itself,
2. an example from the 46 redundant standards previously identified by TRPA
3. a brief assessment of the potential relative harm that may be caused by that type of overlap, and
4. one or more potential solutions to reduce or eliminate the type of overlap.

Typology of Overlapping Standards

1. Complete Overlap

Complete overlap occurs when two different standards regulate the same constituent with the same numerical target. This is the most obviously apparent category of overlap, with a clear link between standards. Atmospheric deposition of dissolved inorganic nitrogen, for example, is controlled by different standards in the littoral and pelagic zones of the lake, although both numeric targets are the same and it is a deposition limit that is intended, wherever it occurs. Because atmospheric deposition is not expected to vary between the pelagic and littoral zones, there is no reason to regulate the process with two separate standards.

Although this type of overlap results in little harm. There is some duplication of oversight and recordkeeping, but it is unlikely to cause conflicts between regulating and regulated parties. However, the potential for harm exists if one of the standards is revised without revising the other; maintaining completely overlapping standards requires the oversight to ensure that no conflict is created between the standards (i.e., that the overlap does not move into another type). Elimination of complete overlap involves eliminating one of the overlapping standards, or combining them into one standard statement.

2. Wholly Encompassing Standards

This occurs when the achievement of one standard (the encompassing standard) would necessarily entail the achievement of another (the encompassed standard). For example, the Deer Disturbance-Free Zone standard prohibits activity that may cause disturbances to deer in areas mapped as "meadows," but those mapped areas are wholly contained within the defined Stream Environment Zones (SEZ) and are also protected by the existing standard to preserve SEZ function. The SEZ functions that support wildlife and plant communities are intricately linked to – and often the same as – the functions that cycle nutrients and provide the aesthetic quality of SEZ communities. Preventing the degradation of these functions (i.e., achieving the Non-Degradation of SEZ function standard) would necessarily achieve the Deer Disturbance-Free Zone standard.

There are two ways to reduce the overlap inherent in wholly encompassing standards. Obviously, the wholly encompassed standard could be eliminated. However, it is frequently the case that the wholly encompassed standard is regulating a different environmental threshold than the encompassing standard – in the example above, the two standards stem from the wildlife and soil conservation thresholds. In these cases, a re-evaluation of the encompassed standard may be appropriate to ensure that it is specifically regulating the appropriate target. If it is important to provide more protection than the encompassing standard does, it may be necessary to increase the level of protection in the encompassed standard.

3. Competing Targets

Competing targets occur when two or more standards address the same constituent in different ways. In addition to obviously different numerical targets (e.g., one standard to maintain NOx emissions at or below the 1981 level; and another standard to reduce NOx produced in the basin consistent with the water quality thresholds), it may also occur due to differences in the baseline (e.g., maintain NOx emissions at or below the 1981 level; reduce dissolved inorganic nitrogen (DIN) loading from all sources by 25 percent of the 1973-81 annual average; reduce DIN from atmospheric sources by 20% of the 1973-81 baseline average) or target (reduce loading of algal nutrients from all sources as required to achieve ambient standards for primary productivity and transparency).

The relative harm caused by this category of overlap is greater than any of the other categories. In addition to difficulties in oversight and recordkeeping, it is likely to cause conflict between regulating and regulated parties.

Competing targets result largely from inadequate specificity in the standards, and can be resolved by amending the competing standards to numerically specify the appropriate target(s). This target may be an annual load, a flux, a concentration, or other metric. The more specific the standard and the more direct and consistent its measurement the better.

To maintain equivalent protection in the case of standards that refer to different baselines, the amended targets should be calculated from the currently specified baselines in both standards. This calculation maintains the rationale for the baseline provided by the original threshold standard while at the same time clarifying the details of implementation. Typically, the more stringent of the competing targets should be cited as the new target.

4. Indirect Overlap

Indirect overlap occurs when one standard regulates an overarching category and additional standards regulate constituents of that category. For example, the Pelagic Nitrogen Loading standard calls for a 25% reduction in dissolved inorganic nitrogen (DIN) from all sources (1973-81 baseline), while further standards call for specified reductions in DIN loading from groundwater sources (30%), from surface runoff (50%), and from atmospheric sources (20%), as well as reductions in algal nutrients as required to achieve the ambient standards for primary productivity and transparency.

Indirect overlap can cause confusion over how to document and/or improve compliance, as well as confusion over when the target is achieved. Indirect overlap is best resolved by amending the standards to more precisely define the regulated constituent (e.g., sampling and analysis methods) and the numerical target (e.g., concentration or annual flux) of the standard.

5. Policy and Management Statements as Standards

A number of policy and management statements have been adopted by TRPA as standards. Often, these standards simply call for other standards to be achieved. For example, there are standards that simply state, "it is the policy of the TRPA Governing Board in the development of the Regional Plan to reduce fumes from diesel engines to the extent possible," and "attain existing water quality standards." While these can sometimes be considered a part of the "wholly encompassing standards" category, they are different enough to merit their own category.

The corrosive influence of policy statements as standards is in the vagueness of those statements. The statements more often describe broad and aspirational goals than they do measurable and achievable standards. The negative impact of policy statements as standards can be resolved by separating the overarching goals from the threshold standards. Management standards reflect the strategies designed to meet those goals, and can be addressed by amending those management-based standards to include both numerical targets and timeframes for the enactment of those policies.

There are two possible ways to resolve the issues that arise from management standards and policy statements without specific targets. First, the standards could be specifically identified as broad statements of a goal provided for guidance or context only, with no enforceability. Second, the ambiguity could be resolved by adding specific details to the standard that reformulate it to something that is quantifiable and measurable, and that can be objectively evaluated. For example, the standard "attain existing water quality standards" could be amended to require a numerical reduction in the incidences of water quality violations over the next five years.

Discussion

Here we discuss the areas of overlap identified above and the options that TRPA has to attempt to resolve various types of overlap and to minimize the impact of that overlap. In considering the effects of overlapping standards and the available options to address those effects, we assume that any revision would have the following priorities:

1. Must maintain equivalent levels of protection.
2. Reduce uncertainty and potential conflict during implementation of the threshold evaluation.
3. Reduce uncertainty and duplication of effort in TRPA's oversight and documentation processes.

In some cases, the identified overlap could be reduced or eliminated by revising the existing standards to better comply with the SMART (specific, measurable, achievable, relevant, and time-based) criteria. The SMART framework is designed to enable objective and informative evaluation of the effectiveness of programs and actions. Goals that are SMART enable the development of evaluation and reporting structures that:

1. Promote accountability for the achievement of objectives through the assessment of outcomes and the effectiveness of activities and policies.
2. Accelerate attainment through improved resource allocation and decision making and promotion of learning and knowledge sharing among partners.

Evaluation of redundant standards with the SMART criteria could help to clarify ambiguities in the reason for the standards, and potential revisions or updates to the standard could ensure that evaluation of the goal will provide decision makers with the information they need to track progress towards attainment. When standards are amended to resolve the types of overlap described in the typology, applying the SMART criteria can contribute significantly to the resolution of overlap. For example, a desired outcome (e.g., the attainment of existing water quality standards) may be defined to be more specific and measurable by focusing on the number of incidences in which the outcome is not achieved (e.g., reduce annual incidences of exceedance of existing water quality standards from year to year). The outcome-based standard then becomes more than a simple restatement of the existing standards, while still serving the goal it was intended to serve.

In addition to the 46 previously identified overlapping standards, some further sources of overlap may exist that were not specifically noted by the Assessment as redundant. Some standards reference one another. For example, the Phytoplankton Primary Productivity standard calls for an annual mean phytoplankton primary productivity at or below 52 $gmC/m^2/yr$ and the annual average Secchi disk transparency standard requires an annual average Secchi depth of 29.7 m. At the same time, the separate pelagic phosphorus loading standard requires a reduction in the loading of dissolved phosphorus as required to achieve the ambient standards for primary productivity and transparency. This type of overlap, which would fall into Type 4 (indirect overlap) defined above, was not consistently highlighted in the Assessment as redundant. Neither the phytoplankton primary productivity standard nor the annual average Secchi disk transparency standard was identified in the Assessment as redundant, although the pelagic phosphorus loading standards were. Following an examination of the 46 already identified overlapping standards, it may be necessary to perform a wider-ranging assessment of redundancy in the full set of 173 existing standards with this typology as a guide.

In accordance with best practices, TSAC has recommended that TRPA move toward standards based on outcomes rather than activities or intermediate results (TSAC, 2017). The outcomes are frequently the result of a number of interconnected environmental processes, such that attaining an outcome standard (e.g., Secchi depth of 29.7 m) will necessarily depend on controlling the inputs or the intermediate products of those processes. For example, street sweeping and stormwater best management practices (inputs) can help reduce sediment and nutrient loads (intermediate products), which ultimately leads to increased lake clarity (outcome).

There is an ongoing effort to develop conceptual models for processes within the Tahoe basin for which threshold standards exist. Overlapping thresholds could be evaluated within the context of conceptual models to better understand the level of protection, identify weakness, gaps, or confusion in existing standards and guide the review and development of future standards. It is important to recognize that the interconnectedness of processes will make some level of apparent overlap unavoidable if goals are to be achieved. For example, stream restoration activities may contribute to achieving multiple standards (nutrients, suspended sediments, water temperature); stream restoration alone, though, is likely not sufficient to achieve the numerical targets of all of those standards. Multiple standards may in fact be needed to motivate a diversity of projects or types of protections that work together to achieve the goals for the Tahoe Basin.

In other cases, two competing standards may be intended to address different environmental thresholds within the basin. An example of this would be the multiple nitrogen standards identified above as competing targets (type 3). Two different oxides of nitrogen (NOx) standard were enacted to maintain air quality within the Tahoe Basin, while the DIN standard was motivated by lake clarity. In this case, these competing standards are aimed at achieving different outcomes, and the redundancy offers protection from two different sources of pollution.

A third standard, however, calls for the reduction of "[NOx] produced within the basin consistent with the water quality thresholds." This standard is aimed at reducing the impact of atmospheric deposition of nitrogen on water clarity – the same goal as the various water quality standards that call for specific reductions in DIN. The overlap of this third standard does not serve to impart any environmental protection not already offered by the other water quality standards, and is therefore unnecessarily redundant.

Summary of Findings

Overlap in standards can cause confusion about intent and can increase monitoring costs. The overlap typology presented herein provide a path forward in defining and understanding the types and sources of overlap. The resolution strategies presented here, especially in conjunction with the implementation of the SMART criteria, can provide a path towards reducing the confusion and financial burden associated with monitoring redundant standards.

In addition to developing the typology of overlap, we discussed a number of technical and administrative issues stemming from redundancy, summarized below.

1. There are likely additional overlapping standards not identified during TRPA's initial assessment of overlap.
2. Different types of overlap result in different levels of harm, enabling TRPA to prioritize efforts to resolve overlap.
3. Application of SMART criteria to existing overlapping standards is a powerful tool to resolve overlap.
4. Because of interconnected environmental processes, some level of apparent overlap in standards is unavoidable. This apparent overlap, though, may not rise to the level of functional overlap described here.

The aim of this assessment was to document a comprehensive typology of threshold overlap to contribute to the TRPA's administrative clean-up of all existing standards. This effort provides the fundamental framework for further evaluations that will help guide the TRPA in improving existing standards and ensuring that any future modifications do not introduce unnecessary overlap or confusion.

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TSAC WO-004 report;
Alan Heyvaert and Dan Segan, 2018-07-20

Structuring Data to Facilitate Management of Threshold Standards

Executive Summary

In a previous study the Tahoe Science Advisory Council (TSAC) reviewed natural resource management systems from around the country and documented their findings in terms of best practices for establishing environmental management goals and for evaluating progress towards those goals (TSAC, 2017). The Council identified four core principles and eight programmatic characteristics that were considered essential for effective natural resource evaluation and management. This document builds on that earlier work by providing guidance on three essential elements needed for structuring information to inform threshold standard development and outcome tracking. These essential elements include:

1) The development of a conceptual framework to communicate broad-scale socio-ecological system goals and interactions across threshold categories;
2) Elucidation of system functions and causal linkages through conceptual models; and
3) Tracking progress toward specified outcomes through indicators selected from causal networks or result chains.

The conceptual framework recommended for Tahoe Basin thresholds management is derived from decades of environmental resource management research based on Pressure-State-Response (PSR) relationships. This has been expanded over time to better represent complex social-ecological systems, where the driving forces from social, demographic and economic developments produce activities that create pressures on environmental states and yield changes or impacts on ecosystem services that ultimately require management responses (DAPSIR: Driver-Activity-Pressure-State-Impact-Response). This basic conceptualization has been used extensively for different types of problems around the world. It has proven to be a flexible and useful framework that can be tailored to the specific requirements of each system. It serves as the foundation for communicating and deliberating on complex environmental issues and for collaborative consideration of potential management responses.

The conceptual model represents our understanding of system function, based on those factors represented within the conceptual framework. It condenses a universe of potentially relevant environmental factors and interactions into a set of diagrams and associated narratives that identify and organize the key attributes of these complex systems into a simplified representation of system structure and dynamics. It shows where management responses can provide benefits by maintaining or restoring desired features or ecosystem services (as benefits humans obtain from

properly functioning ecosystems). The conceptual model also indicates where assumptions or uncertainties are present that may require additional investigations, optimally conducted within an adaptive management framework to inform future decisions.

As scientific and management understanding improves, the preliminary conceptual models contribute to more sophisticated causal networks that represent key interactions, management options and optimal nodes for tracking indicators of progress.

The results chain represents a specific pathway in the conceptual model that identifies a set of causal linkages leading from a management action to a desired final outcome. This also identifies the indicators needed for tracking progress toward that desired outcome. It is structured to show the inputs needed to support a management response strategy that is then evaluated in terms of both outputs and outcomes as measurements of progress toward achieving a specific target or goal.

The final component is a monitoring and evaluation plan that provides the protocols and the support necessary for indicator and status assessments to measure the effectiveness of management actions. This monitoring and evaluation approach is informed by conceptual models and by results chains that clearly represent cause-and-effect relationships between inputs from management actions and expected outcomes. In cases where outcomes can be framed as testable hypotheses, then specific actions should be implemented and evaluated as part of an adaptive management program.

In summary, four primary recommendations arise from this work that will improve the effectiveness of the threshold system and environmental quality in the Basin.

1. Adopt a conceptual framework (DAPSIR) that identifies the important social-ecological drivers of change, associated impacts and the resulting management responses. This serves as a high-level collaboration and communications tool that defines outcome-based goals and helps to integrate across threshold categories.
2. Develop conceptual models for each goal representing the key ecosystem attributes and linkages. These conceptual models should capture the current scientific thinking on interactions and processes along with administrative options for management actions (responses) that are expected to improve conditions of the key attributes.
3. Use the conceptual models to articulate causal network-based result chains that link management actions with their expected influence on the pressures and states (conditions) of the system and ultimately to desired outcomes.
4. Identify a limited set of indicators from the causal relationships to establish a monitoring and evaluation plan that tracks progress toward outcome-based

goals, and evaluate the response to management actions within an adaptive management framework.

Taken together these recommendations will yield a Tahoe threshold system that is adaptable, results oriented and responsive to social-environmental changes. It will provide structure to data and information that improves communication and provides stakeholders with a coherent vision of how the threshold system is applied to manage environmental resources in the Tahoe Basin, and it will show how management actions can be evaluated as part of an adaptive management process.

Introduction

The TRPA Threshold Update Initiative is one of seven strategic priorities set by the TRPA Governing Board in 2015. Followed by the 2015 Threshold Evaluation Report, this set the stage for comprehensive review of the environmental threshold system to 1) ensure a representative, relevant, and scientifically rigorous set of standards; 2) to establish a cost-effective, feasible and informative monitoring and evaluation plan to support threshold standards; and 3) to develop a robust and repeatable process for review of standards in the future.

Preliminary guidance was provided in the Tahoe Science Advisory Council's 2017 review of other natural resource evaluation and management systems from around the country (TSAC, 2017). This review suggested that outcome-based metrics are preferred over output measures, and that intermediate indicators can provide more timely feedback on response to management actions than long-term targets. The TRPA threshold standards currently include a mix of outcomes, outputs, inputs, and aspirational statements. These different types of standards and the lack of a consistent terminology creates confusion around intent. The terminology and evaluation methods used can be better organized to promote a more structured approach to threshold management.

This document provides guidance on how information and data can be structured within a management system using conceptual models and representations of causal linkages that connect actions to outcomes. This becomes useful when characterizing the factors relevant to choosing key attributes and associated indicators for tracking impacts resulting from management actions, and it clarifies how different types of information inform the environmental management system.

Background

Threshold standards at Tahoe are defined as the standards "necessary to maintain a significant scenic, recreational, educational, scientific or natural value of the region or to maintain public health and safety within the region" (Public Law 96-551, 1980). There are currently 173 threshold standards across nine resource categories administered by the TRPA. The Bi-State Compact that established TRPA instructed TRPA to develop the threshold standards in consultation with partners and to develop and enforce a regional plan to ensure the standards were attained and maintained.

The Council's review of natural resource management programs from around the country found that management objectives tend to grow over time, ultimately encompassing large numbers of targeted outcomes and indicators that are difficult or expensive to track and are not directly linked to management actions or specific objectives (TSAC, 2017). As a consequence, many of these programs are now seeking to reduce their tracking requirements to a more concise set of primary objectives and indicators that more closely link decisions and management actions to desired results. Some form of problem structuring method is generally adopted to guide this process and to focus efforts on key indicators and processes that inform policy decisions and management actions to achieve desired results.

One of the most common pitfalls in developing an effective resource management program is the failure to build a common understanding of how management actions are linked to desired outcomes. This understanding is best constructed through a problem structuring approach that defines the boundaries of relevant issues and brings together stakeholder perspectives and available information needed to link policy to action and evaluation. There is an extensive literature on problem structuring methods, and a diverse set of approaches have been developed for use in a variety of fields and disciplines. Examples from the business world include Strength, Weakness, Opportunity and Threat (SWOT) assessment and Strategic Options Development and Analysis (SODA) for more complex problems. The Pressure-State-Response (PSR) framework (OECD, 1993) is an example of a problem structuring method that has been used often in environmental resource management. More recently, the PSR approach has evolved into a Driving Forces-Pressure-State-Impact-Response (DPSIR) framework (EEA, 2003), which better represents human–environmental interactions and related information flows (Figure 1). Over time the DPSIR theme has been extended and revised in many ways to address different perceived requirements (Gari et al., 2015), but each of these variations has attempted to structure an approach for problem specification that recognizes the complex, interacting, dynamic, non-linear and multidisciplinary characteristics typical of ecosystem management.

We will focus on key aspects of the PSR and DPSIR frameworks here, since they are widely used and have an extended history of development and application as conceptual frameworks for representing complex social-ecological systems (Vugteveen et al., 2015). Most importantly, this approach can be adapted and customized as needed to meet the specific needs of TRPA and their associated stakeholders, which is how the Puget Sound Partnership used it for their program (TSAC, 2017). It is this continued adaptation and customization of the conceptual framework that will ultimately increase its utility and successful application at Tahoe.

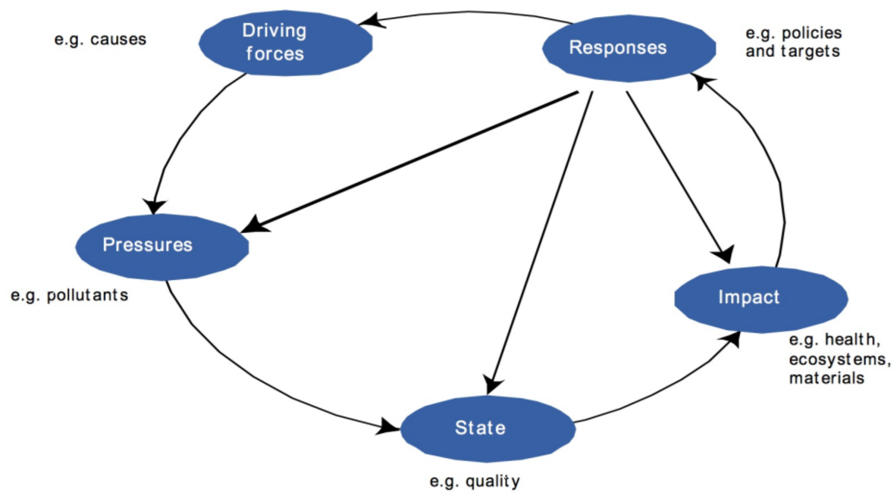


Figure 1. DPSIR framework for reporting on environmental issues (EEA, 2003). Note that management actions may affect multiple points in the framework, so indicators can be used at each of these steps in the framework.

Stem et al. (2005) noted that the conceptual framework is but one part of a two-component system that also must include effectiveness monitoring and evaluation. A traditional but simplistic approach for conducting environmental evaluations was to first define the indicators, then collect the data and analyze it, and ultimately write up the results. This is insufficient, however, since data are not usually evaluated in the context of project interventions or desired outcomes (Margoluis et al., 2009). As a result, it has been difficult to demonstrate solid evidence of success from management interventions or to learn from the implementation of specific actions.

Adaptive management provides a data-driven feedback and hypothesis-testing framework for the results of management actions. It structures the monitoring and evaluation approach into an evaluation-response cycle that promotes "learning while doing." Specifically, adaptive management attempts to reduce management uncertainty through an iterative approach that evaluates response to selected actions or projects directed at achieving specified objectives (see Appendix A). It may not be appropriate or applicable in all cases, but over time, and properly implemented, this iteration contributes to a continuous improvement in management planning and project implementation through a Plan, Do, Check or study, and Act or adjust (PDCA) cycle, originally developed for quality control methods in manufacturing and business (Deming, 1993).

The combination of these approaches has been discussed by Vugteveen et al. (2015), who emphasized the integrated roles of an information cycle and a capacity building cycle for environmental management. Figure 2 illustrates how the adaptive management process is supported by both a technical information cycle (adaptive monitoring) and an institutional or social learning cycle (adaptive governance) that focuses on deliberation and planning steps to determine whether management actions perform as intended and should be continued or should be replaced or modified to achieve objectives. The intent of this iterative sequence of decision making, monitoring, and assessment is to increase technical management understanding and capacity, including innovations that achieve desired outcomes.

Two specific tools are fundamental to implementing a successful environmental management program in complex systems. The first of these is development of conceptual models that succinctly represent dominant characteristics and processes evident within the coupled human and natural system under study. The second is development of causal effect results chains that show how specific management actions are expected to manifest as desired outcomes in the context of integrated resource management.

A consortium of twenty-three conservation organizations working as the Conservation Measures Partnership (CMP) have collectively developed a set of recommended procedures for project design, management and monitoring that incorporate adaptive management practices. Significantly, conceptual models are considered fundamental to the adaptive management approach recommended in their Open Standards for the Practice of Conservation, while results chains serve as a tool for communicating why specific outcomes are anticipated from management actions (CMP, 2013).

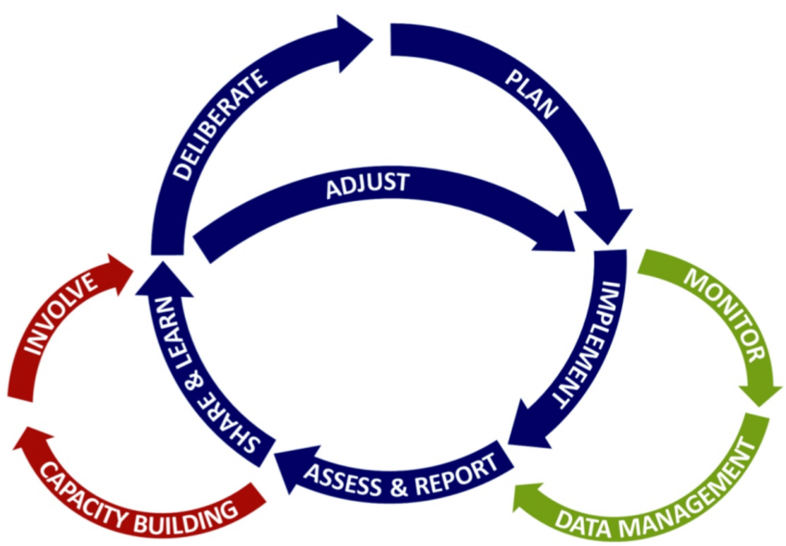


Figure 2. The overall environmental management process cycle (center, in blue) represents an adaptive management approach that involves an information cycle (right, in green) based on adaptive monitoring (right), and a capacity building cycle (left, in red) serving scientific and societal capacity building (left); from Vugteveen et al., 2015.

The Conceptual Framework

The conceptual framework organizes and communicates our general understanding of complex interactions within the coupled social-ecological system. The use of a conceptual framework ensures that a system-based approach is used in addressing environmental challenges. This approach acknowledges at the highest level that challenges in managing the system are interconnected and dynamic. The linkages captured in a conceptual framework diagram can be used to break down silos between resources areas, and to avoid myopic management interventions with negative unintended consequences.

The flexibility of a DPSIR framework and its adaptability make it a compelling approach for threshold management in the Tahoe Basin. Specifically, we recommend the DAPSIR conceptual framework from Elliot et al. (2017), which includes one additional term to represent the human activities (resulting from societal driving forces) that give rise to pressures on the ecosystem. This formulation (Figure 3) clarifies some ambiguities that became evident in application of the original DPSIR framework (Patricio et al., 2016). It shows that specific human activities resulting from driving forces cause the pressures, while responses are properly considered as measures that introduce prevention, mitigation or compensation for these activities and the resulting pressures (Elliot et al., 2017).

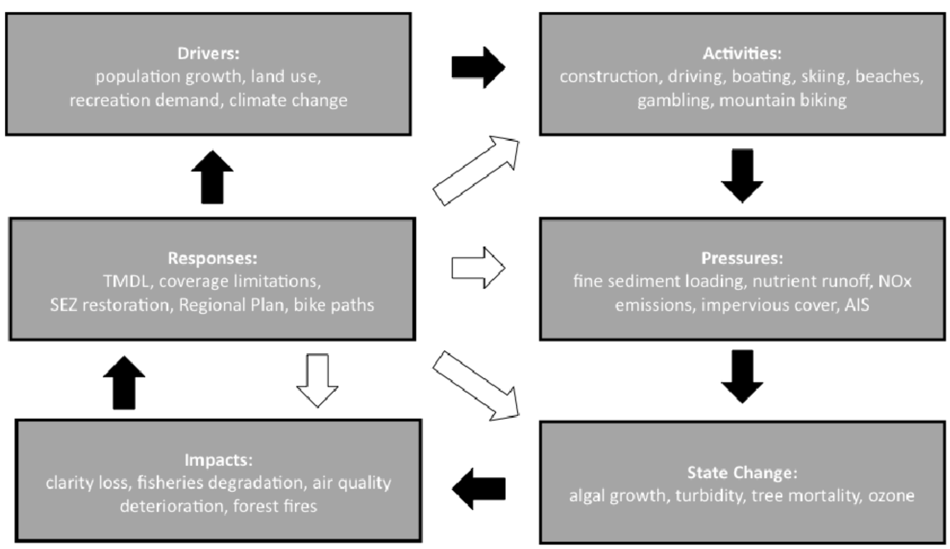


Figure 3. Outline of the categories represented in a DAPSIR conceptual framework with examples for Tahoe. Each category would be developed in narrative detail for the TRPA thresholds.

Given that terminology is fundamental to consistent and effective application of a conceptual framework and its associated tools, we provide some brief preliminary definitions for DAPSIR components as they would be applicable to a Tahoe thresholds system. Over time the TRPA should work with their stakeholders to revise and update these definitions so they are customized for Tahoe and reflect the knowledge gained in application to thresholds.

- Driving Forces are considered the social, demographic, technologic and economic developments in society that motivate human activities to fulfill basic human needs. Examples of potential driving forces at Tahoe would be population growth in surrounding communities, decreased housing affordability, recreation demand, climate change and emergence of electric vehicles.

- Activities are derived from the driving forces that induce human behavior that cause changes in the environment. Examples would be increased boating, higher density development, more road traffic.

- Pressures result from human activities that use resources or cause direct environmental alterations, whether from land use, hydrologic modification, physical, chemical or biological emissions. Examples would be increased impervious area from development, atmospheric deposition of nutrients from automobiles, or introduction of aquatic invasive species (AIS) from recreational boating.

- State changes result from pressures on the ecosystem. Thus, changes in physical, chemical and biological processes resulting from pressures interact to affect different ecosystem and built environment characteristics that can be measured by their attributes. Algae concentrations in the lake change from nutrient loading, native food-web changes occur with the introduction of AIS. Note that stressors are the components of state that are changed by pressures. Excess loading from impervious runoff is a stressor that causes a state change in lake water nutrient concentrations.

- Impacts on ecosystem services and human welfare is a consequence of changes in the quality and functioning of the ecosystem (state changes), including the production of ecosystem goods and services on which human well-being and economic resilience depend. Impacts include effects on obvious factors like clean water and air, as well as less obvious factors like water clarity, aesthetic scenic elements and cultural assets. Note that benefits can also be represented in this category, which shifts the perspective toward benefits humans derive from a healthy environment rather than a focus on negative effects of humans on the environment (Vugteveen et al., 2015).

- Responses are considered as measures or explicit actions that prevent, mitigate, compensate or adapt for changes in the state of environmental factors. Response measures taken by groups or individuals in society and government can be implemented at any stage of the DAPSIR cycle, but generally operate on activities, pressures or impacts. The reduced application of winter traction sands, boat inspections for AIS, and storm-water infiltration are examples of management strategy responses at Tahoe.

With almost two hundred standards across nine threshold categories, the requirements for resource management in the Lake Tahoe Basin are sufficiently complex to benefit from a problem structuring approach, while also presenting an opportunity to demonstrate the benefits of its application across thresholds. The TRPA could develop a DAPSIR conceptual framework for each of the nine threshold areas. These efforts to define primary driving forces, activities, pressures, impacts, and management responses would inform the selection of goals and targets for conceptual model development and then the selection of appropriate indicators. Some factors for each component term may be similar across thresholds, especially for driving forces. Note that the intent of response measures generally is not to manage natural variability and exogenous factors that operate outside of the system, but to affect change on selected factors within the system.

Although initial development of the conceptual framework can be completed relatively quickly, the resulting product should not be considered static. Instead, it should be examined and revised periodically to reflect ongoing changes in the environment and societal pressures along with corresponding evolution of knowledge about those factors and the continued examination of linkages and indicators from causal network modeling to inform responsive management actions.

Developing Conceptual Models

A conceptual model facilitates understanding the complex interaction of multiple variables across space and time. These models consist of diagrams and associated narratives that organize the connections between key factors in complex systems and simplify our understanding of system structure, interactions and dynamics. When developed as part of multi-stakeholder collaborations they also contribute to a shared learning process that supports subsequent development of decision support tools, predictive mathematical models, performance indicators and results-based assessments (EPA, 2015).

Recommendations for developing conceptual models at the threshold category level should draw on work described by Margolis et al. (2009). Important elements of this approach have been adopted by the Conservation Measures Partnership in their Open Standards for the Practice of Conservation (CMP, 2013), and though the focus of application is on conservation projects and biodiversity, these same principles and tools are broadly applicable to environmental programs more generally. Indeed, some Tahoe studies have included conceptual models that reflect this structural approach in their development, as with the nearshore (Heyvaert et al., 2013), while other studies have adopted related representations (Hymanson and Collopy, 2010).

The overall approach for constructing conceptual models recognizes several important steps and specific features described by Margoluis et al. (2009) and by CMP (2013). At Tahoe this approach should be applied to the development of a conceptual model for each of the nine threshold categories, following the general structure shown in Figure 4 and following steps shown below, adapted from Margoluis et al. (2009). These are intended to represent key attributes and interacting factors relevant to the dominant items and goals listed for terms in the conceptual framework.

(1) Define what the program for that threshold category intends to ultimately accomplish. This requires identification of scope (boundaries) and vision (goals and targets in Figure 4). The DAPSIR conceptual framework for each threshold category should inform this step, but if not yet available then a preliminary consensus among stakeholders would substitute. Limit the selection of primary goals and targets (desired outcomes) within each threshold category. Although the Nature Conservancy recommends no more than eight targets as a general rule of thumb (TNC, 2007), they are not simultaneously working across multiple thresholds in their project designs, so a lower number for each threshold category would be advisable.

(2) Moving from right to left in Figure 4, brainstorm the direct threats affecting the targets (final outcomes). Outcome objectives can be short-term, intermediate, or long-term, but all objectives should be specific, measurable, achievable, relevant and time-based (SMART) representations of each goal. The model should include the main direct threats (pink boxes in Figure 4) and use arrows to indicate which threats are affecting which targets. Direct threats are the human actions (or conditions resulting from human activities) that directly degrade one or more of the specified targets or outcome-based goals.

(3) Add the main contributing factors (orange boxes in Figure 4, also referred to as drivers or underlying root causes (Wood et al., 2000)). Contributing factors typically include social, economic, cultural, political, and other behavioral variables. Use arrows to show the causal links among contributing factors, direct threats, and targets. It is important to limit represented variables to the primary direct threats and contributing or indirect factors that are affecting targets. If the model becomes overly large and convoluted it may obscure the more influential factors and lose its communication value. According to Margoluis et al. (2009) a coarse rule of thumb is to limit the number of contributing factors to approximately 25 or 30 in these conceptual models.

(4) Add management, policy or adaptation strategies and show what part of the conceptual model they are designed to influence. Strategies should directly influence one or more contributing factors to ultimately reduce a threat or to restore desired conditions. These strategies should each link to an objective, which is a specific statement detailing the desired accomplishments or outcomes of a strategy or project (using SMART objectives).

A good model should be as simple as possible while still including the most important details. At the scale of the threshold categories, these conceptual models will still be relatively coarse grained, but they should include the most important details and factors needed to represent dominant sources of resource impacts, mitigation opportunities, constraints and strategies. As with the conceptual frameworks discussed previously, these conceptual models serve best when built collaboratively by goal implementation teams or working groups (TSAC, 2017). Ultimately, each model should be tested with key stakeholders outside of the project team to ensure it reflects a collective understanding, where areas of confusion or uncertainty are noted for further research, analysis or documentation (CMP, 2013). The real utility of a conceptual model is to show how managers expect interventions will influence existing conditions and lead to desired results. These are based on the causal links shown between strategies, factors, objectives and outcomes. A finer grained understanding of these causal linkages is then developed with results chains to document the specific steps expected to achieve objectives and targeted goals.

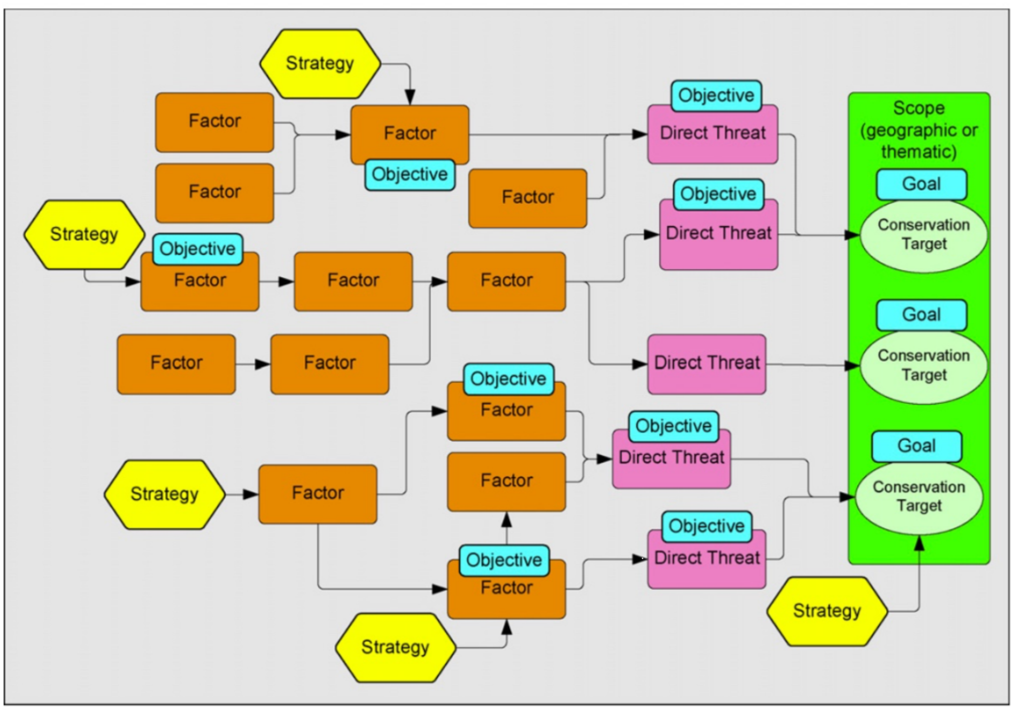
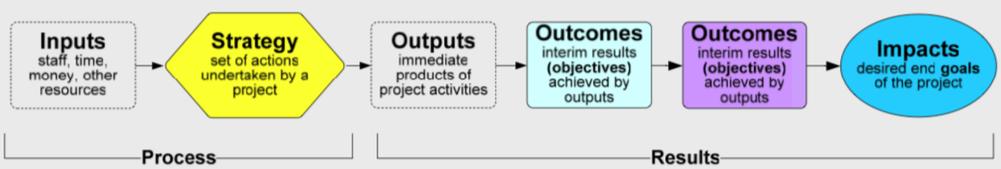


Figure 4. This generic structure for a conceptual model approach is recommended for each of the Tahoe thresholds; from Margoluis et al. (2009).

Constructing Results Chains

The results chain is a tool that identifies precisely how a system is expected to respond to specific management actions. Although similar to (and generally derived from) previously developed conceptual models for system function, the results chain shows more detailed linkages between actions, outcomes and goals, along with any associated objectives and indicators at each step. The general characteristics of a results chain are demonstrated in Figure 5. It is composed of an activity or a strategy (group of activities) that leads through a set of desired outcomes to ultimately achieve the desired results on a particular focal component or target (Margoluis et al., 2013). In these results chains, the outputs are measures of management activities intended to achieve specific outcomes (e.g., acres of restored wetland), while outcomes are the measures of function or restored conditions achieved (e.g., load reduction from wetland restoration), and goals are the primary targets (final outcomes) for which the work is being done (e.g., lake clarity recovery). Tracking of intermediate outcomes becomes important when the final results or impacts represent longer-term goals that do not immediately manifest the expected benefits of management actions.

There is a great deal of confusion over the different terms used to describe the results of a project. What one person calls an "outcome," another calls a "result," and yet a third person calls an "impact." The following figure shows the terms as they are most commonly used by evaluation experts in different fields such as development and public health.



Note: Results chains do not generally show inputs and outputs but rather focus on performance-oriented results

Based on the above figure, the following terms can be defined for use in results chains in biodiversity conservation projects:

- **Strategies** – The actions or interventions that a project implements.
- **Outcome** – The desired future state of a threat or opportunity factor. An **objective** is a formal statement of the desired outcome.
- **Impact** – The desired future state of a conservation target. A **goal** is a formal statement of the desired impact.
- **Result** – A generic term used to describe the desired future state of a target or factor. Includes impacts, outcomes, and outputs.

The above terms refer primarily to a sequence of results in a logical sense. There is also a sequence of results in a temporal sense:

- **Final result** – The ultimate desired result over time.
- **Intermediate result** – A milestone along the way to that final result.

Figure 5. Basic characteristics of a generic results chain; from Margoluis (2013).

Although linear results chains, as described above, provide a direct representation of expected outcomes, they may not adequately represent the convergence of multiple causality lines. A causal network-based approach, which is similar to the flowcharts of process-based simulation models, can better demonstrate the inter-relationships between various causal chains (Niemeijer and de Groot, 2008a). Over the longer-term a conceptual model would be expected to evolve toward a causal network representation of the ecosystem, as increasingly detailed information on direction and strength of multiple interactions is evaluated and incorporated. The linear results chain is a simplified representation of this complexity that reduces the details into a set of responses expected from proposed management actions to achieve a specific outcome. It is structured to show the inputs needed to support a management response strategy that is evaluated in terms of both outputs and outcomes as measurements of progress toward achieving a specific target or goal. Even within the context of a causal network, these objectives are communicated most efficiently through a set of results chains as described above.

As one example, the Sacramento–San Joaquin Delta Regional Ecosystem Restoration Implementation Plan (DRERIP) developed a conceptual modeling approach that linked actions to outcomes through a network of driver-linkage-outcome chains that clearly described actions to be evaluated, assessed the magnitude and certainty of anticipated outcomes, provided estimates of project worth and risk, evaluated the reversibility of actions and identified opportunities for learning through adaptive management (DiGennaro et al., 2012). Developing causal networks from conceptual models can lead ultimately to more quantitative or semi-quantitative approaches that support higher-level analysis, as with structural equation modeling (Grace, 2014), expert elicitation methods (Knol et al., 2010), or process-based models.

Selecting Appropriate Indicators

Each component for the threshold system described above recognizes the essential role of information and data in development of management solutions. Environmental indicators are critical components of this process. They reflect the trends in environmental conditions and progress toward realizing policy targets. Given the number and diversity of potential indicators, however, it is necessary to develop an understanding of the structure within which those data and indicators serve. Most importantly, the relevance and utility of existing indicators must be understood by policy-makers and public stakeholders.

We are accustomed to seeing indicators used in many aspects of modern society; including economics, medicine, weather, sports and other disciplines that routinely apply different types of metrics and indicators to communicate status and process. Ideally, indicators for an environmental management system are selected to represent each step in a conceptual framework, as recommended for the DAPSIR framework (Appendix B).

More commonly, however, most of the initial focus is on state and impact indicators, which are preferable for identifying the seriousness of an environmental problem, while pressure and response indicators are used to evaluate how best to control the problem (Niemeijer and de Groot, 2008b). In this context it is practical to distinguish between different types of indicators that serve specific purposes in assessment of the conceptual framework, as described below (from EEA, 2003, see also Appendix B):

A. ***Descriptive Indicators*** *usually show the development of a variable over time. They are most commonly used as state, pressure or impact indicators.*

B. ***Performance Indicators*** *are connected with target or regulatory values. They provide a 'distance to target' assessment, and are typically state, pressure or impact indicators that clearly link to policy responses.*

C. ***Efficiency Indicators*** *relate drivers to pressures, e.g. energy use per capita or CO_2 emissions per GDP. They provide insight into the efficiency of management products and processes in terms of resources and output measures. Typically represented in monetary terms or physical output measures, these indicators link the levels of environmental and economic resources needed to perform societal functions (with improved efficiency indicating the ability to do more with less).*

D. ***Policy-effectiveness Indicators*** *relate the actual change of environmental variables to policy efforts. They link response indicators to state, driving force, pressure or impact indicators and are crucial in understanding the reasons for observed developments.*

Good indicators usually share a suite of characteristics that improve their utility. Outcome-based goals should conform to SMART criteria (Specific, Measurable, Attainable, Relevant, and Time-bound), as previously described in Council documentation (TSAC, 2017), so these typically apply to indicators as well. In addition to being measurable and having close correspondence with targets or goals, indicators should be repeatable and yield reliable measurements, sensitive and responsive to change in condition, and feasible. Beyond these critieria, indicators should be matched up to key nodes in the conceptual models (or resulting causal networks) and the results chains derived from them. Niemeijer and de Groot (2008b) recommended locating key nodes in a causal network, and identified three types: root-nodes, central nodes, and end-of-chain nodes. Root nodes are those nodes that have many dependent nodes or is a node that influences many other nodes, but is itself influenced by few if any nodes. Central nodes are those that influence and are driven by many other nodes. End-of-chain nodes typically are influenced by many nodes but influence very few nodes. The most useful indicators for understanding system behavior tend to be central nodes with a large number of intersecting linkages, while end-of-chain nodes are used to provide an overall of view on status toward achieving the final goal or target. Root node indicators are typically used to assess the source of environmental problems.

Final selection of indicators should focus on key attributes, or focal components, which are those major elements or features of an ecosystem that require some form of management intervention to ensure their continued viability (CMP, 2013; Rice and Rochet, 2005; Harwell et al., 1999). Considering the complexity of an ecosystem in terms of its focal components helps to organize the relevant information into a limited number of discrete, but not necessarily independent categories (Levin et al., 2014). Intermediate objectives and final outcome targets in the results chain will typically have associated indicators that track progress toward identified outcomes. The Conservation Measures Partnership Open Standards documentation (CMP, 2013) makes several additional recommendations for effective and credible indicators (Appendix C).

As discussed previously, full development of an integrated threshold system will require both the conceptual framework and a well-defined monitoring and evaluation approach (Stem et al., 2005), based on detailed conceptual models and causal results chains. The adaptive management cycle is closed, ultimately, through monitoring and evaluation of indicators that track the effectiveness of management actions. Four different types of monitoring assessment have been identified by Fogueres (2017) during landscape-scale planning for the Lake Tahoe West Restoration Partnership. These include:

1) Implementation monitoring used to show whether the work was completed as designed.
2) Effectiveness or performance monitoring conducted to determine whether projects or management actions are achieving desired outcomes.
3) Validation monitoring used to determine whether models are producing accurate outputs.
4) Compliance monitoring required to meet regulatory standards

Implementation indicators are used to describe or tally the work done to achieve policy or management objectives. These are often referred to as *output indicators*. They track whether management actions have been implemented as designed and to the scale intended. Tracking and reporting on these indicators is considered project implementation monitoring.

Effectiveness indicators are used to measure the change in key attributes of system behavior in response to management action or policy. These are generally referred to as *outcome indicators*. These are the focus of results chains that link expected outcomes from management actions to impacts on ecosystem services or changing conditions.

Indicators from validation monitoring inform model calibrations and demonstrate whether a model is performing as expected, and that it continues to produce reliable output once fully calibrated.

Compliance monitoring determines whether a responsible party is meeting the specifications required from a regulatory framework . Ideally, that regulatory framework has been integrated as representing critical components of the conceptual model for achieving desired goals and ultimate outcomes. If not, the compliance monitoring may still be required, but is not germane to priority objectives of the model.

Intermediate indicators may be useful when the rates of change toward desired goals or targets are slow or less evident within the background noise of natural ecosystem variability. Status monitoring of intermediate outcomes is useful when indicators identified at linkage nodes pertain to interim results required for achieving specified targets (final outcomes).

Assembling the Structural Components

Margoluis et al. (2009) identified two main types of complexity encountered by ecosystem management and conservation efforts: detail complexity that refers to the presence of a large number of variables within a system (Senge, 1990), and dynamic complexity that refers to unpredictable ways in which variables may interact with one another (Salafsky et al., 2002). Integration of the three main structural components described above as part of a modernized Tahoe threshold system will help address both types of complexity.

(1) DAPSIR conceptual framework — The DAPSIR conceptual framework provides a big-picture context within which stakeholders can work collaboratively to anticipate changes resulting from driving social forces and develop a shared understanding of how ecosystem-based management would best function for a complex social-ecological system (Vugteveen et al., 2015) like Tahoe, where the aim is to balance ecological, economic, and social objectives for sustainable development.

(2) Conceptual models — Conceptual models are essential for the application of an adaptive management approach. They are a refinement on the more broadly based conceptual framework and serve to represent interacting factors and processes that affect change within a system. This is where specific goals, final outcome targets, intermediate objectives and potential management strategies are collectively established and documented. Both the conceptual framework and conceptual models serve to communicate current understanding of the social-ecological system, but conceptual models identify the dominant processes and focal components that can be manipulated to effect desired changes within the system. Further, the acceptance of a collaboratively developed conceptual model communicates a shared understanding of ecosystem function and well-being for which the participating stakeholders share management responsibility (Hymanson and Collopy, 2010).

(3) Results chains — The results chain specifies a sequence of causal linkages that extend a specific management strategy through relevant intermediate steps and

objectives to a final outcome or target (CMP, 2013). For the Tahoe thresholds these chains should be based on causal networks that show expected interaction between factors in ecosystem function and the impact of specified management actions (outputs) on a particular set of objectives and the final outcome (desired goal). An associated narrative should represent current scientific understanding of key factors and processes, along with associated uncertainties, and an assessment of certainty for anticipated outcomes.

When these three structural components are combined in a nested series they provide context and detail across multiple scales. Each is a joint exercise between managers, scientists and public stakeholders. Policy and stakeholder engagement is particularly critical in development of the conceptual framework and preliminary conceptual models, while scientific input is especially important for developing causal networks and the associated suite of effectiveness indicators.

The conceptual framework could be developed as a whole for the Tahoe social-ecological system, or individually for each threshold category and then combined. Elliot et al. (2017) show how multiple DAPSIR representations can be functionally nested, for example, which would provide integrated management across thresholds (see Figure 6). Conceptual models and causal network development would normally follow in sequence, but are not necessarily dependent on having a conceptual framework in place first, as the process is iterative in any case. The conceptual framework should provide a coarse-grained contextual overview of each threshold category, or of the threshold system overall, while the conceptual models and causal network chains are increasingly fine-grained representations of system function, linkages and outcome details.

Developing these structural components for one or two threshold categories initially would be a judicious approach. They should be the focus of outcome (or threshold category) implementation teams or target working groups, consisting of committed stakeholders who would collectively develop the structural components and then the resulting monitoring and evaluation plan for that threshold (TSAC, 2017). In some cases, it may be easier to have separate implementation teams focus on specific goals for a threshold category, similar to how working groups currently function for the Tahoe Interagency Executives Steering Committee (TIE-SC). In any case, developing these in sequence will create a staggered reporting cycle that avoids placing excessive demand on program resources, while also facilitating stakeholder engagement and buy-in during the process and for its products.

The goal is to implement a flexible but structured approach that supports an adaptive management cycle, which reduces the uncertainty and unpredictability inherent to dynamic and complex social-ecological systems. The work summarized here demonstrates a systems approach for Tahoe thresholds monitoring and evaluation, where information has specific roles defined by key attributes, expected outcomes, functional linkages, identified feedback loops, anticipated response times, and indicators of key focal components.

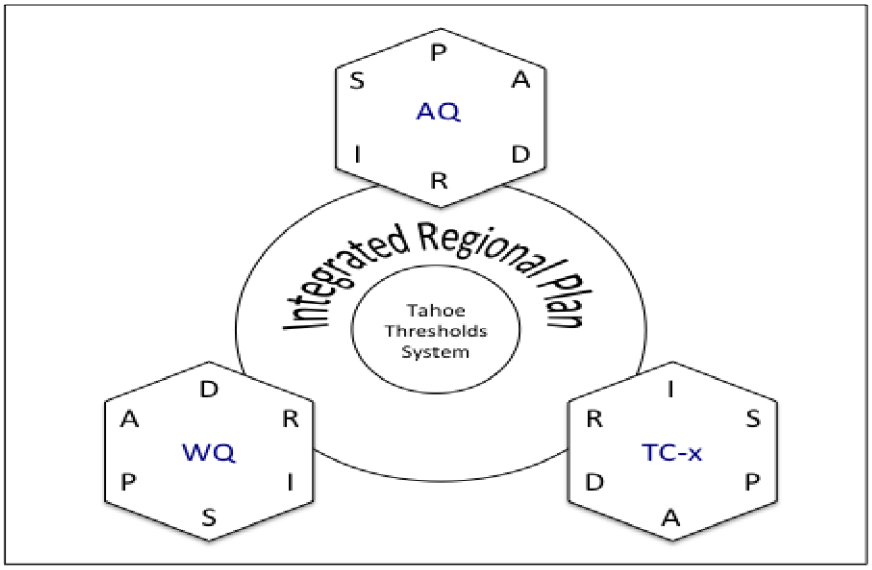


Figure 6. A nested DAPSIR conceptual framework for integrated management of Tahoe threshold categories (TC) for water quality (WQ), air quality (AQ), and the full series of additional categories (represented here as TC-x). Denotation key for DAPSIR elements is: (D) driving forces; (A) activities; (P) pressures; (S) state changes; (I) impacts; (R) responses. Integrated Regional Plan represents the intersection and compilation of factors from each DAPSIR element for these thresholds. In this case, responses from each threshold category are assembled and compared across the Integrated Regional Plan. Framework shown was modified from Elliott et al. (2017).

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Appendix A. Application of Adaptive Management (TSAC, 2017).

Each program in this review has applied some form of adaptive management as part of its strategy for guiding management decision-making in the presence of ongoing uncertainty and changing conditions. First developed as a science-based approach for natural resource management (Holling, 1978; Walters, 1986), adaptive management was intended to reduce uncertainty over time through an iterative approach that evaluates response to selected actions or projects for continuous improvement in management planning and implementation directed at achieving specified objectives. The application of adaptive management can vary widely among programs, however, reflecting unique ecosystem characteristics and the management requirements or constraints for each particular case. Identified steps in the process can range from as few as three to more than twelve.

As summarized by Westgate et al. (2013), the adaptive management cycle includes these following steps:

1. Identification of management goals in collaboration with stakeholders.
2. Specification of multiple management options, one of which can be 'do nothing'.
3. Creation of a rigorous evaluation process for interpreting how the system responds to management interventions. This stage typically involves creation of quantitative conceptual models and/or rigorous experimental design.
4. Implementation of management action(s).
5. Monitoring of system response to management actions (preferably on a regular basis).
6. Adjust management practice in response to results from the monitoring.

While this is the general set of steps for an adaptive management cycle, each program tends to apply its own variation to this overall approach. In Appendix C we show selected examples of the adaptive management cycles used by programs reviewed in this document.

Some authors distinguish between passive and active forms of adaptive management (Walters and Holling, 1990), although the usual case lies somewhere along the spectrum between these two types. Passive adaptive management is more easily implemented and may be appropriate when management constraints limit the testing of alternative actions, but then hypothesis testing is not as rigorous and the pace of learning can be slower. Active adaptive management develops and tests competing hypotheses on anticipated impacts of management actions, usually with several types of actions tested sequentially or in parallel. These generally require a larger investment of resources and may involve greater risk, but in theory can provide statistically testable information in a shorter period (Gregory, 2006).

The Puget Sound Partnership has made extensive use of Open Standards for the Practice of Conservation from the Conservation Measures Partnership (CMP, 2013) in its recovery planning and implementation of adaptive management. We recommend review of this same document by all staff, scientists and stakeholders engaged in thresholds standards review and updating. Additional useful information related to adaptive management, indicator selection and ecosystem assessment approaches can be found in a document produced for the Delta Stewardship Council (Delta Independent Science Board, 2016) and in a technical report for the Puget Sound Partnership (McManus et al., 2014).

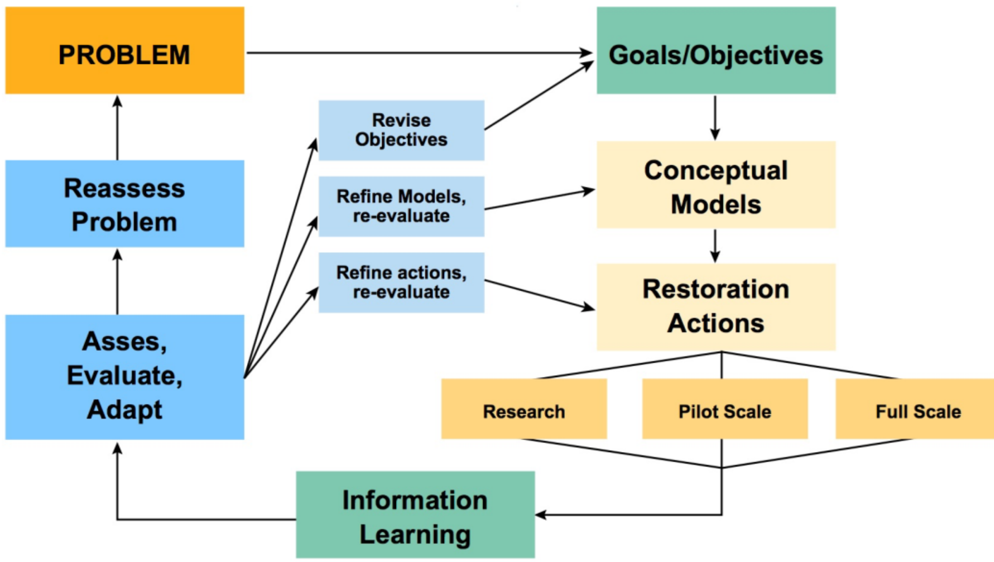

Figure A1. Adaptive management approach developed for the CALFED Bay-Delta Program (from DiGennaro et al., 2012).

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Appendix B. Types of Indictors Recognized for Use in the DPSIR Conceptual Framework.

Ideally, indicators would be identified for each step of the DPSIR framework such that the full portfolio of indicators could be used to assess ecosystem condition as well as the processes and mechanisms that drive ecosystem health. The following are descriptions used by the European Environment Agency for indicators within each category of the DPSIR chain (quoted from EEA, 2003).

> *Indicators for* ***Driving forces*** *describe the social, demographic and economic developments in societies and the corresponding changes in lifestyles, overall levels of consumption and production patterns. Primary driving forces are population growth and developments in the needs and activities of individuals. These primary driving forces provoke changes in the overall levels of production and consumption. Through these changes in production and consumption, the driving forces exert pressure on the environment.*
>
> ***Pressure indicators*** *describe developments in release of substances (emissions), physical and biological agents, the use of resources and the use of land by human activities. The pressures exerted by society are transported and transformed in a variety of natural processes to manifest themselves in changes in environmental conditions. Examples of pressure indicators are CO2-emissions per sector, the use of rock, gravel and sand for construction and the amount of land used for roads.*
>
> ***State indicators*** *give a description of the quantity and quality of physical phenomena (such as temperature), biological phenomena (such as fish stocks) and chemical phenomena (such as atmospheric CO2-concentrations) in a certain area. State indicators may, for instance, describe the forest and wildlife resources present, the concentration of phosphorus and sulphur in lakes, or the level of noise in the neighborhood of airports.*
>
> *Due to pressure on the environment, the state of the environment changes. These changes then have impacts on the functions of the environment, such as human and ecosystem health, resources availability, losses of manufactured capital, and biodiversity.*
>
> ***Impact indicators*** *are used to describe changes in these conditions. Although effects of human change in the environment occur in a sequence: air pollution may cause changes in the radiation balance (primary effect but still a state indicator), which may in turn cause an increase in temperature (secondary effect, also a state indicator), which may provoke a rise of sea level (tertiary effect, but still a state of the environment), it is only the last step: loss of terrestrial biodiversity, that should be called the impact indicator. It is the change in the availability of species that influences human use of the environment. In the strict definition impacts are only those parameters that directly reflect changes in environmental use functions by humans. As humans are a part of the environment, impacts also include health*

impacts.

***Response indicators** refer to responses by groups (and individuals) in society, as well as government attempts to prevent, compensate, ameliorate or adapt to changes in the state of the environment. Some societal responses may be regarded as negative driving forces, since they aim at redirecting prevailing trends in consumption and production patterns. Other responses aim at raising the efficiency of products and processes, through stimulating the development and penetration of clean technologies. Examples of response indicators are the relative amount of cars with catalytic converters and recycling rates of domestic waste. An often used 'overall' response indicator is an indicator describing environmental expenditures.*

Vugteveen et al. (2015) defined an indicator as "a component or a measure of environmentally relevant phenomena used to describe social-ecological conditions, evaluate system changes, or prescribe management goals (Heink and Kowarik, 2010)." In the context of a DPSIR framework they link both research-driven and policy-driven monitoring focused on evaluations of effectiveness, performance and processes (Figure B1), where monitoring and evaluation efforts are required to be credible, legitimate, and salient.

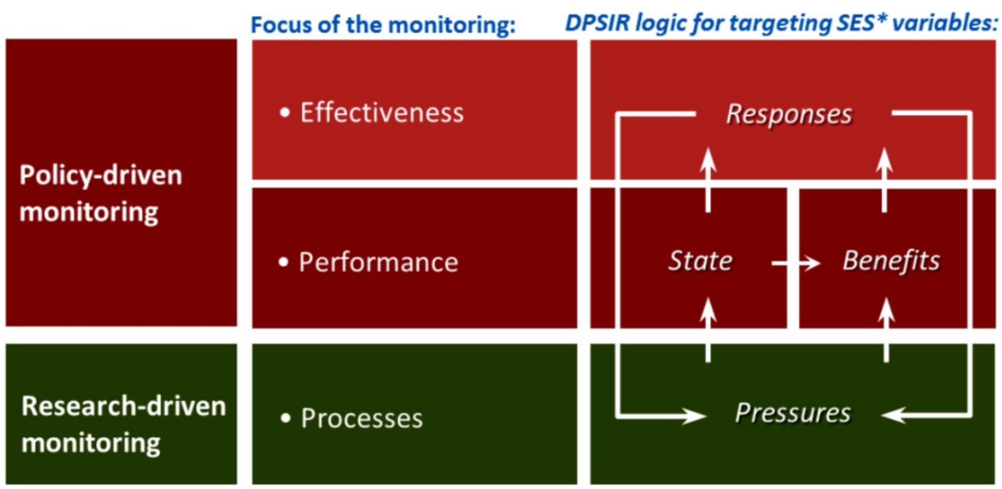

Figure B1. The use of pressure, state, response and benefit (impact) indicators for different monitoring purposes (focus areas) that evaluate effectiveness, performance, or processes (from Vugteveen et al., 2015).

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Appendix C. Characteristics of Useful Indicators.

Conservation Measures Partnership Open Standards documentation makes the following recommendations for effective and credible indicators (CMP, 2013).

1. *Measurable: The indicator can be assessed in quantitative or discreet qualitative terms by some procedure that produces reliable, repeatable, accurate information.*
2. *Precise and Consistent: The indicator means the same thing to all people and does not change over time.*
3. *Specific: The indicator is unambiguously associated with the key attribute of concern and is not significantly affected by other factors.*
4. *Sensitive: The indicator shows detectible and proportional changes in response to changes in threats or conservation actions.*
5. *Timely: The indicator detects change in the key attribute quickly enough that you can make timely decisions on conservation actions.*
6. *Technically Feasible: The indicator is one that could be implemented with existing technologies, not one that must await some great conceptual or technological innovation.*

The most effective and credible indicators will also be:

7. *Cost-effective: The indicator should provide more or better information per unit cost than the alternatives.*
8. *Partner-based: The indicator should be one that works well for key partner institutions in the conservation effort and/or rests on measurements they can or already do collect.*
9. *Publicly Relevant: The indicator should be useful for publicly communicating conservation values and progress to the community.*

Five evaluation questions were used to assess potential indicators for the Puget Sound ecosystem (NOAA Fisheries, 2008):

- *Is the indicator conceptually valid?*
- *Do data exist?*
- *Can the indicator be feasibly implemented?*
- *Are the statistical properties understood and sufficient?*
- *Does the indicator fulfill management and reporting needs?*

For management purposes, one suite of indicators was selected to address key properties of the Puget Sound ecosystem, while another suite of indicators was selected to address the causal mechanisms underlying ecosystem functions.

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